RTI Connext DDS

Core Libraries

User's Manual

Version 6.1.0

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The security features of this product include software developed by the OpenSSL Project for use in the OpenSSL Toolkit (http://www.openssl.org/). This product includes cryptographic software written by Eric Young (eay@cryptsoft.com). This product includes software written by Tim Hudson (tjh@cryptsoft.com).

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Available Documentation

To get you up and running as quickly as possible, the *RTI® Connext® DDS* documentation is divided into several parts.

- RTI Connext DDS Installation Guide — This document describes how to install *Connext DDS*, as well as License Management.

- RTI Connext DDS Getting Started Guide — This document describes the core value and concepts behind the product and takes you step-by-step through the creation of a simple example application. Addendums cover:
  - RTI Connext DDS Core Libraries Getting Started Guide Addendum for Android Systems
  - RTI Connext DDS Core Libraries Getting Started Guide Addendum for Embedded Systems
  - RTI Connext DDS Core Libraries Getting Started Guide Addendum for INtime Systems

- RTI Connext DDS Core Libraries Whats New in 6.1.0— This document describes changes and enhancements in the most recent major release of *Connext*. Those upgrading from a previous version should read this document first.
- RTI Connext DDS Core Libraries Release Notes —This document describes system requirements, what's fixed, and known issues.
- RTI Connext DDS Core Libraries Platform Notes — This document provides platform-specific information, including specific information required to build your applications using *Connext DDS*, such as compiler flags and libraries.
- RTI Connext DDS Core Libraries Database Setup — In most cases, *Connext DDS* does not require a database. However, if you want to use some of the durability features of Connext DDS, you will need a relational database.

- *Migration Guide* on the RTI Community Portal (https://community.rti.com/documentation)—This document describes how to migrate to the current release from a previous *Connext DDS* release, including what compatibility issues you may need to account for during your upgrade. This guide is updated as needed.
- *RTI Connext DDS Core Libraries User's Manual* — This document describes the features of the product and how to use them. It is organized around the structure of the *Connext DDS* APIs and certain common high-level tasks.
- RTI Connext DDS Core Libraries Extensible Types Guide — This document describes how to use Extensible Types, which allow you to define data types in a more flexible way, and to evolve data types over time without giving up portability, interoperability, or the expressiveness of the DDS type system.
- **API Reference HTML Documentation** (README.html) — This extensively cross-referenced documentation, available for all supported programming languages, is your in-depth reference to every operation and configuration parameter in the middleware. Even experienced *Connext DDS* developers will often consult this information.
- **The Programming How To's provide a good place to begin learning the APIs.** These are hyperlinked code snippets to the full API documentation. From the **README.html** file, select one of the supported programming languages, then scroll down to the Programming How To's. Start by reviewing the Publication Example and Subscription Example, which provide step-by step examples of how to send and receive data with *Connext DDS*.

Many readers will also want to look at additional documentation available online. In particular, RTI recommends the following:

- Use the RTI Customer Portal (http://support.rti.com) to download RTI software and contact RTI Support. The RTI Customer Portal requires a username and password. You will receive this in the email confirming your purchase. If you do not have this email, please contact **license@rti.com**. Resetting your login password can be done directly at the RTI Customer Portal.
- The RTI Community Portal (https://community.rti.com) provides a wealth of knowledge to help you use *Connext DDS*, including:
  - Documentation, at https://community.rti.com/documentation
  - Best Practices
  - Example code for specific features, as well as more complete use-case examples,
  - Solutions to common questions,
  - A glossary,
  - Downloads of experimental software,
  - And more.

- Whitepapers and other articles are available from http://www.rti.com/resources.

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About this Document

Paths Mentioned in Documentation

The documentation refers to:

- **<NDDSHOME>**

  This refers to the installation directory for *RTI® Connext® DDS*. The default installation paths are:

  - macOS® systems:
    /Applications/rti_connext_dds-6.1.0
  - Linux systems, non-*root* user:
    /home/<*your user name*>/rti_connext_dds-6.1.0
  - Linux systems, *root* user:
    /opt/rti_connext_dds-6.1.0
  - Windows® systems, user without Administrator privileges:
    <*your home directory*>\rti_connext_dds-6.1.0
  - Windows systems, user with Administrator privileges:
    C:\Program Files\rti_connext_dds-6.1.0

  You may also see **$NDDSHOME** or **%NDDSHOME%**, which refers to an environment variable set to the installation path.

  Wherever you see **<NDDSHOME>** used in a path, replace it with your installation path.

Note for Windows Users: When using a command prompt to enter a command that includes the path **C:\Program Files** (or any directory name that has a space), enclose the path in quotation marks. For example:

```
"C:\Program Files\rti_connext_dds-6.1.0\bin\rtiddsgen"
```

Or if you have defined the **NDDSHOME** environment variable:

```
"%NDDSHOME%\bin\rtiddsgen"
```

- ***<path to examples>***

  By default, examples are copied into your home directory the first time you run *RTI Launcher* or any script in **<NDDSHOME>/bin**. This document refers to the location of the copied examples as ***<path to examples>***.

  Wherever you see ***<path to examples>***, replace it with the appropriate path.

  Default path to the examples:

  - macOS systems: **/Users/*<your user name>*/rti_workspace/6.1.0/examples**
  - Linux systems: **/home/*<your user name>*/rti_workspace/6.1.0/examples**
  - Windows systems: ***<your Windows documents folder>*\rti_workspace\6.1.0\examples**

    Where 'your Windows documents folder' depends on your version of Windows. For example, on Windows 10, the folder is **C:\Users*<your user name>*\Documents**.

  Note: You can specify a different location for **rti_workspace**. You can also specify that you do not want the examples copied to the workspace. For details, see *Controlling Location for RTI Workspace and Copying of Examples* in the *RTI Connext DDS Installation Guide*.

Programming Language Conventions

The terminology and example code in this manual assume you are using Traditional C++ without namespace support.

C, Modern C++, C++/CLI, C#, and Java APIs are also available; they are fully described in the API Reference HTML documentation. (Note: the Modern C++ API is not available for all platforms, check the RTI Connext DDS Core Libraries Platform Notes to see if it is available for your platform.)

Namespace support in Traditional C++, C++/CLI, and C# is also available; see the API Reference HTML documentation (from the **Modules** page, select **Using DDS:: Namespace**) for details. In the Modern C++ API all types, constants and functions are always in namespaces.

Traditional vs. Modern C++

Connext DDS provides two different C++ APIs, which we refer to as the "Traditional C++" and "Modern C++" APIs. They provide substantially different programming paradigms and patterns. The Traditional

API could be considered as simply "C with classes," while the Modern API incorporates modern C++ techniques, most notably:

- Generic programming
- Integration with the standard library
- Automatic object lifecycle management, providing full value types and reference types
- C++11 support, such as move operations, initializer lists, and support for range for-loops.

These different programming styles make the Modern C++ API differ significantly with respect to the other language APIs in several aspects; to name a few:

- 3.3 Creating User Data Types with IDL on page 75
- 3.8 Interacting Dynamically with User Data Types on page 154
- 3.9 Working with DDS Data Samples on page 158
- 4.1.1 Creating and Deleting DDS Entities on page 167
- 8.4 Using DataReaders to Access Data (Read & Take) on page 548
- QoS policies and QoS management
- Naming conventions

This manual points out these kinds of differences whenever they are substantial.

Extensions to the DDS Standard

Connext DDS implements the DDS Standard published by the OMG. It also includes features that are extensions to DDS. These include additional Quality of Service parameters, function calls, structure fields, etc.

Extensions also include product-specific APIs that complement the DDS API. These include APIs to create and use transport plug-ins, and APIs to control the verbosity and logging capabilities. These APIs are prefixed with NDDS, such as **NDDSTransportSupport::register_transport()**.

Environment Variables

Connext DDS documentation refers to path names that have been customized during installation. NDDSHOME refers to the installation directory of *Connext DDS*.

Names of Supported Platforms

Connext DDS runs on several different target platforms. To support this vast array of platforms, *Connext DDS* separates the executable, library, and object files for each platform into individual directories.

Each platform name has four parts: hardware architecture, operating system, operating system version and compiler. For example, **x64Linux2.6gcc4.4.5** is the directory that contains files specific to Linux® version 2.6 for the x64 Intel processor, compiled with gcc version 4.4.5.

For a full list of supported platforms, see the RTI Connext DDS Core Libraries Platform Notes.

Additional Resources

The details of each API (such as function parameters, return values, etc.) and examples are in the API Reference HTML documentation. In case of discrepancies between the information in this document and the API Reference HTML documentation, the latter should be considered more up-to-date.

Part 1: Welcome to RTI Connext DDS

RTI® Connext® DDS solutions provide a flexible connectivity software framework for integrating data sources of all types. At its core is the world's leading ultra-high performance, distributed networking *Databus*. It connects data within applications as well as across devices, systems and networks. *Connext DDS* also delivers large data sets with microsecond performance and granular quality-of-service control. *Connext DDS* is a standards-based, open architecture that connects devices from deeply embedded real-time platforms to enterprise servers across a variety of networks.

Part 1 introduces the general concepts behind data-centric publish-subscribe communications and provides a brief tour of *Connext DDS*.

- Overview (Chapter 1 on page 6)
- Data-Centric Publish-Subscribe Communications (Chapter 2 on page 14)

Chapter 1 Overview

RTI® Connext® DDS is a connectivity framework for distributed real-time applications. *Connext DDS* simplifies application development, deployment and maintenance and provides fast, predictable distribution of time-critical data over a variety of transport networks.

Connext DDS solutions provide a flexible data distribution infrastructure for integrating data sources of all types. At its core is the world's leading ultra-high performance, distributed networking *Connext Databus*. It connects data within applications as well as across devices, systems and networks. *Connext DDS* also delivers large data sets with microsecond performance and granular quality-of-service control. *Connext DDS* is a standards-based, open architecture that connects devices from deeply embedded real-time platforms to enterprise servers across a variety of networks.

With *Connext DDS*, you can:

- Perform complex one-to-many and many-to-many network communications.
- Customize application operation to meet various real-time, reliability, and quality-of-service goals.
- Provide application-transparent fault tolerance and application robustness.
- Use a variety of transports.

This section introduces basic concepts of middleware and common communication models, and describes how *Connext DDS's* feature-set addresses the needs of real-time systems.

1.1 What is Connext DDS?

Connext DDS is a software connectivity framework for real-time distributed applications. It provides the communications service programmers need to distribute time-critical data between embedded and/or enterprise devices or nodes. *Connext DDS* uses the publish-subscribe communications model to make data distribution efficient and robust.

Connext DDS implements the Data-Centric Publish-Subscribe (DCPS) API within the OMG's Data Distribution Service (DDS) for Real-Time Systems. DDS is the first standard developed for the needs of real-time systems. DCPS provides an efficient way to transfer data in a distributed system.

With *Connext DDS*, systems designers and programmers start with a fault-tolerant and flexible communications infrastructure that will work over a wide variety of computer hardware, operating systems, languages, and networking transport protocols. *Connext DDS* is highly configurable so programmers can adapt it to meet the application's specific communication requirements.

1.2 Network Communications Models

The communications model underlying the network middleware is the most important factor in how applications communicate. The communications model impacts the performance, the ease to accomplish different communication transactions, the nature of detecting errors, and the robustness to different error conditions. Unfortunately, there is no "one size fits all" approach to distributed applications. Different communications models are better suited to handle different classes of application domains.

This section describes three main types of network communications models:

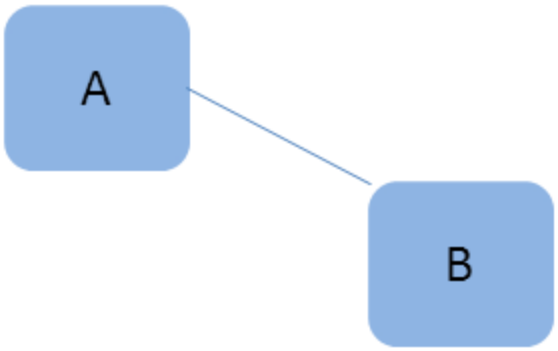
- Point-to-point
- Client-server
- Publish-subscribe

Point-to-point model:

Point-to-point is the simplest form of communication, as illustrated in Figure 1.1: Point-to-Point on the next page. The telephone is an example of an everyday point-to-point communications device. To use a telephone, you must know the address (phone number) of the other party. Once a connection is established, you can have a reasonably high-bandwidth conversation. However, the telephone does not work as well if you have to talk to many people at the same time. The telephone is essentially one-to-one communication.

TCP is a point-to-point network protocol designed in the 1970s. While it provides reliable, high-bandwidth communication, TCP is cumbersome for systems with many communicating nodes.

Figure 1.1: Point-to-Point

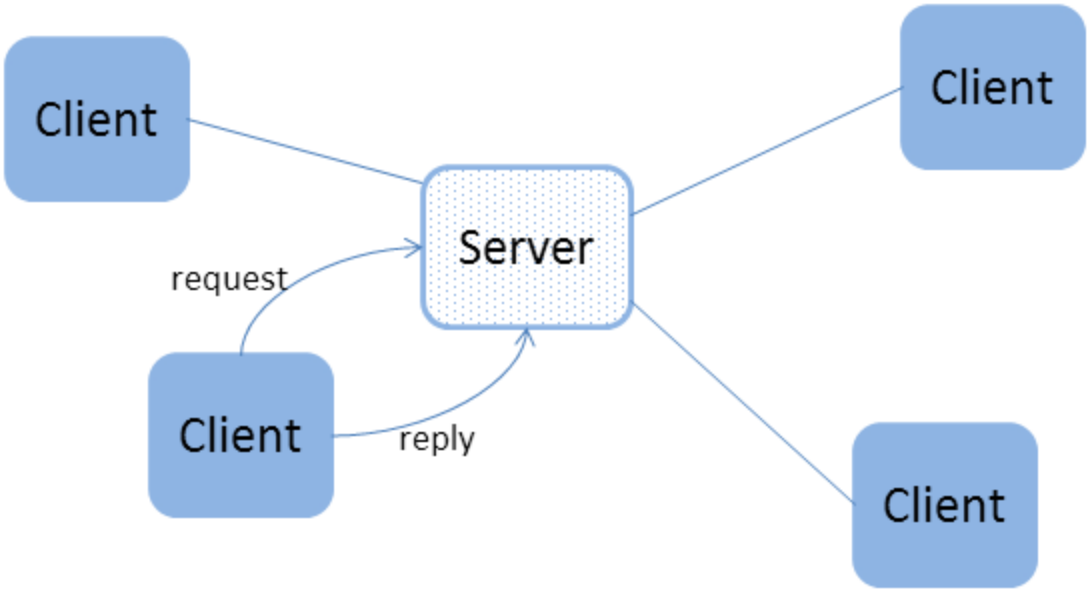


Point-to-point is one-to-one communication.

Client-server model:

To address the scalability issues of the Point-to-Point model, developers turned to the Client-Server model. Client-server networks designate one special server node that connects simultaneously to many client nodes, as illustrated in Figure 1.2: Client-Server below.

Figure 1.2: Client-Server



Client-server is many-to-one communications.

Client-server is a "many-to-one" architecture. Ordering pizza over the phone is an example of client-server communication. Clients must know the phone number of the pizza parlor to place an order. The parlor can handle many orders without knowing ahead of time where people (clients) are located. After the order

(request), the parlor asks the client where the response (pizza) should be sent. In the client-server model, each response is tied to a prior request. As a result, the response can be tailored to each request. In other words, each client makes a request (order) and each reply (pizza) is made for one specific client in mind.

The client-server network architecture works best when information is centralized, such as in databases, transaction processing systems, and file servers. However, if information is being generated at multiple nodes, a client-server architecture requires that all information are sent to the server for later redistribution to the clients. This approach is inefficient and precludes deterministic communications, since the client does not know when new information is available. The time between when the information is available on the server, and when the client asks and receives it adds a variable latency to the system.

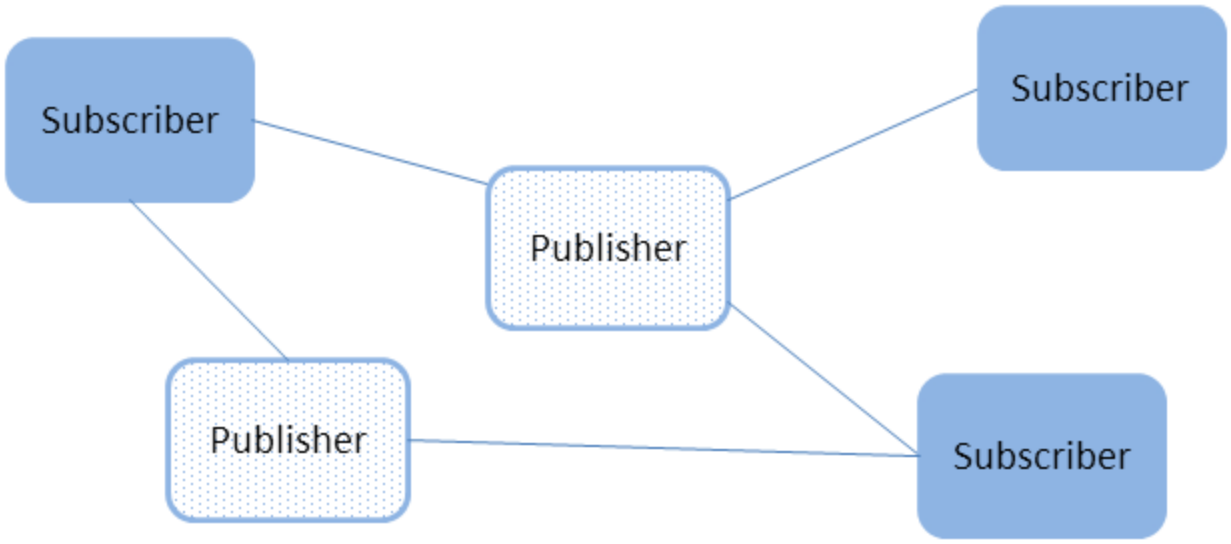
Publish-subscribe model: In the publish-subscribe communications model (Figure 1.3: Publish-Subscribe on the next page), computer applications (nodes) "subscribe" to data they need and "publish" data they want to share. Messages pass directly between the publisher and the subscribers, rather than moving into and out of a centralized server. Most time-sensitive information intended to reach many people is sent by a publish-subscribe system. Examples of publish-subscribe systems in everyday life include television, magazines, and newspapers.

Publish-subscribe communication architectures are good for distributing large quantities of time-sensitive information efficiently, even in the presence of unreliable delivery mechanisms. This direct and simultaneous communication among a variety of nodes makes publish-subscribe network architecture the best choice for systems with complex time-critical data flows.

While the publish-subscribe model provides system architects with many advantages, it may not be the best choice for all types of communications, including:

- File-based transfers (alternate solution: FTP)
- Remote Method Invocation (alternate solutions: CORBA, COM, SOAP)
- Connection-based architectures (alternate solution: TCP/IP)
- Synchronous transfers (alternate solution: CORBA)

Figure 1.3: Publish-Subscribe

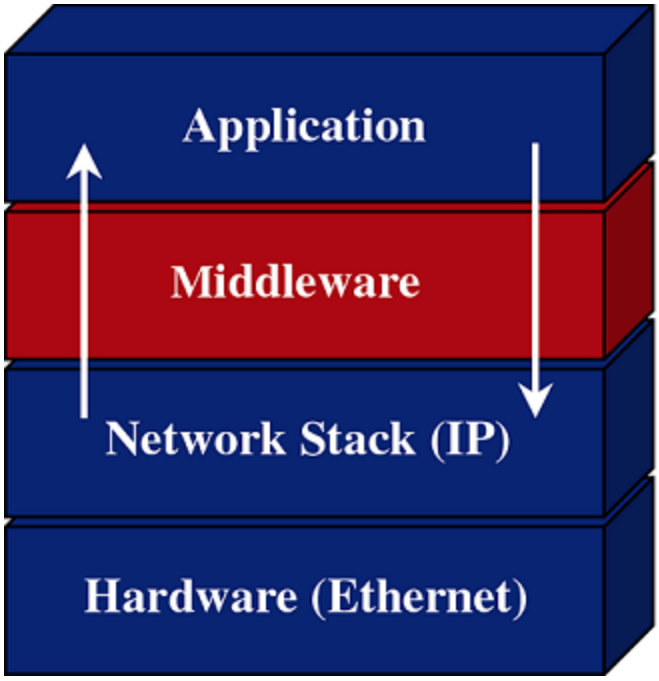


Publish-subscribe is many-to-many communications.

1.3 What is Middleware?

Middleware is a software layer between an application and the operating system. *Network middleware* isolates the application from the details of the underlying computer architecture, operating system and network stack (see Figure 1.4: Network Middleware on the next page). Network middleware simplifies the development of distributed systems by allowing applications to send and receive information without having to program using lower-level protocols such as sockets and TCP or UDP/IP.

Figure 1.4: Network Middleware



Middleware insulates applications from the raw operating-system network stack.

Publish-subscribe communications model: *Connext DDS* is based on a publish-subscribe communications model. Publish-subscribe (PS) provides a simple and intuitive way to distribute data. It decouples the software that creates and sends data—the data *publishers*—from the software that receives and uses the data—the data *subscribers*. Publishers simply declare their intent to send and then publish the data. Subscribers declare their intent to receive, then the data is automatically delivered by the middleware.

Despite the simplicity of the model, PS middleware can handle complex patterns of information flow. The use of PS middleware results in simpler, more modular distributed applications. Perhaps most importantly, PS middleware can automatically handle all network chores, including connections, failures, and network changes, eliminating the need for user applications to program all those special cases. What experienced network middleware developers know is that handling special cases accounts for over 80% of the effort and code.

1.4 Features of Connext DDS

Connext DDS supports mechanisms that go beyond the basic publish-subscribe model. The key benefit is that applications that use *Connext DDS* for their communications are entirely decoupled. Very little of their design time has to be spent on how to handle their mutual interactions. In particular, the applications never need information about the other participating applications, including their existence or locations. *Connext DDS* automatically handles all aspects of message delivery, without requiring any intervention from the user applications, including:

- determining who should receive the messages,
- where recipients are located,
- what happens if messages cannot be delivered.

This is made possible by how *Connext DDS* allows the user to specify Quality of Service (QoS) parameters as a way to configure automatic-discovery mechanisms and specify the behavior used when sending and receiving messages. The mechanisms are configured up-front and require no further effort on the user's part. By exchanging messages in a completely anonymous manner, *Connext DDS* greatly simplifies distributed application design and encourages modular, well-structured programs.

Furthermore, *Connext DDS* includes the following features, which are designed to meet the needs of distributed real-time applications:

- **Data-centric publish-subscribe communications:** Simplifies distributed application programming and provides time-critical data flow with minimal latency.
  - Clear semantics for managing multiple sources of the same data.
  - Efficient data transfer, customizable Quality of Service, and error notification.
  - Guaranteed periodic samples, with maximum rate set by subscriptions.
  - Notification by a callback routine on data arrival to minimize latency.
  - Notification when data does not arrive by an expected deadline.
  - Ability to send the same message to multiple computers efficiently.
- **User-definable data types:** Enables you to tailor the format of the information being sent to each application.
- **Reliable messaging:** Enables subscribing applications to specify reliable delivery of samples.
- **Multiple Communication Networks:** Multiple independent communication networks (DDS *domains*), each using Connext DDS, can be used over the same physical network. Applications are only able to participate in the DDS domains to which they belong. Individual applications can be configured to participate in multiple DDS domains.
- **Symmetric architecture:** Makes your application robust:
  - No central server or privileged nodes, so the system is robust to node failures.
  - Subscriptions and publications can be dynamically added and removed from the system at any time.
- **Pluggable Transports Framework:** Includes the ability to define new transport plug-ins and run over them. *Connext DDS* comes with a standard UDP/IP pluggable transport and a shared memory transport. It can be configured to operate over a variety of transport mechanisms, including backplanes, switched fabrics, and new networking technologies.

- **Multiple Built-in Transports:** Includes UDP/IP and shared memory transports.
- **Multi-language support:** Includes APIs for the C, C++ (Traditional and Modern APIs), C++/CLI, C#, and Java™ programming languages.
- **Multi-platform support:** Includes support for flavors of UNIX®, real-time operating systems, and Windows®. (Consult the RTI Connext DDS Core Libraries Platform Notes to see which platforms are supported in this release.)
- **Compliance with Standards:**
  - API complies with the DCPS layer of the OMG's DDS specification.
  - Data types comply with OMG Interface Definition Language™ (IDL).
  - Data packet format complies with the International Engineering Consortium's (IEC's) publicly available specification for the RTPS wire protocol.

Chapter 2 Data-Centric Publish-Subscribe Communications

This section describes the formal communications model used by *Connext DDS*: the Data-Centric Publish-Subscribe (DCPS) standard. DCPS is a formalization (through a standardized API) and extension of the publish-subscribe communications model presented in 1.2 Network Communications Models on page 7.

2.1 What is DCPS?

DCPS is the portion of the OMG DDS (Data Distribution Service) Standard that addresses data-centric publish-subscribe communications. The DDS standard defines a language-independent model of publish-subscribe communications that has standardized mappings into various implementation languages. *Connext DDS* offers C, Traditional C++, Modern C++, C++/CLI, C#, and Java versions of the DCPS API.

The publish-subscribe approach to distributed communications is a generic mechanism that can be employed by many different types of applications. The DCPS model described in this chapter extends the publish-subscribe model to address the specific needs of real-time, data-critical applications. As you'll see, it provides several mechanisms that allow application developers to control how communications works and how the middleware handles resource limitations and error conditions.

The "data-centric" portion of the term DCPS describes the fundamental concept supported by the design of the API. In data-centric communications, the focus is on the distribution of *data* between communicating applications. A data-centric system is comprised of data publishers and data subscribers. The communications are based on passing data of known types in named streams from publishers to subscribers.

In contrast, in object-centric communications the fundamental concept is the *interface* between the applications. An interface is comprised of a set of methods of known types (number and types of method arguments). An object-centric system is comprised of interface servers and interface clients,

and communications are based on clients invoking methods on named interfaces that are serviced by the corresponding server.

Data and object-centric communications are complementary paradigms in a distributed system. Applications may require both. However, real-time communications often fit a data-centric model more naturally.

2.1.1 DCPS for Real-Time Requirements

DCPS, and specifically the *Connext DDS* implementation, is well suited for real-time applications. For instance, real-time applications often require the following features:

- **Efficiency**

  Real-time systems require efficient data collection and delivery. Only minimal delays should be introduced into the critical data-transfer path. Publish-subscribe is more efficient than client-server in both latency and bandwidth for periodic data exchange.
  Publish-subscribe greatly reduces the overhead required to send data over the network compared to a client-server architecture. Occasional subscription requests, at low bandwidth, replace numerous high-bandwidth client requests. Latency is also reduced, since the outgoing request message time is eliminated. As soon as a new DDS sample becomes available, it is sent to the corresponding subscriptions.
- **Determinism**

  Real-time applications often care about the determinism of delivering periodic data as well as the latency of delivering event data. Once buffers are introduced into a data stream to support reliable connections, new data may be held undelivered for a unpredictable amount of time while waiting for confirmation that old data was received.
  Since publish-subscribe does not inherently require reliable connections, implementations, like *Connext DDS*, can provide configurable trade-offs between the deterministic delivery of new data and the reliable delivery of all data.
- **Flexible delivery bandwidth**

  Typical real-time systems include both real-time and non-real-time nodes. The bandwidth requirements for these nodes—even for the same data—are quite different. For example, an application may be sending DDS samples faster than a non-real-time application is capable of handling. However, a real-time application may want the same data as fast as it is produced.
  DCPS allows subscribers to the same data to set individual limits on how fast data should be delivered to each subscriber. This is similar to how some people get a newspaper every day while others can subscribe to only the Sunday paper.
- **Thread awareness**

Real-time communications must work without slowing the thread that sends DDS samples. On the receiving side, some data streams should have higher priority so that new data for those streams are processed before lower priority streams.

Connext DDS provides user-level configuration of its internal threads that process incoming data. Users may configure *Connext DDS* so that different threads are created with different priorities to process received data of different data streams.

- **Fault-tolerant operation**

  Real-time applications are often in control of systems that are required to run in the presence of component failures. Often, those systems are safety critical or carry financial penalties for loss of service. The applications running those systems are usually designed to be fault-tolerant using redundant hardware and software. Backup applications are often "hot" and interconnected to primary systems so that they can take over as soon as a failure is detected.

  Publish-subscribe is capable of supporting many-to-many connectivity with redundant *DataWriters* and *DataReaders*. This feature is ideal for constructing fault-tolerant or high-availability applications with redundant nodes and robust fault detection and handling services.

- DCPS, and thus *Connext DDS*, was designed and implemented specifically to address the requirements above through configuration parameters known as QosPolicies defined by the DCPS standard (see 4.2 QosPolicies on page 176). 2.2 DDS Data Types, Topics, Keys, Instances, and Samples below introduces basic DCPS terminology and concepts.

2.2 DDS Data Types, Topics, Keys, Instances, and Samples

In data-centric communications, the applications participating in the communication need to share a common view of the types of data being passed around.

Within different programming languages there are several 'primitive' data types that all users of that language naturally share (integers, floating point numbers, characters, booleans, etc.). However, in any non-trivial software system, specialized data types are constructed out of the language primitives. So the data to be shared between applications in the communication system could be structurally simple, using the primitive language types mentioned above, or it could be more complicated, using, for example, C and C++ structs, like this:

```
struct Time {
       long year;
       short day;
       short hour;
       short minute;
       short second;
};
struct StockPrice {
       float price;
       Time timeStamp;
};
```

Within a set of applications using DCPS, the different applications do not automatically know the structure of the data being sent, nor do they necessarily interpret it in the same way (if, for instance, they use different operating systems, were written with different languages, or were compiled with different compilers). There must be a way to share not only the data, but also information about how the data is structured.

In DCPS, data definitions are shared among applications using OMG IDL, a language-independent means of describing data. For more information on data types and IDL, see Data Types and DDS Data Samples (Chapter 3 on page 27).

2.3 Data Topics – What is the Data Called?

Shared knowledge of the data types is a requirement for different applications to communicate with DCPS. The applications must also share a way to identify which data is to be shared. Data (of *any* data type) is uniquely distinguished by using a name called a *Topic*. By definition, a *Topic* corresponds to a single data type. However, several *Topic*s may refer to the same data type.

*Topic*s interconnect *DataWriters* and *DataReaders*. A *DataWriter* is an object in an application that tells *Connext DDS* (and indirectly, other applications) that it has some values of a certain *Topic*. A corresponding *DataReader* is an object in an application that tells *Connext DDS* that it wants to receive values for the same *Topic*. And the data that is passed from the *DataWriter* to the *DataReader* is of the data type associated with the Topic. *DataWriters* and *DataReaders* are described more in 2.5 DataWriters/Publishers and DataReaders/Subscribers on page 20.

For a concrete example, consider a system that distributes stock quotes between applications. The applications could use a data type called StockPrice. There could be multiple *Topic*s of the StockPrice data type, one for each company's stock, such as IBM, MSFT, GE, etc. Each *Topic* uses the same data type.

Data Type: StockPrice

```
struct StockPrice {
    float  price;
    Time  timeStamp;
};
```

Topic: "IBM"

Topic: "MSFT"

Topic: “GE”

Now, an application that keeps track of the current value of a client’s portfolio would subscribe to all of the topics of the stocks owned by the client. As the value of each stock changes, the new price for the corresponding topic is published and sent to the application.

2.4 DDS Samples, Instances, and Keys

The value of data associated with a *Topic* can change over time. The different values of the *Topic* passed between applications are called DDS samples. In our stock-price example, DDS samples show the price of a stock at a certain point in time. So each DDS sample may show a different price.

For a data type, you can select one or more fields within the data type to form a *key*. A *key* is something that can be used to uniquely identify one *instance* of a *Topic* from another *instance* of the same *Topic*. Think of a key as a way to sub-categorize or group related data values for the same *Topic*. Note that not all data types are defined to have keys, and thus, not all topics have keys. For topics without keys, it's as if there is only a single instance of that topic.

However, for *Topics* with keys, a unique value for the key identifies a unique *instance* of the *Topic*. DDS samples are then updates to particular instances of a *Topic*.

For example, let’s change the **StockPrice** data type to include the symbol of the stock. Then instead of having a *Topic* for every stock, which would result in hundreds or thousands of *Topics* and related *DataWriters* and *DataReaders*, each application would only have to publish or subscribe to a single *Topic*, say “StockPrices.” Successive values of a stock would be presented as successive DDS samples of an instance of “StockPrices”, with each instance corresponding to a single stock symbol.

Data Type: StockPrice

```
struct StockPrice {
    float price;
    Time  timeStamp;
    @key char  *symbol;
};
```

Instance 1 = (Topic: “StockPrices”) + (Key: “MSFT”)

sample a, price = $28.00

sample b, price = $27.88

Instance 2 = (Topic: “StockPrices”) + (Key: “IBM”)

sample a, price = $74.02

sample b, price = $73.50

Etc.

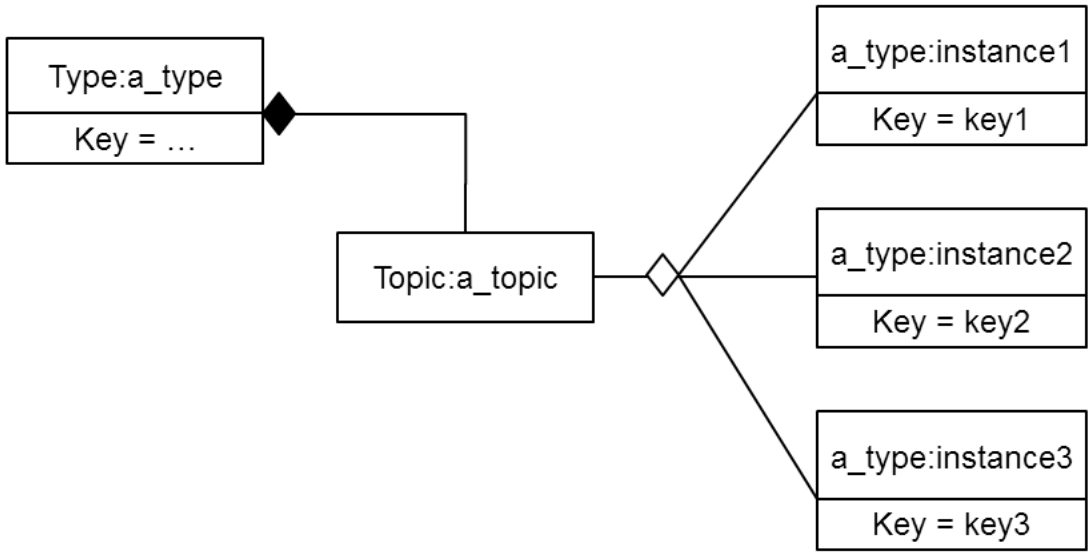
Applications can subscribe to a *Topic* and receive DDS samples for many different instances. Applications can publish DDS samples of one, all, or any number of instances of a *Topic*. Many quality of service parameters actually apply on a *per instance* basis. Keys are also useful for subscribing to a group of related data streams (instances) without pre-knowledge of which data streams (instances) exist at runtime.

For example, just by subscribing to "StockPrices," an application can get values for all of the stocks through a single topic. In addition, the application does not have to subscribe explicitly to any particular stock, so that if a new stock is added, the application will immediately start receiving values for that stock as well.

Many quality of service (QoS) parameters apply on a per-instance basis because each instance is a unique object and therefore has its own lifecycle, owner, and resource limits.

To summarize, the unique values of data being passed using DCPS are called DDS samples. A DDS sample is a combination of a *Topic, an instance,* and the actual *user data of a certain data type*. As seen in Figure 2.1: Relationship of Topics, Keys, and Instances below, a *Topic* identifies data of a single type, ranging from one single instance to a whole collection of instances of that given topic for keyed data types. For more information, see Data Types and DDS Data Samples (Chapter 3 on page 27) and Working with Topics (Chapter 5 on page 215).

Figure 2.1: Relationship of Topics, Keys, and Instances



By using keys, a Topic can identify a collection of data-object instances.

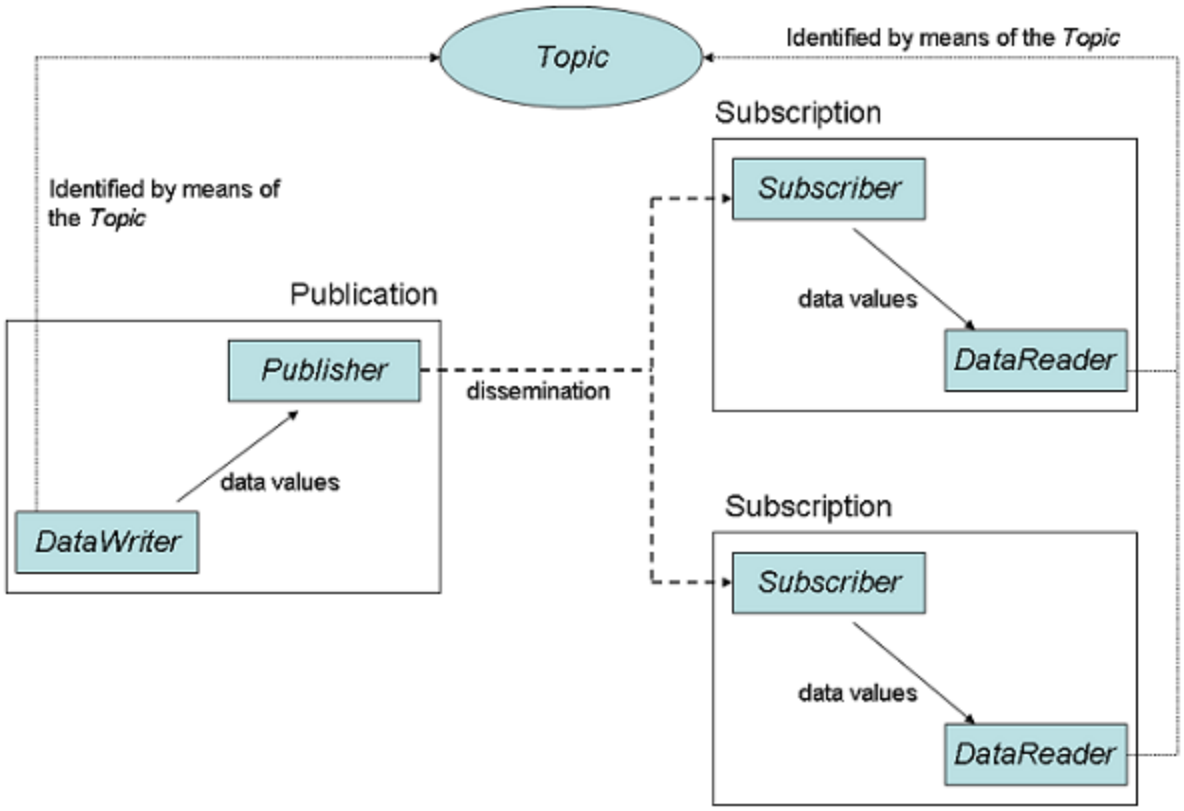
See Chapter 6 Working with Instances on page 256.

2.5 DataWriters/Publishers and DataReaders/Subscribers

In DCPS, applications must use APIs to create entities (objects) in order to establish publish-subscribe communications between each other. The entities and terminology associated with the data itself have been discussed already—*Topics*, keys, instances, DDS samples. This section will introduce the DCPS entities that user code must create to send and receive the data. Note that *Entity* is actually a basic DCPS concept. In object-oriented terms, *Entity* is the base class from which other DCPS classes—*Topic*, *DataWriter*, *DataReader*, *Publisher*, *Subscriber*, *DomainParticipants*—derive. For general information on Entities, see DDS Entities (Chapter 4 on page 165).

The sending side uses objects called *Publishers* and *DataWriters*. The receiving side uses objects called *Subscribers* and *DataReaders*. Figure 2.2: Overview below illustrates the relationship of these objects.

Figure 2.2: Overview



- An application uses *DataWriters* to send data. A *DataWriter* is associated with a single *Topic*. You can have multiple *DataWriters* and *Topics* in a single application. In addition, you can have more than one *DataWriter* for a particular *Topic* in a single application.
- A *Publisher* is the DCPS object responsible for the actual sending of data. *Publishers* own and manage *DataWriters*. A *DataWriter* can only be owned by a single *Publisher* while a *Publisher* can own many *DataWriters*. Thus the same *Publisher* may be sending data for many different *Topics* of

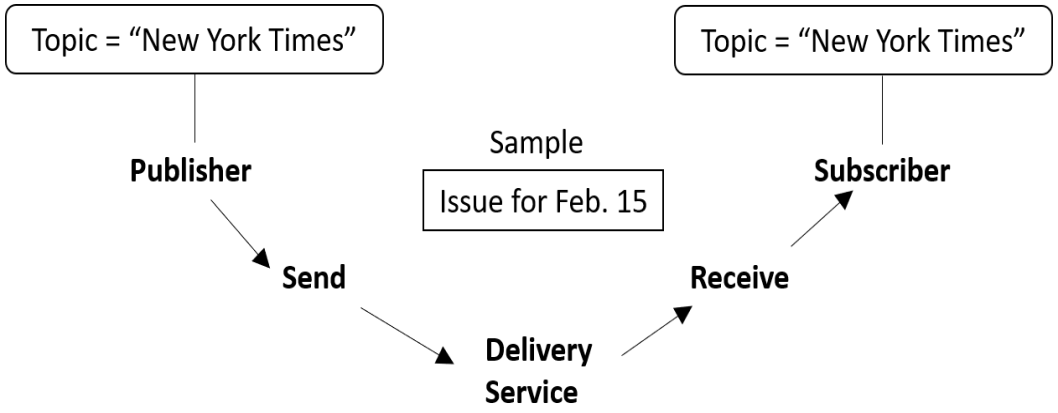
different data types. When user code calls the **write()** method on a *DataWriter*, the DDS data sample is passed to the *Publisher* object which does the actual dissemination of data on the network. For more information, see Sending Data (Chapter 7 on page 269).

- The association between a *DataWriter* and a Publisher is often referred to as a publication although you never create a DCPS object known as a publication.
- An application uses *DataReaders* to access data received over DCPS. A *DataReader* is associated with a single *Topic*. You can have multiple *DataReaders* and *Topics* in a single application. In addition, you can have more than one *DataReader* for a particular *Topic* in a single application.
- A *Subscriber* is the DCPS object responsible for the actual receipt of published data. *Subscribers* own and manage *DataReaders*. A *DataReader* can only be owned by a single *Subscriber* while a *Subscriber* can own many *DataReaders*. Thus the same *Subscriber* may receive data for many different *Topics* of different data types. When data is sent to an application, it is first processed by a *Subscriber;* the DDS data sample is then stored in the appropriate *DataReader*. User code can either register a *listener* to be called when new data arrives or actively poll the *DataReader* for new data using its **read()** and **take()** methods. For more information, see Receiving Data (Chapter 8 on page 481).
- The association between a *DataReader* and a Subscriber is often referred to as a subscription although you never create a DCPS object known as a subscription.

Example:

The publish-subscribe communications model is analogous to that of magazine publications and subscriptions. Think of a publication as a weekly periodical such as *Newsweek*®. The *Topic* is the name of the periodical (in this case the string "Newsweek"). The *type* specifies the format of the information, e.g., a printed magazine. The *user data* is the contents (text and graphics) of each DDS sample (weekly issue). The middleware is the distribution service (usually the US Postal service) that delivers the magazine from where it is created (a printing house) to the individual subscribers (people's homes). This analogy is illustrated in Figure 2.3: An Example of Publish-Subscribe on the next page. Note that by subscribing to a publication, subscribers are requesting current and future DDS samples of that publication (such as once a week in the case of *Newsweek*), so that as new DDS samples are published, they are delivered without having to submit another request for data.

Figure 2.3: An Example of Publish-Subscribe



The publish-subscribe model is analogous to publishing magazines. The Publisher sends DDS samples of a particular Topic to all Subscribers of that Topic. With Newsweek® magazine, the Topic would be "Newsweek." The DDS sample consists of the data (articles and pictures) sent to all Subscribers every week. The middleware (Connext DDS) is the distribution channel: all of the planes, trucks, and people who distribute the weekly issues to the Subscribers.

By default, each DDS sample is propagated individually, independently, and uncorrelated with other DDS samples. However, an application may request that several DDS samples be sent as a coherent set, so that they may be interpreted as such on the receiving side.

2.6 DDS Domains and DomainParticipants

You may have several independent DCPS applications all running on the same set of computers. You may want to isolate one (or more) of those applications so that it isn't affected by the others. To address this issue, DCPS has a concept called *DDS domains*.

DDS domains represent logical, isolated, communication networks. Multiple applications running on the same set of hosts on different DDS domains are completely isolated from each other (even if they are on the same machine). *DataWriters* and *DataReaders* belonging to different DDS domains will never exchange data.

Applications that want to exchange data using DCPS must belong to the same DDS domain. To belong to a DDS domain, DCPS APIs are used to configure and create a *DomainParticipant* with a specific *Domain Index*. DDS domains are differentiated by the *domain index* (an integer value). Applications that have created *DomainParticipants* with the same *domain index* belong to the same DDS domain. *DomainParticipants* own *Topics*, *Publishers,* and *Subscribers,* which in turn owns *DataWriters* and *DataReaders*. Thus all DCPS *Entities* belong to a specific DDS domain.

An application may belong to multiple DDS domains simultaneously by creating multiple *DomainParticipants* with different domain indices. However, *Publishers*/*DataWriters* and *Subscribers*/*DataReaders* only belong to the DDS domain in which they were created.

As mentioned before, multiple DDS domains may be used for application isolation, which is useful when you are testing applications using computers on the same network or even the same computers. By assigning each user different domains, one can guarantee that the data produced by one user's application won't accidentally be received by another. In addition, DDS domains may be a way to scale and construct larger systems that are composed of multi-node subsystems. Each subsystem would use an internal DDS domain for intra-system communications and an external DDS domain to connect to other subsystems.

For more information, see Working with DDS Domains (Chapter 9 on page 595).

2.7 Quality of Service (QoS)

The publish-subscribe approach to distributed communications is a generic mechanism that can be employed by many different types of systems. The DCPS model described here extends the publish-subscribe model to address the needs of real-time, data-critical applications. It provides standardized mechanisms, known as Quality of Service Policies, that allow application developers to configure how communications occur, to limit resources used by the middleware, to detect system incompatibilities and setup error handling routines.

2.7.1 Controlling Behavior with Quality of Service (QoS) Policies

QosPolicies control many aspects of how and when data is distributed between applications. The overall QoS of the DCPS system is made up of the individual QosPolicies for each DCPS *Entity*. There are QosPolicies for *Topic*s, *DataWriters*, *Publishers*, *DataReaders*, *Subscriber*s, and *DomainParticipants*.

On the publishing side, the QoS of each *Topic*, the *Topic*'s *DataWriter*, and the *DataWriter*'s *Publisher* all play a part in controlling how and when DDS samples are sent to the middleware. Similarly, the QoS of the *Topic*, the *Topic*'s *DataReader*, and the *DataReader*'s *Subscriber* control behavior on the subscribing side.

Users will employ QosPolicies to control a variety of behaviors. For example, the DEADLINE policy sets up expectations of how often a *DataReader* expects to see DDS samples. The OWNERSHIP and OWNERSHIP_STRENGTH policy are used together to configure and arbitrate whose data is passed to the *DataReader* when there are multiple *DataWriter*s for the same instance of a *Topic*. The HISTORY policy specifies whether a *DataWriter* should save old data to send to new subscriptions that join the network later. Many other policies exist and they are presented in 4.2 QosPolicies on page 176.

Some QosPolicies represent "contracts" between publications and subscriptions. For communications to take place properly, the QosPolicies set on the *DataWriter* side must be compatible with corresponding policies set on the *DataReader* side.

For example, the RELIABILITY policy is set by the *DataWriter* to state whether it is configured to send data reliably to *DataReaders*. Because it takes additional resources to send data reliably, some *DataWriters* may only support a best-effort level of reliability. This implies that for those *DataWriters*, *Connext DDS* will not spend additional effort to make sure that the data sent is received by *DataReaders* or resend any lost data. However, for certain applications, it could be imperative that their *DataReaders* receive every

piece of data with total reliability. Running a system where the DataWriters have not been configured to support the DataReaders could lead to erratic failures.

To address this issue, and yet keep the publications and subscriptions as decoupled as possible, DCPS provides a way to detect and notify when QosPolicies set by *DataWriters* and *DataReaders* are incompatible. DCPS employs a pattern known as RxO (Requested versus Offered). The *DataReader* sets a "requested" value for a particular QosPolicy. The *DataWriter* sets an "offered" value for that QosPolicy. When *Connext DDS* matches a *DataReader* to a *DataWriter*, QosPolicies are checked to make sure that all requested values can be supported by the offered values.

Note that not all QosPolicies are constrained by the RxO pattern. For example, it does not make sense to compare policies that affect only the *DataWriter* but not the *DataReader* or vice versa.

If the *DataWriter* cannot satisfy the requested QosPolicies of a *DataReader*, *Connext DDS* will not connect the two DDS entities and will notify the applications on each side of the incompatibility if so configured.

For example, a *DataReader* sets its DEADLINE QoS to 4 seconds—that is, the *DataReader* is *requesting* that it receive new data at least every 4 seconds.

In one application, the *DataWriter* sets its DEADLINE QoS to 2 seconds—that is, the *DataWriter* is committing to sending data at least every 2 seconds. This writer can satisfy the request of the reader, and thus, *Connext DDS* will pass the data sent from the writer to the reader.

In another application, the *DataWriter* sets its DEADLINE QoS to 5 seconds. It only commits to sending data at 5 second intervals. This will not satisfy the request of the *DataReader*. *Connext DDS* will flag this incompatibility by calling user-installed listeners in both *DataWriter* and *DataReader* applications and not pass data from the writer to the reader.

For a summary of the QosPolicies supported by *Connext DDS*, see 4.2 QosPolicies on page 176.

2.8 Application Discovery

The DCPS model provides anonymous, transparent, many-to-many communications. Each time an application sends a DDS sample of a particular *Topic*, the middleware distributes the DDS sample to all the applications that want that *Topic*. The publishing application does not need to specify how many applications receive the *Topic*, nor where those applications are located. Similarly, *subscribing applications* do not specify the location of the publications. In addition, new publications and *subscriptions* of the *Topic* can appear at any time, and the middleware will automatically interconnect them.

So how is this all done? Ultimately, in each application for each publication, *Connext DDS* must keep a list of applications that have subscribed to the same *Topic*, nodes on which they are located, and some additional QoS parameters that control how the data is sent. Also, *Connext DDS* must keep a list of applications and publications for each of the *Topics* to which the application has subscribed.

Propagation of this information (the existence of publications and subscriptions and associated QoS) between applications by *Connext DDS* is known as the *discovery* process. While the DDS (DCPS) standard does not specify how discovery occurs, *Connext DDS* uses a standard protocol RTPS for both discovery and formatting on-the-wire packets.

When a *DomainParticipant* is created, *Connext DDS* sends out packets on the network to announce its existence. When an application finds out that another application belongs to the same DDS domain, then it will exchange information about its existing publications and subscriptions and associated QoS with the other application. As new *DataWriters* and *DataReaders* are created, this information is sent to known applications.

The *Discovery* process is entirely configurable by the user and is discussed extensively in Discovery (Chapter 15 on page 758).

Part 2: Core Concepts

This section includes:

- Data Types and DDS Data Samples (Chapter 3 on page 27)
- DDS Entities (Chapter 4 on page 165)
- Working with Topics (Chapter 5 on page 215)
- Working with Instances (Chapter 6 on page 256)
- Sending Data (Chapter 7 on page 269)
- Receiving Data (Chapter 8 on page 481)
- Working with DDS Domains (Chapter 9 on page 595)
- Building Applications (Chapter 10 on page 674)

Chapter 3 Data Types and DDS Data Samples

Note: Information in this chapter is complemented by information in the RTI Connext DDS Core Libraries Extensible Types Guide.

How data is stored or laid out in memory can vary from language to language, compiler to compiler, operating system to operating system, and processor to processor. This combination of language/compiler/operating system/processor is called a *platform*. Any modern middleware must be able to take data from one specific platform (say C/gcc 7.3/Linux/Arm v8) and transparently deliver it to another (for example, Java/JDK 11/Windows/Pentium). This process is commonly called serialization/deserialization, or marshalling/demarshalling.

Messaging products have typically taken one of two approaches to this problem:

1. **Do nothing.** Messages consist only of opaque streams of bytes. The JMS *BytesMessage* is an example of this approach.
2. **Send everything, every time.** Self-describing messages are at the opposite extreme, embedding full reflective information, including data types and field names, with each message. The JMS *MapMessage* and the messages in TIBCO Rendezvous are examples of this approach.

The "do nothing" approach is lightweight on its surface but forces you, the user of the middleware API, to consider all data encoding, alignment, and padding issues. The "send everything" alternative results in large amounts of redundant information being sent with every packet, impacting performance.

Connext DDS takes an intermediate approach. Just as objects in your application program belong to some data type, DDS data samples sent on the same *Connext DDS* topic share a data type. This type defines the fields that exist in the DDS data samples and what their constituent types are. The middleware stores and propagates this meta-information separately from the individual DDS data

samples, allowing it to propagate DDS samples efficiently while handling byte ordering and alignment issues for you.

To publish and/or subscribe to data with *Connext DDS*, you will carry out the following steps:

1. Select a type to describe your data.

   You have a number of choices. You can choose one of these options, or you can mix and match them.

   - Use a built-in type provided by the middleware.

     This option may be sufficient if your data typing needs are very simple. If your data is highly structured, or you need to be able to examine fields within that data for filtering or other purposes, this option may not be appropriate. The built-in types are described in 3.2 Built-in Data Types on page 38.

   - Use the *RTI Code Generator* to define a type at compile-time using a language-independent description language.

     Code generation offers two strong benefits not available with dynamic type definition: (1) it allows you to share type definitions across programming languages, and (2) because the structure of the type is known at compile time, it provides rigorous static type safety.

     The *RTI Code Generator* accepts input in the following formats:

     - **OMG IDL.** This format is a standardized component of the DDS specification. It describes data types with a C++-like syntax. A link to the latest specification can be found here: https://www.omg.org/spec/IDL. This format is described in 3.3 Creating User Data Types with IDL on page 75.
     - **XML in a DDS-specific format.** This XML format is terser, and therefore easier to read and write by hand, than an XSD file. It offers the general benefits of XML-extensibility and ease of integration, while fully supporting DDS-specific data types and concepts. A link to the latest specification, including a description of the XML format, can be found here: https://www.omg.org/spec/DDS-XTypes/. This format is described in 3.4 Creating User Data Types with Extensible Markup Language (XML) on page 120.
     - **XSD format.** You can describe data types with XML schemas (XSD). A link to the latest specification, including a description of the XSD format, can be found here: https://www.omg.org/spec/DDS-XTypes/. This format is described in 3.5 Creating User Data Types with XML Schemas (XSD) on page 131

   - Define a type programmatically at run time.

     This method may be appropriate for applications with dynamic data description needs: applications for which types change frequently or cannot be known ahead of time. It is described in 3.8.2 Defining New Types on page 154.

2. Register your type with a logical name.

   If you've chosen to use a built-in type instead of defining your own, you can omit this step; the middleware pre-registers the built-in types for you.

   This step is described in the 3.8.2 Defining New Types on page 154.
3. Create a *Topic* using the type name you previously registered.

   If you've chosen to use a built-in type instead of defining your own, you will use the API constant corresponding to that type's name.

   Creating and working with *Topics* is discussed in Working with Topics (Chapter 5 on page 215).
4. Create one or more *DataWriters* to publish your data and one or more *DataReaders* to subscribe to it.

   The concrete types of these objects depend on the concrete data type you've selected, in order to provide you with a measure of type safety.

   Creating and working with *DataWriters* and *DataReaders* are described in Sending Data (Chapter 7 on page 269) and Receiving Data (Chapter 8 on page 481), respectively.

Whether publishing or subscribing to data, you will need to know how to create and delete DDS data samples and how to get and set their fields. These tasks are described in 3.9 Working with DDS Data Samples on page 158.

3.1 Introduction to the Type System

A *user data type* is any custom type that your application defines for use with *Connext DDS*. It may be a structure, a union, a value type, an enumeration, or a typedef (or language equivalents).

Your application can have any number of user data types. They can be composed of any of the primitive data types listed below or of other user data types.

Only structures, unions, and value types may be read and written directly by *Connext DDS*; enums, typedefs, and primitive types must be contained within a structure, union, or value type. In order for a *DataReader* and *DataWriter* to communicate with each other, the data types associated with their respective *Topic* definitions must be consistent according to the Type-Consistency Enforcement rules configured using the TypeConsistencyEnforcementQosPolicy on the DataReaderQos (see 8.6.6 TYPE_CONSISTENCY_ENFORCEMENT QosPolicy on page 589).

- octet, char, wchar
- short, unsigned short
- long, unsigned long
- long long, unsigned long long

- float
- double, long double
- boolean
- enum (with or without explicit values)
- bounded and unbounded string and wstring

The following type-building constructs are also supported:

- module (also called a *package* or *namespace*)
- pointer
- array of primitive or user type elements
- bounded/unbounded sequence of elements[1]—a *sequence* is a variable-length ordered collection, such as a vector or list
- typedef
- union
- struct, a complex type that supports inheritance and other object-oriented features
- value type, a deprecated type that is treated identically to a struct for backward compatibility with existing type definitions

To use a data type with *Connext DDS*, you must define that type in a way the middleware understands and then register the type with the middleware. These steps allow *Connext DDS* to serialize, deserialize, and otherwise operate on specific types. They will be described in detail in the following sections.

3.1.1 Sequences

A sequence contains an ordered collection of elements that are all of the same type. The operations supported in the sequence are documented in the API Reference HTML documentation, which is available for all supported programming languages (select **Modules, RTI Connext DDS API Reference, Infrastructure Module, Sequence Support**).

Java sequences implement the java.util.List interface from the standard Collections framework.

In the Modern C++ API, a sequence of type T maps to the type **std::vector<T>**, or to a type with a similar interface, depending on the options and whether it is bounded or unbounded. See 3.3.4 Translations for IDL Types on page 79.

[1]Sequences of sequences are not supported directly. To work around this constraint, typedef the inner sequence and form a sequence of that new type.

Elements in a sequence are accessed with their index, just like elements in an array. Indices start at zero in all APIs except Ada. In Ada, indices start at 1. Unlike arrays, however, sequences can grow in size. A sequence has two sizes associated with it: a physical size (the "maximum") and a logical size (the "length"). The physical size indicates how many elements are currently allocated by the sequence to hold; the logical size indicates how many valid elements the sequence actually holds. The length can vary from zero up to the maximum. Elements cannot be accessed at indices beyond the current length.

A sequence may be declared as bounded or unbounded. A sequence's "bound" is the maximum number of elements that the sequence can contain at any one time. A finite bound is very important because it allows *Connext DDS* to preallocate buffers to hold serialized and deserialized samples of your types; these buffers are used when communicating with other nodes in your distributed system. If a sequence has no bound, *Connext DDS* will not know how large to allocate its buffers and will therefore have to allocate them on the fly as individual samples are read and written—impacting the latency and determinism of your application.

By default, any unbounded sequences found in an IDL file will be given a default bound of 100 elements. This default value can be overwritten using the *RTI Code Generator's* **-sequenceSize** command-line argument (see the RTI Code Generator User's Manual).

When using the C, C++, Java, or .NET APIs, you can change the default behavior and use truly unbounded sequences by using RTI Code Generator's **-unboundedSupport** command-line argument. When using this option, the generated code will deserialize incoming samples as follows:

- First, it will release previous memory associated with the unbounded sequences. The memory associated with an unbounded member is not released until the sample containing the member is reused.
- Second, it will allocate new memory to accommodate the actual size of the unbounded sequences.

To configure unbounded support for code generated with rtiddsgen -unboundedSupport or for DynamicDataWriters/DynamicDataReaders for Topics of types that contain unbounded sequences:

1. Use these threshold QoS properties:
   - **dds.data_writer.history.memory_manager.fast_pool.pool_buffer_max_size** on the *DataWriter*
   - **dds.data_reader.history.memory_manager.fast_pool.pool_buffer_max_size** on the *DataReader*
2. Set the QoS value **reader_resource_limits.dynamically_allocate_fragmented_samples** on the *DataReader* to true.
3. For the Java API, also set these properties accordingly for the Java serialization buffer:
   - **dds.data_writer.history.memory_manager.java_stream.min_size**
   - **dds.data_writer.history.memory_manager.java_stream.trim_to_size**

- **dds.data_reader.history.memory_manager.java_stream.min_size**
- **dds.data_reader.history.memory_manager.java_stream.trim_to_size**

See also:

- 3.2.7.2 Unbounded Built-in Types on page 73
- 22.1.3 Writer-Side Memory Management when Using Java on page 923
- 22.2.2 Reader-Side Memory Management when Using Java on page 927
- 3.10 Data Sample Serialization Limits on page 164

3.1.2 Strings and Wide Strings

Connext DDS supports both strings consisting of single-byte characters (the IDL string type) and strings consisting of wide characters (IDL wstring). The wide characters supported by *Connext DDS* are large enough to store two-byte Unicode/UTF16 characters.

Like sequences, strings may be bounded or unbounded. A string's "bound" is its maximum length (not counting the trailing NULL character in C and C++).

In the Modern C++ API strings map to **std::string** or to a type with a similar interface, depending on the options. See Table 3.8 Specifying Data Types in IDL for the Modern C++ API in 3.3.4 Translations for IDL Types on page 79.

In C and Traditional C++, strings are mapped to char*. Optionally, the mapping in Traditional C++ can be changed to **std::string** by generating code with the option **-useStdString**.

By default, any unbounded string found in an IDL file will be given a default bound of 255 elements. This default value can be overwritten using the *RTI Code Generator's* **-stringSize** command-line argument (see the RTI Code Generator User's Manual).

When using the C, C++, Java, or .NET APIs, you can change the default behavior and use truly unbounded strings by using *Code Generator's* **-unboundedSupport** command-line argument. When using this option, the generated code will deserialize incoming samples as follows:

- First, it will release previous memory associated with the unbounded strings. The memory associated with an unbounded member is not released until the sample containing the member is reused.
- Second, it will allocate new memory to accommodate the actual size of the unbounded strings.

To configure unbounded support for code generated with rtiddsgen -unboundedSupport or for DynamicDataWriters/DynamicDataReaders for Topics of types that contain unbounded strings or wide strings:

1. Use these threshold QoS properties:
   - **dds.data_writer.history.memory_manager.fast_pool.pool_buffer_max_size** on the *DataWriter*
   - **dds.data_reader.history.memory_manager.fast_pool.pool_buffer_max_size** on the *DataReader*
2. Set the QoS value **reader_resource_limits.dynamically_allocate_fragmented_samples** on the *DataReader* to true.
3. For the Java API, also set these properties accordingly for the Java serialization buffer:
   - **dds.data_writer.history.memory_manager.java_stream.min_size**
   - **dds.data_writer.history.memory_manager.java_stream.trim_to_size**
   - **dds.data_reader.history.memory_manager.java_stream.min_size**
   - **dds.data_reader.history.memory_manager.java_stream.trim_to_size**

See also:

- 3.2.7.2 Unbounded Built-in Types on page 73
- 22.1.3 Writer-Side Memory Management when Using Java on page 923
- 22.2.2 Reader-Side Memory Management when Using Java on page 927
- 3.10 Data Sample Serialization Limits on page 164

3.1.2.1 IDL String Encoding

The "Extensible and Dynamic Topic Types for DDS specification" (https://www.omg.org/spec/DDS-XTypes/) standardizes the default encoding for strings to UTF-8. This encoding shall be used as the wire format. Language bindings may use the representation that is most natural in that particular language. If this representation is different than UTF-8, the language binding shall manage the transformation to/from the UTF-8 wire representation.

For example, in Java, IDL strings are mapped to Java String, which represents a string in the UTF-16 format. *Connext DDS* handles the conversion to/from UTF-8 when serializing/deserializing strings in Java.

As an extension, *Connext DDS* offers ISO_8859_1 as an alternative string wire encoding.

This section describes the encoding for IDL strings across different languages in *Connext DDS* and how to configure that encoding.

- C, Traditional C++

  IDL strings are mapped to a NULL-terminated array of DDS_Char (char*). Users are responsible for using the right character encoding (UTF-8 or ISO_8859_1) when populating the string values. This applies to all generated code, DynamicData, and Built-in data types. The middleware does not transform from the language binding encoding to the wire encoding.

- Modern C++

  IDL strings are mapped to **std::string**. **std::string**, which contains any sequence of bytes. Users are responsible for using the right character encoding (UTF-8 or ISO_8859_1) when populating the string values. The middleware does not transform from the language binding encoding to the wire encoding. This applies to all generated code, DynamicData, and Built-in types.

- Ada

  IDL strings are mapped to DDS.String, which is equivalent to a NULL-terminated array of DDS_Char (char*). Users are responsible for using the right character encoding (UTF-8 or ISO_8859_1) when populating the string values. The middleware does not transform from the language binding encoding to the wire encoding. This applies to all generated code and Built-in types.

- Java

  IDL strings are mapped to Java String, which represents a string in the UTF-16 format. *Connext DDS* handles the conversion to/from UTF-8/ISO_8859_1 when serializing/deserializing strings. For generated code and Built-in data types, you can configure the IDL wire string encoding on a per-endpoint basis using the following properties:
  - **dds.data_reader.type_support.cdr_string_encoding_kind**
  - **dds.data_writer.type_support.cdr_string_encoding_kind**

  These properties can be set at the endpoint level or the participant level. The only values currently supported are UTF-8 and ISO-8859-1. By default, the wire character encoding is assumed to be UTF-8.

  For DynamicData, the user can configure the IDL wire string encoding by setting the value of **string_character_encoding** in DynamicDataProperty_t. The following values are supported:
  - StandardCharsets.ISO_8859_1
  - StandardCharsets.UTF_8 (default)

- .NET

  IDL strings are mapped to .NET **System::String** in C++/CLI and **string** in C#. The conversion to/-from UTF-8/ISO_8859_1 when serializing/deserializing strings is automatically handled by *Connext*

DDS. For generated code and built-in data types, you can configure the IDL wire string encoding on a per-endpoint basis using the following properties:

- **dds.data_reader.type_support.cdr_string_encoding_kind**
- **dds.data_writer.type_support.cdr_string_encoding_kind**

These properties can be set at the endpoint level or the participant level. The only values currently supported are UTF-8 and ISO-8859-1. By default, the wire character encoding is assumed to be UTF-8.

For DynamicData, you can configure the IDL wire string encoding by setting the value of **string_character_encoding** in DynamicDataProperty_t. The following values are supported:

- StringEncodingKind::UTF_8 (default)
- StringEncodingKind::ISO_8859_1

3.1.2.1.1 Unicode Normalization when Using UTF-8 Encoding

Connext DDS does not normalize the content of the IDL string fields when they are serialized and sent on the wire. It is responsibility of the application to do that when needed.

Because the content of the string fields is not guaranteed to be normalized, by default, *Connext DDS* normalizes the UTF-8 IDL string values and the literals they are compared with in the filter expression and/or filter parameters before the filtering evaluation occurs. The normalization affects the following features:

- ContentFilteredTopics (see 5.4 ContentFilteredTopics on page 227)
- Query conditions (see 4.6.7 ReadConditions and QueryConditions on page 209)
- TopicQueries (see Chapter 24 Topic Queries on page 962)
- MultiChannel *DataWriters* (see Chapter 20 Multi-channel DataWriters on page 888)

You can turn off filtering normalization by using the *DomainParticipant's* Property Qos property **dds.domain_participant.filtering_unicode_normalization** (see 5.4.9 Unicode Normalization on page 246).

3.1.2.1.2 Filtering Character Encoding

The following filtering features use UTF-8 character encoding by default for IDL strings:

- ContentFilteredTopics (see 5.4 ContentFilteredTopics on page 227)
- Query conditions (see 4.6.7 ReadConditions and QueryConditions on page 209)
- TopicQueries (see Chapter 24 Topic Queries on page 962)
- MultiChannel *DataWriters* (see Chapter 20 Multi-channel DataWriters on page 888)

If the encoding of the IDL strings is ISO 8859-1, change the default filtering behavior by setting the *DomainParticipant's* Property Qos property **dds.domain_participant.filtering_character_encoding** to ISO-8859-1. For additional information about this property, see 5.4.8 Character Encoding on page 246.

3.1.2.2 IDL Wide Strings Encoding

The "Extensible and Dynamic Topic Types for DDS specification" (https://www.omg.org/spec/DDS-XTypes/) standardizes the default encoding for wide strings to UTF-16. This encoding shall be used as the wire format.

When the data representation is Extended CDR version 1, wide-string characters have a size of 4 bytes on the wire with UTF-16 encoding. When the data representation is Extended CDR version 2, wide-string characters have a size of 2 bytes on the wire with UTF-16 encoding.

Language bindings may use the representation that is most natural in that particular language. If this representation is different from UTF-16, the language binding shall manage the transformation to/from the UTF-16 wire representation.

- C, Traditional C++

  IDL wide strings are mapped to a NULL-terminated array of DDS_Wchar (DDS_Wchar*). DDS_WChar is an unsigned 2-byte integer. Users are responsible for using the right character encoding (UTF-16) when populating the wide-string values. This applies to all generated code, DynamicData, and Built-in data types. *Connext DDS* does not transform from the language binding encoding to the wire encoding.
- Modern C++

  IDL wide strings are mapped to **std::wstring**, which contains a sequence of wchar_t. This applies to all generated code, DynamicData, and Built-in data types. When serializing/deserializing, *Connext DDS* assumes that a wchar_t contains a code unit in UTF-16 encoding, even if the size of wchar_t is 4 bytes.
- Ada

  IDL wide strings are mapped to Standard.DDS.Wide_String, which is a NULL-terminated array of Standard.Wide_Character with UTF-16 encoding. This applies to all generated code and Built-in data types.
- Java

  IDL wide strings are mapped to Java String, which represents a string in the UTF-16 format. This applies to all generated code, DynamicData, and Built-in data types.
- .NET

IDL wide strings are mapped to **System::String** in C++/CLI and **string** in C#. These types use the UTF-16 character encoding form. This applies to all generated code, DynamicData, and Built-in data types.

3.1.2.2.1 Unicode Normalization when Using UTF-16 Encoding

Connext DDS does not normalize the content of the IDL wstring fields when they are serialized and sent on the wire. It is responsibility of the application to do that when needed.

Unlike with IDL strings, *Connext DDS* does not normalize the UTF-16 strings used by the filtering operations, either.

3.1.3 Introduction to TypeCode

Type schemas—the names and definitions of a type and its fields—are represented by TypeCode objects (known as DynamicType in the Modern C++ API). A type code value consists of a type code kind (see the **TCKind** enumeration below) and a list of members. For compound types like structs and arrays, this list will recursively include one or more type code values.

```
enum TCKind {
       TK_NULL,
       TK_SHORT,
       TK_LONG,
       TK_USHORT,
       TK_ULONG,
       TK_FLOAT,
       TK_DOUBLE,
       TK_BOOLEAN,
       TK_CHAR,
       TK_OCTET,
       TK_STRUCT,
       TK_UNION
       TK_ENUM,
       TK_STRING,
       TK_SEQUENCE,
       TK_ARRAY,
       TK_ALIAS,
       TK_LONGLONG,
       TK_ULONGLONG,
       TK_LONGDOUBLE,
       TK_WCHAR,
       TK_WSTRING,
       TK_VALUE
}
```

Type codes unambiguously match type representations and provide a more reliable test than comparing the string type names.

The **TypeCode** class, modeled after the corresponding CORBA API, provides access to type-code information. For details on the available operations for the **TypeCode** class, see the API Reference HTML documentation, which is available for all supported programming languages (select **Modules, RTI Connext**

DDS API Reference, Topic Module, Type Code Support or, for the Modern C++ API select **Modules, RTI Connext DDS API Reference, Infrastructure Module, DynamicType and DynamicData**).

Note: Type-code support must be enabled if you are going to use 5.4 ContentFilteredTopics on page 227 with the default SQL filter. You may disable type codes and use a custom filter, as described in 5.4.3 Creating ContentFilteredTopics on page 229.

3.1.3.1 Sending Type Information on the Network

In addition to being used locally, the type information of a *Topic* is published automatically during discovery as part of the built-in topics for publications and subscriptions. See 18.2 Built-in DataReaders on page 826. This allows applications to publish or subscribe to topics of arbitrary types. This functionality is useful for generic system monitoring tools like the *rtiddsspy* debug tool (see the API Reference HTML documentation).

Earlier versions of *Connext DDS* (4.5f and lower) used serialized TypeCodes as the wire representation to communicate types over the network.

The OMG 'Extensible and Dynamic Topic Types for DDS' specification, version 1.3 uses TypeObjects as the wire representation. Types are propagated by serializing the associated TypeObject representation. *Connext DDS* 5.x and higher supports TypeObjects as the wire representation. To maintain backward compatibility with previous releases, *Connext DDS* still supports propagation of TypeCodes; however, support for this feature may be discontinued in future releases.

If your data type has an especially complex type code, you may need to increase the value of the **type_code_max_serialized_length**, **type_object_max_serialized_length**, and **type_object_max_deserialized_length** fields in the *DomainParticipant's* 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649. Or, to prevent the propagation of type information altogether, you can set these values to zero (0). Be aware that some features of monitoring tools, as well as some features of the middleware itself (such as *ContentFilteredTopic*s) will not work correctly if you disable type information propagation.

For additional information on TypeCode versus TypeObject as wire representation, as well as resource limits to configure the propagation, see *Type Representation*, in the RTI Connext DDS Core Libraries Extensible Types Guide.

3.2 Built-in Data Types

Connext DDS provides a set of standard types that are built into the middleware. These types can be used immediately; they do not require you to write IDL, use *RTI Code Generator* (*rtiddsgen*) (see 3.6 Using RTI Code Generator (rtiddsgen) on page 152), or use the dynamic type API (see 3.2.7 Managing Memory for Built-in Types on page 69).

The supported built-in types are **String**, **KeyedString**, **Octets**, and **KeyedOctets**. (The latter two types are called **Bytes** and **KeyedBytes**, respectively, on Java and .NET platforms.)

The built-in type API is located under the DDS namespace in Traditional C++ and .NET. For Java, the API is contained inside the package **com.rti.dds.type.builtin**. In the Modern C++ API they are located in the dds::core namespace.

Built-in data types are discussed in the following sections.

3.2.1 Registering Built-in Types

By default, the built-in types are automatically registered when a *DomainParticipant* is created. You can change this behavior by setting the *DomainParticipant's* **dds.builtin_type.auto_register** property to 0 (false) using the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.

3.2.2 Creating Topics for Built-in Types

To create a topic for a built-in type, just use the standard *DomainParticipant* operations, **create_topic()** or **create_topic_with_profile()** (see 5.1.1 Creating Topics on page 217); for the **type_name** parameter, use the value returned by the **get_type_name()** operation, listed below for each API.

Note: In the following examples, you will see the sentinel "<*BuiltinType*>."
For C and Traditional C++: <*BuiltinType*> = String, KeyedString, Octets or KeyedOctets
For Java and .NET[1]: <*BuiltinType*> = String, KeyedString, Bytes or KeyedBytes

C API:

```
const char* DDS_<BuiltinType>TypeSupport_get_type_name();
```

Traditional C++ API with namespace:

```
const char* DDS::<BuiltinType>TypeSupport::get_type_name();
```

Traditional C++ API without namespace:

```
const char* DDS<BuiltinType>TypeSupport::get_type_name();
```

C++/CLI API:

```
System::String^ DDS:<BuiltinType>TypeSupport::get_type_name();
```

C# API:

```
System.String DDS.<BuiltinType>TypeSupport.get_type_name();
```

Java API:

```
String
com.rti.dds.type.builtin.<BuiltinType>TypeSupport.get_type_name();
```

(This step is not required in the Modern C++ API)

[1]RTI Connext DDS .NET language binding is currently supported for C# and C++/CLI.

3.2.2.1 Topic Creation Examples

For simplicity, error handling is not shown in the following examples.

C Example:

```
DDS_Topic * topic = NULL;
/* Create a builtin type Topic */
topic = DDS_DomainParticipant_create_topic(
        participant, "StringTopic",
        DDS_StringTypeSupport_get_type_name(),
        &DDS_TOPIC_QOS_DEFAULT, NULL,
        DDS_STATUS_MASK_NONE);
```

Traditional C++ Example with namespaces:[1]

```
using namespace DDS;
 ...
/* Create a String builtin type Topic */
Topic * topic = participant->create_topic(
        "StringTopic", StringTypeSupport::get_type_name(),
        DDS_TOPIC_QOS_DEFAULT, NULL, DDS_STATUS_MASK_NONE);
```

Modern C++ Example:

```
dds::topic::Topic<dds::core::StringTopicType> topic(participant, "StringTopic");
```

C++/CLI Example:

```
using namespace DDS;
...
/* Create a builtin type Topic */
Topic^ topic = participant->create_topic(
        "StringTopic", StringTypeSupport::get_type_name(),
         DomainParticipant::TOPIC_QOS_DEFAULT,
         nullptr, StatusMask::STATUS_MASK_NONE);
```

C# Example:

```
using namespace DDS;
... /*
Create a builtin type Topic */
Topic topic = participant.create_topic(
                "StringTopic",  StringTypeSupport.get_type_name(),
                 DomainParticipant.TOPIC_QOS_DEFAULT,
                 null, StatusMask.STATUS_MASK_NONE);
```

[1]This example uses C++ namespaces. If you're not using namespaces in your own code, prefix the name of each DDS class with 'DDS.' For example, DDS::StringDataWriter becomes DDSStringDataWriter.

Java Example:

```
import com.rti.dds.type.builtin.*;
...
/* Create a builtin type Topic */
Topic topic = participant.create_topic(
"StringTopic", StringTypeSupport.get_type_name(),
                DomainParticipant.TOPIC_QOS_DEFAULT,
                null, StatusKind.STATUS_MASK_NONE);
```

3.2.3 String Built-in Type

The String built-in type is represented by a NULL-terminated character array (char *) in C and C++ and an immutable String object in Java and .NET[1]. This type can be used to publish and subscribe to a single string.

3.2.3.1 Creating and Deleting Strings

In C and C++, *Connext DDS* provides a set of operations to create (**DDS::String_alloc()**), destroy (**DDS::String_free()**), and clone strings (**DDS::String_dup()**). Select **Modules, RTI Connext DDS API Reference, Infrastructure Module, String support** in the API Reference HTML documentation, which is available for all supported programming languages.

Memory Considerations in Copy Operations:

When the read/take operations that take a sequence of strings as a parameter are used in copy mode, *Connext DDS* allocates the memory for the string elements in the sequence if they are initialized to NULL.

If the elements are not initialized to NULL, the behavior depends on the language:

- In Java and .NET, the memory associated with the elements is reallocated with every DDS sample, because strings are immutable objects.
- In C and C++, the memory associated with the elements must be large enough to hold the received data. Insufficient memory may result in crashes.

When **take_next_sample()** and **read_next_sample()** are called in C and C++, you must make sure that the input string has enough memory to hold the received data. Insufficient memory may result in crashes.

3.2.3.2 String DataWriter

The string *DataWriter* API matches the standard *DataWriter* API (see 7.3.7 Using a Type-Specific DataWriter (FooDataWriter) on page 307). There are no extensions.

[1] *Connext DDS* .NET language binding is currently supported for C# and C++/CLI.

The following examples show how to write simple strings with a string built-in type *DataWriter*. For simplicity, error handling is not shown.

C Example:

```
DDS_StringDataWriter * stringWriter = ... ;
DDS_ReturnCode_t retCode; char * str = NULL;
/* Write some data */
retCode = DDS_StringDataWriter_write(
       stringWriter, "Hello World!", &DDS_HANDLE_NIL);
str = DDS_String_dup("Hello World!");
retCode = DDS_StringDataWriter_write(
       stringWriter, str, &DDS_HANDLE_NIL);
DDS_String_free(str);
```

Traditional C++ Example with namespaces:[1]

```
#include "ndds/ndds_namespace_cpp.h"
using namespace DDS;
...
StringDataWriter * stringWriter = ... ;
/* Write some data */
ReturnCode_t retCode = stringWriter->write(
       "Hello World!", HANDLE_NIL);
char * str = DDS::String_dup("Hello World!");
retCode = stringWriter->write(str, HANDLE_NIL);
DDS::String_free(str);
```

Modern C++ Example:

```
dds::pub::DataWriter<dds::core::StringTopicType> string_writer(
       participant, string_topic);
string_writer.write("Hello World!");
dds::core::string str = "Hello World!";
string_writer.write(str);
```

C++/CLI Example:

```
using namespace System;
using namespace DDS;
...
StringDataWriter^ stringWriter = ... ;
/* Write some data */
stringWriter->write(
       "Hello World!", InstanceHandle_t::HANDLE_NIL);
String^ str = "Hello World!";
stringWriter->write(
       str, InstanceHandle_t::HANDLE_NIL);
```

[1]This example uses C++ namespaces. If you're not using namespaces in your own code, prefix the name of each DDS class with 'DDS.' For example, DDS::StringDataWriter becomes DDSStringDataWriter.

C# Example:

```
using System;
using DDS;
...
StringDataWriter stringWriter = ... ;
/* Write some data */
stringWriter.write(
       "Hello World!", InstanceHandle_t.HANDLE_NIL);
String str = "Hello World!";
stringWriter.write(
       str, InstanceHandle_t.HANDLE_NIL);
```

Java Example:

```
import com.rti.dds.publication.*;
import com.rti.dds.type.builtin.*;
import com.rti.dds.infrastructure.*;
...
StringDataWriter stringWriter = ... ;
/* Write some data */
stringWriter.write(
       "Hello World!", InstanceHandle_t.HANDLE_NIL);
String str = "Hello World!";
stringWriter.write(
       str, InstanceHandle_t.HANDLE_NIL);
```

3.2.3.3 String DataReader

The string *DataReader* API matches the standard *DataReader* API (see 8.4.1 Using a Type-Specific DataReader (FooDataReader) on page 548). There are no extensions.

The following examples show how to read simple strings with a string built-in type *DataReader*. For simplicity, error handling is not shown.

C Example:

```
struct DDS_StringSeq dataSeq =
       DDS_SEQUENCE_INITIALIZER;
struct DDS_SampleInfoSeq infoSeq =
       DDS_SEQUENCE_INITIALIZER;
DDS_StringDataReader * stringReader = ... ;
DDS_ReturnCode_t retCode;
int i;
/* Take and print the data */
retCode = DDS_StringDataReader_take(
       stringReader, &dataSeq,
        &infoSeq, DDS_LENGTH_UNLIMITED,
        DDS_ANY_SAMPLE_STATE,
        DDS_ANY_VIEW_STATE,
        DDS_ANY_INSTANCE_STATE);
for (i = 0; i < DDS_StringSeq_get_length(&data_seq);
     ++i) {
       if (DDS_SampleInfoSeq_get_reference(
           &info_seq, i)->valid_data) {
               DDS_StringTypeSupport_print_data(
               DDS_StringSeq_get(&data_seq, i));
       }
}
/* Return loan */
retCode = DDS_StringDataReader_return_loan(
       stringReader, &data_seq, &info_seq);
```

Traditional C++ Example with namespaces:[1]

```
#include "ndds/ndds_namespace_cpp.h"
using namespace DDS;
...
StringSeq dataSeq;
SampleInfoSeq infoSeq;
StringDataReader * stringReader = ... ;
/* Take a print the data */
ReturnCode_t retCode = stringReader->take(
                        dataSeq, infoSeq,
                         LENGTH_UNLIMITED,
                         ANY_SAMPLE_STATE,
                         ANY_VIEW_STATE,
                         ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
       if (infoSeq[i].valid_data) {
           StringTypeSupport::print_data(dataSeq[i]);
       }
}
/* Return loan */
```

[1]This example uses C++ namespaces. If you're not using namespaces in your own code, prefix the name of each DDS class with 'DDS.' For example, DDS::StringDataWriter becomes DDSStringDataWriter.

```
retCode = stringReader->return_loan(
       dataSeq, infoSeq);
```

Modern C++ Example:

```
using namespace dds::core;
using namespace dds::sub;
DataReader<StringTopicType> string_reader(
       participant, string_topic);
LoanedSamples<StringTopicType> samples =
       string_reader.take();
for (auto sample : samples) {
       if (sample.info().valid()) {
           std::cout << sample.data() << std::endl;
       }
}
```

C++/CLI Example:

```
using namespace System;
using namespace DDS;
...
StringSeq^ dataSeq = gcnew StringSeq();
SampleInfoSeq^ infoSeq = gcnew SampleInfoSeq();
StringDataReader^ stringReader = ... ;
/* Take and print the data */
stringReader->take(
       dataSeq, infoSeq,
       ResourceLimitsQosPolicy::LENGTH_UNLIMITED,
       SampleStateKind::ANY_SAMPLE_STATE,
       ViewStateKind::ANY_VIEW_STATE,
       InstanceStateKind::ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
       if (infoSeq->get_at(i)->valid_data) {
               StringTypeSupport::print_data(
                       dataSeq->get_at(i));
       }
}
/* Return loan */
stringReader->return_loan(dataSeq, infoSeq);
```

C# Example:

```
using System;
using DDS;
...
StringSeq dataSeq = new StringSeq();
SampleInfoSeq infoSeq = new SampleInfoSeq();
StringDataReader stringReader = ... ;
/* Take and print the data */
stringReader.take(
       dataSeq, infoSeq,
       ResourceLimitsQosPolicy.LENGTH_UNLIMITED,
       SampleStateKind.ANY_SAMPLE_STATE,
       ViewStateKind.ANY_VIEW_STATE,
       InstanceStateKind.ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
       if (infoSeq.get_at(i)).valid_data) {
               StringTypeSupport.print_data(
                       dataSeq.get_at(i));
       }
}
```

Java Example:

```
import com.rti.dds.infrastructure.*;
import com.rti.dds.subscription.*;
import com.rti.dds.type.builtin.*;
...
StringSeq dataSeq = new StringSeq();
SampleInfoSeq infoSeq = new SampleInfoSeq();
StringDataReader stringReader = ... ;
/* Take and print the data */
stringReader.take(
       dataSeq, infoSeq,
       ResourceLimitsQosPolicy.LENGTH_UNLIMITED,
       SampleStateKind.ANY_SAMPLE_STATE,
       ViewStateKind.ANY_VIEW_STATE,
       InstanceStateKind.ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
       if (((SampleInfo)infoSeq.get(i)).valid_data) {
               System.out.println(
                       (String)dataSeq.get(i));
       }
}
/* Return loan */
stringReader.return_loan(dataSeq, infoSeq);
```

3.2.4 KeyedString Built-in Type

The Keyed String built-in type is represented by a (key, value) pair, where key and value are strings. This type can be used to publish and subscribe to keyed strings. The language specific representations of the type are as follows:

C/Traditional C++ Representation (without namespaces):

```
struct DDS_KeyedString {
       char * key;
       char * value;
};
```

Modern C++ Representation:

```
class dds::core::KeyedStringTopicType {
public:
    dds::core::string& key();
    dds::core::string& value();
    // ... see API documentation for full definition
};
```

C++/CLI Representation:

```
namespace DDS {
       public ref struct KeyedString: {
               public:
               System::String^ key;
               System::String^ value;
               ...
       };
};
```

C# Representation:

```
namespace DDS {
       public class KeyedString {
               public System.String key;
               public System.String value;
       };
};
```

Java Representation:

```
 namespace DDS {
        public class KeyedString {
                public System.String key;
                public System.String value;
        };
 };
```

3.2.4.1 Creating and Deleting Keyed Strings

Connext DDS provides a set of constructors/destructors to create/destroy Keyed Strings. For details, see the API Reference HTML documentation, which is available for all supported programming languages (select **Modules, RTI Connext DDS API Reference, Topic Module, Built-in Types**).

If you want to manipulate the memory of the fields '**value**' and '**key**' in the KeyedString struct in C/C++, use the operations **DDS::String_alloc(), DDS::String_dup(),** and **DDS::String_free()**, as described in

the API Reference HTML documentation (select **Modules, RTI Connext DDS API Reference, Infrastructure Module, String Support**).

3.2.4.2 Keyed String DataWriter

The keyed string *DataWriter* API is extended with the following methods (in addition to the standard methods described in 7.3.7 Using a Type-Specific DataWriter (FooDataWriter) on page 307):

```
DDS::ReturnCode_t
DDS::KeyedStringDataWriter::dispose(
               const char* key,
               const DDS::InstanceHandle_t* instance_handle);
DDS::ReturnCode_t
DDS::KeyedStringDataWriter::dispose_w_timestamp(
               const char* key,
               const DDS::InstanceHandle_t* instance_handle,
               const struct DDS::Time_t* source_timestamp);
DDS::ReturnCode_t
DDS::KeyedStringDataWriter::get_key_value(
               char * key,
                const DDS::InstanceHandle_t* handle);
DDS::InstanceHandle_t
DDS::KeyedStringDataWriter::lookup_instance(
               const char * key);
DDS::InstanceHandle_t
DDS::KeyedStringDataWriter::register_instance(
               const char* key);
DDS::InstanceHandle_t
DDS_KeyedStringDataWriter::register_instance_w_timestamp(
               const char * key,
                const struct DDS_Time_t* source_timestamp);
DDS::ReturnCode_t
DDS::KeyedStringDataWriter::unregister_instance(
               const char * key,
                const DDS::InstanceHandle_t* handle);
DDS::ReturnCode_t
DDS::KeyedStringDataWriter::unregister_instance_w_timestamp(
               const char* key,
                const DDS::InstanceHandle_t* handle,
                const struct DDS::Time_t* source_timestamp);
DDS::ReturnCode_t
DDS::KeyedStringDataWriter::write (
               const char * key,
                const char * str,
                const DDS::InstanceHandle_t* handle);
DDS::ReturnCode_t
DDS::KeyedStringDataWriter::write_w_timestamp(
               const char * key,
                const char * str,
                const DDS::InstanceHandle_t* handle,
                const struct DDS::Time_t* source_timestamp);
```

These operations are introduced to provide maximum flexibility in the format of the input parameters for the write and instance management operations. For additional information and a complete description of

the operations, see the API Reference HTML documentation, which is available for all supported programming languages.

The following examples show how to write keyed strings using a keyed string built-in type *DataWriter* and some of the extended APIs. For simplicity, error handling is not shown.

C Example:

```
DDS_KeyedStringDataWriter * stringWriter = ... ;
DDS_ReturnCode_t retCode;
struct DDS_KeyedString * keyedStr = NULL;
char * str = NULL;
/* Write some data using the KeyedString structure */
keyedStr = DDS_KeyedString_new(255, 255);
strcpy(keyedStr->key, "Key 1");
strcpy(keyedStr->value, "Value 1");
retCode = DDS_KeyedStringDataWriter_write_string_w_key(
               stringWriter, keyedStr,
                &DDS_HANDLE_NIL);
DDS_KeyedString_delete(keyedStr);
/* Write some data using individual strings */
retCode = DDS_KeyedStringDataWriter_write_string_w_key(
              stringWriter, "Key 1",
               "Value 1", &DDS_HANDLE_NIL);
str = DDS_String_dup("Value 2");
retCode = DDS_KeyedStringDataWriter_write_string_w_key(
               stringWriter, "Key 1",
               str, &DDS_HANDLE_NIL);
DDS_String_free(str);
```

C++ Example with Namespaces:[1]

```
#include "ndds/ndds_namespace_cpp.h"
using namespace DDS;
...
KeyedStringDataWriter * stringWriter = ... ;
/* Write some data using the KeyedString */
KeyedString * keyedStr = new KeyedString(255, 255);
strcpy(keyedStr->key, "Key 1");
strcpy(keyedStr->value, "Value 1");
ReturnCode_t retCode = stringWriter->write(
       keyedStr, HANDLE_NIL);
delete keyedStr;
```

[1]This example uses C++ namespaces. If you're not using namespaces in your own code, prefix the name of each DDS class with 'DDS.' For example, DDS::StringDataWriter becomes DDSStringDataWriter.

C++/CLI Example:

```
using namespace System;
using namespace DDS;
...
KeyedStringDataWriter^ stringWriter = ... ;
/* Write some data using the KeyedString */
KeyedString^ keyedStr = gcnew KeyedString();
keyedStr->key = "Key 1";
keyedStr->value = "Value 1";
stringWriter->write(
       keyedStr, InstanceHandle_t::HANDLE_NIL);
/* Write some data using individual strings */
stringWriter->write
       "Key 1","Value 1",
       InstanceHandle_t::HANDLE_NIL);
String^ str = "Value 2";
stringWriter->write(
       "Key 1", str,
       InstanceHandle_t::HANDLE_NIL);
```

C# Example:

```
using System;
using DDS;
...
KeyedStringDataWriter stringWriter = ... ;
/* Write some data using the KeyedString */
KeyedString keyedStr = new KeyedString();
keyedStr.key = "Key 1";
keyedStr.value = "Value 1";
stringWriter.write(
       keyedStr, InstanceHandle_t.HANDLE_NIL);
/* Write some data using individual strings */
stringWriter.write(
       "Key 1", "Value 1",
       InstanceHandle_t.HANDLE_NIL);
String str = "Value 2";
stringWriter.write(
       "Key 1", str,
       InstanceHandle_t.HANDLE_NIL);
```

Java Example:

```
import com.rti.dds.publication.*;
import com.rti.dds.type.builtin.*;
import com.rti.dds.infrastructure.*;
...
KeyedStringDataWriter stringWriter = ... ;
/* Write some data using the KeyedString */
KeyedString keyedStr = new KeyedString();
keyedStr.key = "Key 1";
keyedStr.value = "Value 1";
stringWriter.write(
       keyedStr, InstanceHandle_t.HANDLE_NIL);
/* Write some data using individual strings */
stringWriter.write(
```

```
       "Key 1", "Value 1",
       InstanceHandle_t.HANDLE_NIL);
String str = "Value 2";
stringWriter.write(
       "Key 1", str,
       InstanceHandle_t.HANDLE_NIL);
```

3.2.4.3 Keyed String DataReader

The KeyedString *DataReader* API is extended with the following operations (in addition to the standard methods described in 8.4.1 Using a Type-Specific DataReader (FooDataReader) on page 548):

```
DDS::ReturnCode_t
DDS::KeyedStringDataReader::get_key_value(
       char * key,
       const DDS::InstanceHandle_t* handle);
DDS::InstanceHandle_t
DDS::KeyedStringDataReader::lookup_instance(
       const char * key);
```

For additional information and a complete description of these operations in all supported languages, see the API Reference HTML documentation, which is available for all supported programming languages.

Memory considerations in copy operations:

For read/take operations with copy semantics, such as **read_next_sample()** and **take_next_sample()**, *Connext DDS* allocates memory for the fields '**value**' and '**key**' if they are initialized to NULL.

If the fields are not initialized to NULL, the behavior depends on the language:

- In Java and .NET, the memory associated to the fields '**value**' and '**key**' will be reallocated with every DDS sample.
- In C and C++, the memory associated with the fields '**value**' and '**key**' must be large enough to hold the received data. Insufficient memory may result in crashes.

The following examples show how to read keyed strings with a keyed string built-in type *DataReader*. For simplicity, error handling is not shown.

C Example:

```
struct DDS_KeyedStringSeq dataSeq =
       DDS_SEQUENCE_INITIALIZER;
struct DDS_SampleInfoSeq infoSeq =
       DDS_SEQUENCE_INITIALIZER;
DDS_KeyedKeyedStringDataReader * stringReader = ... ;
DDS_ReturnCode_t retCode;
int i;
/* Take and print the data */
retCode = DDS_KeyedStringDataReader_take(
                        stringReader, &dataSeq,
                         &infoSeq,
                         DDS_LENGTH_UNLIMITED,
```

```
                        DDS_ANY_SAMPLE_STATE,
                        DDS_ANY_VIEW_STATE,
                        DDS_ANY_INSTANCE_STATE);
for (i = 0;
     i < DDS_KeyedStringSeq_get_length(&data_seq);
     ++i) {
    if (DDS_SampleInfoSeq_get_reference(
       &info_seq, i)->valid_data) {
           DDS_KeyedStringTypeSupport_print_data(
            DDS_KeyedStringSeq_get_reference(&data_seq, i));
    }
}
/* Return loan */
retCode = DDS_KeyedStringDataReader_return_loan(
               stringReader, &data_seq, &info_seq);
```

C++ Example with Namespaces:[1]

```
#include "ndds/ndds_namespace_cpp.h"
using namespace DDS;
...
KeyedStringSeq dataSeq;
SampleInfoSeq infoSeq;
KeyedStringDataReader * stringReader = ... ;
/* Take a print the data */
ReturnCode_t retCode = stringReader->take(
                       dataSeq, infoSeq,
                        LENGTH_UNLIMITED,
                        ANY_SAMPLE_STATE,
                        ANY_VIEW_STATE,
                        ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
    if (infoSeq[i].valid_data) {
       KeyedStringTypeSupport::print_data(&dataSeq[i]);
       }
}
/* Return loan */
retCode = stringReader->return_loan(dataSeq, infoSeq);
```

C++/CLI Example:

```
using namespace System;
using namespace DDS;
...
KeyedStringSeq^ dataSeq = gcnew KeyedStringSeq();
SampleInfoSeq^ infoSeq = gcnew SampleInfoSeq();
KeyedStringDataReader^ stringReader = ... ;
/* Take and print the data */
stringReader->take(
               dataSeq, infoSeq,
               ResourceLimitsQosPolicy::LENGTH_UNLIMITED,
                SampleStateKind::ANY_SAMPLE_STATE,
                ViewStateKind::ANY_VIEW_STATE,
```

[1]This example uses C++ namespaces. If you're not using namespaces in your own code, prefix the name of each DDS class with 'DDS.' For example, DDS::StringDataWriter becomes DDSStringDataWriter.

```
                InstanceStateKind::ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
       if (infoSeq->get_at(i)->valid_data) {
               KeyedStringTypeSupport::print_data(
                       dataSeq->get_at(i));
       }
}
/* Return loan */
stringReader->return_loan(dataSeq, infoSeq);
```

C# Example:

```
using System;
using DDS;
...
KeyedStringSeq dataSeq = new KeyedStringSeq();
SampleInfoSeq infoSeq = new SampleInfoSeq();
KeyedStringDataReader stringReader = ... ;
/* Take and print the data */
stringReader.take(dataSeq, infoSeq,
                  ResourceLimitsQosPolicy.LENGTH_UNLIMITED,
                  SampleStateKind.ANY_SAMPLE_STATE,
                  ViewStateKind.ANY_VIEW_STATE,
                  InstanceStateKind.ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
       if (infoSeq.get_at(i)).valid_data) {
           KeyedStringTypeSupport.print_data(
               dataSeq.get_at(i));
       }
}
/* Return loan */
stringReader.return_loan(dataSeq, infoSeq);
```

Java Example:

```
import com.rti.dds.infrastructure.*;
import com.rti.dds.subscription.*;
import com.rti.dds.type.builtin.*;
...
KeyedStringSeq dataSeq = new KeyedStringSeq();
SampleInfoSeq infoSeq = new SampleInfoSeq();
KeyedStringDataReader stringReader = ... ;
/* Take and print the data */
stringReader.take(dataSeq, infoSeq,
                  ResourceLimitsQosPolicy.LENGTH_UNLIMITED,
                  SampleStateKind.ANY_SAMPLE_STATE,
                  ViewStateKind.ANY_VIEW_STATE,
                  InstanceStateKind.ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
       if (((SampleInfo)infoSeq.get(i)).valid_data) {
               System.out.println((
               (KeyedString)dataSeq.get(i)).toString());
       }
}
/* Return loan */
stringReader.return_loan(dataSeq, infoSeq);
```

3.2.5 Octets Built-in Type

The octets built-in type is used to send sequences of octets. The language-specific representations are as follows:

C/Traditional C++ Representation (without Namespaces):

```
struct DDS_Octets {
       int length;
       unsigned char * value;
};
```

Modern C++ Representation:

```
class dds::core::BytesTopicType {
public:
    uint8_t& operator [](uint32_t index);
    // ... see API documentation for full definition
};
```

C++/CLI Representation:

```
namespace DDS {
       public ref struct Bytes: {
               public:
               System::Int32 length;
               System::Int32 offset;
               array<System::Byte>^ value;
                ...
       };
};
```

C# Representation:

```
 namespace DDS {
        public class Bytes {
                public System.Int32 length;
                public System.Int32 offset;
                public System.Byte[] value;
                ...
        };
 };
```

Java Representation:

```
package com.rti.dds.type.builtin;
public class Bytes implements Copyable {
       public int length;
       public int offset;
       public byte[] value;
       ...
};
```

3.2.5.1 Creating and Deleting Octets

Connext DDS provides a set of constructors/destructors to create and destroy Octet objects. For details, see the API Reference HTML documentation, which is available for all supported programming languages (select **Modules, RTI Connext DDS API Reference, Topic Module, Built-in Types**).

If you want to manipulate the memory of the value field inside the Octets struct in C/Traditional C++, use the operations **DDS::OctetBuffer_alloc()**, **DDS::OctetBuffer_dup()**, and **DDS::OctetBuffer_free()**, described in the API Reference HTML documentation (select **Modules, RTI Connext DDS API Reference, Infrastructure Module, Octet Buffer Support**).

3.2.5.2 Octets DataWriter

(Note: for Modern C++ API, refer to the API documentation)

In addition to the standard methods (see 7.3.7 Using a Type-Specific DataWriter (FooDataWriter) on page 307), the octets *DataWriter* API is extended with the following methods:

```
DDS::ReturnCode_t DDS::OctetsDataWriter::write(
        const DDS::OctetSeq & octets,
        const DDS::InstanceHandle_t & handle);
DDS::ReturnCode_t DDS::OctetsDataWriter::write(
        const unsigned char * octets,
        int length,
        const DDS::InstanceHandle_t& handle);
DDS::ReturnCode_t DDS::OctetsDataWriter::write_w_timestamp(
        const DDS::OctetSeq & octets,
        const DDS::InstanceHandle_t & handle,
        const DDS::Time_t & source_timestamp);
DDS::ReturnCode_t DDS::OctetsDataWriter::write_w_timestamp(
        const unsigned char * octets,
        int length,
        const DDS::InstanceHandle_t& handle,
        const DDS::Time_t& source_timestamp);
```

These methods are introduced to provide maximum flexibility in the format of the input parameters for the write operations. For additional information and a complete description of these operations in all supported languages, see the API Reference HTML documentation.

The following examples show how to write an array of octets using an octets built-in type *DataWriter* and some of the extended APIs. For simplicity, error handling is not shown.

C Example:

```
DDS_OctetsDataWriter * octetsWriter = ... ;
DDS_ReturnCode_t retCode;
struct DDS_Octets * octets = NULL;
char * octetArray = NULL;
/* Write some data using the Octets structure */
octets = DDS_Octets_new_w_size(1024);
octets->length = 2;
octets->value[0] = 46;
octets->value[1] = 47;
retCode = DDS_OctetsDataWriter_write(
               octetsWriter, octets, &DDS_HANDLE_NIL);
DDS_Octets_delete(octets);
/* Write some data using an octets array */
octetArray = (unsigned char *)malloc(1024);
octetArray[0] = 46;
octetArray[1] = 47;
retCode = DDS_OctetsDataWriter_write_octets (
               octetsWriter, octetArray, 2,
                &DDS_HANDLE_NIL);
free(octetArray);
```

C++ Example with Namespaces:[1]

```
#include "ndds/ndds_namespace_cpp.h"
using namespace DDS;
...
OctetsDataWriter * octetsWriter = ... ;
/* Write some data using the Octets structure */
Octets * octets = new Octets(1024);
octets->length = 2;
octets->value[0] = 46;
octets->value[1] = 47;
ReturnCode_t  retCode = octetsWriter->write(octets, HANDLE_NIL);
delete octets;
/* Write some data using an octet array */
unsigned char * octetArray = new unsigned char[1024];
octetArray[0] = 46;
octetArray[1] = 47;
retCode = octetsWriter->write(octetArray, 2, HANDLE_NIL);
delete []octetArray;
```

[1]This example uses C++ namespaces. If you're not using namespaces in your own code, prefix the name of each DDS class with 'DDS.' For example, DDS::StringDataWriter becomes DDSStringDataWriter.

C++/CLI Example:

```
using namespace System;
using namespace DDS;
...
BytesDataWriter^ octetsWriter = ...;
/* Write some data using Bytes */
Bytes^ octets = gcnew Bytes(1024);
octets->value[0] =46;
octets->value[1] =47;
octets.length = 2;
octets.offset = 0;
octetWriter->write(octets, InstanceHandle_t::HANDLE_NIL);
/* Write some data using individual strings */
array<Byte>^ octetAray = gcnew array<Byte>(1024);
octetArray[0] = 46;
octetArray[1] = 47;
octetsWriter->write(octetArray, 0, 2, InstanceHandle_t::HANDLE_NIL);
```

C# Example:

```
using System;
using DDS;
...
BytesDataWriter stringWriter = ...;
/* Write some data using the Bytes */
Bytes octets = new Bytes(1024);
octets.value[0] = 46;
octets.value[1] = 47;
octets.length = 2;
octets.offset = 0;
octetWriter.write(octets, InstanceHandle_t.HANDLE_NIL);
/* Write some data using individual strings */
byte[] octetArray = new byte[1024];
octetArray[0] = 46;
octetArray[1] = 47;
octetsWriter.write(octetArray, 0, 2, InstanceHandle_t.HANDLE_NIL);
```

Java Example:

```
import com.rti.dds.publication.*;
import com.rti.dds.type.builtin.*;
import com.rti.dds.infrastructure.*;
...
BytesDataWriter octetsWriter = ... ;
/* Write some data using the Bytes class*/
Bytes octets = new Bytes(1024);
octets.length = 2;
octets.offset = 0;
octets.value[0] = 46;
octets.value[1] = 47;
octetsWriter.write(octets, InstanceHandle_t.HANDLE_NIL);
/* Write some data using a byte array */
byte[] octetArray = new byte[1024];
octetArray[0] = 46;
octetArray[1] = 47;
octetsWriter.write(octetArray, 0, 2, InstanceHandle_t.HANDLE_NIL);
```

3.2.5.3 Octets DataReader

(Note: for the Modern C++ API, refer to the API Reference HTML documentation)

The octets *DataReader* API matches the standard *DataReader* API (see 8.4.1 Using a Type-Specific DataReader (FooDataReader) on page 548). There are no extensions.

Memory considerations in copy operations:

For read/take operations with copy semantics, such as **read_next_sample()** and **take_next_sample()**, *Connext DDS* allocates memory for the field 'value' if it is initialized to NULL.

If the field 'value' is not initialized to NULL, the behavior depends on the language:

- In Java and .NET, the memory for the field 'value' will be reallocated if the current size is not large enough to hold the received data.
- In C and C++, the memory associated with the field 'value' must be big enough to hold the received data. Insufficient memory may result in crashes.

The following examples show how to read octets with an octets built-in type *DataReader*. For simplicity, error handling is not shown.

C Example:

```
struct DDS_OctetsSeq dataSeq = DDS_SEQUENCE_INITIALIZER;
struct DDS_SampleInfoSeq infoSeq = DDS_SEQUENCE_INITIALIZER;
DDS_OctetsDataReader * octetsReader = ... ;
DDS_ReturnCode_t retCode;
int i;
/* Take and print the data */
retCode = DDS_OctetsDataReader_take(
               octetsReader, &dataSeq,
                &infoSeq, DDS_LENGTH_UNLIMITED,
                DDS_ANY_SAMPLE_STATE,
                DDS_ANY_VIEW_STATE,
                DDS_ANY_INSTANCE_STATE);
for (i = 0; i < DDS_OctetsSeq_get_length(&dataSeq); ++i) {
    if (DDS_SampleInfoSeq_get_reference(
        &infoSeq, i)->valid_data) {
            DDS_OctetsTypeSupport_print_data(
               DDS_OctetsSeq_get_reference(&dataSeq, i));
    }
}
/* Return loan */
retCode = DDS_OctetsDataReader_return_loan(
       octetsReader, &dataSeq, &infoSeq);
```

C++ Example with Namespaces:[1]

```
#include "ndds/ndds_namespace_cpp.h"
using namespace DDS;
...
OctetsSeq dataSeq;
SampleInfoSeq infoSeq;
OctetsDataReader * octetsReader = ... ;
/* Take a print the data */
ReturnCode_t retCode = octetsReader->take(
               dataSeq, infoSeq,
                LENGTH_UNLIMITED, ANY_SAMPLE_STATE,
               ANY_VIEW_STATE, ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
    if (infoSeq[i].valid_data) {
        OctetsTypeSupport::print_data(&dataSeq[i]);
    }
}
/* Return loan */
retCode = octetsReader->return_loan(dataSeq, infoSeq);
```

C++/CLI Example:

```
using namespace System;
using namespace DDS;
...
BytesSeq^ dataSeq = gcnew BytesSeq();
SampleInfoSeq^ infoSeq = gcnew SampleInfoSeq();
BytesDataReader^ octetsReader = ... ;
/* Take and print the data */
octetsReader->take(
               dataSeq, infoSeq,
                ResourceLimitsQosPolicy::LENGTH_UNLIMITED,
                SampleStateKind::ANY_SAMPLE_STATE,
                ViewStateKind::ANY_VIEW_STATE,
                InstanceStateKind::ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
    if (infoSeq->get_at(i)->valid_data) {
        BytesTypeSupport::print_data(dataSeq->get_at(i));
    }
}
/* Return loan */
octetsReader->return_loan(dataSeq, infoSeq);
```

[1]This example uses C++ namespaces. If you're not using namespaces in your own code, prefix the name of each DDS class with 'DDS.' For example, DDS::StringDataWriter becomes DDSStringDataWriter.

C# Example:

```
using System;
using DDS;
...
BytesSeq dataSeq = new BytesSeq();
SampleInfoSeq infoSeq = new SampleInfoSeq();
BytesDataReader octetsReader = ... ;
/* Take and print the data */
octetsReader.take(
               dataSeq, infoSeq,
                ResourceLimitsQosPolicy.LENGTH_UNLIMITED,
                SampleStateKind.ANY_SAMPLE_STATE,
                ViewStateKind.ANY_VIEW_STATE,
                InstanceStateKind.ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
    if (infoSeq.get_at(i)).valid_data) {
        BytesTypeSupport.print_data(dataSeq.get_at(i));
    }
}
/* Return loan */
octetsReader.return_loan(dataSeq, infoSeq);
```

Java Example:

```
import com.rti.dds.infrastructure.*;
import com.rti.dds.subscription.*;
import com.rti.dds.type.builtin.*;
...
BytesSeq dataSeq = new BytesSeq();
SampleInfoSeq infoSeq = new SampleInfoSeq();
BytesDataReader octetsReader = ... ;
/* Take and print the data */
octetsReader.take(dataSeq, infoSeq,
                ResourceLimitsQosPolicy.LENGTH_UNLIMITED,
                SampleStateKind.ANY_SAMPLE_STATE,
                ViewStateKind.ANY_VIEW_STATE,
                InstanceStateKind.ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
    if (((SampleInfo)infoSeq.get(i)).valid_data) {
        System.out.println(((Bytes)dataSeq.get(i)).toString());
    }
}
/* Return loan */
octetsReader.return_loan(dataSeq, infoSeq);
```

3.2.6 KeyedOctets Built-in Type

The keyed octets built-in type is used to send sequences of octets with a key. The language-specific representations of the type are as follows:

C/Traditional C++ Representation (without Namespaces):

```
struct DDS_KeyedOctets {
    char * key;
    int length;
    unsigned char * value;
};
```

Modern C++ Representation:

```
 class dds::core::KeyedStringTopicType {
 public:
     dds::core::string& key();
     uint8_t& operator [](uint32_t index);
     // ... see API documentation for full definition
 };
```

C++/CLI Representation:

```
namespace DDS {
    public ref struct KeyedBytes {
      public:
        System::String^ key;
        System::Int32 length;
        System::Int32 offset;
        array<System::Byte>^ value;
        ...
    };
};
```

C# Representation:

```
namespace DDS {
    public class KeyedBytes {
       public System.String key;
        public System.Int32 length;
        public System.Int32 offset;
        public System.Byte[] value;
        ...
    };
};
```

Java Representation:

```
package com.rti.dds.type.builtin;
public class KeyedBytes {
    public String key;
    public int length;
    public int offset;
    public byte[] value;
    ...
};
```

3.2.6.1 Creating and Deleting KeyedOctets

Connext DDS provides a set of constructors/destructors to create/destroy KeyedOctets objects. For details, see the API Reference HTML documentation, which is available for all supported programming languages (select **Modules, RTI Connext DDS API Reference, Topic Module, Built-in Types**).

To manipulate the memory of the **value** field in the KeyedOctets struct in C/C++: use **DDS::OctetBuffer_alloc()**, **DDS::OctetBuffer_dup()**, and **DDS::OctetBuffer_free()**. See the API Reference HTML documentation (select **Modules, RTI Connext DDS API Reference, Infrastructure Module, Octet Buffer Support**).

To manipulate the memory of the **key** field in the KeyedOctets struct in C/C++: use **DDS::String_alloc()**, **DDS::String_dup()**, and **DDS::String_free()**. See the API Reference HTML documentation (select **Modules, RTI Connext DDS API Reference, Infrastructure Module, String Support**).

3.2.6.2 Keyed Octets DataWriter

In addition to the standard methods (see 7.3.7 Using a Type-Specific DataWriter (FooDataWriter) on page 307), the keyed octets *DataWriter* API is extended with the following methods:

```
DDS::ReturnCode_t
DDS::KeyedOctetsDataWriter::dispose(
    const char* key,
    const DDS::InstanceHandle_t & instance_handle);
DDS::ReturnCode_t
DDS::KeyedOctetsDataWriter::dispose_w_timestamp(
    const char* key,
    const DDS::InstanceHandle_t & instance_handle,
    const DDS::Time_t & source_timestamp);
DDS::ReturnCode_t
DDS::KeyedOctetsDataWriter::get_key_value(
    char * key,
    const DDS::InstanceHandle_t& handle);
DDS::InstanceHandle_t
DDS::KeyedOctetsDataWriter::lookup_instance(
    const char * key);
DDS::InstanceHandle_t
DDS::KeyedOctetsDataWriter::register_instance(
    const char* key);
DDS::InstanceHandle_t
DDS::KeyedOctetsDataWriter::
    register_instance_w_timestamp(
    const char * key,
    const DDS::Time_t & source_timestamp);
DDS::ReturnCode_t
DDS::KeyedOctetsDataWriter::unregister_instance(
    const char * key,
    const DDS::InstanceHandle_t & handle);
DDS::ReturnCode_t
DDS::KeyedOctetsDataWriter::
unregister_instance_w_timestamp(
    const char* key,
    const DDS::InstanceHandle_t & handle,
```

```
    const DDS::Time_t & source_timestamp);
DDS::ReturnCode_t
DDS::KeyedOctetsDataWriter::write(
    const char * key,
    const unsigned char * octets,
    int length,
    const DDS::InstanceHandle_t& handle);
DDS::ReturnCode_t
DDS::KeyedOctetsDataWriter::write(
    const char * key,
    const DDS::OctetSeq & octets,
    const DDS::InstanceHandle_t & handle);
DDS::ReturnCode_t
DDS::KeyedOctetsDataWriter::write_w_timestamp(
    const char * key,
    const unsigned char * octets,
    int length,
    const DDS::InstanceHandle_t& handle,
    const DDS::Time_t& source_timestamp);
DDS::ReturnCode_t
DDS::KeyedOctetsDataWriter::write_w_timestamp(
    const char * key,
    const DDS::OctetSeq & octets,
    const DDS::InstanceHandle_t & handle,
    const DDS::Time_t & source_timestamp);
```

These methods are introduced to provide maximum flexibility in the format of the input parameters for the write and instance management operations. For more information and a complete description of these operations in all supported languages, see the API Reference HTML documentation.

The following examples show how to write keyed octets using a keyed octets built-in type *DataWriter* and some of the extended APIs. For simplicity, error handling is not shown.

C Example:

```
DDS_KeyedOctetsDataWriter * octetsWriter = ... ;
DDS_ReturnCode_t retCode;
struct DDS_KeyedOctets * octets = NULL;
char * octetArray = NULL;
/* Write some data using KeyedOctets structure */
octets = DDS_KeyedOctets_new_w_size(128,1024);
strcpy(octets->key, "Key 1");
octets->length = 2;
octets->value[0] = 46;
octets->value[1] = 47;
retCode = DDS_KeyedOctetsDataWriter_write(
       octetsWriter, octets, &DDS_HANDLE_NIL);
DDS_KeyedOctets_delete(octets);
/* Write some data using an octets array */
octetArray = (unsigned char *)malloc(1024);
octetArray[0] = 46;
octetArray[1] = 47;
retCode =
```

```
DDS_KeyedOctetsDataWriter_write_octets_w_key (
       octetsWriter, "Key 1",
       octetArray, 2, &DDS_HANDLE_NIL);
free(octetArray);
```

C++ Example with Namespaces:[1]

```
#include "ndds/ndds_namespace_cpp.h"
using namespace DDS;
...
KeyedOctetsDataWriter * octetsWriter = ...;
/* Write some data using KeyedOctets */
KeyedOctets * octets = new KeyedOctets(128,1024);
strcpy(octets->key, "Key 1");
octets->length = 2;
octets->value[0] = 46;
octets->value[1] = 47;
ReturnCode_t retCode =
       octetsWriter->write(octets, HANDLE_NIL);
delete octets;
/* Write some data using an octet array */
unsigned char * octetArray = new unsigned char[1024];
octetArray[0] = 46;
octetArray[1] = 47;
retCode = octetsWriter->write(
       "Key 1", octetArray, 2, HANDLE_NIL);
delete []octetArray;
```

C++/CLI Example:

```
using namespace System;
using namespace DDS;
...
KeyedOctetsDataWriter^ octetsWriter = ... ;
/* Write some data using KeyedBytes */
KeyedBytes^ octets = gcnew KeyedBytes(1024);
octets->key = "Key 1";
octets->value[0] =46;
octets->value[1] =47;
octets.length = 2;
octets.offset = 0;
octetWriter->write(
       octets, InstanceHandle_t::HANDLE_NIL);
/* Write some data using individual strings */
```

[1]This example uses C++ namespaces. If you're not using namespaces in your own code, prefix the name of each DDS class with 'DDS.' For example, DDS::StringDataWriter becomes DDSStringDataWriter.

```
array<Byte>^ octetAray = gcnew array<Byte>(1024);
octetArray[0] = 46;
octetArray[1] = 47;
octetsWriter->write(
        "Key 1", octetArray,
       0, 2, InstanceHandle_t::HANDLE_NIL);
```

C# Example:

```
using System;
using DDS;
...
KeyedBytesDataWriter stringWriter = ... ;
/* Write some data using the KeyedBytes */
KeyedBytes octets = new KeyedBytes(1024);
octets.key = "Key 1";
octets.value[0] = 46;
octets.value[1] = 47;
octets.length = 2;
octets.offset = 0;
octetWriter.write(octets,
       InstanceHandle_t.HANDLE_NIL);
/* Write some data using individual strings */
byte[] octetArray = new byte[1024];
octetArray[0] = 46;
octetArray[1] = 47;
octetsWriter.write(
        "Key 1", octetArray,
       0, 2, InstanceHandle_t.HANDLE_NIL);
```

Java Example:

```
import com.rti.dds.publication.*;
import com.rti.dds.type.builtin.*;
import com.rti.dds.infrastructure.*;
...
KeyedBytesDataWriter octetsWriter = ... ;
/* Write some data using KeyedBytes class */
KeyedBytes octets = new KeyedBytes(1024);
octets.key = "Key 1";
octets.length = 2;
octets.offset = 0;
octets.value[0] = 46;
octets.value[1] = 47;
octetsWriter.write(octets,
       InstanceHandle_t.HANDLE_NIL);
/* Write some data using a byte array */
byte[] octetArray = new byte[1024];
octetArray[0] = 46;
```

```
octetArray[1] = 47;
octetsWriter.write(
        "Key 1", octetArray,

0, 2, InstanceHandle_t.HANDLE_NIL);
```

3.2.6.3 Keyed Octets DataReader

The KeyedOctets *DataReader* API is extended with the following methods (in addition to the standard methods described in 8.4.1 Using a Type-Specific DataReader (FooDataReader) on page 548):

```
DDS::ReturnCode_t
DDS::KeyedOctetsDataReader::get_key_value(
       char * key,
       const DDS::InstanceHandle_t* handle);

DDS::InstanceHandle_t
DDS::KeyedOctetsDataReader::lookup_instance(
       const char * key);
```

For more information and a complete description of these operations in all supported languages, see the API Reference HTML documentation.

Memory considerations in copy operations:

For read/take operations with copy semantics, such as **read_next_sample()** and **take_next_sample()**, Connext DDS allocates memory for the fields '**value**' and '**key**' if they are initialized to NULL.

If the fields are not initialized to NULL, the behavior depends on the language:

- In Java and .NET, the memory of the field '**value**' will be reallocated if the current size is not large enough to hold the received data. The memory associated with the field '**key**' will be reallocated with every DDS sample (the key is an immutable object).
- In C and C++, the memory associated with the fields '**value**' and '**key**' must be large enough to hold the received data. Insufficient memory may result in crashes.

The following examples show how to read keyed octets with a keyed octets built-in type *DataReader*. For simplicity, error handling is not shown.

C Example:

```
struct DDS_KeyedOctetsSeq dataSeq =
       DDS_SEQUENCE_INITIALIZER;
struct DDS_SampleInfoSeq infoSeq =
       DDS_SEQUENCE_INITIALIZER;
DDS_KeyedOctetsDataReader * octetsReader = ... ;
DDS_ReturnCode_t retCode;
```

```
int i;
/* Take and print the data */
retCode = DDS_KeyedOctetsDataReader_take(
        octetsReader,
        &dataSeq, &infoSeq, DDS_LENGTH_UNLIMITED,
        DDS_ANY_SAMPLE_STATE, DDS_ANY_VIEW_STATE,
        DDS_ANY_INSTANCE_STATE);
for (i = 0;
     i < DDS_KeyedOctetsSeq_get_length(&data_seq);
     ++i) {
       if (DDS_SampleInfoSeq_get_reference(
       &info_seq, i)->valid_data) {
           DDS_KeyedOctetsTypeSupport_print_data(
               DDS_KeyedOctetsSeq_get_reference(
                   &data_seq, i));
       }
}
/* Return loan */
retCode = DDS_KeyedOctetsDataReader_return_loan(
                octetsReader, &data_seq, &info_seq);
```

C++ Example with Namespaces:[1]

```
#include "ndds/ndds_namespace_cpp.h"
using namespace DDS;
...
KeyedOctetsSeq dataSeq;
SampleInfoSeq infoSeq;
KeyedOctetsDataReader * octetsReader = ... ;
/* Take and print the data */
ReturnCode_t retCode = octetsReader->take(
        dataSeq, infoSeq, LENGTH_UNLIMITED,
        ANY_SAMPLE_STATE, ANY_VIEW_STATE,
       ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
    if (infoSeq[i].valid_data) {
       KeyedOctetsTypeSupport::print_data(
                       &dataSeq[i]);
       }
}
/* Return loan */
retCode = octetsReader->return_loan(
       dataSeq, infoSeq);
```

C++/CLI Example:

```
using namespace System;
using namespace DDS;
...
KeyedBytesSeq^ dataSeq = gcnew KeyedBytesSeq();
SampleInfoSeq^ infoSeq = gcnew SampleInfoSeq();
KeyedBytesDataReader^ octetsReader = ... ;
```

[1]This example uses C++ namespaces. If you're not using namespaces in your own code, prefix the name of each DDS class with 'DDS.' For example, DDS::StringDataWriter becomes DDSStringDataWriter.

```
/* Take and print the data */
octetsReader->take(dataSeq, infoSeq,
    ResourceLimitsQosPolicy::LENGTH_UNLIMITED,
    SampleStateKind::ANY_SAMPLE_STATE,
    ViewStateKind::ANY_VIEW_STATE,
    InstanceStateKind::ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i){
       if (infoSeq->get_at(i)->valid_data){
           KeyedBytesTypeSupport::print_data(
                       dataSeq->get_at(i));
       }
}
/* Return loan */
octetsReader->return_loan(dataSeq, infoSeq);
```

C# Example:

```
using System;
using DDS;
...
KeyedBytesSeq dataSeq = new KeyedButesSeq();
SampleInfoSeq infoSeq = new SampleInfoSeq();
KeyedBytesDataReader octetsReader = ... ;
/* Take and print the data */
octetsReader.take(dataSeq, infoSeq,
    ResourceLimitsQosPolicy.LENGTH_UNLIMITED,
    SampleStateKind.ANY_SAMPLE_STATE,
    ViewStateKind.ANY_VIEW_STATE,
    InstanceStateKind.ANY_INSTANCE_STATE);
for (int i = 0; i < data_seq.length(); ++i) {
       if (infoSeq.get_at(i)).valid_data) {
           KeyedBytesTypeSupport.print_data(
                       dataSeq.get_at(i));
       }
}
/* Return loan */
octetsReader.return_loan(dataSeq, infoSeq);
```

Java Example:

```
import com.rti.dds.infrastructure.*;
import com.rti.dds.subscription.*;
import com.rti.dds.type.builtin.*;
...
KeyedBytesSeq dataSeq = new KeyedBytesSeq();
SampleInfoSeq infoSeq = new SampleInfoSeq();
KeyedBytesDataReader octetsReader = ... ;
/* Take and print the data */
octetsReader.take(dataSeq, infoSeq,
    ResourceLimitsQosPolicy.LENGTH_UNLIMITED,
    SampleStateKind.ANY_SAMPLE_STATE,
    ViewStateKind.ANY_VIEW_STATE,
    InstanceStateKind.ANY_INSTANCE_STATE);

for (int i = 0; i < data_seq.length(); ++i){
    if (((SampleInfo)infoSeq.get(i)).valid_data){
       System.out.println(
```

```
        ((KeyedBytes)dataSeq.get(i)).toString());
        }
}
/* Return loan */
octetsReader.return_loan(dataSeq, infoSeq);
```

3.2.7 Managing Memory for Built-in Types

When a DDS sample is written, the *DataWriter* serializes it and stores the result in a buffer obtained from a pool of preallocated buffers. In the same way, when a DDS sample is received, the *DataReader* deserializes it and stores the result in a DDS sample coming from a pool of preallocated DDS samples.

By default, the buffers on the *DataWriter* and the samples on the *DataReader* are preallocated with their maximum size. For example:

```
struct MyString {
    string<128> value;
};
```

This IDL-defined type has a maximum serialized size of 133 bytes (4 bytes for length + 128 characters + 1 NULL terminating character). So the serialization buffers will have a size of 133 bytes. The buffer can hold samples with 128 characters strings. Consequently, the preallocated samples will be sized to keep this length.

However, for built-in types, the maximum size of the buffers/DDS samples is unknown and depends on the nature of the application using the built-in type.

For example, a video surveillance application that is using the keyed octets built-in type to publish a stream of images will require bigger buffers than a market-data application that uses the same built-in type to publish market-data values.

To accommodate both kinds of applications and optimize memory usage, you can configure the maximum size of the built-in types on a per-*DataWriter* or per-*Datareader* basis using the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436. Table 3.1 Properties for Allocating Size of Built-in Types, per DataWriter and DataReader lists the supported built-in type properties. When the properties are defined in the *DomainParticipant*, they are applicable to all *DataWriters* and *DataReaders* belonging to the *DomainParticipant*, unless they are overwritten in the *DataWriters* and *DataReaders*.

> These properties must be set consistently with respect to the corresponding ***.max_size** properties in the *DomainParticipant* (see Table 3.2 Properties for Allocating Size of Built-in Types, per DomainParticipant). The value of the **alloc_size** property must be less than or equal to the **max_size** property with the same name prefix in the *DomainParticipant*.

Unbounded built-in types are only supported in the C, C++, Java, and .NET APIs.

3.2.7.1 Examples—Setting the Maximum Size for a String Programmatically on page 71 includes examples of how to set the maximum size of a string built-in type for a *DataWriter* programmatically, for

each API. You can also set the maximum size of the built-in types using XML QoS Profiles. For example, the following XML shows how to set the maximum size of a string built-in type for a *DataWriter*.

```
<dds>
<qos_library name="BuiltinExampleLibrary">
        <qos_profile name="BuiltinExampleProfile">
            <datawriter_qos>
                <property>
                    <value>
                        <element>
                        <name>dds.builtin_type.string.alloc_size</name>
                        <value>2048</value>
                        </element>
                    </value>
                </property>
            </datawriter_qos>
            <datareader_qos>
                <property>
                    <value>
                        <element>
                        <name>dds.builtin_type.string.alloc_size</name>
                        <value>2048</value>
                        </element>
                    </value>
                </property>
            </datareader_qos>
        </qos_profile>
    </qos_library>
</dds>
```

Table 3.1 Properties for Allocating Size of Built-in Types, per DataWriter and DataReader

Built-in Type	Property	Description
string	dds.builtin_type.string.alloc_size	Maximum size of the strings published by the DataWriter or received by the DataReader (includes the NULL-terminated character). Default: dds.builtin_type.string.max_size if defined (see Table 3.2 Properties for Allocating Size of Built-in Types, per DomainParticipant). Otherwise, 1024.
keyedstring	dds.builtin_type.keyed_string.alloc_key_size	Maximum size of the keys used by the DataWriter or DataReader (includes the NULL-terminated character). Default: dds.builtin_type.keyed_string.max_key_size if defined (see Table 3.2 Properties for Allocating Size of Built-in Types, per DomainParticipant). Otherwise, 1024.
	dds.builtin_type.keyed_string.alloc_size	Maximum size of the strings published by the DataWriter or received by the DataReader (includes the NULL-terminated character). Default: dds.builtin_type.keyed_string.max_size if defined (see Table 3.2 Properties for Allocating Size of Built-in Types, per DomainParticipant). Otherwise, 1024.

Table 3.1 Properties for Allocating Size of Built-in Types, per DataWriter and DataReader

Built-in Type	Property	Description
octets	dds.builtin_type.octets.alloc_size	Maximum size of the octet sequences published by the DataWriter or DataReader. Default: dds.builtin_type.octets.max_size if defined (see Table 3.2 Properties for Allocating Size of Built-in Types, per DomainParticipant). Otherwise, 2048.
keyed-octets	dds.builtin_type.keyed_octets.alloc_key_size	Maximum size of the key published by the DataWriter or received by the DataReader (includes the NULL-terminated character). Default: dds.builtin_type.keyed_octets.max_key_size if defined (see Table 3.2 Properties for Allocating Size of Built-in Types, per DomainParticipant). Otherwise, 1024.
	dds.builtin_type.keyed_octets.alloc_size	Maximum size of the octet sequences published by the DataWriter or DataReader. Default: dds.builtin_type.keyed_octets.max_size if defined (see Table 3.2 Properties for Allocating Size of Built-in Types, per DomainParticipant). Otherwise, 2048.

3.2.7.1 Examples–Setting the Maximum Size for a String Programmatically

For simplicity, error handling is not shown in the following examples.

C Example:

```
DDS_DataWriter * writer = NULL;
DDS_StringDataWriter * stringWriter = NULL;
DDS_Publisher * publisher = ... ;
DDS_Topic * stringTopic = ... ;
struct DDS_DataWriterQos writerQos =
       DDS_DataWriterQos_INITIALIZER;
DDS_ReturnCode_t retCode;
retCode = DDS_DomainParticipant_get_default_datawriter_qos (
                participant, &writerQos);
retCode = DDS_PropertyQosPolicyHelper_add_property (
       &writerQos.property,
       "dds.builtin_type.string.alloc_size", "1000",
        DDS_BOOLEAN_FALSE);
writer = DDS_Publisher_create_datawriter(
                publisher, stringTopic, &writerQos,
                NULL, DDS_STATUS_MASK_NONE);
stringWriter = DDS_StringDataWriter_narrow(writer);
DDS_DataWriterQos_finalize(&writerQos);
```

Traditional C++ Example with Namespaces: [1]

```
#include "ndds/ndds_namespace_cpp.h"
```

[1] This example uses C++ namespaces. If you're not using namespaces in your own code, prefix the name of each DDS class with 'DDS.' For example, DDS::StringDataWriter becomes DDSStringDataWriter.

```
using namespace DDS;
...
Publisher * publisher = ... ;
Topic * stringTopic = ... ;
DataWriterQos writerQos;
ReturnCode_t retCode =
       participant->get_default_datawriter_qos(writerQos);
retCode = PropertyQosPolicyHelper::add_property (
                &writerQos.property,
               "dds.builtin_type.string.alloc_size",
               "1000", BOOLEAN_FALSE);
DataWriter * writer = publisher->create_datawriter(
               stringTopic, writerQos,
               NULL, STATUS_MASK_NONE);
StringDataWriter * stringWriter =
               StringDataWriter::narrow(writer);
```

Modern C++ Example:

```
dds::pub::qos::DataWriterQos writer_qos =
    participant.default_datawriter_qos();
writer_qos.policy<rti::core::policy::Property>().set({
    "dds.builtin_type.string.alloc_size", "1000"});
dds::pub::DataWriter<dds::core::StringTopicType> writer(
    publisher, string_topic, writer_qos);
```

C++/CLI Example:

```
using namespace DDS;
...
Topic^ stringTopic = ... ;
Publisher^ publisher = ... ;
DataWriterQos^ writerQos = gcnew DataWriterQos();
participant->get_default_datawriter_qos(writerQos);
PropertyQosPolicyHelper::add_property(
               writerQos->property_qos,
               "dds.builtin_type.string.alloc_size",
               "1000", false);
DataWriter^ writer = publisher->create_datawriter(
               stringTopic, writerQos,
               nullptr, StatusMask::STATUS_MASK_NONE);
StringDataWriter^ stringWriter =
               safe_cast<StringDataWriter^>(writer);
```

C# Example:

```
using DDS;
...
```

```
Topic stringTopic = ... ;
Publisher publisher = ... ;
DataWriterQos writerQos = new DataWriterQos();
participant.get_default_datawriter_qos(writerQos);
PropertyQosPolicyHelper.add_property (
               writerQos.property_qos,
               "dds.builtin_type.string.alloc_size",
               "1000", false);
StringDataWriter stringWriter =
       (StringDataWriter) publisher.create_datawriter(
               stringTopic, writerQos, null,
               StatusMask.STATUS_MASK_NONE);
```

Java Example:

```
import com.rti.dds.publication.*;
import com.rti.dds.type.builtin.*;
import com.rti.dds.infrastructure.*;
...
Topic stringTopic = ... ;
Publisher publisher = ... ;
DataWriterQos writerQos = new DataWriterQos();
participant.get_default_datawriter_qos(writerQos);
PropertyQosPolicyHelper.add_property (
               writerQos.property,
               "dds.builtin_type.string.alloc_size",
               "1000", false);
StringDataWriter stringWriter =
        (StringDataWriter) publisher.create_datawriter(
               stringTopic, writerQos,
               null, StatusKind.STATUS_MASK_NONE);
```

3.2.7.2 Unbounded Built-in Types

In some scenarios, the maximum size of a built-in type is not known in advance and there is no a reasonable maximum size. For example, this could occur in a file transfer application using the built-in type Octets. Setting a large value for the **dds.builtin_type.*.alloc_size** property would involve high memory usage.

For the above use case, you can configure the built-in type to be unbounded by setting the property **dds.builtin_type.*.alloc_size** to the maximum value of a 32-bit signed integer: 2,147,483,647. Then the middleware will not preallocate the *DataReader* queue's samples to their maximum size. Instead, it will deserialize incoming samples by dynamically allocating and deallocating memory to accommodate the actual size of the sample value.

To configure unbounded support for built-in types:

1. Use these threshold QoS properties:
   - **dds.data_writer.history.memory_manager.fast_pool.pool_buffer_max_size** on the *DataWriter*
   - **dds.data_reader.history.memory_manager.fast_pool.pool_buffer_max_size** on the *DataReader*
2. Set the QoS value **reader_resource_limits.dynamically_allocate_fragmented_samples** on the *DataReader* to true.
3. For the Java API, also set these properties accordingly for the Java serialization buffer:
   - **dds.data_writer.history.memory_manager.java_stream.min_size**
   - **dds.data_writer.history.memory_manager.java_stream.trim_to_size**
   - **dds.data_reader.history.memory_manager.java_stream.min_size**
   - **dds.data_reader.history.memory_manager.java_stream.trim_to_size**

See these sections:

- 22.1.3 Writer-Side Memory Management when Using Java on page 923
- 22.2.2 Reader-Side Memory Management when Using Java on page 927

Unbounded built-in types are only supported in the C, C++, .NET, and Java APIs.

3.2.8 Type Codes for Built-in Types

The type codes associated with the built-in types are generated from the following IDL type definitions:

```
module DDS {
       /* String */
       struct String {
               string<max_size> value;
       };
       /* KeyedString */
       struct KeyedString {
               @key string<max_size> key;
               string<max_size> value;
       };
       /* Octets */
       struct Octets {
               sequence<octet, max_size> value;
       };
       /* KeyedOctets */
       struct KeyedOctets {
               @key string<max_size> key;
               sequence<octet, max_size> value;
```

```
        };
};
```

The maximum size (**max_size**) of the strings and sequences that will be included in the type code definitions can be configured on a per-*DomainParticipant*-basis by using the properties in Table 3.2 Properties for Allocating Size of Built-in Types, per DomainParticipant.

Table 3.2 Properties for Allocating Size of Built-in Types, per DomainParticipant

Built-in Type	Property	Description
String	dds.builtin_type.string.max_size	Maximum size of the strings published by the *DataWriters* and received by the *DataReaders* belonging to a *DomainParticipant* (includes the NULL-terminated character). Default: 1024
KeyedString	dds.builtin_type.keyed_string.max_key_size	Maximum size of the keys used by the *DataWriters* and *DataReaders* belonging to a *DomainParticipant* (includes the NULL-terminated character). Default: 1024
	dds.builtin_type.keyed_string.max_size	Maximum size of the strings published by the *DataWriters* and received by the *DataReaders* belonging to a *DomainParticipant* using the built-in type (includes the NULL-terminated character). Default: 1024
Octets	dds.builtin_type.octets.max_size	Maximum size of the octet sequences published by the *DataWriters* and *DataReaders* belonging to a *DomainParticipant*. Default: 2048
Keyed-Octets	dds.builtin_type.keyed_octets.max_key_size	Maximum size of the key published by the *DataWriter* and received by the *DataReaders* belonging to the *DomainParticipant* (includes the NULL-terminated character). Default:1024.
	dds.builtin_type.keyed_octets.max_size	Maximum size of the octet sequences published by the *DataWriters* and *DataReaders* belonging to a *DomainParticipant*. Default: 2048

3.3 Creating User Data Types with IDL

You can create user data types in a text file using IDL (Interface Description Language). IDL is programming-language independent, so the same file can be used to generate code in C, Traditional C++, Modern C++, C++/CLI, Ada, and Java (the languages supported by *RTI Code Generator* (*rtiddsgen*)). *RTI Code Generator* parses the IDL file and automatically generates all the necessary routines and wrapper functions to bind the types for use by *Connext DDS* at run time. You will end up with a set of required routines and structures that your application and *Connext DDS* will use to manipulate the data.

Connext DDS only uses a subset of the IDL 4.2 (https://www.omg.org/spec/IDL) syntax. IDL was originally defined by the OMG for the use of CORBA client/server applications in an enterprise setting. Not all of the constructs that can be described by the language are as useful in the context of high-performance

data-centric embedded applications. These include the constructs that define method and function prototypes like "interface."

RTI Code Generator will parse any file that follows version 4.2 of the IDL specification. It will ignore and show a warning for all syntax that is not recognized by *Connext DDS*.

Certain keywords are considered reserved by the IDL specification; see Table 3.3 Reserved IDL Keywords.

Table 3.3 Reserved IDL Keywords

abstract	any	alias	attribute	bitfield
bitmask	bitset	boolean	case	char
component	connector	const	consumes	context
custom	default	double	exception	emits
enum	eventtype	factory	FALSE	finder
fixed	float	getraises	home	import
in	inout	interface	local	long
manages	map	mirrorport	module	multiple
native	Object	octet	oneway	out
primarykey	private	port	porttype	provides
public	publishes	raises	readonly	setraises
sequence	short	string	struct	supports
switch	TRUE	truncatable	typedef	typeid
typename	typeprefix	unsigned	union	uses
ValueBase	valuetype	void	wchar	wstring
int8	uint8	int16	int32	int64
uint16	uint32	uint64		

The IDL constructs supported by *RTI Code Generator* are described in Table 3.5 Specifying Data Types in IDL for C through Table 3.9 Specifying Data Types in IDL for Java. Use these tables to map primitive types to their equivalent IDL syntax, and vice versa.

For C and Traditional C++, *RTI Code Generator* uses typedefs instead of the language keywords for primitive types. For example, DDS_Long instead of long or DDS_Double instead of double. This ensures that the types are of the same size regardless of the platform.

The number of bytes sent on the wire for each data type is determined by the Common Data Representation (CDR) defined in the OMG 'Extensible and Dynamic Topic Types for DDS' specification, version 1.3. There are two different CDR representations, encoding version 1 and encoding version 2. *Connext DDS* implements both. See the RTI Connext DDS Core Libraries Extensible Types Guide for more information.

3.3.1 Variable-Length Types

When *RTI Code Generator* generates code for data structures with variable-length types—strings and sequences—it includes functions that create, initialize and finalize (destroy) those objects. These support functions will properly initialize pointers and allocate and deallocate the memory used for variable-length types. All *Connext DDS* APIs assume that the data structures passed to them are properly initialized.

For variable-length types, the actual length (instead of the maximum length) of data is transmitted on the wire when the DDS sample is written (regardless of whether the type has hard-coded bounds).

3.3.1.1 Sequences

In C, Traditional C++, C++/CLI, C#, and Ada, sequences provide the concept of memory "ownership." A sequence may own the memory allocated to it or be loaned memory from another source. If a sequence owns its memory, it will manage its underlying memory storage buffer itself. When a sequence's maximum size is changed, the sequence will free and reallocate its buffer as needed. However, if a sequence was created with loaned memory by user code, then its memory is not its own to free or reallocate. Therefore, you cannot set the maximum size of a sequence whose memory is loaned. See the API Reference HTML documentation (select Modules, RTI Connext DDS API Reference, Infrastructure Module, Sequence Support) for more information about how to loan and unloan memory for sequence.

In IDL, as described above, a sequence may be declared as bounded or unbounded. A sequence's "bound" is the greatest value its maximum may take. If you use the initializer functions *RTI Code Generator* provides for your types, all sequences will have their maximums set to their declared bounds. However, the amount of data transmitted on the wire when the DDS sample is written will vary.

In the the Modern C++ and Java APIs, sequences always own the memory.

3.3.1.2 Strings and Wide Strings

Note: This section doesn't apply to the Modern C++ API, where strings map to **std::string** or **dds::core::string**, which behaves similarly. It also does not apply to the Traditional C++ API when generating code with the option **-useStdString**, which maps strings to **std::string**.

The initialization functions that *RTI Code Generator* provides for your types will allocate all of the memory for strings in a type to their declared bounds. Take care—if you assign a string pointer (char *) in a data structure allocated or initialized by a *Connext DDS*-generated function, you should release (free) the memory originally allocated for the string, otherwise the memory will be leaked.

To Java and .NET users, an IDL string is a String object: it is immutable and knows its own length. C and C++ users must take care, however, as there is no way to determine how much memory is allocated to a character pointer "string"; all that can be determined is the string's current logical length. In some cases, *Connext DDS* may need to copy a string into a structure that user code has provided. *Connext DDS* does not free the memory of the string provided to it, as it cannot know from where that memory was allocated.

In the C and C++ APIs, *Connext DDS* therefore uses the following conventions:

- A string's memory is "owned" by the structure that contains that string. Calling the finalization function provided for a type will free all recursively contained strings. If you have allocated a contained string in a special way, you must be careful to clean up your own memory and assign the pointer to NULL *before* calling the type's **finalize()** method, so that *Connext DDS* will skip over that string.
- You must provide a non-NULL string pointer for *Connext DDS* to copy into. Otherwise, *Connext DDS* will log an error.
- When you provide a non-NULL string pointer in your data structure, *Connext DDS* will copy into the provided memory without performing any additional memory allocations. Be careful—if you provide *Connext DDS* with an uninitialized pointer or allocate a string that is too short, you may corrupt the memory or cause a program crash. *Connext DDS* will never try to copy a string that is longer than the bound of the destination string. However, your application must insure that any string that it allocates is long enough.

Connext DDS provides a small set of C functions for dealing with strings. These functions simplify common tasks, avoid some platform-specific issues (such as the lack of a **strdup()** function on some platforms), and provide facilities for dealing with wide strings, for which no standard C library exists. *Connext DDS* always uses these functions internally for managing string memory; you are recommended—but not required—to use them as well. See the API Reference HTML documentation, which is available for all supported programming languages (select **Modules, RTI DDS API Reference, Infrastructure Module, String Support)** for more information about strings.

3.3.2 Value Types

Note: It is recommended to use structures (which support inheritance) instead of value types. For details, see the OMG 'Extensible and Dynamic Topic Types for DDS' specification, version 1.3 and the RTI Connext DDS Core Libraries Extensible Types Guide.

A value type is like a structure, but with support for additional object-oriented features such as inheritance. It is similar to what is sometimes referred to in Java as a *POJO*—a Plain Old Java Object.

Readers familiar with value types in the context of CORBA should consult Table 3.4 Value Type Support to see which value type-related IDL keywords are supported and what their behavior is in the context of *Connext DDS*.

Table 3.4 Value Type Support

Aspect	Level of Support in RTI Code Generator
Inheritance	Single inheritance from other value types
Public state members	Supported
Private state members	Become public when code is generated
Custom keyword	Ignored (the value type is parsed without the keyword and code is generated to work with it)
Abstract value types	No code generated (the value type is parsed, but no code is generated)
Operations	No code generated (the value type is parsed, but no code is generated)
Truncatable keyword	Ignored (the value type is parsed without the keyword and code is generated to work with it)

3.3.3 Type Codes

Type codes are always enabled when you run *RTI Code Generator*. Locally, your application can access the type code for a generated type "Foo" by calling the **FooTypeSupport::get_typecode()** (Traditional C++ Notation) operation in the code for the type generated by *RTI Code Generator*.

3.3.4 Translations for IDL Types

This section describes how to specify your data types in an IDL file. *RTI Code Generator* supports all the types listed in the following tables:

- Table 3.5 Specifying Data Types in IDL for C
- Table 3.6 Specifying Data Types in IDL for Traditional C++
- Table 3.7 Specifying Data Types in IDL for C++/CLI
- Table 3.8 Specifying Data Types in IDL for the Modern C++ API
- Table 3.9 Specifying Data Types in IDL for Java
- Table 3.10 Specifying Data Types in IDL for Ada

In each table, the middle column shows the IDL syntax for a data type in an IDL file. The rightmost column shows the corresponding language mapping created by *RTI Code Generator*.

Table 3.5 Specifying Data Types in IDL for C

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

char
 	
(see Note 1 below)
	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_Char char_member;`
		`} PrimitiveStruct;`

wchar	`struct PrimitiveStruct {`
	`  wchar wchar_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_Wchar wchar_member;`
		`} PrimitiveStruct;`

octet	`struct PrimitiveStruct {`
	`  octet octet_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_Octet octect_member;`
		`} PrimitiveStruct;`

int8
(see Note 16 below)
	`struct PrimitiveStruct {`
	`  int8 int8_member;`
	`};`
		`typedef struct PrimitiveStruct {`
		`  DDS_Int8 int8_member;`
		`} PrimitiveStruct;`

uint8
(see Note 16 below)
	`struct PrimitiveStruct {`
	`  uint8 uint8_member;`
	`}`
		`typedef struct PrimitiveStruct {`
		`  DDS_UInt8 uint8_member;`
		`} PrimitiveStruct;`

short or int16	`struct PrimitiveStruct {`
	`  int16 short_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_Short short_member;`
		`} PrimitiveStruct;`

unsigned short or uint16	`struct PrimitiveStruct {`
	`  uint16`
	`  unsigned_short_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_UnsignedShort`
		`  unsigned_short_member;`
		`} PrimitiveStruct;`

long or int32	`struct PrimitiveStruct {`
	`  int32 long_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_Long long_member;`
		`} PrimitiveStruct;`

unsigned long or uint32	`struct PrimitiveStruct {`
	`  uint32`
	`  unsigned_long_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_UnsignedLong`
		`  unsigned_long_member;`
		`} PrimitiveStruct;`

long long or int64	`struct PrimitiveStruct {`
	`  int64 long_long_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_LongLong long_long_member;`
		`} PrimitiveStruct;`

unsigned long long or uint64	`struct PrimitiveStruct {`
	`  uint64`
	`  unsigned_long_long_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_UnsignedLongLong`
		`  unsigned_long_long_member;`
		`} PrimitiveStruct;`

float	`struct PrimitiveStruct {`
	`  float float_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_Float float_member;`
		`} PrimitiveStruct;`

Table 3.5 Specifying Data Types in IDL for C

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

double	`struct PrimitiveStruct {`
	`  double double_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_Double double_member;`
		`} PrimitiveStruct;`

long double
 	
(see Note 2 below)
	`struct PrimitiveStruct {`
	`  long double`
	`  long_double_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_LongDouble`
		`  long_double_member;`
		`} PrimitiveStruct;`

@external or pointer
 	
(see Note 9 below)
	`struct MyStruct {`
	`  @external long member;`
	`}`
	or
	`struct MyStruct {`
	`  long * member;`
	`};`
		`typedef struct MyStruct {`
		`  DDS_Long * member;`
		`} MyStruct;`

boolean	`struct PrimitiveStruct {`
	`  boolean boolean_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_Boolean boolean_member;`
		`} PrimitiveStruct;`

enum	`enum PrimitiveEnum {`
	`  ENUM1,`
	`  ENUM2,`
	`  ENUM3`
	`};`
	
	`enum PrimitiveEnum {`
	`  ENUM1 = 10,`
	`  ENUM2 = 20,`
	`  ENUM3 = 30`
	`};`
	`enum PrimitiveEnum {`
	`  @value (10) ENUM1,`
	`  @value (20) ENUM2,`
	`  @value (30) ENUM3`
	`}`
		`typedef enum PrimitiveEnum`
		`{`
		`  ENUM1,`
		`  ENUM2,`
		`  ENUM3`
		`} PrimitiveEnum;`
		
		`typedef enum PrimitiveEnum`
		`{`
		`  ENUM1 = 10,`
		`  ENUM2 = 20,`
		`  ENUM3 = 30`
		`} PrimitiveEnum;`

constant	`const short SIZE = 5;`	`#define SIZE 5`

struct
 	
(see Note 10 below)
	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  char char_member;`
		`} PrimitiveStruct;`

union
 	
(see Note 3 and Note 10 below)
	`union PrimitiveUnion`
	`switch (long){`
	`  case 1:`
	`  short short_member;`
	`  default:`
	`  long long_member;`
	`};`
		`typedef struct PrimitiveUnion`
		`{`
		`  DDS_Long _d;`
		`  struct {`
		`  DDS_Short short_member;`
		`  DDS_Long long_member;`
		`  } _u;`
		`} PrimitiveUnion;`

typedef	`typedef short TypedefShort;`	`typedef DDS_Short TypedefShort;`

Table 3.5 Specifying Data Types in IDL for C

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

array of above types	`struct OneDArrayStruct {`
	`  short short_array[2];`
	`};`
	
	`struct TwoDArrayStruct {`
	`  short short_array[1][2];`
	`};`
		`typedef struct OneDArrayStruct`
		`{`
		`  DDS_Short short_array[2];`
		`} OneDArrayStruct;`
		
		`typedef struct TwoDArrayStruct`
		`{`
		`  DDS_Short short_array[1][2];`
		`} TwoDArrayStruct;`

bounded sequence of above types
 	
(see Note 11 and Note 15 below)
	`struct SequenceStruct {`
	`  sequence<short,4>`
	`  short_sequence;`
	`};`
		`typedef struct SequenceStruct`
		`{`
		`  DDSShortSeq short_sequence;`
		`} SequenceStruct;`
		
		Note: Sequences of primitive types have been predefined by *Connext DDS*.

unbounded sequence of above types
 	
(see Note 11 and Note 15 below)
	`struct SequenceStruct {`
	`  sequence<short> short_`
	`sequence;`
	`};`
		`typedef struct SequenceStruct`
		`{`
		`  DDSShortSeq short_sequence;`
		`} SequenceStruct;`
		
		See Note 12 below.

array of sequences	`struct ArraysOfSequences{`
	`  sequence<short,4>`
	`  sequences_array[2];`
	`};`
		`typedef struct ArraysOfSequences`
		`{`
		`  DDS_ShortSeq sequences_array[2];`
		`} ArraysOfSequences;`

sequence of arrays
 	
(see Note 11 below)
	`typedef short ShortArray[2];`
	
	`struct SequenceofArrays {`
	`  sequence<ShortArray,2>`
	`  arrays_sequence;`
	`};`
		`typedef DDS_Short ShortArray[2];`
		
		`DDS_SEQUENCE_NO_GET(ShortArraySeq,ShortArray);`
		
		`typedef struct SequenceOfArrays`
		`{`
		`  ShortArraySeq arrays_sequence;`
		`} SequenceOfArrays;`
		
		DDS_SEQUENCE_NO_GET is a *Connext DDS* macro that defines a new sequence type for a user data type. In this case, the user data type is ShortArray.

sequence of sequences
 	
(see Note 4 and Note 11 below)
	`typedef sequence<short,4>`
	`  ShortSequence;`
	
	`struct SequencesOfSequences {`
	`  sequence<ShortSequence,2>`
	`  sequences_sequence;`
	`};`
		`typedef DDS_ShortSeq ShortSequence;`
		
		`DDS_SEQUENCE(ShortSequenceSeq,`
		`  ShortSequence);`
		`typedef struct`
		`  SequencesOfSequences {`
		`  ShortSequenceSeq sequences_sequence;`
		`} SequencesOfSequences;`

bounded string	`struct PrimitiveStruct {`
	`  string<20> string_member;`
	`};`
		`typedef struct PrimitiveStruct {`
		`  char* string_member;`
		`  /* maximum length = (20) */`
		`} PrimitiveStruct;`

Table 3.5 Specifying Data Types in IDL for C

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

unbounded string	`struct PrimitiveStruct {`
	`  string string_member;`
	`};`
		`typedef struct PrimitiveStruct {`
		`  char* string_member;`
		`  /* maximum length = (255) */`
		`} PrimitiveStruct;`
		See Note 12 below.

bounded wstring	`struct PrimitiveStruct {`
	`  wstring<20> wstring_member;`
	`};`
		`typedef struct PrimitiveStruct {`
		`  DDS_Wchar * wstring_member;`
		`  /* maximum length = (20) */`
		`} PrimitiveStruct;`

unbounded wstring	`struct PrimitiveStruct {`
	`  wstring wstring_member;`
	`};`
		`typedef struct PrimitiveStruct {`
		`  DDS_Wchar * wstring_member;`
		`  /* maximum length = (255) */`
		`} PrimitiveStruct;`
		See Note 12 below.

module	`module PackageName {`
	`  struct Foo {`
	`  long field;`
	`  };`
	`};`
		With the **-namespace** option (only available for C++):
		`namespace PackageName{`
		`  typedef struct Foo {`
		`  DDS_Long field;`
		`  } Foo;`
		`};`
		Without the **-namespace** option:
		`typedef struct PackageName_Foo {`
		`  DDS_Long field;`
		`} PackageName_Foo;`

valuetype
(see Note 9 and Note 10 below)
	`valuetype MyValueType {`
	`  public MyValueType2 * member;`
	`};`
	`valuetype MyValueType {`
	`  public MyValueType2 member;`
	`};`
	`valuetype MyValueType:`
	`  MyBaseValueType  {`
	`  public MyValueType2 * member;`
	`};`
		`typedef struct MyValueType {`
		`  MyValueType2 * member;`
		`} MyValueType;`
		`typedef struct MyValueType {`
		`  MyValueType2  member;`
		`} MyValueType;`
		`typedef struct MyValueType`
		`{`
		`  MyBaseValueType parent;`
		`  MyValueType2 * member;`
		`} MyValueType;`

Table 3.6 Specifying Data Types in IDL for Traditional C++

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

char
(see Note 1 below)
	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_Char char_member;`
		`} PrimitiveStruct;`

Table 3.6 Specifying Data Types in IDL for Traditional C++

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

wchar	`struct PrimitiveStruct {`
	`  wchar wchar_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_Wchar wchar_member;`
		`} PrimitiveStruct;`

octet	`struct PrimitiveStruct {`
	`  octet octet_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_Octet octect_member;`
		`} PrimitiveStruct;`

int8
(see Note 16 below)
	`struct PrimitiveStruct {`
	`  int8 int8_member;`
	`};`
		`class PrimitiveStruct {`
		`  DDS_Int8 int8_member;`
		`} PrimitiveStruct;`

uint8
(see Note 16 below)
	`struct PrimitiveStruct {`
	`  uint8 uint8_member;`
	`};`
		`class PrimitiveStruct {`
		`  DDS_UInt8 uint8_member;`
		`} PrimitiveStruct;`

short or int16	`struct PrimitiveStruct {`
	`  int16 short_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_Short short_member;`
		`} PrimitiveStruct;`

unsigned short or uint16	`struct PrimitiveStruct {`
	`  uint16`
	`  unsigned_short_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_UnsignedShort`
		`  unsigned_short_member;`
		`} PrimitiveStruct;`

long or int32	`struct PrimitiveStruct {`
	`  int32 long_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_Long long_member;`
		`} PrimitiveStruct;`

unsigned long or uint32	`struct PrimitiveStruct {`
	`  uint32`
	`  unsigned_long_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_UnsignedLong`
		`  unsigned_long_member;`
		`} PrimitiveStruct;`

long long or int64	`struct PrimitiveStruct {`
	`  int64 long_long_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_LongLong`
		`  long_long_member;`
		`} PrimitiveStruct;`

unsigned long long or uint64	`struct PrimitiveStruct {`
	`  uint64`
	`  unsigned_long_long_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_UnsignedLongLong`
		`  unsigned_long_long_member;`
		`} PrimitiveStruct;`

float	`struct PrimitiveStruct {`
	`  float float_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  DDS_Float float_member;`
		`} PrimitiveStruct;`

double	`struct PrimitiveStruct {`
	`  double double_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_Double double_member;`
		`} PrimitiveStruct;`

Table 3.6 Specifying Data Types in IDL for Traditional C++

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

long double
 	
(see Note 2 below)
	`struct PrimitiveStruct {`
	`  long double`
	`  long_double_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_LongDouble`
		`  long_double_member;`
		`} PrimitiveStruct;`

@external or pointer
 	
(see Note 9 below)
	`struct MyStruct {`
	`  @external long member;`
	`}`
	or
	`struct MyStruct {`
	`  long * member;`
	`};`
		`class MyStruct {`
		`  DDS_Long * member;`
		`} MyStruct;`

boolean	`struct PrimitiveStruct {`
	`  boolean boolean_member;`
	`};`
		`class PrimitiveStruct`
		`{`
		`  DDS_Boolean boolean_member;`
		`} PrimitiveStruct;`

enum	`enum PrimitiveEnum {`
	`  ENUM1,`
	`  ENUM2,`
	`  ENUM3`
	`};`
	
	`enum PrimitiveEnum {`
	`  ENUM1 = 10,`
	`  ENUM2 = 20,`
	`  ENUM3 = 30`
	`};`
	`enum PrimitiveEnum {`
	`  @value (10) ENUM1,`
	`  @value (20) ENUM2,`
	`  @value (30) ENUM3`
	`}`
		`typedef enum PrimitiveEnum`
		`{`
		`  ENUM1,`
		`  ENUM2,`
		`  ENUM3`
		`} PrimitiveEnum;`
		
		`typedef enum PrimitiveEnum`
		`{`
		`  ENUM1 = 10,`
		`  ENUM2 = 20,`
		`  ENUM3 = 30`
		`} PrimitiveEnum;`

constant	`const short SIZE = 5;`	`static const DDS_Short size = 5;`

struct
 	
(see Note 10 below)
	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`typedef struct PrimitiveStruct`
		`{`
		`  char char_member;`
		`} PrimitiveStruct;`

union
 	
(see Note 3 and Note 10 below)
	`union PrimitiveUnion switch (long)`
	`{`
	`  case 1:`
	`  short short_member;`
	`  default:`
	`  long long_member;`
	`};`
		`class PrimitiveUnion`
		`{`
		`  DDS_Long _d;`
		`  class{`
		`  DDS_Short short_member;`
		`  DDS_Long long_member;`
		`  } _u;`
		`} PrimitiveUnion;`

typedef	`typedef short TypedefShort;`	`typedef DDS_Short TypedefShort;`

Table 3.6 Specifying Data Types in IDL for Traditional C++

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

array of above types	`struct OneDArrayStruct {`
	`  short short_array[2];`
	`};`
	
	`struct TwoDArrayStruct {`
	`  short short_array[1][2];`
	`};`
		`class OneDArrayStruct`
		`{`
		`  DDS_Short short_array[2];`
		`} OneDArrayStruct;`
		
		`class TwoDArrayStruct`
		`{`
		`  DDS_Short short_array[1][2];`
		`} TwoDArrayStruct;`

bounded sequence of above types
 	
(see Note 11 and Note 15 below)
	`struct SequenceStruct {`
	`  sequence<short,4>`
	`  short_sequence;`
	`};`
		`class SequenceStruct`
		`{`
		`  DDSShortSeq short_sequence;`
		`} SequenceStruct;`
		
		Note: Sequences of primitive types have been predefined by *Connext DDS*.

unbounded sequence of above types
 	
(see Note 11 and Note 15 below)
	`struct SequenceStruct {`
	`  sequence<short>`
	`  short_sequence;`
	`};`
		`typedef struct SequenceStruct`
		`{`
		`  DDSShortSeq short_sequence;`
		`} SequenceStruct;`
		
		See Note 12 below.

array of sequences	`struct ArraysOfSequences{`
	`  sequence<short,4>`
	`  sequences_array[2];`
	`};`
		`class ArraysOfSequences`
		`{`
		`  DDS_ShortSeq sequences_array[2];`
		`} ArraysOfSequences;`

sequence of arrays
 	
(see Note 11 below)
	`typedef short ShortArray[2];`
	
	`struct SequenceofArrays {`
	`  sequence<ShortArray,2>`
	`  arrays_sequence;`
	`};`
		`typedef DDS_Short ShortArray[2];`
		
		`DDS_SEQUENCE_NO_GET(ShortArraySeq,`
		`  ShortArray);`
		`class SequenceOfArrays`
		`{`
		`  ShortArraySeq arrays_sequence;`
		`} SequenceOfArrays;`
		
		DDS_SEQUENCE_NO_GET is a *Connext DDS* macro that defines a new sequence type for a user data type. In this case, the user data type is ShortArray.

sequence of sequences
 	
(see Note 4 and Note 11 below)
	`typedef sequence<short,4>`
	`  ShortSequence;`
	
	`struct SequencesOfSequences{`
	`  sequence<ShortSequence,2>`
	`  sequences_sequence;`
	`};`
		`typedef DDS_ShortSeq ShortSequence;`
		
		`DDS_SEQUENCE(ShortSequenceSeq, ShortSequence);`
		
		`class SequencesOfSequences{`
		`  ShortSequenceSeq sequences_sequence;`
		`} SequencesOfSequences;`

bounded string	`struct PrimitiveStruct {`
	`  string<20> string_member;`
	`};`
		`class PrimitiveStruct {`
		`  char* string_member;`
		`  /* maximum length = (20) */`
		`} PrimitiveStruct;`

Table 3.6 Specifying Data Types in IDL for Traditional C++

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

unbounded string	`struct PrimitiveStruct {`
	`  string string_member;`
	`};`
		`class PrimitiveStruct {`
		`  char* string_member;`
		`  /* maximum length = (255) */`
		`} PrimitiveStruct;`
		See Note 12 below.

bounded wstring	`struct PrimitiveStruct {`
	`  wstring<20> wstring_member;`
	`};`
		`class PrimitiveStruct {`
		`  DDS_Wchar * wstring_member;`
		`  /* maximum length = (20) */`
		`} PrimitiveStruct;`

unbounded wstring	`struct PrimitiveStruct {`
	`  wstring wstring_member;`
	`};`
		`class PrimitiveStruct {`
		`  DDS_Wchar * wstring_member;`
		`  /* maximum length = (255) */`
		`} PrimitiveStruct;`
		See Note 12 below.

module	`module PackageName {`
	`  struct Foo {`
	`  long field;`
	`  };`
	`};`
		With the **-namespace** option (only available for C++):
		`namespace PackageName{`
		`  typedef struct Foo {`
		`  DDS_Long field;`
		`  } Foo;`
		`};`
		Without the **-namespace** option:
		`class PackageName_Foo {`
		`  DDS_Long field;`
		`} PackageName_Foo;`

valuetype
 	
(see Note 9 and Note 10 below)
	`valuetype MyValueType {`
	`  public MyValueType2 * member;`
	`};`
	
	`valuetype MyValueType {`
	`  public MyValueType2 member;`
	`};`
	
	`valuetype MyValueType:`
	`  MyBaseValueType  {`
	`  public MyValueType2 * member;`
	`};`
		`class MyValueType {`
		`public:`
		`  MyValueType2 * member;`
		`};`
		
		`class MyValueType {`
		`public:`
		`  MyValueType2  member;`
		`};`
		
		`class MyValueType :`
		`public MyBaseValueType`
		`{`
		`public:`
		`  MyValueType2 * member;`
		`};`

Table 3.7 Specifying Data Types in IDL for C++/CLI

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

char
 	
(see Note 1 below)
	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::Char char_member;`
		`};`

Table 3.7 Specifying Data Types in IDL for C++/CLI

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

wchar	`struct PrimitiveStruct {`
	`  wchar wchar_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::Char wchar_member;`
		`};`

octet	`struct PrimitiveStruct {`
	`  octet octet_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::Byte octet_member;`
		`};`

short or int16	`struct PrimitiveStruct {`
	`  int16 short_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::Int16 short_member;`
		`};`

unsigned short or uint16	`struct PrimitiveStruct {`
	`  uint16`
	`  unsigned_short_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::UInt16`
		`  unsigned_short_member;`
		`};`

long or int32	`struct PrimitiveStruct {`
	`  int32 long_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::Int32 long_member;`
		`};`

unsigned long or uint32	`struct PrimitiveStruct {`
	`  uint32`
	`  unsigned_long_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::UInt32`
		`  unsigned_long_member;`
		`};`

long long or int64	`struct PrimitiveStruct {`
	`  int64 long_long_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::Int64`
		`  long_long_member;`
		`};`

unsigned long long or uint64	`struct PrimitiveStruct {`
	`  uint64`
	`  unsigned_long_long_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::UInt64`
		`  unsigned_long_long_member;`
		`};`

float	`struct PrimitiveStruct {`
	`  float float_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::Single`
		`  float_member;`
		`};`

double	`struct PrimitiveStruct {`
	`  double double_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::Double`
		`  double_member;`
		`} PrimitiveStruct;`

long double
(see Note 2 below)
	`struct PrimitiveStruct {`
	`  long double`
	`  long_double_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  DDS::LongDouble`
		`  long_double_member;`
		`} PrimitiveStruct;`

boolean	`struct PrimitiveStruct {`
	`  boolean boolean_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::Boolean`
		`  boolean_member;`
		`};`

Table 3.7 Specifying Data Types in IDL for C++/CLI

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

enum	`enum PrimitiveEnum {`
	`  ENUM1,`
	`  ENUM2,`
	`  ENUM3`
	`};`
	
	`enum PrimitiveEnum {`
	`  ENUM1 = 10,`
	`  ENUM2 = 20,`
	`  ENUM3 = 30`
	`};`
	`enum PrimitiveEnum {`
	`  @value (10) ENUM1,`
	`  @value (20) ENUM2,`
	`  @value (30) ENUM3`
	`}`
		`public enum class`
		`PrimitiveEnum : System::Int32 {`
		`  ENUM1,`
		`  ENUM2,`
		`  ENUM3`
		`};`
		
		`public enum class`
		`PrimitiveEnum : System::Int32 {`
		`  ENUM1 = 10,`
		`  ENUM2 = 20,`
		`  ENUM3 = 30`
		`};`

constant	`const short SIZE = 5;`	`public ref class SIZE {`
		`  public:`
		`  static System::Int16`
		`  VALUE = 5;`
		`};`

struct
 	
(see Note 10 below)
	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::Char char_member;`
		`};`

union
 	
(see Note 3 and Note 10 below)
	`union PrimitiveUnion switch (long){`
	`  case 1:`
	`  short short_member;`
	`  default:`
	`  long long_member;`
	`};`
		`public ref class PrimitiveUnion`
		`{`
		`  System::Int32 _d;`
		
		`  struct PrimitiveUnion_u {`
		`  System::Int16 short_member;`
		`  System::Int32 long_member;`
		`  } _u;`
		`};`

array of above types	`struct OneDArrayStruct {`
	`  short short_array[2];`
	`};`
		`public ref class OneDArrayStruct {`
		`  array<System::Int16>^`
		`  short_array; /*length == 2*/`
		`};`

bounded sequence of above types
(see Note 11 and Note 15 below)
	`struct SequenceStruct {`
	`  sequence<short,4>`
	`  short_sequence;`
	`};`
		`public ref class SequenceStruct {`
		`  ShortSeq^ short_sequence;`
		`  /*max = 4*/`
		`};`
		Note: Sequences of primitive types have been predefined by *Connext DDS*

unbounded sequence of above types
(see Note 11 and Note 15 below)
	`struct SequenceStruct {`
	`  sequence<short>`
	`  short_sequence;`
	`};`
		`public ref class SequenceStruct {`
		`  ShortSeq^ short_sequence;`
		`  /*max = <default bound>*/`
		`};`
		See Note 12 below.

Table 3.7 Specifying Data Types in IDL for C++/CLI

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

array of sequences	`struct ArraysOfSequences{`
	`  sequence<short,4>`
	`  sequences_array[2];`
	`};`
		`public ref class ArraysOfSequences`
		`{`
		`  array<DDS::ShortSeq^>^`
		`  sequences_array;`
		`  // maximum length = (2)`
		`};`

bounded string	`struct PrimitiveStruct {`
	`  string<20> string_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::String^ string_member;`
		`  // maximum length = (20)`
		`};`

unbounded string	`struct PrimitiveStruct {`
	`  string string_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::String^ string_member;`
		`  // maximum length = (255)`
		`};`
		See Note 12 below.

bounded wstring	`struct PrimitiveStruct {`
	`  wstring<20> wstring_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::String^ string_member;`
		`  // maximum length = (20)`
		`};`

unbounded wstring	`struct PrimitiveStruct {`
	`  wstring wstring_member;`
	`};`
		`public ref class PrimitiveStruct {`
		`  System::String^ string_member;`
		`  // maximum length = (255)`
		`};`
		See Note 12 below.

module	`module PackageName {`
	`  struct Foo {`
	`  long field;`
	`  };`
	`};`
		`namespace PackageName {`
		`  public ref class Foo {`
		`  System::Int32 field;`
		`  };`
		`};`

Table 3.8 Specifying Data Types in IDL for the Modern C++ API

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

char	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  char char_member() const OMG_NOEXCEPT;`
		`  void char_member(char value);`
		`}`

wchar	`struct PrimitiveStruct {`
	`  wchar wchar_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  wchar_t wchar_member() const OMG_NOEXCEPT;`
		`  void wchar_member(wchar_t value);`
		`};`

octet	`struct PrimitiveStruct {`
	`  octet octet_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  uint8_t octet_member() const OMG_NOEXCEPT;`
		`  void octet_member(uint8_t value);`
		`};`

Table 3.8 Specifying Data Types in IDL for the Modern C++ API

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

int8
(see Note 16 below)
	`struct PrimitiveStruct {`
	`  int8 int8_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  int8_t int8_member() const OMG_NOEXCEPT;`
		`  void int8_member(int8_t value);`
		`};`

uint8
(see Note 16 below)
	`struct PrimitiveStruct {`
	`  uint8 uint8_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  uint8_t uint8_member() const OMG_NOEXCEPT;`
		`  void uint8_member(uint8_t value);`
		`};`

short or int16	`struct PrimitiveStruct {`
	`  int16 short_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  int16_t short_member() const OMG_NOEXCEPT;`
		`  void short_member(int16_t value);`
		`};`

unsigned short or uint16	`struct PrimitiveStruct {`
	`  uint16`
	`  unsigned_short_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  uint16_t unsigned_short_member()`
		`  const OMG_NOEXCEPT;`
		`  void unsigned_short_member(uint16_t value);`
		`};`

long or int32	`struct PrimitiveStruct {`
	`  int32 long_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  int32_t long_member() const OMG_NOEXCEPT;`
		`  void long_member(int32_t value);`
		`};`

unsigned long or uint32	`struct PrimitiveStruct {`
	`  uint32`
	`  unsigned_long_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  uint32_t unsigned_long_member() const OMG_NOEXCEPT;`
		`  void unsigned_long_member(uint32_t value);`
		`};`

long long or int64	`struct PrimitiveStruct {`
	`  int64 long_long_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  rti::core::int64 long_long_member()`
		`  const OMG_NOEXCEPT;`
		`  void long_long_member(rti::core::int64 value);`
		`};`

unsigned long long or uint64	`struct PrimitiveStruct {`
	`  uint64`
	`  unsigned_long_long_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  rti::core::uint64 unsigned_long_long_member);`
		`  rti::core::uint64 unsigned_long_long_member()`
		`  const OMG_NOEXCEPT;`
		`};`

float	`struct PrimitiveStruct {`
	`  float float_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  float float_member() const OMG_NOEXCEPT;`
		`  void float_member(float value);`
		`};`

double	`struct PrimitiveStruct {`
	`  double double_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  double double_member() const OMG_NOEXCEPT;`
		`  void double_member(double value);`
		`};`

Table 3.8 Specifying Data Types in IDL for the Modern C++ API

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

long double
 	
(see Note 2 below)
	`struct PrimitiveStruct {`
	`  long double`
	`  long_double_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  rti::core::LongDouble& long_double_member()`
		`  const OMG_NOEXCEPT;`
		`  const rti::core::LongDouble& long_double_member()`
		`  const OMG_NOEXCEPT;`
		`  void long_double_member(`
		`  const rti::core::LongDouble& value);`
		`}`

pointer
 	
(see Note 9 below)
	`struct MyStruct {`
	`  long * member;`
	`}`
		`class PrimitiveStruct {`
		`  dds::core::external<int32_t>& member();`
		`  const dds::core::external<int32_t>& member() const;`
		`  void member(dds::core::external<int32_t> value);`
		`};`

boolean	`struct PrimitiveStruct {`
	`  boolean boolean_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  bool boolean_member() const OMG_NOEXCEPT;`
		`  void boolean_member(bool value);`
		`};`

enum	`enum PrimitiveEnum {`
	`  ENUM1,`
	`  ENUM2,`
	`  ENUM3`
	`};`
	
	`enum PrimitiveEnum {`
	`  ENUM1 = 10,`
	`  ENUM2 = 20,`
	`  ENUM3 = 30`
	`};`
	`enum PrimitiveEnum {`
	`  @value (10) ENUM1,`
	`  @value (20) ENUM2,`
	`  @value (30) ENUM3`
	`}`
		`struct PrimitiveEnum_def {`
		`  enum type {`
		`  ENUM1,`
		`  ENUM2,`
		`  ENUM3`
		`  };`
		`};`
		`typedef dds::core::safe_enum<PrimitiveEnum_def>`
		`PrimitiveEnum;`
		
		`struct PrimitiveEnum_def {`
		`  enum type {`
		`  ENUM1 = 10,`
		`  ENUM2 = 20,`
		`  ENUM3 = 30`
		`  };`
		`};`
		`typedef dds::core::safe_enum<PrimitiveEnum_def>`
		`PrimitiveEnum;`

constant	`const short SIZE = 5;`	`static const int16_t SIZE = 5;`

struct
 	
(see Note 10 and Note 14 below)
	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  ....`
		`  char char_member() const OMG_NOEXCEPT;`
		`  void char_member(char value);`
		`}`

Table 3.8 Specifying Data Types in IDL for the Modern C++ API

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

union
 	
(see Note 3 and Note 10 below)
	`union PrimitiveUnion switch (long){`
	`  case 1:`
	`  short short_member;`
	`  default:`
	`  long long_member;`
	`};`
		`class PrimitiveUnion {`
		`public:`
		`  int32_t _d() const ;`
		`  void _d(int32_t value);`
		`  int16_t short_member() const;`
		`  void short_member(int16_t value);`
		`  int32_t long_member() const ;`
		`  void long_member(int32_t value);`
		`  static int32_t default_discriminator();`
		
		`private:`
		`  int32_t m_d_;`
		`  struct Union_ {`
		`  int16_t m_short_member_;`
		`  int32_t m_long_member_;`
		`  Union_();`
		`  Union_(`
		`  int16_t short_member,`
		`  int32_t long_member);`
		`  };`
		`  Union_ m_u_;`
		`};`

typedef	`typedef short TypedefShort;`	`typedef int16_t TypedefShort;` `struct TypedefShort_AliasTag_t {};`

array of above types	`struct OneDArrayStruct {`
	`  short short_array[2];`
	`};`
	
	`struct TwoDArrayStruct {`
	`  short short_array[1][2];`
	`};`
		`class OneDArrayStruct {`
		`public:`
		`  dds::core::array<int16_t, 2>& short_array()`
		`  OMG_NOEXCEPT;`
		`  const dds::core::array<int16_t, 2>& short_array()`
		`  const OMG_NOEXCEPT;`
		`  void short_array(const dds::core::array`
		`  <int16_t, 2>& value);`
		`};`
		
		`class TwoDArrayStruct {`
		`public:`
		`  dds::core::array<dds::core::array<int16_t, 2>, 1>`
		`  & short_array() OMG_NOEXCEPT;`
		`  const dds::core::array<dds::core::array`
		`  <int16_t, 2>, 1> & short_array()`
		`  const OMG_NOEXCEPT;`
		`  void short_array(`
		`  const dds::core::array`
		`  <dds::core::array<int16_t, 2>, 1>& value);`
		`};`

Table 3.8 Specifying Data Types in IDL for the Modern C++ API

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

bounded sequence of above types	`struct SequenceStruct {`
	`  sequence<short,4> short_`
	`sequence;`
	`};`
		`class SequenceStruct {`
		`public:`
		`  rti::core::bounded_sequence<int16_t, 4>`
		`  & short_sequence() OMG_NOEXCEPT;`
		`  const rti::core::bounded_sequence`
		`  <int16_t, 4>& short_sequence()`
		`  const OMG_ NOEXCEPT;`
		`  void short_sequence(const`
		`  rti::core::bounded_sequence<int16_t, 4>& value);`
		`};`
		The type bounded_sequence is similar to std::vector, but enforces the bound set in the IDL type, and uses the bound to optimize how the memory is reserved.
		With -alwaysUseStdVector, see "unbounded sequence"

unbounded sequence of above types
 	
(see Note 15 below)
	`struct SequenceStruct {`
	`  sequence<short> short_sequence;`
	`};`
		With -unboundedSupport, -alwaysUseStdVector, or the annotation @use_vector (see 3.3.9.7 The @use_vector annotation on page 118):
		`class SequenceStruct {`
		`public:`
		`  std::vector<int16_t>`
		`  & short_sequence() OMG_NOEXCEPT;`
		`  const std::vector<int16_t>`
		`  & short_sequence() const OMG_NOEXCEPT;`
		`  void short_sequence(`
		`  const std::vector<int16_t>& value);`
		`};`
		Without -unboundedSupport, see bounded sequence of above types above.
		See Note 12 below.

array of sequences	`struct ArraysOfSequences{`
	`  sequence<short,4>`
	`  sequences_array[2];`
	`};`
		`class ArraysOfSequences {`
		`public:`
		`  ...`
		`  dds::core::array`
		`  <rti::core::bounded_sequence<int16_t, 4>, 2>`
		`  & sequences_array() OMG_NOEXCEPT;`
		`  const dds::core::array`
		`  <rti::core::bounded_sequence<int16_t, 4>, 2>`
		`  & sequences_array() const OMG_NOEXCEPT;`
		`  void sequences_array(`
		`  const dds::core::array`
		`  <rti::core::bounded_sequence<int16_t, 4>, 2>`
		`  & value);`
		`};`

sequence of arrays
 	
(see Note 15 below)
	`typedef short ShortArray[2];`
	
	`struct SequenceofArrays {`
	`  sequence<ShortArray,2>`
	`  arrays_sequence;`
	`};`
		`typedef dds::core::array<int16_t, 2> ShortArray;`
		
		`class SequenceofArrays {`
		`public:`
		`  ...`
		`  rti::core::bounded_sequence<ShortArray, 2>`
		`  & arrays_sequence() OMG_NOEXCEPT;`
		`  const rti::core::bounded_sequence<ShortArray, 2>`
		`  & arrays_sequence() const OMG_NOEXCEPT;`
		`  void arrays_sequence(`
		`  const rti::core::bounded_sequence<ShortArray, 2>`
		`  & value);`
		`};`
		See 3.3.4 Translations for IDL Types on page 79.

Table 3.8 Specifying Data Types in IDL for the Modern C++ API

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

sequence of sequences
 	
(see Note 4 below)
	`typedef sequence<short,4>`
	`  ShortSequence;`
	
	`struct SequencesOfSequences{`
	`  sequence<ShortSequence,2>`
	`  sequences_sequence;`
	`};`
		`typedef rti::core::bounded_sequence<int16_t, 4>`
		`ShortSequence;`
		
		`class SequencesOfSequences {`
		`public:`
		`  ...`
		`  rti::core::bounded_sequence<ShortSequence, 2>`
		`  & sequences_sequence() OMG_NOEXCEPT;`
		`  const rti::core::bounded_sequence<ShortSequence, 2>`
		`  & sequences_sequence() const OMG_NOEXCEPT;`
		`  void sequences_sequence(`
		`  const`
		`  rti::core::bounded_sequence<ShortSequence, 2>`
		`  & value);`
		`};`
		
		See 3.3.4 Translations for IDL Types on page 79.

bounded string	`struct PrimitiveStruct {`
	`  string<20> string_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  std::string& string_member() OMG_NOEXCEPT;`
		`  const std::string& string_member() const OMG_`
		`NOEXCEPT;`
		`  void string_member(const std::string& value);`
		`};`
		
		See 3.3.4 Translations for IDL Types on page 79.

unbounded string	`struct PrimitiveStruct {`
	`  string string_member;`
	`};`
		See Note 12 below.
		
		See 3.3.4 Translations for IDL Types on page 79.

bounded wstring	`struct PrimitiveStruct {`
	`  wstring<20>`
	`  wstring_member;`
	`};`
		`class PrimitiveStruct {`
		`public:`
		`  std::wstring& string_member() OMG_NOEXCEPT;`
		`  const std::wstring& string_member()`
		`  const OMG_NOEXCEPT;`
		`  void string_member(`
		`  const std::wstring& value);`
		`};`
		
		See 3.3.4 Translations for IDL Types on page 79.

unbounded wstring	`struct PrimitiveStruct {`
	`  wstring wstring_member;`
	`};`
		See Note 12 below.
		
		See 3.3.4 Translations for IDL Types on page 79.

module	`module PackageName {`
	`  struct Foo {`
	`  long field;`
	`  };`
	`};`
		`namespace PackageName {`
		`  class Foo {`
		`  public:`
		`  int32_t field() const OMG_NOEXCEPT;`
		`  void field(int32_t value);`
		`  };`
		`};`

Table 3.8 Specifying Data Types in IDL for the Modern C++ API

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

valuetype
 	
(see Note 9 and Note 10 below)
	`valuetype MyBaseValueType  {`
	`    public long  member;`
	`};`
	
	`valuetype MyValueType:`
	`MyBaseValueType  {`
	`    public short * member2;`
	`};`
		`class MyBaseValueType {`
		`public:`
		`    int32_t member() const OMG_NOEXCEPT;`
		`    void member(int32_t value);`
		`};`
		
		`class MyValueType : public MyBaseValueType {`
		`public:`
		`    int16_t * member2() const OMG_NOEXCEPT;`
		`    void member2(int16_t * value);`
		`};`

Table 3.9 Specifying Data Types in IDL for Java

IDL Type	Example Entry in IDL file	Example Java Output Generated by RTI Code Generator (rtiddsgen)

char
 	
(see Note 5 below)
	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public char char_member;`
		`  ...`
		`}`

wchar
 	
(see Note 5 below)
	`struct PrimitiveStruct {`
	`  wchar wchar_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public char wchar_member;`
		`  ...`
		`}`

octet	`struct PrimitiveStruct {`
	`  octet octet_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public byte octet_member;`
		`  ...`
		`}`

int8
(see Note 16 below)
	`struct PrimitiveStruct {`
	`    int8 int8_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`    public byte int8_member;`
		`    ...`
		`}`

uint8
(see Note 16 below)
	`struct PrimitiveStruct {`
	`    uint8 uint8_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`    public byte uint8_member;`
		`    ...`
		`}`

short or int16	`struct PrimitiveStruct {`
	`  int16 short_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public short short_member;`
		`  ...`
		`}`

Table 3.9 Specifying Data Types in IDL for Java

IDL Type	Example Entry in IDL file	Example Java Output Generated by RTI Code Generator (rtiddsgen)

unsigned short or uint16
 	
(see Note 6 below)
	`struct PrimitiveStruct {`
	`  uint16`
	`  unsigned_short_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public short unsigned_short_member;`
		`  ...`
		`}`

long or int32	`struct PrimitiveStruct {`
	`  int32 long_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public int long_member;`
		`  ...`
		`}`

unsigned long or uint32
 	
(see Note 6 below)
	`struct PrimitiveStruct {`
	`  uint32`
	`  unsigned_long_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public int unsigned_long_member;`
		`  ...`
		`}`

long long int64	`struct PrimitiveStruct {`
	`  int64 long_long_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public long long_long_member;`
		`  ...`
		`}`

unsigned long long or uint64
 	
(see Note 7 below)
	`struct PrimitiveStruct {`
	`  uint64`
	`  unsigned_long_long_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public long unsigned_long_long_member;`
		`  ...`
		`}`

float	`struct PrimitiveStruct {`
	`  float float_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public float float_member;`
		`  ...`
		`}`

double	`struct PrimitiveStruct {`
	`  double double_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public double double_member;`
		`  ...`
		`}`

long double
 	
(see Note 7 below)
	`struct PrimitiveStruct {`
	`  long double long_double_`
	`member;`
		`public class PrimitiveStruct`
		`{`
		`  public double long_double_member;`
		`  ...`
		`}`

pointer
 	
(see Note 9 below)
	`struct MyStruct {`
	`  long * member;`
	`};`
		`public class MyStruct {`
		`  public int member;`
		`  ...`
		`};`

boolean	`struct PrimitiveStruct {`
	`  boolean boolean_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public boolean boolean_member;`
		`  ...`
		`}`

Table 3.9 Specifying Data Types in IDL for Java

IDL Type	Example Entry in IDL file	Example Java Output Generated by RTI Code Generator (rtiddsgen)

enum	`enum PrimitiveEnum {`
	`  ENUM1,`
	`  ENUM2,`
	`  ENUM3`
	`};`
		`public class PrimitiveEnum extends Enum`
		`{`
		`  public static PrimitiveEnum ENUM1 =`
		`  new PrimitiveEnum ("ENUM1", 0);`
		`  public static PrimitiveEnum ENUM2 =`
		`  new PrimitiveEnum ("ENUM2", 1);`
		`  public static PrimitiveEnum ENUM3 =`
		`  new PrimitiveEnum ("ENUM3", 2);`
		`  public static PrimitiveEnum`
		`  valueOf(int ordinal);`
		`  ...`
		`}`

	`enum PrimitiveEnum {`
	`  @value (10) ENUM1,`
	`  @value (20) ENUM2,`
	`  @value (30) ENUM3`
	`}`
		`public class PrimitiveEnum extends Enum`
		`{`
		`  public static PrimitiveEnum ENUM1 =`
		`  new PrimitiveEnum ("ENUM1", 10);`
		`  public static PrimitiveEnum ENUM2 =`
		`  new PrimitiveEnum ("ENUM2", 10);`
		`  public static PrimitiveEnum ENUM3 =`
		`  new PrimitiveEnum ("ENUM3", 20);`
		`  public static PrimitiveEnum`
		`  valueOf(int ordinal);`
		`  ...`
		`}`

constant	`const short SIZE = 5;`	`public class SIZE {`
		`  public static final short VALUE = 5;`
		`}`

struct
 	
(see Note 10 below)
	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`public class PrimitiveStruct`
		`{`
		`  public char char_member;`
		`}`

union
 	
(see Note 10 below)
	`union PrimitiveUnion`
	`switch (long){`
	`case 1:`
	`  short short_member;`
	`default:`
	`  long long_member;`
	`};`
		`public class PrimitiveUnion {`
		`  public int _d;`
		`  public short short_member;`
		`  public int long_member;`
		`  ...`
		`}`

typedef of primitives, enums, strings
(see Note 8 below)
	`typedef short ShortType;`
	
	`struct PrimitiveStruct {`
	`  ShortType short_member;`
	`};`
		`/* typedefs are unwounded to original`
		`  type when used */`
		`public class PrimitiveStruct`
		`{`
		`  public short short_member;`
		`  ...`
		`}`

typedef of sequences or arrays
(see Note 8 below)
	`typedef short ShortArray[2];`	`/* Wrapper class */`
		`public class ShortArray`
		`{`
		`  public short[] userData =`
		`  new short[2];`
		`  ...`
		`}`

Table 3.9 Specifying Data Types in IDL for Java

IDL Type	Example Entry in IDL file	Example Java Output Generated by RTI Code Generator (rtiddsgen)

array	`struct OneDArrayStruct {`
	`  short short_array[2];`
	`};`
		`public class OneDArrayStruct`
		`{`
		`  public short[] short_array =`
		`  new short[2];`
		`  ...`
		`}`

	`struct TwoDArrayStruct {`
	`  short short_array[1][2];`
	`};`
		`public class TwoDArrayStruct`
		`{`
		`  public short[][] short_array =`
		`  new short[1][2];`
		`  ...`
		`}`

bounded sequence
(see Note 11 and Note 15 below)
	`struct SequenceStruct {`
	`  sequence<short,4>`
	`  short_sequence;`
	`};`
		`public class SequenceStruct`
		`{`
		`  public ShortSeq short_sequence =`
		`  new ShortSeq((4));`
		`  ...`
		`}`
		Note: Sequences of primitive types have been predefined by *Connext DDS*.

unbounded sequence
(see Note 11 and Note 15 below)
	`struct SequenceStruct {`
	`  sequence<short> short_`
	`sequence;`
	`};`
		`public class SequenceStruct`
		`{`
		`  public ShortSeq short_sequence =`
		`  new ShortSeq((100));`
		`  ...`
		`}`
		See Note 12 below.

array of sequences	`struct ArraysOfSequences{`
	`  sequence<short,4>`
	`  sequences_array[2];`
	`};`
		`public class ArraysOfSequences`
		`{`
		`  public ShortSeq[] sequences_array =`
		`  new ShortSeq[2];`
		`  ...`
		`}`

sequence of arrays
(see Note 11 below)
	`typedef short ShortArray[2];`
	
	`struct SequenceOfArrays{`
	`  sequence<ShortArray,2>`
	`  arrays_sequence;`
	`};`
		`/* Wrapper class */`
		`public class ShortArray`
		`{`
		`  public short[] userData =`
		`  new short[2];`
		`  ...`
		`}`
		
		`/* Sequence of wrapper class objects */`
		`public final class ShortArraySeq`
		`  extends ArraySequence`
		`{`
		`  ...`
		`}`
		
		`public class SequenceOfArrays`
		`{`
		`  public ShortArraySeq arrays_sequence`
		`  = new ShortArraySeq((2));`
		`  ...`
		`}`

Table 3.9 Specifying Data Types in IDL for Java

IDL Type	Example Entry in IDL file	Example Java Output Generated by RTI Code Generator (rtiddsgen)

sequence of sequences
(see Note 4 and Note 11 below)
	`typedef sequence<short,4> ShortSequence;`
	
	`struct SequencesOfSequences{ sequence<ShortSequence,2> sequences_sequence; };`
		`/* Wrapper class */ public class ShortSequence { public ShortSeq userData = new ShortSeq((4)); ... }`
		
		`/* Sequence of wrapper class objects */ public final class ShortSequenceSeq extends ArraySequence { ... }`
		
		`public class SequencesOfSequences { public ShortSequenceSeq sequences_sequence = new ShortSequenceSeq((2)); ... }`

bounded string	`struct PrimitiveStruct { string<20> string_member; };`	`public class PrimitiveStruct { public String string_member = new String(); /* maximum length = (20) */ ... }`
unbounded string	`struct PrimitiveStruct { string string_member; };`	`public class PrimitiveStruct { public String string_member = new String(); /* maximum length = (255) */ ... }` See Note 12 below.
bounded wstring	`struct PrimitiveStruct { wstring<20> wstring_member; };`	`public class PrimitiveStruct { public String wstring_member = new String(); /* maximum length = (20) */ ... }`
unbounded wstring	`struct PrimitiveStruct { wstring wstring_member; };`	`public class PrimitiveStruct { public String wstring_member = new String(); /* maximum length = (255) */ ... }` See Note 12 below.

Table 3.9 Specifying Data Types in IDL for Java

IDL Type	Example Entry in IDL file	Example Java Output Generated by RTI Code Generator (rtiddsgen)

module	`module PackageName {`
	`  struct Foo {`
	`  long field;`
	`  };`
	`};`
		`package PackageName;`
		
		`public class Foo`
		`{`
		`  public int field;`
		`  ...`
		`}`

valuetype
 	
(see Note 9 and Note 10 below)
	`valuetype MyValueType {`
	`  public MyValueType2 * member;`
	`};`
	
	`valuetype MyValueType {`
	`  public MyValueType2 member;`
	`};`
	
	`valuetype MyValueType:`
	`MyBaseValueType  {`
	`  public MyValueType2 * member;`
	`};`
		`public class MyValueType  {`
		`  public MyValueType2 member;`
		`  ...`
		`};`
		
		`public class MyValueType  {`
		`  public MyValueType2 member;`
		`  ...`
		`};`
		
		`public class MyValueType`
		`extends MyBaseValueType`
		`{`
		`  public MyValueType2 member;`
		`  ...`
		`}`

Table 3.10 Specifying Data Types in IDL for Ada

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

char
 	
(see Note 13 below)
	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`type PrimitiveStruct is record`
		`char_member : aliased`
		`  Standard.DDS.Char;`
		`end record;`

wchar	`struct PrimitiveStruct {`
	`  wchar wchar_member;`
	`};`
		`type PrimitiveStruct is record`
		`wchar_member : aliased`
		`  Standard.DDS.Wchar;`
		`end record;`

octet	`struct PrimitiveStruct {`
	`  octet octet_member;`
	`};`
		`type PrimitiveStruct is record`
		`octet_member: aliased`
		`  Standard.DDS.Octet;`
		`end record;`

short or int16	`struct PrimitiveStruct {`
	`  int16 short_member;`
	`};`
		`type PrimitiveStruct is record`
		`short_member: aliased`
		`  Standard.DDS.Short;`
		`end record;`

unsigned short or uint16	`struct PrimitiveStruct {`
	`  uint16`
	`  unsigned_short_member;`
	`};`
		`type PrimitiveStruct is record`
		`unsigned_short_member: aliased`
		`  Standard.DDS.Unsigned_Short;`
		`end record;`

Table 3.10 Specifying Data Types in IDL for Ada

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

long or int32	`struct PrimitiveStruct {`
	`  int32 long_member;`
	`};`
		`type PrimitiveStruct is record`
		`long_member: aliased`
		`  Standard.DDS.Long;`
		`end record;`

unsigned long or uint32	`struct PrimitiveStruct {`
	`  uint32`
	`  unsigned_long_member;`
	`};`
		`type PrimitiveStruct is record`
		`unsigned_long_member: aliased`
		`  Standard.DDS.Unsigned_Long;`
		`end record;`

long long or int64	`struct PrimitiveStruct {`
	`  int64 long_long_member;`
	`};`
		`type PrimitiveStruct is record`
		`long_long_member: aliased`
		`  Standard.DDS.Long_Long;`
		`end record;`

unsigned long long or uint64	`struct PrimitiveStruct {`
	`  uint64`
	`  unsigned_long_long_member;`
	`};`
		`type PrimitiveStruct is record`
		`unsigned_long_long_member: aliased`
		`  Standard.DDS.Unsigned_Long_Long;`
		`end record;`

float	`struct PrimitiveStruct {`
	`  float float_member;`
	`};`
		`type PrimitiveStruct is record`
		`float_member: aliased`
		`  Standard.DDS.Float;`
		`end record;`

double	`struct PrimitiveStruct {`
	`  double double_member;`
	`};`
		`type PrimitiveStruct is record`
		`double_member: aliased`
		`  Standard.DDS.Double;`
		`end record;`

long double
 	
(see Note 2 below)
	`struct PrimitiveStruct {`
	`  long double`
	`  long_double_member;`
	`};`
		`type PrimitiveStruct is record`
		`long_double_member: aliased`
		`  Standard.DDS.Long_Double;`
		`end record;`

@external or pointer
 	
(see Note 9 below)
	`struct MyStruct {`
	`  @external long member;`
	`}`
	or
	`struct MyStruct {`
	`  long * member;`
	`};`
		`type MyStruct is record`
		`member : access`
		`  Standard.DDS.Long;`
		`end record;`

boolean	`struct PrimitiveStruct {`
	`  boolean boolean_member;`
	`};`
		`type PrimitiveStruct is record`
		`boolean_member: aliased  Standard.DDS.Boolean;`
		`end record;`

Table 3.10 Specifying Data Types in IDL for Ada

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

enum	`enum PrimitiveEnum {`
	`  ENUM1,`
	`  ENUM2,`
	`  ENUM3`
	`};`
	
	`enum PrimitiveEnum {`
	`  ENUM1 = 10,`
	`  ENUM2 = 20,`
	`  ENUM3 = 30`
	`};`
	`enum PrimitiveEnum {`
	`  @value (10) ENUM1,`
	`  @value (20) ENUM2,`
	`  @value (30) ENUM3`
	`}`
		`type PrimitiveEnum is`
		`  (ENUM1,  ENUM2,  ENUM3);`
		
		`type PrimitiveEnum is`
		`  (ENUM1,  ENUM2,  ENUM3);`
		`...`
		`for PrimitiveEnum use`
		`(ENUM1 => 10 , ENUM2 => 20,`
		`ENUM3 => 30);`

constant	`const short SIZE = 5;`	`SIZE : constant` `Standard.DDS.Short := 5;`

struct
 	
(see Note 10 below)
	`struct PrimitiveStruct {`
	`  char char_member;`
	`};`
		`type PrimitiveStruct is record`
		`char_member : aliased`
		`  Standard.DDS.Char;`
		`end record;`

union
 	
(see Note 3 and Note 10 below)
	`union PrimitiveUnion switch (long){`
	`  case 1:`
	`  short short_member;`
	`  default:`
	`  long long_member;`
	`};`
		`type U_PrimitiveUnion is record`
		`short_member : aliased`
		`  Standard.DDS.Short;`
		`long_member : aliased`
		`  Standard.DDS.Long;`
		`end record;`
		
		`type PrimitiveUnion is record`
		`d : Standard.DDS.Long;`
		`u : U_PrimitiveUnion;`
		`end record;`

typedef	`typedef short TypedefShort;`	`type TypedefShort is new` `  Standard.DDS.Short;`

array of above types	`struct OneDArrayStruct {`
	`  short short_array[2];`
	`};`
	
	`struct TwoDArrayStruct {`
	`  short short_array[1][2];`
	`};`
		`type OneDArrayStruct is record`
		`short_array : aliased`
		`  Standard.DDS.Short_Array(1..2);`
		`end record;`
		
		`type`
		`  TwoDArrayStruct_short_array_Array`
		`  is array (1..1, 1..2) of aliased`
		`  Standard.DDS.Short;`
		`type TwoDArrayStruct is record`
		`  short_array : aliased`
		`  TwoDArrayStruct_short_array_Array;`
		`end record;`

Table 3.10 Specifying Data Types in IDL for Ada

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

bounded sequence of above types
 	
(see Note 11 and Note 15 below)
	`struct SequenceStruct {`
	`  sequence<short,4> short_`
	`sequence;`
	`};`
		`type SequenceStruct is record`
		`short_sequence : aliased  Standard.DDS.Short_`
		`Seq.Sequence;`
		`end record;`

unbounded sequence of above types
 	
(see Note 11 and Note 15 below)
	`struct SequenceStruct {`
	`  sequence<short> short_sequence;`
	`};`
		`type SequenceStruct is record`
		`short_sequence : aliased  Standard.DDS.Short_`
		`Seq.Sequence;`
		`end record;`
		
		See Note 13 below.

array of sequences	`struct ArraysOfSequences{`
	`  sequence<short,4>`
	`  sequences_array[2];`
	`};`
		`type`
		`  ArraysOfSequences_sequences_array_Array`
		`  is array (1..2) of aliased`
		`  Standard.DDS.Short_Seq.Sequence;`
		`type ArraysOfSequences is record`
		`  sequences_array : aliased`
		`  ArraysOfSequences_sequences_array_Array;`
		`end record;`

sequence of arrays
 	
(see Note 11 below)
	`typedef short ShortArray[2];`
	`struct SequenceofArrays {`
	`  sequence<ShortArray,2>`
	`  arrays_sequence;`
	`};`
		`type ShortArray is array (1..2)`
		`  of Standard.DDS.Short;`
		`...`
		`type SequenceofArrays is record`
		`  arrays_sequence : aliased`
		`  ADA_IDL_File.ShortArray_Seq.Sequence;`
		`end record;`
		
		Note: ADA_IDL_File.ShortArray_Seq.Sequence is an instantiation of Standard.DDS.Sequences_Generic for the user's data type

sequence of sequences
 	
(see Note 4 and Note 11 below)
	`typedef sequence<short,4>`
	`  ShortSequence;`
	
	`struct SequencesOfSequences{`
	`  sequence<ShortSequence,2>`
	`  sequences_sequence;`
	`};`
		`type ShortSequence is new Standard.DDS.Short_`
		`Seq.Sequence;`
		`...`
		`type SequencesOfSequences is record`
		`  sequences_sequence : aliased`
		`  ADA_IDL_File.ShortSequence_Seq.Sequence;`
		`end record;`
		
		Note: ADA_IDL_File.ShortSequence_Seq.Sequence is an instantiation of Standard.DDS.Sequences_Generic for the user's data type

bounded string	`struct PrimitiveStruct {`
	`  string<20> string_member;`
	`};`
		`type PrimitiveStruct is record`
		`string_member : aliased`
		`  Standard.DDS.String;`
		`--  maximum length = (20)`
		`end record;`

unbounded string	`struct PrimitiveStruct {`
	`  string string_member;`
	`};`
		`type PrimitiveStruct is record`
		`string_member : aliased`
		`  Standard.DDS.String;`
		`  --  maximum length = (255)`
		`end record;`

Table 3.10 Specifying Data Types in IDL for Ada

IDL Type	Example Entry in IDL File	Example Output Generated by RTI Code Generator (rtiddsgen)

bounded wstring	`struct PrimitiveStruct {`
	`  wstring<20> wstring_member;`
	`};`
		`type PrimitiveStruct is record`
		`wstring_member : aliased`
		`  Standard.DDS.Wide_String;`
		`  --  maximum length = (20)`
		`end record;`

unbounded wstring	`struct PrimitiveStruct {`
	`  wstring wstring_member;`
	`};`
		`type PrimitiveStruct is record`
		`wstring_member : aliased`
		`  Standard.DDS.Wide_String;`
		`  --  maximum length = (255)`
		`end record;`

module	`module PackageName {`
	`  struct Foo {`
	`  long field;`
	`  };`
	`};`
		`package  PackageName is`
		`type Foo is record`
		`field : aliased Standard.DDS.Long;`
		`end record;`
		`end PackageName;`

valuetype
 	
(see Note 9 and Note 10 below)
	`valuetype MyBaseValueType  {`
	`  valuetype MyBaseValueType  {`
	`  public long  member;`
	`};`
	
	`valuetype MyValueType:`
	`MyBaseValueType  {`
	`  public short * member2;`
	`};`
		`type MyBaseValueType is record`
		`member : aliased Standard.DDS.Long;`
		`end record;`
		
		`type MyValueType is record`
		`parent : ADA_IDL_File.MyBaseValueType;`
		`member2 : access Standard.DDS.Short;`
		`end record;`

Notes for the above tables:

Note 1: In C and C++, primitive types are not represented as native language types (e.g. long, char, etc.) but as custom types in the DDS namespace (DDS_Long, DDS_Char, etc.). These typedefs are used to ensure that a field's size is the same across platforms.

Note 2: Some platforms do not support long double or have different sizes for that type than defined by IDL (16 bytes). On such platforms, DDS_LongDouble (as well as the unsigned version) is mapped to a character array that matches the expected size of that type by default.

If you are using a platform whose native mapping has exactly the expected size, you can instruct *Connext DDS* to use the native type instead. That is, if sizeof(long double) == 16, you can tell *Connext DDS* to map DDS_LongDouble to long double by defining the following macro either in code or on the compile line:

```
-DRTI_CDR_SIZEOF_LONG_DOUBLE=16
```

Note 3: Unions in IDL are mapped to structs in C, C++ and records in ADA, so that *Connext DDS* will not have to dynamically allocate memory for unions containing variable-length fields such as strings or sequences. To be efficient, the entire struct (or class in C++/CLI) is not sent when the union is published. Instead, *Connext DDS*

uses the discriminator field of the struct to decide what field in the struct is actually sent on the wire.

Note 4: So-called "anonymous sequences" —sequences of sequences in which the sequence element has no type name of its own—are not supported in IDL. For example, this is *not* supported:

```
sequence<sequence<short,4>,4> MySequence;
```

Sequences of typedef'ed types, where the typedef is really a sequence, are supported.

For example, this is supported:

```
typedef sequence<short,4> MyShortSequence;
sequence<MyShortSequence,4> MySequence;
```

Note 5: IDL wchar and char are mapped to Java char, 16-bit unsigned quantities representing Unicode characters as specified in the standard OMG IDL to Java mapping. In C++/CLI, char and wchar are mapped to System::Char.

Note 6: The unsigned version for integer types is mapped to its signed version as specified in the standard OMG IDL to Java mapping.

Note 7: There is no current support in Java for the IDL long double type. This type is mapped to double as specified in the standard OMG IDL to Java mapping.

Note 8: Java does not have a typedef construct, nor does C++/CLI. Typedefs for types that are neither arrays nor sequences (struct, unions, strings, wstrings, primitive types and enums) are "unwound" to their original type until a simple IDL type or user-defined IDL type (of the non-typedef variety) is encountered. For typedefs of sequences or arrays, *RTI Code Generator* will generate wrapper classes.

Note 9: See 3.3.9.4 The @external Annotation on page 115.

Note 10: In-line nested types are not supported inside structures, unions or valuetypes. For example, this is *not* supported:

```
struct Outer {
    short outer_short;
    struct Inner {
       char inner_char;
       short inner_short;
    } outer_nested_inner;
};
```

Note 11: The sequence <Type>Seq is implicitly declared in the IDL file and therefore it cannot be declared explicitly by the user. For example, this is not supported:

```
typedef sequence<Foo> FooSeq; //error
```

However, if *RTI Code Generator's* option, -typeSequenceSuffix <Suffix>, is used and the <Suffix> is not 'Seq', the sequence would be:

```
typedef sequence<Foo> Foo<Suffix>; //no error
```

Note 12: *RTI Code Generator* will supply a default bound for sequences and strings. You can specify that bound with the **-sequenceSize** or **-stringSize** command-line option, respectively. See the RTI Code Generator User's Manual.

Note 13: In ADA, primitive types are not represented as native language types (e.g. , Character, etc.) but as custom types in the DDS namespace (Standard.DDS.Long, Standard.DDS.Char, etc.). These typedefs are used to ensure that a field's size is the same across platforms.

Note 14: Every type provides a default constructor, a copy constructor, a move constructor, a constructor with parameters to set all the type's members, a destructor, a copy-assignment operator, and a move-assignment operator. Types also include equality operators, the operator << and a namespace-level swap function.

```
PrimitiveStruct();
explicit PrimitiveStruct(char char_member);
PrimitiveStruct(PrimitiveStruct&& other_) OMG_NOEXCEPT;
PrimitiveStruct& operator=(PrimitiveStruct&&  other_) OMG_NOEXCEPT;
bool operator == (const PrimitiveStruct& other_) const;
bool operator != (const PrimitiveStruct& other_) const;
void swap(PrimitiveStruct& other_) OMG_NOEXCEPT ;
std::ostream& operator << (std::ostream& o,const PrimitiveStruct&
sample);
```

Note 15: Sequences of pointers are not supported. For example, this is NOT supported:

```
sequence<long*, 100>;
```

Sequences of typedef'ed types, where the typedef is really a pointer, are supported. For example, this is supported:

```
typedef long* pointerToLong;
sequence<pointerToLong, 100>;
```

Note 16: int8 and uint8 are supported only at the API level. They are still considered octets for type matching purposes.

3.3.5 Escaped Identifiers

To use an IDL keyword as an identifier, the keyword must be "escaped" by prepending an underscore, '_'. In addition, you must run *RTI Code Generator* with the **-enableEscapeChar** option. For example:

```
struct MyStruct {
    octet _octet; // octet is a keyword. To use the type
```

```
                    // as a member name we add '_'
};
```

The use of '_' is a purely lexical convention that turns off keyword checking. The generated code will not contain '_'. For example, the mapping to C would be as follows:

```
struct MyStruct {
    unsigned char octet;
};
```

Note: If you generate code from an IDL file to a language 'X' (for example, C++), the keywords of this language cannot be used as IDL identifiers, even if they are escaped. For example:

```
struct MyStruct {
    long int; // error
    long _int; // error
};
```

3.3.6 Namespaces In IDL Files

In IDL, the **module** keyword is used to create namespaces for the declaration of types defined within the file.

Here is an example IDL definition:

```
module PackageName {
    struct Foo {
        long field;
    };
};
```

C Mapping:

The name of the module is concatenated to the name of the structure to create the namespace. The resulting code looks like this:

```
typedef struct PackageName_Foo {
    DDS_Long field;
} PackageName_Foo;
```

C++ Mapping:

In the Traditional C++ API, when using the **-namespace** command-line option, *RTI Code Generator* generates a namespace, such as the following:

```
namespace PackageName{
    class Foo {
        public:
            DDS_Long field;
    }
}
```

Without the **-namespace** option, the mapping adds the module to the name of the class:

```
class PackageName_Foo {
    public:
```

```
        DDS_Long field;
}
```

In the Modern C++ API, namespaces are always used.

C++/CLI Mapping:

Independently of the usage of the **-namespace** command-line option, *RTI Code Generator* generates a namespace, such as the following:

```
namespace PackageName{
    public ref struct Foo: public DDS::ICopyable<Foo^> {
        public:
            System::Int32 field;
};
}
```

Java Mapping:

A **Foo.java** file will be created in a directory called **PackageName** to use the equivalent concept as defined by Java. The file **PackageName/Foo.java** will contain a declaration of Foo class:

```
package PackageName;
       public class Foo {
       public int field;
};
```

In a more complex example, consider the following IDL definition:

```
 module PackageName {
     struct Bar {
         long field;
     };
     struct Foo {
         Bar barField;
     };
 };
```

When *RTI Code Generator* generates code for the above definition, it will resolve the **Bar** type to be within the scope of the **PackageName** module and automatically generate fully qualified type names.

C Mapping:

```
typedef struct PackageName_Bar {
       DDS_Long field;
} PackageName_Bar;
typedef struct PackageName_Foo {
       PackageName_Bar barField;
} PackageName_Foo;
```

C++ Mapping:

With **-namespace**:

```
namespace PackageName {
    class Bar {
        public:
            DDS_Long field;
    };
    class Foo {
        public:
            PackageName::Bar barField;
    };
};
```

Without **-namespace**:

```
 class PackageName_Bar {
     public:
         DDS_Long field;
 };
 class PackageName_Foo {
     public:
         PackageName_Bar barField;
 };
```

C++/CLI Mapping:

```
namespace PackageName{
    public ref struct Bar: public DDS::ICopyable<Bar^> {
        public:
            System::Int32 field;
    };
    public ref struct Foo: public DDS::ICopyable<Foo^> {
        public:
            PackageName::Bar^ barField;
    };
};
```

Java Mapping:

PackageName/Bar.java and **PackageName/Foo.java** would be created with the following code, respectively:

```
package PackageName;
public class Bar {
    public
        int field;
};

package PackageName;
public class Foo {
    public
        PackageName.Bar barField = PackageName.Bar.create();
};
```

3.3.7 Referring to Other IDL Files

IDL files may refer to other IDL files using a syntax borrowed from C, C++, and C++/CLI preprocessors. For example:

Bar.idl

```
struct Bar {
};
```

Foo.idl

```
#include "Bar.idl"
struct Foo {
    Bar m1;
};
```

The parsing of **Foo** in the above scenario will be successful, since **Bar** can be found in **Bar.idl**. (If Bar was not declared in **Bar.idl**, *Code Generator* would report an error indicating that the symbol could not be found.)

Code Generator will look for the included files, in this example, **Bar.idl**, in the following directories and in this order:

1. The working directory where *Code Generator* was executed.
2. The directory or directories specified by the user using the **-I** command-line option (if any).
3. The directory where the input file is.

Please note that when invoking *Code Generator* and specifying **Foo.idl** as a parameter, only the data types defined *in that file* will be generated. If **Foo.idl** includes another file, such as **Bar.idl**, you would also need to invoke *Code Generator* using **Bar.idl** as a parameter.

If *Code Generator* encounters an **#include** statement and you are generating code for C, C+, or C+/CLI, *Code Generator* will assume that code has been generated for **Bar.idl** with corresponding header files, **Bar.h** and **BarPlugin.h**.

The generated code will automatically add these files where needed in the **Foo** generated code, in order to compile correctly:

```
#include “Bar.h”
#include “BarPlugin.h”
```

Because Java types do not refer to one another in the same way, it is not possible for *Code Generator* to automatically generate Java import statements based on an IDL **#include** statement. **#include** statements will not generate any specific code when Java code is generated. To add imports to your generated Java code, you should use the **@copy** directive (see 3.3.9.5 The @copy and Related Annotations on page 116).

3.3.8 Preprocessor Directives

RTI Code Generator supports the standard preprocessor directives defined by the IDL specification, such as #if, #endif, #include, and #define.

To support these directives, *RTI Code Generator* calls an external C preprocessor before parsing the IDL file. On Windows systems, the preprocessor is '**cl.exe**.' On other architectures, the preprocessor is '**cpp**.' You can change the default preprocessor with the **–ppPath** option. If you do not want to run the pre-processor, use the **–ppDisable** option (see the RTI Code Generator User's Manual).

3.3.9 Using Builtin Annotations

RTI Code Generator supports the following builtin annotations, which can be used in your IDL File:

- Described in this document:
  - @key (3.3.9.1 The @key Annotation on the next page)
  - @nested (3.3.9.2 The @nested Annotation on page 114)
  - @value (3.3.9.3 The @value Annotation on page 115)
  - @external (3.3.9.4 The @external Annotation on page 115)
- Described in the RTI Connext DDS Core Libraries Extensible Types Guide:
  - @extensibility
  - @id
  - @hashid
  - @autoid
  - @optional
  - @appendable
  - @mutable
  - @final
  - @default
  - @default_literal
  - @min
  - @max
  - @range
  - @allowed_data_representation

These annotations are described two standard documents: Interface Definition Language (Version 4) and Extensible and Dynamic Topic Types for DDS (Version 1.2).

In addition, RTI provides the following RTI-specific annotations:

- @copy (3.3.9.5 The @copy and Related Annotations on page 116)
- @resolve_name (3.3.9.6 The @resolve_name Annotation on page 117)
- @use_vector (3.3.9.7 The @use_vector annotation on page 118)
- @top_level (Replaced by @nested. See 3.3.9.2 The @nested Annotation on the next page.)
- @transfer_mode (3.3.9.8 The @transfer_mode annotation on page 119)
- @language_binding (3.3.9.9 The @language_binding Annotation on page 120)

3.3.9.1 The @key Annotation

To declare a key for your data type, insert the @key annotation in the IDL file before one or more fields of the data type.

With each key, *Connext DDS* associates an internal 16-byte representation, called a ***key-hash***.

If the maximum size of the serialized key is greater than 16 bytes, to generate the key-hash, *Connext DDS* computes the MD5 key-hash of the serialized key in network-byte order. Otherwise (if the maximum size of the serialized key is <= 16 bytes), the key-hash is the serialized key in network-byte order.

Only **struct** definitions in IDL may have key fields. When *RTI Code Generator* encounters **@key**, it considers the previously declared field in the enclosing structure to be part of the key. Table 3.11 Example Keys shows some examples of keys.

Table 3.11 Example Keys

Type	Key Fields

`struct NoKey {`
`  long member1;`
`  long member2;`
`}`	

`struct SimpleKey {`
`  @key long member1;`
`  long member2;`
`}`
	`member1`

`struct NestedNoKey {`
`  SimpleKey member1;`
`  long member2;`
`}`	

`struct NestedKey {`
`  @key SimpleKey member1;`
`  long member2;`
`}`
	`member1.member1`

Table 3.11 Example Keys

Type	Key Fields

`struct NestedKey2 {`
`  @key NoKey member1;`
`  long member2;`
`}`
	`member1.member1`
	`member1.member2`

`valuetype BaseValueKey {`
`  @key public long member1;`
`}`
	`member1`

`valuetype DerivedValueKey :BaseValueKey {`
`  @key public long member2;`
`}`
	`member1`
	`member2`

`valuetype DerivedValue : BaseValueKey {`
`  public long member2;`
`}`
	`member1`

`struct ArrayKey {`
`  @key long member1[3];`
`}`
	`member1[0]`
	`member1[1]`
	`member1[2]`

3.3.9.2 The @nested Annotation

By default, *RTI Code Generator* generates user-level type-specific methods for all structures/unions found in an IDL file. These methods include the methods used by *DataWriters* and *DataReaders* to send and receive data of a given type. General methods for writing and reading that take a void pointer are not offered by *Connext DDS* because they are not type safe. Instead, type-specific methods must be created to support a particular data type.

We use the term 'top-level type' to refer to the data type for which you intend to create a DCPS *Topic* that can be published or subscribed to. For top-level types, *RTI Code Generator* must create all of the type-specific methods previously described in addition to the code to serialize/deserialize those types. However, some of structures/unions defined in the IDL file are only embedded within higher-level structures and are not meant to be published or subscribed to individually. For non-top-level types, the *DataWriters* and *DataReaders* methods to send or receive data of those types are superfluous and do not need to be created. Although the existence of these methods is not a problem in and of itself, code space can be saved if these methods are not generated in the first place.

You can mark non-top-level types in an IDL file with the annotation @nested to tell RTI Code Generator not to generate type-specific methods. Code will still be generated to serialize and deserialize those types, since they may be embedded in top-level types.

The top-level directive can also be used but with the opposite meaning. @top_level or //@top-level (true) indicates that the type is top level, therefore, @top_level (false) would be equivalent to @nested.

In this example, *RTI Code Generator* will generate *DataWriter/DataReader* code for TopLevelStruct only:

```
@nested
struct EmbeddedStruct {
    short member;
};
struct TopLevelStruct{
    EmbeddedStruct member;
};
```

3.3.9.3 The @value Annotation

The @value annotation can be used to set specific values to members of enumerations. For example:

```
enum MyEnum {
    @value (17) e17,
    @value (2) e2,
    @value (3) e3
}
```

It is equivalent to:

```
enum MyEnum {
    e17 =17,
    e2 = 2,
    e3 =3
}
```

3.3.9.4 The @external Annotation

A member declared as external using the @external annotation (or the * modifier) within an aggregated type indicates that it is desirable for the implementation to store the member in storage external to the enclosing aggregated type object.

For example:

```
struct MyStruct {
    @external long member;
}
```

This is equivalent to the following structure, although the usage of the @external annotation is preferred because it is standard:

```
struct MyStruct {
    long *member;
};
```

The @external annotation only has effect in C, C++, Modern C++, and Ada applications where the members will be mapped to references (pointers). In other languages, the annotation is ignored because the members are always mapped as references.

In Modern C++ the annotation maps to the type dds::core::external<T>, a type similar to shared_ptr.

3.3.9.5 The @copy and Related Annotations

To copy a line of text verbatim into the generated code files, use the **@copy** annotation in the IDL file. The @copy annotation can only be applied using the comment syntax (//@). The @copy annotation is particularly useful when you want your generated code to contain text that is valid in the target programming language but is not valid IDL. It is often used to add user comments or headers or preprocessor commands into the generated code.

```
//@copy (// Modification History)
//@copy (// --------------------
//@copy (// 17Jul05aaa, Created.)
//@copy
//@copy (// #include "MyTypes.h")
```

These variations allow you to use the same IDL file for multiple languages:

`@copy-c`	Copies code if the language is C or C++
`@copy-cppcli`	Copies code if the language is C++/CLI
`@copy-java`	Copies code if the language is Java.
`@copy-ada`	Copies code if the language is Ada.

For example, to add import statements to generated Java code:

```
//@copy-java (import java.util.*;)
```

The above line would be ignored if the same IDL file was used to generate non-Java code.

In C, C++, and C++/CLI, the lines are copied into all of the **foo*.[h, c, cxx, cpp]** files generated from **foo.idl**. For Java, the lines are copied into all of the ***.java** files that were generated from the original ".idl" file. The lines will not be copied into any additional files that are generated using the **-example** command line option.

@copy-java-begin copies a line of text at the beginning of all the Java files generated for a type. The annotation only applies to the first type that is immediately below in the IDL file. A similar annotation for Ada files is also available, **@copy-ada-begin**.

If you want *RTI Code Generator* to copy lines only into the files that declare the data types—**foo.h** for C, C++, and C++/CLI, **foo.java** for Java—use the **//@copy*declaration** forms of this annotation.

Note that the first whitespace character to follow **//@copy** is considered a delimiter and will not be copied into generated files. All subsequent text found on the line, including any leading whitespaces will be copied.

`//@copy-declaration`	Copies the text into the file where the type is declared (<type>.h for C and C++, or <type>.java for Java)
`//@copy-c-declaration`	Same as //@copy-declaration, but for C and C++ code

`//@copy-cppcli-declaration`	Same as //@copy-declaration, but for C++/CLI code
`//@copy-java-declaration`	Same as //@copy-declaration, but for Java-only code
`//@copy-ada-declaration`	Same as //@copy-declaration, but for Ada-only code
`//@copy-java-declaration-begin`	Same as //@copy-java-declaration, but only copies the text into the file where the type is declared
`//@copy-ada-declaration-begin`	Same as //@copy-java-declaration-begin, but only for Ada-only code

3.3.9.6 The @resolve_name Annotation

By default, *RTI Code Generator* tries to resolve all the references to types and constants in an IDL file. For example:

```
module PackageName {
    struct Foo {
        Bar barField;
    };
};
```

The compilation of the previous IDL file will report an error like the following:

```
ERROR com.rti.ndds.nddsgen.Main Foo.idl line x:x member type 'Bar' not found
```

In most cases, this is the expected behavior. However, in some cases, you may want to skip the resolution step. For example, assume that the Bar type is defined in a separate IDL file and that you are running *RTI Code Generator* without an external preprocessor by using the command-line option **-ppDisable** (maybe because the preprocessor is not available in their host platform, see 3.3.8 Preprocessor Directives on page 112):

Bar.idl

```
module PackageName {
    struct Bar {
        long field;
    };
};
```

Foo.idl

```
#include "Bar.idl"
module PackageName {
    struct Foo {
        Bar barField;
    };
};
```

In this case, compiling **Foo.idl** would generate the 'not found' error. However, Bar is defined in Bar.idl. To specify that *RTI Code Generator* should not resolve a type reference, use the **//@resolve_name** annotation and set the value to false. For example:

```
#include "Bar.idl"
module PackageName {
    struct Foo {
        @resolve_name(false) Bar barField;
    };
};
```

When this annotation is used, then for the field to which it applies, *RTI Code Generator* will assume that the type is an unkeyed 'structure' and it will use the type name unmodified in the generated code.

Java mapping:

```
package PackageName;
public class Foo {
    public Bar barField = Bar.create();
};
```

C++ mapping:

```
namespace PackageName {
class Foo {
    public:
        Bar barField;
    };
};
```

It is up to you to include the correct header files (or if using Java, to import the correct packages) so that the compiler resolves the 'Bar' type correctly. If needed, this can be done using the copy directives (see 3.3.9.5 The @copy and Related Annotations on page 116).

When applied to an aggregated type in IDL, the annotation applies to all types within the type, including the base type if defined. For example:

```
@resolve_name(false)
struct MyStructure: MyBaseStructure
{
    Foo member1;
    Bar member2;
};
```

3.3.9.7 The @use_vector annotation

The @use_vector annotation can be used in Modern C++ to indicate that a bounded sequence should be mapped to std::vector; otherwise it will be mapped to rti:core::bounded_sequence.

For example :

```
struct MyStruct {
    @use_vector sequence<long, 10> my_bounded_seq;
}
```

As an alternative, you can use *rtiddsgen's* **-alwaysUseStdVector** option to indicate that all bounded sequences should be mapped to std::vector. Unbounded sequences always map to std::vector.

3.3.9.8 The @transfer_mode annotation

The @transfer_mode annotation can be used to indicate how to send a sample of the annotated type. There are two possible values for this annotation: SHMEM_REF and INBAND.

The annotation can be used only while generating code for C and C++ (Traditional and Modern) APIs. For other languages, the annotation is ignored.

@transfer_mode(SHMEM_REF) indicates that a sample can be sent as a shared memory reference instead of sending the serialized sample, when the *DataReader(s)* are on the same node as the *DataWriter* writing the sample. See 23.6 Zero Copy Transfer Over Shared Memory on page 953 for more information.

@transfer_mode(INBAND) indicates that a sample is always serialized and sent inband using the underlying transports. This is the default mode when the annotation is not present.

The use of @transfer_mode annotation without a parameter is not allowed and will generate an error during code generation.

It is sufficient to mark only the top-level types with the @transfer_mode annotation. In this example, a sample of type **CameraImage** can be sent as a shared memory reference, even though the included type **Dimension** is not explicitly annotated:

```
struct Dimension {
    long height;
    long width;
};

@transfer_mode(SHMEM_REF)
struct CameraImage {
   long long timestamp;
   Dimension dimension;
   octet data[8294400][4];
};
```

RTI Code Generator will return an error while parsing the IDL file if the following requirements are not met:

- All fixed and appendable types (described in RTI Connext DDS Core Libraries Extensible Types Guide) annotated with @transfer_mode(SHMEM_REF) should be fixed-size types. A fixed-size type is a type whose wire representation always has the same size. This includes primitive members, arrays of fixed-size types, and structs containing only members of fixed-size types. In the above example, the types **CameraImage** and **Dimension** should not contain variable-length members such as strings, sequences, and optional and external members.
- Mutable types annotated with @transfer_mode(SHMEM_REF) can contain variable-length members when the type is also annotated with FLAT_DATA language_binding.

The @transfer_mode annotation can be applied to modules, structs, valuetypes, and unions. When applied to a module, all the types within the module inherit the language binding value specified in the module.

3.3.9.9 The @language_binding Annotation

The @language_binding annotation allows selecting the language binding for a type, either the plain language binding (default option when the annotation is not specified) or the RTI FlatData™ language binding.

PLAIN is the regular language binding that maps IDL types to their regular C or C++ representation as C structs or C++ classes.

FLAT_DATA is a special language binding in which the in-memory representation is the same as the wire representation. See 23.5 FlatData Language Binding on page 940 for a detailed description.

For example:

```
@language_binding(PLAIN) // or no annotation
struct MyNormalType {
    ...
};

@language_binding(FLAT_DATA)
struct MyFlatType {
    ...
};
```

A few notes about the @language_binding annotation:

- The annotation can be applied to modules, structs, valuetypes, and unions. When applied to a module, all the types within the module inherit the language binding value specified in the module.
- Every member type needs to have the same language binding as the type that contains it. For example, see the IDL in 23.5.2.1 Selecting FlatData Language Binding on page 941: if **CameraImage** is marked with FLAT_DATA language binding, **Resolution** must be marked, too.
- FLAT_DATA is only supported in the Traditional C++ and Modern C++ language APIs. The annotation will be ignored for other languages. See 23.5.2.3 Languages Supported by FlatData Language Binding on page 951.

3.4 Creating User Data Types with Extensible Markup Language (XML)

You can describe user data types with Extensible Markup Language (XML) notation. *Connext DDS* provides DTD and XSD files that describe the XML format; see **<NDDSHOME>/resource/app/app_support/rtiddsgen/schema/rti_dds_topic_types.dtd** and **<NDDSHOME>/resource/app/app_support/rtiddsgen/schema/rti_dds_topic_types.xsd**, respectively. (<NDDSHOME> is described in Paths Mentioned in Documentation on page 1.)

The XML validation performed by *RTI Code Generator* always uses the DTD definition. If the <!DOCTYPE> tag is not in the XML file, *RTI Code Generator* will look for the default DTD document in **<NDDSHOME>/resource/schema**. Otherwise, it will use the location specified in <!DOCTYPE>.

We recommend including a reference to the XSD/DTD files in the XML documents. This provides helpful features in code editors such as Visual Studio® and Eclipse™, including validation and auto-completion while you are editing the XML. We recommend including the reference to the XSD document in the XML files because it provides stricter validation and better auto-completion than the DTD document.

To include a reference to the XSD document in your XML file, use the attribute **xsi:noNamespaceSchemaLocation** in the <types> tag. For example:

```
<?xml version="1.0" encoding="UTF-8"?>
<types xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation=
"<NDDSHOME>/resource/app/app_support/rtiddsgen/schema/rti_dds_topic_types.xsd">
    ...
</types>
```

To include a reference to the DTD document in your XML file, use the <!DOCTYPE> tag. For example:

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE types SYSTEM
"<NDDSHOME>/resource/app/app_support/rtiddsgen/schema/rti_dds_topic_types.dtd">
      <types>
          ...
      </types>
```

Table 3.12 Mapping Type System Constructs to XML shows how to map the type system constructs into XML. For information on the annotations in the table, see 3.3.9 Using Builtin Annotations on page 112.

Table 3.12 Mapping Type System Constructs to XML

Type/Construct		Example	
IDL	XML	IDL	XML
char	char8	`char char_member;`	`<member name="char_member" type="char8"/>`
wchar	char16	`wchar wchar_member;`	`<member name="wchar_member" type="char16"/>`
octet	byte	`octet octet_member;`	`<member name="octet_member" type="byte"/>`
int8[1]	int8	`int8 int8_member;`	`<member name="int8_member" type="int8"/>`

[1]This type is supported only at the API level. It is still considered an octet for type matching purposes.

Table 3.12 Mapping Type System Constructs to XML

Type/Construct		Example	
IDL	XML	IDL	XML
uint8[1]	uint8	`uint8 uint8_member;`	`<member name=”uint8_member” type=”uint8”/>`
short or int16	int16	`int16 short_member;`	`<member name="short_member" type="int16"/>`
unsigned short or uint16	uint16	`uint16 unsigned_short_member;`	`<member name="unsigned_short_member" type="uint16"/>`
long or int32	int32	`int32 long_member;`	`<member name="long_member"type="int32"/>`
unsigned long or uint32	uint32	`uint32 unsigned_long_member;`	`<member name="unsigned_long_member" type="uint32"/>`
long long or int64	int64	`int64 long_long_member;`	`<member name="long_long_member" type="int64"/>`
unsigned long long or uint64	uint64	`uint64 unsigned_long_long_ member;`	`<member name="unsigned_long_long_member" type="uint64"/>`
float	float32	`float float_member;`	`<member name="float_member" type="float32"/>`
double	float64	`double double_member;`	`<member name="double_member" type="float64"/>`
long double	float128	`long double long_double_member;`	`<member name= "long_double_member" type="float128"/>`
boolean	boolean	`struct PrimitiveStruct { boolean boolean_ member; };`	`<struct name="PrimitiveStruct"> <member name="boolean_member" type="boolean"/> </struct>`

[1]This type is supported only at the API level. It is still considered an octet for type matching purposes.

Table 3.12 Mapping Type System Constructs to XML

Type/Construct		Example	
IDL	XML	IDL	XML
unbounded string	string without stringMaxLength attribute or with stringMaxLength set to -1	`struct PrimitiveStruct { string string_member; };`	`<struct name="PrimitiveStruct"> <member name="string_member" type="string"/> </struct>` or `<struct name="PrimitiveStruct"> <member name="string_member" type="string" stringMaxLength="-1"/> </struct>`
bounded string	string with stringMaxLength attribute	`struct PrimitiveStruct { string<20> string_member; };`	`<struct name="PrimitiveStruct"> <member name="string_member" type="string" stringMaxLength="20"/> </struct>`
unbounded wstring	wstring without stringMaxLength attribute or with stringMaxLength set to -1	`struct PrimitiveStruct { wstring wstring_member; };`	`<struct name="PrimitiveStruct"> <member name="wstring_member" type="wstring"/> </struct>` or `<struct name="PrimitiveStruct"> <member name="wstring_member" type="wstring" stringMaxLength="-1"/> </struct>`
bounded wstring	wstring with stringMaxLength attribute	`struct PrimitiveStruct { wstring<20> wstring_member; };`	`<struct name="PrimitiveStruct"> <member name="wstring_member" type="wstring" stringMaxLength="20"/> </struct>`
enum	enum tag	`enum PrimitiveEnum { ENUM1, ENUM2, ENUM3 };`	`<enum name="PrimitiveEnum"> <enumerator name="ENUM1"/> <enumerator name="ENUM2"/> <enumerator name="ENUM3"/> </enum>`
		`enum PrimitiveEnum { ENUM1=10, ENUM2=20, ENUM3 } enum PrimitiveEnum { @value (10) ENUM1, @value (20) ENUM2, @value (30) ENUM3 }`	`<enum name="PrimitiveEnum"> <enumerator name="ENUM1" value="10"/> <enumerator name="ENUM2" value="20"/> <enumerator name="ENUM3" value="30"/> </enum>`
constant	const tag	`const double PI = 3.1415;`	`<const name="PI" type="double" value="3.1415"/>`
struct	struct tag	`struct PrimitiveStruct { short short_member; };`	`<struct name="PrimitiveStruct"> <member name="short_member" type="short"/> </struct>`

Table 3.12 Mapping Type System Constructs to XML

Type/Construct		Example	
IDL	XML	IDL	XML
union	union tag	union PrimitiveUnion switch (long) { case 1: short short_member; case 2: case 3: float float_member; default: long long_member; };	<union name="PrimitiveUnion"> <discriminator type="long"/> <case> <caseDiscriminator value="1"/> <member name="short_member" type="short"/> </case> <case> <caseDiscriminator value="2"/> <caseDiscriminator value="3"/> <member name="float_member" type="float"/> </case> <case> <caseDiscriminator value="default"/> <member name="long_member" type="long"/> </case> </union>
valuetyp-e	valuetype tag	valuetype BaseValueType { public long long_ member; }; valuetype DerivedValueType: BaseValueType { public long long_member_2; };	<valuetype name="BaseValueType"> <member name="long_member" type="long" visibility="public"/> </valuetype> <valuetype name="DerivedValueType" baseClass="BaseValueType"> <member name="long_member_2" type="long" visibility="public"/> </valuetype>
typedef	typedef tag	typedef short ShortType;	<typedef name="ShortType" type="short"/>
		struct PrimitiveStruct { short short_member; }; typedef PrimitiveStruct PrimitiveStructType;	<struct name="PrimitiveStruct"> <member name="short_member" type="short"/> </struct> <typedef name="PrimitiveStructType" type="nonBasic" nonBasicTypeName="PrimitiveStruct"/>
arrays	Attribute ar-rayDi-mensions	struct OneArrayStruct { short short_array [2]; };	<struct name="OneArrayStruct"> <member name="short_array" type="short" arrayDimensions="2"/> </struct>
		struct TwoArrayStruct { short short_array[1] [2]; };	<struct name="TwoArrayStruct"> <member name="short_array" type="short" arrayDimensions="1,2"/> </struct>

Table 3.12 Mapping Type System Constructs to XML

Type/Construct		Example	
IDL	XML	IDL	XML
bounded sequence	Attribute sequenceMaxLength > 0	`struct SequenceStruct { sequence<short,4> short_sequence; };`	`<struct name="SequenceStruct"> <member name="short_sequence" type="short" sequenceMaxLength="4"/> </struct>`
unbounded sequence	Attribute sequenceMaxLength set to -1	`struct SequenceStruct { sequence<short> short_sequence; };`	`<struct name="SequenceStruct"> <member name="short_sequence" type="short" sequenceMaxLength="-1"/> </struct>`
array of sequences	Attributes sequenceMaxLength and arrayDimensions	`struct ArrayOfSequencesStruct { sequence<short,4> short_sequence_array [2]; };`	`<struct name= "ArrayOfSequenceStruct"> <member name= "short_sequence_array" type="short" arrayDimensions="2" sequenceMaxLength="4"/> </struct>`
sequence of arrays	Must be implemented with a typedef tag	`typedef short ShortArray[2]; struct SequenceOfArraysStruct { sequence<ShortArray,2> short_array_ sequence; };`	`<typedef name="ShortArray" type="short" dimensions="2"/> <struct name= "SequenceOfArrayStruct"> <member name= "short_array_sequence" type="nonBasic" nonBasicTypeName="ShortSequence" sequenceMaxLength="2"/> </struct>`
sequence of sequences	Must be implemented with a typedef tag	`typedef sequence<short,4> ShortSequence; struct SequenceOfSequencesStruct { sequence<ShortSequence ,2> short_sequence_ sequence; };`	`<typedef name="ShortSequence" type="short"sequenceMaxLength="4"/> <struct name="SequenceofSequencesStruct"> <member name="short_sequence_sequence" type="nonBasic" nonBasicTypeName="ShortSequence" sequenceMax-Length="2"/> </struct>`
module	module tag	`module PackageName { struct PrimitiveStruct { long long_member; }; };`	`<module name="PackageName"> <struct name="PrimitiveStruct"> <member name="long_member" type="long"/> </struct> </module>`
include	include tag	`#include "PrimitiveTypes.idl"`	`<include file="PrimitiveTypes.xml"/>`

Table 3.12 Mapping Type System Constructs to XML

Type/Construct		Example	
IDL	XML	IDL	XML

@key annotation [1]	key attribute with values true, false, 0, or 1
	Default (if not present): 0
		`struct KeyedPrimitiveStruct {`
		`  @key short`
		`  short_member;`
		`};`
			`<struct name="KeyedPrimitiveStruct">`
			`  <member name="short_member"`
			`  type="short" key="true"/>`
			`</struct>`

@external or pointer	external attribute with values true, false, 0, or 1
	Default (if not present): 0
		`struct PrimitiveStruct {`
		`  @external long`
		`  long_member;`
		`};`
			`<struct name="PointerStruct">`
			`  <member name="long_member"`
			`  type="long"`
			`  external="true"/>`
			`</struct>`

@optional annotation	optional attribute with values true, false, 0 ,or 1
	Default (if not present): 0
		`struct Point {`
		`  long x;`
		`  long y;`
		`  @optional long z;`
		`};`
			`<struct name= "Point">`
			`  <member name="x" type="int32"/>`
			`  <member name="y" type="int32"/>`
			`  <member name="z" type="int32" optional="true"/>`
			`</struct>`

@id annotation	id attribute
	Default (if not present): id calculated based on the @autoid value of the enclosing type and module(s)
		`@mutable`
		`struct Point {`
		`  @id(56) long x;`
		`  @id(57) long y;`
		`  long z;`
		`};`
			`<struct name="Point" extensibility="mutable">`
			`  <member name="x" id="56" type="long"/>`
			`  <member name="y" id="57" type="long"/>`
			`  <!-- z id is 58 -->`
			`  <member name="y" type="long"/>`
			`</struct>`

[1] For information on this and the other annotations, see 3.3.9 Using Builtin Annotations on page 112.

Table 3.12 Mapping Type System Constructs to XML

Type/Construct		Example	
IDL	XML	IDL	XML

@hashid annotation	hashid attribute containing the string that must be hashed to compute the id
	Default (if not present). id calculated based on the @autoid value of the enclosing type and module(s)
		`@mutable`
		`struct Point {`
		`  @hashid long x;`
		`  @hashid("other_y")`
		`  long y;`
		`};`
			`<struct name= "Point" extensibility= "mutable">`
			`  <member name="x" hashid="x" type="int32"/>`
			`  <member name="y" hashid="other_y" type="int32"/>`
			`</struct>`

@value annotation	value attribute
	Default (if not present): value of the previous enumerator plus 1
		`enum PrimitiveEnum {`
		`  @value (10) ENUM1,`
		`  @value (20) ENUM2,`
		`ENUM3`
		`}`
			`<enum name="PrimitiveEnum">`
			`  <enumerator name="ENUM1" value="10"/>`
			`  <enumerator name="ENUM2" value="20"/>`
			`  <!-- ENUM3 id is 21 -->`
			`  <enumerator name="ENUM3"/>`
			`</enum>`

@default_literal annotation	defaultLiteral attribute with values true, false, 0, or 1
	Default (if not present): 0
		`enum MyEnum {`
		`  ENUM1,`
		`  @default_literal`
		`ENUM2`
		`};`
			`<enum name="MyEnum">`
			`  <enumerator name="ENUM1"/>`
			`  <enumerator name="ENUM2" defaultLiteral="true"/>`
			`</enum>`

@default annotation	default attribute
	Default (if not present in this member or its alias types): 0, the empty string, or whichever enumerator is the defaultLiteral
		`@default(24)`
		`typedef long`
		`MyLongTypedefWithDefau`
		`lt;`
		
		`struct Point {`
		`  @default(42)`
		`  long x;`
		
		`MyLongTypedefWithDefau`
		`lt y;`
		`};`
			`<typedef name="MyLongTypedefWithDefault" type="long"`
			`default="24"/>`
			`<struct name="Point">`
			`  <member name="x" type="long" default="42"/>`
			`  <member name="y" type="nonBasic"`
			`nonBasicTypeName="MyLongTypedefWithDefault"/> <!-- default is`
			`24 -->`
			`</struct>`

Table 3.12 Mapping Type System Constructs to XML

Type/Construct		Example	
IDL	XML	IDL	XML

@min annotation	min attribute
	Default (if not present in this member or its alias types): the minimum possible value of the type
		`struct Point {`
		`  @min(-32)`
		`  long x;`
		`  long y;`
		`};`
			`<struct name="Point">`
			`  <member name="x" type="long" min="-32"/>`
			`  <member name="y" type="long"/>`
			`</struct>`

@max annotation	max attribute
	Default (if not present in this member or its alias types): the maximum possible value of the type
		`struct Point {`
		`  @max(31)`
		`  long x;`
		`  long y;`
		`};`
			`<struct name="Point">`
			`  <member name="x" type="long" max="31"/>`
			`  <member name="y" type="long"/>`
			`</struct>`

@range annotation	Not supported. Use min and max attributes instead.	`struct Point {`
		`  @range(min = -32, max = 31)`
		`  long x;`
		`  long y;`
		`};`
			`<struct name="Point">`
			`  <member name="x" type="long" min="32" max="31"/>`
			`  <member name="y" type="long"/>`
			`</struct>`

@autoid annotation	autoid attribute with "hash" or "sequential" values
	Default (if not present): the @autoid value in ancestor module(s) or sequential if not specified
		`@mutable`
		`@hashid(HASH)`
		`struct Point {`
		`  long x;`
		`  long y;`
		`};`
			`<struct name="Point" extensibility="mutable" autoid="hash">`
			`  <member name="x" type="long"/>`
			`  <member name="y" type="long"/>`
			`</struct>`

Table 3.12 Mapping Type System Constructs to XML

Type/Construct		Example	
IDL	XML	IDL	XML

@nested or @top-level annotation	nested attribute with values true, false, 0 ,or 1
	Default (if not present): 0
		`@nested`
		`struct TopLevelPrimitiveStruct {`
		`  short short_member;`
		`};`
		or
		`@top_level(false)`
		`struct TopLevelPrimitiveStruct {`
		`  short short_member;`
		`};`
			`<struct name=`
			`  "TopLevelPrimitiveStruct"`
			`  nested="true">`
			`<member name=`
			`  "short_member"`
			`  type="short"/>`
			`</struct>`

@extensibility, @mutable, @appendable, or @final annotation	extensibility attribute with values final, appendable, or mutable
	Default (if not present): appendable
		`@mutable`
		`struct Point {`
		`  long x;`
		`  long y;`
		`};`
			`<struct name="Point" extensibility="mutable">`
			`  <member name="x" type="long"/>`
			`  <member name="y" type="long"/>`
			`</struct>`

@allowed_data_representation	allowed_data_representation attribute with values xcdr, xcdr2, or xml
	Default (if not present): xcdr2 for FlatData language binding; the @allowed_data_representation value in ancestor module(s) or (xcdr|xcdr2) for plain language binding
		`@allowed_data_representation(XCDR2)`
		`@mutable`
		`struct Point {`
		`  long x;`
		`  long y;`
		`};`
			`<struct name= "Point" extensibility= "mutable" allowed_data_representation="xcdr2">`
			`  <member name="x" type="int32"/>`
			`  <member name="y" type="int32"/>`
			`</struct>`

Table 3.12 Mapping Type System Constructs to XML

Type/Construct		Example	
IDL	XML	IDL	XML

@use_vector	useVector attribute with values true, false, 0 ,or 1
	Default (if not present): false unless code generated with -alwaysUseStdVector
		`struct Image {`
		`  @use_vector`
		`  sequence<octet, 1048576> pixels;`
		`};`
			`<struct name= "Image">`
			`  <member name="pixels"  sequenceMaxLength="1048576" useVector="true" type="byte"/>`
			`</struct>`

@language_binding annotation	languageBinding attribute with values plain or flat_data.
	Default (if not present): the @language_binding value in ancestor module(s) or plain if not specified
		`@language_binding (FLAT_DATA)`
		`@final`
		`struct Point {`
		`  long x;`
		`  long y;`
		`};`
			`<struct name="Point" extensibility="final" languageBinding="flat_data">`
			`  <member name="x" type="long"/>`
			`  <member name="y" type="long"/>`
			`</struct>`

@transfer_mode annotation	transferMode attribute with values inband or shmem_ref.
	Default (if not present): the @transfer_mode value in ancestor module(s) or inband if not specified
		`@transfer_mode(SHMEM_REF)`
		`struct Point {`
		`  long x;`
		`  long y;`
		`};`
			`<struct name="Point" transferMode="shmem_ref">`
			`  <member name="x" type="long"/>`
			`  <member name="y" type="long"/>`
			`</struct>`

Table 3.12 Mapping Type System Constructs to XML

Type/Construct		Example	
IDL	XML	IDL	XML
@resolve-name annotation	resolveName attribute with values true, false, 0, or 1 Default (if not present): @resolve_ name of the parent type or false if not specified on parent	`struct UnresolvedPrimitiveStruct { @resolve_name(false) PrimitiveStruct primitive_member; };`	`<struct name= "UnresolvedPrimitiveStruct"> <member name="primitive_member" type="PrimitiveStruct" resolveName="false"/> </struct>`
Other annotations	directive tag	`//@copy (This text will be copied in the generated files)`	`<directive kind="copy"> This text will be copied in the generated files </directive>`

3.5 Creating User Data Types with XML Schemas (XSD)

You can describe data types with XML schemas (XSD). The format is based on the standard IDL-to-WSDL mapping described in the OMG document "CORBA to WSDL/SOAP Interworking Specification."

Example Header for XSD:

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
 xmlns:dds="http://www.omg.org/dds"
 xmlns:tns="http://www.omg.org/IDL-Mapped/"
 targetNamespace="http://www.omg.org/IDL-Mapped/">
<xsd:import namespace="http://www.omg.org/dds"
 schemaLocation="rti_dds_topic_types_common.xsd"/>
...
</xsd:schema>
```

Table 3.13 Mapping Type System Constructs to XSD describes how to map IDL types to XSD. The *Connext DDS* code generator, *rtiddsgen*, will only accept XSD files that follow this mapping.

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD

char	dds:char[1]	struct PrimitiveStruct
		  char char_member;
		};
			<xsd:complexType name= "PrimitiveStruct">
			<xsd:sequence>
			  <xsd:element name="char_member"
			  minOccurs="1" maxOccurs="1"
			  type="dds:char">
			  </xsd:sequence>
			</xsd:complexType>

wchar	dds:wchar[2]	struct PrimitiveStruct {
		  wchar wchar_member;
		};
			<xsd:complexType name="PrimitiveStruct">
			<xsd:sequence>
			  <xsd:element name="wchar_member"
			  minOccurs="1" maxOccurs="1"
			  type="dds:wchar">
			</xsd:sequence>
			</xsd:complexType>

octet	xsd: unsignedByte	struct PrimitiveStruct {
		  octet octet_member;
		};
			<xsd:complexType name="PrimitiveStruct">
			<xsd:sequence>
			  <xsd:element name="octet_member"
			  minOccurs="1" maxOccurs="1"
			  type="xsd:unsignedByte">
			</xsd:sequence>
			</xsd:complexType>

int8[3]	dds:int8[4]	struct PrimitiveStruct {
		  int8 int8_member;
		};
			<xsd:complexType name= "PrimitiveStruct">
			  <xsd:sequence>
			  <xsd:element name="int8_member"
			  minOccurs="1" maxOccurs="1"
			  type="dds:int8"/>
			  </xsd:sequence>
			</xsd:complexType>

[1]All files that use the primitive types char, wchar, int8, uint8, long double, and wstring must reference rti_dds_topic_types_common.xsd. See 3.5.1 Primitive Types on page 151.

[2]All files that use the primitive types char, wchar, int8, uint8, long double, and wstring must reference rti_dds_topic_types_common.xsd. See 3.5.1 Primitive Types on page 151

[3]This type is supported only at the API level. It is still considered an octet for type matching purposes.

[4]All files that use the primitive types char, wchar, int8, uint8, long double, and wstring must reference rti_dds_topic_types_common.xsd. See 3.5.1 Primitive Types on page 151.

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD
uint8[1]	dds:uint8[2]	struct PrimitiveStruct { uint8 uint8_member; };	<xsd:complexType name= "PrimitiveStruct"> <xsd:sequence> <xsd:element name="uint8_member" minOccurs="1" maxOccurs="1" type="dds:uint8"/> </xsd:sequence> </xsd:complexType>
short or int16	xsd:short	struct PrimitiveStruct { int16 short_member; };	<xsd:complexType name="PrimitiveStruct"> <xsd:sequence> <xsd:element name="short_member" minOccurs="1" maxOccurs="1" type="xsd:short"/> </xsd:sequence> </xsd:complexType>
un-signed short or uint16	xsd: un-signedShort	struct PrimitiveStruct { uint16 unsigned_short_member; };	<xsd:complexType name="PrimitiveStruct"> <xsd:sequence> <xsd:element name= "unsigned_short_member" minOccurs="1" maxOccurs="1" type="xsd:unsignedShort"/> </xsd:sequence> </xsd:complexType>
long or int32	xsd:int	struct PrimitiveStruct { int32 long_member; };	<xsd:complexType name="PrimitiveStruct"> <xsd:sequence> <xsd:element name="long_member" minOccurs="1" maxOccurs="1" type="xsd:int"/> </xsd:sequence> </xsd:complexType>
un-signed long or uint32	xsd: unsignedInt	struct PrimitiveStruct { uint32 unsigned_long_member; };	<xsd:complexType name="PrimitiveStruct"> <xsd:sequence> <xsd:element name= "unsigned_long_member" minOccurs="1" maxOccurs="1" type="xsd:unsignedInt"/> </xsd:sequence> </xsd:complexType>

[1]This type is supported only at the API level. It is still considered an octet for type matching purposes.

[2]All files that use the primitive types char, wchar, int8, uint8, long double, and wstring must reference rti_dds_topic_types_common.xsd. See 3.5.1 Primitive Types on page 151.

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD

long
long or
int64
	xsd:long	struct
		PrimitiveStruct {
		int64
		long_long_member;
		};
			<xsd:complexType name="PrimitiveStruct">
			<xsd:sequence>
			<xsd:elementname=
			"long_long_member"
			minOccurs="1" maxOccurs="1"
			type="xsd:long"/>
			</xsd:sequence>
			</xsd:complexType>

un-
signed
long
long or
uint64
	xsd:
	unsignedLong
		struct
		PrimitiveStruct {
		uint64
		unsigned_long_long_
		member;
		};
			<xsd:complexType name="PrimitiveStruct">
			<xsd:sequence>
			<xsd:element name=
			"unsigned_long_long_member"
			minOccurs="1" maxOccurs="1"
			type="xsd:unsignedLong"/>
			</xsd:sequence>
			</xsd:complexType>

float	xsd:float	struct
		PrimitiveStruct {
		float float_member;
		};
			<xsd:complexType name="PrimitiveStruct">
			<xsd:sequence>
			<xsd:element name="float_member"
			minOccurs="1" maxOccurs="1"
			type="xsd:float"/>
			</xsd:sequence>
			</xsd:complexType>

double	xsd:double	struct
		PrimitiveStruct {
		double double_
		member;
		};
			<xsd:complexType name="PrimitiveStruct">
			<xsd:sequence>
			<xsd:element name="double_member"
			minOccurs="1" maxOccurs="1"
			type="xsd:double"/>
			</xsd:sequence>
			</xsd:complexType>

long
double
	dds:
	longDouble
		struct
		PrimitiveStruct {
		long double
		long_double_member;
		};
			<xsd:complexType name="PrimitiveStruct">
			<xsd:sequence>
			<xsd:element name= "long_double_member"
			minOccurs="1" maxOccurs="1"
			type="dds:longDouble"/>
			</xsd:sequence>
			</xsd:complexType>

boolea-
n
	xsd:boolean	struct
		PrimitiveStruct {
		boolean boolean_
		member;
		};
			<xsd:complexType name="PrimitiveStruct">
			<xsd:sequence>
			<xsd:element name="boolean_member"
			minOccurs="1" maxOccurs="1"
			type="xsd:boolean"/>
			</xsd:sequence>
			</xsd:complexType>

un-
bound-
ed
string
	xsd:string	struct
		PrimitiveStruct {
		string string_
		member;
		};
			<xsd:complexType name="PrimitiveStruct">
			<xsd:sequence>
			<xsd:element name="string_member"
			minOccurs="1" maxOccurs="1"
			type="xsd:string"/>
			</xsd:sequence>
			</xsd:complexType>

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD
bound-ed string	xsd:string with restriction to specify max-imum length	`struct PrimitiveStruct { string<20> string_member; };`	`<xsd:complexType name= "PrimitiveStruct_string_member_BoundedString"> <xsd:sequence> <xsd:element name="item" minOccurs="1" maxOccurs="1"> <xsd:simpleType> <xsd:restriction base="xsd:string"> <xsd:maxLength value="20" fixed="true"/> </xsd:restriction> </xsd:simpleType> </xsd:element> </xsd:sequence> </xsd:complexType>`  `<xsd:complexType name= "PrimitiveStruct"> <xsd:sequence> <xsd:element name="string_member" minOccurs="1" maxOccurs="1" type= "tns:PrimitiveStruct_string_member_BoundedString"/> </xsd:sequence> </xsd:complexType>`
un-bound-ed wstring	dds:wstring [1]	`struct PrimitiveStruct { wstring wstring_member; };`	`<xsd:complexType name="PrimitiveStruct"> <xsd:sequence> <xsd:element name="wstring_member" minOccurs="1" maxOccurs="1" type="dds:wstring"/> </xsd:sequence> </xsd:complexType>`

[1] All files that use the primitive types char, wchar, int8, uint8, long double and wstring must reference rti_dds_topic_types_common.xsd. See 3.5.1 Primitive Types on page 151

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD
bounded wstring	xsd:wstring with restriction to specify maximum length	`struct PrimitiveStruct { wstring<20> wstring_member; };`	`<xsd:complexType name= "PrimitiveStruct_wstring_member_BoundedString"> <xsd:sequence> <xsd:element name="item" minOccurs="1" maxOccurs="1"> <xsd:simpleType> <xsd:restriction base="dds:wstring"> <xsd:maxLength value="20" fixed="true"/> </xsd:restriction> </xsd:simpleType> </xsd:element> </xsd:sequence> </xsd:complexType>`  `<xsd:complexType name= "PrimitiveStruct"> <xsd:sequence> <xsd:element name="wstring_member" minOccurs="1" maxOccurs="1" type= "tns:PrimitiveStruct_wstring_member_BoundedString"/> </xsd:sequence> </xsd:complexType>`

enum	xsd:simpleType with enumeration	`enum PrimitiveEnum { ENUM1, ENUM2, ENUM3 };`	`<xsd:simpleType name="PrimitiveEnum"> <xsd:restriction base="xsd:string"> <xsd:enumeration value="ENUM1"/> <xsd:enumeration value="ENUM2"/> <xsd:enumeration value="ENUM3"/> </xsd:restriction> </xsd:simpleType>`
			
			`<xsd:simpleType name="PrimitiveEnum"> <xsd:restriction base="xsd:string"> <xsd:enumeration value="ENUM1"> <xsd:annotation> <xsd:appinfo> <ordinal>10</ordinal> </xsd:appinfo> </xsd:annotation> </xsd:enumeration> <xsd:enumeration value="ENUM2"> <xsd:annotation> <xsd:appinfo> <ordinal>20</ordinal> </xsd:appinfo> </xsd:annotation> </xsd:enumeration> <xsd:enumeration value="ENUM3"> <xsd:annotation> <xsd:appinfo> <ordinal>30</ordinal> </xsd:appinfo> </xsd:annotation> </xsd:enumeration> </xsd:restriction> </xsd:simpleType>`

Table 3.13 Mapping Type System Constructs to XSD

<table>
<tr><th colspan="2">Type/Construct</th><th colspan="2">Example</th></tr>
<tr><th>IDL</th><th>XSD</th><th>IDL</th><th>XSD</th></tr>
<tr><td></td><td></td><td>

```
enum PrimitiveEnum {
    ENUM1 = 10,
    ENUM2 = 20,
    ENUM3 = 30
};
```

</td><td>

```
<xsd:simpleType name="PrimitiveEnum">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="ENUM1">
      <xsd:annotation>
        <xsd:appinfo>
          <ordinal>10</ordinal>
        </xsd:appinfo>
      </xsd:annotation>
    </xsd:enumeration>
    <xsd:enumeration value="ENUM2">
      <xsd:annotation>
        <xsd:appinfo>
          <ordinal>20</ordinal>
        </xsd:appinfo>
      </xsd:annotation>
    </xsd:enumeration>
    <xsd:enumeration value="ENUM3">
      <xsd:annotation>
        <xsd:appinfo>
          <ordinal>30</ordinal>
        </xsd:appinfo>
      </xsd:annotation>
    </xsd:enumeration>
  </xsd:restriction>
</xsd:simpleType>
```

</td></tr>
<tr><td>con-stant</td><td colspan="3">IDL constants are mapped by substituting their value directly in the generated file</td></tr>
<tr><td>struct</td><td>xsd:-complexType with xsd:sequence</td><td>

```
struct PrimitiveStruct
{
 short short_member;
};
```

</td><td>

```
<xsd:complexType name="PrimitiveStruct">
  <xsd:sequence>
    <xsd:element name="short_member"
     minOccurs="1" maxOccurs="1"
     type="xsd:short"/>
  </xsd:sequence>
</xsd:complexType>
```

</td></tr>
</table>

Table 3.13 Mapping Type System Constructs to XSD

<table>
<tr><th colspan="2">Type/Construct</th><th colspan="2">Example</th></tr>
<tr><th>IDL</th><th>XSD</th><th>IDL</th><th>XSD</th></tr>
<tr><td>union</td><td>xsd:-complexType with xsd:choice</td><td>

```
union PrimitiveUnion
switch (long) {
  case 1:
    short short_
member;
  default:
    long long_member;
};
```

</td><td>

```
<xsd:complexType name="PrimitiveUnion">
  <xsd:sequence>
    <xsd:element name="discriminator"
     type="xsd:int"/>
    <xsd:choice>
      <!-- case 1 -->[1]
      <xsd:element name="short_member"
      minOccurs="0" maxOccurs="1"
      type="xsd:short">
        <xsd:annotation>
          <xsd:appinfo>
            <case>1</case>
          </xsd:appinfo>
       </xsd:annotation>
      </xsd:element>
      <!-- case default -->
      <xsd:element name="long_member"
       minOccurs="0" maxOccurs="1"
       type="xsd:int">
        <xsd:annotation>
            <xsd:appinfo>
                <case>default</case>
            </xsd:appinfo>
        </xsd:annotation>
      </xsd:element>
    </xsd:choice>
  </xsd:sequence>
</xsd:complexType>
```

</td></tr>
</table>

[1]The discriminant values can be described using comments (as specified by the standard) or xsd:annotation tags. We recommend using annotations because comments may be removed by XSD/XML parsers.

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD
value-type	xsd:-complexType with @valuetype annotation	valuetype BaseValueType { public long long_member; }; valuetype DerivedValueType: BaseValueType { public long long_member2; public long long_member3; };	<xsd:complexType name="BaseValueType"> <xsd:sequence> <xsd:element name=”long_member" maxOccurs="1" minOccurs="1" type="xs:int"/> <!-- @visibility public --> </xsd:sequence> </xs:complexType> <!-- @valuetype true --> <xs:complexType name="DerivedValueType"> <xs:complexContent> <xs:extension base="BaseValueType"> <xs:sequence> <xs:element name="long_member2" maxOccurs="1" minOccurs="1" type="xs:int"/> <!-- @visibility public --> <xs:element name="long_member3" maxOccurs="1" minOccurs="1" type="xs:int"/> <!-- @visibility public --> </xs:sequence> </xs:extension> </xs:complexContent> </xs:complexType> <!-- @valuetype true -->
ty-pedef	Type defin-itions are mapped to XML schema type re-strictions	typedef short ShortType; struct PrimitiveStruct { short short_member; }; typedef PrimitiveType = PrimitiveStructType;	<xsd:simpleType name="ShortType"> <xsd:restriction base="xsd:short"/> </xsd:simpleType> <!— Struct definition --> <xsd:complexType name="PrimitiveStruct"> <xsd:sequence> <xsd:element name="short_member" minOccurs="1" maxOccurs="1" type="xsd:short"/> </xsd:sequence> </xsd:complexType> <!— Typedef definition --> <xsd:complexType name="PrimitiveTypeStructType"> <xsd:complexContent> <xsd:restriction base=”PrimitiveStruct”> <xsd:sequence> <xsd:element name="short_member" minOccurs="1" maxOccurs="1" type="xsd:short"/> </xsd:sequence> </xsd:restriction> </xsd:complexContent> </xsd:complexType>

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD
arrays	n xsd:-complexType with sequence containing one element with min & max occurs There is one xsd:-complexType per array dimension	`struct OneArrayStruct { short short_array [2]; };`	`<!-- Array type --> <xsd:complexType name= "OneArrayStruct_short_array_ArrayOfShort"> <xsd:sequence> <xsd:element name="item" minOccurs="2" maxOccurs="2" type="xsd:short"> </xsd:element> </xsd:sequence> </xsd:complexType> <!-- Struct w unidimensional array member --> <xsd:complexType name="OneArrayStruct"> <xsd:sequence> <xsd:element name="short_array" minOccurs="1" maxOccurs="1" type= "OneArrayStruct_short_array_ArrayOfShort"/> </xsd:sequence> </xsd:complexType>`
arrays (cont'd)	n xsd:-complexType with sequence containing one element with min & max occurs There is one xsd:-complexType per array dimension	`struct TwoArrayStruct { short short_array [2][1]; };`	`<!--Second dimension array type --> <xsd:complexType name= "TwoArrayStruct_short_array_ArrayOfShort"> <xsd:sequence> <xsd:element name="item" minOccurs="2" maxOccurs="2" type="xsd:short"> </xsd:element> </xsd:sequence> </xsd:complexType> <!-- First dimension array type --> <xsd:complexType name= "TwoArrayStruct_short_array_ArrayOfArrayOfShort"> <xsd:sequence> <xsd:element name="item" minOccurs="1" maxOccurs="1" type= "TwoArrayStruct_short_array_ArrayOfShort"> </xsd:element> </xsd:sequence> </xsd:complexType> <!--Struct containing a bidimensional array member --> <xsd:complexType name="TwoArrayStruct"> <xsd:sequence> <xsd:element name="short_array" minOccurs="1" maxOccurs="1" type= "TwoArrayStruct_short_array_ArrayOfArrayOfShort"/> </xsd:sequence> </xsd:complexType>`

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD
bounded sequence	xsd:complexType with sequence containing one element with min & max occurs	`struct SequenceStruct { sequence<short,4> short_sequence; };`	`<!-- Sequence type --> <xsd:complexType name= "SequenceStruct_short_sequence_SequenceOfShort"> <xsd:sequence> <xsd:element name="item" minOccurs="0" maxOccurs="4" type="xsd:short"> </xsd:element> </xsd:sequence> </xsd:complexType> <!-- Struct containing a bounded sequence member --> <xsd:complexType name="SequenceStruct"> <xsd:sequence> <xsd:element name="short_sequence" minOccurs="1" maxOccurs="1" type= "SequenceStruct_short_sequence_SequenceOfShort"/> </xsd:sequence> </xsd:complexType>`
unbounded sequence	xsd:complexType with sequence containing one element with min & max occurs	`struct SequenceStruct { sequence<short> short_sequence; };`	`<!-- Sequence type --> <xsd:complexType name= "SequenceStruct_short_sequence_SequenceOfShort"> <xsd:sequence> <xsd:element name="item" minOccurs="0" maxOccurs="unbounded" type="xsd:short"/> </xsd:sequence> </xsd:complexType> <!-- Struct containing unbounded sequence member --> <xsd:complexType name="SequenceStruct"> <xsd:sequence> <xsd:element name="short_sequence" minOccurs="1" maxOccurs="1" type= "SequenceStruct_short_sequence_SequenceOfShort"/> </xsd:sequence> </xsd:complexType>`

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD

array of sequences	n + 1 xsd:complexType with sequence containing one element with min & max occurrences.
	There is one xsd:complexType per array dimension and one xsd:complexType for the sequence.
		struct
		
		ArrayOfSequencesStruct {
		sequence<short,4>
		sequence_sequence [2];
		};
			<!-- Sequence declaration -->
			<xsd:complexType name=
			"ArrayOfSequencesStruct_sequence_array_SequenceOfShort">
			<xsd:sequence>
			<xsd:element name="item"
			minOccurs="0" maxOccurs="4"
			type="xsd:short">
			</xsd:element>
			</xsd:sequence>
			</xsd:complexType>
			<!-- Array declaration -->
			<xsd:complexType name=
			"ArrayOfSequencesStruct_sequence_array_ArrayOf
			SequenceOfShort">
			<xsd:sequence>
			<xsd:element name="item"
			minOccurs="2" maxOccurs="2"
			type=
			"ArrayOfSequencesStruct_sequence_array_SequenceOfShort">
			</xsd:element>
			</xsd:sequence>
			</xsd:complexType>
			
			<!-- Structure containing a member that is an
			array of sequences -->
			<xsd:complexType name="ArrayOfSequencesStruct">
			<xsd:sequence>
			<xsd:element name="sequence_array"
			minOccurs="1" maxOccurs="1"
			type=
			"ArrayOfSequencesStruct_sequence_array_ArrayOf
			SequenceOfShort"/>
			</xsd:sequence>
			</xsd:complexType>

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD

sequence of arrays	Sequences of arrays must be implemented using an explicit type definition (typedef) for the array	`typedef short ShortArray[2];`
		
		`struct SequenceOfArraysStruct {`
		
		`sequence<ShortArray, 2> arrays_sequence;`
		`};`
			`<!-- Array declaration -->`
			`<xsd:complexType name="ShortArray">`
			`<xsd:sequence>`
			`<xsd:element name="item"`
			`minOccurs="2" maxOccurs="2"`
			`type="xsd:short">`
			`</xsd:element>`
			`</xsd:sequence>`
			`</xsd:complexType>`
			
			`<!-- Sequence declaration -->`
			`<xsd:complexType name=`
			`"SequencesOfArraysStruct_array_sequence_SequenceOfShortArray">`
			`<xsd:sequence>`
			`<xsd:element name="item"`
			`minOccurs="0" maxOccurs="2" type="ShortArray">`
			`</xsd:element>`
			`</xsd:sequence>`
			`</xsd:complexType>`
			
			`<!-- Struct containing a sequence of arrays -->`
			`<xsd:complexType name="SequenceOfArraysStruct">`
			`<xsd:sequence>`
			`<xsd:element name="arrays_sequence"`
			`minOccurs="1" maxOccurs="1"`
			`type=`
			`"SequencesOfArraysStruct_arrays_sequence_SequenceOfShortArray"/>`
			`</xsd:sequence>`
			`</xsd:complexType>`

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD

sequence of sequences	Sequences of sequences must be implemented using an explicit type definition (typedef) for the second sequence	`typedef sequence<short,4> ShortSequence;`
		
		`struct SequenceOfSequences {`
		
		`sequence<ShortSequence,2> sequences_sequence;`
		`};`
			`<!-- Internal sequence declaration -->`
			`<xsd:complexType name="ShortSequence">`
			`<xsd:sequence>`
			`<xsd:element name="item"`
			`minOccurs="0" maxOccurs="4"`
			`type="xsd:short">`
			`</xsd:element>`
			`</xsd:sequence>`
			`</xsd:complexType>`
			
			`<!-- External sequence declaration -->`
			`<xsd:complexType name=`
			
			`"SequencesOfSequences_sequences_sequence_`
			`SequenceOfShortSequence">`
			`<xsd:sequence>`
			`<xsd:element name="item"`
			`minOccurs="0" maxOccurs="2"`
			`type="ShortSequence">`
			`</xsd:element>`
			`</xsd:sequence>`
			`</xsd:complexType>`
			
			`<!--Struct containing sequence of sequences -->`
			`<xsd:complexType name="SequenceOfSequences">`
			`<xsd:sequence>`
			`<xsd:element name="sequences_sequence"`
			`minOccurs="1" maxOccurs="1"`
			`type="SequencesOfSequences_`
			`sequences_sequence_SequenceOfShortSequence"/>`
			`</xsd:sequence>`
			`</xsd:complexType>`

module	Modules are mapped adding the name of the module before the name of each type inside the module	`module PackageName {`
		`struct PrimitiveStruct {`
		`long long_member;`
		`};`
		`};`
			`<xsd:complexType name=`
			`"PackageName.PrimitiveStruct">`
			`<xsd:sequence>`
			`<xsd:element name="long_member"`
			`minOccurs="1" maxOccurs="1"`
			`type="xsd:int"/>`
			`</xsd:sequence>`
			`</xsd:complexType>`

include	xsd:include	`#include "PrimitiveType.idl"`	`<xsd:include schemaLocation=` `"PrimitiveType.xsd"/>`

@key annotation[1]	<!--
	@key <true|false|1|0>
	-->
	Default (if not specified): false
		`struct KeyedPrimitiveStruct {`
		`@key short short_member;`
		`};`
			`<xsd:complexType`
			`name="KeyedPrimitiveStruct">`
			`<xsd:sequence>`
			`<xsd:element name="long_member"`
			`minOccurs="1" maxOccurs="1"`
			`type="xsd:int"/>`
			`<!-- @key true -->`
			`</xsd:sequence>`
			`</xsd:complexType>`

[1]For information on this and the other annotations, see 3.3.9 Using Builtin Annotations on page 112.

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD

@external or pointer	<!-- @external <true|-false|1|0> -->
	Default if not specified: false
		`struct PrimitiveStruct {`
		`  @external long`
		`  long_member;`
		`};`
			`<xsd:complexType`
			` name="PrimitiveStruct">`
			`  <xsd:sequence>`
			`  <xsd:element`
			`  name="long_member"`
			`  minOccurs="1"`
			`  maxOccurs="1"`
			`  type="xsd:int"/>`
			`  <!-- @external true -->`
			`  </xsd:sequence>`
			`</xsd:complexType>`

@optional annotation	minOccurs attribute set to 0 or 1
	Default (if not present): 1
		`struct Point {`
		`  long x;`
		`  long y;`
		`  @optional long z;`
		`};`
			`<xsd:complexType name= "Point">`
			`  <xsd:sequence>`
			`  <xsd:element name="x" minOccurs="1" maxOccurs="1"`
			`type="xsd:int"/>`
			`  <xsd:element name="y" minOccurs="1" maxOccurs="1"`
			`type="xsd:int"/>`
			`  <xsd:element name="z" minOccurs="0" maxOccurs="1"`
			`type="xsd:int"/>`
			`  </xsd:sequence>`
			`</xsd:complexType>`
			`<!-- @struct true -->`

@id annotation	<!-- @id <value> -->
	Default (if not present): id calculated based on the @autoid value of the enclosing type and module(s)
		`@mutable`
		`struct Point {`
		`  @id(56) long x;`
		`  @id(57) long y;`
		`  long z;`
		`};`
			`<xsd:complexType name= "Point">`
			`  <xsd:sequence>`
			`  <xsd:element name="x" minOccurs="1" maxOccurs="1"`
			`type="xsd:int"/>`
			`  <!-- @id 56 -->`
			`  <xsd:element name="y" minOccurs="1" maxOccurs="1"`
			`type="xsd:int"/>`
			`  <!-- @id 57 -->`
			`  <xsd:element name="z" minOccurs="1" maxOccurs="1"`
			`type="xsd:int"/>`
			`  </xsd:sequence>`
			`</xsd:complexType>`
			`<!-- @struct true -->`
			`<!-- @extensibility mutable-->`

@hashid annotation	<!-- @hashid [<value>] →
	Default (if not present). id calculated based on the @autoid value of the enclosing type and module(s)
		`@mutable`
		`struct Point {`
		`  @hashid long x;`
		`  @hashid(“other_y”)`
		`  long y;`
		`};`
			`<xsd:complexType name= "Point">`
			`  <xsd:sequence>`
			`  <xsd:element name="x" minOccurs="1" maxOccurs="1"`
			`type="xsd:int"/>`
			`  <!-- @hashid -->`
			`  <xsd:element name="y" minOccurs="1" maxOccurs="1"`
			`type="xsd:int"/>`
			`  <!-- @hashid other_y-->`
			`  </xsd:sequence>`
			`</xsd:complexType>`
			`<!-- @struct true -->`
			`<!-- @extensibility mutable-->`

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD

@value annotation	<!-- @ordinal <value>-->
	Default (if not present): the value of the previous enumerator plus 1
		`enum PrimitiveEnum {`
		`  @value (10) ENUM1,`
		`  @value (20) ENUM2,`
		`  ENUM3`
		`}`
			`<xsd:simpleType name="PrimitiveEnum">`
			`  <xsd:restriction base="xsd:string">`
			`  <xsd:enumeration value="ENUM1">`
			`  <xsd:annotation>`
			`  <xsd:appinfo>`
			`  <ordinal>10</ordinal>`
			`  </xsd:appinfo>`
			`  </xsd:annotation>`
			`  </xsd:enumeration>`
			`  <!-- @ordinal 10-->`
			`  <xsd:enumeration value="ENUM2">`
			`  <xsd:annotation>`
			`  <xsd:appinfo>`
			`  <ordinal>20</ordinal>`
			`  </xsd:appinfo>`
			`  </xsd:annotation>`
			`  </xsd:enumeration>`
			`  <!-- @ordinal 20-->`
			`  <xsd:enumeration value="ENUM3">`
			`  </xsd:enumeration>`
			`  </xsd:restriction>`
			`</xsd:simpleType>`

@default_literal annotation	default_literal appinfo annotation with values true, false, 0, or 1
	Default (if not present): 0"
		`enum MyEnum {`
		`  ENUM1,`
		`  @default_literal`
		`  ENUM2`
		`};`
			`<xsd:simpleType name="MyEnum">`
			`  <xsd:restriction base="xsd:string">`
			`  <xsd:enumeration value="ENUM1">`
			`  </xsd:enumeration>`
			`  <xsd:enumeration value="ENUM2">`
			`  <xsd:annotation>`
			`  <xsd:appinfo>`
			`  <default_literal>true</default_literal>`
			`  </xsd:appinfo>`
			`  </xsd:annotation>`
			`  </xsd:enumeration>`
			`  </xsd:restriction>`
			`</xsd:simpleType>`

@default annotation	default attribute for elements inside a structure, default appinfo annotation for type definitions
	Default (if not present in this member or its alias types): 0, the empty string, or whichever enumerator is the default_literal
		`@default(24)`
		`typedef long`
		`MyLongTypedefWithDefault;`
		`struct Point {`
		`  @default(42)`
		`  long x;`
		
		`MyLongTypedefWithDefault y;`
		`};`
			`<xsd:simpleType name="MyLongTypedefWithDefault">`
			`  <xsd:restriction base="xsd:int">`
			`  <xsd:annotation>`
			`  <xsd:appinfo>`
			`  <default>24</default>`
			`  </xsd:appinfo>`
			`  </xsd:annotation>`
			`  </xsd:restriction>`
			`</xsd:simpleType>`
			`<xsd:complexType name= "Point">`
			`  <xsd:sequence>`
			`  <xsd:element name="x" minOccurs="1" maxOccurs="1"`
			`type="xsd:int" default="42"/>`
			`  <xsd:element name="y" minOccurs="1" maxOccurs="1"`
			`type="tns:MyLongTypedefWithDefault"/>`
			`  </xsd:sequence>`
			`</xsd:complexType>`

Table 3.13 Mapping Type System Constructs to XSD

<table>
<tr><th colspan="2">Type/Construct</th><th colspan="2">Example</th></tr>
<tr><th>IDL</th><th>XSD</th><th>IDL</th><th>XSD</th></tr>
<tr><td>@default annotation (strings)</td><td>default attribute for alias elements inside a structure, default appinfo annotation for type definitions and regular strings inside a structure
Default (if not present in this member or its alias types): 0, the empty string, or whichever enumerator is the default_literal</td><td><pre>@default("myDefault")
typedef string
MyStringTypedefWithDefault;
struct DefaultString
{
  @default("string")
  string x;

MyStringTypedefWithDefault y;
  @default
("myDefaultDefault")

MyStringTypedefWithDefault z;
};</pre></td><td><pre><xsd:simpleType name="MyStringTypedefWithDefault">
  <xsd:restriction base="xsd:string">
    <xsd:annotation>
      <xsd:appinfo>
        <default>"myDefault"</default>
      </xsd:appinfo>
    </xsd:annotation>
    <xsd:maxLength value="255" fixed="true"/>
   </xsd:restriction>
</xsd:simpleType>
  <xsd:complexType name="DefaultString_x_BoundedString">
    <xsd:sequence>
      <xsd:element name="item" minOccurs="1" maxOccurs="1">
        <xsd:simpleType>
          <xsd:restriction base="xsd:string">
            <xsd:maxLength value="255" fixed="true"/>
          </xsd:restriction>
        </xsd:simpleType>
       </xsd:element>
     </xsd:sequence>
   </xsd:complexType>
  <xsd:complexType name= "DefaultString">
  <xsd:sequence>
    <xsd:element name="x" minOccurs="1" maxOccurs="1"
type=""tns:DefaultString_x_BoundedString"">
      <xsd:annotation>
        <xsd:appinfo>
          <default>"string"</default>
          </xsd:appinfo>
      </xsd:annotation>
    </xsd:element>
    <xsd:element name="y" minOccurs="1" maxOccurs="1"
type="tns:MyStringTypedefWithDefault"/>
     <xsd:element name="z" minOccurs="1" maxOccurs="1"
type="tns:MyStringTypedefWithDefault"
default="myDefaultDefault"/>
  </xsd:sequence>
</xsd:complexType></pre></td></tr>
</table>

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD

@min annotation	minInclusive attribute for elements inside a structure, min appinfo annotation for type definitions
	Default (if not present in this member or its alias types): the minimum possible value of the type
		`@min(-32)`
		`typedef long myLongDefault;`
		`struct Point {`
		`  @min(-32)`
		`  long x;`
		`  long y;`
		`  myLongDefault myX;`
		`};`
			`<xsd:simpleType name="myLongDefault">`
			`  <xsd:restriction base="xsd:int">`
			`  <xsd:annotation>`
			`  <xsd:appinfo>`
			`  <min>-32</min>`
			`  </xsd:appinfo>`
			`  </xsd:annotation>`
			`  </xsd:restriction>`
			`</xsd:simpleType>`
			`<xsd:complexType name= "Point">`
			`  <xsd:sequence>`
			`  <xsd:element name="x" minOccurs="1" maxOccurs="1">`
			`  <xsd:simpleType>`
			`  <xsd:restriction base="xsd:int">`
			`  <xsd:minInclusive value="-32"/>`
			`  </xsd:restriction>`
			`  </xsd:simpleType>`
			`  </xsd:element>`
			`  <xsd:element name="y" minOccurs="1" maxOccurs="1" type="xsd:int"/>`
			`  <xsd:element name="myX" minOccurs="1" maxOccurs="1" type="tns:myLongDefault"/>`
			`  </xsd:sequence>`
			`</xsd:complexType>`

@max annotation	maxInclusive attribute for elements inside an structure, max appinfo annotation for types definitions
	Default (if not present in this member or its alias types): the maximum possible value of the type
		`@max(31)`
		`typedef long myLongDefault;`
		`struct Point {`
		`  @max(31)`
		`  long x;`
		`  long y;`
		`  myLongDefault myX;`
		`};`
			`<xsd:simpleType name="myLongDefault">`
			`  <xsd:restriction base="xsd:int">`
			`  <xsd:annotation>`
			`  <xsd:appinfo>`
			`  <max>31</max>`
			`  </xsd:appinfo>`
			`  </xsd:annotation>`
			`  </xsd:restriction>`
			`</xsd:simpleType>`
			`<xsd:complexType name= "Point">`
			`  <xsd:sequence>`
			`  <xsd:element name="x" minOccurs="1" maxOccurs="1">`
			`  <xsd:simpleType>`
			`  <xsd:restriction base="xsd:int">`
			`  <xsd:maxInclusive value="31"/>`
			`  </xsd:restriction>`
			`  </xsd:simpleType>`
			`  </xsd:element>`
			`  <xsd:element name="y" minOccurs="1" maxOccurs="1" type="xsd:int"/>`
			`  <xsd:element name="myX" minOccurs="1" maxOccurs="1" type="tns:myLongDefault"/>`
			`  </xsd:sequence>`
			`</xsd:complexType>`

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD

@range annotation	Not supported. Use min and max attributes instead	`@range(min = -32, max = 31)`
		`typedef long myLongDefault;`
		`struct Point {`
		`  @range(min = -32, max = 31)`
		`  long x;`
		`  long y;`
		`  myLongDefault myX;`
		`};`
			`<xsd:simpleType name="myLongDefault">`
			`  <xsd:restriction base="xsd:int">`
			`  <xsd:annotation>`
			`  <xsd:appinfo>`
			`  <min>-32</min>`
			`  <max>31</max>`
			`  </xsd:appinfo>`
			`  </xsd:annotation>`
			`  </xsd:restriction>`
			`</xsd:simpleType>`
			`<xsd:complexType name= "Point">`
			`  <xsd:sequence>`
			`  <xsd:element name="x" minOccurs="1" maxOccurs="1">`
			`  <xsd:simpleType>`
			`  <xsd:restriction base="xsd:int">`
			`  <xsd:minInclusive value="-32"/>`
			`  <xsd:maxInclusive value="31"/>`
			`  </xsd:restriction>`
			`  </xsd:simpleType>`
			`  </xsd:element>`
			`  <xsd:element name="y" minOccurs="1" maxOccurs="1" type=""xsd:int""/>`
			`  <xsd:element name="myX" minOccurs="1" maxOccurs="1" type="tns:myLongDefault"/>`
			`  </xsd:sequence>`
			`</xsd:complexType>`

@autoid annotation	<!-- @autoid [<hash|sequential>] -->
	Default (if not present): the @autoid value in ancestor module(s) or sequential if not specified.
		`@mutable`
		`@autoid(HASH)`
		`struct Point {`
		`  long x;`
		`  long y;`
		`};`
			`<xsd:complexType name= "Point">`
			`  <xsd:sequence>`
			`  <xsd:element name="x" minOccurs="1" maxOccurs="1" type="xsd:int"/>`
			`  <xsd:element name="y" minOccurs="1" maxOccurs="1" type="xsd:int"/>`
			`  </xsd:sequence>`
			`</xsd:complexType>`
			`<!-- @struct true -->`
			`<!-- @autoid hash-->`
			`<!-- @extensibility mutable-->`

@nested or @toplevel annotation	<!-- @topLevel <true|-false|1|0> -->
	Default (if not specified): true
		`@nested`
		`struct`
		
		`TopLevelPrimitiveStruct {`
		`  short short_member;`
		`};`
		or
		`@top-level(false)`
		`struct`
		
		`TopLevelPrimitiveStruct {`
		`  short short_member;`
		`};`
			`<xsd:complexType`
			`  name="TopLevelPrimitiveStruct">`
			`  <xsd:sequence>`
			`  <xsd:element name="short_member"`
			`  minOccurs="1" maxOccurs="1"`
			`  type="xsd:short"/>`
			`  </xsd:sequence>`
			`</xsd:complexType>`
			`<!-- @nested true-->`

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD

@extensibility, @mutable, @appendable, or @final annotation	<!-- @extensibility <final|appendable|mutable> -->
	Default (if not present): appendable
		`@mutable`
		`struct Point {`
		`  long x;`
		`  long y;`
		`};`
			`<xsd:complexType name= "Point">`
			`  <xsd:sequence>`
			`  <xsd:element name="x" minOccurs="1" maxOccurs="1" type="xsd:int"/>`
			`  <xsd:element name="y" minOccurs="1" maxOccurs="1" type="xsd:int"/>`
			`  </xsd:sequence>`
			`  </xsd:complexType>`
			`<!-- @struct true -->`
			`<!-- @extensibility mutable-->`

@allowed_data_representation	<!-- @allowed_data_representation <xcdr|xcdr2|xml> -->
	Default (if not present): xcdr2 for flat data language binding; the @allowed_data_representation value in ancestor module(s) or (xcdr|xcdr2) for plain language
		`@allowed_data_representation(XCDR2)`
		`@mutable`
		`struct Point {`
		`  long x;`
		`  long y;`
		`};`
			`<xsd:complexType name= "Point">`
			`  <xsd:sequence>`
			`  <xsd:element name="x" minOccurs="1" maxOccurs="1" type="xsd:int"/>`
			`  <xsd:element name="y" minOccurs="1" maxOccurs="1" type="xsd:int"/>`
			`  </xsd:sequence>`
			`</xsd:complexType>`
			`<!-- @struct true -->`
			`<!-- @allowed_data_representation xcdr2-->`
			`<!-- @extensibility mutable-->`

@use_vector annotation	<!-- @use_vector <true|false|1|0> -->
	Default (if not present): false unless code generated with -alwaysUseStdVector
		`@use_vector`
		
		`sequence<boolean,5>`
		`myBooleanSeq;`
			`<xsd:element name="myBooleanSeq"`
			` minOccurs="1" maxOccurs="1"`
			` type=`
			`"tns:SequenceType_myBooleanSeq_SequenceOfboolean"/>`
			`<!-- @use_vector true -->`

Table 3.13 Mapping Type System Constructs to XSD

Type/Construct		Example	
IDL	XSD	IDL	XSD
@language_binding annotation	<!-- @languageBinding <plain|flat_data> --> Default (if not present): the @language_binding value in ancestor module(s) or plain if not specified	`@language_binding (FLAT_DATA) @final struct Point { long x; long y; };`	`<xsd:complexType name= "Point"> <xsd:sequence> <xsd:element name="x" minOccurs="1" maxOccurs="1" type="xsd:int"/> <xsd:element name="y" minOccurs="1" maxOccurs="1" type="xsd:int"/> </xsd:sequence> </xsd:complexType> <!-- @struct true --> <!-- @language_binding flat_data--> <!-- @extensibility final-->`
@transfer_mode annotation	<!-- @transferMode <in-band|shmem_ref> --> Default (if not present): the @transfer_mode value in ancestor module(s) or in-band if not specified	`@language_binding (SHMEM_REF) struct Point { long x; long y; };`	`<xsd:complexType name= "Point"> <xsd:sequence> <xsd:element name="x" minOccurs="1" maxOccurs="1" type="xsd:int"/> <xsd:element name="y" minOccurs="1" maxOccurs="1" type="xsd:int"/> </xsd:sequence> </xsd:complexType> <!-- @struct true --> <!-- @transfer_mode shmem_ref-->`
@resolve_name annotation	<!-- @resolveName <true|-false|1|0> --> Default (if not specified): @resolve_name of the parent type or false if not specified on parent	`struct Unre-solvedPrim-itiveStruct { @resolve_name (false) Prim-itiveStruct primitive_member; };`	`<xsd:complexType name="UnresolvedPrimitiveStruct"> <xsd:sequence> <xsd:element name="primitive_member" minOccurs="1" maxOccurs="1" type="PrimitiveStruct"/> <!-- @resolveName false --> </xsd:sequence> </xsd:complexType>`
other annotations	<!-- @<directive kind> <value> -->	`//@copy This text will be copied in the generated files`	`<!--@copy This text will be copied in the generated files -->`

3.5.1 Primitive Types

The primitive types char, wchar, long double, and wstring are not supported natively in XSD. *Connext DDS* provides definitions for these types in the file **<NDDSHOME>/resource/app/app_**

support/rtiddsgen/schema. All files that use the primitive types char, wchar, long double and wstring must reference **rti_dds_topic_types_common.xsd**. For example:

```
<?xml version="1.0" encoding="UTF-8"?>
    <xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
     xmlns:dds="http://www.omg.org/dds">
        <xsd:import namespace="http://www.omg.org/dds"
         schemaLocation="rti_dds_topic_types_common.xsd"/>
       <xsd:complexType name="Foo">
            <xsd:sequence>
                <xsd:element name="myChar" minOccurs="1"
                 maxOccurs="1" type="dds:char"/>
            </xsd:sequence>
       </xsd:complexType>
    </xsd:schema>
```

3.6 Using RTI Code Generator (rtiddsgen)

RTI Code Generator creates the code needed to define and register a user-data type with *Connext DDS*. Using this tool is optional if:

- You are using dynamic types (see 3.8 Interacting Dynamically with User Data Types on page 154)
- You are using one of the built-in types (see 3.2 Built-in Data Types on page 38)

See the RTI Code Generator User's Manual for more information.

3.7 Using Generated Types without Connext DDS (Standalone)

You can use the generated type-specific source and header files without linking the *Connext DDS* libraries or even including the *Connext DDS* header files. That is, the files generated by *RTI Code Generator* for your data types can be used standalone.

The directory **<NDDSHOME>/resource/app/app_support/rtiddsgen/standalone** contains the required helper files:

- include: header and templates files for C and C++.
- src: source files for C and C++.
- class: Java jar file.

3.7.1 Using Standalone Types in C

The generated files that can be used standalone are:

- **<idl file name>.c**: Types source file
- **<idl file name>.h**: Types header file

The type plug-in code (**<idl file>Plugin.[c,h]**) and type-support code (**<idl file>Support.[c,h]**) cannot be used standalone.

To use the generated types in a standalone manner:

1. Include the directory **<NDDSHOME>/resource/app/app_support/rtiddsgen/standalone/include** in the list of directories to be searched for header files.
2. Add the source files, **ndds_standalone_type.c** and **<idl file name>.c**, to your project.
3. Include the file **<idl file name>.h** in the source files that will use the generated types in a standalone manner.
4. Compile the project using the following two preprocessor definitions:
   - NDDS_STANDALONE_TYPE
   - The definition for your platform (RTI_VXWORKS, RTI_QNX, RTI_WIN32, RTI_INTY, RTI_LYNX or RTI_UNIX)

3.7.2 Using Standalone Types in C++

(This section applies to the Traditional C++ API only)

The generated files that can be used standalone are:

- **<idl file name>.cxx**: Types source file
- **<idl file name>.h**: Types header file

The type-plugin code (**<*idl file*>Plugin.[cxx,h]**) and type-support code (**<*idl file*>Support.[cxx,h]**) cannot be used standalone.

To use the generated types in a standalone manner:

1. Include the directory **<NDDSHOME>/resource/app/app_support/rtiddsgen/standalone/include** in the list of directories to be searched for header files.
2. Add the source files, **ndds_standalone_type.cxx** and **<*idl file name*>.cxx**, to your project.
3. Include the file <*idl file name*>.h in the source files that will use the *RTI Code Generator* types in a standalone manner.

4. Compile the project using the following two preprocessor definitions:
   - NDDS_STANDALONE_TYPE
   - The definition for your platform (such as RTI_VXWORKS, RTI_QNX, RTI_WIN32, RTI_INTY, RTI_LYNX or RTI_UNIX)

3.7.3 Standalone Types in Java

The generated files that can be used standalone are:

- **<idl type>.java**
- **<idl type>Seq.java**

The type code (<*idl file*>**TypeCode.java**), type-support code (<*idl type*>**TypeSupport.java**), *DataReader* code (<*idl file*>**DataReader.java**) and *DataWriter* code (<*idl file*>**DataWriter.java**) cannot be used standalone.

To use the generated types in a standalone manner:

1. Include the file **ndds_standalone_type.jar** in the classpath of your project.
2. Compile the project using the standalone types files (<*idl type*>**.java** and <*idl type*>**Seq.java**).

3.8 Interacting Dynamically with User Data Types

3.8.1 Type Schemas and TypeCode Objects

Type schemas—the names and definitions of a type and its fields—are represented by TypeCode objects, described in 3.1.3 Introduction to TypeCode on page 37.

3.8.2 Defining New Types

> This section does not apply when using the separate add-on product, *Ada Language Support*, which does not support Dynamic Types.

Locally, your application can access the type code for a generated type "Foo" by calling the **FooTypeSupport::get_typecode()** (Traditional C++ Notation) operation in the code for the type generated by *RTI Code Generator*. But you can also create TypeCodes at run time without any code generation.

Creating a TypeCode is parallel to the way you would define the type statically: you define the type itself with some name, then you add members to it, each with its own name and type.

For example, consider the following statically defined type. It might be in C, C++, or IDL; the syntax is largely the same.

```
struct MyType {
       long my_integer;
       float my_float;
       bool my_bool;
       @key string<128> my_string;

};
```

This is how you would define the same type at run time in the Traditional C++ API:

```
DDS_ExceptionCode_t ex = DDS_NO_EXCEPTION_CODE;
DDS_StructMemberSeq structMembers; // ignore for now
DDS_TypeCodeFactory* factory =
       DDS_TypeCodeFactory::get_instance();
DDS_TypeCode* structTc = factory->create_struct_tc(
               "MyType", structMembers, ex);
// If structTc is NULL, check 'ex' for more information.
structTc->add_member(
               "my_integer", DDS_TYPECODE_MEMBER_ID_INVALID,
               factory->get_primitive_tc(DDS_TK_LONG),
               DDS_TYPECODE_NONKEY_REQUIRED_MEMBER, ex);
structTc->add_member(
               "my_float", DDS_TYPECODE_MEMBER_ID_INVALID,
               factory->get_primitive_tc(DDS_TK_FLOAT),
               DDS_TYPECODE_NONKEY_REQUIRED_MEMBER, ex);
structTc->add_member(
               "my_bool", DDS_TYPECODE_MEMBER_ID_INVALID,
               factory->get_primitive_tc(DDS_TK_BOOLEAN),
               DDS_TYPECODE_NONKEY_REQUIRED_MEMBER, ex);
structTc->add_member(
               "my_string", DDS_TYPECODE_MEMBER_ID_INVALID,
               factory->create_string_tc(128),
               DDS_TYPECODE_KEY_MEMBER, ex);
```

More detailed documentation for the methods and constants you see above, including example code, can be found in the API Reference HTML documentation, which is available for all supported programming languages.

If, as in the example above, you know all of the fields that will exist in the type at the time of its construction, you can use the **StructMemberSeq** to simplify the code:

```
DDS_StructMemberSeq structMembers;
structMembers.ensure_length(4, 4);
DDS_TypeCodeFactory* factory = DDS_TypeCodeFactory::get_instance();
structMembers[0].name = DDS_String_dup("my_integer");
structMembers[0].type = factory->get_primitive_tc(DDS_TK_LONG);
structMembers[1].name = DDS_String_dup("my_float");
structMembers[1].type = factory->get_primitive_tc(DDS_TK_FLOAT);
structMembers[2].name = DDS_String_dup("my_bool");
structMembers[2].type = factory->get_primitive_tc(DDS_TK_BOOLEAN);
structMembers[3].name = DDS_String_dup("my_string");
structMembers[3].type = factory->create_string_tc(128);
structMembers[3].is_key = DDS_BOOLEAN_TRUE;
DDS_ExceptionCode_t ex = DDS_NO_EXCEPTION_CODE;
DDS_TypeCode* structTc =
       factory->create_struct_tc(
       "MyType", structMembers, ex);
```

After you have defined the TypeCode, you will register it with a *DomainParticipant* using a logical name (note: this step is not required in the Modern C++ API). You will use this logical name later when you create a *Topic*.

```
DDSDynamicDataTypeSupport* type_support =
        new DDSDynamicDataTypeSupport(structTc,
                DDS_DYNAMIC_DATA_TYPE_PROPERTY_DEFAULT);
DDS_ReturnCode_t retcode =
       type_support->register_type(participant,
                "My Logical Type Name");
```

For code examples for the Modern C++ API, please refer to the API Reference HTML documentation: Modules, Programming How-To's, DynamicType and DynamicData Use Cases.

Now that you have created a type, you will need to know how to interact with objects of that type. See 3.8.3 Sending Only a Few Fields below for more information.

3.8.3 Sending Only a Few Fields

In some cases, your data model may contain a large number of potential fields, but it may not be desirable or appropriate to include a value for every one of them with every DDS data sample.

- **It may use too much bandwidth.** You may have a very large data structure, parts of which are updated very frequently. Rather than resending the entire data structure with every change, you may wish to send only those fields that have changed and rely on the recipients to reassemble the complete state themselves.
- **It may not make sense.** Some fields may only have meaning in the presence of other fields. For example, you may have an event stream in which certain fields are only relevant for certain kinds of events.

To support these and similar cases, *Connext DDS* supports mutable types and optional members (see the RTI Connext DDS Core Libraries Extensible Types Guide).

3.8.4 Sending Type Information on the Network

In addition to being used locally, the type information of a *Topic* is published automatically during discovery as part of the builtin topics for publications and subscriptions. See 3.1.3.1 Sending Type Information on the Network on page 38.

3.8.4.1 Type Codes for Built-in Types

The type codes associated with the built-in types are generated from the following IDL type definitions:

```
module DDS {
        /* String */
        struct String {
                string<max_size> value;
        };
        /* KeyedString */
        struct KeyedString {
                string<max_size> key; //@key
                string<max_size> value;
        };
        /* Octets */
        struct Octets {
                sequence<octet, max_size> value;
        };
        /* KeyedOctets */
        struct KeyedOctets {
                string<max_size> key; //@key
                sequence<octet, max_size> value;
        };
};
```

The maximum size (**max_size**) of the strings and sequences that will be included in the type code definitions can be configured on a per-*DomainParticipant*-basis by using the properties in Table 3.14 Properties for Allocating Size of Built-in Types, per DomainParticipant.

Table 3.14 Properties for Allocating Size of Built-in Types, per DomainParticipant

Built-in Type	Property	Description
String	dds.builtin_type.string.max_size	Maximum size of the strings published by the *DataWriters* and received by the *DataReaders* belonging to a *DomainParticipant* (includes the NULL-terminated character). Default: 1024

Table 3.14 Properties for Allocating Size of Built-in Types, per DomainParticipant

Built-in Type	Property	Description
KeyedString	dds.builtin_type.keyed_string.max_key_size	Maximum size of the keys used by the *DataWriters* and *DataReaders* belonging to a *DomainParticipant* (includes the NULL-terminated character). Default: 1024
	dds.builtin_type.keyed_string.max_size	Maximum size of the strings published by the *DataWriters* and received by the *DataReaders* belonging to a *DomainParticipant* using the built-in type (includes the NULL-terminated character). Default: 1024
Octets	dds.builtin_type.octets.max_size	Maximum size of the octet sequences published by the *DataWriters* and *DataReaders* belonging to a *DomainParticipant*. Default: 2048
Keyed-Octets	dds.builtin_type.keyed_octets.max_key_size	Maximum size of the key published by the *DataWriter* and received by the *DataReaders* belonging to the *DomainParticipant* (includes the NULL-terminated character). Default: 1024.
	dds.builtin_type.keyed_octets.max_size	Maximum size of the octet sequences published by the *DataWriters* and *DataReaders* belonging to a *DomainParticipant*. Default: 2048

3.9 Working with DDS Data Samples

You should now understand how to define and work with data types, whether you're using the simple data types built into the middleware (see 3.2 Built-in Data Types on page 38), dynamically defined types (see 3.2.7 Managing Memory for Built-in Types on page 69), or code generated from IDL or XML files (see 3.3 Creating User Data Types with IDL on page 75 and 3.4 Creating User Data Types with Extensible Markup Language (XML) on page 120).

Now that you have chosen one or more data types to work with, this section will help you understand how to create and manipulate objects of those types.

3.9.1 Objects of Concrete Types

If you use one of the built-in types or decide to generate custom types from an IDL or XML file, your *Connext DDS* data type is like any other data type in your application: a class or structure with fields, methods, and other members that you interact with directly.

In C

You create and delete your own objects from factories, just as you create *Connext DDS* objects from factories. In the case of user data types, the factory is a singleton object called the type support. Objects allocated from these factories are deeply allocated and fully initialized.

```
/* In the generated header file: */
struct MyData {
    char* myString;
};
/* In your code: */
MyData* sample = MyDataTypeSupport_create_data();
char* str = sample->myString; /*empty, non-NULL string*/
/* ... */
MyDataTypeSupport_delete_data(sample);
```

In Traditional C++:

Without the **-constructor** option, you create and delete objects using the TypeSupport factories.

```
MyData* sample = MyDataTypeSupport::create_data();
char* str = sample->myString; // empty, non-NULL string
// ...
MyDataTypeSupport::delete_data(sample);
```

With the **-constructor** option, generated types have a default constructor, a copy constructor, and a destructor. In this case the TypeSupport data creation methods are not available.

```
// In the header file
class MyType
{
   MyType();
   MyType(const MyType& that);
   ~MyType();
   MyType& operator=(const MyType& that);
};
```

In Modern C++:

Generated types have value-type semantics and provide a default constructor, a constructor with parameters to initialize all the members, a copy constructor and assignment operator, a move constructor and move-assignment operator, a destructor, equality operators, a swap function and an overloaded operator<<. Data members are accessed using getters and setters.

```
// In the generated header file
class MyData {
public:
    MyData();
    explicit MyData(const std::string& myString);

// Note: the implicit destructor, copy and
// move constructors, and assignment operators
// are available
   std::string& myString() OMG_NOEXCEPT;
    const std::string& myString() const OMG_NOEXCEPT;
    void myString(const std::string& value);
```

```
    bool operator == (const MyData& other_) const;
    bool operator != (const MyData& other_) const;
    private:
// ...
};

void swap(MyData& a, MyData& b) OMG_NOEXCEPT
    std::ostream& operator <<
    (std::ostream& o,const MyData& sample);


// In your code:
MyData sample("Hello");
sample.myString("Bye");
```

In C# and C++/CLI:

You can use a no-argument constructor to allocate objects. Those objects will be deallocated by the garbage collector as appropriate.

```
// In the generated code (C++/CLI):
public ref struct MyData {
    public: System::String^ myString;
};

// In your code, if you are using C#:
MyData sample = new MyData();
System.String str = sample.myString;
// empty, non-null string

// In your code, if you are using C++/CLI:
MyData^ sample = gcnew MyData();
System::String^ str = sample->myString;
// empty, non-nullptr string
```

In Java:

You can use a no-argument constructor to allocate objects. Those objects will be deallocated by the garbage collector as appropriate.

```
// In the generated code:
public class MyData {
    public String myString = "";
}
// In your code:
MyData sample = new MyData();
```

```
String str = sample->myString;
// empty, non-null string
```

3.9.2 Objects of Dynamically Defined Types

If you are working with a data type that was discovered or defined at run time, you will use the reflective API provided by the DynamicData class to get and set the fields of your object.

Consider the following type definition:

```
struct MyData {
       long myInteger;
};
```

As with a statically defined type, you will create objects from a TypeSupport factory. How to create or otherwise obtain a TypeCode, and how to subsequently create from it a DynamicDataTypeSupport, is described in 3.8.2 Defining New Types on page 154. In the Modern C++ API you will use the DynamicData constructor, which receives a DynamicType.

For more information about the DynamicData and DynamicDataTypeSupport classes, consult the API Reference HTML documentation, which is available for all supported programming languages (select **Modules, RTI Connext DDS API Reference, Topic Module, Dynamic Data**).

In C:

```
DDS_DynamicDataTypeSupport* support = ...;
DDS_DynamicData* sample = DDS_DynamicDataTypeSupport_create_data(support);
DDS_Long theInteger = 0;
DDS_ReturnCode_t success = DDS_DynamicData_set_long(sample,
                "myInteger", DDS_DYNAMIC_DATA_MEMBER_ID_UNSPECIFIED, 5);
/* Error handling omitted. */
success = DDS_DynamicData_get_long(    sample, &theInteger,
               "myInteger", DDS_DYNAMIC_DATA_MEMBER_ID_UNSPECIFIED);
/* Error handling omitted. "theInteger" now contains the value 5
   if no error occurred.
 */
```

In Traditional C++:

```
DDSDynamicDataTypeSupport* support = ...;
DDS_DynamicData* sample = support->create_data();
DDS_ReturnCode_t success = sample->set_long("myInteger",
                DDS_DYNAMIC_DATA_MEMBER_ID_UNSPECIFIED, 5);
// Error handling omitted.
DDS_Long theInteger = 0;
success = sample->get_long(    &theInteger, "myInteger",
                DDS_DYNAMIC_DATA_MEMBER_ID_UNSPECIFIED);
// Error handling omitted.
// "theInteger" now contains the value 5 if no error occurred.
```

In Modern C++:

```
using namespace dds::core::xtypes;
```

```
StructType type(
    "MyData", {
        Member("myInteger", primitive_type<int32_t>())
    }
);
DynamicData sample(type);
sample.value("myInteger", 5);
int32_t the_int = sample.value<int32_t>("myInteger");
// "the_int" now contains the value 5 if no exception was thrown
```

In C++/CLI:

```
using DDS;
DynamicDataTypeSupport^ support = ...;
DynamicData^ sample = support->create_data();
sample->set_long("myInteger",
                        DynamicData::MEMBER_ID_UNSPECIFIED, 5);
int theInteger = sample->get_long("myInteger",
                 0 /*redundant w/ field name*/);
/* Exception handling omitted.
 * "theInteger" now contains the value 5 if no error occurred.
 */
```

In C#:

```
using namespace DDS;
DynamicDataTypeSupport support = ...;
DynamicData sample = support.create_data();
sample.set_long("myInteger", DynamicData.MEMBER_ID_UNSPECIFIED, 5);
int theInteger = sample.get_long("myInteger",
                        DynamicData.MEMBER_ID_UNSPECIFIED);
/* Exception handling omitted.
 * "theInteger" now contains the value 5 if no error occurred.
 */
```

In Java:

```
import com.rti.dds.dynamicdata.*;
DynamicDataTypeSupport support = ...;
DynamicData sample = (DynamicData) support.create_data();
sample.set_int("myInteger", DynamicData.MEMBER_ID_UNSPECIFIED, 5);
int theInteger = sample.get_int("myInteger",
                        DynamicData.MEMBER_ID_UNSPECIFIED);
/* Exception handling omitted.
 * "theInteger" now contains the value 5 if no error occurred.
 */
```

The Modern C++ API provides convenience functions to convert among DynamicData samples and typed samples (such as MyData, from the previous example). For example:

```
#include "MyData.hpp"
// ...
MyData typed_sample(44);
DynamicData dynamic_sample = rti::core::xtypes::convert(typed_sample);
assert (dynamic_sample.value<int32_t>("myInteger") == 44);
```

```
dynamic_sample.value("myInteger", 33);
typed_sample = rti::core::xtypes::convert<MyData>(dynamic_sample);
assert (typed_sample.myInteger() == 33);
```

3.9.3 Serializing and Deserializing Data Samples

There are two TypePlugin operations to serialize a sample into a buffer and deserialize a sample from a buffer. The sample serialization/deserialization uses CDR representation.

The feature is supported in the following languages: C, Modern and Traditional C++, Java, and .NET.

C:

```
#include "FooSupport.h"
FooTypeSupport_serialize_data_to_cdr_buffer(...)
FooTypeSupport_deserialize_data_from_cdr_buffer(...)
```

Traditional C++

```
#include "FooSupport.h"
FooTypeSupport::serialize_data_to_cdr_buffer(...)
FooTypeSupport::deserialize_data_from_cdr_buffer(...)
```

Modern C++

```
#include "Foo.hpp"
dds::topic::topic_type_support<Foo>::to_cdr_buffer(...)
dds::topic::topic_type_support<Foo>::from_cdr_buffer(...)
```

Java:

```
FooTypeSupport.get_instance().serialize_to_cdr_buffer(...)
FooTypeSupport.get_instance().deserialize_from_cdr_buffer(...)
```

C++/CLI:

```
FooTypeSupport::serialize_data_to_cdr_buffer(...)
FooTypeSupport::deserialize_data_from_cdr_buffer(...)
```

C#:

```
FooTypeSupport.serialize_data_to_cdr_buffer(...)
FooTypeSupport.deserialize_data_from_cdr_buffer(...)
```

3.9.4 Accessing the Discriminator Value in a Union

A union type can only hold a single member. The **member_id** for this member is equal to the discriminator value. To get the value of the discriminator, use the operation **get_member_info_by_index()** on the DynamicData using an index value of 0. This operation fills in a DynamicDataMemberInfo structure, which includes a **member_id** field that is the value of the discriminator.

Once you know the discriminator value, you can use the proper version of **get_<*type*>()** (such as **get_long()**) to access the member value.

For example:

```
DynamicDataMemberInfo memberInfo = new DynamicDataMemberInfo();
myDynamicData.get_member_info_by_index(memberInfo, 0);
int discriminatorValue = memberInfo.member_id;
int myMemberValue = myDynamicData.get_long(null, discriminatorValue);
```

The Modern C++ API provides the method **discriminator_value()** to achieve the same result:

```
int32_t my_member_value = my_dynamic_data.value<int32_t>(
       my_dynamic_data.discriminator_value());
```

3.10 Data Sample Serialization Limits

Connext DDS does not support data types with samples whose maximum serialized size is bigger than 2,147,482,623 bytes. If the maximum serialized size is bigger than this, the behavior is undefined.

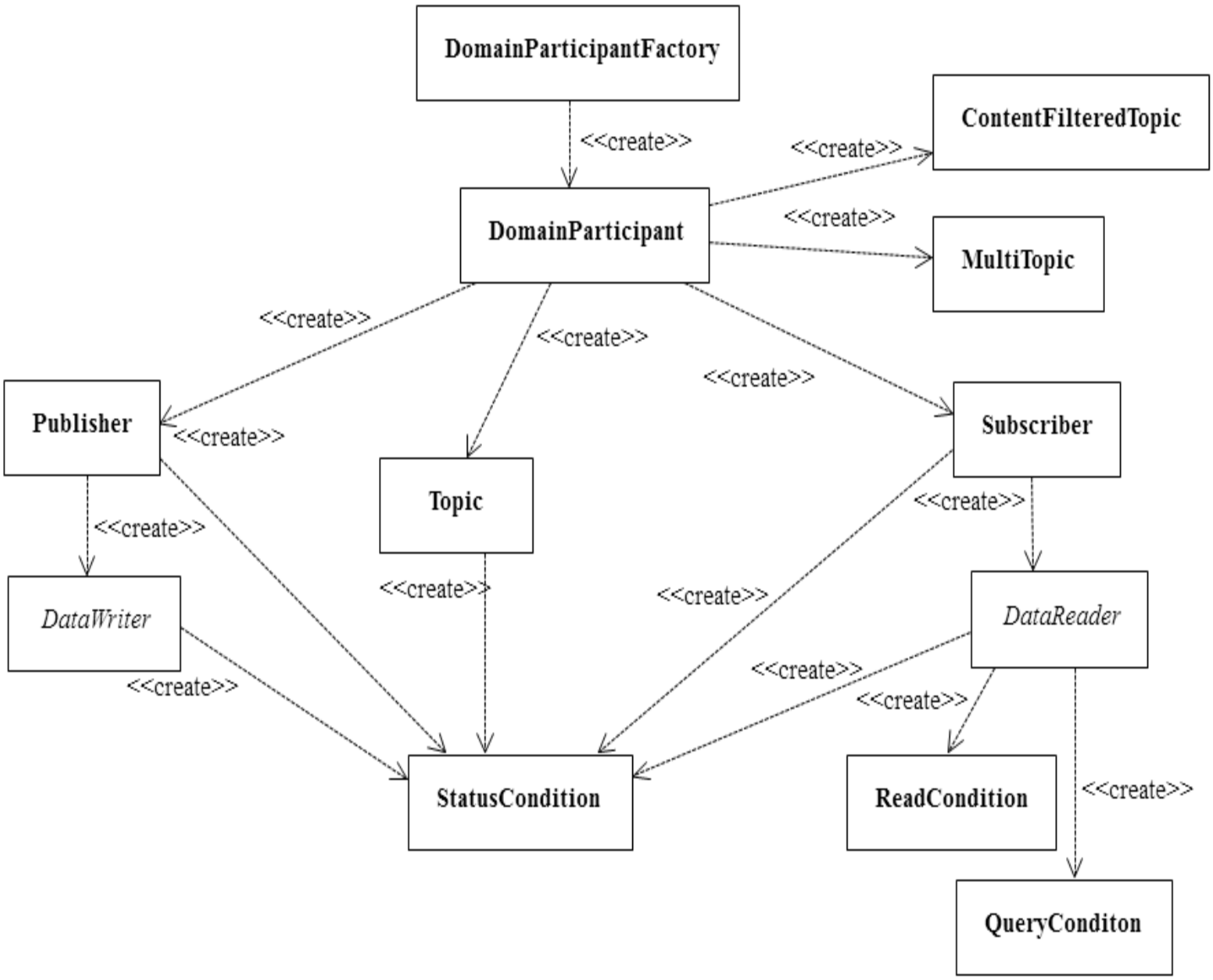
For types containing unbounded sequences or strings where the code is generated using the **-unboundedSupport** command-line option in *RTI Code Generator*, the maximum serialized size is implicitly set to 2,147,482,623.

Chapter 4 DDS Entities

The main classes extend an abstract base class called a DDS *Entity*. Every DDS *Entity* has a set of associated events known as statuses and a set of associated Quality of Service Policies (QosPolicies). In addition, a *Listener* may be registered with the *Entity* to be called when status changes occur. DDS *Entities* may also have attached DDS *Conditions*, which provide a way to wait for status changes. Figure 4.1: Overview of DDS Entities on the next page presents an overview in a UML diagram.

This section describes the common operations and general designed patterns shared by all DDS *Entities* including *DomainParticipant*s, *Topics*, *Publishers*, *DataWriter*s, *Subscriber*s, and *DataReader*s. In subsequent chapters, the specific statuses, *Listeners*, *Conditions*, and QosPolicies for each class will be discussed in detail.

Figure 4.1: Overview of DDS Entities



4.1 Common Operations for All DDS Entities

All DDS *Entities* (*DomainParticipant*s, *Topics*, Publishers, *DataWriter*s, *Subscriber*s, and *DataReader*s) provide operations for:

4.1.1 Creating and Deleting DDS Entities

- C, Traditional C++, Java, and .NET:

  The factory design pattern is used in creating and deleting DDS *Entities*. Instead of declaring and constructing or destructing *Entities* directly, a factory object is used to create an *Entity*. Almost all *Entity* factories are objects that are also *Entities*. The only exception is the factory for a *DomainParticipant*. See Table 4.1 Entity Factories.

Table 4.1 Entity Factories

Entity	Created by
DomainParticipant	DomainParticipantFactory (a static singleton object provided by *Connext DDS*)
Topic	*DomainParticipant*
Publisher	
Subscriber	
DataWriter	
DataReader	
DataWriter	*Publisher*
DataReader	*Subscriber*

All *Entities* that are factories have:

- Operations to create and delete child *Entities*. For example:

  DDSPublisher::create_datawriter()

  DDSDomainParticipant::delete_topic()
- Operations to get and set the default QoS values used when creating child *Entities*. For example:

  DDSSubscriber::get_default_datareader_qos()

  DDSDomainParticipantFactory::set_default_participant_qos()
- And 7.4.2 ENTITYFACTORY QosPolicy on page 347 to specify whether or not the newly created child *Entity* should be automatically enabled upon creation.

DataWriters may be created by a *DomainParticipant* or a *Publisher*. Similarly, *DataReaders* may be created by a *DomainParticipant* or a *Subscriber*.

An entity that is a factory cannot be deleted until *all* the child *Entities* created by it have been deleted.

Each *Entity* obtained through **create_<entity>()** must eventually be deleted by calling **delete_<entity>()**, or by calling **delete_contained_entities()**.

- Modern C++:

  In the Modern C++ API the factory pattern is not explicit. Entities have constructors and destructors. The first argument to an Entity's constructor is its "factory" (except for the DomainParticipant). For example:

```
// Note: this example shows the simplest version of each Entity's constructor:
dds::domain::DomainParticipant participant(MY_DOMAIN_ID);
dds::topic::Topic<Foo> topic(participant, "Example Foo");
dds::sub::Subscriber subscriber(participant);
dds::sub::DataReader<Foo> reader(subscriber, topic);
dds::pub::Publisher publisher(participant);
dds::pub::DataWriter<Foo> writer(publisher, topic);
```

  Entities are *reference types*. In a reference type copy operations, such as copy-construction and copy-assignment are shallow. The reference types are modeled after shared pointers. Similar to pointers, it is important to distinguish between an entity and a reference (or handle) to it. A single entity may have multiple references. Copying a reference does not copy the entity it is referring to—creating additional references from the existing reference(s) is a relatively inexpensive operation.

  The lifecycle of references and the entity they are referring to is not the same. In general, the entity lives as long as there is at least one reference to it. When the last reference to the entity ceases to exists, the entity it is referring to is destroyed.

  Applications can override the automatic destruction of Entities. An Entity can be explicitly closed (by calling the method **close()**) or retained (by calling **retain()**)

  Closing an Entity destroys the underlying object and invalidates all references to it.

  Retaining an Entity disables the automatic destruction when it loses all its reference. A retained Entity can be looked up (see 9.2.4 Looking Up DomainParticipants on page 603) and has to be explicitly destroyed with **close()**.

4.1.2 Enabling DDS Entities

The **enable()** operation changes an *Entity* from a non-operational to an operational state. *Entity* objects can be created disabled or enabled. This is controlled by the value of the 7.4.2 ENTITYFACTORY QosPolicy on page 347 on the corresponding *factory* for the *Entity* (not on the *Entity* itself).

By default, all *Entities* are automatically created in the enabled state. This means that as soon as the *Entity* is created, it is ready to be used. In some cases, you may want to create the *Entity* in a 'disabled' state. For example, by default, as soon as you create a *DataReader*, the *DataReader* will start receiving new DDS samples for its *Topic* if they are being sent. However, your application may still be initializing other components and may not be ready to process the data at that time. In that case, you can tell the *Subscriber* to

create the *DataReader* in a disabled state. After all of the other parts of the application have been created and initialized, then the *DataReader* can be enabled to actually receive messages.

To create a particular entity in a disabled state, modify the EntityFactory QosPolicy of its corresponding *factory entity* before calling **create_<*entity*>()**. For example, to create a disabled *DataReader*, modify the *Subscriber's* QoS as follows:

```
DDS_SubscriberQos subscriber_qos;
subscriber->get_qos(subscriber_qos);
subscriber_qos.entity_factory.autoenable_created_entities = DDS_BOOLEAN_FALSE;
subscriber->set_qos(subscriber_qos);
DDSDataReader* datareader =
    subscriber->create_datareader(topic, DDS_DATAREADER_QOS_DEFAULT, listener);
```

When the application is ready to process received data, it can enable the *DataReader*:

```
datareader->enable();
```

4.1.2.1 Rules for Calling enable()

In the following, a 'Factory' refers to a *DomainParticipant*, *Publisher*, or *Subscriber*; a 'child' refers to an entity created by the factory:

- If the factory is disabled, its children are always created disabled.
- If the factory is enabled, its children will be created according to the setting in the factory's EntityFactoryQoS value.
- Calling **enable()** on a child whose factory object is still disabled will fail and return DDS_RECODE_RECONDITION_NOT_MET.
- Calling **enable()** on a factory with EntityFactoryQoS set to DDS_BOOLEAN_TRUE will *recursively* enable all of the factory's children. If the factory's EntityFactoryQoS is set to DDS_BOOLEAN_FALSE, only the factory itself will be enabled.
- Calling **enable()** on an entity that is already enabled returns DDS_RETCODE_OK and has no effect.
- There is no complementary "**disable**" operation. You cannot disable an entity after it is enabled. Disabled *Entities* must have been created in that state.
- An entity's *Listener* will only be invoked if the entity is enabled.
- The existence of an entity is not propagated to other *DomainParticipant*s until the entity is enabled (see Discovery (Chapter 15 on page 758)).
- If a *DataWriter*/*DataReader* is to be created in an enabled state, then the associated *Topic* must already be enabled. The enabled state of the *Topic* does not matter, if the *Publisher*/*Subscriber* has its EntityFactory QosPolicy to create children in a disabled state.

- When calling **enable()** for a *DataWriter*/*DataReader*, both the *Publisher*/*Subscriber* and the *Topic* must be enabled, or the operation will fail and return DDS_RETCODE_PRECONDITION_NOT_MET.

The following operations may be invoked on disabled *Entities*:

- **get_qos()** and **set_qos()**Some DDS-specified QosPolicies are *immutable*—they cannot be changed after an *Entity* is enabled. This means that for those policies, if the entity was created in the disabled state, **get**/**set_qos()** can be used to change the values of those policies until **enabled()** is called on the *Entity*. After the *Entity* is enabled, changing the values of those policies will not affect the *Entity*. However, there are *mutable* QosPolicies whose values can be changed at anytime–even after the *Entity* has been enabled.

  Finally, there are extended QosPolicies that are not a part of the DDS specification but offered by *Connext DDS* to control extended features for an *Entity*. Some of those extended QosPolicies cannot be changed after the *Entity* has been created—regardless of whether the *Entity* is enabled or disabled.

  Into which exact categories a QosPolicy falls—mutable at any time, immutable after enable, immutable after creation—is described in the documentation for the specific policy.
- **get_status_changes()** and **get_*_status()**The status of an *Entity* can be retrieved at any time (but the status of a disabled *Entity* never changes). (Note: **get_*_status()** resets the related status so it no longer considered "changed.")
- **get_statuscondition()**An *Entity's StatusCondition* can be checked at any time (although the status of a disabled *Entity* never changes).
- **get_listener()** and **set_listener()**An *Entity's Listener* can be changed at any time.
- **create_*()** and **delete_*()**A factory *Entity* can still be used to create or delete any child *Entity* that it can produce. Note: following the rules discussed previously, a disabled *Entity* will always create its children in a disabled state, no matter what the value of the EntityFactory QosPolicy is.
- **lookup_*()**An *Entity* can always look up children it has previously created.

Most other operations are not allowed on disabled *Entities*. Executing one of those operations when an *Entity* is disabled will result in a return code of DDS_RETCODE_NOT_ENABLED. The documentation for a particular operation will explicitly state if it is not allowed to be used if the *Entity* is disabled.

The builtin transports are implicitly registered when (a) the *DomainParticipant* is enabled, (b) the first *DataWriter/DataReader* is created, or (c) you look up a builtin data reader, whichever happens first. Any changes to the builtin transport properties that are made after the builtin transports have been registered will have no affect on any *DataWriters/DataReaders*.

4.1.3 Getting an Entity's Instance Handle

The *Entity* class provides an operation to retrieve an instance handle for the object. The operation is simply:

```
InstanceHandle_t get_instance_handle()
```

An instance handle is a global ID for the entity that can be used in methods that allow user applications to determine if the entity was locally created, if an entity is owned (created) by another entity, etc.

4.1.4 Getting Status and Status Changes

The **get_status_changes()** operation retrieves the set of events, also known in DDS terminology as *communication statuses*, in the *Entity* that have changed since the last time **get_status_changes()** was called. This method actually returns a value that must be bitwise AND'ed with an enumerated bit mask to test whether or not a specific status has changed. The operation can be used in a polling mechanism to see if any statuses related to the *Entity* have changed. If an entity is disabled, all communication statuses are in the "unchanged" state so the list returned by the **get_status_changes()** operation will be empty.

A set of statuses is defined for each class of *Entities*. For each status, there is a corresponding operation, **get_<status-name>_status()**, that can be used to get its current value. For example, a *DataWriter* has a **DDS_OFFERED_DEADLINE_MISSED** status; it also has a **get_offered_deadline_missed_status()** operation:

```
DDS_StatusMask statuses;
DDS_OfferedDeadlineMissedStatus deadline_stat;
statuses = datawriter->get_status_changes();
if (statuses & DDS_OFFERED_DEADLINE_MISSED_STATUS) {
datawriter->get_offered_deadline_missed_status(
                &deadline_stat);
       printf("Deadline missed %d times.\n",
                deadline_stat.total_count);
}
```

To reset a status (so that it is no longer considered "changed"), call **get_<status-name>_status()**. Or, in the case of the **DDS_DATA_AVAILABLE** status, call **read()**, **take()**, or one of their variants.

> **I**f you use a *StatusCondition* to be notified that a particular status has changed, the *StatusCondition's* **trigger_value** will remain true unless you call **get_*_status()** to reset the status.

See also: 4.3 Statuses on page 183 and 4.6.8 StatusConditions on page 212.

4.1.5 Getting and Setting Listeners

Each type of *Entity* has an associated *Listener*, see 4.4 Listeners on page 189. A *Listener* represents a set of functions that users may install to be called asynchronously when the state of *communication statuses* change.

The **get_listener()** operation returns the current *Listener* attached to the *Entity*.

The **set_listener()** operation installs a *Listener* on an *Entity*. The *Listener* will only be invoked on the changes of statuses specified by the accompanying mask. Only one listener can be attached to each *Entity*. If a *Listener* was already attached, **set_listener()** will replace it with the new one.

The **get_listener()** and **set_listener()** operations are directly provided by the *DomainParticipant*, *Topic*, *Publisher*, *DataWriter*, *Subscriber*, and *DataReader* classes so that listeners and masks used in the argument list are specific to each *Entity*.

Note: The **set_listener()** operation is not synchronized with the listener callbacks, so it is possible to set a new listener on an participant while the old listener is in a callback. Therefore you should be careful not to delete any listener that has been set on an enabled participant unless some application-specific means are available of ensuring that the old listener cannot still be in use.

See 4.4 Listeners on page 189 for more information about *Listeners*.

4.1.6 Getting the StatusCondition

Each type of *Entity* may have an attached *StatusCondition*, which can be accessed through the **get_statuscondition()** operation. You can attach the *StatusCondition* to a *WaitSet*, to cause your application to wait for specific status changes that affect the *Entity*.

See 4.6 Conditions and WaitSets on page 202 for more information about *StatusConditions* and *WaitSets*.

4.1.7 Getting, Setting, and Comparing QosPolicies

Each type of *Entity* has an associated set of QosPolicies (see 4.2 QosPolicies on page 176). QosPolicies allow you to configure and set properties for the Entity.

While most QosPolicies are defined by the DDS specification, some are offered by *Connext DDS* as extensions to control parameters specific to the implementation.

There are two ways to specify a QoS policy:

- Programmatically, as described in this section.
- QosPolicies can also be configured from XML resources (files, strings)—with this approach, you can change the QoS without recompiling the application. The QoS settings are automatically loaded by the DomainParticipantFactory when the first *DomainParticipant* is created. See Configuring QoS with XML (Chapter 19 on page 842).

The **get_qos()** operation retrieves the current values for the set of QosPolicies defined for the *Entity*.

QosPolicies can be set programmatically when an Entity is created, or modified with the Entity's **set_qos()** operation.

The **set_qos()** operation sets the QosPolicies of the entity. Note: not all QosPolicy changes will take effect instantaneously; there may be a delay since some QosPolicies set for one entity, for example, a

DataReader, may actually affect the operation of a matched entity in another application, for example, a *DataWriter*.

The **get_qos()** and **set_qos()** operations are passed QoS structures that are specific to each derived entity class, since the set of QosPolicies that effect each class of *Entities* is different.

The **equals()** operation compares two Entity's QoS structures for equality. It takes two parameters for the two *Entities*' QoS structures to be compared, then returns TRUE is they are equal (all values are the same) or FALSE if they are not equal.

Each QosPolicy has default values (listed in the API Reference HTML documentation). If you want to use custom values, there are three ways to change QosPolicy settings:

- Before Entity creation (if custom values should be used for multiple *Entities*). See 4.1.7.1 Changing the QoS Defaults Used to Create DDS Entities: set_default_*_qos() below.
- During Entity creation (if custom values are only needed for a particular Entity). See 4.1.7.2 Setting QoS During Entity Creation on the next page.
- After Entity creation (if the values initially specified for a particular Entity are no longer appropriate). See 4.1.7.3 Changing the QoS for an Existing Entity on page 175.

Regardless of when or how you make QoS changes, there are some rules to follow:

- Some QosPolicies interact with each other and thus must be set in a consistent manner. For instance, the maximum value of the HISTORY QosPolicy's *depth* parameter is limited by values set in the RESOURCE_LIMITS QosPolicy. If the values within a QosPolicy structure are inconsistent, then **set_qos()** will return the error INCONSISTENT_POLICY, and the operation will have no effect.
- Some policies can only be set when the *Entity* is created, or before the *Entity* is enabled. Others can be changed at any time. In general, all standard DDS QosPolicies can be changed before the *Entity* is enabled. A subset can be changed after the *Entity* is enabled. *Connext DDS*-specific QosPolicies either cannot be changed after creation or can be changed at any time. The changeability of each QosPolicy is documented in the API Reference HTML documentation as well as in Table 4.2 QosPolicies. If you attempt to change a policy after it cannot be changed, **set_qos()** will fail with a return IMMUTABLE_POLICY.

4.1.7.1 Changing the QoS Defaults Used to Create DDS Entities: set_default_*_qos()

Each parent factory has a set of default QoS settings that are used when the child entity is created. The *DomainParticipantFactory* has default QoS values for creating *DomainParticipants*. A *DomainParticipant* has a set of default QoS for each type of entity that can be created from the *DomainParticipant* (*Topic, Publisher*, *Subscriber, DataWriter,* and *DataReader*). Likewise, a *Publisher* has a set of default QoS values used when creating *DataWriters*, and a *Subscriber* has a set of default QoS values used when creating *DataReaders*.

An entity's QoS are set when it is created. Once an entity is created, all of its QoS—for itself and its child *Entities*—are fixed unless you call **set_qos()** or **set_qos_with_profile()** on that entity. Calling **set_default_<*entity*>_qos()** on a parent entity will have no effect on child *Entities* that have already been created.

You can change these default values so that they are automatically applied when new child *Entities* are created. For example, suppose you want all *DataWriters* for a particular *Publisher* to have their RELIABILITY QosPolicy set to RELIABLE. Instead of making this change for each *DataWriter* when it is created, you can change the default used when any *DataWriter* is created from the *Publisher* by using the *Publisher*'s **set_default_datawriter_qos()** operation.

```
DDS_DataWriterQos default_datawriter_qos;
// get the current default values
publisher->get_default_datawriter_qos(default_datawriter_qos);
// change to desired default values
default_datawriter_qos.reliability.kind =
               DDS_RELIABLE_RELIABILITY_QOS;
// set the new default values
publisher->set_default_datawriter_qos(default_datawriter_qos);
// created datawriters will use new default values
datawriter =
    publisher->create_datawriter(topic, NULL, NULL, NULL);
```

It is not safe to get or set the default QoS values for an entity while another thread may be simultaneously calling **get_default_<*entity*>_qos()**, **set_default_<*entity*>_qos()**, or **create_<*entity*>()** with **DDS_<*ENTITY*>_QOS_DEFAULT** as the **qos** parameter (for the same entity).

Another way to make QoS changes is by using XML resources (files, strings). For more information, see Configuring QoS with XML (Chapter 19 on page 842).

4.1.7.2 Setting QoS During Entity Creation

If you only want to change a QosPolicy for a particular entity, you can pass in the desired QosPolicies for an entity in its creation routine.

To customize an entity's QoS before creating it:

1. (C API Only) Initialize a QoS object with the appropriate INITIALIZER constructor.
2. Call the relevant **get_<*entity*>_default_qos()** method.
3. Modify the QoS values as desired.
4. Create the entity.

For example, to change the RELIABLE QosPolicy for a *DataWriter* before creating it:

```
// Initialize the QoS object
DDS_DataWriterQos datawriter_qos;
// Get the default values
publisher->get_default_datawriter_qos(datawriter_qos);
// Modify the QoS values as desired
datawriter_qos.reliability.kind = DDS_BEST_EFFORT_RELIABILITY_QOS;
// Create the DataWriter with new values
datawriter = publisher->create_datawriter(
    topic, datawriter_qos, NULL, NULL);
```

Another way to set QoS during entity creation is by using a QoS profile. For more information, see Configuring QoS with XML (Chapter 19 on page 842).

4.1.7.3 Changing the QoS for an Existing Entity

Some policies can also be changed after the entity has been created. To change such a policy after the entity has been created, use the entity's **set_qos()** operation.

For example, suppose you want to tweak the DEADLINE QoS for an existing *DataWriter*:

```
DDS_DataWriterQos datawriter_qos;
// get the current values
datawriter->get_qos(datawriter_qos);
// make desired changes
datawriter_qos.deadline.period.sec = 3;
datawriter_qos.deadline.period.nanosec = 0;
// set new values
datawriter->set_qos(datawriter_qos);
```

Another way to make QoS changes is by using a QoS profile. For more information, see Configuring QoS with XML (Chapter 19 on page 842).

Note: In the code examples presented in this section, we are not testing for the return code for the **set_qos()**, **set_default_*_qos()** functions. If the values used in the QosPolicy structures are inconsistent then the functions will fail and return **INCONSISTENT_POLICY**. In addition, **set_qos()** may return **IMMUTABLE_POLICY** if you try to change a QosPolicy on an *Entity* after that policy has become immutable. *User code should test for and address those anomalous conditions.*

4.1.7.4 Default QoS Values

Connext DDS provides special constants for each *Entity* type that can be used in **set_qos()** and **set_default_*_qos()** to reset the QosPolicy values to the original DDS default values:

- DDS_PARTICIPANT_QOS_DEFAULT
- DDS_PUBLISHER_QOS_DEFAULT
- DDS_SUBSCRIBER_QOS_DEFAULT

- DDS_DATAWRITER_QOS_DEFAULT
- DDS_DATAREADER_QOS_DEFAULT
- DDS_TOPIC_QOS_DEFAULT

For example, if you want to set a *DataWriter's* QoS back to their DDS-specified default values:

```
datawriter->set_qos(DDS_DATAWRITER_QOS_DEFAULT);
```

Or if you want to reset the default QosPolicies used by a *Publisher* to create *DataWriters* back to their DDS-specified default values:

```
publisher->set_default_datawriter_qos(DDS_DATAWRITER_QOS_DEFAULT);
```

These defaults *cannot* be used to initialize a QoS structure for an entity. For example, the following is NOT allowed:

```
DataWriterQos dataWriterQos = DATAWRITER_QOS_DEFAULT;
// modify QoS...
create_datawriter(dataWriterQos);
```

4.2 QosPolicies

Connext DDS's behavior is controlled by the Quality of Service (QoS) policies of the data communication *Entities* (*DomainParticipant, Topic, Publisher, Subscriber, DataWriter,* and *DataReader*) used in your applications. This section summarizes each of the QosPolicies that you can set for the various *Entities*.

The *QosPolicy* class is the abstract base class for all the QosPolicies. It provides the basic mechanism for an application to specify quality of service parameters. Table 4.2 QosPolicies lists each supported QosPolicy (in alphabetical order), provides a summary, and points to a section in the manual that provides further details.

The detailed description of a QosPolicy that applies to multiple *Entities* is provided in the first chapter that discusses an *Entity* whose behavior the QoS affects. Otherwise, the discussion of a QosPolicy can be found in the chapter of the particular *Entity* to which the policy applies. As you will see in the detailed description sections, all QosPolicies have one or more parameters that are used to configure the policy. The how's and why's of tuning the parameters are also discussed in those sections.

As first discussed in 2.7.1 Controlling Behavior with Quality of Service (QoS) Policies on page 23, QosPolicies may interact with each other, and certain values of QosPolicies can be incompatible with the values set for other policies.

The **set_qos()** operation will fail if you attempt to specify a set of values that would result in an inconsistent set of policies. To indicate a failure, **set_qos()** will return INCONSISTENT_POLICY. 4.2.1 QoS Requested vs. Offered Compatibility—the RxO Property on page 180 provides further information on QoS compatibility within an *Entity* as well as across matching *Entities*, as does the discussion/reference section for each QosPolicy listed in Table 4.2 QosPolicies.

The values of some QosPolicies cannot be changed after the *Entity* is created or after the *Entity* is enabled. Others may be changed at any time. The detailed section on each QosPolicy states when each policy can be changed. If you attempt to change a QosPolicy after it becomes immutable (because the associated *Entity* has been created or enabled, depending on the policy), **set_qos()** will fail with a return code of IMMUTABLE_POLICY.

Table 4.2 QosPolicies

QosPolicy	Summary
Asynchronous-Publisher	Configures the mechanism that sends user data in an external middleware thread. See 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344.
Availability	This QoS policy is used in the context of two features: For a *Collaborative DataWriter*, specifies the group of *DataWriters* expected to collaboratively provide data and the timeouts that control when to allow data to be available that may skip DDS samples. For a *Durable Subscription*, configures a set of Durable Subscriptions on a *DataWriter*. See 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369.
Batch	Specifies and configures the mechanism that allows *Connext DDS* to collect multiple DDS data samples to be sent in a single network packet, to take advantage of the efficiency of sending larger packets and thus increase effective throughput. See 7.5.2 BATCH QosPolicy (DDS Extension) on page 373.
Database	Various settings and resource limits used by *Connext DDS* to control its internal database. See 9.5.1 DATABASE QosPolicy (DDS Extension) on page 632.
DataReaderProtocol	This QosPolicy configures the *Connext DDS* on-the-network protocol, RTPS. See 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565.
DataReaderResourceLimits	Various settings that configure how *DataReaders* allocate and use physical memory for internal resources. See 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571.
DataRepresentation	Specifies which versions of the Extended Common Data Representation (CDR) (version 1 or version 2) and which data compression setting algorithms are offered and requested for your data. See 7.5.3 DATA_REPRESENTATION QosPolicy on page 379.
DataTag	This QosPolicy can be used to associate a set of tags in the form of (name, value) pairs with a *DataReader* or *DataWriter*. The Access Control plugin may use these tags to determine publish and subscribe permissions. See 7.5.4 DATATAG QosPolicy on page 386.
DataWriterProtocol	This QosPolicy configures the *Connext DDS* on-the-network protocol, RTPS. See 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.
DataWriterResourceLimits	Controls how many threads can concurrently block on a write() call of this *DataWriter*. Also controls the number of batches managed by the *DataWriter* and the instance-replacement kind used by the *DataWriter*. See 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400.
Deadline	For a *DataReader*, specifies the maximum expected elapsed time between arriving DDS data samples. For a *DataWriter*, specifies a commitment to publish DDS samples with no greater elapsed time between them. See 7.5.7 DEADLINE QosPolicy on page 404.

Table 4.2 QosPolicies

QosPolicy	Summary
DestinationOrder	Controls how *Connext DDS* will deal with data sent by multiple *DataWriters* for the same topic. Can be set to "by reception timestamp" or to "by source timestamp." See 7.5.8 DESTINATION_ORDER QosPolicy on page 406.
Discovery	Configures the mechanism used by *Connext DDS* to automatically discover and connect with new remote applications. See 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635.
DiscoveryConfig	Controls the amount of delay in discovering *Entities* in the system and the amount of discovery traffic in the network. See 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639.
DomainParticipantResourceLimits	Various settings that configure how *DomainParticipants* allocate and use physical memory for internal resources, including the maximum sizes of various properties. See 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649.
Durability	Specifies whether or not *Connext DDS* will store and deliver data that were previously published to new *DataReaders*. See 7.5.9 DURABILITY QosPolicy on page 410.
DurabilityService	Various settings to configure the external Persistence Service used by *Connext DDS* for *DataWriters* with a Durability QoS setting of Persistent Durability. See 7.5.10 DURABILITY SERVICE QosPolicy on page 414.
EntityFactory	Controls whether or not child *Entities* are created in the enabled state. See 7.4.2 ENTITYFACTORY QosPolicy on page 347.
EntityName	Assigns a name and role_name to an *Entity*. See 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416.
Event	Configures the *DomainParticipant's* internal thread that handles timed events. See 9.5.5 EVENT QosPolicy (DDS Extension) on page 656.
ExclusiveArea	Configures multi-thread concurrency and deadlock prevention capabilities. See 7.4.3 EXCLUSIVE_AREA QosPolicy (DDS Extension) on page 350.
GroupData	Along with 5.2.1 TOPIC_DATA QosPolicy on page 224 and 7.5.30 USER_DATA QosPolicy on page 462, this QosPolicy is used to attach a buffer of bytes to *Connext DDS*'s discovery meta-data. See 7.4.4 GROUP_DATA QosPolicy on page 352.
History	Specifies how much data must be stored by *Connext DDS* for the *DataWriter* or *DataReader*. This QosPolicy affects the 7.5.21 RELIABILITY QosPolicy on page 444 as well as the 7.5.9 DURABILITY QosPolicy on page 410. See 7.5.12 HISTORY QosPolicy on page 418.
LatencyBudget	Suggestion to *Connext DDS* on how much time is allowed to deliver data. See 7.5.13 LATENCYBUDGET QoS Policy on page 423.
Lifespan	Specifies how long *Connext DDS* should consider data sent by an user application to be valid. See 7.5.14 LIFESPAN QoS Policy on page 423.
Liveliness	Specifies and configures the mechanism that allows *DataReaders* to detect when *DataWriters* become disconnected or "dead." See 7.5.15 LIVELINESS QosPolicy on page 425.
Logging	Configures the properties associated with *Connext DDS* logging. See 9.4.1 LOGGING QosPolicy (DDS Extension) on page 627.

Table 4.2 QosPolicies

QosPolicy	Summary
MultiChannel	Configures a *DataWriter*'s ability to send data on different multicast groups (addresses) based on the value of the data. See 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429.
Ownership	Along with Ownership Strength, specifies if *DataReaders* for a topic can receive data from multiple *DataWriters* at the same time. See 7.5.17 OWNERSHIP QosPolicy on page 432.
OwnershipStrength	Used to arbitrate among multiple *DataWriters* of the same instance of a Topic when Ownership QoSPolicy is EXLUSIVE. See 7.5.18 OWNERSHIP_STRENGTH QosPolicy on page 435.
Partition	Adds string identifiers that are used for matching *DataReaders* and *DataWriters* for the same *Topic*. See 7.4.5 PARTITION QosPolicy on page 355.
Presentation	Controls how *Connext DDS* presents data received by an application to the *DataReaders* of the data. See 7.4.6 PRESENTATION QosPolicy on page 361.
Profile	Configures the way that XML documents containing QoS profiles are loaded by RTI. See 9.4.2 PROFILE QosPolicy (DDS Extension) on page 628.
Property	Stores name/value(string) pairs that can be used to configure certain parameters of *Connext DDS* that are not exposed through formal QoS policies. It can also be used to store and propagate application-specific name/value pairs, which can be retrieved by user code during discovery. See 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.
PublishMode	Specifies how *Connext DDS* sends application data on the network. By default, data is sent in the user thread that calls the *DataWriter's* write() operation. However, this QosPolicy can be used to tell *Connext DDS* to use its own thread to send the data. See 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441.
ReaderDataLifeCycle	Controls how a *DataReader* manages the lifecycle of the data that it has received. See 8.6.3 READER_DATA_LIFECYCLE QoS Policy on page 581.
ReceiverPool	Configures threads used by *Connext DDS* to receive and process data from transports (for example, UDP sockets). See 9.5.6 RECEIVER_POOL QosPolicy (DDS Extension) on page 658.
Reliability	Specifies whether or not *Connext DDS* will deliver data reliably. See 7.5.21 RELIABILITY QosPolicy on page 444.
ResourceLimits	Controls the amount of physical memory allocated for *Entities*, if dynamic allocations are allowed, and how they occur. Also controls memory usage among different instance values for keyed topics. See 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.
Service	Intended for use by RTI infrastructure services. User applications should not modify its value. See 7.5.23 SERVICE QosPolicy (DDS Extension) on page 452.
SystemResourceLimits	Configures *DomainParticipant*-independent resources used by *Connext DDS*. Mainly used to change the maximum number of *DomainParticipants* that can be created within a single process (address space). See 9.4.3 SYSTEM_RESOURCE_LIMITS QoS Policy (DDS Extension) on page 630.
TimeBasedFilter	Set by a *DataReader* to limit the number of new data values received over a period of time. See 8.6.4 TIME_BASED_FILTER QosPolicy on page 583.
TopicData	Along with Group Data QosPolicy and User Data QosPolicy, used to attach a buffer of bytes to *Connext DDS*'s discovery meta-data. See 5.2.1 TOPIC_DATA QosPolicy on page 224.

Table 4.2 QosPolicies

QosPolicy	Summary
TopicQueryDispatch	Configures the ability of a *DataWriter* to publish historical samples in response to a TopicQuery. See 7.5.24 TOPIC_QUERY_DISPATCH_QosPolicy (DDS Extension) on page 453.
TransferMode	Configures the properties of a Zero Copy *DataWriter*. See 7.5.25 TRANSFER_MODE QosPolicy on page 454.
TransportBuiltin	Specifies which built-in transport plugins are used. See 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660.
TransportMulticast	Specifies the multicast address on which a *DataReader* wants to receive its data. Can specify a port number as well as a subset of the available transports with which to receive the multicast data. See 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586.
TransportMulticastMapping	Specifies the automatic mapping between a list of topic expressions and multicast address that can be used by a *DataReader* to receive data for a specific topic. See 9.5.8 TRANSPORT_MULTICAST_MAPPING QosPolicy (DDS Extension) on page 661.
TransportPriority	Set by a *DataWriter* or *DataReader* to tell *Connext DDS* that the data being sent is a different "priority" than other data. See 7.5.26 TRANSPORT_PRIORITY QosPolicy on page 455.
TransportSelection	Allows you to select which physical transports a *DataWriter* or *DataReader* may use to send or receive its data. See 7.5.27 TRANSPORT_SELECTION QosPolicy (DDS Extension) on page 456.
TransportUnicast	Specifies a subset of transports and port number that can be used by an Entity to receive data. See 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458.
TypeConsistencyEnforcement	Defines rules that determine whether the type used to publish a given data stream is consistent with that used to subscribe to it. See 8.6.6 TYPE_CONSISTENCY_ENFORCEMENT QosPolicy on page 589.
TypeSupport	Used to attach application-specific value(s) to a *DataWriter* or *DataReader*. These values are passed to the serialization or deserialization routine of the associated data type. Also controls whether padding bytes are set to 0 during serialization. See 7.5.29 TYPESUPPORT QosPolicy (DDS Extension) on page 461.
UserData	Along with Topic Data QosPolicy and Group Data QosPolicy, used to attach a buffer of bytes to *Connext DDS*'s discovery meta-data. See 7.5.30 USER_DATA QosPolicy on page 462.
WireProtocol	Specifies IDs used by the RTPS wire protocol to create globally unique identifiers. See 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664.
WriterDataLifeCycle	Controls how a *DataWriter* handles the lifecycle of the instances (keys) that the *DataWriter* is registered to manage. See 7.5.31 WRITER_DATA_LIFECYCLE QoS Policy on page 464.

4.2.1 QoS Requested vs. Offered Compatibility–the RxO Property

Some QosPolicies that apply to *Entities* on the sending and receiving sides must have their values set in a compatible manner. This is known as the policy's 'requested vs. offered' (RxO) property. *Entities* on the publishing side 'offer' to provide a certain behavior. *Entities* on the subscribing side 'request' certain behavior. For *Connext DDS* to connect the sending entity to the receiving entity, the offered behavior must satisfy the requested behavior.

For some QosPolicies, the allowed values may be graduated in a way that the offered value will satisfy the requested value if the offered value is either greater than or less than the requested value. For example, if a *DataWriter*'s DEADLINE QosPolicy specifies a duration less than or equal to a *DataReader*'s DEADLINE QosPolicy, then the *DataWriter* is promising to publish data at least as fast or faster than the *DataReader* requires new data to be received. This is a compatible situation (see 7.5.7 DEADLINE QosPolicy on page 404).

Other QosPolicies require the values on the sending side and the subscribing side to be exactly equal for compatibility to be met. For example, if a *DataWriter*'s OWNERSHIP QosPolicy is set to SHARED, and the matching *DataReader*'s value is set to EXCLUSIVE, then this is an incompatible situation since the *DataReader* and *DataWriter* have different expectations of what will happen if more than one *DataWriter* publishes an instance of the *Topic* (see 7.5.17 OWNERSHIP QosPolicy on page 432).

Finally there are QosPolicies that do not require compatibility between the sending entity and the receiving entity, or that only apply to one side or the other. Whether or not related *Entities* on the publishing and subscribing sides must use compatible settings for a QosPolicy is indicated in the policy's RxO property, which is provided in the detailed section on each QosPolicy.

- **RxO = YES** The policy is set at both the publishing and subscribing ends and the values must be set in a compatible manner. What it means to be compatible is defined by the QosPolicy.
- **RxO = NO** The policy is set only on one end or at both the publishing and subscribing ends, but the two settings are independent. There the requested vs. offered semantics are not used for these QosPolicies.

For those QosPolicies that follow the RxO semantics, *Connext DDS* will compare the values of those policies for compatibility. If they are compatible, then *Connext DDS* will connect the sending entity to the receiving entity allowing data to be sent between them. If they are found to be incompatible, then *Connext DDS* will not interconnect the *Entities* preventing data to be sent between them.

In addition, *Connext DDS* will record this event by changing the associated communication status in both the sending and receiving applications, see 4.3.1 Types of Communication Status on page 183. Also, if you have installed *Listeners* on the associated *Entities*, then *Connext DDS* will invoke the associated callback functions to notify user code that an incompatible QoS combination has been found, see 4.4.1 Types of Listeners on page 190.

For *Publishers* and *DataWriters*, the status corresponding to this situation is **OFFERED_INCOMPATIBLE_QOS_STATUS**. For *Subscribers* and *DataReaders*, the corresponding status is **REQUESTED_INCOMPATIBLE_QOS_STATUS**. The question of why a *DataReader* is not receiving data sent from a matching *DataWriter* can often be answered if you have instrumented the application with *Listeners* for the statuses noted previously.

4.2.2 Special QosPolicy Handling Considerations for C

Many QosPolicy structures contain variable-length sequences to store their parameters. In the C++, C++/CLI, C# and Java languages, the memory allocation related to sequences are handled automatically through constructors/destructors and overloaded operators. However, the C language is limited in what it provides to automatically handle memory management. Thus, *Connext DDS* provides functions and macros in C to initialize, copy, and finalize (free) QosPolicy structures defined for *Entities*.

In the C language, it is not safe to use an *Entity*'s QosPolicy structure declared in user code unless it has been initialized first. In addition, user code should always finalize an *Entity*'s QosPolicy structure to release any memory allocated for the sequences–even if the *Entity*'s QosPolicy structure was declared as a local, stack variable.

Thus, for a general *Entity*'s QosPolicy, *Connext DDS* will provide:

- **DDS_<Entity>Qos_INITIALIZER** This is a macro that should be used when a **DDS_<Entity>Qos** structure is declared in a C application.

```
struct DDS_<Entity>Qos qos = DDS_<Entity>Qos_INITIALIZER;
```

- **DDS_<Entity>Qos_initialize()** This is a function that can be used to initialize a **DDS_<Entity>Qos** structure instead of the macro above.

```
struct DDS_<Entity>Qos qos;
DDS_<Entity>QOS_initialize(&qos);
```

- **DDS_<Entity>Qos_finalize()** This is a function that should be used to finalize a **DDS_<Entity>Qos** structure when the structure is no longer needed. It will free any memory allocated for sequences contained in the structure.

```
struct DDS_<Entity>Qos qos = DDS_<Entity>Qos_INITIALIZER;
...
<use qos>
...
// now done with qos
DDS_<Entity>QoS_finalize(&qos);
```

- **DDS<Entity>Qos_copy()** This is a function that can be used to copy one **DDS_<Entity>Qos** structure to another. It will copy the sequences contained in the source structure and allocate memory for sequence elements if needed. In the code below, both **dstQos** and **srcQos** must have been initialized at some point earlier in the code.

```
DDS_<Entity>QOS_copy(&dstQos, &srcQos);
```

4.3 Statuses

This section describes the different *statuses* that exist for an entity. A status represents a state or an event regarding the entity. For instance, maybe *Connext DDS* found a matching *DataReader* for a *DataWriter,* or new data has arrived for a *DataReader*.

Your application can retrieve an *Entity's* status by:

- explicitly checking for *any* status changes with **get_status_changes()**.
- explicitly checking a *specific* status with **get_<*status_name*>_status()**.
- using a *Listener*, which provides asynchronous notification when a status changes.
- using *StatusConditions* and *WaitSets*, which provide a way to wait for status changes.

If you want your application to be notified of status changes asynchronously: create and install a *Listener* for the *Entity.* Then internal *Connext DDS* threads will call the listener methods when the status changes. See 4.4 Listeners on page 189.

If you want your application to wait for status changes: set up *StatusConditions* to indicate the statuses of interest, attach the *StatusConditions* to a *WaitSet*, and then call the *WaitSet*'s **wait()** operation. The call to **wait()** will block until statuses in the attached *Conditions* changes (or until a timeout period expires). See 4.6 Conditions and WaitSets on page 202.

4.3.1 Types of Communication Status

Each *Entity* is associated with a set of *Status* objects representing the "communication status" of that *Entity*. The list of statuses actively monitored by *Connext DDS* is provided in Table 4.3 Communication Statuses. A status structure contains values that give you more information about the status; for example, how many times the event has occurred since the last time the user checked the status, or how many time the event has occurred in total.

Changes to status values cause activation of corresponding *StatusCondition* objects and trigger invocation of the corresponding *Listener* functions to asynchronously inform the application that the status has changed. For example, a change in a *Topic's* **INCONSISTENT_TOPIC_STATUS** may trigger the *TopicListener's* **on_inconsistent_topic()** callback routine (if such a *Listener* is installed).

Table 4.3 Communication Statuses

Related Entity	Status (DDS_*_STATUS)	Description	Reference
Topic	INCONSISTENT_TOPIC	Another *Topic* exists with the same name but different characteristics–for example, a different type.	5.3.1 INCONSISTENT_TOPIC Status on page 226

Table 4.3 Communication Statuses

Related Entity	Status (DDS_*_STATUS)	Description	Reference
DataWriter	APPLICATION_ACKNOWLEDGMENT	This status indicates that a *DataWriter* has received an application-level acknowledgment for a DDS sample. The listener provides the identities of the DDS sample and acknowledging *DataReader*, as well as user-specified response data sent from the *DataReader* by the acknowledgment message.	7.3.12 Application Acknowledgment on page 316
	DATA_WRITER_CACHE	The status of the *DataWriter's* cache. This status does not have a Listener.	7.3.6.2 DATA_WRITER_CACHE_STATUS on page 296
	DATA_WRITER_PROTOCOL	The status of a *DataWriter's* internal protocol related metrics (such as the number of DDS samples pushed, pulled, filtered) and the status of wire protocol traffic. This status does not have a Listener.	7.3.6.3 DATA_WRITER_PROTOCOL_STATUS on page 297
DataWriter cont'd	LIVELINESS_LOST	The liveliness that the *DataWriter* has committed to (through its Liveliness QosPolicy) was not respected (assert_liveliness() or write() not called in time), thus *DataReaders* may consider the *DataWriter* as no longer active.	7.3.6.4 LIVELINESS_LOST Status on page 301
	OFFERED_DEADLINE_MISSED	The deadline that the *DataWriter* has committed through its Deadline QosPolicy was not respected for a specific instance of the *Topic*.	7.3.6.5 OFFERED_DEADLINE_MISSED Status on page 302
	OFFERED_INCOMPATIBLE_QOS	An offered QosPolicy value was incompatible with what was requested by a *DataReader* of the same Topic.	7.3.6.6 OFFERED_INCOMPATIBLE_QOS Status on page 302
	PUBLICATION_MATCHED	The *DataWriter* found a *DataReader* that matches the *Topic*, has compatible QoSs and a common partition, or a previously matched *DataReader* has been deleted.	7.3.6.7 PUBLICATION_MATCHED Status on page 303
	RELIABLE_WRITER_CACHE_CHANGED	The number of unacknowledged DDS samples in a reliable *DataWriter's* cache has reached one of the predefined trigger points.	7.3.6.8 RELIABLE_WRITER_CACHE_CHANGED Status (DDS Extension) on page 304
	RELIABLE_READER_ACTIVITY_CHANGED	One or more reliable *DataReaders* has either been discovered, deleted, or changed between active and inactive state as specified by the LivelinessQosPolicy of the *DataReader*.	7.3.6.9 RELIABLE_READER_ACTIVITY_CHANGED Status (DDS Extension) on page 306
Subscriber	DATA_ON_READERS	New data is available for any of the readers that were created from the *Subscriber*.	8.2.9 Statuses for Subscribers on page 500

Table 4.3 Communication Statuses

Related Entity	Status (DDS_*_STATUS)	Description	Reference
DataReader	DATA_AVAILABLE	New data (one or more DDS samples) are available for the specific *DataReader*.	8.3.7.1 DATA_AVAILABLE Status on page 514
	DATA_READER_CACHE	The status of the reader's cache. This status does not have a Listener.	8.3.7.2 DATA_READER_CACHE_STATUS on page 514
	DATA_READER_PROTOCOL	The status of a *DataReader's* internal protocol related metrics (such as the number of DDS samples received, filtered, rejected) and the status of wire protocol traffic. This status does not have a Listener.	8.3.7.3 DATA_READER_PROTOCOL_STATUS on page 517
	LIVELINESS_CHANGED	The liveliness of one or more *DataWriters* that were writing instances read by the *DataReader* has either been discovered, deleted, or changed between active and inactive state as specified by the LivelinessQosPolicy of the *DataWriter*.	8.3.7.4 LIVELINESS_CHANGED Status on page 521
DataReader cont'd	REQUESTED_DEADLINE_MISSED	New data was not received for an instance of the *Topic* within the time period set by the *DataReader's* Deadline QosPolicy.	8.3.7.5 REQUESTED_DEADLINE_MISSED Status on page 523
	REQUESTED_INCOMPATIBLE_QOS	A requested QosPolicy value was incompatible with what was offered by a *DataWriter* of the same *Topic*.	8.3.7.6 REQUESTED_INCOMPATIBLE_QOS Status on page 523
	SAMPLE_LOST	A DDS sample sent by *Connext DDS* has been lost (never received).	8.3.7.7 SAMPLE_LOST Status on page 524
	SAMPLE_REJECTED	A received DDS sample has been rejected due to a resource limit (buffers filled).	8.3.7.8 SAMPLE_REJECTED Status on page 527
	SUBSCRIPTION_MATCHED	The *DataReader* has found a *DataWriter* that matches the *Topic*, has compatible QoSs and a common partition, or an existing matched *DataWriter* has been deleted.	8.3.7.9 SUBSCRIPTION_MATCHED Status on page 528

Statuses can be grouped into two categories:

- Plain communication status:

  In addition to a flag that indicates whether or not a status has changed, a *plain* communication status also contains state and thus has a corresponding structure to hold its current value.

- Read communication status:

  A read communication status is more like an event and has no state other than whether or not it has occurred. Only two statuses listed in Table 4.3 Communication Statuses are *read* communications statuses: **DATA_AVAILABLE** and **DATA_ON_READERS**.

As mentioned in 4.1.4 Getting Status and Status Changes on page 171, all *Entities* have a **get_status_changes()** operation that can be used to explicitly poll for changes in any status related to the entity. For *plain* statuses, each entry has operations to get the current value of the status; for example, the *Topic* class has a **get_inconsistent_topic_status()** operation. For *read* statuses, your application should use the **take()** operation on the *DataReader* to retrieve the newly arrived data that is indicated by **DATA_AVAILABLE** and **DATA_ON_READER**.

Note that the two read communication statuses do not change independently. If data arrives for a *DataReader*, then its **DATA_AVAILABLE** status changes. At the same time, the DATA_ON_READERS status changes for the *DataReader's Subscriber*.

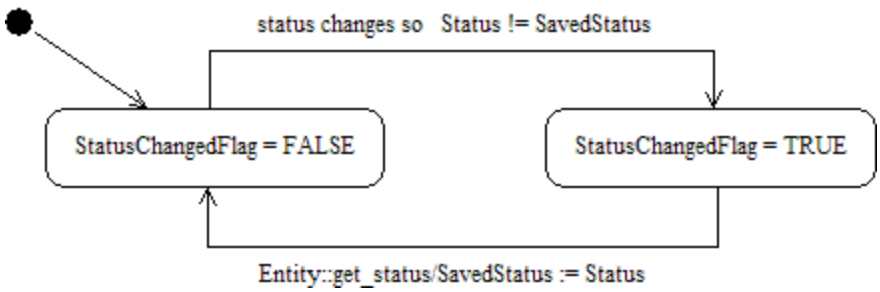
Both types of status have a **StatusChangedFlag**. This flag indicates whether that particular communication status has changed since the last time the status was read by the application. The way the **StatusChangedFlag** is maintained is slightly different for the *plain* communication status and the *read* communication status, as described in the following sections:

- 4.3.1.1 Changes in Plain Communication Status below
- 4.3.1.2 Changes in Read Communication Status on the next page

4.3.1.1 Changes in Plain Communication Status

As seen in Figure 4.2: Status Changes for Plain Communication Status below, for the plain communication status, the StatusChangedFlag flag is initially set to FALSE. It becomes TRUE whenever the plain communication status changes and is reset to FALSE each time the application accesses the plain communication status via the proper **get_*_status()** operation.

Figure 4.2: Status Changes for Plain Communication Status



The communication status is also reset to FALSE whenever the associated listener operation is called, as the listener implicitly accesses the status which is passed as a parameter to the operation.

The fact that the status is reset prior to calling the listener means that if the application calls the **get_*_status()** operation from inside the listener, it will see the status already reset.

An exception to this rule is when the associated listener is the 'nil' listener. The 'nil' listener is treated as a NO-OP and the act of calling the 'nil' listener does not reset the communication status. (See 4.4.1 Types of Listeners on page 190.)

For example, the value of the StatusChangedFlag associated with the **REQUESTED_DEADLINE_MISSED** status will become TRUE each time new deadline occurs (which increases the RequestedDeadlineMissed status' **total_count** field). The value changes to FALSE when the application accesses the status via the corresponding **get_requested_deadline_missed_status()** operation on the proper Entity.

4.3.1.2 Changes in Read Communication Status

As seen in Figure 4.3: Status Changes for Read Communication Status on the next page, for the read communication status, the StatusChangedFlag flag is initially set to FALSE. The StatusChangedFlag becomes TRUE when either a DDS data sample arrives or the ViewStateKind, SampleStateKind, or InstanceStateKind of any existing DDS sample changes for any reason other than a call to one of the read/take operations. Specifically, any of the following events will cause the StatusChangedFlag to become TRUE:

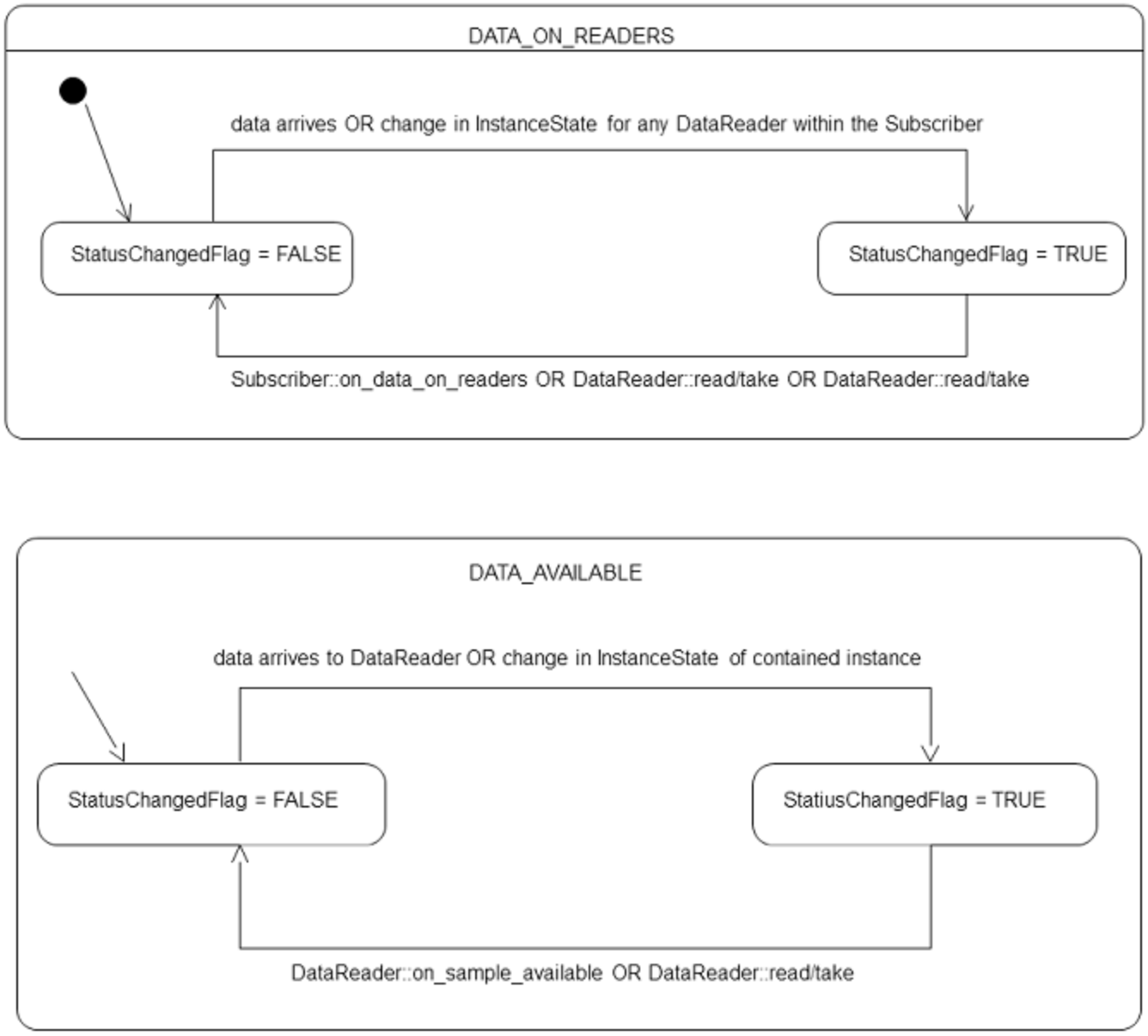
- The arrival of new data.
- A change in the InstanceStateKind of a contained instance. This can be caused by either:
  - Notification that an instance has been disposed by:
    - the *DataWriter* that owns it, if OWNERSHIP = EXCLUSIVE
    - or by any *DataWriter,* if OWNERSHIP = SHARED
  - The loss of liveliness of the *DataWriter* of an instance for which there is no other *DataWriter*.
  - The arrival of the notification that an instance has been unregistered by the only *DataWriter* that is known to be writing the instance.

Depending on the **kind** of **StatusChangedFlag**, the flag transitions to FALSE (that is, the status is reset) as follows:

- The **DATA_AVAILABLE** StatusChangedFlag becomes FALSE when either **on_data_available()** is called or the read/take operation (or their variants) is called on the associated *DataReader*.
- The **DATA_ON_READERS** StatusChangedFlag becomes FALSE when any of the following occurs:
  - **on_data_on_readers()** is called.
  - **on_data_available()** is called on any *DataReader* belonging to the *Subscriber*.

- **read()**, **take()**, or one of their variants is called on any *DataReader* belonging to the *Subscriber*.

Figure 4.3: Status Changes for Read Communication Status



4.3.2 Special Status-Handling Considerations for C

Some status structures contain variable-length sequences to store their values. In the C++, C++/CLI, C# and Java languages, the memory allocation related to sequences are handled automatically through constructors/destructors and overloaded operators. However, the C language is limited in what it provides to

automatically handle memory management. Thus, *Connext DDS* provides functions and macros in C to initialize, copy, and finalize (free) status structures.

In the C language, it is not safe to use a status structure that has internal sequences declared in user code unless it has been initialized first. In addition, user code should always finalize a status structure to release any memory allocated for the sequences–even if the status structure was declared as a local, stack variable.

Thus, for a general status structure, *Connext DDS* will provide:

- DDS_<*STATUS*>STATUS_INITIALIZER This is a macro that should be used when a **DDS_<*Status*>Status** structure is declared in a C application.

```
struct DDS_<Status>Status status = DDS_<Status>Status_INITIALIZER;
```

- **DDS_<*Status*>Status_initialize()** This is a function that can be used to initialize a **DDS_<*Status*>Status** structure instead of the macro above.

```
struct DDS_<Status>Status status;
DDS_<Status>Status_initialize(&Status);
```

- **DDS_<*Status*>Status_finalize()** This is a function that should be used to finalize a **DDS_<*Status*>Status** structure when the structure is no longer needed. It will free any memory allocated for sequences contained in the structure.

```
struct DDS_<Status>Status status = DDS_<Status>Status_INITIALIZER;
...
<use status>
...
// now done with Status
DDS_<Status>Status_finalize(&status);
```

- **DDS<*Status*>Status_copy()** This is a function that can be used to copy one **DDS_<*Status*>Status** structure to another. It will copy the sequences contained in the source structure and allocate memory for sequence elements if needed. In the code below, both **dstStatus** and **srcStatus** must have been initialized at some point earlier in the code.

```
DDS_<Status>Status_copy(&dstStatus, &srcStatus);
```

Note that many status structures do not have sequences internally. For those structures, you do not need to use the macro and methods provided above. However, they have still been created for your convenience.

4.4 Listeners

Listeners are triggered by changes in an entity's status. For instance, maybe *Connext DDS* found a matching *DataReader* for a *DataWriter,* or new data has arrived for a *DataReader*.

You can use either *Listeners* or *WaitSets* to be notified of events. *WaitSets* block a thread until data is available. This is the safest way to get data, because it does not affect any middleware threads. In contrast, *Listeners* allow an application to be called back from a *Connext DDS* thread. This provides better latency

than *WaitSets*, because the application can handle the event in the same thread that is generating the notification (so there is no time spent context-switching between threads).

There is also the possibility that notifications can be lost when using *WaitSets*, because most notifications contain a status update for only the most recent event. For example, imagine a system where a *DataReader* is trying to detect that *DataWriters* have lost liveliness. If two *DataWriters* lose liveliness at about the same, a listener that handles the **on_liveliness_changed** status will be called back once for each *DataWriter* that lost liveliness. When **on_liveliness_changed** is called back the first time, the LivelinessChangedStatus will contain the handle for one of the *DataWriters*, and the second time the callback is called it will contain the handle for the other *DataWriter*. However, if *WaitSets* are used and the *DataWriters* become not alive at about the same time, it's possible that by the time the *WaitSet* is notified that the first *DataWriter* has lost liveliness, the second one also loses liveliness, and the LivelinessChangedStatus contains only the most recent *DataWriter* to lose liveliness.

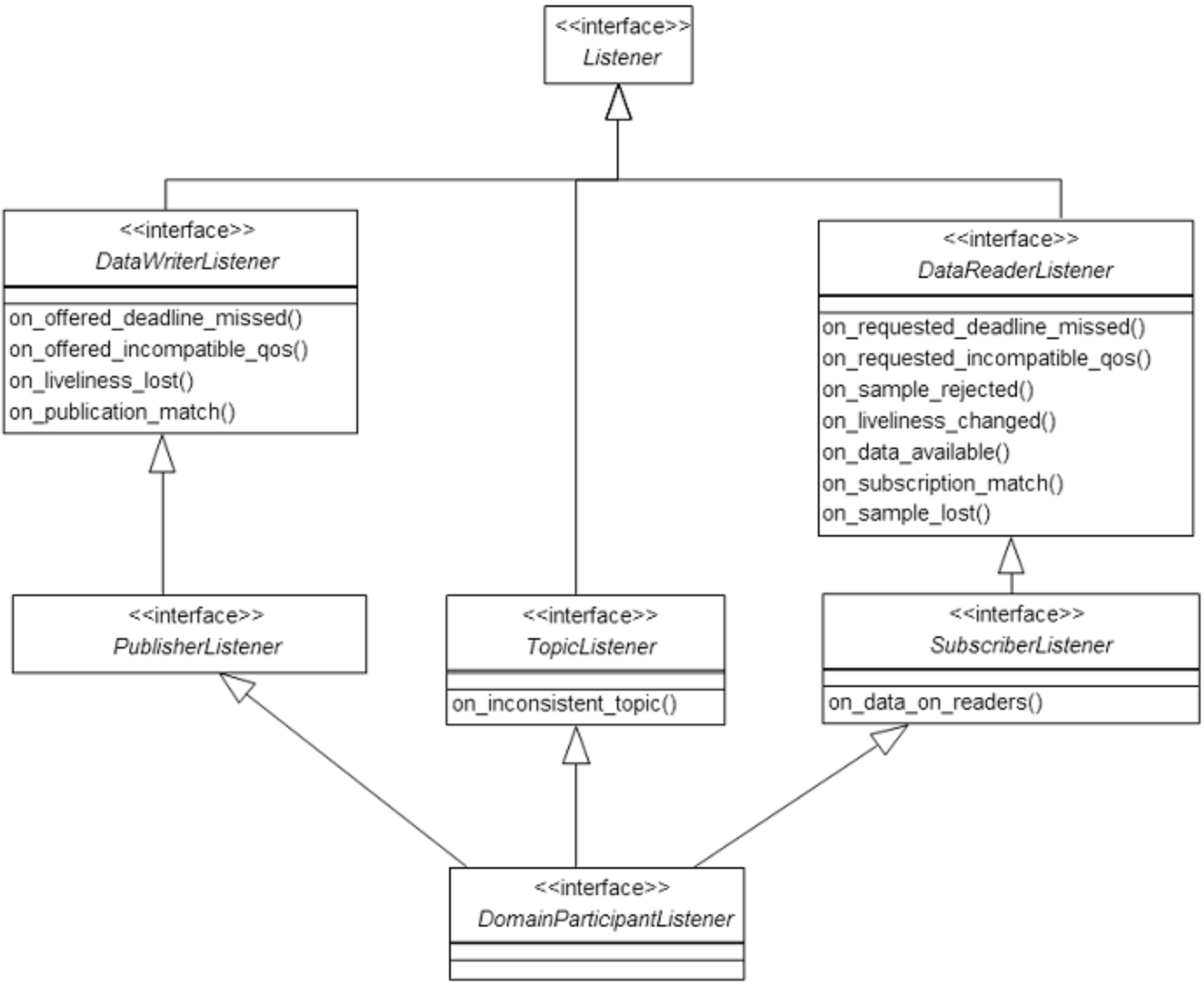
The danger of using *Listeners* is that they are called back from a *Connext DDS* thread, so performing any slow processing in a *Listener* callback can degrade the performance of *Connext DDS* (by causing lost data, lost liveliness, etc.).

This section describes *Listeners* and how to use them.

4.4.1 Types of Listeners

The *Listener* class is the abstract base class for all listeners. Each entity class (*DomainParticipant, Topic, Publisher, DataWriter*, *Subscriber*, and *DataReader*) has its own derived *Listener* class that add methods for handling entity-specific statuses. The hierarchy of *Listener* classes is presented in Figure 4.4: Listener Class Hierarchy on the next page. The methods are called by an internal *Connext DDS* thread when the corresponding status for the *Entity* changes value.

Figure 4.4: Listener Class Hierarchy



You can choose which changes in status will trigger a callback by installing a listener with a bit-mask. Bits in the mask correspond to different statuses. The bits that are true indicate that the listener will be called back when there are changes in the corresponding status.

You can specify a listener and set its bit-mask before or after you create an *Entity*:

During Entity creation:

```
DDS_StatusMask mask = DDS_REQUESTED_DEADLINE_MISSED_STATUS |
                      DDS_DATA_AVAILABLE_STATUS;
datareader = subscriber->create_datareader(topic,
               DDS_DATAREADER_QOS_DEFAULT,
                listener, mask);
```

or afterwards:

```
DDS_StatusMask mask = DDS_REQUESTED_DEADLINE_MISSED_STATUS |
                      DDS_DATA_AVAILABLE_STATUS;
datareader->set_listener(listener, mask);
```

As you can see in the above examples, there are two components involved when setting up listeners: the listener itself and the mask. Both of these can be null. Table 4.4 Effect of Different Combinations of Listeners and Status Bit Masks describes what happens when a status change occurs. See 4.4.5 Hierarchical Processing of Listeners on page 194 for more information.

Table 4.4 Effect of Different Combinations of Listeners and Status Bit Masks

	No Bits Set in Mask	Some/All Bits Set in Mask
Listener is Specified	*Connext DDS* finds the next most relevant listener for the changed status.	For the statuses that are enabled in the mask, the most relevant listener will be called. The 'statusChangedFlag' for the relevant status is reset.
Listener is NULL	*Connext DDS* behaves as if the listener is not installed and finds the next most relevant listener for that status.	*Connext DDS* behaves as if the listener callback is installed, but the callback is doing nothing. This is called a 'nil' listener.

4.4.2 Creating and Deleting Listeners

There is no factory for creating or deleting a *Listener*; use the natural means in each language binding (for example, "new" or "delete" in C++ or Java). For example:

```
class HelloWorldListener : public DDSDataReaderListener {
    virtual void on_data_available(DDSDataReader* reader);
};
void HelloWorldListener::on_data_available(DDSDataReader* reader)
{
    printf("received data\n");
}
// Create a Listener
HelloWorldListener *reader_listener = NULL;
reader_listener = new HelloWorldListener();
// Delete a Listener
delete reader_listener;
```

A listener cannot be deleted until the entity it is attached to has been deleted. For example, you must delete the *DataReader* before deleting the *DataReader's* listener.

Note: Due to a thread-safety issue, the destruction of a *DomainParticipantListener* from an enabled *DomainParticipant* should be avoided—even if the *DomainParticipantListener* has been removed from the *DomainParticipant*. (This limitation does not affect the Java API.)

4.4.3 Special Considerations for Listeners in C

In C, a *Listener* is a structure with function pointers to the user callback routines. Often, you may only be interested in a subset of the statuses that can be monitored with the *Listener*. In those cases, you may not set all of the functions pointers in a listener structure to a valid function. In that situation, we recommend that the unused, callback-function pointers are set to **NULL**. While setting the **DDS_StatusMask** to enable only the callbacks for the statuses in which you are interested (and thus only enabling callbacks on the functions that actually exist) is safe, we still recommend that you clear all of the unused callback pointers in the *Listener* structure.

To help, in the C language, we provide a macro that can be used to initialize a Listener structure so that all of its callback pointers are set to **NULL**. For example

```
DDS_<Entity>Listener listener = DDS_<Entity>Listener_INITIALIZER;
// now only need to set the listener callback pointers for statuses // to be monitored
```

There is no need to do this in languages other than C.

4.4.4 Special Considerations for Listeners in Modern C++

In the Modern C++ API, the *Entity* constructors and **set_listener** functions expect a **std::shared_ptr**. The *Entity* keeps a reference to that **shared_ptr** preventing its deletion at least until the *Entity* has been destroyed or the *Listener* reset.

In addition to each *Listener* base class (such as **dds::sub::DataReaderListener**), which contains a set of pure virtual functions, a class with a default implementation for each callback that does nothing is provided (such as **dds::sub::NoOpDataReaderListener**).

The following example shows how to create a *DataReaderListener*:

```
class HelloWorldListener : public dds::sub::NoOpDataReaderListener<HelloWorld> {
    void on_data_available(dds::sub::DataReader<HelloWorld> reader) override
    {
          auto samples = reader.take();
          std::cout << "Received " << samples.length() << " samples\n";
    }
};

void create_reader_with_listener()
{
    // ...
    auto reader_listener = std::make_shared<HelloWorldListener>();
    dds::sub::DataReader<HelloWorld> reader(subscriber, topic, qos, reader_listener);
    // ...
}
```

It is not recommended to keep a reference to the *Entity* as a member of a *Listener* class. Doing so creates a cycle between these two references preventing each other's destruction. If you do need to keep a reference, you must later reset the *Listener* or explicitly close the *Entity*.

4.4.5 Hierarchical Processing of Listeners

As seen in Figure 4.4: Listener Class Hierarchy on page 191, *Listeners* for some *Entities* derive from the *Connext DDS Listeners* for related *Entities*. This means that the derived *Listener* has all of the methods of its parent class. You can install *Listeners* at all levels of the object hierarchy. At the top is the *DomainParticipantListener*; only one can be installed in a *DomainParticipant*. Then every *Subscriber* and *Publisher* can have their own *Listener*. Finally, each *Topic*, *DataReader* and *DataWriter* can have their own listeners. All are optional.

Suppose, however, that an *Entity* does not install a *Listener*, or installs a *Listener* that does not have particular communication status selected in the bitmask. In this case, if/when that particular status changes for that Entity, the corresponding *Listener* for that *Entity's parent* is called. Status changes are "propagated" from child *Entity* to parent *Entity* until a *Listener* is found that is registered for that status. *Connext DDS* will give up and drop the status-change event only if no *Listeners* have been installed in the object hierarchy to be called back for the specific status. This is true for *plain* communication statuses. *Read* communication statuses are handle somewhat differently, see 4.4.5.1 Processing Read Communication Statuses on the next page.

For example, suppose that *Connext DDS* finds a matching *DataWriter* for a local *DataReader*. This event will change the **SUBSCRIPTION_MATCHED** status. So the local *DataReader* object is checked to see if the application has installed a listener that handles the **SUBSCRIPTION_MATCH** status. If not, the *Subscriber* that created the *DataReader* is checked to see if *it* has a listener installed that handles the same event. If not, the *DomainParticipant* is checked. The *DomainParticipantListener* methods are called only if none of the descendent *Entities* of the *DomainParticipant* have listeners that handle the particular status that has changed. Again, all listeners are optional. Your application does not have to handle any communication statuses.

Table 4.5 Listener Callback Functions lists the callback functions that are available for each *Entity*'s status listener.

Table 4.5 Listener Callback Functions

Entity Listener for:		Callback Functions
DomainParticipants	Topics	on_inconsistent_topic()
	Publishers and DataWriters	on_liveliness_lost()
		on_offered_deadline_missed()
		on_offered_incompatible_qos()
		on_publication_matched()
		on_reliable_reader_activity_changed()
		on_reliable_writer_cache_changed()
	Subscribers	on_data_on_readers()
	Subscribers and DataReaders	on_data_available
		on_liveliness_changed()
		on_requested_deadline_missed()
		on_requested_incompatible_qos()
		on_sample_lost()
		on_sample_rejected()
		on_subscription_matched()

4.4.5.1 Processing Read Communication Statuses

The processing of the **DATA_ON_READERS** and **DATA_AVAILABLE** read communication statuses are handled slightly differently since, when new data arrives for a *DataReader*, both statuses change simultaneously. However, only one, if any, *Listener* will be called to handle the event.

If there is a *Listener* installed to handle the **DATA_ON_READERS** status in the *DataReader*'s *Subscriber* or in the *DomainParticipant*, then that *Listener's* **on_data_on_readers()** function will be called back. The *DataReaderListener's* **on_data_available()** function is called only if the DATA_ON_READERS status is not handle by any relevant listeners.

This can be useful if you have generic processing to do whenever new data arrives for any *DataReader*. You can execute the generic code in the **on_data_on_readers()** method, and then dispatch the processing of the actual data to the specific *DataReaderListener*'s **on_data_available()** function by calling the **notify_datareaders()** method on the *Subscriber*.

For example:

```
void on_data_on_readers (DDSSubscriber *subscriber)
{
    // Do some general processing that needs to be done
    // whenever new data arrives, but is independent of
    // any particular DataReader
    < generic processing code here >


    // Now dispatch the actual processing of the data
    // to the specific DataReader for which the data
    // was received
    subscriber->notify_datareaders();
}
```

4.4.6 Operations Allowed within Listener Callbacks

Due to the potential for deadlock, some *Connext DDS* APIs should not be invoked within the functions of listener callbacks. Exactly which *Connext DDS* APIs are restricted depends on the *Entity* upon which the *Listener* is installed, as well as the configuration of 'Exclusive Areas,' as discussed in 4.5 Exclusive Areas (EAs) on the next page.

Please read and understand 4.5 Exclusive Areas (EAs) on the next page and 4.5.1 Restricted Operations in Listener Callbacks on page 200 to ensure that the calls made from your *Listeners* are allowed and will not cause potential deadlock situations.

4.4.7 Best Practices with Listeners

Note: All the issues described below can be avoided by using a *Waitset*.

- Avoid blocking or performing a lot of processing in Listener callbacks

  Listeners are invoked by internal threads that perform critical functions within the middleware and need to run in a timely manner (see Connext DDS Threading Model (Chapter 21 on page 900)). By default, *Connext DDS* creates a few threads to use to receive data and only a single thread to handle periodic events.

  Because of this, user applications installing *Listeners* should never block in a *Listener* callback. There are several negative consequences of blocking in a listener callback:

  - The application may lose data for the *DataReader* the listener is installed on, because the receive thread is not removing it from the socket buffer and it gets overwritten (see 21.3 Receive Threads on page 903).
  - The application may receive strictly reliable data with a delay, because the receive thread is not removing it from the socket buffer and if it gets overwritten it must be re-sent.
  - The application may lose or delay data for other *DataReaders*, because by default all *DataReaders* created with the same *DomainParticipant* share the same threads.

  - The application may not be notified of periodic events on time (see 21.2 Event Thread on page 902).

  If the application needs to make a blocking call when data is available, or when another event occurs, the application should use a *WaitSet*. (see 4.6 Conditions and WaitSets on page 202).

- Avoid taking application mutexes/semaphores in *Listener* callbacks

  Taking application mutexes/sempahores within a *Listener* callback may lead to unexpected deadlock scenarios. When a *Listener* callback is invoked, the EA (Exclusive Area) of the Entity 'E' to which the callback applies is taken by the middleware. If the application takes an application mutex 'M' within a critical section in which the application makes DDS calls affecting 'E', this may lead to following deadlock:

  The middleware thread is within the entity EA trying to acquire the mutex 'M'. At the same time, the application thread has acquired 'M' and is blocked trying to acquire the entity EA.

- Do not write data with a *DataWriter* within the **on_data_available()** callback

  Avoid writing data with a *DataWriter* within the DataReaderListener's **on_data_available()** callback. If the write operation blocks because e.g. the send window is full, this will lead to a deadlock.

- Do not call **wait_for_acknowledgements()** within the **on_data_available()** callback

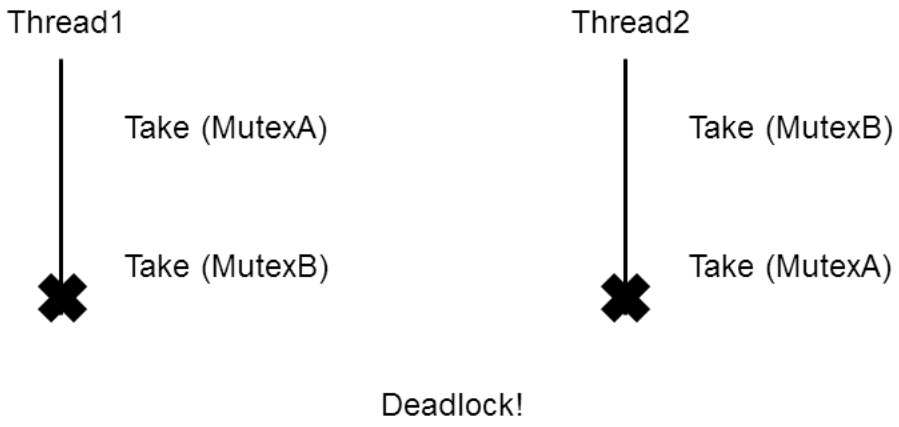
  Do not call the *DataWriter's* **wait_for_acknowledgments()** within the DataReaderListener's **on_data_available()** callback. This will lead to deadlock.

4.5 Exclusive Areas (EAs)

Listener callbacks are invoked by internal *Connext DDS* threads. To prevent undesirable, multi-threaded interaction, the internal threads may take and hold semaphores (mutexes) used for mutual exclusion. In your listener callbacks, you may want to invoke functions provided by the *Connext DDS* API. Internally, those *Connext DDS* functions also may take mutexes to prevent errors due to multi-threaded access to critical data or operations.

Once there are multiple mutexes to protect different critical regions, the possibility for deadlock exists. Consider Figure 4.5: Multiple Mutexes Leading to a Deadlock Condition on the next page's scenario, in which there are two threads and two mutexes.

Figure 4.5: Multiple Mutexes Leading to a Deadlock Condition



Thread1 takes MutexA while simultaneously Thread2 takes MutexB. Then, Thread1 takes MutexB and simultaneously Thread2 takes MutexA. Now both threads are blocked since they hold a mutex that the other thread is trying to take. This is a deadlock condition.

While the probability of entering the deadlock situation in Figure 4.5: Multiple Mutexes Leading to a Deadlock Condition above depends on execution timing, when there are multiple threads and multiple mutexes, care must be taken in writing code to prevent those situations from existing in the first place. *Connext DDS* has been carefully created and analyzed so that we know our threads internally are safe from deadlock interactions.

However, when *Connext DDS* threads that are holding mutexes call user code in listeners, it is possible for user code to inadvertently cause the threads to deadlock if *Connext DDS* APIs that try to take other mutexes are invoked. To help you avoid this situation, RTI has defined a concept known as *Exclusive Areas*, some restrictions regarding the use of *Connext DDS* APIs within user callback code, and a QoS policy that allows you to configure *Exclusive Areas*.

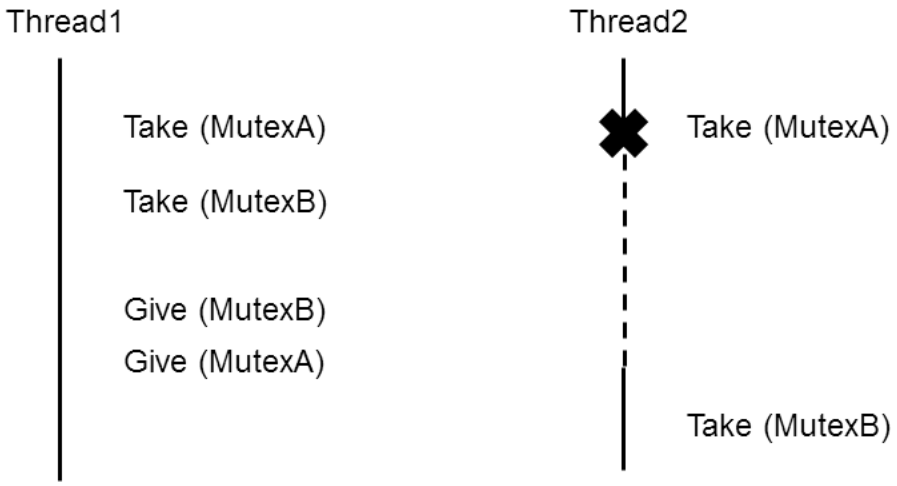
Connext DDS uses *Exclusive Areas* (EAs) to encapsulate mutexes and critical regions. Only one thread at a time can be executing code within an EA. The formal definition of EAs and their implementation ensures safety from deadlock and efficient entering and exiting of EAs. While every *Entity* created by *Connext DDS* has an associated EA, EAs may be shared among several *Entities*. A thread is automatically in the entity's EA when it is calling the entity's listener.

Connext DDS allows you to configure all the *Entities* within an application in a single DDS domain to share a single *Exclusive Area*. This would greatly restrict the concurrency of thread execution within *Connext DDS*'s multi-threaded core. However, doing so would release all restrictions on using *Connext DDS* APIs within your callback code.

You may also have the best of both worlds by configuring a set of *Entities* to share a global EA and others to have their own. For the *Entities* that have their own EAs, the types of *Connext DDS* operations that you can call from the *Entity*'s callback are restricted.

To understand why the general EA framework limits the operations that can be called in an EA, consider a modification to the example previously presented in Figure 4.5: Multiple Mutexes Leading to a Deadlock Condition on the previous page. Suppose we create a rule that is followed when we write our code. "For all situations in which a thread has to take multiple mutexes, we write our code so that the mutexes are always taken in the same order." Following the rule will ensure us that the code we write cannot enter a deadlock situation due to the taking of the mutexes, see Figure 4.6: Taking Multiple Mutexes in a Specific Order to Eliminate Deadlock below.

Figure 4.6: Taking Multiple Mutexes in a Specific Order to Eliminate Deadlock



By creating an order in which multiple mutexes are taken, you can guarantee that no deadlock situation will arise. In this case, if a thread must take both MutexA and MutexB, we write our code so that in those cases MutexA is always taken before MutexB.

Connext DDS defines an ordering of the mutexes it creates. Generally speaking, there are three ordered levels of Exclusive Areas:

- **ParticipantEA**

  There is only one ParticipantEA per participant. The creation and deletion of all *Entities* (**create_xxx(), delete_xxx()**) take the ParticipantEA. In addition, the **enable()** method for an *Entity* and the setting of the *Entity*'s QoS, **set_qos()**, also take the ParticipantEA. There are other functions that take the ParticipantEA: **get_discovered_participants()**, **get_publishers()**, **get_subscribers()**, **get_discovered_topics()**, **ignore_participant()**, **ignore_topic(), ignore_publication(), ignore_subscription()**, **remove_peer()**, and **register_type()**.

- **SubscriberEA**

  This EA is created on a per-*Subscriber* basis by default. You can assume that the methods of a *Subscriber* will take the SubscriberEA. In addition, the *DataReaders* created by a *Subscriber* share the EA of its parent. This means that the methods of a *DataReader* (including **take()** and **read()**) will take the EA of its *Subscriber*. Therefore, **operations on** *DataReaders* **of the same** *Subscriber***, will be serialized**, even when invoked from multiple concurrent application threads. As mentioned, the **enable()** and **set_qos()** methods of both *Subscribers* and *DataReaders* will take the ParticipantEA. The same is true for the **create_datareader()** and **delete_datareader()** methods of the *Subscriber*.

- **PublisherEA**

  This EA is created on a per-*Publisher* basis by default. You can assume that the methods of a *Publisher* will take the PublisherEA. In addition, the *DataWriters* created by a *Publisher* share the EA of its parent. This means that the methods of a *DataWriter* including **write()** will take the EA of its *Publisher*. Therefore, **operations on** *DataWriters* **of the same** *Publisher* **will be serialized**, even when invoked from multiple concurrent application threads. As mentioned, the **enable()** and **set_qos()** methods of both *Publishers* and *DataWriters* will take the ParticipantEA, as well as the **create_datawriter()** and **delete_datawriter()** methods of the *Publisher*.

In addition, you should also be aware that:

- The three EA levels are ordered in the following manner:
  ParticipantEA < SubscriberEA < PublisherEA
- When executing user code in a listener callback of an *Entity*, the internal *Connext DDS* thread is already in the EA of that *Entity* or used by that *Entity*.
- If a thread is in an EA, it can call methods associated with either a higher EA level or that share the *same* EA. It cannot call methods associated with a lower EA level *nor* ones that use a *different* EA at the same level.

4.5.1 Restricted Operations in Listener Callbacks

Based on the background and rules provided in 4.5 Exclusive Areas (EAs) on page 197, this section describes how EAs restrict you from using various *Connext DDS* APIs from within the Listener callbacks of different *Entities*. Reader callbacks take the SubscriberEA. Writer callbacks take the PublisherEA. DomainParticipant callbacks take the ParticipantEA.

> These restrictions do not apply to builtin topic listener callbacks.

By default, each *Publisher* and *Subscriber* creates and uses its own EA, and shares it with its children *DataWriters* and *DataReaders*, respectively. In that case:

Within a *DataWriter/DataReader's Listener* callback, do not:

- Create any *Entities*
- Delete any *Entities*
- Enable any *Entities*
- Set QoS on any *Entities*

Within a *Subscriber*/*DataReader's Listener* callback, do not call any operations on:

- Other *Subscribers*
- *DataReaders* that belong to other *Subscribers*
- *Publishers*/*DataWriters* that have been configured to use the ParticipantEA (see below)

Within a *Publisher*/*DataWriter Listener* callback, do not call any operations on:

- Other *Publishers*
- *DataWriters* that belong to other *Publishers*
- Any *Subscribers*
- Any *DataReaders*

Connext DDS will enforce the rules to avoid deadlock, and any attempt to call an illegal method from within a *Listener* callback will return DDS_RETCODE_ILLEGAL_OPERATION.

However, as previously mentioned, if you are willing to trade-off concurrency for flexibility, you may configure individual *Publishers* and *Subscribers* (and thus their *DataWriters* and *DataReaders*) to share the EA of their participant. In the limit, only a single ParticipantEA is shared among all *Entities*. When doing so, the restrictions above are lifted at a cost of greatly reduced concurrency. You may create/delete/enable/set_qos's and generally call all of the methods of any other entity in the Listener callbacks of *Entities* that share the ParticipantEA.

Use the 7.4.3 EXCLUSIVE_AREA QosPolicy (DDS Extension) on page 350 of the *Publisher* or *Subscriber* to set whether or not to use a shared exclusive area. By default, *Publishers* and *Subscribers* will create and use their own individual EAs. You can configure a subset of the *Publishers* and *Subscribers* to share the ParticipantEA if you need the Listeners associated with those *Entities* or child *Entities* to be able to call any of the restricted methods listed above.

Regardless of how the EXCLUSIVE_AREA QosPolicy is set, the following operations are never allowed in any *Listener* callback:

- Destruction of the entity to which the *Listener* is attached. For instance, a *DataWriter*/*DataReader Listener* callback must not destroy its *DataWriter*/*DataReader*.

- Within the *TopicListener* callback, you cannot call any operations on *DataReaders*, *DataWriters*, *Publishers*, *Subscriber*s or *DomainParticipants*.

4.6 Conditions and WaitSets

Conditions and *WaitSets* provide another way for *Connext DDS* to communicate status changes (including the arrival of data) to your application. While a *Listener* is used to provide a callback for asynchronous access, *Conditions* and *WaitSets* provide synchronous data access. In other words, *Listeners* are notification-based and *Conditions* are wait-based.

A *WaitSet* allows an application to wait until one or more attached *Conditions* becomes true (or until a timeout expires).

Briefly, your application can create a *WaitSet*, attach one or more *Conditions* to it, then call the *WaitSet's* **wait()** operation. The **wait()** blocks until one or more of the *WaitSet's* attached *Conditions* becomes TRUE.

A *Condition* has a **trigger_value** that can be TRUE or FALSE. You can retrieve the current value by calling the *Condition*'s only operation, **get_trigger_value()**.

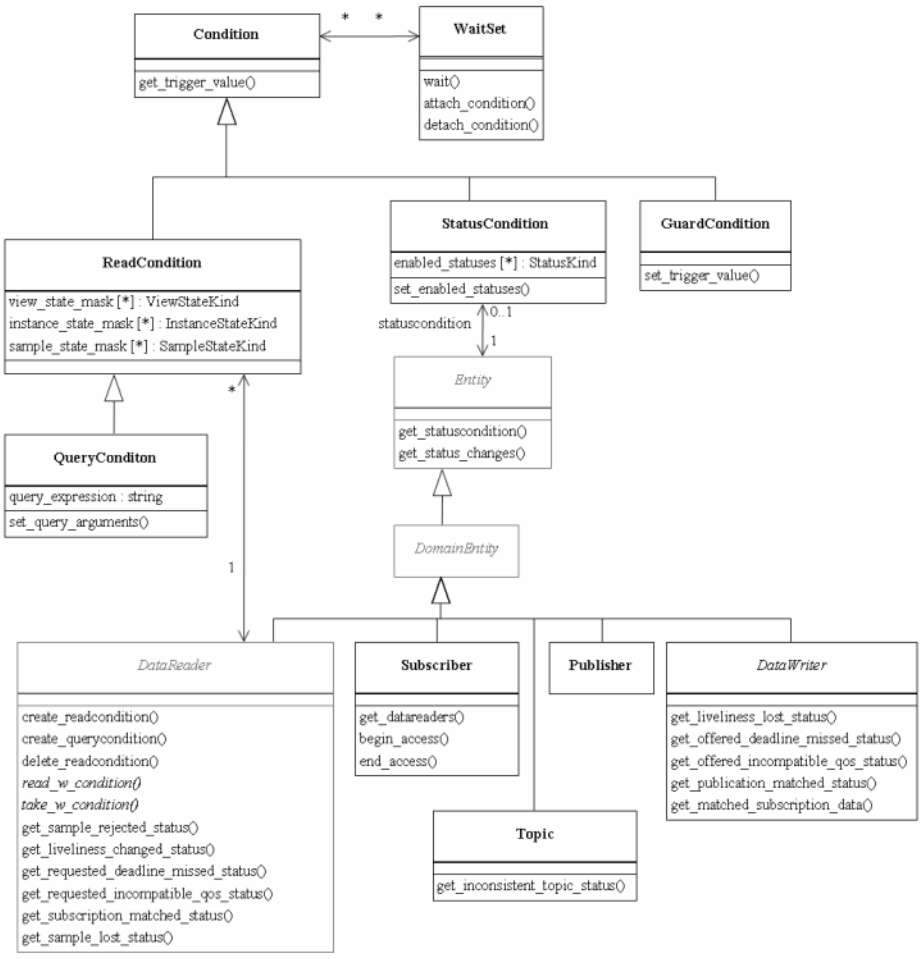
There are three kinds of *Conditions.* A *Condition* is a root class for all the conditions that may be attached to a *WaitSet*. This basic class is specialized in three classes:

- 4.6.6 GuardConditions on page 209 are created by your application. Each *GuardCondition* has a single, user-settable, boolean **trigger_value**. Your application can manually trigger the *GuardCondition* by calling **set_trigger_value()**. *Connext DDS* does not trigger or clear this type of condition—it is completely controlled by your application.
- 4.6.7 ReadConditions and QueryConditions on page 209 are created by your application, but triggered by *Connext DDS*. *ReadCondition*s provide a way for you to specify the DDS data samples that you want to wait for, by indicating the desired sample-states, view-states, and instance-states[1].
- 4.6.8 StatusConditions on page 212 are created automatically by *Connext DDS*, one for each *Entity*. A *StatusCondition* is triggered by *Connext DDS* when there is a change to any of that *Entity's* enabled statuses.

Figure 4.7: Conditions and WaitSets on the next page shows the relationship between these objects and other *Entities* in the system.

[1]These states are described in 8.4.6 The SampleInfo Structure on page 560.

Figure 4.7: Conditions and WaitSets



A *WaitSet* can be associated with more than one *Entity* (including multiple *DomainParticipants*). It can be used to wait on *Conditions* associated with different *DomainParticipants*. A *WaitSet* can only be in use by one application thread at a time.

4.6.1 Creating and Deleting WaitSets

There is no factory for creating or deleting a *WaitSet*; use the natural means in each language binding (for example, “new” or “delete” in C++ or Java).

There are two ways to create a *WaitSet*—with or without specifying *WaitSet* properties (**DDS_WaitSetProperty_t**, described in Table 4.6 WaitSet Properties (DDS_WaitSet_Property_t)). 4.6.3 Waiting for Conditions on page 205 describes how the properties are used.

Table 4.6 WaitSet Properties (DDS_WaitSet_Property_t)

Type	Field Name	Description
long	max_event_count	Maximum number of trigger events to cause a *WaitSet* to wake up.
DDS_Duration_t	max_event_delay	Maximum delay from occurrence of first trigger event to cause a *WaitSet* to wake up. This value should reflect the maximum acceptable latency increase (time delay from occurrence of the event to waking up the *WaitSet*) incurred as a result of waiting for additional events before waking up the *WaitSet*.

To create a *WaitSet* with default behavior:

```
WaitSet* waitset = new WaitSet();
```

To create a *WaitSet* with properties:

```
DDS_WaitSetProperty_t prop;
Prop.max_event_count = 5;
DDSWaitSet* waitset = new DDSWaitSet(prop);
```

To delete a *WaitSet*:

```
delete waitset;
```

4.6.2 WaitSet Operations

WaitSets have only a few operations, as listed in Table 4.7 WaitSet Operations. For details, see the API Reference HTML documentation.

Table 4.7 WaitSet Operations

Operation	Description
attach_condition	Attaches a *Condition* to this *WaitSet*. You may attach a *Condition* to a *WaitSet* that is currently being waited upon (via the **wait()** operation). In this case, if the *Condition* has a **trigger_value** of TRUE, then attaching the *Condition* will unblock the *WaitSet*. Adding a *Condition* that is already attached to the *WaitSet* has no effect. If the Condition cannot be attached, *Connext DDS* will return an OUT_OF_RESOURCES error code.
detach_condition	Detaches a *Condition* from the *WaitSet*. Attempting to detach a *Condition* that is not to attached the *WaitSet* will result in a PRECONDITION_NOT_MET error code.
wait	Blocks execution of the thread until one or more attached *Conditions* becomes true, or until a user-specified timeout expires. See 4.6.3 Waiting for Conditions on the next page.

Table 4.7 WaitSet Operations

Operation	Description
dispatch	(Modern C++ API only) Blocks execution of the thread until one or more attached *Conditions* becomes true, or until a user-specified timeout expires. Then it calls the handlers attached to the active conditions and returns. For more information see the API Reference HTML documentation for the DDS Modern C++ API (Modules, Infrastructure Module, Conditions and WaitSets).
get_conditions	Retrieves a list of attached *Conditions*.
get_property	Retrieves the DDS_WaitSetProperty_t structure of the associated *WaitSet*.
set_property	Sets the DDS_WaitSetProperty_t structure, to configure the associated *WaitSet* to return after one or more trigger events have occurred.

4.6.3 Waiting for Conditions

The *WaitSet's* **wait()** operation allows an application thread to wait for any of the attached *Conditions* to trigger (become TRUE).

If any of the attached *Conditions* are already TRUE when **wait()** is called, it returns immediately.

If none of the attached *Conditions* are already TRUE, **wait()** blocks—suspending the calling thread. The waiting behavior depends on whether or not properties were set when the WaitSet was created:

- **If properties *are not* specified when the *WaitSet* is created:**

  The *WaitSet* will wake up as soon as a trigger event occurs (that is, when an attached *Condition* becomes true). This is the default behavior if properties are not specified.

  This 'immediate wake-up' behavior is optimal if you want to minimize latency (to wake up and process the data or event as soon as possible). However, "waking up" involves a context switch—the operating system must signal and schedule the thread that is waiting on the *WaitSet*. A context switch consumes significant CPU and therefore waking up on each data update is not optimal in situations where the application needs to maximize throughput (the number of messages processed per second). This is especially true if the receiver is CPU limited.

- **If properties *are* specified when the *WaitSet* is created:**

  The properties configure the waiting behavior of a *WaitSet*. If no conditions are true at the time of the call to wait, the *WaitSet* will wait for (a) **max_event_count** trigger events to occur, (b) up to **max_event_delay** time from the occurrence of the first trigger event, or (c) up to the timeout maximum wait duration specified in the call to **wait()**. (**Note:** The resolution of the timeout period is constrained by the resolution of the system clock.)

If **wait()** does not timeout, it returns a list of the attached *Conditions* that became TRUE and therefore unblocked the wait.

If **wait()** does timeout, it returns TIMEOUT and an empty list of *Conditions*.

Only one application thread can be waiting on the same *WaitSet*. If **wait()** is called on a *WaitSet* that already has a thread blocking on it, the operation will immediately return PRECONDITION_NOT_MET.

> If you detach a *Condition* from a *Waitset* that is currently in a wait state (that is, you are waiting on it), **wait()** may return OK *and* an empty sequence of conditions.

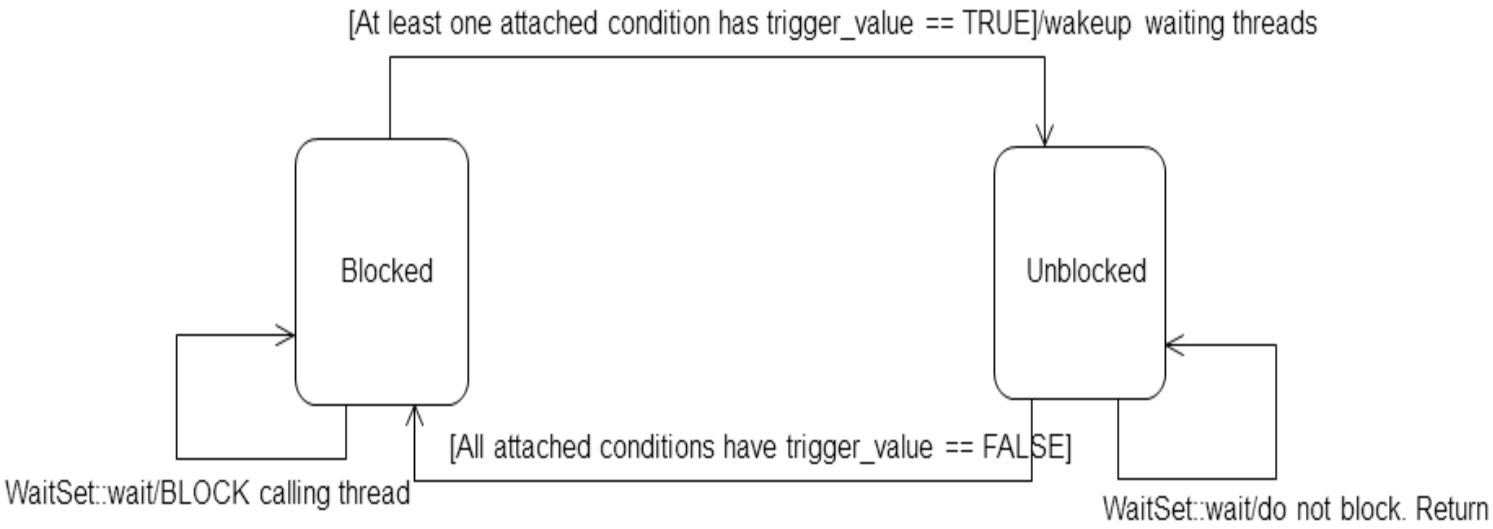
4.6.3.1 How WaitSets Block

The blocking behavior of the *WaitSet* is illustrated in Figure 4.8: WaitSet Blocking Behavior below. The result of a **wait()** operation depends on the state of the *WaitSet*, which in turn depends on whether at least one attached *Condition* has a **trigger_value** of TRUE.

If the **wait()** operation is called on a *WaitSet* with state BLOCKED, it will block the calling thread. If **wait()** is called on a *WaitSet* with state UNBLOCKED, it will return immediately.

When the *WaitSet* transitions from BLOCKED to UNBLOCKED, it wakes up the thread (if there is one) that had called **wait()** on it. There is no implied "event queuing" in the awakening of a *WaitSet*. That is, if several *Conditions* attached to the *WaitSet* have their **trigger_value** transition to true in sequence, *Connext DDS* will only unblock the *WaitSet* once.

Figure 4.8: WaitSet Blocking Behavior



4.6.4 Processing Triggered Conditions–What to do when Wait() Returns

When **wait()** returns, it provides a list of the attached *Condition* objects that have a **trigger_value** of true. Your application can use this list to do the following for each *Condition* in the returned list:

- If it is a *StatusCondition:*
  - First, call **get_status_changes()** to see what status changed.
  - If the status changes refer to plain communication status: call **get_<***communication_status***>()** on the relevant *Entity*.
  - If the status changes refer to DATA_ON_READERS[1]: call **get_datareaders()** on the relevant *Subscriber*.
  - If the status changes refer to DATA_AVAILABLE: call **read()** or **take()** on the relevant *DataReader*.
- If it is a *ReadCondition* or a *QueryCondition*: You may want to call **read_w_condition()** or **take_w_condition()** on the *DataReader,* with the *ReadCondition* as a parameter (see 8.4.3.6 read_w_condition and take_w_condition on page 556).

  Note that this is just a suggestion, you do not have to use the "w_condition" operations (or any read/-take operations, for that matter) simply because you used a *WaitSet*. The "w_condition" operations are just a convenient way to use the same status masks that were set on the *ReadCondition* or *QueryCondition*.
- If it is a *GuardCondition*: check to see which *GuardCondition* changed, then react accordingly. Recall that *GuardConditions* are completely controlled by your application.

See 4.6.5 Conditions and WaitSet Example below to see how to determine which of the attached *Conditions* is in the returned list.

4.6.5 Conditions and WaitSet Example

This example creates a *WaitSet* and then waits for one or more attached *Conditions* to become true.

```
// Create a WaitSet
WaitSet* waitset = new WaitSet();
// Attach Conditions
DDSCondition* cond1 = ...;
DDSCondition* cond2 = entity->get_statuscondition();
DDSCondition* cond3 = reader->create_readcondition(
                                DDS_NOT_READ_SAMPLE_STATE,
                                DDS_ANY_VIEW_STATE,
                                DDS_ANY_INSTANCE_STATE);
DDSCondition* cond4 = new DDSGuardCondition();
DDSCondition* cond5 = ...;
```

[1] And then read/take on the returned *DataReader* objects.

```
DDS_ReturnCode_t retcode;

retcode = waitset->attach_condition(cond1);
if (retcode != DDS_RETCODE_OK) {
      // ... error
}
retcode = waitset->attach_condition(cond2);
if (retcode != DDS_RETCODE_OK) {
      // ... error
}
retcode = waitset->attach_condition(cond3);
if (retcode != DDS_RETCODE_OK) {
      // ... error
}
retcode = waitset->attach_condition(cond4);
if (retcode != DDS_RETCODE_OK) {
      // ... error
}
retcode = waitset->attach_condition(cond5);
if (retcode != DDS_RETCODE_OK) {
      // ... error
}
// Wait for a condition to trigger or timeout
DDS_Duration_t timeout = { 0, 1000000 }; // 1ms
DDSConditionSeq active_conditions; // holder for active conditions
bool is_cond1_triggered = false;
bool is_cond2_triggered = false;
DDS_ReturnCode_t retcode;

retcode = waitset->wait(active_conditions, timeout);
if (retcode == DDS_RETCODE_TIMEOUT) {
    // handle timeout
    printf("Wait timed out. No conditions were triggered.\n");
  }
else if (retcode != DDS_RETCODE_OK) {
      // ... check for cause of failure
} else {
  // success
     if (active_conditions.length() == 0) {
           printf("Wait timed out!! No conditions triggered.\n");
     } else
          // check if "cond1" or "cond2" are triggered:
         for(i = 0; i < active_conditions.length(); ++i) {
            if (active_conditions[i] == cond1) {
                printf("Cond1 was triggered!");
                is_cond1_triggered = true;
            }
            if (active_conditions[i] == cond2) {
                printf("Cond2 was triggered!");
                is_cond2_triggered = true;
            }
            if (is_cond1_triggered && is_cond2_triggered) {
                break;
            }
        }
   }
}
```

```
if (is_cond1_triggered) {
     // ... do something because "cond1" was triggered ...
}
if (is_cond2_triggered) {
     // ... do something because "cond2" was triggered ...
}
// Delete the waitset
delete waitset;
waitset = NULL;
```

4.6.6 GuardConditions

GuardConditions are created by your application. *GuardConditions* provide a way for your application to manually awaken a *WaitSet*. Like all *Conditions*, it has a single boolean **trigger_value**. Your application can manually trigger the *GuardCondition* by calling **set_trigger_value()**.

Connext DDS does not trigger or clear this type of condition—it is completely controlled by your application.

A GuardCondition has no factory. It is created as an object directly by the natural means in each language binding (e.g., using "new" in C++ or Java). For example:

```
// Create a Guard Condition
Condition* my_guard_condition = new GuardCondition();
// Delete a Guard Condition
delete my_guard_condition;
```

When first created, the **trigger_value** is FALSE.

A GuardCondition has only two operations, **get_trigger_value()** and **set_trigger_value()**.

When your application calls **set_trigger_value(DDS_BOOLEAN_TRUE)**, *Connext DDS* will awaken any *WaitSet* to which the *GuardCondition* is attached.

4.6.7 ReadConditions and QueryConditions

ReadConditions are created by your application, but triggered by *Connext DDS*. *ReadCondition*s provide a way for you to specify the DDS data samples that you want to wait for, by indicating the desired sample-states, view-states, and instance-states (see 6.1 Instance States on page 257). Then *Connext DDS* will trigger the *ReadCondition* when suitable DDS samples are available.

A *QueryCondition* is a special *ReadCondition* that allows you to specify a query expression and parameters, so you can filter on the locally available (already received) data. *QueryConditions* use the same SQL-based filtering syntax as ContentFilteredTopics for query expressions, parameters, etc. Unlike ContentFilteredTopics, *QueryConditions* are applied to data already received, so they do not affect the reception of data.

Multiple mask combinations can be associated with a single content filter. This is important because the maximum number of content filters that may be created per *DataReader* is 32, but more than 32

QueryConditions may be created per *DataReader*, if they are different mask-combinations of the same content filter.

ReadConditions and *QueryConditions* are created by using the *DataReader's* **create_readcondition()** and **create_querycondition()** operations. For example:

```
DDSReadCondition* my_read_condition =
       reader->create_readcondition(
                         DDS_NOT_READ_SAMPLE_STATE,
                         DDS_ANY_VIEW_STATE,
                         DDS_ANY_INSTANCE_STATE);
DDSQueryCondition* my_query_condition =
       reader->create_querycondition(
                        DDS_NOT_READ_SAMPLE_STATE,
                        DDS_ANY_VIEW_STATE,
                        DDS_ANY_INSTANCE_STATE
                        query_expression,
                        query_parameters);
```

You can also use the alternative *DataReader* operations, **create_readcondition_w_params()** and **create_querycondition_w_params()**, which perform the same action as **create_readcondition()** and **create_querycondition()**, but allow the application to explicitly set the masks in the DDS_ReadConditionParams and DDS_QueryConditionParams structures (see Table 4.9 DDS_ReadConditionParams and Table 4.10 DDS_QueryConditionParams).

In addition, **create_readcondition_w_params()** and **create_querycondition_w_params()** allow selecting between TopicQuery samples and LIVE samples (see Topic Queries (Chapter 24 on page 962)).

A *DataReader* can have multiple attached *ReadConditions* and *QueryConditions*. A *ReadCondition* or *QueryCondition* may only be attached to one *DataReader*.

To delete a *ReadCondition* or *QueryCondition*, use the *DataReader's* **delete_readcondition()** operation:

```
DDS_ReturnCode_t  delete_readcondition (DDSReadCondition *condition)
```

After a *ReadCondition* is triggered, use the *FooDataReader's* read/take "with condition" operations (see 8.4.3.6 read_w_condition and take_w_condition on page 556) to access the DDS samples.

Table 4.8 ReadCondition and QueryCondition Operations lists the operations available on *ReadConditions*.

Table 4.8 ReadCondition and QueryCondition Operations

Operation	Description
get_datareader	Returns the *DataReader* to which the *ReadCondition* or *QueryCondition* is attached.
get_instance_state_mask	Returns the instance states that were specified when the *ReadCondition* or *QueryCondition* was created. These are the DDS sample's instance states that *Connext DDS* checks to determine whether or not to trigger the *ReadCondition* or *QueryCondition*.

Table 4.8 ReadCondition and QueryCondition Operations

Operation	Description
get_ sample_ state_mask	Returns the sample-states that were specified when the *ReadCondition* or *QueryCondition* was created. These are the sample states that *Connext DDS* checks to determine whether or not to trigger the *ReadCondition* or *QueryCondition.*
get_view_ state_mask	Returns the view-states that were specified when the *ReadCondition* or *QueryCondition* was created. These are the view states that *Connext DDS* checks to determine whether or not to trigger the *ReadCondition* or *QueryCondition.*
get_stream_ kind_mask	Retrieves the stream kind mask for the condition.

Table 4.9 DDS_ReadConditionParams

Type	Field Name	Description
DDS_SampleStateMask	sample_states	Sample state of the data samples that are of interest.
DDS_ViewStateMask	view_states	View state of the data samples that are of interest.
DDS_InstanceStateMask	instance_states	Instance state of the data samples that are of interest.
DDS_StreamKindMask	stream_kinds	Stream kind of the data samples that are of interest.

Table 4.10 DDS_QueryConditionParams

Type	Field Name	Description
struct DDS_ReadConditionParams	as_readconditionparam	Read condition parameters
char *	query_expression	Expression for the query.
struct DDS_StringSeq	query_parameters	Parameters for the query expression.

4.6.7.1 How ReadConditions are Triggered

A *ReadCondition* has a **trigger_value** that determines whether the attached *WaitSet* is BLOCKED or UNBLOCKED. Unlike the *StatusCondition*, the **trigger_value** of the *ReadCondition* is tied to the presence of at least one DDS sample with a sample-state, view-state, and instance-state that matches those set in the *ReadCondition*. Furthermore, for the *QueryCondition* to have a **trigger_value**==TRUE, the data associated with the DDS sample must be such that the **query_expression** evaluates to TRUE.

The **trigger_value** of a *ReadCondition* depends on the presence of DDS samples on the associated *DataReader.* This implies that a single 'take' operation can potentially change the **trigger_value** of several *ReadConditions* or *QueryCondition*s. For example, if all DDS samples are taken, any *ReadConditions* and

QueryConditions associated with the *DataReader* that had **trigger_value**==TRUE before will see the **trigger_value** change to FALSE. Note that this does not guarantee that *WaitSet* objects that were separately attached to those conditions will not be awakened. Once we have **trigger_value**==TRUE on a condition, it may wake up the attached *WaitSet*, the condition transitioning to **trigger_value**==FALSE does not necessarily 'unwakeup' the *WaitSet,* since 'unwakening' may not be possible. The consequence is that an application blocked on a *WaitSet* may return from **wait()** with a list of conditions, some of which are no longer "active." This is unavoidable if multiple threads are concurrently waiting on separate *WaitSet* objects and taking data associated with the same *DataReader*.

Consider the following example: A *ReadCondition* that has a sample_state_mask = {NOT_READ} will have a **trigger_value** of TRUE whenever a new DDS sample arrives and will transition to FALSE as soon as all the newly arrived DDS samples are either read (so their status changes to READ) or taken (so they are no longer managed by Connext DDS). However, if the same *ReadCondition* had a **sample_state_mask** = {READ, NOT_READ}, then the **trigger_value** would only become FALSE once all the newly arrived DDS samples are *taken* (it is not sufficient to just *read* them, since that would only change the SampleState to READ), which overlaps the mask on the *ReadCondition*.

4.6.7.2 QueryConditions

A *QueryCondition* is a special *ReadCondition* that allows your application to also specify a filter on the locally available data.

The query expression is similar to a SQL WHERE clause and can be parameterized by arguments that are dynamically changeable by the **set_query_parameters()** operation.

QueryConditions are triggered in the same manner as *ReadConditions*, with the additional requirement that the DDS sample must also satisfy the conditions of the content filter associated with the *QueryCondition*.

Table 4.11 QueryCondition Operations

Operation	Description
get_query_expression	Returns the query expression specified when the *QueryCondition* was created.
get_query_parameters	Returns the query parameters associated with the *QueryCondition*. That is, the parameters specified on the last successful call to **set_query_parameters(),** or if **set_query_parameters()** was never called, the arguments specified when the *QueryCondition* was created.
set_query_parameters	Changes the query parameters associated with the *QueryCondition*.

4.6.8 StatusConditions

StatusConditions are created automatically by *Connext DDS*, one for each *Entity*. *Connext DDS* will trigger the *StatusCondition* when there is a change to any of that *Entity's* enabled statuses.

By default, when *Connext DDS* creates a *StatusCondition*, all status bits are turned on, which means it will check for all statuses to determine when to trigger the *StatusCondition*. If you only want *Connext DDS* to check for specific statuses, you can use the *StatusCondition's* **set_enabled_statuses()** operation and set just the desired status bits.

The **trigger_value** of the *StatusCondition* depends on the communication status of the *Entity* (e.g., arrival of data, loss of information, etc.), 'filtered' by the set of enabled statuses on the ***StatusCondition***.

The set of enabled statuses and its relation to ***Listeners*** and ***WaitSet***s is detailed in 4.6.8.1 How StatusConditions are Triggered below.

Table 4.12 StatusCondition Operations lists the operations available on *StatusConditions*.

Table 4.12 StatusCondition Operations

Operation	Description
set_enabled_statuses	Defines the list of communication statuses that are taken into account to determine the **trigger_value** of the *StatusCondition*. This operation may change the **trigger_value** of the *StatusCondition*. *WaitSets* behavior depend on the changes of the trigger_value of their attached conditions. Therefore, any *WaitSet* to which the *StatusCondition* is attached is potentially affected by this operation. If this function is not invoked, the default list of enabled statuses includes all the statuses.
get_enabled_statuses	Retrieves the list of communication statuses that are taken into account to determine the **trigger_value** of the *StatusCondition*. This operation returns the statuses that were explicitly set on the last call to **set_enabled_statuses()** or, if **set_enabled_statuses()** was never called, the default list
get_entity	Returns the *Entity* associated with the *StatusCondition*. Note that there is exactly one *Entity* associated with each *StatusCondition*.

Unlike other types of *Conditions*, *StatusConditions* are created by *Connext DDS*, not by your application. To access an *Entity's StatusCondition*, use the *Entity's* **get_statuscondition()** operation. For example:

```
Condition* my_status_condition = entity->get_statuscondition();
```

In the Modern C++ API, use the *StatusCondition* constructor to obtain a reference to the *Entity's* condition. For example:

```
dds::core::cond::StatusCondition my_status_condition(entity)
```

After a *StatusCondition* is triggered, call the *Entity's* **get_status_changes()** operation to see which status (es) changed.

Note: Not all statuses will activate the *StatusCondition*. Refer to the API Reference HTML documentation of the individual statuses for that information.

4.6.8.1 How StatusConditions are Triggered

The **trigger_value** of a *StatusCondition* is the boolean OR of the **ChangedStatusFlag** of all the communication statuses to which it is sensitive. That is, **trigger_value is** FALSE only if *all* the values of the **ChangedStatusFlags** are FALSE.

The sensitivity of the *StatusCondition* to a particular communication status is controlled by the list of **enabled_statuses** set on the *Condition* by means of the **set_enabled_statuses()** operation.

Once a *StatusCondition's* **trigger_value** becomes true, it remains true until the status that changed is reset. To reset a status, call the related **get_*_status()** operation. Or, in the case of the data available status, call **read()**, **take()**, or one of their variants.

Therefore, if you are using a *StatusCondition* on a *WaitSet* to be notified of events, your thread will wake up when one of the statuses associated with the *StatusCondition* becomes true. If you do not reset the status, the *StatusCondition's* **trigger_value** remains true and your *WaitSet* will not block again—it will immediately wake up when you call **wait()**.

4.6.9 Using Both Listeners and WaitSets

You can use *Listeners* and *WaitSets* in the same application. For example, you may want to use *WaitSets* and *Conditions* to access the data, and *Listeners* to be warned asynchronously of erroneous communication statuses.

We recommend that you choose one or the other mechanism for each particular communication status (not both). However, if both are enabled, the *Listener* mechanism is used first, then the *WaitSet* objects are signaled.

Chapter 5 Working with Topics

For a *DataWriter* and *DataReader* to communicate, they need to use the same *Topic*. A *Topic* includes a name and an association with a user data type that has been registered with *Connext DDS*. Topic names are how different parts of the communication system find each other. *Topics* are named streams of data of the same data type. *DataWriters* publish DDS samples into the stream; *DataReaders* subscribe to data from the stream. More than *one* Topic can use the same user data type, but each *Topic* needs a unique name.

Topics, *DataWriters*, and *DataReaders* relate to each other as follows:

- Multiple *Topics* (each with a unique name) can use the same user data type.
- Applications may have multiple *DataWriters* for each *Topic*.
- Applications may have multiple *DataReaders* for each *Topic*.
- *DataWriters* and *DataReaders* must be associated with the same *Topic* in order for them to be connected.
- *Topics* are created and deleted by a *DomainParticipant,* and as such, are owned by that *DomainParticipant*. When two applications (*DomainParticipants*) want to use the same *Topic*, they must both create the *Topic* (even if the applications are on the same node).

Connext DDS uses 'Builtin Topics' to discover and keep track of remote entities, such as new participants in the DDS domain. Builtin Topics are discussed in Built-In Topics (Chapter 18 on page 825).

5.1 Topics

Before you can create a Topic, you need a user data type (see Data Types and DDS Data Samples (Chapter 3 on page 27)) and a DomainParticipant (DomainParticipants (9.3 on page 604)). The user data type must be registered with the *DomainParticipant* (see 3.2.8 Type Codes for Built-in Types on page 74).

Once you have created a *Topic*, what do you do with it? Topics are primarily used as parameters in other *Entities*' operations. For instance, a Topic is required when a *Publisher* or *Subscriber* creates a *DataWriter* or *DataReader*, respectively. *Topics* do have a few operations of their own, as listed in Table 5.1 Topic Operations. For details on using these operations, see the reference section or the API Reference HTML documentation.

Figure 5.1: Topic Module

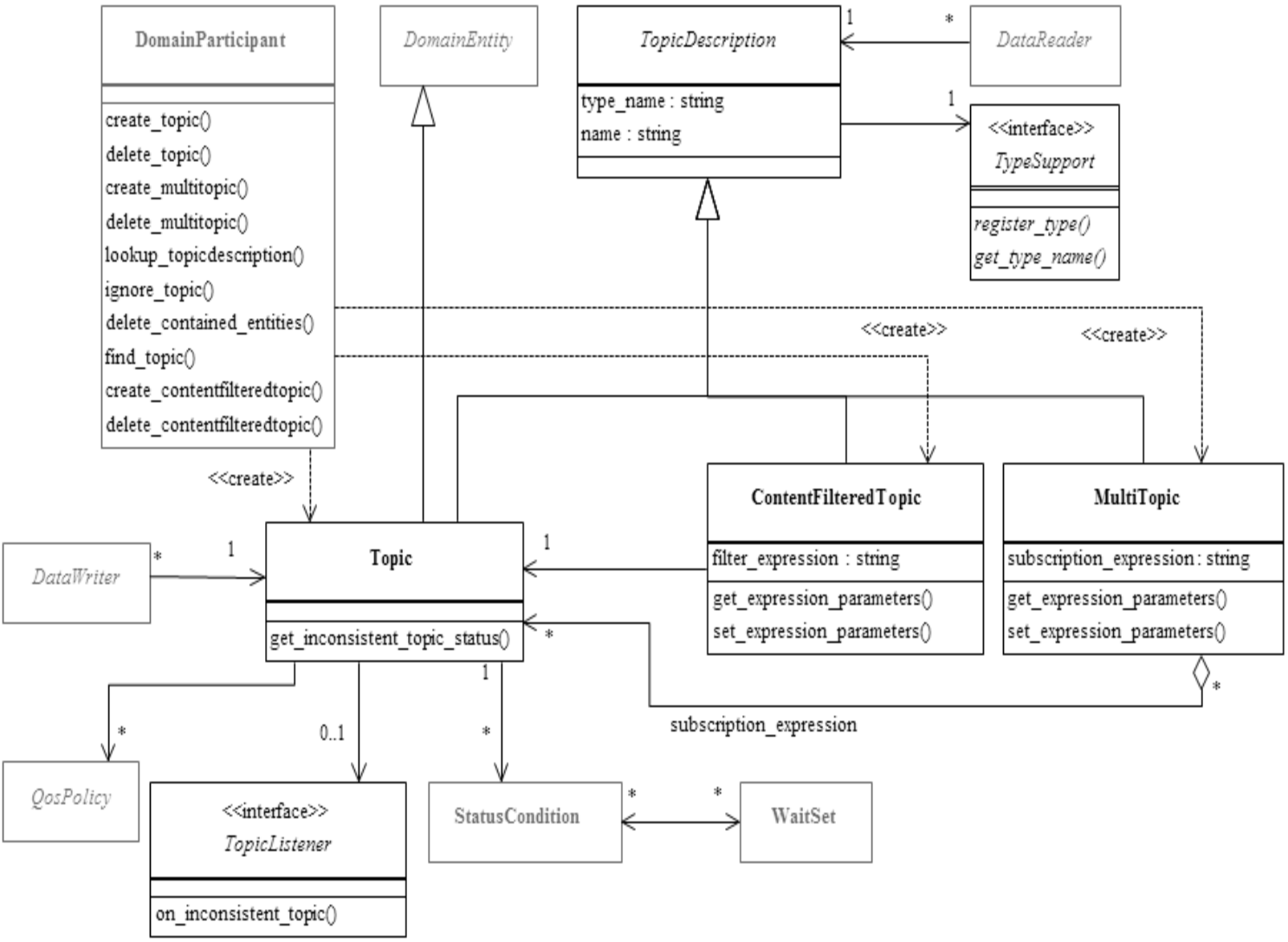


Table 5.1 Topic Operations

Purpose	Operation	Description	Reference
Configuring the Topic	enable	Enables the *Topic*.	4.1.2 Enabling DDS Entities on page 168
	get_qos	Gets the *Topic's* current QosPolicy settings. This is most often used in preparation for calling set_qos().	5.1.3 Setting Topic QosPolicies on page 219
	set_qos	Sets the *Topic's* QoS. You can use this operation to change the values for the *Topic's* QosPolicies. Note, however, that not all QosPolicies can be changed after the *Topic* has been created.	
	equals	Compares two *Topic's* QoS structures for equality.	5.1.3.2 Comparing QoS Values on page 221
	set_qos_with_profile	Sets the *Topic's* QoS based on a specified QoS profile.	
	get_listener	Gets the currently installed Listener.	5.1.5 Setting Up TopicListeners on page 223
	set_listener	Sets the *Topic's Listener*. If you create the *Topic* without a *Listener*, you can use this operation to add one later. Setting the listener to NULL will remove the listener from the *Topic*.	
	narrow	A type-safe way to cast a pointer. This takes a DDSTopicDescription pointer and 'narrows' it to a DDSTopic pointer.	7.3.7 Using a Type-Specific DataWriter (FooDataWriter) on page 307
Checking Status	get_inconsistent_topic_status	Allows an application to retrieve a *Topic's* INCONSISTENT_TOPIC_STATUS status.	5.3.1 INCONSISTENT_TOPIC Status on page 226
	get_status_changes	Gets a list of statuses that have changed since the last time the application read the status or the listeners were called.	4.1.4 Getting Status and Status Changes on page 171
Navigating Relationships	get_name	Gets the *topic_name* string used to create the *Topic*.	5.1.1 Creating Topics below
	get_type_name	Gets the *type_name* used to create the *Topic*.	
	get_participant	Gets the *DomainParticipant* to which this *Topic* belongs.	5.1.6.1 Finding a Topic's DomainParticipant on page 223

5.1.1 Creating Topics

Topics are created using the *DomainParticipant*'s **create_topic()** or **create_topic_with_profile()** operation.

A QoS profile is way to use QoS settings from an XML file or string. With this approach, you can change QoS settings without recompiling the application. For details, see Configuring QoS with XML (Chapter 19 on page 842).

```
DDSTopic * create_topic (
       const char *topic_name,
       const char *type_name,
       const DDS_TopicQos &qos,
       DDSTopicListener *listener,
       DDS_StatusMask mask)
DDSTopic * create_topic_with_profile (
       const char *topic_name,
       const char *type_name,
       const char *library_name,
       const char *profile_name,
       DDSTopicListener *listener,
       DDS_StatusMask mask)
```

Where:

topic_name Name for the new *Topic*, must not exceed 255 characters.

type_name Name for the user data type, must not exceed 255 characters. It must be the same name that was used to register the DDS type, and the DDS type must be registered with the same DomainParticipant used to create this *Topic*. See 3.6 Using RTI Code Generator (rtiddsgen) on page 152.

qos If you want to use the default QoS settings (described in the API Reference HTML documentation), use DDS_TOPIC_QOS_DEFAULT for this parameter (see Figure 5.2: Creating a Topic with Default QosPolicies on the next page). If you want to customize any of the QosPolicies, supply a QoS structure (see 5.1.3 Setting Topic QosPolicies on the next page).

If you use **DDS_TOPIC_QOS_DEFAULT**, it is *not* safe to create the topic while another thread may be simultaneously calling the *DomainParticipant's* **set_default_topic_qos()** operation.

listener *Listeners* are callback routines. *Connext DDS* uses them to notify your application of specific events (status changes) that may occur with respect to the *Topic*. The *listener* parameter may be set to NULL if you do not want to install a *Listener*. If you use NULL, the *Listener* of the DomainParticipant to which the *Topic* belongs will be used instead (if it is set). For more information on *TopicListeners*, see 5.1.5 Setting Up TopicListeners on page 223.

mask This bit-mask indicates which status changes will cause the *Listener* to be invoked. The bits in the mask that are set must have corresponding callbacks implemented in the *Listener*. If you use NULL for the *Listener*, use DDS_STATUS_MASK_NONE for this parameter. If the *Listener* implements all callbacks, use DDS_STATUS_MASK_ALL. For information on statuses, see 4.4 Listeners on page 189.

library_name A QoS Library is a named set of QoS profiles. See 19.3 QoS Profiles on page 844. If NULL is used for **library_name**, the *DomainParticipant's* default library is assumed.

profile_name A QoS profile groups a set of related QoS, usually one per entity. See 19.3 QoS Profiles on page 844. If NULL is used for **profile_name**, the *DomainParticipant's* default profile is assumed and **library_name** is ignored.

It is not safe to create a topic while another thread is calling **lookup_topicdescription()** for that same topic (see 9.3.8 Looking up Topic Descriptions on page 623).

Figure 5.2: Creating a Topic with Default QosPolicies

```
const char *type_name = NULL;
// register the DDS type
type_name = FooTypeSupport::get_type_name();
retcode = FooTypeSupport::register_type(
       participant, type_name);
if (retcode != DDS_RETCODE_OK) {
    // handle error
}
// create the topic
DDSTopic* topic = participant->create_topic(
       "Example Foo", type_name,
       DDS_TOPIC_QOS_DEFAULT,
       NULL, DDS_STATUS_MASK_NONE);
if (topic == NULL) {
    // process error here
};
```

For more examples, see 5.1.3.1 Configuring QoS Settings when the Topic is Created on page 221.

5.1.2 Deleting Topics

To delete a Topic, use the DomainParticipant's **delete_topic()** operation:

```
DDS_ReturnCode_t delete_topic (DDSTopic *  topic)
```

Note, however, that you cannot delete a Topic if there are any existing *DataReaders* or *DataWriters* (belonging to the same *DomainParticipant*) that are still using it. All *DataReaders* and *DataWriters* associated with the *Topic* must be deleted first.

Note: In the Modern C++ API, *Entities* are automatically destroyed.

5.1.3 Setting Topic QosPolicies

A *Topic's* QosPolicies control its behavior, or more specifically, the behavior of the *DataWriters* and *DataReaders* of the *Topic*. You can think of the policies as the 'properties' for the *Topic*. The **DDS_TopicQos** structure has the following format:

```
DDS_TopicQos struct  {
       DDS_TopicDataQosPolicy           topic_data;
       DDS_DurabilityQosPolicy          durability;
       DDS_DurabilityServiceQosPolicy   durability_service;
       DDS_DeadlineQosPolicy            deadline;
       DDS_LatencyBudgetQosPolicy       latency_budget;
       DDS_LivelinessQosPolicy          liveliness;
       DDS_ReliabilityQosPolicy         reliability;
       DDS_DestinationOrderQosPolicy    destination_order;
       DDS_HistoryQosPolicy             history;
       DDS_ResourceLimitsQosPolicy      resource_limits;
       DDS_TransportPriorityQosPolicy   transport_priority;
       DDS_LifespanQosPolicy            lifespan;
       DDS_OwnershipQosPolicy           ownership;
```

```
        DDS_DataRepresentationQosPolicy   representation
} DDS_TopicQos;
```

Table 5.2 Topic QosPolicies summarizes the meaning of each policy (arranged alphabetically). For information on *why* you would want to change a particular QosPolicy, see the section noted in the **Reference** column. For defaults and valid ranges, please refer to the API Reference HTML documentation for each policy.

Table 5.2 Topic QosPolicies

QosPolicy	Description
DataRepresentation	Specifies which versions of the Extended Common Data Representation (CDR) are offered and requested. See 7.5.3 DATA_REPRESENTATION QosPolicy on page 379. During Publisher_copy_from_topic_qos, only the first DataRepresentationId_t element is copied to the DataWriterQos. The whole sequence is copied to the DataReaderQos during Subscriber_copy_from_topic_qos.
Deadline	For a *DataReader*, specifies the maximum expected elapsed time between arriving DDS data samples. For a *DataWriter*, specifies a commitment to publish DDS samples with no greater elapsed time between them. See 7.5.7 DEADLINE QosPolicy on page 404.
DestinationOrder	Controls how *Connext DDS* will deal with data sent by multiple *DataWriters* for the same topic. Can be set to "by reception timestamp" or to "by source timestamp". See 7.5.8 DESTINATION_ORDER QosPolicy on page 406.
Durability	Specifies whether or not *Connext DDS* will store and deliver data that were previously published to new *DataReaders*. See 7.5.9 DURABILITY QosPolicy on page 410.
DurabilityService	Various settings to configure the external Persistence Service used by *Connext DDS* for *DataWriters* with a Durability QoS setting of Persistent Durability. See 7.5.10 DURABILITY SERVICE QosPolicy on page 414.
History	Specifies how much data must to stored by *Connext DDS* for the *DataWriter* or *DataReader*. This QosPolicy affects the 7.5.21 RELIABILITY QosPolicy on page 444 as well as the 7.5.9 DURABILITY QosPolicy on page 410. See 7.5.12 HISTORY QosPolicy on page 418.
LatencyBudget	Suggestion to *Connext DDS* on how much time is allowed to deliver data. See 7.5.13 LATENCYBUDGET QoS Policy on page 423.
Lifespan	Specifies how long *Connext DDS* should consider data sent by an user application to be valid. See 7.5.14 LIFESPAN QoS Policy on page 423.
Liveliness	Specifies and configures the mechanism that allows *DataReaders* to detect when *DataWriters* become disconnected or "dead." See 7.5.15 LIVELINESS QosPolicy on page 425.
Ownership	Along with Ownership Strength, specifies if *DataReaders* for a topic can receive data from multiple *DataWriters* at the same time. See 7.5.17 OWNERSHIP QosPolicy on page 432.
Reliability	Specifies whether or not *Connext DDS* will deliver data reliably. See 7.5.21 RELIABILITY QosPolicy on page 444.
ResourceLimits	Controls the amount of physical memory allocated for entities, if dynamic allocations are allowed, and how they occur. Also controls memory usage among different instance values for keyed topics. See 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.
TopicData	Along with Group Data QosPolicy and User Data QosPolicy, used to attach a buffer of bytes to *Connext DDS*'s discovery meta-data. See 5.2.1 TOPIC_DATA QosPolicy on page 224.

Table 5.2 Topic QosPolicies

QosPolicy	Description
TransportPriority	Set by a *DataWriter* to tell *Connext DDS* that the data being sent is a different "priority" than other data. See 7.5.26 TRANSPORT_PRIORITY QosPolicy on page 455.

5.1.3.1 Configuring QoS Settings when the Topic is Created

As described in 5.1.1 Creating Topics on page 217, there are different ways to create a Topic, depending on how you want to specify its QoS (with or without a QoS profile).

In Figure 5.2: Creating a Topic with Default QosPolicies on page 219, we saw an example of how to create a Topic with default QosPolicies by using the special constant, DDS_TOPIC_QOS_DEFAULT, which indicates that the default QoS values for a *Topic* should be used. The default Topic QoS values are configured in the DomainParticipant; you can change them with the DomainParticipant's **set_default_topic_qos()** or **set_default_topic_qos_with_profile()** operations (see 9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622).

To create a Topic with non-default QoS values, without using a QoS profile, use the *DomainParticipant*'s **get_default_topic_qos()** operation to initialize a DDS_TopicQos structure. Then change the policies from their default values before passing the QoS structure to **create_topic()**.

You can also create a *Topic* and specify its QoS settings via a QoS profile. To do so, call **create_topic_with_profile()**.

If you want to use a QoS profile, but then make some changes to the QoS before creating the Topic, call **get_topic_qos_from_profile()**, modify the QoS and use the modified QoS when calling **create_topic()**.

5.1.3.2 Comparing QoS Values

The **equals()** operation compares two *Topic's* DDS_TopicQoS structures for equality. It takes two parameters for the two *Topics*' QoS structures to be compared, then returns TRUE is they are equal (all values are the same) or FALSE if they are not equal.

5.1.3.3 Changing QoS Settings After the Topic Has Been Created

There are two ways to change an existing Topic's QoS after it is has been created—again depending on whether or not you are using a QoS Profile.

To change QoS programmatically (that is, without using a QoS Profile), see the example code in Figure 5.3: Changing the QoS of an Existing Topic (without a QoS Profile) on the next page. It retrieves the current values by calling the Topic's **get_qos()** operation. Then it modifies the value and calls **set_qos()** to apply the new value. Note, however, that some QosPolicies cannot be changed after the Topic has been enabled—this restriction is noted in the descriptions of the individual QosPolicies.

You can also change a *Topic's* (and all other Entities') QoS by using a QoS Profile. For an example, see Figure 5.4: Changing the QoS of an Existing Topic with a QoS Profile below. For more information, see Configuring QoS with XML (Chapter 19 on page 842).

For the C API, use DDS_TopicQos_INITIALIZER or DDS_TopicQos_initialize(). See 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 5.3: Changing the QoS of an Existing Topic (without a QoS Profile)

```
DDS_TopicQos topic_qos;
// Get current QoS. topic points to an existing DDSTopic.
if (topic->get_qos(topic_qos) != DDS_RETCODE_OK) {
    // handle error
}
// Next, make changes.
// New ownership kind will be Exclusive
topic_qos.ownership.kind = DDS_EXCLUSIVE_OWNERSHIP_QOS;
// Set the new QoS
if (topic->set_qos(topic_qos) != DDS_RETCODE_OK ) {
    // handle error
}
```

Figure 5.4: Changing the QoS of an Existing Topic with a QoS Profile

```
retcode = topic->set_qos_with_profile(
     "FooProfileLibrary","FooProfile");
if (retcode != DDS_RETCODE_OK) {
// handle error
}
```

5.1.4 Copying QoS From a Topic to a DataWriter or DataReader

Only the TOPIC_DATA QosPolicy strictly applies to *Topics*—it is described in this section, while the others are described in the sections noted Table 5.2 Topic QosPolicies. The rest of the QosPolicies for a *Topic* can also be set on the corresponding *DataWriter*s and/or *DataReader*s. Actually, the values that *Connext DDS* uses for those policies are taken directly from those set on the *DataWriters* and *DataReaders*. The values for those policies are stored only for reference in the **DDS_TopicQos** structure.

Because many QosPolicies affect the behavior of matching *DataWriters* and *DataReaders*, the **DDS_TopicQos** structure is provided as a convenient way to set the values for those policies in a single place in the application. Otherwise, you would have to modify the individual QosPolicies within separate *DataWriter* and *DataReader* QoS structures. And because some QosPolicies are compared between *DataReaders* and *DataWriters*, you will need to make certain that the individual values that you set are compatible (see 4.2.1 QoS Requested vs. Offered Compatibility—the RxO Property on page 180).

The use of the **DDS_TopicQos** structure to set the values of any QosPolicy except TOPIC_DATA—which only applies to *Topics*—is really a way to share a single set of values with the associated *DataWriters* and *DataReaders*, as well as to avoid creating those entities with inconsistent QosPolicies.

To cause a DataWriter to use its *Topic's* QoS settings, either:

- Pass DDS_DATAWRITER_QOS_USE_TOPIC_QOS to **create_datawriter()**, or
- Call the *Publisher's* **copy_from_topic_qos()** operation

To cause a *DataReader* to use its *Topic's* QoS settings, either:

- Pass DDS_DATAREADER_QOS_USE_TOPIC_QOS to **create_datareader()**, or
- Call the *Subscriber's* **copy_from_topic_qos()** operation

Please refer to the API Reference HTML documentation for the *Publisher*'s **create_datawriter()** and *Subscriber*'s **create_datareader()** methods for more information about using values from the *Topic* QosPolicies when creating *DataWriters* and *DataReaders*.

5.1.5 Setting Up TopicListeners

When you create a Topic, you have the option of giving it a *Listener*. A Topic*Listener* includes just one callback routine, **on_inconsistent_topic()**. If you create a *TopicListener* (either as part of the *Topic* creation call, or later with the **set_listener()** operation), *Connext DDS* will invoke the *TopicListener*'s **on_inconsistent_topic()** method whenever it detects that another application has created a *Topic* with same name but associated with a different user data type. For more information, see 5.3.1 INCONSISTENT_TOPIC Status on page 226.

Note: Some operations cannot be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

If a *Topic*'s Listener has not been set and *Connext DDS* detects an inconsistent Topic, the *DomainParticipantListener* (if it exists) will be notified instead (see 9.3.6 Setting Up DomainParticipantListeners on page 615). So you only need to set up a **TopicListener** if you need to perform specific actions when there is an error on that particular *Topic*. In most cases, you can set the *TopicListener* to NULL and process inconsistent-topic errors in the *DomainParticipantListener* instead.

5.1.6 Navigating Relationships Among Entities

5.1.6.1 Finding a Topic's DomainParticipant

To retrieve a handle to the Topic's *DomainParticipant*, use the **get_participant()** operation:

```
DDSDomainParticipant* DDSTopicDescription::get_participant()
```

Notice that this method belongs to the **DDSTopicDescription** class, which is the base class for **DDSTopic**.

5.1.6.2 Retrieving a Topic's Name or DDS Type Name

If you want to retrieve the *topic_name* or *type_name* used in the **create_topic()** operation, use these methods:

```
const char* DDSTopicDescription::get_type_name();
const char* DDSTopicDescription::get_name();
```

Notice that these methods belong to the **DDSTopicDescription** class, which is the base class for **DDSTopic**.

5.2 Topic QosPolicies

This section describes the only QosPolicy that strictly applies to *Topics* (and no other types of *Entities*)—the TOPIC_DATA QosPolicy. For a complete list of the QosPolicies that can be set for *Topics*, see Table 5.2 Topic QosPolicies.

Most of the QosPolicies that can be set on a *Topic* can also be set on the corresponding *DataWriter* and/or *DataReader*. The *Topic's* QosPolicy is essentially just a place to store QoS settings that you plan to share with multiple entities that use that *Topic* (see how in 5.1.3 Setting Topic QosPolicies on page 219); they are not used otherwise and are not propagated on the wire.

5.2.1 TOPIC_DATA QosPolicy

This QosPolicy provides an area where your application can store additional information related to the *Topic*. This information is passed between applications during discovery (see Discovery (Chapter 15 on page 758)) using builtin-topics (see Built-In Topics (Chapter 18 on page 825)). How this information is used will be up to user code. *Connext DDS* does not do anything with the information stored as TOPIC_DATA except to pass it to other applications. Use cases are usually application-to-application identification, authentication, authorization, and encryption purposes.

The value of the TOPIC_DATA QosPolicy is sent to remote applications when they are first discovered, as well as when the *Topic*'s **set_qos()** method is called after changing the value of the TOPIC_DATA. User code can set listeners on the builtin *DataReaders* of the builtin *Topics* used by *Connext DDS* to propagate discovery information. Methods in the builtin topic listeners will be called whenever new applications, *DataReaders*, and *DataWriters* are found. Within the user callback, you will have access to the TOPIC_DATA that was set for the associated *Topic*.

Currently, TOPIC_DATA of the associated *Topic* is only propagated with the information that declares a *DataWriter* or *DataReader*. Thus, you will need to access the value of TOPIC_DATA through DDS_PublicationBuiltinTopicData or DDS_SubscriptionBuiltinTopicData (see Built-In Topics (Chapter 18 on page 825)).

The structure for the TOPIC_DATA QosPolicy includes just one field, as seen in Table 5.3 DDS_TopicDataQosPolicy. The field is a sequence of octets that translates to a contiguous buffer of bytes whose contents and length is set by the user. The maximum size for the data are set in the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649.

Table 5.3 DDS_TopicDataQosPolicy

Type	Field Name	Description
DDS_OctetSeq	value	default: empty

This policy is similar to the GROUP_DATA (7.4.4 GROUP_DATA QosPolicy on page 352) and USER_DATA (7.5.30 USER_DATA QosPolicy on page 462) policies that apply to other types of *Entities*.

5.2.1.1 Example

One possible use of TOPIC_DATA is to send an associated XML schema that can be used to process the data stored in the associated user data structure of the *Topic*. The schema, which can be passed as a long sequence of characters, could be used by an XML parser to take DDS samples of the data received for a *Topic* and convert them for updating some graphical user interface, web application or database.

5.2.1.2 Properties

This QosPolicy can be modified at any time. A change in the QosPolicy will cause *Connext DDS* to send packets containing the new TOPIC_DATA to all of the other applications in the DDS domain.

Because *Topics* are created independently by the applications that use the *Topic*, there may be different instances of the same *Topic* (same topic name and DDS data type) in different applications. The TOPIC_DATA for different instances of the same *Topic* may be set differently by different applications.

5.2.1.3 Related QosPolicies

- 7.4.4 GROUP_DATA QosPolicy on page 352
- 7.5.30 USER_DATA QosPolicy on page 462
- 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649

5.2.1.4 Applicable DDS Entities

- 5.1 Topics on page 215

5.2.1.5 System Resource Considerations

As mentioned earlier, the maximum size of the TOPIC_DATA is set in the **topic_data_max_length** field of the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649. Because *Connext DDS* will allocate memory based on this value, you should only increase this value if you need to. If your system does not use TOPIC_DATA, then you can set this value to 0 to save

memory. Setting the value of the TOPIC_DATA QosPolicy to hold data longer than the value set in the **topic_data_max_length** field will result in failure and an INCONSISTENT_QOS_POLICY return code.

However, should you decide to change the maximum size of TOPIC_DATA, you *must* make certain that all applications in the DDS domain have changed the value of **topic_data_max_length** to be the same. If two applications have different limits on the size of TOPIC_DATA, and one application sets the TOPIC_DATA QosPolicy to hold data that is greater than the maximum size set by another application, then the *DataWriters* and *DataReaders* of that *Topic* between the two applications will *not* connect. This is also true for the GROUP_DATA (7.4.4 GROUP_DATA QosPolicy on page 352) and USER_DATA (7.5.30 USER_DATA QosPolicy on page 462) QosPolicies.

5.3 Status Indicator for Topics

There is only one communication status defined for a *Topic*, ON_INCONSISTENT_TOPIC. You can use the **get_inconsistent_topic_status()** operation to access the current value of the status or use a *TopicListener* to catch the change in the status as it occurs. See 4.4 Listeners on page 189 for a general discussion on Listeners and Statuses.

5.3.1 INCONSISTENT_TOPIC Status

In order for a *DataReader* and a *DataWriter* with the same *Topic* to communicate,their DDS types must be consistent according to the *DataReader's* type-consistency enforcement policy value, defined in its 8.6.6 TYPE_CONSISTENCY_ENFORCEMENT QosPolicy on page 589). This status indicates that another *DomainParticipant* has created a *Topic* using the same name as the local Topic, but with an inconsistent DDS type.

The status is a structure of type **DDS_InconsistentTopicStatus**, see Table 5.4 DDS_InconsistentTopicStatus Structure. The **total_count** keeps track of the total number of (*DataReader, DataWriter*) pairs with topic names that match the Topic to which this status is attached, but whose DDS types are inconsistent. The *TopicListener's* **on_inconsistent_topic()** operation is invoked when this status changes (an inconsistent topic is found). You can also retrieve the current value by calling the *Topic's* **get_inconsistent_topic_status()** operation.

The value of **total_count_change** reflects the number of inconsistent topics that were found since the last time **get_inconsistent_topic_status()** was called by user code or **on_inconsistent_topic()** was invoked by *Connext DDS*.

Table 5.4 DDS_InconsistentTopicStatus Structure

Type	Field Name	Description
DDS_Long	total_count	Total cumulative count of (*DataReader, DataWriter*) pairs whose topic names match the Topic to which this status is attached, but whose DDS types are inconsistent.

Table 5.4 DDS_InconsistentTopicStatus Structure

Type	Field Name	Description
DDS_Long	total_count_change	The change in total_count since the last time this status was read.

5.4 ContentFilteredTopics

A ContentFilteredTopic is a *Topic* with filtering properties. It makes it possible to subscribe to topics and at the same time specify that you are only interested in a subset of the *Topic's* data.

For example, suppose you have a *Topic* that contains a temperature reading for a boiler, but you are only interested in temperatures outside the normal operating range. A ContentFilteredTopic can be used to limit the number of DDS data samples a *DataReader* has to process and may also reduce the amount of data sent over the network.

5.4.1 Overview

A ContentFilteredTopic creates a relationship between a *Topic*, also called the related topic, and user-specified filtering properties. The filtering properties consist of an expression and a set of parameters.

- The filter expression evaluates a logical expression on the Topic content. The filter expression is similar to the WHERE clause in a SQL expression.
- The parameters are strings that give values to the 'parameters' in the filter expression. There must be one parameter string for each parameter in the filter expression.

A ContentFilteredTopic is a type of topic description, and can be used to create *DataReaders.* However, a ContentFilteredTopic is *not* an entity—it does not have QosPolicies or *Listeners*.

A ContentFilteredTopic relates to other entities in *Connext DDS* as follows:

- ContentFilteredTopics are used when creating *DataReaders*, not *DataWriters*.
- Multiple *DataReaders* can be created with the same ContentFilteredTopic.
- A ContentFilteredTopic belongs to (is created/deleted by) a *DomainParticipant*.
- A ContentFilteredTopic and *Topic* must be in the same *DomainParticipant*.
- A ContentFilteredTopic can only be related to a single *Topic*.
- A Topic can be related to multiple ContentFilteredTopics.
- A ContentFilteredTopic can have the same name as a *Topic*, but ContentFilteredTopics must have unique names within the same *DomainParticipant*.
- A *DataReader* created with a ContentFilteredTopic will use the related Topic's QoS and *Listeners*.

- Changing filter parameters on a ContentFilteredTopic causes *all DataReaders* using the same ContentFilteredTopic to see the change.
- A *Topic* cannot be deleted as long as at least one ContentFilteredTopic that has been created with it exists.
- A ContentFilteredTopic cannot be deleted as long as at least one *DataReader* that has been created with the ContentFilteredTopic exists.

5.4.2 Where Filtering is Applied–Publishing vs. Subscribing Side

Filtering may be performed on either side of the distributed application. (The *DataWriter* obtains the filter expression and parameters from the *DataReader* during discovery.)

When batching is enabled, content filtering is always done on the reader side.

Connext DDS also supports network-switch filtering for multi-channel *DataWriters* (see Multi-channel DataWriters (Chapter 20 on page 888)).

A *DataWriter* will automatically filter DDS data samples for a *DataReader* if *all* of the following are true; otherwise filtering is performed by the *DataReader*.

1. The *DataWriter* is filtering for no more than **writer_resource_limits.max_remote_reader_filters** *DataReaders* at the same time.
   - There is a resource-limit on the *DataWriter* called **writer_resource_limits.max_remote_reader_filters** (see 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400). This value can be from [0, (2^31)-2] or DDS_LENGTH_UNLIMITED (default). 0 means do not filter any *DataReader*; 1 to (2^31)-2 means that the *DataWriter* will filter for up to the specified number of *DataReaders*, and the *Datawriter* will store the result of the filtering per sample per *DataReader*; DDS_LENGTH_UNLIMITED means that the *DataWriter* will filter for up to (2^31)-2 *DataReaders*, but in this case the *DataWriter* will not store the filtering result per sample per *DataReader*: if a sample is resent (such as due to a loss of reliable communication), the sample will be filtered again.
   - If a *DataWriter* is filtering **max_remote_reader_filters** *DataReaders* at the same time and a new filtered *DataReader* is created, then the newly created *DataReader* (**max_remote_reader_filters** + 1) is not filtered. Even if one of the first (**max_remote_reader_filters**) *DataReaders* is deleted, that already created *DataReader* (**max_remote_reader_filters** + 1) will *still* not be filtered. However, any subsequently created *DataReaders* will be filtered as long as the number of *DataReaders* currently being filtered is not more than **writer_resource_limits.max_remote_reader_filters**.
2. The *DataReader* is not subscribing to data using multicast.
3. There are no more than 4 matching *DataReaders* in the same locator (transport destination, for example IP address + port).

4. The *DataWriter* has infinite liveliness. (See 7.5.15 LIVELINESS QosPolicy on page 425.)
5. The *DataWriter* is *not* using an Asynchronous Publisher. (That is, the *DataWriter's* 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441 **kind** is set to DDS_SYNCHRONOUS_PUBLISHER_MODE_QOS.)

   Note: *Connext DDS* supports limited writer-side filtering if asynchronous publishing is enabled. The middleware will not send any sample to a locator if the sample is filtered out by all the *DataReaders* receiving samples on that locator. However, if there is one *DataReader* to which the sample has to be sent, all the *DataReaders* on the locator will perform reader-side filtering for the incoming sample.
6. If you are using a custom filter (not the default one), it must be registered in the *DomainParticipant* of the *DataWriter* and the *DataReader*.
7. The *DataWriter* is not configured to use batching.

   When batching is enabled, content filtering is always done on the reader side. See 7.5.2 BATCH QosPolicy (DDS Extension) on page 373.

5.4.3 Creating ContentFilteredTopics

To create a ContentFilteredTopic that uses the default SQL filter, use the *DomainParticipant's* **create_contentfilteredtopic()** operation:

```
DDS_ContentFilteredTopic *create_contentfilteredtopic(
        const char * name,
         const DDS_Topic * related_topic,
         const char * filter_expression,
         const DDS_StringSeq & expression_parameters)
```

Or, to use a custom filter or the builtin STRINGMATCH filter (see 5.4.7 STRINGMATCH Filter Expression Notation on page 244), use the **create_contentfilteredtopic_with_filter()** variation:

```
DDS_ContentFilteredTopic *create_contentfilteredtopic_with_filter(
        const char * name,
        DDSTopic * related_topic,
        const char *  filter_expression,
        const DDS_StringSeq & expression_parameters,
        const char * filter_name = DDS_SQLFILTER_NAME)
```

Where:

name — Name of the ContentFilteredTopic. Note that it *is* legal for a ContentFilteredTopic to have the same name as a Topic in the same *DomainParticipant*, but a ContentFilteredTopic cannot have the same name as another ContentFilteredTopic in the same *DomainParticipant*. This parameter cannot be NULL.

related_topic — The related Topic to be filtered. The related topic must be in the same *DomainParticipant* as the ContentFilteredTopic. This parameter cannot be NULL. The same related topic can be used in many different ContentFilteredTopics.

filter_expression	A logical expression on the contents on the Topic. If the expression evaluates to TRUE, a DDS sample is received; otherwise it is discarded. This parameter cannot be NULL. The notation for this expression depends on the filter that you are using (specified by the **filter_name** parameter). See 5.4.6 SQL Filter Expression Notation on page 235 and 5.4.7 STRINGMATCH Filter Expression Notation on page 244. The **filter_expression** can be changed with **set_expression()** (5.4.5.2 Setting an Expression's Filter and Parameters on page 234).
expression_parameters	A string sequence of filter expression parameters. Each parameter corresponds to a positional argument in the filter expression: element 0 corresponds to positional argument 0, element 1 to positional argument 1, and so forth. The **expression_parameters** can be changed with **set_expression_parameters()** or **set_expression()** (5.4.5.2 Setting an Expression's Filter and Parameters on page 234), **append_to_expression_parameter()** (5.4.5.3 Appending a String to an Expression Parameter on page 234) and **remove_from_expression_parameter()** (5.4.5.4 Removing a String from an Expression Parameter on page 235).
filter_name	Name of the content filter to use for filtering. The filter must have been previously registered with the *DomainParticipant* (see 5.4.10.2 Registering a Custom Filter on page 248). There are two builtin filters, DDS_SQLFILTER_NAME[1] (the default filter) and DDS_STRINGMATCHFILTER_NAME–these are automatically registered. To use the STRINGMATCH filter, call **create_contentfilteredtopic_with_filter()** with "DDS_STRINGMATCHFILTER_NAME" as the **filter_name**. STRINGMATCH filter expressions have the syntax: **<field name> MATCH <***string pattern***>** (see 5.4.7 STRINGMATCH Filter Expression Notation on page 244). 2

To summarize:

- To use the builtin default SQL filter:
  - Call **create_contentfilteredtopic()**
  - See 5.4.6 SQL Filter Expression Notation on page 235
- To use the builtin STRINGMATCH filter:
  - Call **create_contentfilteredtopic_with_filter()**, setting the **filter_name** to **DDS_STRINGMATCHFILTER_NAME**
  - See 5.4.7 STRINGMATCH Filter Expression Notation on page 244
- To use a custom filter:
  - Call **create_contentfilteredtopic_with_filter()**, setting the **filter_name** to a registered custom filter

[1] In the Java and C# APIs, you can access the names of the builtin filters by using DomainParticipant.SQLFILTER_NAME and DomainParticipant.STRINGMATCHFILTER_NAME.

[2] In the Java and C# APIs, you can access the names of the builtin filters by using DomainParticipant.SQLFILTER_NAME and DomainParticipant.STRINGMATCHFILTER_NAME.

Be careful with memory management of the string sequence in some of the ContentFilteredTopic APIs. See the **String Support** section in the API Reference HTML documentation (within the **Infrastructure** module) for details on sequences.

5.4.3.1 Creating ContentFilteredTopics for Built-in DDS Types

To create a ContentFilteredTopic for a built-in DDS type (see 3.2 Built-in Data Types on page 38), use the standard *DomainParticipant* operations, **create_contentfilteredtopic()** or **create_contentfilteredtopic_with_filter**.

The field names used in the filter expressions for the built-in SQL (see 5.4.6 SQL Filter Expression Notation on page 235) and StringMatch filters (see 5.4.7 STRINGMATCH Filter Expression Notation on page 244) must correspond to the names provided in the IDL description of the built-in DDS types.

ContentFilteredTopic Creation Examples:

For simplicity, error handling is not shown in the following examples.

C Example:

```
DDS_Topic * topic = NULL;
DDS_ContentFilteredTopic * contentFilteredTopic = NULL;
struct DDS_StringSeq parameters = DDS_SEQUENCE_INITIALIZER;
/* Create a string ContentFilteredTopic */
topic = DDS_DomainParticipant_create_topic(
       participant, "StringTopic",
       DDS_StringTypeSupport_get_type_name(),
       &DDS_TOPIC_QOS_DEFAULT,NULL,
       DDS_STATUS_MASK_NONE);
contentFilteredTopic =
    DDS_DomainParticipant_create_contentfilteredtopic(
       participant,
       "StringContentFilteredTopic",
       topic,
       "value = 'Hello World!'", &parameters);
```

Traditional C++ Example with Namespaces:

```
using namespace DDS;
...
/* Create a String ContentFilteredTopic */
Topic * topic = participant->create_topic(
       "StringTopic",
       StringTypeSupport::get_type_name(),
       TOPIC_QOS_DEFAULT,
       NULL, STATUS_MASK_NONE);
StringSeq parameters;
ContentFilteredTopic * contentFilteredTopic =
    participant->create_contentfilteredtopic(
       "StringContentFilteredTopic", topic,
       "value = 'Hello World!'", parameters);
```

Modern C++ Example:

```
using dds::core::StringTopicType;
```

```
dds::topic::Topic<StringTopicType> topic(participant, "StringTopic");
dds::topic::ContentFilteredTopic<StringTopicType> content_filtered_topic(
        topic,
        "StringContentFilteredTopic",
        dds::topic::Filter("value = 'Hello World!'"));
```

C++/CLI Example:

```
using namespace DDS;
...
/* Create a String ContentFilteredTopic */
Topic^ topic = participant->create_topic(
       "StringTopic", StringTypeSupport::get_type_name(),
        DomainParticipant::TOPIC_QOS_DEFAULT,
        nullptr, StatusMask::STATUS_MASK_NONE);
StringSeq^ parameters = gcnew StringSeq();
ContentFilteredTopic^ contentFilteredTopic =
       participant->create_contentfilteredtopic(
               "StringContentFilteredTopic", topic,
               "value = 'Hello World!'", parameters);
```

C# Example:

```
using namespace DDS;
...
/* Create a String ContentFilteredTopic */
Topic topic = participant.create_topic(
       "StringTopic",  StringTypeSupport.get_type_name(),
        DomainParticipant.TOPIC_QOS_DEFAULT,
        null, StatusMask.STATUS_MASK_NONE);
StringSeq parameters = new StringSeq();
ContentFilteredTopic contentFilteredTopic =
       participant.create_contentfilteredtopic(
               "StringContentFilteredTopic", topic,
               "value = 'Hello World!'", parameters);
```

Java Example:

```
import com.rti.dds.type.builtin.*;
...
/* Create a String ContentFilteredTopic */
Topic topic = participant.create_topic(
       "StringTopic", StringTypeSupport.get_type_name(),
        DomainParticipant.TOPIC_QOS_DEFAULT,
        null, StatusKind.STATUS_MASK_NONE);
StringSeq parameters = new StringSeq();
ContentFilteredTopic contentFilteredTopic =
       participant.create_contentfilteredtopic(
               "StringContentFilteredTopic", topic,
               "value = 'Hello World!'", parameters);
```

5.4.4 Deleting ContentFilteredTopics

To delete a ContentFilteredTopic, use the *DomainParticipant's* **delete_contentfilteredtopic()** operation:

Make sure no *DataReaders* are using the ContentFilteredTopic. (If this is not true, the operation returns **PRECONDITION_NOT_MET**.)

Delete the ContentFilteredTopic by using the *DomainParticipant's* **delete_contentfilteredtopic()** operation.

```
DDS_ReturnCode_t delete_contentfilteredtopic
        (DDSContentFilteredTopic * a_contentfilteredtopic)
```

5.4.5 Using a ContentFilteredTopic

Once you've created a ContentFilteredTopic, you can use the operations listed in Table 5.5 ContentFilteredTopic Operations.

Table 5.5 ContentFilteredTopic Operations

Operation	Description	Reference
append_to_expression_parameter	Concatenates a string value to the input expression parameter	5.4.5.3 Appending a String to an Expression Parameter on the next page
get_expression_parameters	Gets the expression parameters.	5.4.5.1 Getting the Current Expression Parameters below
get_filter_expression	Gets the expression.	5.4.5.5 Getting the Filter Expression on page 235
get_related_topic	Gets the related Topic.	5.4.5.6 Getting the Related Topic on page 235
narrow	Casts a DDS_TopicDescription pointer to a ContentFilteredTopic pointer.	5.4.5.7 'Narrowing' a ContentFilteredTopic to a TopicDescription on page 235
remove_from_expression_parameter	Removes a string value from the input expression parameter	5.4.5.4 Removing a String from an Expression Parameter on page 235
set_expression	Changes the filter expression and parameters.	5.4.5.2 Setting an Expression's Filter and Parameters on the next page
set_expression_parameters	Changes the expression parameters.	

5.4.5.1 Getting the Current Expression Parameters

To get the expression parameters, use the ContentFilteredTopic's **get_expression_parameters()** operation:

```
DDS_ReturnCode_t get_expression_parameters(struct DDS_StringSeq & parameters)
```

Where:

parameters The filter expression parameters.

The memory for the strings in this sequence is managed as described in the **String Support** section of the API Reference HTML documentation (within the **Infrastructure** module). In particular, be careful to avoid a situation in which *Connext DDS* allocates a string on your behalf and you then reuse that string in such a way that *Connext DDS* believes it to have more memory allocated to it than it actually does. This parameter cannot be NULL.

This operation gives you the expression parameters that were specified on the last successful call to **set_expression_parameters()** or **set_expression()**, or if they were never called, the parameters specified when the ContentFilteredTopic was created.

5.4.5.2 Setting an Expression's Filter and Parameters

To change the filter expression and expression parameters associated with a ContentFilteredTopic:

```
DDS_ReturnCode set_expression(
       const char * expression,
       const struct DDS_StringSeq & parameters)
```

To change just the expression parameters (not the filter expression):

```
DDS_ReturnCode_t set_expression_parameters(const struct DDS_StringSeq & parameters)
```

Where:

expression	The new expression to be set in the ContentFilteredTopic.
parameters	The filter expression parameters. Each element in the parameter sequence corresponds to a positional parameter in the filter expression. When using the default DDS_SQLFILTER_NAME, parameter strings are automatically converted to the member type. For example, "4" is converted to the integer 4. This parameter cannot be NULL.

The ContentFilteredTopic's operations do not manage the sequences; you must ensure that the parameter sequences are valid. Please refer to the **String Support** section in the API Reference HTML documentation (within the Infrastructure module) for details on sequences.

5.4.5.3 Appending a String to an Expression Parameter

To concatenate a string to an expression parameter, use the ContentFilteredTopic's **append_to_expression_parameter()** operation:

```
DDS_ReturnCode_t append_to_expression_parameter(const DDS_Long index, const char* value);
```

When using the STRINGMATCH filter, **index** must be 0.

This function is only intended to be used with the builtin SQL and STRINGMATCH filters. This function can be used in expression parameters associated with MATCH operators (see 5.4.6.5 SQL Extension: Regular Expression Matching on page 241) to add a pattern to the match pattern list. For example, if **filter_expression** is:

```
symbol MATCH 'IBM'
```

Then **append_to_expression_parameter(0, "MSFT")** would generate the expression:

```
symbol MATCH 'IBM,MSFT'
```

5.4.5.4 Removing a String from an Expression Parameter

To remove a string from an expression parameter use the ContentFilteredTopic's **remove_from_expression_parameter()** operation:

```
DDS_ReturnCode_t remove_from_expression_parameter(const DDS_Long index, const char* value)
```

When using the STRINGMATCH filter, **index** must be 0.

This function is only intended to be used with the builtin SQL and STRINGMATCH filters. It can be used in expression parameters associated with MATCH operators (see 5.4.6.5 SQL Extension: Regular Expression Matching on page 241) to remove a pattern from the match pattern list. For example, if **filter_expression** is:

```
symbol MATCH 'IBM,MSFT'
```

Then **remove_from_expression_parameter(0, "IBM")** would generate the expression:

```
symbol MATCH 'MSFT'
```

5.4.5.5 Getting the Filter Expression

To get the filter expression that was specified when the ContentFilteredTopic was created or when **set_expression()** was used:

```
const char* get_filter_expression ()
```

5.4.5.6 Getting the Related Topic

To get the related *Topic* that was specified when the ContentFilteredTopic was created:

```
DDS_Topic * get_related_topic ()
```

5.4.5.7 'Narrowing' a ContentFilteredTopic to a TopicDescription

To safely cast a DDS_TopicDescription pointer to a ContentFilteredTopic pointer, use the ContentFilteredTopic's **narrow()** operation:

```
DDS_TopicDescription* narrow ()
```

5.4.6 SQL Filter Expression Notation

A SQL filter expression is similar to the **WHERE** clause in SQL. The SQL expression format provided by *Connext DDS* also supports the **MATCH** operator as an extended operator (see 5.4.6.5 SQL Extension: Regular Expression Matching on page 241).

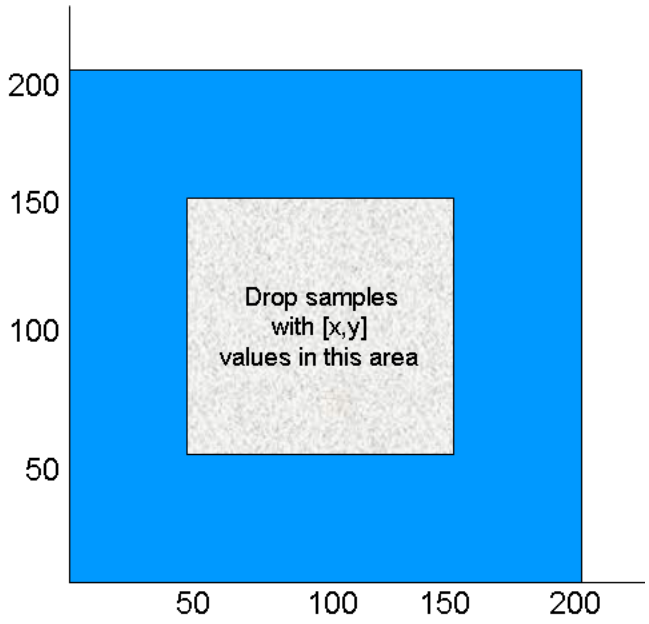
The following sections provide more information:

- 5.4.6.1 Example SQL Filter Expressions below
- 5.4.6.2 SQL Grammar on the next page
- 5.4.6.3 Token Expressions on page 239
- 5.4.6.4 Type Compatibility in the Predicate on page 241
- 5.4.6.5 SQL Extension: Regular Expression Matching on page 241
- 5.4.6.6 Composite Members on page 242
- 5.4.6.7 Strings on page 243
- 5.4.6.8 Enumerations on page 243
- 5.4.6.9 Pointers on page 243
- 5.4.6.10 Arrays on page 243
- 5.4.6.11 Sequences on page 244

5.4.6.1 Example SQL Filter Expressions

Assume that you have a *Topic* with two floats, X and Y, which are the coordinates of an object moving inside a rectangle measuring 200 x 200 units. This object moves quite a bit, generating lots of DDS samples that you are not interested in. Instead you only want to receive DDS samples *outside* the middle of the rectangle, as seen in Figure 5.5: Filtering Example below. That is, you want to filter *out* data points in the gray box.

Figure 5.5: Filtering Example



The filter expression would look like this (remember the expression is written so that DDS samples that we *do* want will *pass*):

```
"(X < 50 or X > 150) and (Y < 50 or Y > 150)"
```

Suppose you would like the ability to adjust the coordinates that are considered outside the acceptable range (changing the size of the gray box). You can achieve this by changing the whole filter expression, using **set_expression()**, or by using filter parameters. The expression can be written using filter parameters as follows:

```
"(X < %0 or X > %1) and (Y < %2 or Y > %3)"
```

Recall that when you create a ContentFilteredTopic (see 5.4.3 Creating ContentFilteredTopics on page 229), you pass a **expression_parameters** string sequence as one of the parameters. Each element in the string sequence corresponds to one argument.

See the **String** and **Sequence Support** sections of the API Reference HTML documentation (from the **Modules** page, select **RTI Connext DDS API Reference, Infrastructure Module**).

In C++, the filter parameters could be assigned like this:

```
FilterParameter[0] = "50";
FilterParameter[1] = "150";
FilterParameter[2] = "50";
FilterParameter[3] = "150";
```

With these parameters, the filter expression is identical to the first approach. However, it is now possible to change the parameters by calling **set_expression_parameters()**. For example, perhaps you decide that you only want to see data points where X < 10 or X > 190. To make this change:

```
FilterParameter[0] = 10
FilterParameter[1] = 190
set_expression_parameters(....)
```

The new filter parameters will affect all *DataReaders* that have been created with this ContentFilteredTopic.

5.4.6.2 SQL Grammar

This section describes the subset of SQL syntax, in Backus–Naur Form (BNF), that you can use to form filter expressions.

The following notational conventions are used:

NonTerminals are typeset in italics.

'Terminals' are quoted and typeset in a fixed-width font. They are written in upper case in most cases in the BNF-grammar below, but should be case insensitive.

TOKENS are typeset in bold.

The notation (element // ',') represents a non-empty, comma-separated list of elements.

```
Expression ::= FilterExpression
           |   TopicExpression
           |   QueryExpression
           .
FilterExpression ::= Condition
TopicExpression  ::= SelectFrom { Where } ';'
QueryExpression  ::= { Condition }{ 'ORDER BY' (FIELDNAME // ',') }
                     .
SelectFrom       ::= 'SELECT' Aggregation 'FROM' Selection
                 .
Aggregation      ::= '*'
                 |   (SubjectFieldSpec // ',')
                 .
SubjectFieldSpec ::= FIELDNAME
                 |   FIELDNAME 'AS' IDENTIFIER
                 |   FIELDNAME IDENTIFIER
                 .
Selection   ::= TOPICNAME
            |   TOPICNAME NaturalJoin JoinItem
            .
JoinItem    ::= TOPICNAME
            |   TOPICNAME NaturalJoin JoinItem
            |   '(' TOPICNAME NaturalJoin JoinItem ')'
            .
NaturalJoin ::= 'INNER JOIN'
            |   'INNER NATURAL JOIN'
            |   'NATURAL JOIN'
            |   'NATURAL INNER JOIN'
            .
Where       ::= 'WHERE' Condition
            .
Condition   ::= Predicate
            |   Condition 'AND' Condition
            |   Condition 'OR' Condition
            |   'NOT' Condition
            |   '(' Condition ')'
            .
Predicate   ::= ComparisonPredicate
            |   BetweenPredicate
            .
ComparisonPredicate ::= ComparisonTerm RelOp ComparisonTerm
                    .
ComparisonTerm      ::= FieldIdentifier
                    | Parameter
                    .
BetweenPredicate    ::= FieldIdentifier 'BETWEEN' Range
                    |   FieldIdentifier 'NOT BETWEEN' Range
                    .
FieldIdentifier      ::= FIELDNAME
                    | IDENTIFIER
                    .
RelOp     ::= '=' | '>' | '>=' | '<' | '<=' | '<>' | 'LIKE' | 'MATCH'
          .
```

```
Range     ::= Parameter 'AND' Parameter
          .
Parameter ::= INTEGERVALUE
          |   CHARVALUE
          |   FLOATVALUE
          |   STRING
          |   ENUMERATEDVALUE
          |   BOOLEANVALUE
          |   PARAMETER
```

INNER JOIN, INNER NATURAL JOIN, NATURAL JOIN, and NATURAL INNER JOIN are all aliases, in the sense that they have the same semantics. They are all supported because they all are part of the SQL standard.

5.4.6.3 Token Expressions

The syntax and meaning of the tokens used in SQL grammar is described as follows:

IDENTIFIER—An identifier for a FIELDNAME, defined as any series of characters 'a', ..., 'z', 'A', ..., 'Z', '0', ..., '9', '_' but may *not* start with a digit.

```
IDENTIFIER: LETTER (PART_LETTER)*
```

where LETTER: ["A"-"Z","_","a"-"z"] PART_LETTER: ["A"-"Z","_","a"-"z","0"-"9"]

FIELDNAME—A reference to a field in the data structure. A dot '**.**' is used to navigate through nested structures. The number of dots that may be used in a FIELDNAME is unlimited. The FIELDNAME can refer to fields at any depth in the data structure. The names of the field are those specified in the IDL definition of the corresponding structure, which may or may not match the fieldnames that appear on the language-specific (e.g., C/C++, Java) mapping of the structure. To reference the n+1 element in an array or sequence, use the notation `'[n]'`, where `n` is a natural number (zero included). FIELDNAME must resolve to a primitive IDL type; that is either boolean, octet, (unsigned) short, (unsigned) long, (unsigned) long long, float double, char, wchar, string, wstring, or enum.

```
FIELDNAME: FieldNamePart ( "." FieldNamePart )*
```

where FieldNamePart : IDENTIFIER ("[" Index "]")* Index> : (["0"-"9"])+ | ["0x","0X"](["0"-"9", "A"-"F", "a"-"f"])+

Primitive IDL types referenced by FIELDNAME are treated as different types in Predicate according to the following table:

Predicate Data Type	IDL Type
BOOLEANVALUE	boolean
INTEGERVALUE	octet, (unsigned) short, (unsigned) long, (unsigned) long long
FLOATVALUE	float, double
CHARVALUE	char, wchar

Predicate Data Type	IDL Type
STRING	string, wstring
ENUMERATEDVALUE	enum

TOPICNAME—An identifier for a topic, and is defined as any series of characters 'a', ..., 'z', 'A', ..., 'Z', '0', ..., '9', '_' but may *not* start with a digit.

```
TOPICNAME : IDENTIFIER
```

INTEGERVALUE—Any series of digits, optionally preceded by a plus or minus sign, representing a decimal integer value within the range of the system. '**L**' or '**l**' must be used for long long, otherwise long is assumed. A hexadecimal number is preceded by **0x** and must be a valid hexadecimal expression.

```
INTEGERVALUE : (["+","-"])? (["0"-"9"])+ [("L","l")]?
       | (["+","-"])? ["0x","0X"](["0"-"9",
        "A"-"F", "a"-"f"])+ [("L","l")]?
```

CHARVALUE—A single character enclosed between single quotes.

```
        CHARVALUE : "'" (~["'"])? "'"
```

FLOATVALUE—Any series of digits, optionally preceded by a plus or minus sign and optionally including a floating point ('**.**'). '**F**' or '**f**' must be used for float, otherwise double is assumed. A power-of-ten expression may be postfixed, which has the syntax **e***n* or **E***n*, where ***n*** is a number, optionally preceded by a plus or minus sign.

```
FLOATVALUE : (["+","-"])? (["0"-"9"])* (".")? (["0"-"9"])+
        (EXPONENT)?[("F",'f')]?
```

where EXPONENT: ["e","E"] (["+","-"])? (["0"-"9"])+

STRING—Any series of characters encapsulated in single quotes, except the single quote itself.

```
STRING : "'" (~["'"])* "'"
```

ENUMERATEDVALUE—A reference to a value declared within an enumeration. Enumerated values consist of the name of the enumeration label enclosed in single quotes. The name used for the enumeration label must correspond to the label names specified in the IDL definition of the enumeration.

```
ENUMERATEDVALUE : "'" ["A" - "Z", "a" - "z"]
["A" - "Z", "a" - "z", "_", "0" - "9"]* "'"
```

BOOLEANVALUE—Can either be **TRUE** or **FALSE**, and is case insensitive.

```
BOOLEANVALUE : ["TRUE","FALSE"]
```

PARAMETER—Takes the form **%***n*, where ***n*** represents a natural number (zero included) smaller than 100. It refers to the (n + 1)th argument in the given context. This argument can only be in primitive type value format. It cannot be a FIELDNAME.

```
PARAMETER : "%" (["0"-"9"])+
```

5.4.6.4 Type Compatibility in the Predicate

As seen in Table 5.6 Valid Type Comparisons, only certain combinations of type comparisons are valid in the Predicate.

Table 5.6 Valid Type Comparisons

	BOOLEAN VALUE	INTEGER VALUE	FLOAT VALUE	CHAR VALUE	STRING	ENUMERATED VALUE
BOOLEAN	YES					
INTEGERVALUE		YES	YES			
FLOATVALUE		YES	YES			
CHARVALUE				YES	YES	YES
STRING				YES	YES [1]	YES
ENUMERATED VALUE		YES		YES[2]	YES [3]	YES [4]

5.4.6.5 SQL Extension: Regular Expression Matching

The relational operator **MATCH** may only be used with string fields. The right-hand operator is a string pattern. A string pattern specifies a template that the left-hand field must match.

MATCH is case-sensitive. The following characters have special meaning, unless escaped by the escape character: `,\/?*[]-^!\%`.

The pattern allows limited "wild card" matching under the rules in Table 5.7 Wild Card Matching.

The syntax is similar to the POSIX® **fnmatch** syntax. (See http://www.open-group.org/onlinepubs/000095399/functions/fnmatch.html.) Some example expressions include:

---

[a] See 5.4.6.5 SQL Extension: Regular Expression Matching below.

[2] Because of the formal notation of the Enumeration values, they are compatible with string and char literals, but they are not compatible with string or char variables, i.e., "MyEnum='EnumValue'" is correct, but "MyEnum=MyString" is not allowed.

[3] Because of the formal notation of the Enumeration values, they are compatible with string and char literals, but they are not compatible with string or char variables, i.e., "MyEnum='EnumValue'" is correct, but "MyEnum=MyString" is not allowed.

[4] Only for same-type Enums.

This expression evaluates to TRUE if the value of **symbol** is equal to **NASDAQ/MSFT**:

```
symbol MATCH 'NASDAQ/MSFT'
```

This expression evaluates to TRUE if the value of **symbol** is equal to **NASDAQ/IBM** or **NASDAQ/MSFT**:

```
symbol MATCH 'NASDAQ/IBM,NASDAQ/MSFT'
```

This expression evaluates to TRUE if the value of **symbol** is equal to **NASDAQ** *and* starts with a letter between M and Y:

```
symbol MATCH 'NASDAQ/[M-Y]*'
```

Table 5.7 Wild Card Matching

Character	Meaning
,	A , separates a list of alternate patterns. The field string is matched if it matches one or more of the patterns.
/	A / in the pattern string matches a / in the field string. It separates a sequence of mandatory substrings.
?	A ? in the pattern string matches any single non-special characters in the field string.
*	A * in the pattern string matches 0 or more non-special characters in field string.
%	This special character is used to designate filter expression parameters.
\	Escape character for special characters.
[charlist]	Matches any one of the characters in charlist.
[!charlist] or [^charlist]	*(Not supported)* Matches any one of the characters *not* in charlist.
[s-e]	Matches any character from **s** to **e**, inclusive.
[!s-e] or [^s-e]	*(Not supported)* Matches any character *not* in the interval **s** to **e**.

5.4.6.6 Composite Members

Any member can be used in the filter expression, with the following exceptions:

- 128-bit floating point numbers (long doubles) are not supported
- bitfields are not supported
- **LIKE** is not supported

Composite members are accessed using the familiar dot notation, such as "**x.y.z > 5**". For unions, the notation is special due to the nature of the IDL union type.

On the publishing side, you can access the union discriminator with **myunion._d** and the actual member with **myunion._u.mymember**. If you want to use a ContentFilteredTopic on the subscriber side and filter

a DDS sample with a top-level union, you can access the union discriminator directly with **_d** and the actual member with **mymember** in the filter expression.

5.4.6.7 Strings

The filter expression and parameters can use IDL strings. String constants must appear between single quotation marks (').

For example:

```
" fish = 'salmon' "
```

Strings used as parameter values must contain the enclosing quotation marks (') within the parameter value; do not place the quotation marks within the expression statement. For example, the expression " symbol MATCH %0 " with parameter 0 set to " 'IBM' " is legal, whereas the expression " symbol MATCH '%0' " with parameter 0 set to " IBM " will not compile.

5.4.6.8 Enumerations

A filter expression can use enumeration values, such as GREEN, instead of the numerical value. For example, if **x** is an enumeration of GREEN, YELLOW and RED, the following expressions are valid:

```
"x = 'GREEN'"
"X < 'RED'"
```

5.4.6.9 Pointers

Pointers can be used in filter expressions and are automatically dereferenced to the correct value.

For example:

```
struct Point {
    long x;
    long y;
};
struct Rectangle {
    Point *u_l;
    Point *l_r;
};
```

The following expression is valid on a *Topic* of type Rectangle:

```
"u_l.x > l_r.x"
```

5.4.6.10 Arrays

Arrays are accessed with the familiar **[]** notation.

For example:

```
struct ArrayType {
    long value[255][5];
```

```
};
```

The following expression is valid on a *Topic* of type ArrayType:

```
"value[244][2] = 5"
```

In order to compare an array of bytes(octets in idl), instead of comparing each individual element of the array using **[]** notation, *Connext DDS* provides a helper function, **hex()**. The **hex()** function can be used to represent an array of bytes (octets in IDL). To use the **hex()** function, use the notation **&hex()** and pass the byte array as a sequence of hexadecimal values.

For example:

```
&hex  (07 08 09 0A 0B 0c 0D 0E 0F 10 11 12 13 14 15 16)
```

Here the leftmost-pair represents the byte at index 0.

Note: If the length of the octet array represented by the **hex()** function does not match the length of the field being compared, it will result in a compilation error.

For example:

```
struct ArrayType {
    octet value[2];
};
```

The following expression is valid:

```
"value = &hex(12 0A)"
```

5.4.6.11 Sequences

Sequence elements can be accessed using the `()` or `[]` notation.

For example:

```
struct SequenceType {
    sequence<long> s;
};
```

The following expressions are valid on a *Topic* of type SequenceType:

```
"s(1) = 5"
"s[1] = 5"
```

5.4.7 STRINGMATCH Filter Expression Notation

The STRINGMATCH Filter is a subset of the SQL filter; it only supports the MATCH relational operator on a single string field. It is introduced mainly for the use case of partitioning data according to channels in the *DataWriter's* 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429 in Market Data applications.

A STRINGMATCH filter expression has the following syntax:

```
<field name> MATCH <string pattern>
```

The STRINGMATCH filter is provided to support the narrow use case of filtering a single string field of the DDS sample against a comma-separated list of matching string values. It is intended to be used in conjunction with ContentFilteredTopic helper routines **append_to_expression_parameter()** (5.4.5.3 Appending a String to an Expression Parameter on page 234) and **remove_from_expression_parameter()** (5.4.5.4 Removing a String from an Expression Parameter on page 235), which allow you to easily append and remove individual string values from the comma-separated list of string values.

The STRINGMATCH filter must contain only one <field name>, and a single occurrence of the MATCH operator. The <string pattern> must be either the single parameter %0, or a single, comma-separated list of strings without intervening spaces.

During creation of a STRINGMATCH filter, the <string pattern> is automatically parameterized. That is, during creation, if the <string pattern> specified in the filter expression is not the parameter %0, then the comma-separated list of strings is copied to the initial contents of parameter 0 and the <string pattern> in the filter expression is replaced with the parameter %0.

The initial matching string list is converted to an explicit parameter value so that subsequent additions and deletions of string values to and from the list of matching strings may be performed with the **append_to_expression_parameter()** and **remove_from_expression_parameter()** operations mentioned above.

5.4.7.1 Example STRINGMATCH Filter Expressions

This expression evaluates to TRUE if the value of **symbol** is equal to **NASDAQ/MSFT**:

```
symbol MATCH 'NASDAQ/MSFT'
```

This expression evaluates to TRUE if the value of **symbol** is equal to **NASDAQ/IBM** or **NASDAQ/MSFT**:

```
symbol MATCH 'NASDAQ/IBM,NASDAQ/MSFT'
```

This expression evaluates to TRUE if the value of **symbol** is equal to **NASDAQ** *and* starts with a letter between M and Y:

```
symbol MATCH 'NASDAQ/[M-Y]*'
```

```
symbol MATCH 'NASDAQ/MSFT'
```

5.4.7.2 STRINGMATCH Filter Expression Parameters

In the builtin STRINGMATCH filter, there is one, and only one, parameter: parameter 0. (If you want to add more parameters, see 5.4.5.3 Appending a String to an Expression Parameter on page 234.) The parameter can be specified explicitly using the same syntax as the SQL filter or implicitly by using a constant string pattern. For example:

```
symbol MATCH %0   (Explicit parameter)
symbol MATCH 'IBM' (Implicit parameter initialized to IBM)
```

Strings used as parameter values must contain the enclosing quotation marks (') within the parameter value; do not place the quotation marks within the expression statement. For example, the expression " symbol MATCH %0 " with parameter 0 set to " 'IBM' " is legal, whereas the expression " symbol MATCH '%0' " with parameter 0 set to " IBM " will not compile.

5.4.8 Character Encoding

Connext DDS offers ISO 8859-1 as an alternative encoding for IDL strings. The default is UTF-8. To configure ISO 8859-1 for filtering of IDL strings, set the value of the *DomainParticipant's* Property Qos property **dds.domain_participant.filtering_character_encoding** to ISO-8859-1.

The possible values for **dds.domain_participant.filtering_character_encoding** are:

- UTF-8 (default value)
- ISO-8859-1

This property is applicable to the following filtering features:

- ContentFilteredTopics (see 5.4 ContentFilteredTopics on page 227)
- Query conditions (see 4.6.7 ReadConditions and QueryConditions on page 209)
- TopicQueries (see Chapter 24 Topic Queries on page 962)
- MultiChannel *DataWriters* (see Chapter 20 Multi-channel DataWriters on page 888)

5.4.9 Unicode Normalization

Unicode supports multiple ways to encode some characters, most notably accented characters. A composed character in Unicode can often have a number of different ways of representing the character. For example:

Precomposed L̂ is represented by \u1e3c

Composed L̂ = L + ^ is represented by \u004c + \u032d

The lexical comparison of the two characters above will return false. To do the correct comparison, the characters need to be normalized—that is, reduced to the same character composition.

When the character encoding for filtering of IDL strings is UTF-8, the Unicode normalization behavior can be controlled using a *DomainParticipant* Property Qos property called **dds.domain_participant.filtering_unicode_normalization**.

The possible values of the normalization property are:

- OFF: Disables normalization
- NFD: Canonical Decomposition
- NFC (default value): Canonical Decomposition, followed by Canonical Composition
- NFKC: Compatibility Decomposition, followed by Canonical Composition
- NFKC_Casefold: Casefold followed by NFKC normalization

This property is applicable to the following filtering features:

- ContentFilteredTopics (see 5.4 ContentFilteredTopics on page 227)
- Query conditions (see 4.6.7 ReadConditions and QueryConditions on page 209)
- TopicQueries (see Chapter 24 Topic Queries on page 962)
- MultiChannel *DataWriters* (see Chapter 20 Multi-channel DataWriters on page 888)

Because normalization may affect performance, and it is enabled by default, the property allows disabling the normalization process per *DomainParticipant* using the value OFF. However, be aware that doing this may lead to unexpected behavior.

5.4.10 Custom Content Filters

By default, a ContentFilteredTopic will use a SQL-like content filter, DDS_SQLFILTER_NAME (see 5.4.6 SQL Filter Expression Notation on page 235), which implements a superset of the content filter. There is another builtin filter, **DDS_STRINGMATCHFILTER_NAME** (see 5.4.7 STRINGMATCH Filter Expression Notation on page 244). Both of these are automatically registered.

If you want to use a different filter, **you must register it first**, then create the ContentFilteredTopic using **create_contentfilteredtopic_with_filter()** (see 5.4.3 Creating ContentFilteredTopics on page 229).

One reason to use a custom filter is that the default filter can only filter based on relational operations between topic members, not on a computation involving topic members. For example, if you want to filter based on the sum of the members, you must create your own filter.

Note:

- The API for using a custom content filter is subject to change in a future release.

5.4.10.1 Filtering on the Writer Side with Custom Filters

There are two approaches for performing writer-side filtering. The first approach is to evaluate each written DDS sample against filters of all the readers that have content filter specified and identify the readers whose filter passes the DDS sample.

The second approach is to evaluate the written DDS sample once for the writer and then rely on the filter implementation to provide a set of readers whose filter passes the DDS sample. This approach allows the filter implementation to cache the result of filtering, if possible. For example, consider a scenario where the data is described by the struct shown below, where 10<x<20:

```
struct MyData {
       int x;
       int y;
};
```

If the filter expression is based only on the ***x*** field, the filter implementation can maintain a hash map for all the different values of ***x*** and cache the filtering results in the hash map. Then any future evaluations will only be O(1), because it only requires a lookup in the hash map.

But if in the same example, a reader has a content filter that is based on both ***x*** and ***y***, or just ***y,*** the filter implementation cannot cache the result—because the filter was only maintaining a hash map for ***x***. In this case, the filter implementation can inform *Connext DDS* that it will not be caching the result for those *DataReaders*. The filter can use DDS_ExpressionProperty to indicate to the middleware whether or not it will cache the results for *DataReader*. Table 5.8 DDS_ExpressionProperty describes DDS_ExpressionProperty.

Table 5.8 DDS_ExpressionProperty

Type	Field Name	Description
DDS_Boolean	key_only_filter	Indicates if the filter expression is based only on key fields. In this case, *Connext DDS* itself can cache the filtering results.
DDS_Boolean	writer_side_filter_optimization	Indicates if the filter implementation can cache the filtering result for the expression provided. If this is true then *Connext DDS* will do no caching or explicit filter evaluation for the associated *DataReader*. It will instead rely on the filter implementation to provide appropriate results.

5.4.10.2 Registering a Custom Filter

To use a custom filter, it must be registered in the following places:

- Register the custom filter in any subscribing application in which the filter is used to create a ContentFilteredTopic and corresponding *DataReader*.
- In each publishing application, you only need to register the custom filter if you want to perform writer-side filtering. A *DataWriter* created with an associated filter will use that filter if it discovers a matched *DataReader* that uses the same filter.

For example, suppose Application A on the subscription side creates a *Topic* named **X** and a ContentFilteredTopic named **filteredX** (and a corresponding *DataReader*), using a previously registered content filter, **myFilter**. With only that, you will have filtering on the subscription side. If you also want to

perform filtering in any application that publishes *Topic* **X**, then you also need to register the same definition of the ContentFilter **myFilter** in that application.

To register a new filter, use the *DomainParticipant's* **register_contentfilter()** operation[1]:

```
DDS_ReturnCode_t register_contentfilter(
       const char * filter_name,
        const DDSContentFilter * contentfilter)
```

- **filter_name**

  The name of the filter. The name must be unique within the *DomainParticipant*. The **filter_name** cannot have a length of 0. The same filtering functions and handle can be registered under different names.
- **content_filter**

  This class specifies the functions that will be used to process the filter.

You must derive from the DDSContentFilter base class and implement the virtual compile below, evaluate below, and finalize below functions described below.

Optionally, you can derive from the DDSWriterContentFilter base class instead, to implement additional filtering operations that will be used by the *DataWriter*. When performing writer-side filtering, these operations allow a DDS sample to be evaluated once for the *DataWriter*, instead of evaluating the DDS sample for every *DataReader* that is matched with the *DataWriter*. An instance of the derived class is then used as an argument when calling **register_contentfilter()**.

- **compile**

  The function that will be used to compile a filter expression and parameters. *Connext DDS* will call this function when a ContentFilteredTopic is created and when the filter parameters are changed. This parameter cannot be NULL. See 5.4.10.5 Compile Function on page 251. This is a member of DDSContentFilter and DDSWriterContentFilter.
- **evaluate**

  The function that will be called by *Connext DDS* each time a DDS sample is received. Its purpose is to evaluate the DDS sample based on the filter. This parameter cannot be NULL. See 5.4.10.6 Evaluate Function on page 252. This is a member of DDSContentFilter and DDSWriterContentFilter.
- **finalize**

[1]This operation is an extension to the DDS standard.

The function that will be called by *Connext DDS* when an instance of the custom content filter is no longer needed. This parameter may be NULL. See 5.4.10.7 Finalize Function on page 253. This is a member of DDSContentFilter and DDSWriterContentFilter.

- **writer_attach**

  The function that will be used to create some state required to perform filtering on the writer side using the operations provided in DDSWriterContentFilter. *Connext DDS* will call this function for every *DataWriter;* it will be called only the *first time* the *DataWriter* matches a *DataReader* using the specified filter. This function will not be called for any subsequent *DataReaders* that match the *DataWriter* and are using the same filter. See 5.4.10.8 Writer Attach Function on page 253. This is a member of DDSWriterContentFilter.
- **writer_detach**

  The function that will be used to delete any state created using the writer_attach function. *Connext DDS* will call this function when the *DataWriter* is deleted. See 5.4.10.9 Writer Detach Function on page 253. This is a member of DDSWriterContentFilter.
- **writer_compile**

  The function that will be used by the *DataWriter* to compile filter expression and parameters provided by the reader. *Connext DDS* will call this function when the *DataWriter* discovers a *DataReader* with a ContentFilteredTopic or when a *DataWriter* is notified of a change in *DataReader's* filter parameter. This function will receive as an input a **DDS_Cookie_t** which uniquely identifies the *DataReader* for which the function was invoked. See 5.4.10.10 Writer Compile Function on page 254. This is a member of DDSWriterContentFilter.
- **writer_evaluate**

  The function that will be called by *Connext DDS* every time a *DataWriter* writes a new DDS sample. Its purpose is to evaluate the DDS sample for all the readers for which the *DataWriter* is performing writer-side filtering and return the list of **DDS_Cookie_t** associated with the *DataReaders* whose filter pass the DDS sample. See 5.4.10.11 Writer Evaluate Function on page 254.
- **writer_return_loan**

  The function that will be called by *Connext DDS* to return the loan on a sequence of **DDS_Cookie_t** provided by the **writer_evaluate** function. See 5.4.10.12 Writer Return Loan Function on page 255. This is a member of DDSWriterContentFilter.
- **writer_finalize**

  The function that will be called by *Connext DDS* to notify the filter implementation that the *DataWriter* is no longer matching with a *DataReader* for which it was previously performing writer-side filtering. This will allow the filter to purge any state it was maintaining for the

DataReader. See 5.4.10.13 Writer Finalize Function on page 255. This is a member of DDSWriterContentFilter.

5.4.10.3 Unregistering a Custom Filter

To unregister a filter, use the *DomainParticipant's* **unregister_contentfilter()** operation[1], which is useful if you want to reuse a particular filter name. (Note: You do not have to unregister the filter before deleting the parent *DomainParticipant*. If you do not need to reuse the filter name to register another filter, there is no reason to unregister the filter.)

```
DDS_ReturnCode_t unregister_contentfilter(const char * filter_name)
```

filter_name	The name of the previously registered filter. The name must be unique within the *DomainParticipant*. The **filter_name** cannot have a length of 0.

If you attempt to unregister a filter that is still being used by a ContentFilteredTopic, **unregister_contentfilter()** will return **PRECONDITION_NOT_MET**.

If there are still existing discovered *DataReaders* with the same **filter_name** and the filter's **compile** function has previously been called on the discovered *DataReaders*, the filter's **finalize** function will be called on those discovered *DataReaders* before the content filter is unregistered. This means filtering will be performed on the application that is creating the *DataReader*.

5.4.10.4 Retrieving a ContentFilter

If you know the name of a ContentFilter, you can get a pointer to its structure. If the ContentFilter has not already been registered, this operation will return NULL.

```
DDS_ContentFilter *lookup_contentfilter (const char * filter_name)
```

5.4.10.5 Compile Function

The **compile** function specified in the ContentFilter will be used to compile a filter expression and parameters. Please note that the term 'compile' is intentionally defined very broadly. It is entirely up to you, as the user, to decide what this function should do. The only requirement is that the **error_code** parameter passed to the compile function must return **OK** on successful execution. For example:

```
DDS_ReturnCode_t sample_compile_function(
    void **  new_compile_data, const char * expression,
    const DDS_StringSeq & parameters,
    const DDS_TypeCode * type_code,
    const char *  type_class_name,
    void *  old_compile_data)
{
  *new_compile_data = (void*)DDS_String_dup(parameters[0]);
```

[1]This operation is an extension to the DDS standard.

```
  return DDS_RETCODE_OK;
}
```

Where:

new_compile_data	A user-specified opaque pointer of this instance of the content filter. This value is passed to the **evaluate** and **finalize** functions
expression	An ASCIIZ string with the filter expression the ContentFilteredTopic was created with. Note that the memory used by the parameter pointer is owned by *Connext DDS*. If you want to manipulate this string, you *must* make a copy of it first. Do not free the memory for this string.
parameters	A string sequence of expression parameters used to create the ContentFilteredTopic. The string sequence is equal (but not identical) to the string sequence passed to **create_contentfilteredtopic()** (see **expression_parameters** in 5.4.3 Creating ContentFilteredTopics on page 229). The sequence passed to the **compile** function is owned by *Connext DDS* and must not be referred to outside the **compile** function.
type_code	A pointer to the type code of the related *Topic*. A type code is a description of the topic members, such as their type (long, octet, etc.), but does not contain any information with respect to the memory layout of the structures. The type code can be used to write filters that can be used with any type. See 3.7 Using Generated Types without Connext DDS (Standalone) on page 152. [Note: If you are using the Java API, this parameter will always be NULL.]
type_class_name	Fully qualified class name of the related *Topic*.
old_compile_data	The **new_compile_data** value from a *previous* call to this instance of a content filter. If **compile** is called more than once for an instance of a ContentFilteredTopic (such as if the expression parameters are changed), then the **new_compile_data** value returned by the previous invocation is passed in the **old_compile_data** parameter (which can be NULL). If this is a new instance of the filter, NULL is passed. This parameter is useful for freeing or reusing previously allocated resources.

5.4.10.6 Evaluate Function

The **evaluate** function specified in the ContentFilter will be called each time a DDS sample is received. This function's purpose is to determine if a DDS sample should be filtered out (not put in the receive queue).

For example:

```
DDS_Boolean sample_evaluate_function(
      void* compile_data,
      const void* sample,
      struct DDS_FilterSampleInfo * meta_data) {
  char *parameter = (char*)compile_data;
  DDS_Long x;
  Foo *foo_sample = (Foo*)sample;
  sscanf(parameter,"%d",&x);
  return (foo_sample->x > x ? DDS_BOOLEAN_FALSE : DDS_BOOLEAN_TRUE);
}
```

The function may use the following parameters:

compile_data	The last return value from the **compile** function for this instance of the content filter. Can be NULL.
sample	A pointer to a C structure with the data to filter. Note that the **evaluate** function always receives *deserialized* data.
meta_data	A pointer to the meta data associated with the DDS sample.

Note: Currently the **meta_data** field only supports **related_sample_identity** (described in Table 7.17 DDS_WriteParams_t).

5.4.10.7 Finalize Function

The **finalize** function specified in the ContentFilter will be called when an instance of the custom content filter is no longer needed. When this function is called, it is safe to free all resources used by this particular instance of the custom content filter.

For example:

```
void sample_finalize_function ( void* compile_data) {
    /* free parameter string from compile function */
    DDS_String_free((char *)compile_data);
}
```

The **finalize** function may use the following optional parameters:

system_key	See 5.4.10.5 Compile Function on page 251.
handle	This is the opaque returned by the last call to the **compile** function.

5.4.10.8 Writer Attach Function

The **writer_attach** function specified in the WriterContentFilter will be used to create some state that can be used by the filter to perform writer-side filtering more efficiently. It is entirely up to you, as the implementer of the filter, to decide if the filter requires this state.

The function has the following parameter:

writer_filter_data	A user-specified opaque pointer to some state created on the writer side that will help perform writer-side filtering efficiently.

5.4.10.9 Writer Detach Function

The **writer_detach** function specified in the WriterContentFilter will be used to free up any state that was created using the **writer_attach** function.

The function has the following parameter:

writer_filter_data	A pointer to the state created using the **writer_attach** function.

5.4.10.10 Writer Compile Function

The **writer_compile** function specified in the WriterContentFilter will be used by a *DataWriter* to compile a filter expression and parameters associated with a *DataReader* for which the *DataWriter* is performing filtering. The function will receive as input a **DDS_Cookie_t** that uniquely identifies the *DataReader* for which the function was invoked.

The function has the following parameters:

writer_filter_data	A pointer to the state created using the **writer_attach** function.
prop	A pointer to DDS_ExpressionProperty. This is an output parameter. It allows you to indicate to *Connext DDS* if a filter expression can be optimized (as described in 5.4.10.1 Filtering on the Writer Side with Custom Filters on page 247).
expression	An ASCIIZ string with the filter expression the ContentFilteredTopic was created with. Note that the memory used by the parameter pointer is owned by *Connext DDS*. If you want to manipulate this string, you must make a copy of it first. Do not free the memory for this string.
parameters	A string sequence of expression parameters used to create the ContentFilteredTopic. The string sequence is equal (but not identical) to the string sequence passed to **create_contentfilteredtopic()** (see **expression_parameters** in 5.4.3 Creating ContentFilteredTopics on page 229). The sequence passed to the **compile** function is owned by *Connext DDS* and must not be referred to outside the **writer_compile** function.
type_code	A pointer to the type code of the related Topic. A type code is a description of the topic members, such as their type (long, octet, etc.), but does not contain any information with respect to the memory layout of the structures. The type code can be used to write filters that can be used with any type. See 3.7 Using Generated Types without Connext DDS (Standalone) on page 152. [Note: If you are using the Java API, this parameter will always be NULL.]
type_class_name	The fully qualified class name of the related Topic.
cookie	A **DDS_Cookie_t** to uniquely identify the *DataReader* for which the **writer_compile** function was called.

5.4.10.11 Writer Evaluate Function

The **writer_evaluate** function specified in the WriterContentFilter will be used by a *DataWriter* to retrieve the list of *DataReaders* whose filter passed the DDS sample. The **writer_evaluate** function returns a sequence of cookies which identifies the set of *DataReaders* whose filter passes the DDS sample.

The function has the following parameters:

writer_filter_data	A pointer to the state created using the **writer_attach** function.
sample	A pointer to the data to be filtered. Note that the **writer_evaluate** function always receives *deserialized* data.
meta_data	A pointer to the meta-data associated with the DDS sample.

Note: Currently the **meta_data** field only supports **related_sample_identity** (described in Table 7.17 DDS_WriteParams_t).

5.4.10.12 Writer Return Loan Function

Connext DDS uses the **writer_return_loan** function specified in the WriterContentFilter to indicate to the filter implementation that it has finished using the sequence of cookies returned by the filter's **writer_evaluate** function. Your filter implementation should *not* free the memory associated with the cookie sequence before the **writer_return_loan** function is called.

The function has the following parameters:

writer_filter_data	A pointer to the state created using the **writer_attach** function.
cookies	The sequence of cookies for which the **writer_return_loan** function was called.

5.4.10.13 Writer Finalize Function

The **writer_finalize** function specified in the WriterContentFilter will be called when the *DataWriter* no longer matches with a *DataReader* that was created with ContentFilteredTopic. This will allow the filter implementation to delete any state it was maintaining for the *DataReader*.

The function has the following parameters:

writer_filter_data	A pointer to the state created using the **writer_attach** function.
cookie	A **DDS_Cookie_t** to uniquely identify the *DataReader* for which the writer_finalize was called.

Chapter 6 Working with Instances

Instances are a way for an application to represent unique objects within a *Topic*, by specifying one or more key fields that form a unique identifier for the instance. Examples include identifying unique commercial flights within a "Flight Status" *Topic* or a unique sensor measuring the temperature in a "Temperature" *Topic*.

Modeling data using instances can provide several benefits to a system, including:

- An application can represent dynamic behavior of objects that come and go in a system, such as aircraft that may fly within range of a radar system and then fly out of range. See 6.1 Instance States on the next page for more details.
- Many QoS policies are applied per instance. For example, the 7.5.12 HISTORY QosPolicy on page 418 **depth** is applied per instance. This allows an application to specify: "Keep the last N samples for every instance this *DataReader* receives." See 6.3.1 QoS Policies that are Applied per Instance on page 265 for more examples.
- An application can use *DataReader* methods such as **read_instance()** and **take_instance()** to process all the samples for an instance at once.
- ContentFilteredTopics are more efficient when filtering instances. Using ContentFilteredTopics in combination with instances is a great way to allow applications to take advantage of writer-side filtering to only subscribe to logical subsets of a *Topic* by specifying the instances that they are interested in.

Instances are defined by key fields that make up a unique identifier of the object being represented. Key fields are similar to primary keys in a database—each unique combination of key field values represents a unique instance. Key fields are specified using the @key directive, as shown in 2.4 DDS Samples, Instances, and Keys on page 18.

Table 6.1 Example Keys and Instances

Instance (object represented in data)	Key (field/s uniquely identifying object)	Data type	Sample (update to object)

Commercial flight being tracked	Airline name and flight number, such as:
	Airline: "United Airlines"
	Flight number: 901
		`@key string airline`
		`@key short flight_num`
		`float lat`
		`float long`
			UA, 901, 37.7749, 122.4194
			UA, 901, 37.7748, 122.4195

Sensor that is sending data, such as an individual temperature sensor	Unique identifier of that sensor, such as: "Floor-08-South"	`@key string sensor_id` `long temperature`	**Floor-08-South,** 78 **Floor-08-South,** 79

Car being monitored	Vehicle identification number (VIN) of the car	`@key string VIN`
		`float lat`
		`float long`
			JH4DA9370MS016526, 37.7749, 122.4194
			JH4DA9370MS016526, 37.7748, 122.4195

See the following sections:

- 6.1 Instance States below
- 6.2 Instance Memory Management on page 263
- 6.3 QoS Configuration and Instances on page 265

See also more details on instances from the *DataWriter* and *DataReader* perspectives:

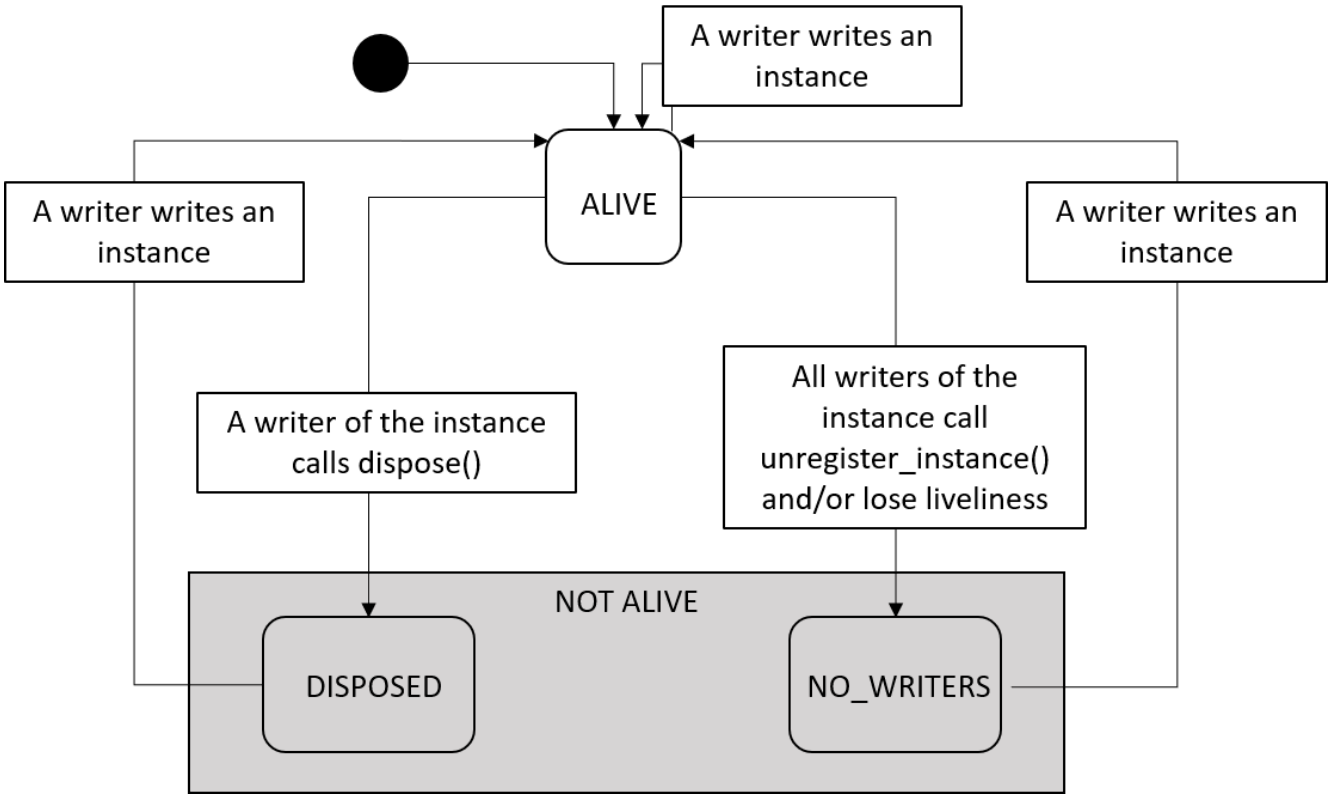
- For the *DataWriter*: 7.3.14 Managing Instances (Working with Keyed Data Types) on page 324
- For the *DataReader*: 8.3.8 Accessing and Managing Instances (Working with Keyed Data Types) on page 530

6.1 Instance States

Instances can be in one of three states:

- **ALIVE**: An existing *DataWriter* has written a sample of the instance.
- **NOT_ALIVE_DISPOSED**: A *DataWriter* that has written the instance has called **dispose()** on the instance. (See 7.3.14.3 Disposing Instances on page 327 for further clarification when using EXCLUSIVE Ownership.)
- **NOT_ALIVE_NO_WRITERS**: All *DataWriters* that have written the instances have gone away (more on that later), or called **unregister_instance()** to unregister themselves from the instance.

Figure 6.1: Overview of Instance States and Transitions



6.1.1 ALIVE Details

The **ALIVE** instance state indicates that there is a *DataWriter* actively updating that instance, and no *DataWriter* has declared the instance to be "disposed" (see below).

An instance becomes **ALIVE** when a *DataWriter* writes a sample of that instance. This is true regardless of the previous state of the instance. For example, if an instance is **NOT_ALIVE_DISPOSED**, it becomes alive again when a *DataWriter* writes the instance. The only way for the instance to transition to becoming **ALIVE** is for a *DataWriter* to write a sample of that instance.

Instances and OWNERSHIP QoS: If the *DataWriters'* QoS is set to OWNERSHIP = EXCLUSIVE, the *DataWriter* with the highest OWNERSHIP_STRENGTH that has written the instance is the owner of the instance, unless it unregisters the instance, loses liveliness, or is deleted. If the instance has been disposed, only the *DataWriter* that owns that instance can make it transition to the **ALIVE** state by writing that instance. See 7.5.17 OWNERSHIP QosPolicy on page 432.

6.1.2 NOT_ALIVE_DISPOSED Details

The **NOT_ALIVE_DISPOSED** instance state indicates that a *DataWriter* has explicitly changed the state of an instance to **NOT_ALIVE_DISPOSED** by calling the **dispose()** method on the instance. The meaning of an instance becoming **NOT_ALIVE_DISPOSED** is part of the design of a system.

When a *DataWriter* calls **dispose()** on an instance, a dispose message is propagated from the *DataWriter* to its matching *DataReaders* to tell those *DataReaders* that the instance's state is changed to **NOT_ALIVE_DISPOSED**.

Many systems use the **NOT_ALIVE_DISPOSED** instance state to indicate that the object that the instance represents has gone away. For example, in a "FlightData" topic, a system may use the **NOT_ALIVE_DISPOSED** instance state to indicate that the aircraft tracked by a radar system has flown out of range or has landed.

One common misconception is that the memory belonging to a disposed instance is immediately freed when the *DataWriter* calls **dispose()**. This is not true, because the dispose message needs to be propagated to *DataReaders*. This means that information about the instance—and the fact that it was disposed—is kept in the *DataWriter's* queue based on QoS policies such as 7.5.21 RELIABILITY QosPolicy on page 444, 7.5.9 DURABILITY QosPolicy on page 410, and 7.5.12 HISTORY QosPolicy on page 418. See 6.3.2 QoS Policies that Affect Instance Management on page 266 for more information on managing resources for instances.

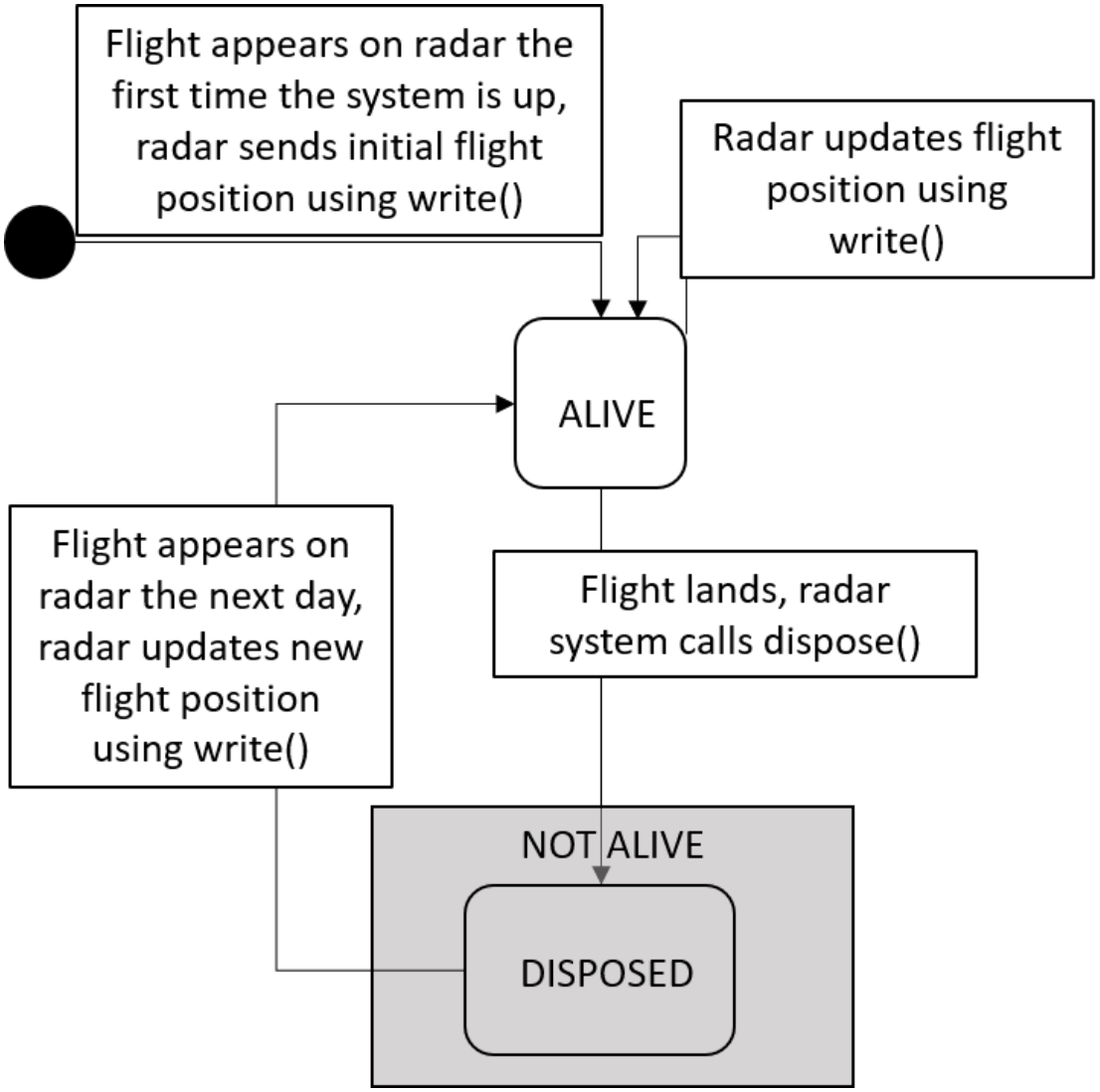
An instance can transition from **NOT_ALIVE_DISPOSED** to **ALIVE** if a *DataWriter* writes a new sample of that instance. An example of a system that transitions an instance to **NOT_ALIVE_DISPOSED** and then back to **ALIVE** is a radar system at an airport. It could be tracking a flight with the following key fields:

airline = UA

flight_num = 901

In this example, when the flight arrives on radar, the instance becomes **ALIVE**. When the flight lands, it becomes **NOT_ALIVE_DISPOSED**. The same flight flies every day, so it transitions from **NOT_ALIVE_DISPOSED** to **ALIVE** when the flight arrives again the next day. This maps to the state diagram shown in Figure 6.2: Instance State Diagram: Example for Flight Data on the next page.

Figure 6.2: Instance State Diagram: Example for Flight Data



Instances and OWNERSHIP QoS: If the *DataWriters'* QoS policy is set to OWNERSHIP = EXCLUSIVE, the *DataWriter* with the highest OWNERSHIP_STRENGTH that has written the instance is the owner of the instance. It is also the only *DataWriter* that can dispose the instance. It does not lose ownership by disposing. Other *DataWriters* can call **dispose(),** but their dispose will have no effect on the instance state. OWNERSHIP is generally used for redundancy purposes, so it makes sense for only one owning *DataWriter* at a time to affect the instance state. See 7.5.17 OWNERSHIP QosPolicy on page 432 for further details.

6.1.3 NOT_ALIVE_NO_WRITERS Details

The **NOT_ALIVE_NO_WRITERS** instance state indicates that there are no active *DataWriters* that are currently updating the instance.

An instance becomes **NOT_ALIVE_NO_WRITERS** if all *DataWriters* that have written that instance have unregistered themselves from the instance or become not alive themselves (through losing liveliness, losing discovery liveliness, or being deleted). This means that if all *DataWriters* that have written samples for an instance are deleted, the instance changes state to **NOT_ALIVE_NO_WRITERS**.

Currently the state transition from **NOT_ALIVE_NO_WRITERS** to **ALIVE** happens only if new data is received, not if a previously-known writer is determined to be alive. Take for example a system where there is only a single *DataWriter* of an instance. If that *DataWriter* loses liveliness due to a temporary network disconnection, the *DataReaders* will detect that the instance is **NOT_ALIVE_NO_WRITERS**. When the network disconnection is resolved, the *DataReaders* will detect that the *DataWriter* has regained liveliness, but will not change the instance state to ALIVE until the *DataWriter* sends a new sample of that instance.

6.1.4 Transitions between NOT_ALIVE States

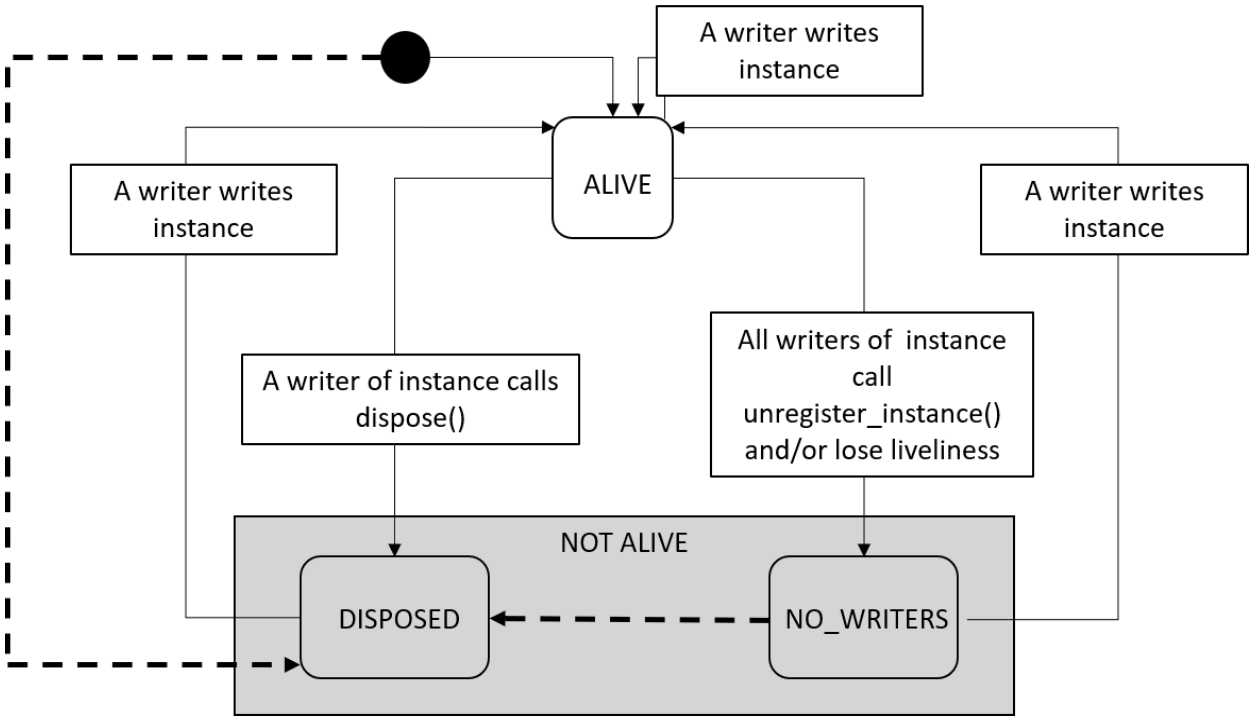
By default, there is no state transition between the **NOT_ALIVE_NO_WRITERS** and **NOT_ALIVE_DISPOSED** states, but this can be overridden by using the QoS settings **propagate_dispose_of_unregistered_instances** and **propagate_unregister_of_disposed_instances** on a *DataReader* via the 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565.

Setting **propagate_dispose_of_unregistered_instances** to true means that if all *DataWriters* lose liveliness (so the instance becomes **NOT_ALIVE_NO_WRITERS**), and then a *DataWriter* calls **dispose()** on the instance, the *DataReader* will recognize that instance as **NOT_ALIVE_DISPOSED** once the *DataWriter* regains liveliness.

Setting **propagate_dispose_of_unregistered_instances** to true could also mean that the first message a *DataReader* receives about an instance is **NOT_ALIVE_DISPOSED**. In Figure 6.3: Instance State Transitions: propagate_dispose_of_unregistered_instances = true on the next page, there is a new initial state transition from a *DataReader* never having seen an instance to seeing it as **NOT_ALIVE_DISPOSED**. In this case, the *DataReader* recognizes that the instance went from never existing (as far as the *DataReader* is concerned) to **NOT_ALIVE_DISPOSED**.

It is recommended that if you set **propagate_dispose_of_unregistered_instances** to true, you also set **serialize_key_with_dispose** to true (see 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388). This QoS will allow the subscribing application to retrieve the key value of the instance through the **FooDataReader_get_key_value** API, even though a valid sample for that instance has not been received.

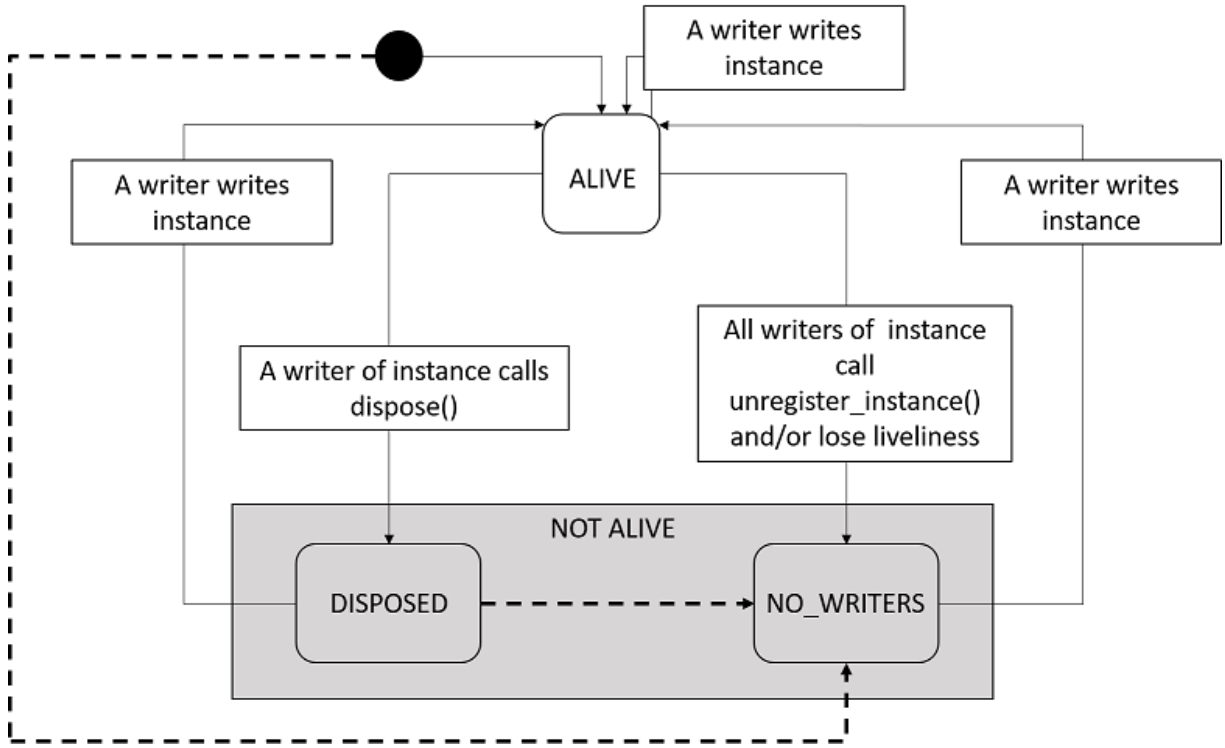
Figure 6.3: Instance State Transitions: propagate_dispose_of_unregistered_instances = true



*Transitions shown with dashed lines are only available when **propagate_dispose_of_unregistered_instances** = true.*

The **propagate_unregister_of_disposed_instances** QoS setting in the 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565 works in a similar way to **propagate_dispose_of_unregistered_instances**, but allows state transitions from the instance being disposed or not existing to **NOT_ALIVE_NO_WRITERS**. See Figure 6.4: Instance State Transitions: propagate_unregister_of_disposed_instances = true on the next page. By default, only the resources for instances in the **NOT_ALIVE_NO_WRITERS** instance state are reclaimable in the *DataReader* queue. In a system with finite instance resource limits, the **propagate_unregister_of_disposed_instances** setting allows an application to dispose instances to signal that the instance has gone away and then unregister those instances to make sure that the instances' resources are reclaimable for use by new instances. Depending on your system requirements, another approach to reclaiming instance resources in the *DataReader* queue is to set **autopurge_disposed_instances_delay** to zero. See 8.3.8.6 Instance Resource Limits and Memory Management on page 535 for more details.

Figure 6.4: Instance State Transitions: propagate_unregister_of_disposed_instances = true



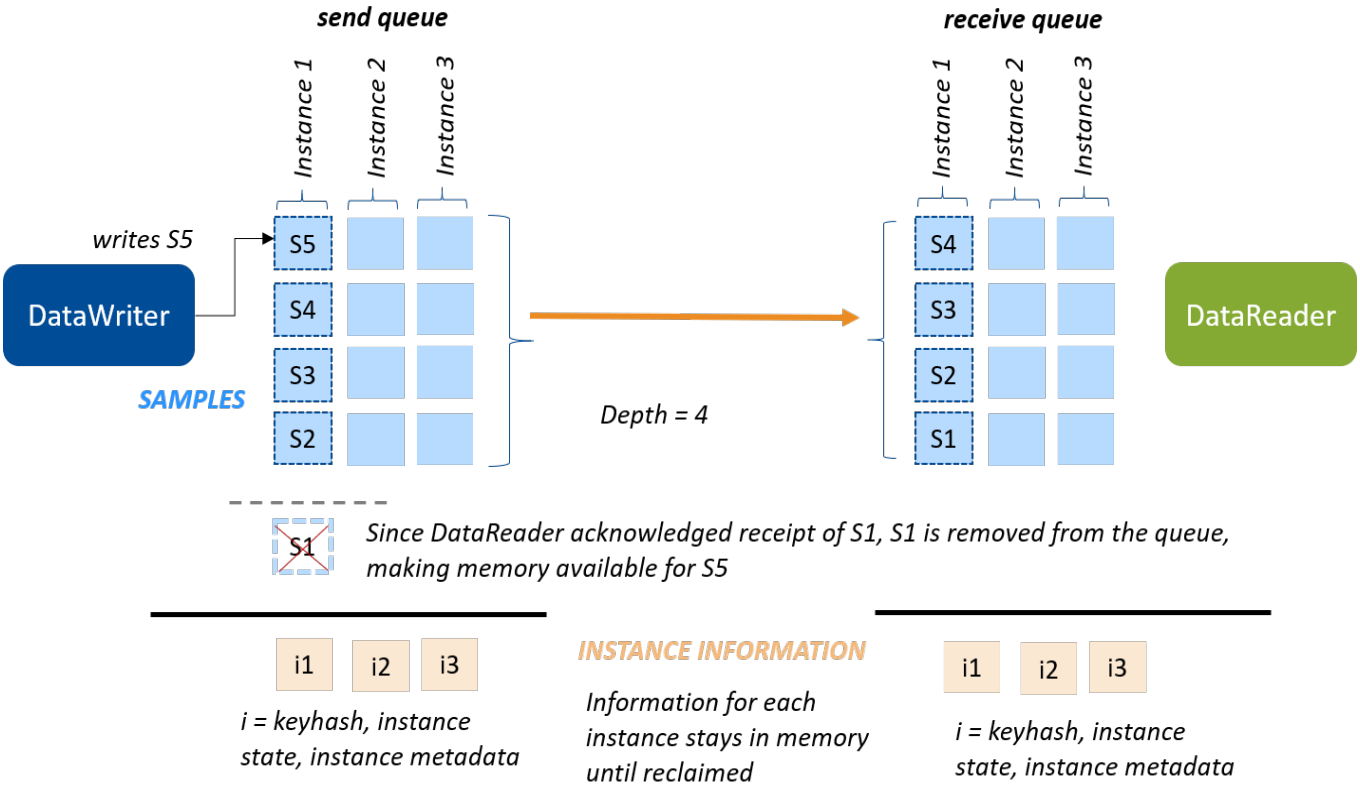
*Transitions shown with dashed lines are only available when **propagate_unregister_of_disposed_instances** = true.*

6.2 Instance Memory Management

When an application creates keyed *DataWriters* and *DataReaders* (these are *DataWriters* and *DataReaders* whose *Topics* are keyed), *Connext DDS* needs to allocate memory for instance metadata. (Such metadata is not required for non-keyed data.) This includes memory for instance-specific metadata such as maintaining the current state of each instance and memory for instance keyhashes. Keyhashes are 16-byte representations of unique instances that are sent along with a sample. They allow *DataWriters* and *DataReaders* to quickly identify each unique instance without comparing all individual key fields.

The memory used for instances is separate from sample memory. A *DataWriter* or *DataReader* may have metadata stored for an instance even if there are currently no samples in the *DataWriter's* or *DataReader's* queue. Furthermore, memory related to instances and instance metadata is not deleted, but reclaimed. How memory is reclaimed for instances depends on how your QoS is set, and those QoS settings differ between *DataWriters* and *DataReaders*. For example, disposing an instance does not necessarily free up memory, depending on how your QoS is configured. (By default, the QoS settings do not free instance memory when instances are disposed.)

Figure 6.5: Comparing Sample Memory and Instance Memory



Consider a reliable, volatile *DataWriter* that writes a sample of an instance for the first time. The *DataWriter* stores the sample in its queue. At the same time, the *DataWriter* stores the keyhash for that instance, the state of the instance (**ALIVE**), and additional metadata about the instance. All matching *DataReaders* acknowledge the sample, so the *DataWriter* removes the sample from its queue, allowing that memory to be reused by another sample; however, the instance metadata is still valid, and continues to be stored.

Similarly, when each *DataReader* receives the first update about an instance, it stores the sample in its queue; it also stores the instance's keyhash and state (**ALIVE**), and additional metadata about the instance. When the *DataReader* takes the sample from the queue, the sample is removed from the queue, allowing that memory to be reused by another sample; however, the instance metadata is still valid and continues to be stored.

Details on how *DataWriters* and *DataReaders* allocate and reclaim memory for instances can be found in the following sections:

- Details on the QoS policies that configure memory management on *DataWriters* are covered in 7.3.14.7 Instance Memory Management on page 329.

- Details on the QoS that configure memory management on *DataReaders* are covered in 8.3.8.6 Instance Resource Limits and Memory Management on page 535.

6.3 QoS Configuration and Instances

Some QoS policies are applied *per instance*, and other QoS policies configure instance management:

6.3.1 QoS Policies that are Applied per Instance

Several QoS policies (listed below) are applied per instance. This means that the QoS policy that's specified on the *DataWriter* or *DataReader* is applied separately for each instance created. QoS policies cannot be specified *uniquely* per instance, however. For example, if you are representing airline flights as different instances, you can't have a DEADLINE **period** of 1 second applied to one flight and a DEADLINE **period** of 2 seconds applied to another flight. The DEADLINE **period** (of, say, 1 second) is applied to *each flight*. In other words, you want to be notified if the flight position *DataReader* does not get an update about *each individual flight* within 1 second: the DEADLINE **period** is applied *per instance, for all instances*.

6.3.1.1 DEADLINE QosPolicy

The 7.5.7 DEADLINE QosPolicy on page 404 is checked separately for every instance. When notified of a missed deadline, a *DataWriter* or *DataReader* can check the last instance that missed the deadline using the instance handle in the status.

This allows a *DataWriter* to detect that it has not written a particular instance as frequently as it has offered in its deadline period, even if it has updated other instances.

This allows a *DataReader* to detect that it has not seen an update of an individual instance within the deadline period, even if it has seen updates from other instances during that time. This can be used to detect errors due to the *DataWriter* failing to write a particular instance. It can also detect network errors, where updates for a particular instance have been dropped or delayed.

6.3.1.2 DESTINATION_ORDER QosPolicy

The 7.5.8 DESTINATION_ORDER QosPolicy on page 406 contains a configuration option that allows a *DataWriter* or *DataReader* to order data across the whole Topic *for each instance*.

6.3.1.3 HISTORY QosPolicy

The 7.5.12 HISTORY QosPolicy on page 418 **depth** is applied for each instance created. For example, if **depth** = 1, the *DataWriter* or *DataReader* will keep one sample for each instance.

This allows an application to specify how much history it wants to keep per instance for reliability purposes. For example, if data is modeled as state data—meaning that only the most recent sample of the data

is important—the *DataWriter* and *DataReader* can set the history **depth** to 1. This allows them to send and receive only the most recent state for each instance.

6.3.1.4 DURABILITY QosPolicy

The 7.5.9 DURABILITY QosPolicy on page 410 **writer_depth** is applied for each instance created. For example, if **writer_depth** = 1, the *DataWriter* will keep one sample for each instance, for late-joining *DataReaders*.

This allows an application to specify how many samples it wants to keep per instance for later joiners. For example, if data is modeled as state data—meaning that only the most recent sample of the data is important—the *DataWriter* can set the **writer_depth** to 1. This allows it to send only the most recent state for each instance to late-joining *DataReaders*.

6.3.1.5 PRESENTATION QosPolicy

The 7.4.6 PRESENTATION QosPolicy on page 361 contains a configuration option to determine the scope of coherency and ordering of data in the *DataReader's* queue. If coherency is enabled, this allows a *Publisher* or *Subscriber* to specify whether each coherent set is per instance. If ordered access is enabled, this allows a *Publisher* or *Subscriber* to specify whether data should be ordered per *Topic* or per instance.

6.3.1.6 TIME_BASED_FILTER QosPolicy

The 8.6.4 TIME_BASED_FILTER QosPolicy on page 583 filters out samples of each instance that arrive within the specified **minimum_separation**. For example, if the **minimum_separation** is 1 second, the *DataReader* will receive samples of instance A at most once a second, and samples of instance B at most once a second. A sample of instance A may arrive immediately after a sample of instance B, and will not be filtered out.

6.3.2 QoS Policies that Affect Instance Management

There are additional QoS policies that affect instances, primarily by controlling the limits or memory growth of instances, or by controlling which instance information is sent over the network.

6.3.2.1 DataWriter and DataReader

The following policies affect both the *DataWriter* and *DataReader*.

6.3.2.1.1 OWNERSHIP QosPolicy

If *DataWriters* have 7.5.17 OWNERSHIP QosPolicy on page 432 set to EXCLUSIVE, a *DataWriter* with higher OWNERSHIP_STRENGTH is the owner of any instances it writes. If a *DataWriter* calls **unregister_instance()**, it gives up ownership of the instance. If it calls **dispose()**, it does not give up ownership of the instance, so no other *DataWriter* can update that instance or its state.

6.3.2.1.2 RESOURCE_LIMITS QosPolicy

The 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 contains a field named **max_instances** that controls the maximum number of instances that may be stored for the *DataWriter* or *DataReader*.

6.3.2.2 DataWriter

The following policies apply to the *DataWriter*.

6.3.2.2.1 OWNERSHIP_STRENGTH QosPolicy

The *DataWriter* with highest 7.5.18 OWNERSHIP_STRENGTH QosPolicy on page 435 will own the instances that it writes. This means that if a lower-strength *DataWriter* attempts to update any of those instances by writing or calling dispose on the instance, it does not affect the instance or its state.

6.3.2.2.2 DATA_WRITER_RESOURCE_LIMITS QosPolicy

The **instance_replacement** and **replace_empty_instances** fields in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400 control how instances can be replaced and the memory reclaimed if **max_instances** is reached. See 7.5.6.1 Configuring DataWriter Instance Replacement on page 402 for more information.

The **autoregister_instances** field controls whether to automatically register instances when a non-NIL handle is passed to the **write()** call.

6.3.2.2.3 WRITER_DATA_LIFECYCLE QosPolicy

The **autodispose_unregistered_instances** field in the 7.5.31 WRITER_DATA_LIFECYCLE QoS Policy on page 464 controls whether a *DataWriter* automatically disposes instances when they are unregistered. (By default, it doesn't.)

The **autopurge_unregistered_instances_delay** and **autopurge_disposed_instances_delay** fields control whether/when a *DataWriter* purges instances if they are NOT_ALIVE_NO_WRITERS or NOT_ALIVE_DISPOSED. Once all samples for an instance have been fully acknowledged by existing *DataReaders*, both the instance and the samples for that instance will be purged (see 7.3.8.2 write() behavior with KEEP_LAST and KEEP_ALL on page 311 for a definition of "fully ACK'ed").

See 7.3.14.7 Instance Memory Management on page 329 for more information on how this affects *DataWriter* memory usage.

6.3.2.2.4 DATA_WRITER_PROTOCOL QosPolicy

The **disable_inline_keyhash** field in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388 controls whether or not a keyhash is propagated on the wire with each sample. This field allows the user to control whether bandwidth is used to send the keyhash with every sample, or CPU is used by the subscribing application to calculate the keyhash for every sample.

The **serialize_key_with_dispose** field controls whether or not the serialized key is propagated on the wire with dispose samples. This field is useful when **propagate_dispose_of_unregistered_instances** in the 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565 is also true.

6.3.2.3 DataReader

The following policies apply to the *DataReader*.

6.3.2.3.1 DATA_READER_PROTOCOL QosPolicy

The **propagate_unregister_of_disposed_instances** and **propagate_dispose_of_unregistered_instances** fields in the 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565 control whether a *DataReader* can see state transitions between NOT_ALIVE instance states. See 6.1 Instance States on page 257 for more information.

6.3.2.3.2 DATA_READER_RESOURCE_LIMITS QosPolicy

The **initial_remote_writers_per_instance** and **max_remote_writers_per_instance** fields in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571 control the number of *DataWriters* from which a *DataReader* may receive samples for a single instance.

The **max_total_instances** field controls the maximum number of instances that a *DataReader* will maintain state for. See 8.3.8.6 Instance Resource Limits and Memory Management on page 535 for more information.

The **max_remote_virtual_writers_per_instance** field controls the maximum number of virtual remote writers that can be associated with an instance.

The **instance_replacement** field controls how instances can be replaced and the memory reclaimed if **max_instances** is reached. See 8.6.2.3 Configuring DataReader Instance Replacement on page 578 for more information.

6.3.2.3.3 READER_DATA_LIFECYCLE QosPolicy

The **autopurge_nowriter_samples_delay** and **autopurge_disposed_samples_delay** fields in the 8.6.3 READER_DATA_LIFECYCLE QoS Policy on page 581 control whether/when to purge samples that are associated with instances in the **NOT_ALIVE_NO_WRITERS** or **NOT_ALIVE_DISPOSED** states, freeing up queue space and allowing instance information to be purged.

The **autopurge_disposed_instances_delay** field controls whether to purge instance memory when an instance becomes NOT_ALIVE_DISPOSED. The **autopurge_nowriter_instances_delay** field controls whether to purge instance memory when an instance becomes NOT_ALIVE_NOWRITERS.

Chapter 7 Sending Data

This section discusses how to create, configure, and use *Publishers* and *DataWriters* to send data. It describes how these *Entities* interact, as well as the types of operations that are available for them.

The goal of this section is to help you become familiar with the *Entities* you need for sending data. For up-to-date details such as formal parameters and return codes on any mentioned operations, please see the API Reference HTML documentation.

7.1 Preview: Steps to Sending Data

To send DDS samples of a data instance:

1. Create and configure the required *Entities*:
    a. Create a *DomainParticipant* (see 9.3.1 Creating a DomainParticipant on page 610).
    b. Register user data types[1] with the *DomainParticipant*. For example, the '**FooDataType**'. (This step is not necessary in the Modern C++ API--the Topic instantiation automatically registers the type)
    c. Use the *DomainParticipant* to create a *Topic* with the registered data type.
    d. Optionally[2], use the *DomainParticipant* to create a *Publisher*.
    e. Use the *Publisher* or *DomainParticipant* to create a *DataWriter* for the *Topic*.

[1] Type registration is not required for built-in types (see 3.2.1 Registering Built-in Types on page 39).

[2] You are not required to explicitly create a *Publisher*; instead, you can use the 'implicit *Publisher*' created from the *DomainParticipant*. See 7.2.1 Creating Publishers Explicitly vs. Implicitly on page 274.

f. Use a type-safe method to cast the generic *DataWriter* created by the *Publisher* to a type-specific *DataWriter*. For example, '**FooDataWriter**'. (This step doesn't apply to the Modern C++ API where you directly instantiate a type-safe '**DataWriter<Foo>**.')

g. Optionally, register data instances with the *DataWriter*. If the *Topic*'s user data type contain *key* fields, then registering a data *instance* (data with a specific key value) will improve performance when repeatedly sending data with the same key. You may register many different data instances; each registration will return an *instance handle* corresponding to the specific key value. For non-keyed data types, instance registration has no effect. See 2.4 DDS Samples, Instances, and Keys on page 18 for more information on keyed data types and instances.

2. Every time there is changed data to be published:
   a. Store the data in a variable of the correct data type (for instance, variable '**Foo**' of the type '**FooDataType**').
   b. Call the **FooDataWriter's write()** operation, passing it a reference to the variable '**Foo**'.
      - For non-keyed data types or for non-registered instances, also pass in **DDS_HANDLE_NIL**.
      - For keyed data types, pass in the instance handle corresponding to the instance stored in 'Foo', if you have registered the instance previously. This means that the data stored in 'Foo' has the same key value that was used to create instance handle.
   c. The **write()** function will take a snapshot of the contents of '**Foo**' and store it in *Connext DDS* internal buffers from where the DDS data sample is sent under the criteria set by the *Publisher's* and *DataWriter's* QosPolicies. If there are matched *DataReaders*, then the DDS data sample will have been passed to the physical transport plug-in/device driver by the time that **write()** returns.

7.2 Publishers

An application that intends to publish information needs the following *Entities*: *DomainParticipant*, *Topic*, *Publisher*, and *DataWriter*. All *Entities* have a corresponding specialized *Listener* and a set of QosPolicies. A *Listener* is how *Connext DDS* notifies your application of status changes relevant to the Entity. The QosPolicies allow your application to configure the behavior and resources of the Entity.

- A *DomainParticipant* defines the DDS domain in which the information will be made available.
- A *Topic* defines the name under which the data will be published, as well as the type (format) of the data itself.
- An application writes data using a *DataWriter*. The *DataWriter* is bound at creation time to a *Topic*, thus specifying the name under which the *DataWriter* will publish the data and the type associated

with the data. The application uses the *DataWriter*'s **write()** operation to indicate that a new value of the data is available for dissemination.

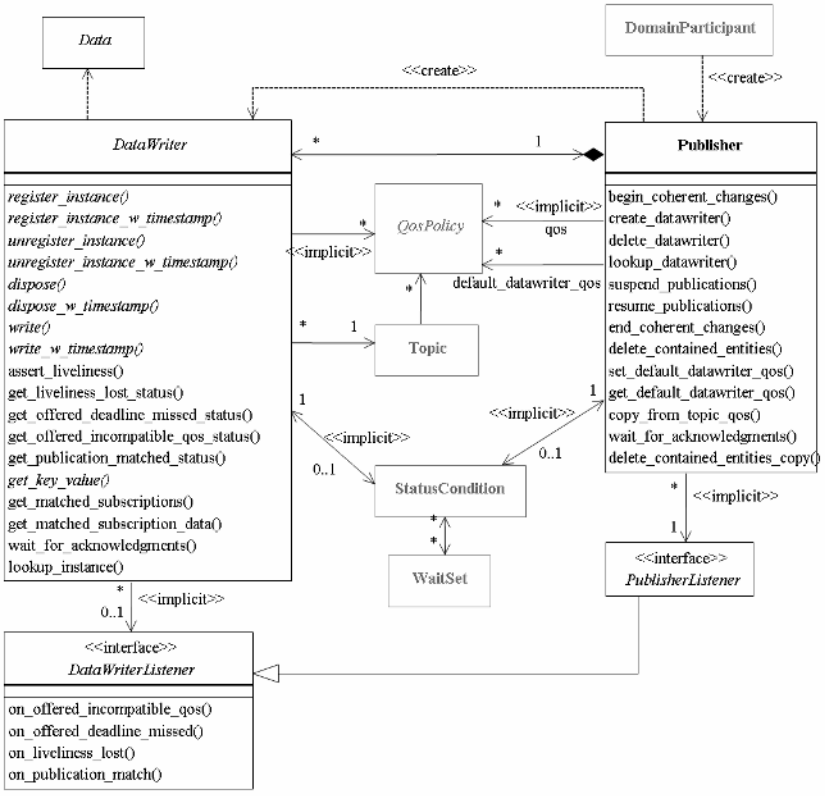
- A *Publisher* manages the activities of several *DataWriters*. The *Publisher* determines when the data is actually sent to other applications. Depending on the settings of various QosPolicies of the *Publisher* and *DataWriter*, data may be buffered to be sent with the data of other *DataWriters* or not sent at all. By default, the data is sent as soon as the *DataWriter*'s **write()** function is called.

  You may have multiple *Publishers*, each managing a different set of *DataWriters*, or you may choose to use one *Publisher* for all your *DataWriters*.

  For more information, see 7.2.1 Creating Publishers Explicitly vs. Implicitly on page 274.

Figure 7.1: Publication Module below shows how these *Entities* are related, as well as the methods defined for each *Entity*.

Figure 7.1: Publication Module



Publishers are used to perform the operations listed in Table 7.1 Publisher Operations on the next page. You can find more information about the operations by looking in the section listed under the **Reference** column. For details such as formal parameters and return codes, please see the API Reference HTML documentation.

Some operations cannot be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

Table 7.1 Publisher Operations

Working with ...	Operation	Description	Reference
DataWriters	begin_coherent_changes	Indicates that the application will begin a coherent set of modifications.	7.3.10 Writing Coherent Sets of DDS Data Samples on page 315
	create_datawriter	Creates a *DataWriter* that will belong to the Publisher.	7.3.1 Creating DataWriters on page 291
	create_datawriter_with_profile	Sets the *DataWriter's* QoS based on a specified QoS profile.	
	copy_from_topic_qos	Copies relevant QosPolicies from a *Topic* into a DataWriterQoS structure.	7.2.4.6 Other Publisher QoS-Related Operations on page 282
DataWriters cont'd	delete_contained_entities	Deletes all of the *DataWriters* that were created by the *Publisher*.	7.2.3.1 Deleting Contained DataWriters on page 277
	delete_datawriter	*Deletes* a *DataWriter* that belongs to the *Publisher*.	7.3.3 Deleting DataWriters on page 292
	end_coherent_changes	Ends the coherent set initiated by begin_coherent_changes().	7.3.10 Writing Coherent Sets of DDS Data Samples on page 315
DataWriters cont'd	get_all_datawriters	Retrieves all the *DataWriters* created from this *Publisher*.	7.3.2 Getting All DataWriters on page 292
	get_default_datawriter_qos	Copies the *Publisher's* default DataWriterQoS values into a DataWriterQos structure.	7.3.15 Setting DataWriter QosPolicies on page 332
	get_status_changes	Will always return 0 since there are no Statuses currently defined for *Publishers*.	4.1.4 Getting Status and Status Changes on page 171
	lookup_datawriter	Retrieves a *DataWriter* previously created for a specific *Topic*.	7.2.6 Finding a Publisher's Related DDS Entities on page 285

Table 7.1 Publisher Operations

Working with ...	Operation	Description	Reference
DataWriters cont'd	set_default_ datawriter_qos	Sets or changes the default DataWriterQos values.	7.2.4.5 Getting and Setting Default QoS for DataWriters on page 281
	set_default_ datawriter_ qos_with_profile	Sets or changes the default DataWriterQos values based on a QoS profile.	
	wait_for_ acknowledgments	Blocks until all data written by the *Publisher's* reliable *DataWriters* are acknowledged by all matched reliable *DataReaders*, or until the a specified timeout duration, max_wait, elapses.	7.2.7 Waiting for Acknowledgments in a Publisher on page 285
	is_sample_app_ acknowledged	Indicates if a sample has been application-acknowledged by all the matching *DataReaders* that were alive when the sample was written. If a *DataReader* does not enable application acknowledgment (by setting the ReliabilityQosPolicy's acknowledgment_kind to a value other than DDS_PROTOCOL_ ACKNOWLEDGMENT_MODE), the sample is considered application-acknowledged for that *DataReader*.	7.3.12 Application Acknowledgment on page 316
Libraries and Profiles	get_default_library	Gets the *Publisher's* default QoS profile library.	7.2.4.4 Getting and Setting the Publisher's Default QoS Profile and Library on page 281
	get_default_profile	Gets the *Publisher's* default QoS profile.	
	get_default_profile_ library	Gets the library that contains the *Publisher's* default QoS profile.	
	set_default_library	Sets the default library for a *Publisher*.	
	set_default_profile	Sets the default profile for a *Publisher*.	
Participants	get_participant	Gets the *DomainParticipant* that was used to create the *Publisher*.	7.2.6 Finding a Publisher's Related DDS Entities on page 285

Table 7.1 Publisher Operations

Working with ...	Operation	Description	Reference
Publishers	enable	Enables the *Publisher*.	4.1.2 Enabling DDS Entities on page 168
	equals	Compares two *Publisher's* QoS structures for equality.	7.2.4.2 Comparing QoS Values on page 280
	get_qos	Gets the *Publisher's* current QosPolicy settings. This is most often used in preparation for calling set_qos().	7.2.4 Setting Publisher QosPolicies on page 277
	set_qos	Sets the *Publisher's* QoS. You can use this operation to change the values for the *Publisher's* QosPolicies. Note, however, that not all QosPolicies can be changed after the *Publisher* has been created.	
	set_qos_with_profile	Sets the *Publisher's* QoS based on a specified QoS profile.	
Publishers cont'd	get_listener	Gets the currently installed Listener.	7.2.5 Setting Up PublisherListeners on page 283
	set_listener	Sets the *Publisher's* Listener. If you created the *Publisher* without a Listener, you can use this operation to add one later.	
	suspend_publications	Provides a *hint* that multiple data-objects within the Publisher are about to be written. *Connext DDS* does not currently use this hint.	7.2.9 Suspending and Resuming Publications on page 286
	resume_publications	Reverses the action of suspend_publications().	

7.2.1 Creating Publishers Explicitly vs. Implicitly

To send data, your application must have a Publisher. However, you are not required to explicitly create one. If you do not create one, the middleware will implicitly create a *Publisher* the first time you create a *DataWriter* using the *DomainParticipant's* operations. It will be created with default QoS (DDS_PUBLISHER_QOS_DEFAULT) and no Listener.

A *Publisher* (implicit or explicit) gets its own default QoS and the default QoS for its child *DataWriters* from the *DomainParticipant*. These default QoS are set when the *Publisher* is created. (This is true for *Subscribers* and *DataReaders*, too.)

The 'implicit *Publisher*' can be accessed using the *DomainParticipant's* **get_implicit_publisher()** operation (see 9.3.10 Getting the Implicit Publisher or Subscriber on page 624). You can use this 'implicit *Publisher*' just like any other *Publisher* (it has the same operations, QosPolicies, etc.). So you can change the mutable QoS and set a Listener if desired.

DataWriters are created by calling **create_datawriter()** or **create_datawriter_with_profile()**—these operations exist for *DomainParticipants* and *Publishers*. If you use the *DomainParticipant* to create a

DataWriter, it will belong to the implicit *Publisher*. If you use a *Publisher* to create a *DataWriter*, it will belong to that *Publisher*.

The middleware will use the same implicit *Publisher* for all *DataWriters* that are created using the *DomainParticipant's* operations.

Having the middleware implicitly create a *Publisher* allows you to skip the step of creating a *Publisher*. However, having all your *DataWriters* belong to the same *Publisher* can reduce the concurrency of the system because all the write operations will be serialized.

7.2.2 Creating Publishers

Before you can explicitly create a *Publisher*, you need a *DomainParticipant* (see 9.3 DomainParticipants on page 604). To create a *Publisher*, use the *DomainParticipant's* **create_publisher()** or **create_publisher_with_profile()** operations.

A QoS profile is way to use QoS settings from an XML file or string. With this approach, you can change QoS settings without recompiling the application. For details, see Configuring QoS with XML (Chapter 19 on page 842).

Note: The Modern C++ API Publishers provide constructors whose first and only required argument is the *DomainParticipant*.

```
DDSPublisher * create_publisher (
    const DDS_PublisherQos &qos,
    DDSPublisherListener *listener,
    DDS_StatusMask mask)
DDSPublisher * create_publisher_with_profile (
    const char *library_name,
    const char *profile_name,
    DDSPublisherListener *listener,
    DDS_StatusMask mask)
```

Where:

qos

If you want the default QoS settings (described in the API Reference HTML documentation), use **DDS_PUBLISHER_QOS_DEFAULT** for this parameter (see Figure 7.2: Creating a Publisher with Default QosPolicies on the next page).

If you want to customize any of the QosPolicies, supply a QoS structure (see Figure 7.3: Creating a Publisher with Non-Default QosPolicies (not from a profile) on page 279). The QoS structure for a *Publisher* is described in 7.4 Publisher/Subscriber QosPolicies on page 344.

Note: If you use **DDS_PUBLISHER_QOS_DEFAULT**, it is not safe to create the *Publisher* while another thread may be simultaneously calling **set_default_publisher_qos()**.

listener

Listeners are callback routines. *Connext DDS* uses them to notify your application when specific events (status changes) occur with respect to the *Publisher* or the *DataWriters* created by the *Publisher*.

The *listener* parameter may be set to NULL if you do not want to install a *Listener*. If you use NULL, the *Listener* of the *DomainParticipant* to which the *Publisher* belongs will be used instead (if it is set). For more information on *PublisherListeners*, see 7.2.5 Setting Up PublisherListeners on page 283.

mask	This bit-mask indicates which status changes will cause the *Publisher*'s *Listener* to be invoked. The bits set in the mask must have corresponding callbacks implemented in the *Listener.* If you use NULL for the *Listener*, use **DDS_STATUS_MASK_NONE** for this parameter. If the *Listener* implements all callbacks, use **DDS_STATUS_MASK_ALL**. For information on statuses, see 4.4 Listeners on page 189.
library_name	A QoS Library is a named set of QoS profiles. See 19.3 QoS Profiles on page 844. If NULL is used for **library_name**, the *DomainParticipant's* default library is assumed (see 7.2.4.4 Getting and Setting the Publisher's Default QoS Profile and Library on page 281).
profile_name	A QoS profile groups a set of related QoS, usually one per entity. See 19.3 QoS Profiles on page 844. If NULL is used for **profile_name**, the *DomainParticipant's* default profile is assumed and **library_name** is ignored

Figure 7.2: Creating a Publisher with Default QosPolicies

```
// create the publisher
DDSPublisher* publisher =
    participant->create_publisher(
       DDS_PUBLISHER_QOS_DEFAULT,
       NULL, DDS_STATUS_MASK_NONE);
if (publisher == NULL) {
    // handle error
};
```

For more examples, see 7.2.4.1 Configuring QoS Settings when the Publisher is Created on page 278.

After you create a *Publisher*, the next step is to use the *Publisher* to create a *DataWriter* for each *Topic*, see 7.3.1 Creating DataWriters on page 291. For a list of operations you can perform with a *Publisher*, see Table 7.1 Publisher Operations.

7.2.3 Deleting Publishers

(Note: in the Modern C++ API, *Entities* are automatically destroyed, see 4.1.1 Creating and Deleting DDS Entities on page 167)

This section applies to both implicitly and explicitly created *Publishers*.

To delete a *Publisher*:

1. You must first delete all *DataWriters* that were created with the *Publisher*. Use the *Publisher's* **delete_datawriter()** operation to delete them one at a time, or use the **delete_contained_entities()** operation (7.2.3.1 Deleting Contained DataWriters on the next page) to delete them all at the same time.

   ```
   DDS_ReturnCode_t delete_datawriter (DDSDataWriter *a_datawriter)
   ```

2. Delete the *Publisher* by using the *DomainParticipant's* delete_publisher() operation.

   ```
   DDS_ReturnCode_t delete_publisher (DDSPublisher *p)
   ```

Note: A *Publisher* cannot be deleted within a *Listener* callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

7.2.3.1 Deleting Contained DataWriters

The *Publisher's* **delete_contained_entities()** operation deletes all the *DataWriters* that were created by the *Publisher*.

```
DDS_ReturnCode_t delete_contained_entities ()
```

After this operation returns successfully, the application may delete the *Publisher* (see 7.2.3 Deleting Publishers on the previous page).

7.2.4 Setting Publisher QosPolicies

A *Publisher's* QosPolicies control its behavior. Think of the policies as the configuration and behavior 'properties' of the *Publisher*. The **DDS_PublisherQos** structure has the following format:

```
DDS_PublisherQos struct  {
    DDS_PresentationQosPolicy  presentation;
    DDS_PartitionQosPolicy  partition;
    DDS_GroupDataQosPolicy  group_data;
    DDS_EntityFactoryQosPolicy  entity_factory;
    DDS_AsynchronousPublisherQosPolicy  asynchronous_publisher;
    DDS_ExclusiveAreaQosPolicy  exclusive_area;
    DDS_EntityNameQosPolicy  publisher_name;
} DDS_PublisherQos;
```

Note: set_qos() cannot always be used in a listener callback; see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

Table 7.2 Publisher QosPolicies summarizes the meaning of each policy. (They appear alphabetically in the table.) For information on *why* you would want to change a particular QosPolicy, see the referenced section. For defaults and valid ranges, please refer to the API Reference HTML documentation for each policy.

Table 7.2 Publisher QosPolicies

QosPolicy	Description
7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344	Configures the mechanism that sends user data in an external middleware thread.
7.4.2 ENTITYFACTORY QosPolicy on page 347	Controls whether or not child *Entities* are created in the enabled state.
7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416	Assigns a **name** and **role_name** to a *Publisher*.

Table 7.2 Publisher QosPolicies

QosPolicy	Description
7.4.3 EXCLUSIVE_AREA QosPolicy (DDS Extension) on page 350	Configures multi-thread concurrency and deadlock prevention capabilities.
7.4.4 GROUP_DATA QosPolicy on page 352	Along with 5.2.1 TOPIC_DATA QosPolicy on page 224 and 7.5.30 USER_DATA QosPolicy on page 462, this QosPolicy is used to attach a buffer of bytes to *Connext DDS*'s discovery meta-data.
7.4.5 PARTITION QosPolicy on page 355	Adds string identifiers that are used for matching *DataReaders* and *DataWriters* for the same *Topic*.
7.4.6 PRESENTATION QosPolicy on page 361	Controls how *Connext DDS* presents data received by an application to the *DataReaders* of the data.

7.2.4.1 Configuring QoS Settings when the Publisher is Created

As described in 7.2.2 Creating Publishers on page 275, there are different ways to create a *Publisher,* depending on how you want to specify its QoS (with or without a QoS Profile).

- In Figure 7.2: Creating a Publisher with Default QosPolicies on page 276 we saw an example of how to explicitly create a *Publisher* with default QosPolicies. It used the special constant, **DDS_PUBLISHER_QOS_DEFAULT**, which indicates that the default QoS values for a *Publisher* should be used. Default *Publisher* QosPolicies are configured in the *DomainParticipant*; you can change them with the *DomainParticipant's* **set_default_publisher_qos()** or **set_default_publisher_qos_with_profile()** operation (see 9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622).
- To create a *Publisher* with non-default QoS settings, without using a QoS profile, see Figure 7.3: Creating a Publisher with Non-Default QosPolicies (not from a profile) on the next page. It uses the *DomainParticipant*'s **get_default_publisher_qos()** method to initialize a **DDS_PublisherQos** structure. Then the policies are modified from their default values before the QoS structure is passed to **create_publisher()**.
- You can also create a *Publisher* and specify its QoS settings via a QoS Profile. To do so, call **create_publisher_with_profile()**, as seen in Figure 7.4: Creating a Publisher with a QoS Profile on the next page.
- If you want to use a QoS profile, but then make some changes to the QoS before creating the *Publisher*, call the DomainParticipantFactory's **get_publisher_qos_from_profile()**, modify the QoS and use the modified QoS structure when calling **create_publisher()**, as seen in Figure 7.5: Getting QoS Values from a Profile, Changing QoS Values, Creating a Publisher with Modified QoS Values on the next page.

For more information, see 7.2.2 Creating Publishers on page 275 and Configuring QoS with XML (Chapter 19 on page 842).

Figure 7.3: Creating a Publisher with Non-Default QosPolicies (not from a profile)

```
DDS_PublisherQos publisher_qos;[1]
// get defaults
if (participant->get_default_publisher_qos(publisher_qos) != DDS_RETCODE_OK){
    // handle error
}
// make QoS changes here
// for example, this changes the ENTITY_FACTORY QoS
publisher_qos.entity_factory.autoenable_created_entities = DDS_BOOLEAN_FALSE;
    // create the publisher
    DDSPublisher* publisher = participant->create_publisher(publisher_qos,
        NULL, DDS_STATUS_MASK_NONE);
if (publisher == NULL) {
    // handle error
}
```

Figure 7.4: Creating a Publisher with a QoS Profile

```
// create the publisher with QoS profile
DDSPublisher* publisher = participant->create_publisher_with_profile(
    "MyPublisherLibary", "MyPublisherProfile",
    NULL, DDS_STATUS_MASK_NONE);
if (publisher == NULL) {
    // handle error
}
```

Figure 7.5: Getting QoS Values from a Profile, Changing QoS Values, Creating a Publisher with Modified QoS Values

```
DDS_PublisherQos publisher_qos;[2]
// Get publisher QoS from profile
retcode = factory->get_publisher_qos_from_profile(publisher_qos,
    "PublisherLibrary", "PublisherProfile");
if (retcode != DDS_RETCODE_OK) {
    // handle error
}
// Makes QoS changes here
// New entity_factory autoenable_created_entities will be true
publisher_qos.entity_factory.autoenable_created_entities = DDS_BOOLEAN_TRUE;
// create the publisher with modified QoS
DDSPublisher* publisher = participant->create_publisher(
    "Example Foo", type_name, publisher_qos,
    NULL, DDS_STATUS_MASK_NONE);
if (publisher == NULL) {
    // handle error
}
```

[1]For the C API, you need to use DDS_PublisherQos_INITIALIZER or DDS_PublisherQos_initialize(). See 4.2.2 Special QosPolicy Handling Considerations for C on page 182

[2]For the C API, you need to use DDS_PublisherQos_INITIALIZER or DDS_PublisherQos_initialize(). See 4.2.2 Special QosPolicy Handling Considerations for C on page 182

7.2.4.2 Comparing QoS Values

The **equals()** operation compares two *Publisher's* DDS_PublisherQoS structures for equality. It takes two parameters for the two *Publisher's* QoS structures to be compared, then returns TRUE is they are equal (all values are the same) or FALSE if they are not equal.

7.2.4.3 Changing QoS Settings After the Publisher Has Been Created

There are 2 ways to change an existing *Publisher's* QoS after it is has been created—again depending on whether or not you are using a QoS Profile.

- To change an existing *Publisher*'s QoS programmatically (that is, without using a QoS profile): **get_qos()** and **set_qos()**. See the example code in Figure 7.6: Changing the QoS of an Existing Publisher below. It retrieves the current values by calling the *Publisher*'s **get_qos()** operation. Then it modify the value and call **set_qos()** to apply the new value. Note, however, that some QosPolicies cannot be changed after the *Publisher* has been enabled—this restriction is noted in the descriptions of the individual QosPolicies.
- You can also change a *Publisher's* (and all other *Entities*') QoS by using a QoS Profile and calling **set_qos_with_profile()**. For an example, see Figure 7.7: Changing the QoS of an Existing Publisher with a QoS Profile below. For more information, see Configuring QoS with XML (Chapter 19 on page 842).

Figure 7.6: Changing the QoS of an Existing Publisher

```
DDS_PublisherQos publisher_qos;[1]
// Get current QoS. publisher points to an existing DDSPublisher.
if (publisher->get_qos(publisher_qos) != DDS_RETCODE_OK) {
    // handle error
}
// make changes
// New entity_factory autoenable_created_entities will be true
publisher_qos.entity_factory.autoenable_created_entities =DDS_BOOLEAN_TRUE;
// Set the new QoS
if (publisher->set_qos(publisher_qos) != DDS_RETCODE_OK ) {
    // handle error
}
```

Figure 7.7: Changing the QoS of an Existing Publisher with a QoS Profile

```
retcode = publisher->set_qos_with_profile(
    "PublisherProfileLibrary","PublisherProfile");
if (retcode != DDS_RETCODE_OK) {
    // handle error
}
```

[1] For the C API, you need to use DDS_PublisherQos_INITIALIZER or DDS_PublisherQos_initialize(). See 4.2.2 Special QosPolicy Handling Considerations for C on page 182

7.2.4.4 Getting and Setting the Publisher's Default QoS Profile and Library

You can retrieve the default QoS profile used to create *Publishers* with the **get_default_profile()** operation.

You can also get the default library for *Publishers*, as well as the library that contains the *Publisher's* default profile (these are not necessarily the same library); these operations are called **get_default_library()** and **get_default_library_profile()**, respectively. These operations are for informational purposes only (that is, you do not need to use them as a precursor to setting a library or profile.) For more information, see Configuring QoS with XML (Chapter 19 on page 842).

```
virtual const char *  get_default_library ()
const char *  get_default_profile ()
const char *  get_default_profile_library ()
```

There are also operations for setting the *Publisher's* default library and profile:

```
DDS_ReturnCode_t set_default_library (const char *  library_name)
DDS_ReturnCode_t set_default_profile (const char *  library_name,
    const char *  profile_name)
```

These operations only affect which library/profile will be used as the default the next time a default *Publisher* library/profile is needed during a call to one of this *Publisher's* operations.

When calling a *Publisher* operation that requires a **profile_name** parameter, you can use NULL to refer to the default profile. (This same information applies to setting a default library.) If the default library/profile is not set, the *Publisher* inherits the default from the *DomainParticipant*.

set_default_profile() does not set the default QoS for *DataWriters* created by the *Publisher;* for this functionality, use the *Publisher's* **set_default_datawriter_qos_with_profile()**, see 7.2.4.5 Getting and Setting Default QoS for DataWriters below (you may pass in NULL aftercalling the *Publisher's* **set_default_profile()**).

set_default_profile() does not set the default QoS for newly created *Publishers*; for this functionality, use the *DomainParticipant's* **set_default_publisher_qos_with_profile()** operation, see 9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622.

7.2.4.5 Getting and Setting Default QoS for DataWriters

These operations set the default QoS that will be used for new *DataWriters* if **create_datawriter()** is called with DDS_DATAWRITER_QOS_DEFAULT as the **qos** parameter:

```
DDS_ReturnCode_t set_default_datawriter_qos (const DDS_DataWriterQos &qos)
DDS_ReturnCode_t set_default_datawriter_qos_with_profile (
   const char *library_name,
   const char *profile_name)
```

The above operations may potentially allocate memory, depending on the sequences contained in some QoS policies.

To get the default QoS that will be used for creating *DataWriters* if **create_datawriter()** is called with DDS_PARTICIPANT_QOS_DEFAULT as the **qos** parameter:

```
DDS_ReturnCode_t get_default_datawriter_qos (DDS_DataWriterQos & qos)
```

This operation gets the QoS settings that were specified on the last successful call to **set_default_datawriter_qos()** or **set_default_datawriter_qos_with_profile()**, or if the call was never made, the default values listed in DDS_DataWriterQos.

Note: It is not safe to set the default *DataWriter* QoS values while another thread may be simultaneously calling **get_default_datawriter_qos(), set_default_datawriter_qos(),** or **create_datawriter()** with DDS_DATAWRITER_QOS_DEFAULT as the **qos** parameter. It is also not safe to get the default *DataWriter* QoS values while another thread may be simultaneously calling **set_default_datawriter_qos()**.

7.2.4.6 Other Publisher QoS-Related Operations

- **Copying a Topic's QoS into a DataWriter's QoS**

  This method is provided as a convenience for setting the values in a *DataWriterQos* structure before using that structure to create a *DataWriter*. As explained in 5.1.3 Setting Topic QosPolicies on page 219, most of the policies in a *TopicQos* structure do not apply directly to the *Topic* itself, but to the associated *DataWriters* and *DataReaders* of that *Topic*. The *TopicQos* serves as a single container where the values of QosPolicies that must be set compatibly across matching *DataWriters* and *DataReaders* can be stored.

  Thus instead of setting the values of the individual QosPolicies that make up a *DataWriterQos* structure every time you need to create a *DataWriter* for a *Topic*, you can use the *Publisher*'s **copy_from_topic_qos()** operation to "import" the *Topic*'s QosPolicies into a *DataWriterQos* structure. This operation copies the relevant policies in the *TopicQos* to the corresponding policies in the *DataWriterQos*.

  This copy operation will often be used in combination with the *Publisher's* **get_default_datawriter_qos()** and the *Topic*'s **get_qos()** operations. The *Topic*'s QoS values are merged on top of the *Publisher's* default *DataWriter* QosPolicies with the result used to create a new *DataWriter*, or to set the QoS of an existing one (see 7.3.15 Setting DataWriter QosPolicies on page 332).
- **Copying a Publisher's QoS**

  C API users should use the **DDS_PublisherQos_copy()** operation rather than using structure assignment when copying between two QoS structures. The **copy()** operation will perform a deep copy so that policies that allocate heap memory such as sequences are copied correctly. In C++, C++/CLI, C# and Java, a copy constructor is provided to take care of sequences automatically.

- **Clearing QoS-Related Memory**

  Some QosPolicies contain sequences that allocate memory dynamically as they grow or shrink. The C API's DDS_PublisherQos_finalize() operation frees the memory used by sequences but otherwise leaves the QoS unchanged. C API users should call **finalize()** on all DDS_PublisherQos objects before they are freed, or for QoS structures allocated on the stack, before they go out of scope. In C++, C++/CLI, C# and Java, the memory used by sequences is freed in the destructor.

7.2.5 Setting Up PublisherListeners

Like all *Entities*, *Publishers* may optionally have *Listeners*. *Listeners* are user-defined objects that implement a DDS-defined interface (i.e. a pre-defined set of callback functions). *Listeners* provide the means for *Connext DDS* to notify applications of any changes in *Statuses* (events) that may be relevant to it. By writing the callback functions in the *Listener* and installing the *Listener* into the *Publisher*, applications can be notified to handle the events of interest. For more general information on *Listeners* and *Statuses*, see 4.4 Listeners on page 189.

Note: Some operations cannot be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

As illustrated in Figure 7.1: Publication Module on page 271, the *PublisherListener* interface extends the *DataWriterListener* interface. In other words, the *PublisherListener* interface contains all the functions in the *DataWriterListener* interface. There are no *Publisher*-specific *statuses*, and thus there are no *Publisher*-specific functions.

Instead, the methods of a *PublisherListener* will be called back for changes in the *Statuses* of any of the *DataWriters* that the *Publisher* has created. This is only true if the *DataWriter* itself does not have a *DataWriterListener* installed, see 7.3.4 Setting Up DataWriterListeners on page 293. If a *DataWriterListener* has been installed and has been enabled to handle a *Status* change for the *DataWriter*, then *Connext DDS* will call the method of the *DataWriterListener* instead.

If you want a *Publisher* to handle status events for its *DataWriters*, you can set up a *PublisherListener* during the *Publisher's* creation or use the **set_listener()** method after the *Publisher* is created. The last parameter is a bit-mask with which you should set which *Status* events that the *PublisherListener* will handle. For example,

```
DDS_StatusMask mask = DDS_OFFERED_DEADLINE_MISSED_STATUS |
                      DDS_OFFERED_INCOMPATIBLE_QOS_STATUS;
publisher = participant->create_publisher(
               DDS_PUBLISHER_QOS_DEFAULT, listener, mask);
```

or

```
DDS_StatusMask mask = DDS_OFFERED_DEADLINE_MISSED_STATUS |
                      DDS_OFFERED_INCOMPATIBLE_QOS_STATUS;
publisher->set_listener(listener, mask);
```

As previously mentioned, the callbacks in the *PublisherListener* act as 'default' callbacks for all the *DataWriter*s contained within. When *Connext DDS* wants to notify a *DataWriter* of a relevant *Status* change (for example, PUBLICATION_MATCHED), it first checks to see if the *DataWriter* has the corresponding *DataWriterListener* callback enabled (such as the **on_publication_matched()** operation). If so, *Connext DDS* dispatches the event to the *DataWriterListener* callback. Otherwise, *Connext DDS* dispatches the event to the corresponding *PublisherListener* callback.

A particular callback in a *DataWriter* is *not* enabled if either:

- The application installed a NULL *DataWriterListener* (meaning there are *no* callbacks for the *DataWriter* at all).
- The application has disabled the callback for a *DataWriterListener*. This is done by turning off the associated status bit in the *mask* parameter passed to the **set_listener()** or **create_datawriter()** call when installing the *DataWriterListener* on the *DataWriter*. For more information on *DataWriterListeners*, see 7.3.4 Setting Up DataWriterListeners on page 293.

Similarly, the callbacks in the *DomainParticipantListener* act as 'default' callbacks for all the *Publishers* that belong to it. For more information on *DomainParticipantListeners*, see 9.3.6 Setting Up DomainParticipantListeners on page 615.

For example, Figure 7.8: Example Code to Create a Publisher with a Simple Listener below shows how to create a *Publisher* with a *Listener* that simply prints the events it receives.

Figure 7.8: Example Code to Create a Publisher with a Simple Listener

```
class MyPublisherListener : public DDSPublisherListener {
public:
  virtual void on_offered_deadline_missed(
       DDSDataWriter* writer,
       const DDS_OfferedDeadlineMissedStatus& status);
  virtual void on_liveliness_lost(
       DDSDataWriter* writer,
       const DDS_LivelinessLostStatus& status);
  virtual void on_offered_incompatible_qos(
       DDSDataWriter* writer,
       const DDS_OfferedIncompatibleQosStatus& status);
  virtual void on_publication_matched(
       DDSDataWriter* writer,
       const DDS_PublicationMatchedStatus& status);
  virtual void on_reliable_writer_cache_changed(
       DDSDataWriter* writer,
       const DDS_ReliableWriterCacheChangedStatus& status);
  virtual void on_reliable_reader_activity_changed (
       DDSDataWriter* writer,
       const DDS_ReliableReaderActivityChangedStatus& status);
};
```

```
void MyPublisherListener::on_offered_deadline_missed(
       DDSDataWriter* writer,
       const DDS_OfferedDeadlineMissedStatus& status)
{
    printf("on_offered_deadline_missed\n");
}
// ...Implement all remaining listeners in a similar manner...
DDSPublisherListener *myPubListener = new MyPublisherListener();
DDSPublisher* publisher =
    participant->create_publisher(DDS_PUBLISHER_QOS_DEFAULT,
        myPubListener, DDS_STATUS_MASK_ALL);
```

7.2.6 Finding a Publisher's Related DDS Entities

These *Publisher* operations are useful for obtaining a handle to related *Entities*:

- **get_participant()**: Gets the *DomainParticipant* with which a *Publisher* was created.
- **lookup_datawriter()**: Finds a *DataWriter* created by the *Publisher* with a *Topic* of a particular name. Note that in the event that multiple *DataWriters* were created by the same *Publisher* with the same *Topic*, any one of them may be returned by this method. (In the Modern C++ API this method is a freestanding function, **dds::pub::find()**)
- **DDS_Publisher_as_Entity()**: This method is provided for C applications and is necessary when invoking the parent class *Entity* methods on *Publishers*. For example, to call the *Entity* method **get_status_changes()** on a *Publisher,* my_pub, do the following:

```
DDS_Entity_get_status_changes(DDS_Publisher_as_Entity(my_pub))
```

DDS_Publisher_as_Entity() is not provided in the C++, C++/CLI, C# and Java APIs because the object-oriented features of those languages make it unnecessary.

7.2.7 Waiting for Acknowledgments in a Publisher

The *Publisher's* **wait_for_acknowledgments()** operation blocks the calling thread until either all data written by the *Publisher's* reliable *DataWriters* is acknowledged or the duration specified by the **max_wait** parameter elapses, whichever happens first.

Note that if a thread is blocked in the call to **wait_for_acknowledgments()** on a *Publisher* and a different thread writes new DDS samples on any of the *Publisher's* reliable *DataWriters*, the new DDS samples must be acknowledged before unblocking the thread that is waiting on **wait_for_acknowledgments()**.

```
DDS_ReturnCode_t wait_for_acknowledgments (const DDS_Duration_t &  max_wait)
```

This operation returns **DDS_RETCODE_OK** if all the DDS samples were acknowledged, or **DDS_RETCODE_TIMEOUT** if the **max_wait** duration expired first.

There is a similar operation available for individual *DataWriters*, see 7.3.11 Waiting for Acknowledgments in a DataWriter on page 316.

The reliability protocol used by *Connext DDS* is discussed in Reliable Communications (Chapter 11 on page 682).

7.2.8 Statuses for Publishers

There are no statuses specific to the Publisher itself. The following statuses can be monitored by the *PublisherListener* for the *Publisher*'s *DataWriters*.

- 7.3.6.5 OFFERED_DEADLINE_MISSED Status on page 302
- 7.3.6.4 LIVELINESS_LOST Status on page 301
- 7.3.6.6 OFFERED_INCOMPATIBLE_QOS Status on page 302
- 7.3.6.7 PUBLICATION_MATCHED Status on page 303
- 7.3.6.8 RELIABLE_WRITER_CACHE_CHANGED Status (DDS Extension) on page 304
- 7.3.6.9 RELIABLE_READER_ACTIVITY_CHANGED Status (DDS Extension) on page 306

7.2.9 Suspending and Resuming Publications

The operations **suspend_publications()** and **resume_publications()** provide a *hint* to *Connext DDS* that multiple data-objects within the Publisher are about to be written. *Connext DDS* does not currently use this hint.

7.3 DataWriters

To create a *DataWriter*, you need a *DomainParticipant* and a *Topic*.

You need a *DataWriter* for each *Topic* that you want to publish. Once you have a *DataWriter*, you can use it to perform the operations listed in Table 7.3 DataWriter Operations. The most important operation is **write()**, described in 7.3.8 Writing Data on page 308. For more details on all operations, see the API Reference HTML documentation.

DataWriters are created by using operations on a *DomainParticipant* or a *Publisher*, as described in 7.3.1 Creating DataWriters on page 291. If you use the *DomainParticipant's* operations, the *DataWriter* will belong to an implicit *Publisher* that is automatically created by the middleware. If you use a *Publisher's* operations, the *DataWriter* will belong to that *Publisher*. So either way, the *DataWriter* belongs to a *Publisher*.

Note: Some operations cannot be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

Table 7.3 DataWriter Operations

Working with ...	Operation	Description	Reference
DataWriters	assert_liveliness	Manually asserts the liveliness of the *DataWriter*.	7.3.17 Asserting Liveliness on page 343
	enable	Enables the *DataWriter*.	4.1.2 Enabling DDS Entities on page 168
	equals	Compares two *DataWriter's* QoS structures for equality.	7.3.15.2 Comparing QoS Values on page 337
	get_qos	Gets the QoS.	7.3.15 Setting DataWriter QosPolicies on page 332
	lookup_instance	Gets a handle, given an instance. (Useful for keyed data types only.)	7.3.14.5 Looking up an Instance Handle on page 329
	set_qos	Modifies the QoS.	7.3.15 Setting DataWriter QosPolicies on page 332
	set_qos_with_profile	Modifies the QoS based on a QoS profile.	7.3.15 Setting DataWriter QosPolicies on page 332
	get_listener	Gets the currently installed Listener.	7.3.4 Setting Up DataWriterListeners on page 293
	set_listener	Replaces the Listener.	

Table 7.3 DataWriter Operations

Working with ...	Operation	Description	Reference
FooDataWriter (See 7.3.7 Using a Type-Specific DataWriter (FooDataWriter) on page 307)	dispose	States that the instance no longer exists. (Useful for keyed data types only.)	7.3.14.3 Disposing Instances on page 327
	dispose_w_ timestamp	Same as dispose, but allows the application to override the automatic source_timestamp. (Useful for keyed data types only.)	
	flush	Makes the batch available to be sent on the network.	7.3.9 Flushing Batches of DDS Data Samples on page 314
	get_key_value	Maps an instance_handle to the corresponding key.	7.3.14.6 Getting the Key Value for an Instance on page 329
	narrow	A type-safe way to cast a pointer. This takes a DDSDataWriter pointer and 'narrows' it to a 'FooDataWriter' where 'Foo' is the related data type.	7.3.7 Using a Type-Specific DataWriter (FooDataWriter) on page 307
	register_instance	States the intent of the *DataWriter* to write values of the data-instance that matches a specified key. Improves the performance of subsequent writes to the instance. (Useful for keyed data types only.)	7.3.14.2 Registering Instances on page 325 and 7.3.14.4 Unregistering Instances on page 327
	register_instance_ w_ timestamp	Like register_instance, but allows the application to override the automatic source_timestamp. (Useful for keyed data types only.)	
	unregister_instance	Reverses register_instance. Relinquishes the ownership of the instance. (Useful for keyed data types only.)	
	unregister_instance_w_ timestamp	Like unregister_instance, but allows the application to override the automatic source_timestamp. (Useful for keyed data types only.)	
	write	Writes a new value for a data-instance.	7.3.8 Writing Data on page 308
	write_w_timestamp	Same as write, but allows the application to override the automatic source_timestamp.	
FooDataWriter (See 7.3.7 Using a Type-Specific DataWriter (FooDataWriter) on page 307)	write_w_params	Same as write, but allows the application to specify parameters such as source timestamp and instance handle.	7.3.8 Writing Data on page 308
	dispose_w_params	Same as dispose, but allows the application to specify parameters such as source timestamp and instance handle..	7.3.14.3 Disposing Instances on page 327
	register_w_params	Same as register, but allows the application to specify parameters such as source timestamp, instance handle.	7.3.14.2 Registering Instances on page 325 and 7.3.14.4 Unregistering Instances on page 327
	unregister_w_ params	Same as unregister, but allows the application to specify parameters such as source timestamp, and instance handle.	

Table 7.3 DataWriter Operations

Working with ...	Operation	Description	Reference
Matched Subscriptions	get_matched_subscriptions	Gets a list of subscriptions that have a matching *Topic* and compatible QoS. These are the subscriptions currently associated with the *DataWriter*.	7.3.16.1 Finding Matching Subscriptions on page 341
	get_matched_subscription_data	Gets information on a subscription with a matching *Topic* and compatible QoS.	
	get_matched_subscription_locators	Gets a list of locators for subscriptions that have a matching Topic and compatible QoS. These are the subscriptions currently associated with the *DataWriter*.	
	get_matched_subscription_participant_data	Gets information about the *DomainParticipant* of a matching subscription.	7.3.16.2 Finding the Matching Subscription's ParticipantBuiltinTopicData on page 342
	is_matched_subscription_active	Enables you to query whether the matched *DataReader* (identified using the instance handle returned by **get_matched_subscriptions**) is active. **get_matched_subscriptions** returns all matching *DataReaders*, including those that are not active. This operation enables you to see which matching *DataReaders* are active.	7.3.16.1 Finding Matching Subscriptions on page 341
Status	get_status_changes	Gets a list of statuses that have changed since the last time the application read the status or the listeners were called.	4.1.4 Getting Status and Status Changes on page 171

Table 7.3 DataWriter Operations

Working with ...	Operation	Description	Reference
	get_liveliness_lost_status	Gets LIVELINESS_LOST status.	
	get_offered_deadline_missed_status	Gets OFFERED_DEADLINE_MISSED status.	
	get_offered_incompatible_qos_status	Gets OFFERED_INCOMPATIBLE_QOS status.	
	get_publication_match_status	Gets PUBLICATION_MATCHED_QOS status.	
Status cont'd	get_reliable_writer_cache_changed_status	Gets RELIABLE_WRITER_CACHE_CHANGED status	7.3.6 Statuses for DataWriters on page 295
	get_reliable_reader_activity_changed_status	Gets RELIABLE_READER_ACTIVITY_CHANGED status	
	get_datawriter_cache_status	Gets DATA_WRITER_CACHE_status	
	get_datawriter_protocol_status	Gets DATA_WRITER_PROTOCOL status	
	get_matched_subscription_datawriter_protocol_status	Gets DATA_WRITER_PROTOCOL status for this *DataWriter*, per matched subscription identified by the subscription_handle.	7.3.6 Statuses for DataWriters on page 295
	get_matched_subscription_datawriter_protocol_status_by_locator	Gets DATA_WRITER_PROTOCOL status for this *DataWriter*, per matched subscription as identified by a locator.	
Other	get_publisher	Gets the *Publisher* to which the *DataWriter* belongs.	7.3.16.3 Finding Related DDS Entities on page 343
	get_topic	Get the Topic associated with the *DataWriter*.	
	wait_for_acknowledgements	Blocks the calling thread until either all data written by the *DataWriter* is acknowledged by all matched Reliable *DataReaders*, or until the a specified timeout duration, max_wait, elapses.	7.3.11 Waiting for Acknowledgments in a DataWriter on page 316

7.3.1 Creating DataWriters

Before you can create a *DataWriter*, you need a *DomainParticipant*, a *Topic,* and optionally, a *Publisher*.

DataWriters are created by calling **create_datawriter()** or **create_datawriter_with_profile()**—these operations exist for *DomainParticipants* and *Publishers*. If you use the *DomainParticipant* to create a *DataWriter*, it will belong to the implicit *Publisher* described in 7.2.1 Creating Publishers Explicitly vs. Implicitly on page 274. If you use a *Publisher's* operations to create a *DataWriter*, it will belong to that *Publisher*.

A *QoS profile* is way to use QoS settings from an XML file or string. With this approach, you can change QoS settings without recompiling the application. For details, see Configuring QoS with XML (Chapter 19 on page 842).

Note: In the Modern C++ API *DataWriters* provide constructors whose first argument is a *Publisher*. The only required arguments are the publisher and the topic.

```
DDSDataWriter* create_datawriter (
   DDSTopic *topic,
   const DDS_DataWriterQos &qos,
   DDSDataWriterListener *listener,
   DDS_StatusMask mask)
DDSDataWriter * create_datawriter_with_profile(
   DDSTopic * topic,
   const char * library_name,
   const char * profile_name,
   DDSDataWriterListener * listener,
   DDS_StatusMask mask)
```

Where:

topic — The *Topic* that the *DataWriter* will publish. This must have been previously created by the same *DomainParticipant*.

qos — If you want the default QoS settings (described in the API Reference HTML documentation), use the constant DDS_DATAWRITER_QOS_DEFAULT for this parameter (see Figure 7.9: Creating a DataWriter with Default QosPolicies and a Listener on the next page). If you want to customize any of the QosPolicies, supply a QoS structure (see 7.3.15 Setting DataWriter QosPolicies on page 332).

Note: If you use DDS_DATAWRITER_QOS_DEFAULT for the **qos** parameter, it is not safe to create the *DataWriter* while another thread may be simultaneously calling the *Publisher's* **set_default_datawriter_qos()** operation.

listener — *Listeners* are callback routines. *Connext DDS* uses them to notify your application of specific events (status changes) that may occur with respect to the *DataWriter*. The *listener* parameter may be set to NULL; in this case, the *PublisherListener* (or if that is NULL, the *DomainParticipantListener*) will be used instead. For more information, see 7.3.4 Setting Up DataWriterListeners on page 293

mask — This bit-mask indicates which status changes will cause the *Listener* to be invoked. The bits set in the mask must have corresponding callbacks implemented in the *Listener*. If you use NULL for the *Listener*, use DDS_STATUS_MASK_NONE for this parameter. If the *Listener* implements all callbacks, use DDS_STATUS_MASK_ALL. For information on statuses, see 4.4 Listeners on page 189.

library_name — A QoS Library is a named set of QoS profiles. See 19.3 QoS Profiles on page 844.

profile_name A QoS profile groups a set of related QoS, usually one per entity. See 19.3 QoS Profiles on page 844.

For more examples on how to create a *DataWriter*, see 7.3.15.1 Configuring QoS Settings when the DataWriter is Created on page 336

After you create a *DataWriter*, you can use it to write data. See 7.3.8 Writing Data on page 308.

Note: When a *DataWriter* is created, only those transports already registered are available to the *DataWriter*. The built-in transports are implicitly registered when (a) the *DomainParticipant* is enabled, (b) the first *DataWriter* is created, or (c) you look up a built-in data reader, whichever happens first.

Figure 7.9: Creating a DataWriter with Default QosPolicies and a Listener

```
// MyWriterListener is user defined, extends DDSDataWriterListener
DDSDataWriterListener* writer_listener = new MyWriterListener();
DDSDataWriter* writer = publisher->create_datawriter(
    topic,
    DDS_DATAWRITER_QOS_DEFAULT,
    writer_listener,
    DDS_STATUS_MASK_ALL);
if (writer == NULL) {
    // ... error
};
// narrow it for your specific data type
FooDataWriter* foo_writer = FooDataWriter::narrow(writer);
```

7.3.2 Getting All DataWriters

To retrieve all the *DataWriters* created by the *Publisher*, use the *Publisher's* **get_all_datawriters()** operation:

```
DDS_ReturnCode_t get_all_datawriters(DDS_Publisher* self,
                                     struct DDS_DataWriterSeq* writers);
```

In the Modern C++ API, use the freestanding function **rti::pub::find_datawriters()**.

7.3.3 Deleting DataWriters

(Note: in the Modern C++ API, *Entities* are automatically destroyed, see 4.1.1 Creating and Deleting DDS Entities on page 167)

To delete a single *DataWriter*, use the *Publisher*'s **delete_datawriter()** operation:

```
DDS_ReturnCode_t delete_datawriter (
       DDSDataWriter *a_datawriter)
```

Note: A *DataWriter* cannot be deleted within its own writer listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200

To delete all of a Publisher's DataWriters, use the Publisher's **delete_contained_entities()** operation (see 7.2.3.1 Deleting Contained DataWriters on page 277).

7.3.4 Setting Up DataWriterListeners

DataWriters may optionally have *Listeners*. *Listeners* are essentially callback routines and provide the means for *Connext DDS* to notify your application of the occurrence of events (status changes) relevant to the *DataWriter*. For more general information on *Listeners*, see 4.4 Listeners on page 189.

Note: Some operations cannot be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

If you do not implement a *DataWriterListener*, the associated *PublisherListener* is used instead. If that *Publisher* also does not have a *Listener*, then the *DomainParticipant*'s *Listener* is used if one exists (see 7.2.5 Setting Up PublisherListeners on page 283 and 9.3.6 Setting Up DomainParticipantListeners on page 615).

Listeners are typically set up when the *DataWriter* is created (see 7.2 Publishers on page 270). You can also set one up after creation by using the **set_listener()** operation. *Connext DDS* will invoke a *DataWriter*'s *Listener* to report the status changes listed in Table 7.4 DataWriterListener Callbacks (if the Listener is set up to handle the particular status, see 7.3.4 Setting Up DataWriterListeners above).

Table 7.4 DataWriterListener Callbacks

This DataWriterListener callback...	... is triggered by ...
on_instance_replaced()	A replacement of an existing instance by a new instance; see 7.5.6.1 Configuring DataWriter Instance Replacement on page 402
on_liveliness_lost	A change to 7.3.6.4 LIVELINESS_LOST Status on page 301
on_offered_deadline_missed	A change to 7.3.6.5 OFFERED_DEADLINE_MISSED Status on page 302
on_offered_incompatible_qos	A change to 7.3.6.6 OFFERED_INCOMPATIBLE_QOS Status on page 302
on_publication_matched	A change to 7.3.6.7 PUBLICATION_MATCHED Status on page 303
on_reliable_writer_cache_changed	A change to 7.3.6.8 RELIABLE_WRITER_CACHE_CHANGED Status (DDS Extension) on page 304
on_reliable_reader_activity_changed	A change to 7.3.6.9 RELIABLE_READER_ACTIVITY_CHANGED Status (DDS Extension) on page 306
on_sample_removed	Removal of a sample from the *DataWriter* queue, when the sample was written with a cookie using the **write_w_params** API or if the *DataWriter* supports loaned samples, which are used by Zero Copy over shared memory and FlatData language binding (see Chapter 23 Sending Large Data on page 934)
on_application_acknowledgment	Application acknowledgment (see 7.3.6.1 APPLICATION_ACKNOWLEDGMENT_STATUS on page 295)

Table 7.4 DataWriterListener Callbacks

This DataWriterListener callback...	... is triggered by ...
on_service_request_accepted	A change to 7.3.6.10 SERVICE_REQUEST_ACCEPTED Status (DDS Extension) on page 307.

7.3.5 Checking DataWriter Status

You can access an individual communication status for a *DataWriter* with the operations shown in Table 7.5 DataWriter Status Operations.

Table 7.5 DataWriter Status Operations

Use this operation...	...to retrieve this status:
get_datawriter_cache_status	7.3.6.2 DATA_WRITER_CACHE_STATUS on page 296
get_datawriter_protocol_status	7.3.6.3 DATA_WRITER_PROTOCOL_STATUS on page 297
get_matched_subscription_datawriter_protocol_status	
get_matched_subscription_datawriter_protocol_status_by_locator	
get_liveliness_lost_status	7.3.6.4 LIVELINESS_LOST Status on page 301
get_offered_deadline_missed_status	7.3.6.5 OFFERED_DEADLINE_MISSED Status on page 302
get_offered_incompatible_qos_status	7.3.6.6 OFFERED_INCOMPATIBLE_QOS Status on page 302
get_publication_match_status	7.3.6.7 PUBLICATION_MATCHED Status on page 303
get_reliable_writer_cache_changed_status	7.3.6.8 RELIABLE_WRITER_CACHE_CHANGED Status (DDS Extension) on page 304
get_reliable_reader_activity_changed_status	7.3.6.9 RELIABLE_READER_ACTIVITY_CHANGED Status (DDS Extension) on page 306
get_service_request_accepted_status	7.3.6.10 SERVICE_REQUEST_ACCEPTED Status (DDS Extension) on page 307
get_status_changes	A list of what changed in all of the above.

These methods are useful in the event that no *Listener* callback is set to receive notifications of status changes. If a *Listener* is used, the callback will contain the new status information, in which case calling these methods is unlikely to be necessary.

The **get_status_changes()** operation provides a list of statuses that have changed since the last time the status changes were 'reset.' A status change is reset each time the application calls the corresponding **get_*_status()**, as well as each time *Connext DDS* returns from calling the *Listener* callback associated with that status.

For more on status, see 7.3.4 Setting Up DataWriterListeners on page 293, 7.3.6 Statuses for DataWriters below, and 4.4 Listeners on page 189.

7.3.6 Statuses for DataWriters

There are several types of statuses available for a *DataWriter*. You can use the **get_*_status()** operations (7.3.15 Setting DataWriter QosPolicies on page 332) to access them, or use a *DataWriterListener* (7.3.4 Setting Up DataWriterListeners on page 293) to listen for changes in their values. Each status has an associated data structure and is described in more detail in the following sections.

- 7.3.6.1 APPLICATION_ACKNOWLEDGMENT_STATUS below
- 7.3.6.2 DATA_WRITER_CACHE_STATUS on the next page
- 7.3.6.3 DATA_WRITER_PROTOCOL_STATUS on page 297
- 7.3.6.4 LIVELINESS_LOST Status on page 301
- 7.3.6.5 OFFERED_DEADLINE_MISSED Status on page 302
- 7.3.6.6 OFFERED_INCOMPATIBLE_QOS Status on page 302
- 7.3.6.7 PUBLICATION_MATCHED Status on page 303
- 7.3.6.8 RELIABLE_WRITER_CACHE_CHANGED Status (DDS Extension) on page 304
- 7.3.6.9 RELIABLE_READER_ACTIVITY_CHANGED Status (DDS Extension) on page 306
- 7.3.6.10 SERVICE_REQUEST_ACCEPTED Status (DDS Extension) on page 307

7.3.6.1 APPLICATION_ACKNOWLEDGMENT_STATUS

This status indicates that a *DataWriter* has received an application-level acknowledgment for a DDS sample, and triggers a *DataWriter* callback:

```
void DDSDataWriterListener::on_application_acknowledgment(
   DDSDataWriter * writer,
   const DDS_AcknowledgmentInfo & info)
```

on_application_acknowledgment() is called when a DDS sample is application-level acknowledged. It provides identities of the DDS sample and the acknowledging *DataReader*, as well as user-specified response data sent from the *DataReader* by the acknowledgment message—see Table 7.6 DDS_AcknowledgmentInfo.

Table 7.6 DDS_AcknowledgmentInfo

Type	Field Name	Description
DDS_InstanceHandle_t	subscription_handle	Subscription handle of the acknowledging *DataReader*.
struct DDS_SampleIdentity_t	sample_identity	Identity of the DDS sample being acknowledged.
DDS_Boolean	valid_response_data	Flag indicating validity of the user response data in the acknowledgment.
struct DDS_AckResponseData_t	response_data	User data payload of application-level acknowledgment message.

This status is only applicable when the *DataWriter's* Reliability QosPolicy's **acknowledgment_kind** is DDS_APPLICATION_AUTO_ACKNOWLEDGMENT_MODE or DDS_APPLICATION_EXPLICIT_ACKNOWLEDGMENT_MODE.

7.3.6.2 DATA_WRITER_CACHE_STATUS

This status keeps track of the number of DDS samples and instances in the *DataWriter's* queue. For information on instance states, see 6.1 Instance States on page 257.

This status does not have an associated *Listener*. You can access this status by calling the *DataWriter's* **get_datawriter_cache_status()** operation, which will return the status structure described in Table 7.7 DDS_DataWriterCacheStatus.

Table 7.7 DDS_DataWriterCacheStatus

Type	Field Name	Description
DDS_Long	sample_count_peak	Highest number of DDS samples in the *DataWriter's* queue over the lifetime of the *DataWriter*.
DDS_Long	sample_count	Current number of DDS samples in the *DataWriter's* queue. This number includes meta-samples, which represent the unregistration or disposal of an instance.
DDS_LongLong	alive_instance_count	Number of instances currently in the *DataWriter's* queue that have an **instance_state** of ALIVE.
DDS_LongLong	alive_instance_count_peak	Highest number of ALIVE instances in the *DataWriter's* queue over the lifetime of the *DataWriter*.
DDS_LongLong	disposed_instance_count	Number of instances currently in the *DataWriter's* queue that have an **instance_state** of NOT_ALIVE_DISPOSED.
DDS_LongLong	disposed_instance_count_peak	Highest number of NOT_ALIVE_DISPOSED instances in the *DataWriter's* queue over the lifetime of the *DataWriter*.
DDS_LongLong	unregistered_instance_count	Number of instances currently in the *DataWriter's* queue that the *DataWriter* has unregistered from via the **unregister_instance** operation.
DDS_LongLong	unregistered_instance_count_peak	Highest number of instances that the *DataWriter* has unregistered from, over the lifetime of the *DataWriter*.

7.3.6.3 DATA_WRITER_PROTOCOL_STATUS

This status includes internal protocol related metrics (such as the number of DDS samples pushed, pulled, filtered) and the status of wire-protocol traffic.

- **Pulled DDS samples** are DDS samples sent for repairs (that is, DDS samples that had to be resent), for late joiners, and all DDS samples sent by the local *DataWriter* when **push_on_write** (in 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388) is DDS_BOOLEAN_FALSE.
- **Pushed DDS samples** are DDS samples sent on **write()** when **push_on_write** is DDS_BOOLEAN_TRUE.
- **Filtered DDS samples** are DDS samples that are not sent due to *DataWriter* filtering (time-based filtering and ContentFilteredTopics), but this field is not currently supported.

This status does not have an associated Listener. You can access this status by calling the following operations on the *DataWriter* (all of which return the status structure described in Table 7.8 DDS_DataWriterProtocolStatus):

- **get_datawriter_protocol_status()** returns the sum of the protocol status for all the matched subscriptions for the *DataWriter*.
- **get_matched_subscription_datawriter_protocol_status()** returns the protocol status of a particular matched subscription, identified by a subscription_handle.
- **get_matched_subscription_datawriter_protocol_status_by_locator()** returns the protocol status of a particular matched subscription, identified by a locator. (See 15.2.1.1 Locator Format on page 763.)

Note: Status/data for a matched subscription is kept even if the *DataReader* is not active (has not responded to a heartbeat message with an ACK/NACK message after **max_heartbeat_retries** has been reached). The status/data will be removed only if the *DataReader* is gone: that is, the *DataReader* is destroyed and this change is propagated through a discovery update, or the *DataReader's DomainParticipant* is gone (either gracefully or its liveliness expired and *Connext DDS* is configured to purge not-alive participants). Once a matched *DataReader* is gone, its status is deleted. If you try to get the status/data for a matched *DataReader* that is gone, the 'get status' or 'get data' call will return an error.

Table 7.8 DDS_DataWriterProtocolStatus

Type	Field Name	Description
DDS_LongLong	pushed_sample_count	The number of user DDS samples pushed on write from this *DataWriter* to a matching *DataReader*. This field counts protocol (RTPS) messages pushed by a *DataWriter* when writing, unregistering, and disposing. The count is the number of sends done internally, and it may be greater than the number of user writes. This field counts whole samples, not fragments (in the case of large data). The fragment count is tracked in the **pushed_fragment_count**.
	pushed_sample_count_change	Change in the **pushed_sample_count** since the last time the status was read.
	pushed_sample_bytes	The number of bytes of user DDS samples pushed on write from this *DataWriter* to a matching *DataReader*. This field counts bytes of protocol (RTPS) messages pushed by a *DataWriter* when writing, unregistering, and disposing. The count of bytes corresponds to the number of sends done internally, and it may be greater than the number of user writes. When data fragmentation is used (for large data), this statistic is incremented as fragments are written.
	pushed_sample_bytes_change	Change in **pushed_sample_bytes** since the last time the status was read.
DDS_LongLong	sent_heartbeat_count	The number of Heartbeats sent between this *DataWriter* and matching *DataReader*s.
	sent_heartbeat_count_change	Change in the **sent_heartbeat_count** since the last time the status was read.
	sent_heartbeat_bytes	The number of bytes of Heartbeats sent between this *DataWriter* and matching *DataReaders*.
	sent_heartbeat_bytes_change	The incremental change in the number of bytes of Heartbeats sent between this *DataWriter* and matching *DataReaders* since the last time the status was read.
DDS_LongLong	pulled_sample_count	The number of user DDS samples pulled from this *DataWriter* by matching *DataReaders*. When data fragmentation is used, this statistic is incremented as fragments are written.
	pulled_sample_count_change	Change in the **pulled_sample_count** since the last time the status was read.
	pulled_sample_bytes	The number of bytes of user DDS samples pulled from this *DataWriter* by matching *DataReaders*. When data fragmentation is used, this statistic is incremented as fragments are written.
	pulled_sample_bytes_change	Change in **pulled_sample_bytes** since the last time the status was read.

Table 7.8 DDS_DataWriterProtocolStatus

Type	Field Name	Description
DDS_LongLong	received_ack_count	The number of ACKs from a *DataReader* received by this *DataWriter*.
	received_ack_count_change	Change in the **received_ack_count** since the last time the status was read.
	received_ack_bytes	The number of bytes of ACKs from a *DataReader* received by this *DataWriter*.
	received_ack_bytes_change	Change in **received_ack_bytes** since the last time the status was read.
DDS_LongLong	received_nack_count	The number of NACKs from a *DataReader* received by this *DataWriter*.
	received_nack_count_change	Change in the **received_nack_count** since the last time the status was read.
	received_nack_bytes	The number of bytes of NACKs from a *DataReader* received by this *DataWriter*.
	received_nack_bytes_change	Change in the **received_nack_bytes** since the last time the status was read.
DDS_LongLong	sent_gap_count	The number of GAPs sent from this *DataWriter* to matching *DataReaders*.
	sent_gap_count_change	Change in the **sent_gap_count** since the last time the status was read.
	sent_gap_bytes	The number of bytes of GAPs sent from this *DataWriter* to matching *DataReaders*.
	sent_gap_bytes_change	Change in the **sent_gap_bytes** since the last time the status was read.
DDS_LongLong	rejected_sample_count	These fields are currently not used.
	rejected_sample_count_change	
DDS_Long	send_window_size	Current maximum number of outstanding DDS samples allowed in the *DataWriter's* queue.

Table 7.8 DDS_DataWriterProtocolStatus

Type	Field Name	Description
DDS_LongLong	pushed_fragment_count	The number of fragments (DATA_FRAG messages) that have been pushed from this *DataWriter* to a *DataReader*. This count is incremented as each DATA_FRAG message is sent, not when the entire sample has been sent. Applicable only when data is fragmented.
	pushed_fragment_bytes	The number of bytes of DATA_FRAG messages that have been pushed by this *DataWriter*. This statistic is incremented as each DATA_FRAG message is sent, not when the entire sample has been sent. Applicable only when data is fragmented.
	pulled_fragment_count	The number of fragments (DATA_FRAG messages) that have been pulled from this *DataWriter* by a *DataReader*. This count is incremented as each DATA_FRAG message is sent, not when the entire sample has been sent. Applicable only when data is fragmented.
	pulled_fragment_bytes	The number of bytes of DATA_FRAG messages that have been pulled from this *DataWriter* by a *DataReader*. This statistic is incremented as each DATA_FRAG message is sent, not when the entire sample has been sent. Applicable only when data is fragmented.
DDS_LongLong	received_nack_fragment_count	The number of NACK_FRAG messages that have been received by this *DataWriter*. NACK FRAG RTPS messages are sent when large data is used in conjunction with reliable communication. They have the same properties as NACK messages, but instead of applying to samples, they apply to fragments. Applicable only when data is fragmented.
	received_nack_fragment_bytes	The number of bytes of NACK_FRAG messages that have been received by this *DataWriter*. NACK FRAG RTPS messages are sent when large data is used in conjunction with reliable communication. They have the same properties as NACK messages, but instead of applying to samples, they apply to fragments. Applicable only when data is fragmented.

Table 7.8 DDS_DataWriterProtocolStatus

Type	Field Name	Description
DDS_SequenceNumber_t	first_available_sample_sequence_number	Sequence number of the first available DDS sample in the *DataWriter's* reliability queue.
	last_available_sample_sequence_number	Sequence number of the last available DDS sample in the *DataWriter's* reliability queue.
	first_unacknowledged_sample_sequence_number	Sequence number of the first unacknowledged DDS sample in the *DataWriter's* reliability queue.
	first_available_sample_virtual_sequence_number	Virtual sequence number of the first available DDS sample in the *DataWriter's* reliability queue.
	last_available_sample_virtual_sequence_number	Virtual sequence number of the last available DDS sample in the *DataWriter's* reliability queue.
	first_unacknowledged_sample_virtual_sequence_number	Virtual sequence number of the first unacknowledged DDS sample in the *DataWriter's* reliability queue.
DDS_SequenceNumber_t	first_unacknowledged_sample_subscription_handle	Instance Handle of the matching remote *DataReader* for which the *DataWriter* has kept the first available DDS sample in the reliability queue.
	first_unelapsed_keep_duration_sample_sequence_number	Sequence number of the first DDS sample kept in the *DataWriter's* queue whose keep_duration (applied when **disable_positive_acks** is set) has not yet elapsed.

7.3.6.4 LIVELINESS_LOST Status

A change to this status indicates that the *DataWriter* failed to signal its liveliness within the time specified by the 7.5.15 LIVELINESS QosPolicy on page 425.

It is different than the 7.3.6.9 RELIABLE_READER_ACTIVITY_CHANGED Status (DDS Extension) on page 306 status that provides information about the liveliness of a *DataWriter's* matched *DataReaders*; this status reflects the *DataWriter's own* liveliness.

The structure for this status appears in Table 7.9 DDS_LivelinessLostStatus.

Table 7.9 DDS_LivelinessLostStatus

Type	Field Name	Description
DDS_Long	total_count	Cumulative number of times the *DataWriter* failed to explicitly signal its liveliness within the liveliness period.
DDS_Long	total_count_change	The change in total_count since the last time the Listener was called or the status was read.

The *DataWriterListener's* **on_liveliness_lost()** callback is invoked when this status changes. You can also retrieve the value by calling the *DataWriter's* **get_liveliness_lost_status()** operation.

7.3.6.5 OFFERED_DEADLINE_MISSED Status

A change to this status indicates that the *DataWriter* failed to write data within the time period set in its 7.5.7 DEADLINE QosPolicy on page 404.

The structure for this status appears in Table 7.10 DDS_OfferedDeadlineMissedStatus.

Table 7.10 DDS_OfferedDeadlineMissedStatus

Type	Field Name	Description
DDS_Long	total_count	Cumulative number of times the *DataWriter* failed to write within its offered deadline.
DDS_Long	total_count_change	The change in total_count since the last time the *Listener* was called or the status was read.
DDS_InstanceHandle_t	last_instance_handle	Handle to the last data-instance in the *DataWriter* for which an offered deadline was missed.

The *DataWriterListener's* **on_offered_deadline_missed()** operation is invoked when this status changes. You can also retrieve the value by calling the *DataWriter's* **get_deadline_missed_status()** operation.

7.3.6.6 OFFERED_INCOMPATIBLE_QOS Status

A change to this status indicates that the *DataWriter* discovered a *DataReader* for the same *Topic*, but that *DataReader* had requested QoS settings incompatible with this *DataWriter's* offered QoS.

The structure for this status appears in Table 7.11 DDS_OfferedIncompatibleQoSStatus.

Table 7.11 DDS_OfferedIncompatibleQoSStatus

Type	Field Name	Description
DDS_Long	total_ count	Cumulative number of times the *DataWriter* discovered a DataReader for the same *Topic* with a requested QoS that is incompatible with that offered by the *DataWriter*.

Table 7.11 DDS_OfferedIncompatibleQoSStatus

Type	Field Name	Description
DDS_Long	total_ count_ change	The change in total_count since the last time the *Listener* was called or the status was read.
DDS_QosPolicyId_t	last_ policy_id	The ID of the QosPolicy that was found to be incompatible the last time an incompatibility was detected. (Note: if there are multiple incompatible policies, only one of them is reported here.)
DDS_ QosPolicyCountSeq	policies	A list containing–for each policy–the total number of times that the *DataWriter* discovered a *DataReader* for the same *Topic* with a requested QoS that is incompatible with that offered by the *DataWriter*.

The *DataWriterListener's* **on_offered_incompatible_qos()** callback is invoked when this status changes. You can also retrieve the value by calling the *DataWriter's* **get_offered_incompatible_qos_status()** operation.

7.3.6.7 PUBLICATION_MATCHED Status

A change to this status indicates that the *DataWriter* discovered a matching *DataReader*.

A 'match' occurs only if the *DataReader* and *DataWriter* have the same *Topic*, same or compatible data type, and compatible QosPolicies. (For more information on compatible data types, see the RTI Connext DDS Core Libraries Extensible Types Guide.) In addition, if user code has directed *Connext DDS* to ignore certain *DataReaders*, then those *DataReaders* will never be matched. See 18.4.2 Ignoring Publications and Subscriptions on page 837 for more on setting up a *DomainParticipant* to ignore specific *DataReaders*.

This status is also changed (and the listener, if any, called) when a match is ended. A local *DataWriter* will become "unmatched" from a remote *DataReader* when that *DataReader* goes away for any of the following reasons:

- The matched *DataReader*'s *DomainParticipant* has lost liveliness.
- This *DataWriter* or the matched *DataReader* has changed QoS such that the entities are now incompatible.
- The matched *DataReader* has been deleted.

This status may reflect changes from multiple match or unmatch events, and the **current_count_change** can be used to determine the number of changes since the listener was called back or the status was checked.

The structure for this status appears in Table 7.12 DDS_PublicationMatchedStatus.

Table 7.12 DDS_PublicationMatchedStatus

Type	Field Name	Description
DDS_Long	total_count	Cumulative number of times that this *DataWriter* discovered a "match" with a *DataReader*. This number increases whenever a new match is discovered. It does not decrease when an existing match goes away for any of the reasons listed above.
	total_count_change	The changes in **total_count** since the last time the listener was called or the status was read. Note that this number will never be negative (because it's the total number of times the *DataWriter* ever matched with a *DataReader*).
	current_count	The number of *DataReaders* currently matched to the *DataWriter*. This number increases when a new match is discovered and decreases when an existing match goes away for any of the reasons listed above.
	current_count_peak	Greatest number of *DataReaders* that matched this *DataWriter* simultaneously. That is, there was no moment in time when more than this many *DataReaders* matched this *DataWriter*. (As a result, **total_count** can be higher than **current_count_peak**.)
	current_count_change	The change in **current_count** since the last time the listener was called or the status was read. Note that a negative **current_count_change** means that one or more *DataReaders* have become unmatched for one or more of the reasons listed above.
DDS_InstanceHandle_t	last_subscription_handle	This InstanceHandle can be used to look up which remote *DataReader* was the last to cause this *DataWriter*'s status to change, using the *DataWriter*'s **get_matched_subscription_data()** method. If the *DataReader* no longer matches this *DataWriter* due to any of the reasons listed above except incompatible QoS, then the *DataReader* has been purged from this *DataWriter*'s *DomainParticipant* discovery database. (See 15.1 What is Discovery? on page 759.) In that case, the *DataWriter*'s **get_matched_subscription_data()** method will not be able to return information about the *DataReader*. The only way to get information about the lost *DataReader* is if you cached the information previously.

The *DataWriterListener's* **on_publication_matched()** callback is invoked when this status changes. You can also retrieve the value by calling the *DataWriter's* **get_publication_match_status()** operation.

7.3.6.8 RELIABLE_WRITER_CACHE_CHANGED Status (DDS Extension)

A change to this status indicates that the number of unacknowledged DDS samples[1] in a reliable *DataWriter*'s cache has reached one of these trigger points:

- The cache is empty (contains no unacknowledged DDS samples)
- The cache is full (the number of unacknowledged DDS samples has reached the value specified in **DDS_ResourceLimitsQosPolicy::max_samples**)

[1] If batching is enabled, this still refers to a number of *DDS samples*, not *batches*.

- The number of unacknowledged DDS samples has reached a high or low watermark. See the **high_watermark** and **low_watermark** fields in Table 7.44 DDS_RtpsReliableWriterProtocol_t of the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.

For more about the reliable protocol used by *Connext DDS* and specifically, what it means for a DDS sample to be 'unacknowledged,' see Reliable Communications (Chapter 11 on page 682).

The structure for this status appears in Table 7.13 DDS_ReliableWriterCacheChangedStatus.The supporting structure, **DDS_ReliableWriterCacheEventCount**, is described in Table 7.14 DDS_ReliableWriterCacheEventCount.

Table 7.13 DDS_ReliableWriterCacheChangedStatus

Type	Field Name	Description
DDS_ReliableWriterCacheEventCount	empty_reliable_writer_cache	How many times the reliable *DataWriter's* cache of unacknowledged DDS samples has become empty.
	full_reliable_writer_cache	How many times the reliable *DataWriter's* cache of unacknowledged DDS samples has become full.
	low_watermark_reliable_writer_cache	How many times the reliable *DataWriter's* cache of unacknowledged DDS samples has fallen to the low watermark.
	high_watermark_reliable_writer_cache	How many times the reliable *DataWriter's* cache of unacknowledged DDS samples has risen to the high watermark.
DDS_Long	unacknowledged_sample_count	The current number of unacknowledged DDS samples in the *DataWriter's* cache.
	unacknowledged_sample_count_peak	The highest value that **unacknowledged_sample_count** has reached until now.
DDS_LongLong	replaced_unacknowledged_sample_count	Total number of unacknowledged samples that have been replaced by a *DataWriter* after applying the KEEP_LAST setting in the 7.5.12 HISTORY QosPolicy on page 418 policy.

Table 7.14 DDS_ReliableWriterCacheEventCount

Type	Field Name	Description
DDS_Long	total_count	The total number of times the event has occurred.
DDS_Long	total_count_change	The number of times the event has occurred since the *Listener* was last invoked or the status read.

The *DataWriterListener's* **on_reliable_writer_cache_changed()** callback is invoked when this status changes. You can also retrieve the value by calling the *DataWriter's* **get_reliable_writer_cache_changed_status()** operation.

If a reliable *DataWriter's* send window is finite, with both **RtpsReliableWriterProtocol_t.min_send_window_size** and **RtpsReliableWriterProtocol_t.max_send_window_size** set to positive values, then **full_reliable_writer_cache_status** counts the number of times the unacknowledged DDS sample count reaches the send window size.

7.3.6.9 RELIABLE_READER_ACTIVITY_CHANGED Status (DDS Extension)

This status indicates that one or more reliable *DataReaders* has become active or inactive.

This status is the reciprocal status to the 8.3.7.4 LIVELINESS_CHANGED Status on page 521 on the *DataReader*. It is different than 7.3.6.4 LIVELINESS_LOST Status on page 301 status on the *DataWriter,* in that the latter informs the *DataWriter* about its *own* liveliness; this status informs the *DataWriter* about the liveliness of its matched *DataReaders*.

A reliable *DataReader* is considered active by a reliable *DataWriter* with which it is matched if that *DataReader* acknowledges the DDS samples that it has been sent in a timely fashion. For the definition of "timely" in this context, see 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.

This status is only used for *DataWriters* whose 7.5.21 RELIABILITY QosPolicy on page 444 is set to RELIABLE. For best-effort *DataWriters*, all counts in this status will remain at zero.

The structure for this status appears in Table 7.15 DDS_ReliableReaderActivityChangedStatus.

Table 7.15 DDS_ReliableReaderActivityChangedStatus

Type	Field Name	Description
DDS_Long	active_count	The current number of reliable readers currently matched with this reliable *DataWriter*.
	inactive_count	The number of reliable readers that have been dropped by this reliable *DataWriter* because they failed to send acknowledgments in a timely fashion.
	active_count_change	The change in the number of active reliable *DataReaders* since the *Listener* was last invoked or the status read.
	inactive_count_change	The change in the number of inactive reliable *DataReaders* since the *Listener* was last invoked or the status read.
DDS_InstanceHandle_t	last_instance_handle	The instance handle of the last reliable *DataReader* to be determined to be inactive.

The *DataWriterListener's* **on_reliable_reader_activity_changed()** callback is invoked when this status changes. You can also retrieve the value by calling the *DataWriter's* **get_reliable_reader_activity_changed_status()** operation.

7.3.6.10 SERVICE_REQUEST_ACCEPTED Status (DDS Extension)

A change to this status indicates that ServiceRequest for the TopicQuery service is dispatched to this *DataWriter* for processing. For more information, see Topic Queries (Chapter 24 on page 962).

The structure for this status appears in Table 7.16 DDS_ServiceRequestAcceptedStatus.

The DataWriterListener's **on_service_request_accepted()** callback is invoked when this status changes.

You can also retrieve the value by calling the *DataWriter's* **get_service_request_accepted_status()** operation.

Table 7.16 DDS_ServiceRequestAcceptedStatus

Type	Field Name	Description
DDS_Long	total_count	The total cumulative number of ServiceRequests that have been accepted by a *DataWriter*.
	total_count_change	The incremental changes in total_count since the last time the listener was called or the status was read.
	current_count	The current number of ServiceRequests that have been accepted by this *DataWriter*.
	current_count_change	The change in current_count since the last time the listener was called or the status was read.
DDS_InstanceHandle_t	last_request_handle	A handle to the last DDS_ServiceRequest that caused the *DataWriter's* status to change.
DDS_Long	service_id	ID of the service to which the accepted Request belongs

7.3.7 Using a Type-Specific DataWriter (FooDataWriter)

(Note: This section does not apply to the Modern C++ API, where a *DataWriter's* data type is part of its template definition: **DataWriter<Foo>**)

Recall that a *Topic* is bound to a data type that specifies the format of the data associated with the *Topic*. Data types are either defined dynamically or in code generated from definitions in IDL or XML; see Data Types and DDS Data Samples (Chapter 3 on page 27). For each of your application's generated data types, such as 'Foo', there will be a FooDataWriter class (or a set of functions in C). This class allows the application to use a type-safe interface to interact with DDS samples of type 'Foo'. You will use the FooDataWriter's **write()** operation used to send data. For dynamically defined data-types, you will use the DynamicDataWriter class.

In fact, you will use the *FooDataWriter* any time you need to perform type-specific operations, such as registering or writing instances. Table 7.3 DataWriter Operations indicates which operations must be called using *FooDataWriter*. For operations that are not type-specific, you can call the operation using either a *FooDataWriter* or a *DDSDataWriter* object[1].

[1] In the C API, the non type-specific operations must be called using a *DDS_DataWriter* pointer.

You may notice that the *Publisher's* **create_datawriter()** operation returns a pointer to an object of type **DDSDataWriter**; this is because the **create_datawriter()** method is used to create *DataWriters* of any data type. However, when executed, the function actually returns a specialization (an object of a derived class) of the *DataWriter* that is specific for the data type of the associated *Topic*. For a *Topic* of type 'Foo', the object actually returned by **create_datawriter()** is a **FooDataWriter**.

To safely cast a generic **DDSDataWriter** pointer to a **FooDataWriter** pointer, you should use the static **narrow()** method of the **FooDataWriter** class. The **narrow()** method will return NULL if the generic **DDSDataWriter** pointer is not pointing at an object that is really a **FooDataWriter**.

For instance, if you create a *Topic* bound to the type '**Alarm**', all *DataWriter*s created for that *Topic* will be of type '**AlarmDataWriter.'** To access the type-specific methods of **AlarmDataWriter**, you must cast the generic **DDSDataWriter** pointer returned by **create_datawriter()**. For example:

```
DDSDataWriter* writer = publisher->create_datawriter(
    topic,writer_qos, NULL, NULL);
AlarmDataWriter *alarm_writer = AlarmDataWriter::narrow(writer);
if (alarm_writer == NULL) {
    // ... error
};
```

In the C API, there is also a way to do the opposite of **narrow()**. **FooDataWriter_as_datawriter()** casts a FooDataWriter as a DDSDataWriter, and **FooDataReader_as_datareader()** casts a FooDataReader as a DDSDataReader.

7.3.8 Writing Data

The **write()** operation informs *Connext DDS* that there is a new value for a data-instance to be published for the corresponding *Topic*. By default, calling **write()** will send the data immediately over the network (assuming that there are matched *DataReaders*). However, you can configure and execute operations on the *DataWriter*'s *Publisher* to buffer the data so that it is sent in a batch with data from other *DataWriters* or even to prevent the data from being sent. Those sending "modes" are configured using the 7.4.6 PRESENTATION QosPolicy on page 361 as well as the *Publisher*'s **suspend/resume_publications()** operations. The actual transport-level communications may be done by a separate, lower-priority thread when the *Publisher* is configured to send the data for its *DataWriters*. For more information on threads, see Connext DDS Threading Model (Chapter 21 on page 900).

When you call **write()**, *Connext DDS* automatically attaches a stamp of the current time that is sent with the DDS data sample to the *DataReader*(s). The timestamp appears in the **source_timestamp** field of the **DDS_SampleInfo** structure that is provided along with your data using *DataReaders* (see 8.4.6 The SampleInfo Structure on page 560).

```
DDS_ReturnCode_t  write (const Foo &instance_data,
    const DDS_InstanceHandle_t &handle)
```

You can use an alternate *DataWriter* operation called **write_w_timestamp()**. This performs the same action as **write()**, but allows the application to explicitly set the **source_timestamp**. This is useful when

you want the user application to set the value of the timestamp instead of the default clock used by *Connext DDS*.

```
DDS_ReturnCode_t  write_w_timestamp (
       const Foo &instance_data,
        const DDS_InstanceHandle_t &handle,
       const DDS_Time_t &source_timestamp)
```

Note that, in general, the application should not mix these two ways of specifying timestamps. That is, for each *DataWriter*, the application should either always use the automatic timestamping mechanism (by calling the normal operations) or always specify a timestamp (by calling the "**w_timestamp**" variants of the operations). Mixing the two methods may result in not receiving sent data.

You can also use an alternate *DataWriter* operation, **write_w_params()**, which performs the same action as **write()**, but allows the application to explicitly set the fields contained in the **DDS_WriteParams** structure, see Table 7.17 DDS_WriteParams_t.

Table 7.17 DDS_WriteParams_t

Type	Field Name	Description
DDS_Boolean	replace_auto	Allows retrieving the actual value of those fields that were automatic. When this field is set to true, the fields that were configured with an automatic value (for example, DDS_AUTO_SAMPLE_IDENTITY in identity) receive their actual value after write_w_params is called.
DDS_SampleIdentity_t	identity	Identity of the DDS sample being written. The identity consists of a pair (Virtual Writer GUID, Virtual Sequence Number). When the value DDS_AUTO_SAMPLE_IDENTITY is used, the **write_w_params()** operation will determine the DDS sample identity as follows: • The Virtual Writer GUID (writer_guid) is the virtual GUID associated with the *DataWriter* writing the DDS sample. This virtual GUID is configured using the member **virtual_guid** in 7.3.6.3 DATA_WRITER_PROTOCOL_STATUS on page 297. • The Virtual Sequence Number (**sequence_number**) is increased by one with respect to the previous value. The virtual sequence numbers for a given virtual GUID must be strictly monotonically increasing. If you try to write a DDS sample with a sequence number smaller or equal to the last sequence number, the write operation will fail. A *DataReader* can inspect the identity of a received DDS sample by accessing the fields **original_publication_virtual_guid** and **original_publication_virtual_sequence_number** in 8.4.6 The SampleInfo Structure on page 560.

Table 7.17 DDS_WriteParams_t

Type	Field Name	Description
DDS_SampleIdentity_t	related_sample_identity	The identity of another DDS sample related to this one. The value of this field identifies another DDS sample that is logically related to the one that is written. For example, the *DataWriter* created by a Replier (sets Introduction to the Request-Reply Communication Pattern (Chapter 26 on page 984)) uses this field to associate the identity of the DDS request sample to reponse sample. To specify that there is no related DDS sample identity use the value DDS_UNKNOWN_SAMPLE_IDENTITY, A *DataReader* can inspect the related DDS sample identity of a received DDS sample by accessing the fields **related_original_publication_virtual_guid** and **related_original_publication_virtual_sequence_number** in 8.4.6 The SampleInfo Structure on page 560.
DDS_Time	source_timestamp	Source timestamp that will be associated to the DDS sample that is written. If source_timestamp is set to DDS_TIMER_INVALID, the middleware will assign the value. A *DataReader* can inspect the source_timestamp value of a received DDS sample by accessing the field **source_timestamp** 8.4.6 The SampleInfo Structure on page 560.
DDS_InstanceHandle_t	handle	The instance handle. This value can be either the handle returned by a previous call to **register_instance()** or the special value DDS_HANDLE_NIL.
DDS_Long	priority	Positive integer designating the relative priority of the DDS sample, used to determine the transmission order of pending transmissions. To use publication priorities, the *DataWriter's* 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441 must be set for asynchronous publishing and the DataWriter must use a FlowController with a highest-priority first scheduling_policy. For Multi-channel *DataWriters*, the publication priority of a DDS sample may be used as a filter criteria for determining channel membership. For more information, see 7.6.4 Prioritized DDS Samples on page 473.
DDS_Long	flag	Flags for the DDS sample, represented as a 32-bit integer, of which only the 16 least-significant bits are used. RTI reserves least-significant bits [0-7] for middleware-specific usage. The application can use least significant bits [8-15]. An application can inspect the flags associated with a received DDS sample by checking the **flag** field in 8.4.6 The SampleInfo Structure on page 560. For details about the reserved bits see 8.4.6 The SampleInfo Structure on page 560. Default 0 (no flags are set).
struct DDS_GUID_t	source_guid	Identifies the application logical data source associated with the sample being written.
struct DDS_GUID_t	related_source_guid	Identifies the application logical data source that is related to the sample being written.
struct DDS_GUID_t	related_reader_guid	Identifies a *DataReader* that is logically related to the sample that is being written.

When using the C API, a newly created variable of type DDS_WriteParams_t should be initialized by setting it to DDS_WRITEPARAMS_DEFAULT.

The **write()** operation also asserts liveliness on the *DataWriter*, the associated *Publisher*, and the associated *DomainParticipant*. It has the same effect with regards to liveliness as an explicit call to **assert_liveliness()**, see 7.3.17 Asserting Liveliness on page 343 and the 7.5.15 LIVELINESS QosPolicy on page 425. Maintaining liveliness is important for *DataReaders* to know that the *DataWriter* still exists and for the proper behavior of the 7.5.17 OWNERSHIP QosPolicy on page 432.

See also: 9.6 Clock Selection on page 671.

7.3.8.1 Blocking During a write()

The **write()** operation may block if the 7.5.21 RELIABILITY QosPolicy on page 444 *kind* is set to Reliable, the send window is full, or the modification would cause data to be lost. Specifically, **write()** may block in the following situations (note that the list may not be exhaustive):

- If the send window is specified (**max/min_send_window_size** fields in the DDS_RtpsReliableWriterProtocol_t structure in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388 are not LENGTH_UNLIMITED) and the send window is full. Blocking in this case occurs with both KEEP_LAST and KEEP_ALL history **kind**s.
- If **max_samples** or **max_samples_per_instance** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 (or **max_batches** in 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400) are exceeded and none of the samples can be replaced because they are not fully ACKed. Blocking in this case only applies to the KEEP_ALL history **kind**.

This operation may also block when using BEST_EFFORT Reliability 7.5.21 RELIABILITY QosPolicy on page 444) and ASYNCHRONOUS Publish Mode (7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441) QoS settings. In this case, the *DataWriter* will queue DDS samples until they are sent by the asynchronous publishing thread. The number of DDS samples that can be stored is determined by the 7.5.12 HISTORY QosPolicy on page 418. If the asynchronous thread does not send DDS samples fast enough (such as when using a slow FlowController (7.6 FlowControllers (DDS Extension) on page 467)), the queue may fill up. In that case, subsequent write calls will block.

If this operation does block for any of the above reasons, the 7.5.21 RELIABILITY QosPolicy on page 444's **max_blocking_time** configures the maximum time the write operation may block (waiting for space to become available). If **max_ blocking_time** elapses before the *DataWriter* can store the modification without exceeding the limits, the operation will fail and return **RETCODE_TIMEOUT** for KEEP_ALL configurations.

7.3.8.2 write() behavior with KEEP_LAST and KEEP_ALL

Following is how the write operation behaves when KEEP_LAST (in the 7.5.12 HISTORY QosPolicy on page 418) and RELIABLE (in the 7.5.21 RELIABILITY QosPolicy on page 444) are used:

- The send window size is determined by the **max/min_send_window_size** fields in the DDS_RtpsReliableWriterProtocol_t structure in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388. If a send window is specified (**max_send_window_size** is not UNLIMITED) and the window is full, the write operation will block until one of the samples in the send window is protocol-acknowledged (ACKed) (Note 1) or until the **max_blocking_time** in the 7.5.21 RELIABILITY QosPolicy on page 444 (**writer_qos.reliability.max_blocking_time**) expires.
- Then, the *DataWriter* will try to add the new sample to the writer history.
- If the instance associated with the sample is present in the writer history and there are **depth** (in the 7.5.12 HISTORY QosPolicy on page 418) samples in the instance, the *DataWriter* will replace the oldest sample of that instance independently of that sample's acknowledged status, and the write operation will return DDS_RETCODE_OK. Otherwise, no sample will be replaced and the write operation will continue.
- If the instance associated with the sample is not present in the writer history and **max_instances** (in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449) is exceeded, the *DataWriter* will try to replace an existing instance (and its samples) according to the value of the **instance_replacement** field in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400 (see 7.5.6.1 Configuring DataWriter Instance Replacement on page 402).
  - If no instance can be replaced, the write operation returns a DDS_RETCODE_OUT_OF_RESOURCES error.
- If **max_samples** (in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449) is exceeded, the *DataWriter* will try to drop a sample from a different instance as follows:
  - The *DataWriter* will try first to remove a fully ACKed (Note 2) sample from a different instance 'I' as long as that sample is not the last remaining sample for the instance 'I'. To find this sample, the *DataWriter* starts iterating from the oldest sample in the writer history to the newest sample.
  - If no such sample is found, the *DataWriter* will replace the oldest sample in the writer history.
- The sample is added to the writer history, and the write operation returns DDS_RETCODE_OK.

Following is how the write operation behaves when KEEP_ALL (in the 7.5.12 HISTORY QosPolicy on page 418) and RELIABLE (in the 7.5.21 RELIABILITY QosPolicy on page 444) are used:

- The send window size is determined by the **max/min_send_window_size** fields in the DDS_RtpsReliableWriterProtocol_t structure in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388. If a send window is specified (**max_send_window_size** is not UNLIMITED) and the window is full, the write operation will block until one of the samples in the send window is protocol-ACKed (Note 1) or until the **max_blocking_time** in the 7.5.21 RELIABILITY QosPolicy on page 444 (**writer_qos.reliability.max_blocking_time**) expires.

- If **writer_qos.reliability.max_blocking_time** expires, the write operation returns DDS_RETCODE_TIMEOUT.

- When a sample is protocol-ACKed (Note 1) before **max_blocking_time** expires, the *DataWriter* will try to add the sample to the writer history as follows:
  - If the instance associated with the sample is not present in the writer history and **max_instances** is exceeded, the *DataWriter* will try to replace an existing instance (and its samples) according to the value of the **instance_replacement** field in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400 (see 7.5.6.1 Configuring DataWriter Instance Replacement on page 402).
    - If no instance can be replaced, the write operation returns a DDS_RETCODE_OUT_OF_RESOURCES error.
  - If **max_samples** is exceeded, the *DataWriter* will go through the samples in the order in which they were added, and it will replace the first sample that is fully ACKed (Note 2).
    - If no fully ACKed sample is found, the *DataWriter* will block (Note 3) until a sample is fully ACKed and can be replaced or **writer_qos.reliability.max_blocking_time** expires. If **writer_qos.reliability.max_blocking_time** expires, the write operation will return DDS_RETCODE_TIMEOUT.
  - If **max_samples_per_instance** is exceeded, the *DataWriter* will go through the samples of the instance in the order in which they were added, and it will replace the first sample that is fully ACKed.
    - If no fully ACKed sample is found, the *DataWriter* will block (Note 3) until a sample is fully ACKed and can be replaced or **writer_qos.reliability.max_blocking_time** expires. If **writer_qos.reliability.max_blocking_time** expires, the write operation will return DDS_RETCODE_TIMEOUT.
  - The sample is added to the writer history, and the write operation returns DDS_RETCODE_OK.

See 7.3.12.1 Application Acknowledgment Kinds on page 317 for more information on the following notes:

Note 1: A sample in the writer history is considered "protocol ACKed" when the sample has been individually ACKed at the RTPS protocol level by each one of the *DataReaders* that matched the *DataWriter* at the moment the sample was added to the *DataWriter* queue.

- Late joiners do not change the protocol ACK state of a sample. If a sample is marked as protocol ACKed because it has been acknowledged by all the matching *DataReaders* and a *DataReader* joins later on, the historical sample is still considered protocol ACKed even if it has not been received by the late joiner.

- If a sample 'S1' is protocol ACKed and a TopicQuery is received, triggering the publication of 'S1', the sample is still considered protocol ACKed. If a sample 'S1' is not ACKed and a TopicQuery is received triggering the publication of 'S1', the *DataWriter* will require that both the matching *DataReaders* on the live RTPS channel and the *DataReader* on the TopicQuery channel individually protocol ACK the sample in order to consider the sample protocol ACKed.

Note 2: A sample in the writer history is considered "fully ACKed" when all of the following conditions are met:

- The sample is protocol-ACKed.
- The sample has been "application-level ACKed" by all the *DataReaders* matching the *DataWriter* that have their **reader_qos.reliability.acknowledgment_kind** set to AUTO_ACKNOWLEDGMENT_MODE or EXPLICIT_ACKNOWLEDGMENT_MODE. Once the sample is application-level ACKed, it cannot change its status to not ACked after new *DataReaders* are matched. (Application-level ACK occurs when the application acknowledges receipt of a sample.)
- If required subscriptions are enabled (see 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369), the sample must also be ACKed by all the required subscriptions configured on the *DataWriter*.

Note 3: It is possible within a single call to the write operation for a *DataWriter* to block both when the send window is full and then again when **max_samples** or **max_samples_per_instance** is exceeded. This can happen because blocking on the send window only considers protocol-ACKed samples, while blocking based on resource limits considers fully-ACKed samples. In any case, the total max blocking time of a single call to the write operation will not exceed **writer_qos.reliability.max_blocking_time**.

The write operation on a *DataWriter* configured to use batching may also block if the sample being written cannot be added to the existing outstanding batch and the batch has to be synchronously flushed within the context of the write thread (see 7.5.2.1 Synchronous and Asynchronous Flushing on page 375). The flushing operation may block under the same scenarios described above for individual samples, taking into account that the send window is applied per batch and not per sample.

The **unregister_instance()** and **dispose()** operations, with regards to KEEP_LAST and KEEP_ALL, behave the same as for the **write()** operation. See 7.3.14.2 Registering Instances on page 325, 7.3.14.4 Unregistering Instances on page 327, and 7.3.14.3 Disposing Instances on page 327.

7.3.9 Flushing Batches of DDS Data Samples

The **flush()** operation makes a batch of DDS data samples available to be sent on the network.

```
DDS_ReturnCode_t flush ()
```

If the *DataWriter's* 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441 **kind** is **not** ASYNCHRONOUS, the batch will be sent on the network immediately in the context of the calling thread.

If the *DataWriter's* PublishModeQosPolicy **kind** is ASYNCHRONOUS, the batch will be sent in the context of the asynchronous publishing thread.

The **flush()** operation may block based on the conditions described in 7.3.8.1 Blocking During a write() on page 311.

If this operation does block, the **max_blocking_time** in the 7.5.21 RELIABILITY QosPolicy on page 444 configures the maximum time the write operation may block (waiting for space to become available). If **max_blocking_time** elapses before the *DataWriter* is able to store the modification without exceeding the limits, the operation will fail and return TIMEOUT.

For more information on batching, see the 7.5.2 BATCH QosPolicy (DDS Extension) on page 373.

7.3.10 Writing Coherent Sets of DDS Data Samples

A publishing application can request that a set of DDS data-sample changes be propagated in such a way that they are interpreted at the receivers' side as a cohesive set of modifications. In this case, the receiver will only be able to access the data after all the modifications in the set are available at the subscribing end.

This is useful in cases where the values are inter-related. For example, suppose you have two data-instances representing the 'altitude' and 'velocity vector' of the same aircraft. If both are changed, it may be important to ensure that reader see both together (otherwise, it may erroneously interpret that the aircraft is on a collision course).

To use this mechanism in C, Traditional C++, Java and .NET:

1. Call the *Publisher's* **begin_coherent_changes()** operation to indicate the start a coherent set.
2. For each DDS sample in the coherent set: call the *FooDataWriter's* **write()** operation.
3. Call the *Publisher's* **end_coherent_changes()** operation to terminate the set.

In the Modern C++ API:

1. Instantiate a **dds::pub::CoherentSet** passing a publisher to the constructor
2. For each DDS sample in the coherent set call **dds::pub::DataWriter<Foo>::write()**.
3. Let the **dds::pub::CoherentSet** destructor terminate the set or explicitly call **dds::pub::CoherentSet::end()**

Calls to **begin_coherent_changes()** and **end_coherent_changes()** can be nested. *Publisher's* samples (samples published by any of the *DataWriters* within the *Publisher*) that are not published within a **begin_coherent_changes/end_coherent_changes** block will not be provided to the *DataReaders* as a set.

See also: the **coherent_access** field in the 7.4.6 PRESENTATION QosPolicy on page 361 and the **coherent_set_info** field in 8.4.6 The SampleInfo Structure on page 560.

7.3.11 Waiting for Acknowledgments in a DataWriter

The *DataWriter's* **wait_for_acknowledgments()** operation blocks the calling thread until either all data written by the reliable *DataWriter* is acknowledged by (a) all reliable *DataReaders* that are matched and alive *and* (b) by all required subscriptions (see 7.3.13 Required Subscriptions on page 322), or until the duration specified by the **max_wait** parameter elapses, whichever happens first.

Note that if a thread is blocked in the call to **wait_for_acknowledgments()** on a *DataWriter* and a different thread writes new DDS samples on the same *DataWriter*, the new DDS samples must be acknowledged before unblocking the thread waiting on **wait_for_acknowledgments()**.

```
DDS_ReturnCode_t wait_for_acknowledgments (
       const DDS_Duration_t &  max_wait)
```

This operation returns **DDS_RETCODE_OK** if all the DDS samples were acknowledged, or **DDS_RETCODE_TIMEOUT** if the **max_wait** duration expired first.

If the *DataWriter* does not have its 7.5.21 RELIABILITY QosPolicy on page 444 **kind** set to RELIABLE, the operation will immediately return **DDS_RETCODE_OK**.

There is a similar operation available at the *Publisher* level, see 7.2.7 Waiting for Acknowledgments in a Publisher on page 285.

The reliability protocol used by *Connext DDS* is discussed in Reliable Communications (Chapter 11 on page 682). The application acknowledgment mechanism is discussed in 7.3.12 Application Acknowledgment below and Guaranteed Delivery of Data (Chapter 14 on page 746).

7.3.12 Application Acknowledgment

The 7.5.21 RELIABILITY QosPolicy on page 444 determines whether or not data published by a *DataWriter* will be reliably delivered by *Connext DDS* to matching *DataReaders*. The reliability protocol used by *Connext DDS* is discussed in Reliable Communications (Chapter 11 on page 682).

With protocol-level reliability alone, the producing application knows that the information is received by the protocol layer on the consuming side. However, the producing application cannot be certain that the consuming application read that information or was able to successfully understand and process it. The information could arrive in the consumer's protocol stack and be placed in the *DataReader* cache but the consuming application could either crash before it reads it from the cache, not read its cache, or read the cache using queries or conditions that prevent that particular DDS data sample from being accessed. Fur-

thermore, the consuming application could access the DDS sample, but not be able to interpret its meaning or process it in the intended way.

The mechanism to let a *DataWriter* know to keep the DDS sample around, not just until it has been acknowledged by the reliability protocol, but until the application has been able to process the DDS sample is aptly called *Application Acknowledgment*. A reliable *DataWriter* will keep the DDS samples until the application acknowledges the DDS samples. When the subscriber application is restarted, the middleware will know that the application did not acknowledge successfully processing the DDS samples and will resend them.

7.3.12.1 Application Acknowledgment Kinds

Connext DDS supports *three* kinds of application acknowledgment, which is configured in the 7.5.21 RELIABILITY QosPolicy on page 444):

1. DDS_PROTOCOL_ACKNOWLEDGMENT_MODE (Default): In essence, this mode is identical to using no application-level acknowledgment. DDS samples are acknowledged according to the Real-Time Publish-Subscribe (RTPS) reliability protocol. RTPS AckNack messages will acknowledge that the middleware received the DDS sample.
2. DDS_APPLICATION_AUTO_ACKNOWLEDGMENT_MODE: DDS samples are automatically acknowledged by the middleware after the subscribing application accesses them, either through calling **take()** or **read()** on the DDS sample. If the **read()** or **take()** operation loans the samples, the acknowledgment is done after the **return_loan()** operation is called. Otherwise, for **read()** or **take()** operations that make a copy, acknowledgment is done after the **read()** or **take()** operations are executed.
3. DDS_APPLICATION_EXPLICIT_ACKNOWLEDGMENT_MODE: DDS samples are acknowledged after the subscribing application explicitly calls acknowledge on the DDS sample. This can be done by either calling the *DataReader's* **acknowledge_sample()** or **acknowledge_all()** operations. When using **acknowledge_sample()**, the application will provide the DDS_SampleInfo to identify the DDS sample being acknowledge. When using acknowledge_all, all the DDS samples that have been read or taken by the reader will be acknowledged.

   Note: Even in DDS_APPLICATION_EXPLICIT_ACKNOWLEDGMENT_MODE, some DDS samples may be automatically acknowledged. This is the case when DDS samples are filtered out by the reader using time-based filter, or using content filters. Additionally, when the reader is explicitly configured to use KEEP_LAST history kind, DDS samples may be replaced in the reader queue due to resource constraints. In that case, the DDS sample will be automatically acknowledged by the middleware if it has not been read by the application before it was replaced. To truly guarantee successful processing of DDS samples, it is recommended to use KEEP_ALL history kind.

7.3.12.2 Explicitly Acknowledging a Single DDS Sample (C++)

```
void MyReaderListener::on_data_available(DDSDataReader *reader)
{
       Foo sample;
       DDS_SampleInfo info;
       FooDataReader* fooReader = FooDataReader::narrow(reader);
       DDS_ReturnCode_t retcode = fooReader->take_next_sample(
                                       sample, info);
       if (retcode == DDS_RETCODE_OK) {
               if (info.valid_data) {
                       // Process sample
                       ...
                       retcode = reader->acknowledge_sample(info);
                       if (retcode != DDS_RETCODE_OK) {
                               // Error
                       }
               }
       } else {
               // Not OK or NO DATA
       }
}
```

7.3.12.3 Explicitly Acknowledging All DDS samples (C++)

```
void MyReaderListener::on_data_available(DDSDataReader *reader)
{
       ...
       // Loop while samples available
       for(;;) {
               retcode = string_reader->take_next_sample(
                               sample, info);
               if (retcode == DDS_RETCODE_NO_DATA) {
                       // No more samples
                       break;
               }
               // Process sample
               ...
       }
       retcode = reader->acknowledge_all();
       if (retcode != DDS_RETCODE_OK) {
               // Error
       }
}
```

7.3.12.4 Notification of Delivery with Application Acknowledgment

A *DataWriter* can get notification of delivery with Application Acknowledgment using two different mechanisms:

- *DataWriter's* **wait_for_acknowledgments()** operation

A *DataWriter* can use the **wait_for_acknowledgments()** operation to be notified when all the DDS samples in the *DataWriter's* queue have been acknowledged. See 7.3.11 Waiting for Acknowledgments in a DataWriter on page 316.

```
retCode = fooWriter->write(sample, DDS_HANDLE_NIL);
if (retCode != DDS_RETCODE_OK) {
   // Error
}
retcode = writer->wait_for_acknowledgments(timeout);
if (retCode != DDS_RETCODE_OK) {
   if (retCode == DDS_RETCODE_TIMEOUT) {
       // Timeout: Sample not acknowledged yet
   } else {
       // Error
   }
}
```

Using **wait_for_acknowledgments()** does not provide a way to get delivery notifications on a per *DataReader* and DDS sample basis. If your application requires acknowledgment of message receipt, use the the second mechanism described below.

- *DataWriter's* listener callback **on_application_acknowledgment()**

  An application can install a *DataWriter* listener callback **on_application_acknowledgment()** to receive a notification when a DDS sample is acknowledged by a *DataReader*. As part of this notification, you can access:

  - The subscription handle of the acknowledging *DataReader*.
  - The Identity of the DDS sample being acknowledged.
  - The response data associated with the DDS sample being acknowledged.

  For more information, see 7.3.6.1 APPLICATION_ACKNOWLEDGMENT_STATUS on page 295.

7.3.12.5 Application-Level Acknowledgment Protocol

When the subscribing application confirms it has successfully processed a DDS sample, an AppAck RTPS message is sent to the publishing application. This message will be resent until the publishing application confirms receipt of the AppAck message by sending an AppAckConf RTPS message. See Figure 7.10: AppAck RTPS Messages Sent when Application Acknowledges a DDS Sample on the next page through Figure 7.12: AppAck RTPS Messages Sent as a Sequence of Intervals, Combined to Optimize for Bandwidth on page 321.

Figure 7.10: AppAck RTPS Messages Sent when Application Acknowledges a DDS Sample

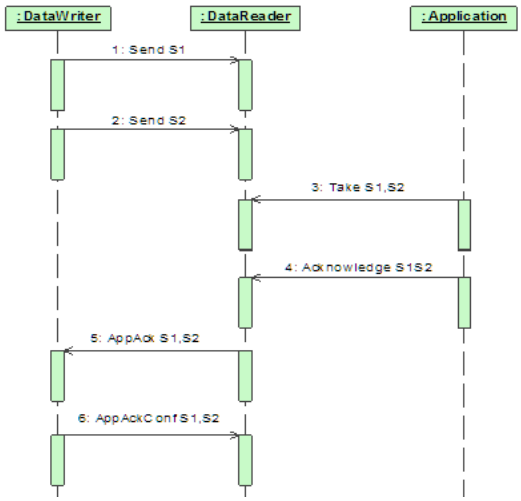


Figure 7.11: AppAck RTPS Messages Resent Until Acknowledged Through AppAckConf RTPS Message

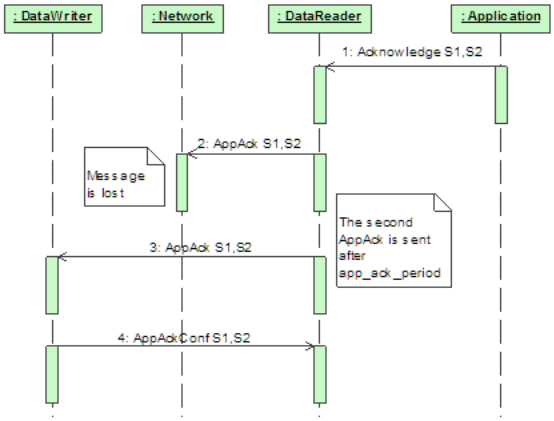
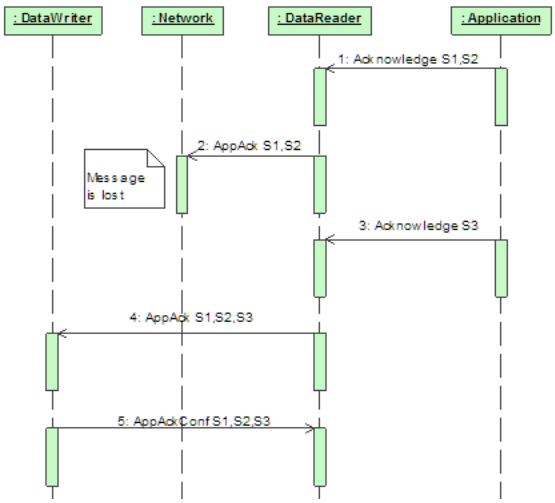


Figure 7.12: AppAck RTPS Messages Sent as a Sequence of Intervals, Combined to Optimize for Bandwidth



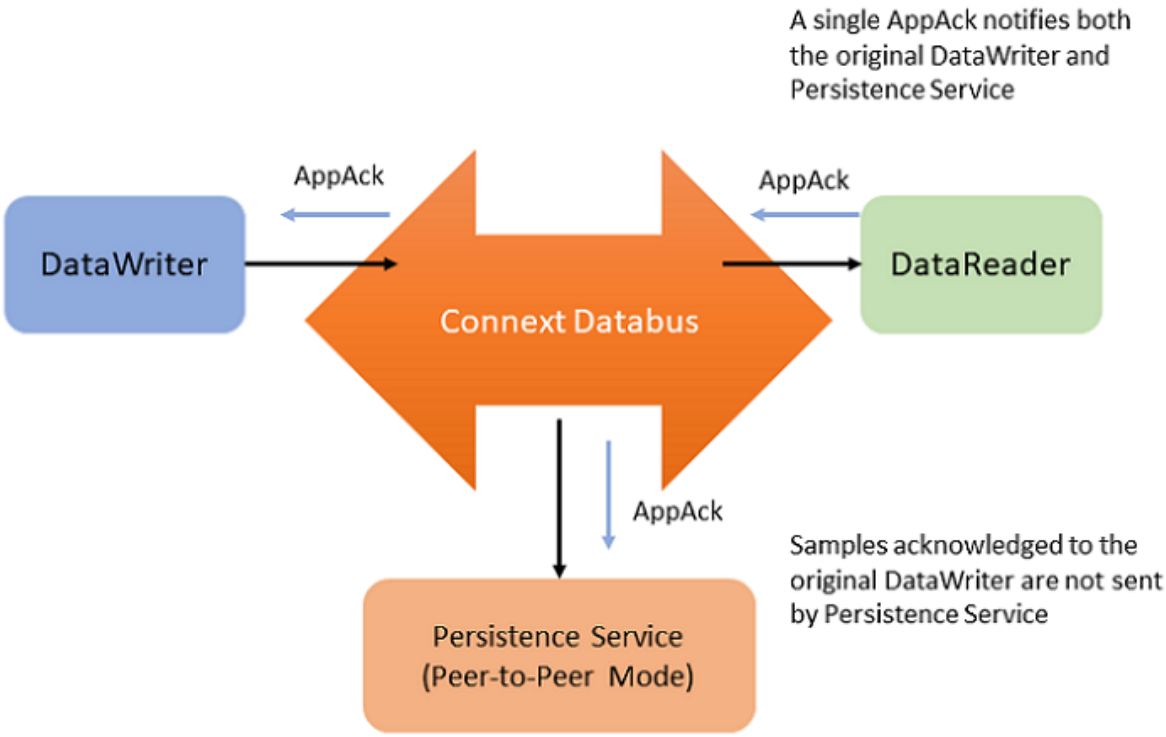
7.3.12.6 Periodic and Non-Periodic AppAck Messages

You can configure whether AppAck RTPS messages are sent immediately or periodically through the 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565. The samples_per_app_ack on page 569 (in Table 8.19 DDS_RtpsReliableReaderProtocol_t) determines the minimum number of DDS samples acknowledged by one application-level Acknowledgment message. The middleware will not send an AppAck message until it has at least this many DDS samples pending acknowledgment. By default, **samples_per_app_ack** is 1 and the AppAck RTPS message is sent immediately. Independently, the app_ack_period on page 568 (in Table 8.19 DDS_RtpsReliableReaderProtocol_t) determines the rate at which a *DataReader* will send AppAck messages.

7.3.12.7 Application Acknowledgment and Persistence Service

Application Acknowledgment is fully supported by *RTI Persistence Service*. The combination of Application Acknowledgment and *Persistence Service* is actually a common configuration. In addition to keeping DDS samples available until fully acknowledged, *Persistence Service*, when used in peer-to-peer mode, can take advantage of AppAck messages to avoid sending duplicate messages to the subscribing application. Because AppAck messages are sent to all matching writers, when the subscriber acknowledges the original publisher, *Persistence Service* will also be notified of this event and will not send out duplicate messages. This is illustrated in Figure 7.13: Application Acknowledgment and Persistence Service on the next page.

Figure 7.13: Application Acknowledgment and Persistence Service



7.3.12.8 Application Acknowledgment and Routing Service

Application Acknowledgment is supported by *RTI Routing Service*: That is, *Routing Service* will acknowledge the DDS sample it has processed. *Routing Service* is an active participant in the *Connext DDS* system and not transparent to the publisher or subscriber. As such, *Routing Service* will acknowledge to the publisher, and the subscriber will acknowledge to *Routing Service*. However, the publisher will not get a notification from the subscriber directly.

7.3.13 Required Subscriptions

The 7.5.9 DURABILITY QosPolicy on page 410 specifies whether acknowledged DDS samples need to be kept in the *DataWriter's* queue and made available to late-joining applications. When a late joining application is discovered, available DDS samples will be sent to the late joiner. With the Durability QoS alone, there is no way to specify or characterize the intended consumers of the information and you do not have control over which DDS samples will be kept for late-joining applications. If while waiting for late-joining applications, the middleware needs to free up DDS samples, it will reclaim DDS samples if they have been previously acknowledged by active/matching readers.

There are scenarios where you know a priori that a particular set of applications will join the system: e.g., a logging service or a known processing application. The *Required Subscription* feature is designed to keep data until these known late joining applications acknowledge the data.

Another use case is when *DataReaders* become temporarily inactive due to not responding to heartbeats, or when the subscriber temporarily became disconnected and purged from the discovery database. In both cases, the *DataWriter* will no longer keep the DDS sample for this *DataReader*. The *Required Subscription* feature will keep the data until these known *DataReaders* have acknowledged the data.

To use Required Subscriptions, the *DataReaders* and *DataWriters* must have their 7.5.21 RELIABILITY QosPolicy on page 444 **kind** set to RELIABLE.

7.3.13.1 Named, Required and Durable Subscriptions

Before describing the Required Subscriptions, it is important to understand a few concepts:

- **Named Subscription**: Through the 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416, each *DataReader* can be given a specific name. This name can be used by tools to identify a specific *DataReader*. Additionally, the *DataReader* can be given a role_name. For example: LOG_APP_1 *DataReader* belongs to the logger applications (**role_name = "LOGGER"**).
- **Required Subscription** is a named subscription to which a *DataWriter* is configured to deliver data to. This is true even if the *DataReaders* serving those subscriptions are not available yet. The *DataWriter* must store the DDS sample until it has been acknowledged by all active reliable *DataReaders* and acknowledged by all required subscriptions. The *DataWriter* is not waiting for a specific *DataReader*, rather it is waiting for *DataReaders* belonging to the required subscription by setting their **role_name** to the subscription name.
- **Durable Subscription** is a required subscription where DDS samples are stored and forwarded by an external service. In this case, the required subscription is served by *RTI Persistence Service*. See 46.9 Configuring Durable Subscriptions in Persistence Service on page 1180.

7.3.13.2 Durability QoS and Required Subscriptions

The 7.5.9 DURABILITY QosPolicy on page 410 and the Required Subscriptions feature complement each other.

The DurabilityQosPolicy determines whether or not *Connext DDS* will store and deliver previously acknowledged DDS samples to new *DataReaders* that join the network later. You can specify to either *not* make the DDS samples available (DDS_VOLATILE_DURABILITY_QOS kind), or to make them available and declare you are storing the DDS samples in memory (DDS_TRANSIENT_LOCAL_DURABILITY_QOS or DDS_TRANSIENT_DURABILITY_QOS kind) or in permanent storage (DDS_PERSISTENT_DURABILITY_QOS).

Required subscriptions help answer the question of *when* a DDS sample is considered acknowledged before the DurabilityQosPolicy determines whether to keep it. When required subscriptions are used, a DDS sample is considered acknowledged by a *DataWriter* when both the active *DataReaders* and a quorum of required subscriptions have acknowledged the DDS sample. (Acknowledging a DDS sample can be done either at the protocol or application level—see 7.3.12 Application Acknowledgment on page 316).

7.3.13.3 Required Subscriptions Configuration

Each *DataReader* can be configured to be part of a named subscription, by giving it a **role_name** using the 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416. A *DataWriter* can then be configured using the 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369 (**required_matched_endpoint_groups**) with a list of required named subscriptions identified by the **role_name**. Additionally, the *DataWriter* can be configured with a *quorum* or minimum number of *DataReaders* from a given named subscription that must receive a DDS sample.

When configured with a list of required subscriptions, a *DataWriter* will store a DDS sample until the DDS sample is acknowledged by all active reliable *DataReaders*, as well as all required subscriptions. When a quorum is specified, a minimum number of *DataReaders* of the required subscription must acknowledge a DDS sample in order for the DDS sample to be considered acknowledged. Specifying a quorum provides a level of redundancy in the system as multiple applications or services acknowledge they have received the DDS sample. Each individual *DataReader* is identified using its own virtual GUID (see 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565).

7.3.14 Managing Instances (Working with Keyed Data Types)

This section applies only to data types that use keys; see 2.4 DDS Samples, Instances, and Keys on page 18. Using the following operations for non-keyed types has no effect. This section describes how instances work on *DataWriters*. See also Chapter 6 Working with Instances on page 256.

Topics come in two flavors: those whose associated data type has specified some fields as defining the 'key,' and those whose associated data type has not. An example of a data-type that specifies key fields is shown in Figure 7.14: Data Type with a Key below.

Figure 7.14: Data Type with a Key

```
typedef struct Flight {
    @key long   flightId;
    string departureAirport;
    string arrivalAirport;
    Time_t departureTime;
    Time_t estimatedArrivalTime;
    Location_t currentPosition;
};
```

7.3.14.1 Writing Instances

If the data type has some fields that act as a 'key,' the *Topic* contains one or more instances whose values can be independently maintained. In Figure 7.14: Data Type with a Key on the previous page, the **flightId** is the 'key'. Different flights will have different values for the key. Each flight is an instance of the *Topic*. Each **write()** (or **write()** variation such as **write_w_timestamp()**) will update the information about a single flight—meaning that when a *DataWriter* calls **write()**, the *DataWriter* is updating the instance represented by the **flightId**.

When a *DataWriter* updates an instance by calling **write()**, a sample of that instance is sent to matching *DataReaders*, and the *DataReaders* consider the instance to be ALIVE.

If the *DataWriter's* 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 specifies a **max_instances** limit that is not infinite, the limit will apply when writing. If a *DataWriter* writes an instance that it has not written before, and it has already reached the **max_instances** limit, it will try to reclaim the memory used by an existing instance. The rules for which instances it can replace are described in 7.3.14.7 Instance Memory Management on page 329.

If the *DataWriter* cannot reclaim the memory used by an existing instance, the **write()** call will fail. For more information on the behavior of the **write()** call when the **max_instances** limit is hit, see 7.3.8.2 write() behavior with KEEP_LAST and KEEP_ALL on page 311.

7.3.14.2 Registering Instances

If your data type has a key, you may improve performance of any operation that modifies the instance, such as any variation of **write()** or **dispose()**, by providing a non-NIL instance handle. An instance handle contains the pre-calculated instance keyhash so that it does not need to be calculated again. The instance handle for an instance can be retrieved once the instance is registered.

A *DataWriter* can register and retrieve an instance handle for an instance in two ways:

- Explicitly, with the **register_instance()** operation. The **register_instance()** operation provides a handle to the instance (of type **DDS_InstanceHandle_t**) that can be used later to refer to the instance.
- Implicitly by providing a NIL instance handle to one of the variations of the **write()** or **dispose()** calls. After one of these calls has been made, the instance handle for the now-registered instance can be retrieved using the *DataWriter* **lookup_instance()** call.

Once you have an instance handle, you can use it while writing to avoid calculating the instance keyhash in every write call. This performance improvement may be significant if your data is relatively small or your key fields are relatively complex. (If your data itself is large or complex, the time to calculate the keyhash may be insignificant relative to the time to serialize your data.)

You can register any number of instances up to the maximum number of instances configured in the *DataWriter*'s 7.5.22 RESOURCE_LIMITS QosPolicy on page 449. Explicit instance registration is

completely optional. Note that registration through the **register_instance()** call only affects the *DataWriter*: matching *DataReaders* are not notified that the instance is **ALIVE** when the *DataWriter* registers the instance. An instance is only recognized as **ALIVE** when a *DataWriter* writes the instance. When an application registers instances and uses the instance handles for increased performance, it must keep a mapping between instance handles and instances. See the **Warning** below.

Figure 7.15: Explicitly Registering an Instance

```
Flight myFlight;
// writer is a previously-created FlightDataWriter
myFlight.flightId = 265;
DDS_InstanceHandle_t fl265Handle =
writer->register_instance(myFlight);
...
// Each time we update the flight, we can pass the handle
myFlight.departureAirport     = "SJC";
myFlight.arrivalAirport       = "LAX";
myFlight.departureTime        = {120000, 0};
myFlight.estimatedArrivalTime = {130200, 0};
myFlight.currentPosition      = { {37, 20}, {121, 53} };
if (writer->write(myFlight, fl265Handle) != DDS_RETCODE_OK) {
// ... handle error
}
// The writer can declare that it will no longer update information about
// this flight by unregistering itself from the instance

if (writer->unregister_instance(myFlight, fl265Handle) !=
DDS_RETCODE_OK) {
// ... handle error
}
```

Warning: If you decide to manage instance handles using your own application logic, make sure you keep a correct mapping between the instance and instance handle. If you pass the wrong instance handle when writing data, *Connext DDS* will assume that you are writing the instance associated with the handle. It does not check that the key fields match that handle, because that would negate the performance improvement from passing the handle. Passing the wrong instance handle can lead to strange behavior, because *Connext DDS* will treat your data sample as though it belongs to the wrong instance.

For example, if you have the History QosPolicy **kind** set to KEEP_LAST and **depth** set to 1 on the *DataReader*, *Connext DDS* should keep the last sample for each instance. But if you pass the wrong instance handle when writing, the *DataReader* will overwrite the wrong sample (in the wrong instance). As a result, a *DataReader* will not get updates for the instance it expects. An incorrect instance handle will affect all QoS policies that are applied per instance; see 6.3.1 QoS Policies that are Applied per Instance on page 265.

When you are done using an instance, you can unregister it. See 7.3.14.4 Unregistering Instances below.

7.3.14.3 Disposing Instances

The **dispose()** operation informs *DataReaders* that, as far as the *DataWriter* knows, the instance no longer exists and can be considered "not alive." When the **dispose()** operation is called, the instance state stored in the **DDS_SampleInfo** structure, accessed through *DataReaders*, will change to **NOT_ALIVE_DISPOSED** for that particular instance.

Often, systems use the **NOT_ALIVE_DISPOSED** state to indicate that some object is completely gone from the system. For example, in a flight tracking system, when a flight lands, a *DataWriter* may dispose of the instance corresponding to the flight. In that case, all *DataReaders* who are monitoring the flight will see the instance state change to **NOT_ALIVE_DISPOSED**, indicating that the flight has landed.

Note: If a *DataWriter* calls **dispose()**, it does not give up ownership of the instance (unlike when it calls **unregister_instance()**, in which case it is declaring that it will no longer have any updates for the instance and therefore does give up ownership of the instance to other *DataWriters* that may still be actively updating the instance).

Attention: Disposing does not free up memory by default. For instance, when the *DataWriter* calls **dispose()** to indicate that a flight has landed, it must keep the dispose message in its queue so all matching *DataReaders* get notified that the flight has landed (i.e., has been disposed). Also, in terms of memory management, *Connext DDS* may reclaim unregistered instances before disposed ones, or not reclaim disposed instances at all, depending on your QoS settings. See 7.3.14.7 Instance Memory Management on page 329.

See also:

- 7.5.31.1 Unregistering vs. Disposing on page 466
- 7.5.5.5 Propagating Serialized Keys with Disposed-Instance Notifications on page 396
- 7.5.31.2 Autodisposing Unregistered Instances on page 466

7.3.14.4 Unregistering Instances

The **unregister_instance()** operation informs *DataReaders* that the *DataWriter* is no longer updating the instance. When a *DataWriter* will no longer update an instance, you can unregister it. To unregister a *DataWriter* from an instance, use the *DataWriter*'s **unregister_instance()** operation. Unregistering tells *Connext DDS* that the *DataWriter* has no more information on this instance; thus, it does not intend to modify that instance anymore, allowing *Connext DDS* to recover any resources it allocated for the instance.

unregister_instance() should only be used on instances that have been previously registered. Instances can be registered explicitly with the **register_instance()** operation, or implicitly with any variation of the **write()** or **dispose()** operations. See Figure 7.15: Explicitly Registering an Instance on page 326.

Once all *DataWriters* have unregistered from an instance, the matched *DataReaders* will eventually get an indication that the instance no longer has any *DataWriters*. This is communicated to the subscribing

application by means of the **DDS_SampleInfo** that accompanies each DDS sample (see 8.4.6 The SampleInfo Structure on page 560). Once there are no *DataWriter*s for the instance, the *DataReader* will see the value of **DDS_InstanceStateKind** for that instance to be **NOT_ALIVE_NO_WRITERS**.

Note that *DataReaders* can't distinguish between a scenario where all *DataWriters* explicitly unregister from an instance and a scenario where all *DataWriters* have lost liveliness. For more information on *DataWriter* liveliness, see the 7.5.15 LIVELINESS QosPolicy on page 425.

The **unregister_instance()** operation may affect the ownership of the instance (see the 7.5.17 OWNERSHIP QosPolicy on page 432). If the **DataWriter** was the exclusive owner of the instance, then calling **unregister_instance()** relinquishes that ownership, and another *DataWriter* can become the exclusive owner of the instance. (In contrast, if a *DataWriter* calls **dispose()**, it does not give up ownership of the instance.)

The **unregister_instance()** operation indicates only that a particular *DataWriter* no longer has any information/data on an instance and thus no longer has anything to say about the instance. It does not indicate that anything about the instance itself has changed, such as its existence or the associated data. For example, a *DataWriter* that is tracking a flight may unregister from an instance when the flight goes out of range—this does not mean that the position of the flight has changed or that the flight has landed, just that the *DataWriter* no longer has any knowledge of the flight; other *DataWriters* may still update the flight's position.

The **autodispose_unregistered_instances** field in the 7.5.31 WRITER_DATA_LIFECYCLE QoS Policy on page 464 controls whether instances are automatically disposed of when they are unregistered. (By default, they are not. See 7.5.31.2 Autodisposing Unregistered Instances on page 466.) When this QoS is true and the *DataWriter* unregisters from an instance, two samples are sent to the *DataReader* to notify it that the instance is both unregistered and disposed. The rules about which instance memory can be reclaimed are documented in 7.3.14.7 Instance Memory Management on the next page.

The **unregister_instance()** operation adds one sample (or two) to the *DataWriter* queue, so the behavior of **unregister_instance()** with regards to KEEP_LAST and KEEP_ALL is the same as for the **write()** operation. See 7.3.8.2 write() behavior with KEEP_LAST and KEEP_ALL on page 311. (Two samples are added if **autodispose_unregistered_instances** is set to TRUE; *Connext DDS* makes a dispose and an unregister sample. See autodispose_unregistered_instances on page 465 in the 7.5.31 WRITER_DATA_LIFECYCLE QoS Policy on page 464.)

See also:

- 7.5.31.1 Unregistering vs. Disposing on page 466
- 7.5.31.2 Autodisposing Unregistered Instances on page 466

7.3.14.5 Looking up an Instance Handle

Some operations, such as **write()**, accept an **instance_handle** parameter. If you need to get such a handle, you can call the *FooDataWriter's* **lookup_instance()** operation, which takes an instance as a parameter

and returns a handle to that instance. This is useful only for keyed data types.

```
DDS_InstanceHandle_t lookup_instance (const Foo & key_holder)
```

The instance must have already been registered, written, or disposed. If the instance is not known to the *DataWriter*, this operation returns **DDS_HANDLE_NIL**.

7.3.14.6 Getting the Key Value for an Instance

Once you have an instance handle (using **register_instance()** or **lookup_instance()**), you can use the *DataWriter*'s **get_key_value()** operation to retrieve the value of the key of the corresponding instance. The key fields of the data structure passed into **get_key_value()** will be filled out with the original values used to generate the instance handle. The key fields are defined when the data type is defined (see 2.4 DDS Samples, Instances, and Keys on page 18).

Following our example in Figure 7.15: Explicitly Registering an Instance on page 326, **register_instance()** returns a **DDS_InstanceHandle_t** that can be used in the call to the **FlightDataWriter**'s **get_key_value()** operation. The value of the key is returned in a structure of type **Flight** with the **flightId** field filled in with the integer 265.

See also: 7.5.5.5 Propagating Serialized Keys with Disposed-Instance Notifications on page 396.

7.3.14.7 Instance Memory Management

In *Connext DDS*, memory is primarily pre-allocated when creating entities. When data is keyed, the memory associated with each instance used for storing instance-specific metadata is allocated when the *DataWriter* is created. Memory is not freed at runtime, unless you delete an entity. Instead, memory is made available to be reused by the *DataWriter*, or 'reclaimed'.

Instance memory in the *DataWriter* is reclaimed two ways:

- **Lazily (Default):** when a resource limit such as **max_instances** is hit. Only once this limit is hit will *Connext DDS* reclaim memory as described in the following sections.
- **Proactively (Non-Default):** after a time delay, configured by **autopurge_unregistered_instance_delay** or **autopurge_disposed_instances_delay**, as long as all samples of that instance are fully-acknowledged (see 7.3.8.2 write() behavior with KEEP_LAST and KEEP_ALL on page 311). In this case, the instance data is purged, freeing up memory for future use (i.e., for "reclaiming").

In the default case, *Connext DDS* has to decide which instances to replace first. This is controlled by the following QoS policies and settings.

7.3.14.7.1 WriterDataLifecycle: autopurge_unregistered_instances_delay

When **autopurge_unregistered_instances_delay** in the 7.5.31 WRITER_DATA_LIFECYCLE QoS Policy on page 464 is 0, *Connext DDS* will clean up all the resources associated with an unregistered instance (most notably, the DDS sample history of non-volatile *DataWriters*) when all the instance's

samples have been acknowledged by all its live *DataReaders*, including the sample that indicates the unregistration. By default, **autopurge_unregistered_instances_delay** is disabled (the delay is INFINITE). If the delay is set to zero, the *DataWriter* will clean up as soon as all the samples are acknowledged after the call to **unregister_instance()**. A non-zero value for the delay can be useful in two ways:

- To keep the historical DDS samples for late-joiners for a period of time.
- In the context of the builtin discovery *DataWriters*, if the applications temporarily lose the connection before the unregistration (which represents the remote entity destruction), to provide the DDS samples that indicate the dispose and unregister actions once the connection is reestablished.

This delay can also be set for discovery data through these fields in the 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639*:*

- **publication_writer_data_lifecycle.autopurge_unregistered_instances_delay**
- **subscription_writer_data_lifecycle.autopurge_unregistered_instances_delay**
- **publication_writer_data_lifecycle.autopurge_disposed_instances_delay**
- **subscription_writer_data_lifecycle.autopurge_disposed_instances_delay**

7.3.14.7.2 DataWriterResourceLimits: replace_empty_instances

The **replace_empty_instances** field in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400 defines whether instances with no samples in the *DataWriter* queue be replaced first, regardless of their instance state. If there are multiple empty instances, **replace_empty_instances** will replace unregistered instances, then disposed instances, then alive instances. If **replace_empty_instances** is true, empty instances will always be replaced first before any instance that may qualify for replacement based on the **instance_replacement** field in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400.

Values: true/false

7.3.14.7.3 DataWriterResourceLimits: instance_replacement

This **instance_replacement** field in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400 defines which instance states can be replaced, and the order in which they are allowed to be replaced. This setting takes effect if all samples for an instance are fully acknowledged.

Values:

- DDS_UNREGISTERED_INSTANCE_REPLACEMENT
- DDS_ALIVE_INSTANCE_REPLACEMENT
- DDS_DISPOSED_INSTANCE_REPLACEMENT

- DDS_ALIVE_THEN_DISPOSED_INSTANCE_REPLACEMENT
- DDS_DISPOSED_THEN_ALIVE_INSTANCE_REPLACEMENT
- DDS_ALIVE_OR_DISPOSED_INSTANCE_REPLACEMENT

Warning: Unregistered instances are always replaced first even if you don't choose DDS_UNREGISTERED_INSTANCE_REPLACEMENT. Because unregistering an instance indicates that the *DataWriter* will no longer update the instance, it is assumed that reclaiming these resources first will avoid information loss in your system.

When a *DataWriter* disposes an instance, it cannot replace the memory related to that instance unless **autopurge_disposed_instances_delay** is finite, the **instance_replacement** field in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400 indicates that disposed instances can be replaced when instance resource limits are reached, or the instance is empty and **replace_empty_instances** is true.

See also:

- 7.5.31.1 Unregistering vs. Disposing on page 466
- 7.5.31.2 Autodisposing Unregistered Instances on page 466

7.3.14.8 Consequences of Unpurged Dispose Messages

There are consequences of having many unpurged dispose messages in the *DataWriter's* queue. If the *DataWriter's* 7.5.9 DURABILITY QosPolicy on page 410 **kind** is not VOLATILE, those dispose messages will be delivered to late-joining *DataReaders*, which may cause an unexpected spike in network traffic. In addition, the *DataReaders* will not notify the application about those previously-disposed instances, because by default *DataReaders* will not propagate dispose messages for instances that were previously unknown. (This behavior can be changed by using the **propagate_dispose_of_unregistered_instances** QoS setting on the *DataReader*.)

Failing to purge disposed instances will cause similar behavior when using TopicQueries. When the *DataWriter* sends the response to the TopicQuery, it will include the unpurged dispose messages, causing high network traffic. In general, all dispose and unregister messages always pass filters (associated with ContentFilteredTopics, TopicQueries, or QueryConditions). This means that even if a TopicQuery's filter expression only specifies a specific key value or set of key values, all dispose messages for all instances in the *DataWriter* queue will be sent in response to the TopicQuery. To avoid this when using TopicQueries, use the special statement at the beginning of the query: "@instance_state = ALIVE AND" followed by the rest of the expression. This prevents the *DataWriter* from sending not-alive samples.

See also:

- 7.5.5.5 Propagating Serialized Keys with Disposed-Instance Notifications on page 396
- 7.5.31.2 Autodisposing Unregistered Instances on page 466

7.3.14.9 Consequences of DataWriters Reclaiming Disposed Instances

If your network is subject to disconnections, and disposed instances are purged, it's possible that a dispose message is not received by every *DataReader*, leading to *DataReaders* recognizing different instance states. This happens if your network disconnection is long enough for a reliable *DataReader* to be marked as inactive and the disposed instance is purged during the disconnection. If the disposed message is not purged during the disconnection, it is still possible for the dispose message to be delivered after reconnection if the 7.5.9 DURABILITY QosPolicy on page 410 is not VOLATILE.

If you have one or more *RTI Routing Service* applications in your network, leading to multiple places where instance state gets cached and might be reclaimed, it is even more likely that a dispose message might not be received by every *DataReader*.

7.3.15 Setting DataWriter QosPolicies

The *DataWriter*'s QosPolicies control its resources and behavior.

The **DDS_DataWriterQos** structure has the following format:

```
DDS_DataWriterQos struct  {
        DDS_DurabilityQosPolicy                 durability;
        DDS_DurabilityServiceQosPolicy          durability_service;
        DDS_DeadlineQosPolicy                   deadline;
        DDS_LatencyBudgetQosPolicy              latency_budget;
        DDS_LivelinessQosPolicy                 liveliness;
        DDS_ReliabilityQosPolicy                reliability;
        DDS_DestinationOrderQosPolicy           destination_order;
        DDS_HistoryQosPolicy                    history;
        DDS_ResourceLimitsQosPolicy             resource_limits;
        DDS_TransportPriorityQosPolicy          transport_priority;
        DDS_LifespanQosPolicy                   lifespan;
        DDS_UserDataQosPolicy                   user_data;
        DDS_OwnershipQosPolicy                  ownership;
        DDS_OwnershipStrengthQosPolicy          ownership_strength;
        DDS_WriterDataLifecycleQosPolicy        writer_data_lifecycle;
        DDS_DataRepresentationQosPolicy         representation;
        DDS_DataTagQosPolicy                    data_tags;
       // extensions to the DDS standard:
        DDS_DataWriterResourceLimitsQosPolicy   writer_resource_limits;
        DDS_DataWriterProtocolQosPolicy         protocol;
        DDS_TransportSelectionQosPolicy         transport_selection;
        DDS_TransportUnicastQosPolicy           unicast;
        DDS_PublishModeQosPolicy                publish_mode;
        DDS_PropertyQosPolicy                   property;
        DDS_ServiceQosPolicy                    service;
```

```
        DDS_BatchQosPolicy                      batch;
        DDS_MultiChannelQosPolicy               multi_channel;
        DDS_AvailabilityQosPolicy               availability;
        DDS_EntityNameQosPolicy                 publication_name;
        DDS_TopicQueryDispatchQosPolicy         topic_query_dispatch;
        DDS_DataWriterTransferModeQosPolicy     transfer_mode;
        DDS_TypeSupportQosPolicy                type_support;
} DDS_DataWriterQos;
```

Note: set_qos() cannot always be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

Table 7.18 DataWriter QosPolicies summarizes the meaning of each policy. (They appear alphabetically in the table.) For information on *why* you would want to change a particular QosPolicy, see the referenced section. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 7.18 DataWriter QosPolicies

QosPolicy	Description
Availability	This QoS policy is used in the context of two features: 7.5.1.1 Availability QoS Policy and Collaborative DataWriters on page 370 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369 For Collaborative DataWriters, Availability specifies the group of *DataWriters* expected to collaboratively provide data and the timeouts that control when to allow data to be available that may skip DDS samples. For Required Subscriptions, Availability configures a set of Required Subscriptions on a *DataWriter*. See 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369
Batch	Specifies and configures the mechanism that allows *Connext DDS* to collect multiple DDS user data samples to be sent in a single network packet, to take advantage of the efficiency of sending larger packets and thus increase effective throughput. See 7.5.2 BATCH QosPolicy (DDS Extension) on page 373.
DataRepresentation	Specifies which version of the Extended Common Data Representation (CDR) is offered. See 7.5.3 DATA_REPRESENTATION QosPolicy on page 379.
DataTag	A sequence of (name, value) string pairs that may be used by the Access Control plugin. See 7.5.4 DATATAG QosPolicy on page 386.
DataWriterProtocol	This QosPolicy configures the *Connext DDS* on-the-network protocol, RTPS. See 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.
DataWriterResourceLimits	Controls how many threads can concurrently block on a write() call of this *DataWriter*. See 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400.
Deadline	For a *DataReader*, it specifies the maximum expected elapsed time between arriving DDS data samples. For a *DataWriter*, it specifies a commitment to publish DDS samples with no greater elapsed time between them. See 7.5.7 DEADLINE QosPolicy on page 404.
DestinationOrder	Controls how *Connext DDS* will deal with data sent by multiple *DataWriters* for the same topic. Can be set to "by reception timestamp" or to "by source timestamp". See 7.5.8 DESTINATION_ORDER QosPolicy on page 406.

Table 7.18 DataWriter QosPolicies

QosPolicy	Description
Durability	Specifies whether or not *Connext DDS* will store and deliver data that were previously published to new *DataReaders*. See 7.5.9 DURABILITY QosPolicy on page 410.
DurabilityService	Various settings to configure the external *Persistence Service* used by *Connext DDS* for *DataWriters* with a Durability QoS setting of Persistent Durability. See 7.5.10 DURABILITY SERVICE QosPolicy on page 414.
EntityName	Assigns a name to a *DataWriter*. See 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416.
History	Specifies how much data must to stored by *Connext DDS* for the *DataWriter* or *DataReader*. This QosPolicy affects the 7.5.21 RELIABILITY QosPolicy on page 444 as well as the 7.5.9 DURABILITY QosPolicy on page 410. See 7.5.12 HISTORY QosPolicy on page 418.
LatencyBudget	Suggestion to *Connext DDS* on how much time is allowed to deliver data. See 7.5.13 LATENCYBUDGET QoS Policy on page 423.
Lifespan	Specifies how long *Connext DDS* should consider data sent by an user application to be valid. See 7.5.14 LIFESPAN QoS Policy on page 423.
Liveliness	Specifies and configures the mechanism that allows *DataReaders* to detect when *DataWriters* become disconnected or "dead." See 7.5.15 LIVELINESS QosPolicy on page 425.
MultiChannel	Configures a *DataWriter's* ability to send data on different multicast groups (addresses) based on the value of the data. See 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429.
Ownership	Along with OwnershipStrength, specifies if *DataReaders* for a topic can receive data from multiple *DataWriters* at the same time. See 7.5.17 OWNERSHIP QosPolicy on page 432.
OwnershipStrength	Used to arbitrate among multiple *DataWriters* of the same instance of a Topic when Ownership QosPolicy is EXCLUSIVE. See 7.5.18 OWNERSHIP_STRENGTH QosPolicy on page 435.
Partition	Adds string identifiers that are used for matching *DataReaders* and *DataWriters* for the same *Topic*. See 7.4.5 PARTITION QosPolicy on page 355.
Property	Stores name/value (string) pairs that can be used to configure certain parameters of *Connext DDS* that are not exposed through formal QoS policies. It can also be used to store and propagate application-specific name/value pairs, which can be retrieved by user code during discovery. See 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.
PublishMode	Specifies how *Connext DDS* sends application data on the network. By default, data is sent in the user thread that calls the *DataWriter*'s **write()** operation. However, this QosPolicy can be used to tell *Connext DDS* to use its own thread to send the data. See 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441.
Reliability	Specifies whether or not *Connext DDS* will deliver data reliably. See 7.5.21 RELIABILITY QosPolicy on page 444.
ResourceLimits	Controls the amount of physical memory allocated for *Entities*, if dynamic allocations are allowed, and how they occur. Also controls memory usage among different instance values for keyed topics. See 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.
Service	Intended for use by RTI infrastructure services. User applications should not modify its value. See 7.5.23 SERVICE QosPolicy (DDS Extension) on page 452.

Table 7.18 DataWriter QosPolicies

QosPolicy	Description
TopicQueryDispatch	Configures the ability of a *DataWriter* to publish samples in response to a TopicQuery. See 7.5.24 TOPIC_QUERY_DISPATCH_QosPolicy (DDS Extension) on page 453.
TransferMode	Configures the properties of a Zero Copy *DataWriter*. See 7.5.25 TRANSFER_MODE QosPolicy on page 454.
TransportPriority	Set by a *DataWriter* to tell *Connext DDS* that the data being sent is a different "priority" than other data. See 7.5.26 TRANSPORT_PRIORITY QosPolicy on page 455.
TransportSelection	Allows you to select which physical transports a *DataWriter* or *DataReader* may use to send or receive its data. See 7.5.27 TRANSPORT_SELECTION QosPolicy (DDS Extension) on page 456.
TransportUnicast	Specifies a subset of transports and port number that can be used by an Entity to receive data. See 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458.
TypeSupport	Used to attach application-specific value(s) to a *DataWriter* or *DataReader*. These values are passed to the serialization or deserialization routine of the associated data type. Also controls whether padding bytes are set to 0 during serialization. See 7.5.29 TYPESUPPORT QosPolicy (DDS Extension) on page 461.
UserData	Along with Topic Data QosPolicy and Group Data QosPolicy, used to attach a buffer of bytes to *Connext DDS*'s discovery meta-data. See 7.5.30 USER_DATA QosPolicy on page 462.
WriterDataLifeCycle	Controls how a *DataWriter* handles the lifecycle of the instances (keys) that the *DataWriter* is registered to manage. See *7.5.31 WRITER_DATA_LIFECYCLE QoS Policy on page 464*.

Many of the *DataWriter* QosPolicies also apply to *DataReaders* (see 8.3 DataReaders on page 501). For a *DataWriter* to communicate with a *DataReader*, their QosPolicies must be compatible. Generally, for the QosPolicies that apply both to the *DataWriter* and the *DataReader*, the setting in the *DataWriter* is considered an "offer" and the setting in the *DataReader* is a "request." Compatibility means that what is offered by the *DataWriter* equals or surpasses what is requested by the *DataReader*. Each policy's description includes compatibility restrictions. For more information on compatibility, see 4.2.1 QoS Requested vs. Offered Compatibility—the RxO Property on page 180.

Some of the policies may be changed after the *DataWriter* has been created. This allows the application to modify the behavior of the *DataWriter* while it is in use. To modify the QoS of an already-created *DataWriter*, use the **get_qos()** and **set_qos()** operations on the *DataWriter*. This is a general pattern for all *Entities*, described in 4.1.7.3 Changing the QoS for an Existing Entity on page 175.

7.3.15.1 Configuring QoS Settings when the DataWriter is Created

As described in 7.3.1 Creating DataWriters on page 291, there are different ways to create a *DataWriter, depending on how you want to specify its QoS (with or without a QoS Profile).*

- In Figure 7.9: Creating a DataWriter with Default QosPolicies and a Listener on page 292, there is an example of how to create a *DataWriter* with default QosPolicies by using the special constant, **DDS_DATAWRITER_QOS_DEFAULT**, which indicates that the default QoS values for a

DataWriter should be used. The default *DataWriter* QoS values are configured in the *Publisher* or *DomainParticipant*; you can change them with **set_default_datawriter_qos()** or **set_default_datawriter_qos_with_profile()**. Then any *DataWriters* created with the *Publisher* will use the new default values. As described in 4.1.7 Getting, Setting, and Comparing QosPolicies on page 172, this is a general pattern that applies to the construction of all *Entities*.

- *To create a DataWriter with non-default QoS without using a QoS Profile,* see the example code in Figure 7.16: Creating a DataWriter with Modified QosPolicies (not from a profile) below. It uses the *Publisher's* **get_default_writer_qos()** method to initialize a **DDS_DataWriterQos** structure. Then the policies are modified from their default values before the structure is used in the **create_datawriter()** method.
- You can also create a *DataWriter* and specify its QoS settings via a QoS Profile. To do so, you will call **create_datawriter_with_profile()**, as seen in Figure 7.17: Creating a DataWriter with a QoS Profile on the next page.
- If you want to use a QoS profile, but then make some changes to the QoS before creating the *DataWriter*, call **get_datawriter_qos_from_profile()** and **create_datawriter()** as seen in Figure 7.18: Getting QoS Values from a Profile, Changing QoS Values, Creating a DataWriter with Modified QoS Values on the next page.

For more information, see 7.3.1 Creating DataWriters on page 291 and Configuring QoS with XML (Chapter 19 on page 842).

Notes:

- The examples in this section use the Traditional C++ API; for examples in the Modern C++ API, see the sections "DataWriter Use Cases," "Qos Use Cases," and "Qos Provider Use Cases" in the API Reference HTML documentation, under "Programming How-To's."
- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 7.16: Creating a DataWriter with Modified QosPolicies (not from a profile)

```
DDS_DataWriterQos writer_qos;
// initialize writer_qos with default values
publisher->get_default_datawriter_qos(writer_qos);
// make QoS changes
writer_qos.history.depth = 5;
// Create the writer with modified qos
DDSDataWriter * writer = publisher->create_datawriter(
    topic, writer_qos, NULL, DDS_STATUS_MASK_NONE);
if (writer == NULL) {
    // ... error
}
// narrow it for your specific data type
FooDataWriter* foo_writer = FooDataWriter::narrow(writer);
```

Figure 7.17: Creating a DataWriter with a QoS Profile

```
// Create the datawriter
DDSDataWriter * writer =
    publisher->create_datawriter_with_profile(
        topic, "MyWriterLibrary", "MyWriterProfile",
        NULL, DDS_STATUS_MASK_NONE);
if (writer == NULL) {
    // ... error
};
// narrow it for your specific data type
FooDataWriter* foo_writer = FooDataWriter::narrow(writer);
```

Figure 7.18: Getting QoS Values from a Profile, Changing QoS Values, Creating a DataWriter with Modified QoS Values

```
DDS_DataWriterQos writer_qos;
// Get writer QoS from profile
retcode = factory->get_datawriter_qos_from_profile(
    writer_qos, "WriterProfileLibrary", "WriterProfile");
if (retcode != DDS_RETCODE_OK) {
    // handle error
}
// Makes QoS changes
writer_qos.history.depth = 5;
DDSDataWriter * writer = publisher->create_datawriter(
    topic, writer_qos, NULL, DDS_STATUS_MASK_NONE);
if (participant == NULL) {
    // handle error
}
```

7.3.15.2 Comparing QoS Values

The **equals()** operation compares two *DataWriter's* DDS_DataWriterQoS structures for equality. It takes two parameters for the two *DataWriter's* QoS structures to be compared, then returns TRUE is they are equal (all values are the same) or FALSE if they are not equal.

7.3.15.3 Changing QoS Settings After the DataWriter Has Been Created

There are two ways to change an existing *DataWriter's* QoS after it is has been created—again depending on whether or not you are using a QoS Profile.

- To change QoS programmatically (that is, without using a QoS Profile), use **get_qos()** and **set_qos()**. See the example code in Figure 7.19: Changing the QoS of an Existing DataWriter (without a QoS Profile) below. It retrieves the current values by calling the *DataWriter's* **get_qos()** operation. Then it modifies the value and calls **set_qos()** to apply the new value. Note, however, that some QosPolicies cannot be changed after the *DataWriter* has been enabled—this restriction is noted in the descriptions of the individual QosPolicies.

- You can also change a *DataWriter's* (and all other *Entities*') QoS by using a QoS Profile and calling **set_qos_with_profile()**. For an example, see Figure 7.20: Changing the QoS of an Existing DataWriter with a QoS Profile below. For more information, see Configuring QoS with XML (Chapter 19 on page 842).

Figure 7.19: Changing the QoS of an Existing DataWriter (without a QoS Profile)

```
DDS_DataWriterQos writer_qos;
// Get current QoS.
if (datawriter->get_qos(writer_qos) != DDS_RETCODE_OK) {
    // handle error
}
// Makes QoS changes here
writer_qos.history.depth = 5;
// Set the new QoS
if (datawriter->set_qos(writer_qos) != DDS_RETCODE_OK ) {
    // handle error
}
```

Note:

- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 7.20: Changing the QoS of an Existing DataWriter with a QoS Profile

```
retcode = writer->set_qos_with_profile(
    "WriterProfileLibrary","WriterProfile");
if (retcode != DDS_RETCODE_OK) {
    // handle error
}
```

7.3.15.4 Using a Topic's QoS to Initialize a DataWriter's QoS

Several *DataWriter* QosPolicies can also be found in the QosPolicies for *Topics* (see 5.1.3 Setting Topic QosPolicies on page 219). The QosPolicies set in the Topic do not directly affect the *DataWriters* (or *DataReaders*) that use that *Topic*. In many ways, some QosPolicies are a *Topic*-level concept, even though the DDS standard allows you to set different values for those policies for different *DataWriters* and *DataReaders* of the same *Topic*. Thus, the policies in the **DDS_TopicQos** structure exist as a way to help centralize and annotate the intended or suggested values of those QosPolicies. *Connext DDS* does not check to see if the actual policies set for a *DataWriter* is aligned with those set in the *Topic* to which it is bound.

There are many ways to use the QosPolicies' values set in the *Topic* when setting the QosPolicies' values in a *DataWriter*. The most straightforward way is to get the values of policies directly from the *Topic* and use them in the policies for the *DataWriter*, as shown in Figure 7.21: Copying Selected QoS from a Topic when Creating a DataWriter below.

Figure 7.21: Copying Selected QoS from a Topic when Creating a DataWriter

```
DDS_DataWriterQos writer_qos;
DDS_TopicQos topic_qos;
// topic and publisher already created
// get current QoS for the topic, default QoS for the writer
if (topic->get_qos(topic_qos) != DDS_RETCODE_OK) {
    // handle error
}
if (publisher->get_default_datawriter_qos(writer_qos)
    != DDS_RETCODE_OK) {
    // handle error
}
// Copy specific policies from topic QoS to writer QoS
writer_qos.deadline = topic_qos.deadline;
writer_qos.reliability = topic_qos.reliability;
// Create the DataWriter with the modified QoS
DDSDataWriter* writer = publisher->create_datawriter(topic,
   writer_qos,NULL, DDS_STATUS_MASK_NONE);
```

Note:

- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

You can use the *Publisher*'s **copy_from_topic_qos()** operation to copy all of the common policies from the *Topic* QoS to a *DataWriter* QoS. This is illustrated in Figure 7.22: Copying all QoS from a Topic when Creating a DataWriter below.

Figure 7.22: Copying all QoS from a Topic when Creating a DataWriter

```
DDS_DataWriterQos writer_qos;
DDS_TopicQos topic_qos;
// topic, publisher, writer_listener already created
if (topic->get_qos(topic_qos) != DDS_RETCODE_OK) {
// handle error
}
if (publisher->get_default_datawriter_qos(writer_qos)
    != DDS_RETCODE_OK)
{
    // handle error
}
// copy relevant QoS from topic into writer's qos
publisher->copy_from_topic_qos(writer_qos, topic_qos);
// Optionally, modify policies as desired
writer_qos.deadline.duration.sec = 1;
writer_qos.deadline.duration.nanosec = 0;
// Create the DataWriter with the modified QoS
DDSDataWriter* writer = publisher->create_datawriter(topic,
    writer_qos, writer_listener, DDS_STATUS_MASK_ALL);
```

In another design pattern, you may want to start with the default QoS values for a *DataWriter* and override them with the QoS values of the *Topic*. Figure 7.23: Combining Default Topic and DataWriter QoS (Option 1) below gives an example of how to do this.

Because this is a common pattern, *Connext DDS* provides a special macro, **DDS_DATAWRITER_QOS_USE_TOPIC_QOS**, that can be used to indicate that the *DataWriter* should be created with the set of QoS values that results from modifying the default *DataWriter* QosPolicies with the QoS values specified by the *Topic*. Figure 7.24: Combining Default Topic and DataWriter QoS (Option 2) on the next page shows how the macro is used.

The code fragments shown in Figure 7.23: Combining Default Topic and DataWriter QoS (Option 1) below and Figure 7.24: Combining Default Topic and DataWriter QoS (Option 2) on the next page result in identical QoS settings for the created *DataWriter*.

Note:

- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 7.23: Combining Default Topic and DataWriter QoS (Option 1)

```
DDS_DataWriterQos writer_qos;
DDS_TopicQos topic_qos;
// topic, publisher, writer_listener already created
if (topic->get_qos(topic_qos) != DDS_RETCODE_OK) {
// handle error
}
if (publisher->get_default_datawriter_qos(writer_qos)
    != DDS_RETCODE_OK) {
// handle error
}
if (publisher->copy_from_topic_qos(writer_qos, topic_qos)
    != DDS_RETCODE_OK) {
// handle error
}
// Create the DataWriter with the combined QoS
DDSDataWriter* writer =
    publisher->create_datawriter(topic, writer_qos,
    writer_listener,DDS_STATUS_MASK_ALL);
```

Figure 7.24: Combining Default Topic and DataWriter QoS (Option 2)

```
// topic, publisher, writer_listener already created
DDSDataWriter* writer = publisher->create_datawriter (topic,
DDS_DATAWRITER_QOS_USE_TOPIC_QOS,
writer_listener, DDS_STATUS_MASK_ALL);
```

For more information on the general use and manipulation of QosPolicies, see 4.1.7 Getting, Setting, and Comparing QosPolicies on page 172.

7.3.16 Navigating Relationships Among DDS Entities

7.3.16.1 Finding Matching Subscriptions

The following *DataWriter* operations can be used to get information on the *DataReaders* that are currently associated with the *DataWriter* (that is, the *DataReaders* to which *Connext DDS* will send the data written by the *DataWriter*). A subscription consists of information about the *DataReader* and its associated *Subscriber* and *Topic*.

- **get_matched_subscriptions()**
- **get_matched_subscription_data()**
- **get_matched_subscription_locators()**

get_matched_subscriptions() will return a sequence of handles to matched *DataReaders*. You can use these handles in the **get_matched_subscription_data()** method to get information about the *DataReader* such as the values of its QosPolicies, as well as information about its *Subscriber* and *Topic*.

get_matched_subscription_locators() retrieves a list of locators for subscriptions currently "associated" with the *DataWriter*. Matched subscription locators include locators for all those subscriptions in the same DDS domain that have a matching Topic, compatible QoS, and a common partition that the *DomainParticipant* has not indicated should be "ignored." These are the locators that *Connext DDS* uses to communicate with matching *DataReaders*. (See 15.2.1.1 Locator Format on page 763.)

Note: In the Modern C++ API, these operations are freestanding functions in the dds::pub or rti::pub namespaces.

You can also get the DATA_WRITER_PROTOCOL_STATUS for matching subscriptions with these operations (see 7.3.6.3 DATA_WRITER_PROTOCOL_STATUS on page 297):

- **get_matched_subscription_datawriter_protocol_status()**
- **get_matched_subscription_datawriter_protocol_status_by_locator()**

Notes:

- The **get_matched_subscriptions()** function includes the return of handles of matched *DataReaders* that are no longer active. All of the handles returned by this function are valid inputs to the **get_matched_subscription_data()** function.
- Status/data for a matched subscription is kept even if the matched *DataReader* is not active. Status/data for a matched subscription will be removed only if the *DataReader* is gone: that is, the *DataReader* is destroyed and this change is propagated through a discovery update, or the *DataReader's DomainParticipant* is gone (either gracefully or its liveliness expired and *Connext DDS* is configured to purge not-alive participants). Once a matched *DataReader* is gone, its status is

deleted. If you try to get the status/data for a matched *DataReader* that is gone, the 'get status' or ' get data' call will return an error.

- If you want to know which matched *DataReaders* are not active, use **is_matched_subscription_active()**. See Table 7.3 DataWriter Operations on page 287.
- *DataReaders* that have been ignored using the *DomainParticipant's* **ignore_subscription()** operation are not considered to be matched even if the *DataReader* has the same *Topic* and compatible QosPolicies. Thus, they will not be included in the list of *DataReaders* returned by **get_matched_subscriptions()** or **get_matched_subscription_locators()**. See 18.4.2 Ignoring Publications and Subscriptions on page 837 for more on **ignore_subscription()**.
- The **get_matched_subscription_data()** operation does not retrieve the **type_code** information from built-in-topic data structures. This information is available through the **on_data_available()** callback (if a DataReaderListener is installed on the SubscriptionBuiltinTopicDataDataReader).

See also: 7.3.16.2 Finding the Matching Subscription's ParticipantBuiltinTopicData below

7.3.16.2 Finding the Matching Subscription's ParticipantBuiltinTopicData

get_matched_subscription_participant_data() allows you to get the DDS_ParticipantBuiltinTopicData (see Table 18.1 Participant Built-in Topic's Data Type (DDS_ParticipantBuiltinTopicData)) of a matched subscription using a subscription handle.

This operation retrieves the information on a discovered *DomainParticipant* associated with the subscription that is currently matching with the *DataWriter*.The subscription handle passed into this operation must correspond to a subscription currently associated with the *DataWriter*. Otherwise, the operation will fail with RETCODE_BAD_PARAMETER. The operation may also fail with RETCODE_PRECONDITION_NOT_MET if the subscription corresponds to the same *DomainParticipant* to which the *DataWriter* belongs.

Use **get_matched_subscriptions()** (see 7.3.16.1 Finding Matching Subscriptions on the previous page) to find the subscriptions that are currently matched with the *DataWriter*.

7.3.16.3 Finding Related DDS Entities

These operations are useful for obtaining a handle to various related *Entities*:

- **get_publisher()**
- **get_topic()**

get_publisher() returns the *Publisher* that created the *DataWriter*. **get_topic()** returns the *Topic* with which the *DataWriter* is associated.

7.3.17 Asserting Liveliness

The **assert_liveliness()** operation can be used to manually assert the liveliness of the *DataWriter* without writing data. This operation is only useful if the kind of 7.5.15 LIVELINESS QosPolicy on page 425 is **MANUAL_BY_PARTICIPANT** or **MANUAL_BY_TOPIC**.

How *DataReaders* determine if *DataWriters* are alive is configured using the 7.5.15 LIVELINESS QosPolicy on page 425. The **lease_duration** parameter of the LIVELINESS QosPolicy is a contract by the *DataWriter* to all of its matched *DataReaders* that it will send a packet within the time value of the **lease_duration** to state that it is still alive.

There are three ways to assert liveliness. One is to have *Connext DDS* itself send liveliness packets periodically when the kind of LIVELINESS QosPolicy is set to **AUTOMATIC**. The other two ways to assert liveliness, used when liveliness is set to **MANUAL**, are to call **write()** to send data or to call the **assert_liveliness()** operation without sending data.

7.3.18 Turbo Mode and Automatic Throttling for DataWriter Performance—Experimental Features

This section describes two experimental features. The *DataWriter* has many QoS settings that can affect the latency and throughput of outgoing data. There are QoS settings to control send window size (see 11.3.2.1 Understanding the Send Queue and Setting its Size on page 691) and settings that allow to aggregate multiple DDS samples together to reduce CPU and bandwidth utilization (see 7.5.2 BATCH QosPolicy (DDS Extension) on page 373 and 7.6 FlowControllers (DDS Extension) on page 467). The choice of settings that provide the best performance depends on several factors, such as the frequency of writing data, the size of the data, or the condition of the network. If these factors do not change over time, you can choose values for those QoS settings that best suit your system. If these factors do change over time in your system, you can use the following properties to let *Connext DDS* automatically adjust the QoS settings as system conditions change:

- **dds.domain_participant.auto_throttle.enable**: Configures the *DomainParticipant* to gather internal measurements (during *DomainParticipant* creation) that are required for the Auto Throttle feature. This allows *DataWriters* belonging to this *DomainParticipant* to use the Auto Throttle feature. Default: false.
- **dds.data_writer.auto_throttle.enable**: Enables automatic throttling in the *DataWriter* so it can automatically adjust the writing rate and the send window size; this minimizes the need for repair DDS samples and improves latency. Default: false. For additional information on automatic throttling, see 7.5.2.4 Turbo Mode: Automatically Adjusting the Number of Bytes in a Batch—Experimental Feature on page 376.

  Note: This property takes effect only in *DataWriters* that belong to a *DomainParticipant* that has set the property **dds.domain_participant.auto_throttle.enable** (described above) to true.

- **dds.data_writer.enable_turbo_mode**: Enables Turbo Mode and adjusts the batch max_data_bytes on page 373 (see 7.5.2 BATCH QosPolicy (DDS Extension) on page 373) based on how frequently the *DataWriter* writes data. Default: false. For additional information, see 7.5.2.4 Turbo Mode: Automatically Adjusting the Number of Bytes in a Batch—Experimental Feature on page 376.

The Built-in QoS profile **BuiltinQosLibExp::Generic.AutoTuning** enables both Turbo Mode and Auto Throttling.

7.4 Publisher/Subscriber QosPolicies

This section provides detailed information on the QosPolicies associated with a *Publisher*. Note that *Subscribers* have the exact same set of policies. Table 7.2 Publisher QosPolicies provides a quick reference. They are presented here in alphabetical order.

- 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) below
- 7.4.2 ENTITYFACTORY QosPolicy on page 347
- 7.4.3 EXCLUSIVE_AREA QosPolicy (DDS Extension) on page 350
- 7.4.4 GROUP_DATA QosPolicy on page 352
- 7.4.5 PARTITION QosPolicy on page 355
- 7.4.6 PRESENTATION QosPolicy on page 361

7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension)

This QosPolicy is used to enable or disable asynchronous publishing, asynchronous batch flushing, and TopicQuery publishing for the *Publisher*.

For each of these features enabled, the *Publisher* will spawn a thread. There is a thread for asynchronous publishing, a thread for asynchronous batch flushing, and a thread for TopicQuery publication.

The asynchronous publisher thread will be shared by all *DataWriters* (belonging to this *Publisher*) that have their 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441 **kind** set to ASYNCHRONOUS. The asynchronous publishing thread will then handle the data transmission chores for those *DataWriters*. This thread will only be spawned when the first of these *DataWriters* is enabled.

The asynchronous publisher thread can be used to reduce amount of time spent in the user thread to send data. You can use it to send large data reliably. Large in this context means that the data cannot be sent as a single packet by a transport. For example, to send data larger than 63K reliably using UDP/IP, you must configure *Connext DDS* to send the data using asynchronous *Publishers*.

The asynchronous batch flushing thread will be shared by all *DataWriters* (belonging to this *Publisher*) that have batching enabled and **max_flush_delay** different than DURATION_INFINITE in 7.5.2

BATCH QosPolicy (DDS Extension) on page 373. This thread will only be spawned when the first of these *DataWriters* is enabled.

The TopicQuery publication thread will be shared by all *DataWriters* (belonging to this Publisher) that have topic query dispatch enabled in 7.5.24 TOPIC_QUERY_DISPATCH_QosPolicy (DDS Extension) on page 453. This thread will only be spawned when the first of these *DataWriters* is enabled.

This QosPolicy allows you to adjust the asynchronous publishing, the asynchronous batch flushing threads, and the TopicQuery publication threads independently.

Batching and asynchronous publication are independent of one another. Flushing a batch on an asynchronous *DataWriter* makes it available for sending to the *DataWriter's* 7.6 FlowControllers (DDS Extension) on page 467. From the point of view of the FlowController, a batch is treated like one large DDS sample.

Connext DDS will sometimes coalesce multiple DDS samples into a single network datagram. For example, DDS samples buffered by a FlowController or sent in response to a negative acknowledgement (NACK) may be coalesced. This behavior is distinct from DDS sample batching. DDS data samples sent by different asynchronous *DataWriters* belonging to the same *Publisher* to the same destination will not be coalesced into a single network packet. Instead, two separate network packets will be sent. Only DDS samples written by the *same DataWriter* and intended for the *same destination* will be coalesced.

This QosPolicy includes the members in Table 7.19 DDS_AsynchronousPublisherQosPolicy.

Table 7.19 DDS_AsynchronousPublisherQosPolicy

Type	Field Name	Description
DDS_Boolean	disable_asynchronous_write	Disables asynchronous publishing. To write asynchronously, this field must be FALSE (the default).
DDS_ThreadSettings_t	thread	Settings for the publishing thread. These settings are OS-dependent (see the RTI Connext DDS Core Libraries Platform Notes).
DDS_Boolean	disable_asynchronous_batch	Disables asynchronous batch flushing. To flush asynchronously, this field must be FALSE (the default).
DDS_ThreadSettings_t	asynchronous_batch_thread	Settings for the asynchronous batch flushing thread. These settings are OS-dependent (see the RTI Connext DDS Core Libraries Platform Notes).
DDS_Boolean	disable_topic_query_publication	Disables TopicQuery publication. To allow publishing TopicQueries responses, this field must be FALSE (the default).
DDS_ThreadSettings_t	topic_query_publication_thread	Settings for the TopicQuery publication thread. These settings are OS-dependent (see the RTI Connext DDS Core Libraries Platform Notes).

7.4.1.1 Properties

This QosPolicy cannot be modified after the *Publisher* is created.

Since it is only for *Publishers*, there are no compatibility restrictions for how it is set on the publishing and subscribing sides.

7.4.1.2 Related PropertyQos Policies

- **dds.domain_participant.asynchronous_publisher_thread_destruction_timeout:** Maximum time in seconds the *DomainParticipant* will wait for the destruction of an asynchronous publisher thread. If this timeout expires before the asynchronous publisher thread is destroyed, the *DomainParticipant* cannot safely release the thread's resources, and it will skip their release. Default: 10 (seconds). Valid values: 1-60 (seconds).

7.4.1.3 Related QosPolicies

- If **disable_asynchronous_write** is TRUE (not the default), then any *DataWriters* created from this *Publisher* must have their 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441 **kind** set to SYNCHRONOUS. (Otherwise **create_datawriter()** will return INCONSISTENT_QOS.)
- If **disable_asynchronous_batch** is TRUE (not the default), then any *DataWriters* created from this *Publisher* must have **max_flush_delay** in 7.5.2 BATCH QosPolicy (DDS Extension) on page 373 set to DURATION_INFINITE. (Otherwise **create_datawriter()** will return INCONSISTENT_QOS.)
- *DataWriters* configured to use the 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429 do not support asynchronous publishing; an error is returned if a multi-channel *DataWriter* is configured for asynchronous publishing.
- If **disable_topic_query_publication** is TRUE (not the default), then any *DataWriters* created from this *Publisher* must have **enable** in 7.5.24 TOPIC_QUERY_DISPATCH_QosPolicy (DDS Extension) on page 453) to TRUE. (Otherwise **create_datawriter()** will return INCONSISTENT_QOS.)

7.4.1.4 Applicable DDS Entities

7.2 Publishers on page 270

7.4.1.5 System Resource Considerations

Three threads can potentially be created:

- For asynchronous publishing, system resource usage depends on the activity of the asynchronous thread controlled by the FlowController (see 7.6 FlowControllers (DDS Extension) on page 467).
- For asynchronous batch flushing, system resource usage depends on the activity of the asynchronous thread controlled by **max_flush_delay** in 7.5.2 BATCH QosPolicy (DDS Extension) on page 373.

- For TopicQuery publication, system resource usage depends on the activity of the TopicQuery publication thread controlled by 7.5.24 TOPIC_QUERY_DISPATCH_QosPolicy (DDS Extension) on page 453.

7.4.2 ENTITYFACTORY QosPolicy

This QosPolicy controls whether or not child *Entities* are created in the enabled state.

This QosPolicy applies to the *DomainParticipantFactory, DomainParticipants*, *Publishers*, and *Subscribers*, which act as 'factories' for the creation of subordinate *Entities*. A *DomainParticipantFactory* is used to create *DomainParticipants*. A *DomainParticipant* is used to create both *Publishers* and *Subscribers*. A *Publisher* is used to create *DataWriter*s, similarly a *Subscriber* is used to create *DataReaders*.

Entities can be created either in an 'enabled' or 'disabled' state. An enabled entity can actively participate in communication. A disabled entity cannot be discovered or take part in communication until it is explicitly enabled. For example, *Connext DDS* will not send data if the **write()** operation is called on a disabled *DataWriter*, nor will *Connext DDS* deliver data to a disabled *DataReader*. You can only enable a disabled entity. Once an entity is enabled, you cannot disable it, see 4.1.2 Enabling DDS Entities on page 168 about the *enable()* method.

The ENTITYFACTORY contains only one member, as illustrated in Table 7.20 DDS_EntityFactoryQosPolicy.

Table 7.20 DDS_EntityFactoryQosPolicy

Type	Field Name	Description
DDS_Boolean	autoenable_created_entities	DDS_BOOLEAN_TRUE: enable *Entities* when they are created DDS_BOOLEAN_FALSE: do not enable *Entities* when they are created

The ENTITYFACTORY QosPolicy controls whether the *Entities* created from the factory are automatically enabled upon creation or are left disabled. For example, if a *Publisher* is configured to autoenable created *Entities*, then all *DataWriter*s created from that *Publisher* will be automatically enabled.

Note: if an entity is disabled, then all of the child *Entities* it creates are also created in a disabled state, regardless of the setting of this QosPolicy. However, enabling a disabled entity will enable all of its children if this QosPolicy is set to autoenable child *Entities*.

Note: an entity can only be enabled; it cannot be disabled after its been enabled.

See 7.4.2.1 Example below for an example of how to set this policy.

There are various reasons why you may want to create *Entities* in the disabled state:

- To get around a "chicken and egg"-type issue. Where you need to have an entity in order to modify it, but you don't want the entity to be used by *Connext DDS* until it has been modified.

  For example, if you create a *DomainParticipant* in the enabled state, it will immediately start sending packets to other nodes trying to discover if other *Connext DDS* applications exist. However, you may want to configure the built-in topic reader listener before discovery occurs. To do this, you need to create a *DomainParticipant* in the disabled state because once enabled, discovery will occur. If you set up the built-in topic reader listener after the *DomainParticipant* is enabled, you may miss some discovery traffic.
- You may want to create *Entities* without having them automatically start to work. This especially pertains to *DataReaders*. If you create a *DataReader* in an enabled state and you are using *DataReaderListeners*, *Connext DDS* will immediately search for matching *DataWriters* and callback the listener as soon as data is published. This may not be what you want to happen if your application is still in the middle of initialization when data arrives.

  So typically, you would create all *Entities* in a disabled state, and then when all parts of the application have been initialized, one would enable all *Entities* at the same time using the *enable()* operation on the *DomainParticipant*, see 4.1.2 Enabling DDS Entities on page 168.
- An entity's existence is not advertised to other participants in the network until the entity is enabled. Instead of sending an individual declaration packet to other applications announcing the existence of the entity, *Connext DDS* can be more efficient in bundling multiple declarations into a single packet when you enable all *Entities* at the same time.

See 4.1.2 Enabling DDS Entities on page 168 for more information about enabled/disabled *Entities*.

7.4.2.1 Example

The code in Figure 7.25: Configuring a Publisher so that New DataWriters are Disabled on the next page illustrates how to use the ENTITYFACTORY QoS.

Note:

- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 7.25: Configuring a Publisher so that New DataWriters are Disabled

```
DDS_PublisherQos publisher_qos;
// topic, publisher, writer_listener already created
if (publisher->get_qos(publisher_qos) != DDS_RETCODE_OK) {
    // handle error
}
publisher_qos.entity_factory.autoenable_created_entities
    = DDS_BOOLEAN_FALSE;
if (publisher->set_qos(publisher_qos) != DDS_RETCODE_OK) {
    // handle error
}
// Subsequently created DataWriters are created disabled and
// must be explicitly enabled by the user-code
DDSDataWriter* writer = publisher->create_datawriter(topic,
    DDS_DATAWRITER_QOS_DEFAULT, writer_listener, DDS_STATUS_MASK_ALL);
// now do other initialization
// Now explicitly enable the DataWriter, this will allow other
// applications to discover the DataWriter and for this application
// to send data when the DataWriter's write() method is called
writer->enable();
```

7.4.2.2 Properties

This QosPolicy can be modified at any time.

It can be set differently on the publishing and subscribing sides.

7.4.2.3 Related QosPolicies

This QosPolicy does not interact with any other policies.

7.4.2.4 Applicable DDS Entities

- 9.2 DomainParticipantFactory on page 597
- 9.3 DomainParticipants on page 604
- 7.2 Publishers on page 270
- 8.2 Subscribers on page 483

7.4.2.5 System Resource Considerations

This QosPolicy does not significantly impact the use of system resources.

7.4.3 EXCLUSIVE_AREA QosPolicy (DDS Extension)

This QosPolicy controls the creation and use of Exclusive Areas. An exclusive area (EA) is a mutex with built-in deadlock protection when multiple EAs are in use. It is used to provide mutual exclusion among different threads of execution. Multiple EAs allow greater concurrency among the internal and user threads when executing *Connext DDS* code.

EAs allow *Connext DDS* to be multi-threaded while preventing threads from a classical deadlock scenario for multi-threaded applications. EAs prevent a *DomainParticipant's* internal threads from deadlocking with each other when executing internal code as well as when executing the code of user-registered listener callbacks.

Within an EA, all calls to the code protected by the EA are single threaded. Each *DomainParticipant*, *Publisher* and *Subscriber* represents a separate EA. All *DataWriters* of the same *Publisher* and all *DataReaders* of the same *Subscriber* share the EA of its parent. This means that the *DataWriters* of the same *Publisher* and the *DataReaders* of the same *Subscriber* are inherently single threaded.

Within an EA, there are limitations on how code protected by a different EA can be accessed. For example, when data is being processed by user code received in the DataReaderListener of a Subscriber EA, the user code may call the *write()* function of a *DataWriter* that is protected by the EA of its *Publisher*. So you can send data in the function called to process received data. However, you cannot create *Entities* or call functions that are protected by the EA of the *DomainParticipant*. See 4.5 Exclusive Areas (EAs) on page 197 for the complete documentation on Exclusive Areas.

With this QoS, you can force a *Publisher* or *Subscriber* to share the same EA as its *DomainParticipant*. Using this capability, the restriction of not being to create *Entities* in a DataReaderListener's **on_data_available()** callback is lifted. However, the trade-off is that the application has reduced concurrency through the *Entities* that share an EA.

Note that the restrictions on calling methods in a different EA only exists for user code that is called in registered Listeners by internal *DomainParticipant* threads. User code may call all *Connext DDS* functions for any *Entities* from their own threads at any time.

The EXCLUSIVE_AREA includes a single member, as listed in Table 7.21 DDS_ExclusiveAreaQosPolicy. For the default value, please see the API Reference HTML documentation.

Table 7.21 DDS_ExclusiveAreaQosPolicy

Type	Field Name	Description
DDS_Boolean	use_shared_exclusive_area	DDS_BOOLEAN_FALSE: subordinates will not use the same EA DDS_BOOLEAN_TRUE: subordinates will use the same EA

The implications and restrictions of using a private or shared EA are discussed in 4.5 Exclusive Areas (EAs) on page 197. The basic trade-off is concurrency versus restrictions on which methods can be called in user, listener, callback functions. To summarize:

Behavior when the *Publisher* or *Subscriber*'s use_shared_exclusive_area is set to *FALSE*:

- The creation of the *Publisher/Subscriber* will create an EA that will be used only by the *Publisher/Subscriber* and the *DataWriters/DataReaders* that belong to them.
- Consequences: This setting maximizes concurrency at the expense of creating a mutex for the *Publisher* or *Subscriber*. In addition, using a separate EA may restrict certain *Connext DDS* operations (see 4.4.6 Operations Allowed within Listener Callbacks on page 196) from being called from the callbacks of Listeners attached to those *Entities* and the *Entities* that they create. This limitation results from a built-in deadlock protection mechanism.

Behavior when the *Publisher* or *Subscriber*'s use_shared_exclusive_area is set to *TRUE*:

- The creation of the *Publisher/Subscriber* does not create a new EA. Instead, the *Publisher/Subscriber*, along with the *DataWriters/DataReaders* that they create, will use a common EA shared with the *DomainParticipant*.
- Consequences: By sharing the same EA among multiple *Entities*, you may decrease the amount of concurrency in the application, which can adversely impact performance. However, this setting does use less resources and allows you to call almost any operation on any Entity within a listener callback (see 4.5 Exclusive Areas (EAs) on page 197 for full details).

7.4.3.1 Example

The code in Figure 7.26: Creating a Publisher with a Shared Exclusive Area below illustrates how to change the EXCLUSIVE_AREA policy.

Note:

- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 7.26: Creating a Publisher with a Shared Exclusive Area

```
DDS_PublisherQos publisher_qos;
// domain, publisher_listener have been previously created
if (participant->get_default_publisher_qos(publisher_qos) !=
    DDS_RETCODE_OK) {
    // handle error
}
publisher_qos.exclusive_area.use_shared_exclusive_area = DDS_BOOLEAN_TRUE;
DDSPublisher* publisher = participant->create_publisher(publisher_qos,
    publisher_listener, DDS_STATUS_MASK_ALL);
```

7.4.3.2 Properties

This QosPolicy cannot be modified after the Entity has been created.

It can be set differently on the publishing and subscribing sides.

7.4.3.3 Related QosPolicies

This QosPolicy does not interact with any other policies.

7.4.3.4 Applicable DDS Entities

- 7.2 Publishers on page 270
- 8.2 Subscribers on page 483

7.4.3.5 System Resource Considerations

This QosPolicy affects the use of operating-system mutexes. When **use_shared_exclusive_area** is *FALSE*, the creation of a *Publisher* or *Subscriber* will create an operating-system mutex.

7.4.4 GROUP_DATA QosPolicy

This QosPolicy provides an area where your application can store additional information related to the *Publisher* and *Subscriber*. This information is passed between applications during discovery (see Discovery (Chapter 15 on page 758)) using built-in-topics (see Built-In Topics (Chapter 18 on page 825)). How this information is used will be up to user code. *Connext DDS* does not do anything with the information stored as GROUP_DATA except to pass it to other applications.

Use cases are often application-to-application identification, authentication, authorization, and encryption purposes. For example, applications can use this QosPolicy to send security certificates to each other for RSA-type security.

The value of the GROUP_DATA QosPolicy is sent to remote applications when they are first discovered, as well as when the *Publisher* or *Subscriber*'s *set_qos()* method is called after changing the value of the GROUP_DATA. User code can set listeners on the built-in *DataReaders* of the built-in *Topics* used by *Connext DDS* to propagate discovery information. Methods in the built-in topic listeners will be called whenever new *DomainParticipants*, *DataReaders*, and *DataWriters* are found. Within the user callback, you will have access to the GROUP_DATA that was set for the associated *Publisher* or *Subscriber*.

Currently, GROUP_DATA of the associated *Publisher* or *Subscriber* is only propagated with the information that declares a *DataWriter* or *DataReader*. Thus, you will need to access the value of GROUP_DATA through DDS_PublicationBuiltinTopicData or DDS_SubscriptionBuiltinTopicData (see Built-In Topics (Chapter 18 on page 825)).

The structure for the GROUP_DATA QosPolicy includes just one field, as seen in Table 7.22 DDS_GroupDataQosPolicy. The field is a sequence of octets that translates to a contiguous buffer of bytes whose contents and length is set by the user. The maximum size for the data are set in the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649.

Table 7.22 DDS_GroupDataQosPolicy

Type	Field Name	Description
DDS_OctetSeq	value	Empty by default

This policy is similar to the 7.5.30 USER_DATA QosPolicy on page 462 and 5.2.1 TOPIC_DATA QosPolicy on page 224 that apply to other types of *Entities*.

7.4.4.1 Example

One possible use of GROUP_DATA is to pass some credential or certificate that your subscriber application can use to accept or reject communication with the *DataWriter*s that belong to the *Publisher* (or vice versa, where the publisher application can validate the permission of *DataReaders* of a *Subscriber* to receive its data). The value of the GROUP_DATA of the *Publisher* is propagated in the 'group_data' field of the DDS_PublicationBuiltinTopicData that is sent with the declaration of each *DataWriter*. Similarly, the value of the GROUP_DATA of the *Subscriber* is propagated in the 'group_data' field of the DDS_SubscriptionBuiltinTopicData that is sent with the declaration of each *DataReader*.

When *Connext DDS* discovers a *DataWriter/DataReader,* the application can be notified of the discovery of the new entity and retrieve information about the *DataWriter/DataReader* QoS by reading the DCPSPublication or DCPSSubscription built-in topics (see Built-In Topics (Chapter 18 on page 825)). Your application can then examine the GROUP_DATA field in the built-in Topic and decide whether or not the *DataWriter/DataReader* should be allowed to communicate with local *DataReaders/DataWriters*. If communication is not allowed, the application can use the *DomainParticipant's* **ignore_publication()** or **ignore_subscription()** operation to reject the newly discovered remote entity as one with which the application allows *Connext DDS* to communicate. See Figure 18.2: Ignoring Publications on page 838 for an example of how to do this.

The code in Figure 7.27: Creating a Publisher with GROUP_DATA below illustrates how to change the GROUP_DATA policy.

Note:

- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 7.27: Creating a Publisher with GROUP_DATA

```
DDS_PublisherQos publisher_qos;
int i = 0;
// Bytes that will be used for the group data. In this case, 8 bytes
// of some information that is meaningful to the user application
char myGroupData[GROUP_DATA_SIZE] =
    { 0x34, 0xaa, 0xfe, 0x31, 0x7a, 0xf2, 0x34, 0xaa};
// assume domainparticipant and publisher_listener already created
```

```
if (participant->get_default_publisher_qos(publisher_qos) !=
    DDS_RETCODE_OK) {
    // handle error
}
// Must set the size of the sequence first
publisher_qos.group_data.value.maximum(GROUP_DATA_SIZE);
publisher_qos.group_data.value.length(GROUP_DATA_SIZE);
for (i = 0; i < GROUP_DATA_SIZE; i++) {
    publisher_qos.group_data.value[i] = myGroupData[i]
}
DDSPublisher* publisher = participant->create_publisher( publisher_qos,
    publisher_listener, DDS_STATUS_MASK_ALL);
```

7.4.4.2 Properties

This QosPolicy can be modified at any time.

It can be set differently on the publishing and subscribing sides.

7.4.4.3 Related QosPolicies

- 5.2.1 TOPIC_DATA QosPolicy on page 224
- 7.5.30 USER_DATA QosPolicy on page 462
- 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649

7.4.4.4 Applicable DDS Entities

- 7.2 Publishers on page 270
- 8.2 Subscribers on page 483

7.4.4.5 System Resource Considerations

The maximum size of the GROUP_DATA is set in the **publisher_group_data_max_length** and **subscriber_group_data_max_length** fields of the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649. Because *Connext DDS* will allocate memory based on this value, you should only increase this value if you need to. If your system does not use GROUP_DATA, then you can set this value to zero to save memory. Setting the value of the GROUP_DATA QosPolicy to hold data longer than the value set in the **[publisher/subscriber]_group_data_max_length** fields will result in failure and an *INCONSISTENT_QOS_POLICY* return code.

However, should you decide to change the maximum size of GROUP_DATA, you *must* make certain that all applications in the DDS domain have changed the value of **[publisher/subscriber]_group_data_max_length** to be the same. If two applications have different limits on the size of GROUP DATA, and one application sets the GROUP_DATA QosPolicy to hold data that is greater than the maximum size set by another application, then the matching *DataWriters* and *DataReaders* of the *Publisher* and *Subscriber* between the two applications will *not* connect. This is also true for the TOPIC_DATA (5.2.1 TOPIC_

DATA QosPolicy on page 224) and USER_DATA (7.5.30 USER_DATA QosPolicy on page 462) QosPolicies.

7.4.5 PARTITION QosPolicy

The PARTITION QoS provides another way to control which *DataWriters* will match—and thus communicate with—which *DataReaders*. It can be used to prevent *DataWriters* and *DataReaders* that would have otherwise matched with the same *Topic* and compatible QosPolicies from talking to each other. Much in the same way that only applications within the same DDS domain will communicate with each other, only *DataWriters* and *DataReaders* that belong to the same partition can talk to each other.

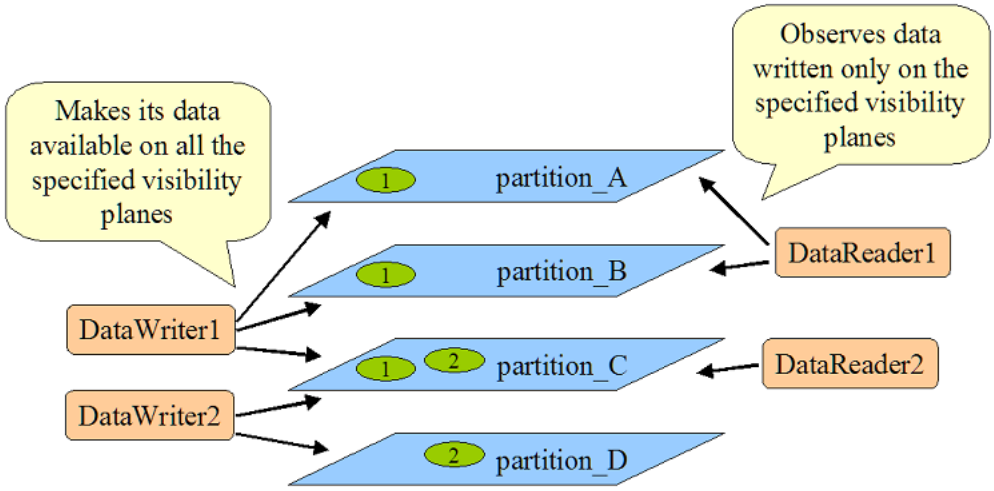
The PARTITION QoS applies to *Publishers* and *Subscribers*, therefore the *DataWriters* and *DataReaders* belong to the partitions as set on the *Publishers* and *Subscribers* that created them. The mechanism implementing the PARTITION QoS is relatively lightweight, and membership in a partition can be dynamically changed. Unlike the creation and destruction of *DomainParticipants*, there is no spawning and killing of threads or allocation and deallocation of memory when *Publishers* and *Subscribers* add or remove themselves from partitions.

The PARTITION QoS consists of a set of partition names that identify the partitions of which the Entity is a member. These names are simply strings, and *DataWriters* and *DataReaders* are considered to be in the same partition if they have at least one partition name in common in the PARTITION QoS set on their *Publishers* or *Subscribers*. By default, *Publishers* and *Subscribers* belong to a single partition whose name is the empty string, ““.

Conceptually each partition name can be thought of as defining a “visibility plane” within the DDS domain. *DataWriter*s will make their data available on all the visibility planes that correspond to its *Publisher’s* partition names, and the *DataReaders* will see the data that is placed on any of the visibility planes that correspond to its *Subscriber*’s partition names.

Figure 7.28: Controlling Visibility of Data with the PARTITION QoS on the next page illustrates the concept of PARTITION QoS. In this figure, all *DataWriter*s and *DataReaders* belong to the same DDS domain and refer to the same *Topic*. *DataWriter1* is configured to belong to three partitions: partition_A, partition_B, and partition_C. *DataWriter2* belongs to partition_C and partition_D.

Figure 7.28: Controlling Visibility of Data with the PARTITION QoS



Similarly, *DataReader1* is configured to belong to partition_A and partition_B, and *DataReader2* belongs only to partition_C. Given this topology, the data written by *DataWriter1* is visible in partitions A, B, and C. The oval tagged with the number "1" represents one DDS data sample written by *DataWriter1*.

Similarly, the data written by *DataWriter2* is visible in partitions C and D. The oval tagged with the number "2" represents one DDS data sample written by *DataWriter2*.

The result is that the data written by *DataWriter1* will be received by both *DataReader1* and *DataReader2*, but the data written by *DataWriter2* will only be visible by *DataReader2*.

Publishers and *Subscribers* always belong to a partition. By default, *Publishers* and *Subscribers* belong to a single partition whose name is the empty string, ““. If you set the PARTITION QoS to be an empty set, *Connext DDS* will assign the *Publisher* or *Subscriber* to the default partition, ““. Thus, for the example above, without using the PARTITION QoS, *DataReaders* 1 and 2 would have received all DDS data DDS samples written by *DataWriters* 1 and 2.

7.4.5.1 Rules for PARTITION Matching

On the *Publisher* side, the PARTITION QosPolicy associates a set of strings (partition names) with the *Publisher*. On the *Subscriber* side, the application also uses the PARTITION QoS to associate partition names with the *Subscriber*.

Taking into account the PARTITION QoS, a *DataWriter* will communicate with a *DataReader* if and only if the following conditions apply:

1. The *DataWriter* and *DataReader* belong to the same DDS domain. That is, their respective *DomainParticipants* are bound to the same DDS domain ID (see 9.3.1 Creating a DomainParticipant on page 610).

2. The *DataWriter* and *DataReader* have matching *Topics*. That is, each is associated with a *Topic* with the same topic_name and data type.
3. The QoS offered by the *DataWriter* is compatible with the QoS requested by the *DataReader*.
4. The application has not used the **ignore_participant()**, **ignore_datareader()**, or **ignore_datawriter()** APIs to prevent the association (see 18.4 Restricting Communication—Ignoring Entities on page 835).
5. The *Publisher* to which the *DataWriter* belongs and the *Subscriber* to which the *DataReader* belongs must have at least one matching partition name.

The last condition reflects the visibility of the data introduced by the PARTITION QoS. Matching partition names is done by string comparison, thus partition names are case sensitive.

Note: Failure to match partitions is not considered an incompatible QoS and does not trigger any listeners or change any status conditions.

7.4.5.2 Pattern Matching for PARTITION Names

You may also add strings that are regular expressions[1] to the PARTITION QosPolicy. A regular expression does not define a set of partitions to which the *Publisher* or *Subscriber* belongs, as much as it is used in the partition matching process to see if a remote entity has a partition name that would be matched with the regular expression. That is, the regular expressions in the PARTITION QoS of a *Publisher* are never matched against those found in the PARTITION QoS of a *Subscriber*. Regular expressions are always matched against "concrete" partition names. Thus, a concrete partition name may not contain any reserved characters that are used to define regular expressions, for example '*', '.', '+', etc.

For more on regular expressions, see 5.4.6.5 SQL Extension: Regular Expression Matching on page 241.

If a PARTITION QoS only contains regular expressions, then the *Publisher* or *Subscriber* will be assigned automatically to the default partition with the empty string name (""). Thus, do not be fooled into thinking that a PARTITION QoS that only contains the string "*" matches another PARTITION QoS that only contains the string "*". Yes, the *Publisher* will match the *Subscriber*, but it is because they both belong to the default "" partition.

DataWriters and *DataReaders* are considered to have a partition in common if the sets of partitions that their associated *Publishers* and *Subscribers* have defined have:

At least one concrete partition name in common

A regular expression in one Entity that matches a concrete partition name in another Entity

The programmatic representation of the PARTITION QoS is shown in Table 7.23 DDS_PartitionQosPolicy. The QosPolicy contains the single string sequence, name. Each element in the sequence

[1] As defined by the POSIX fnmatch API (1003.2-1992 section B.6).

can be a concrete name or a regular expression. The *Entity* will be assigned to the default “” partition if the sequence is empty.

Table 7.23 DDS_PartitionQosPolicy

Type	Field Name	Description
DDS_StringSeq	name	Empty by default. There can be up to 64 names, with a maximum of 256 characters summed across all names.

You can have one long partition string of 256 chars, or multiple shorter strings that add up to 256 or less characters. For example, you can have one string of 4 chars and one string of 252 chars.

7.4.5.3 Example

Since the set of partitions for a *Publisher* or *Subscriber* can be dynamically changed, the Partition QosPolicy is useful to control which *DataWriters* can send data to which *DataReaders* and vice versa—even if all of the *DataWriters* and *DataReaders* are for the same topic. This facility is useful for creating temporary separation groups among *Entities* that would otherwise be connected to and exchange data each other.

Note when using Partitions and Durability: If a Publisher changes partitions after startup, it is possible for a reliable, late-joining DataReader to receive data that was written for both the original and the new partition. For example, suppose a DataWriter with TRANSIENT_LOCAL Durability initially writes DDS samples with Partition A, but later changes to Partition B. In this case, a reliable, late-joining DataReader configured for Partition B will receive whatever DDS samples have been saved for the DataWriter. These may include DDS samples which were written when the DataWriter was using Partition A.

The code in Figure 7.29: Setting Partition Names on a Publisher on the next page illustrates how to change the PARTITION policy.

Note:

- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 7.29: Setting Partition Names on a Publisher

```
DDS_PublisherQos publisher_qos;
// domain, publisher_listener have been previously created
if (participant->get_default_publisher_qos(publisher_qos) !=
    DDS_RETCODE_OK) {
    // handle error
}
// Set the partition QoS
publisher_qos.partition.name.maximum(3);
publisher_qos.partition.name.length(3);
publisher_qos.partition.name[0] = DDS_String_dup("partition_A");
publisher_qos.partition.name[1] = DDS_String_dup("partition_B");
publisher_qos.partition.name[2] = DDS_String_dup("partition_C");
DDSPublisher* publisher = participant->create_publisher(
       publisher_qos, publisher_listener, DDS_STATUS_MASK_ALL);
```

The ability to dynamically control which *DataWriters* are matched to which *DataReaders* (of the same *Topic*) offered by the PARTITION QoS can be used in many different ways. Using partitions, connectivity can be controlled based on location-based partitioning, access-control groups, purpose, or a combination of these and other application-defined criteria. We will examine some of these options via concrete examples.

Example of location-based partitions. Assume you have a set of *Topics* in a traffic management system such as "TrafficAlert," "AccidentReport," and "CongestionStatus." You may want to control the visibility of these *Topics* based on the actual location to which the information applies. You can do this by placing the *Publisher* in a partition that represents the area to which the information applies. This can be done using a string that includes the city, state, and country, such as "USA/California/Santa Clara." A *Subscriber* can then choose whether it wants to see the alerts in a single city, the accidents in a set of states, or the congestion status across the US. Some concrete examples are shown in Table 7.24 Example of Using Location-Based Partitions.

Table 7.24 Example of Using Location-Based Partitions

Publisher Partitions	Subscriber Partitions	Result
Specify a single partition name using the pattern: "<country>/<state>/<city>"	Specify multiple partition names, one per region of interest	Limits the visibility of the data to Subscribers that express interest in the geographical region.
"USA/California/Santa Clara"	(Subscriber participant is irrelevant here.)	Send only information for Santa Clara, California.

Table 7.24 Example of Using Location-Based Partitions

Publisher Partitions	Subscriber Partitions	Result
(Publisher partition is irrelevant here.)	"USA/California/Santa Clara"	Receive only information for Santa Clara, California.
	"USA/California/Santa Clara" "USA/California/Sunnyvale"	Receive information for Santa Clara or Sunnyvale, California.
	"USA/California/*" "USA/Nevada/*"	Receive information for California or Nevada.
	"USA/California/*" "USA/Nevada/Reno" "USA/Nevada/Las Vegas"	Receive information for California and two cities in Nevada.

Example of access-control group partitions. Suppose you have an application where access to the information must be restricted based on reader membership to access-control groups. You can map this group-controlled visibility to partitions by naming all the groups (e.g. executives, payroll, financial, general-staff, consultants, external-people) and assigning the *Publisher* to the set of partitions that represents which groups should have access to the information. The *Subscribers* specify the groups to which they belong, and the partition-matching behavior will ensure that the information is only distributed to *Subscribers* belonging to the appropriate groups. Some concrete examples are shown in Table 7.25 Example of Access-Control Group Partitions.

Table 7.25 Example of Access-Control Group Partitions

Publisher Partitions	Subscriber Partitions	Result
Specify several partition names, one per group that is allowed access:	Specify multiple partition names, one per group to which the Subscriber belongs.	Limits the visibility of the data to Subscribers that belong to the access-groups specified by the Publisher.
"payroll" "financial"	(Subscriber participant is irrelevant here.)	Makes information available only to Subscribers that have access to either financial or payroll information.
(Publisher participant is irrelevant here.)	"executives" "financial"	Gain access to information that is intended for executives or people with access to the finances.

A slight variation of this pattern could be used to confine the information based on security levels.

Example of purpose-based partitions: Assume an application containing subsystems that can be used for multiple purposes, such as training, simulation, and real use. In some occasions it is convenient to be able to dynamically switch the subsystem from operating in the "simulation world" to the "training world" or to the "real world." For supervision purposes, it may be convenient to observe multiple worlds, so that you can compare the each one's results. This can be accomplished by setting a partition name in the *Publisher* that represents the "world" to which it belongs and a set of partition names in the *Subscriber* that model the worlds that it can observe.

7.4.5.4 Properties

This QosPolicy can be modified at any time.

Strictly speaking, this QosPolicy does not have request-offered semantics, although it is matched between *DataWriter*s and *DataReaders*, and communication is established only if there is a match between partition names.

7.4.5.5 Related QosPolicies

- 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649.

7.4.5.6 Applicable DDS *Entities*

- 7.2 Publishers on page 270
- 8.2 Subscribers on page 483

7.4.5.7 System Resource Considerations

Partition names are propagated along with the declarations of the *DataReaders* and the *DataWriter*s and can be examined by user code through built-in topics (see Built-In Topics (Chapter 18 on page 825)). Thus the sum-total length of the partition names will impact the bandwidth needed to transmit those declarations, as well as the memory used to store them.

The maximum number of partitions and the maximum number of characters that can be used for the sum-total length of all partition names are configured using the max_partitions and max_partition_cumulative_characters fields of the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649. Setting more partitions or using longer names than allowed by those limits will result in failure and an INCONSISTENT_QOS_POLICY return code.

However, should you decide to change the maximum number of partitions or maximum cumulative length of partition names, then you *must* make certain that all applications in the DDS domain have changed the values of max_partitions and max_partition_cumulative_characters to be the same. If two applications have different values for those settings, and one application sets the PARTITION QosPolicy to hold more partitions or longer names than set by another application, then the matching *DataWriters* and *DataReaders* of the *Publisher* and *Subscriber* between the two applications will *not* connect. This similar to the restrictions for the GROUP_DATA (7.4.4 GROUP_DATA QosPolicy on page 352), USER_DATA (7.5.30 USER_DATA QosPolicy on page 462), and TOPIC_DATA (5.2.1 TOPIC_DATA QosPolicy on page 224) QosPolicies.

7.4.6 PRESENTATION QosPolicy

Usually *DataReaders* will receive data in the order that it was sent by a *DataWriter*. In addition, data is presented to the *DataReader* as soon as the application receives the next value expected.

Sometimes, you may want a set of data for the same *DataWriter* or different *DataWriters* to be presented to the receiving *DataReader(s)* only after ALL the elements of the set have been received, but not before. You may also want the data to be presented in a different order than it was received. Specifically, for keyed data, you may want *Connext DDS* to present the data in keyed or instance order.

The Presentation QosPolicy allows you to specify different scopes of presentation: within a *DataWriter*, across instances of a *DataWriter*, and even across different *DataWriters* of a publisher. It also controls whether or not a set of changes within the scope must be delivered at the same time or delivered as soon as each element is received. The structure used is shown in Table 7.26 DDS_PresentationQosPolicy.

Table 7.26 DDS_PresentationQosPolicy

Type	Field Name	Description
DDS_Presentation_ QosPolicyAccessScopeKind	access_ scope	Determines the largest scope spanning the entities for which the **ordered_access** and **coherent_access** of samples can be preserved (if **coherent_access** and/or **ordered_access** are TRUE). If both **coherent_access** and **ordered_access** are FALSE, **access_scope's** setting has no effect. • DDS_INSTANCE_PRESENTATION_QOS (default): Scope spans only a single instance. Changes to one instance need not be coherent nor ordered with respect to changes to any other instance. Order and coherent changes apply to each instance separately. • DDS_TOPIC_PRESENTATION_QOS: Scope spans all instances within the same *DataWriter*, but not across instances in different *DataWriters*. • DDS_GROUP_PRESENTATION_QOS: Scope spans all instances belonging to *DataWriters* within the same *Publisher*. • DDS_HIGHEST_OFFERED_PRESENTATION_QOS: Only applies to *Subscribers*. With this setting, the *Subscriber* will use the access scope specified by each remote *Publisher*.
DDS_Boolean	coherent_ access	Controls whether *Connext DDS* will preserve the groupings of changes made by the publishing application by means of **begin_coherent_changes()** and **end_coherent_changes()**. • DDS_BOOLEAN_FALSE (default): Coherency is not preserved. The value of **access_ scope** is ignored. • DDS_BOOLEAN_TRUE: Changes made to instances within each *DataWriter* will be available to the *DataReader* as a coherent set, based on the value of **access_scope**.
DDS_Boolean	ordered_access	Controls whether *Connext DDS* will preserve the order of changes. • DDS_BOOLEAN_FALSE (default): The order of DDS samples is only preserved for each instance, not across instances. The value of **access_scope** is ignored. • DDS_BOOLEAN_TRUE: The order of DDS samples from a *DataWriter* is preserved, based on the value set in **access_scope**.

Table 7.26 DDS_PresentationQosPolicy

Type	Field Name	Description
DDS_Boolean	drop_in-complete_coherent_set	Indicates whether a *DataReader* should drop (and report as lost) samples from an incomplete coherent set (one for which not all the samples were received): • DDS_BOOLEAN_FALSE: The *DataReader* will not drop samples that are part of an incomplete coherent set. • DDS_BOOLEAN_TRUE (default): The *DataReader* will drop samples that are part of an incomplete coherent set. Such samples are reported as lost, with the reason LOST_BY_INCOMPLETE_COHERENT_SET, in the 8.3.7.7 SAMPLE_LOST Status on page 524. Note that a coherent set is also considered incomplete if some of its samples are filtered by content or time on the *DataWriter* side. Samples from an incomplete coherent set have incomplete_coherent_set in the **coherent_set_info** field in the 8.4.6 The SampleInfo Structure on page 560 set to TRUE.

7.4.6.1 Coherent Access

A 'coherent set' is a set of DDS data-sample modifications that must be propagated in such a way that they are interpreted at the receiver's side as a consistent set; that is, the receiver will only be able to access the data after all the modifications in the set are available at the subscribing end.

Coherency enables a publishing application to change the value of several data-instances and have those changes be seen atomically (as a cohesive set) by the readers.

Setting *coherent_access* to TRUE only behaves as described in the DDS specification when the *DataWriter* and *DataReader are* configured for *reliable* delivery. Non-reliable *DataReaders* will never receive DDS samples that belong to a coherent set.

To send a coherent set of DDS data samples, the publishing application uses the *Publisher's* **begin_coherent_changes()** and **end_coherent_changes()** operations (see 7.3.10 Writing Coherent Sets of DDS Data Samples on page 315).

If *coherent_access* is TRUE, then the *access_scope* controls the maximum extent of the coherent changes, as follows:

- If *access_scope* is INSTANCE, the use of **begin_coherent_changes()** and **end_coherent_changes()** has no effect on how the subscriber can access the data. This is because, with the scope limited to each instance, changes to separate instances are considered independent and thus cannot be grouped by a coherent change.
- If *access_scope* is TOPIC, then coherent changes (indicated by their enclosure within calls to **begin_coherent_changes()** and **end_coherent_changes()**) will be made available as such to each remote *DataReader* independently. That is, changes made to instances within the each individual *DataWriter* will be available as a coherent set with respect to other changes to instances in that same

DataWriter, but will not be grouped with changes made to instances belonging to a different *DataWriter*.

- If *access_scope* is GROUP, coherent changes made to instances through a *DataWriter* attached to a common *Publisher* are made available as a unit to remote subscribers.

7.4.6.2 Ordered Access

If *ordered_access* is TRUE, then *access_scope* controls the scope of the order in which DDS samples are presented to the subscribing application, as follows:

- If *access_scope* is INSTANCE, the relative order of DDS samples sent by a *DataWriter* is only preserved on an per-instance basis. If two DDS samples refer to the same instance (identified by *Topic* and a particular value for the key) then the order in which they are stored in the *DataReader's* queue is consistent with the order in which the changes occurred. However, if the two DDS samples belong to different instances, the order in which they are presented may or may not match the order in which the changes occurred.
- If *access_scope* is TOPIC, the relative order of DDS samples sent by a *DataWriter* is preserved for all DDS samples of all instances. The coherent grouping and/or order in which DDS samples appear in the *DataReader*'s queue is consistent with the grouping/order in which the changes occurred—even if the DDS samples affect different instances.
- If *access_scope* is GROUP, the scope spans all instances belonging to *DataWriters* within the same *Publisher*—even if they are instances of different topics. Changes made to instances via *DataWriters* attached to the same *Publisher* are made available to *Subscribers* on the same order they occurred.
- If *access_scope* is HIGHEST_OFFERED, the *Subscriber* will use the access scope specified by each remote *Publisher*.

If the *Subscriber's* **access_scope** is GROUP or HIGHEST_OFFERED and **ordered_access** is TRUE, the application is required to use the *Subscriber's* **begin_access()** and **end_access()** operations to access the DDS samples in order across *DataWriters* of the same group (a *Publisher* with **access_scope** of GROUP). If you do not use these operations, the data may not be ordered across *DataWriters*. See 8.2.5 Beginning and Ending Group-Ordered Access on page 496 for additional details.

Ultimately, the data stored in the *DataReader* queue is accessed by the *DataReader*'s **read()/take()** APIs. The application does not have to access the DDS data samples in the order indicated by the combination of **access_scope** and **ordered_access**. How the application actually gets the data from the *DataReader* is ultimately under the control of the user code. See 8.4 Using DataReaders to Access Data (Read & Take) on page 548 for additional details.

7.4.6.3 Example

Coherency is useful in cases where the values are inter-related (for example, if there are two data-instances representing the altitude and velocity vector of the same aircraft and both are changed, it may be useful to

communicate those values in a way the reader can see both together; otherwise, it may e.g., erroneously interpret that the aircraft is on a collision course).

Ordered access is useful when you need to ensure that DDS samples appear on the *DataReader's* queue in the order sent by one or multiple *DataWriter*s within the same *Publisher*.

To illustrate the effect of the PRESENTATION QosPolicy with TOPIC and INSTANCE access scope, assume the following sequence of DDS samples was written by the *DataWriter*: {A1, B1, C1, A2, B2, C2}. In this example, A, B, and C represent different instances (i.e., different keys). Assume all of these DDS samples have been propagated to the *DataReader's* history queue before your application invokes the **read()** operation. The DDS data-sample sequence returned depends on how the PRESENTATION QoS is set, as shown in Table 7.27 Effect of ordered_access for access_scope INSTANCE and TOPIC.

Table 7.27 Effect of ordered_access for access_scope INSTANCE and TOPIC

PRESENTATION QoS	Sequence retrieved via "read()". Order sent was {A1, B1, C1, A2, B2, C2}
ordered_access = FALSE access_scope = <any>	Any order is possible. For example, {A1,A2,B1,B2,C1,C2}, {A1, B1, C1, A2, B2, C2}, and {C1,B2,A1,A2,B1,C2}
ordered_access = TRUE access_scope = INSTANCE	Order is preserved per instance. Multiple orders are possible. For example, {A1,A2,B1,B2,C1,C2} or {A1, B1, C1, A2, B2, C2} or {B1,B2,A1,A2,C1,C2}
ordered_access = TRUE access_scope = TOPIC	{A1, B1, C1, A2, B2, C2}

To illustrate the effect of a PRESENTATION QosPolicy with GROUP *access_scope*, assume the following sequence of DDS samples was written by two *DataWriters,* W1 and W2, within the same *Publisher*: {(W1,A1), (W2,B1), (W1,C1), (W2,A2), (W1,B2), (W2,C2)}. As in the previous example, A, B, and C represent different instances (i.e., different keys). With *access_scope* set to INSTANCE or TOPIC, the middleware cannot guarantee that the application will receive the DDS samples in the same order they were published by W1 and W2. With access_scope set to GROUP, the middleware is able to provide the DDS samples in order to the application as long as the **read()/take()** operations are invoked within a **begin_access()/end_access()** block (see 8.2.5 Beginning and Ending Group-Ordered Access on page 496).

Table 7.28 Effect of ordered_access for access_scope GROUP

PRESENTATION QoS	Sequence retrieved via "read()". Order sent was {(W1,A1), (W2,B1), (W1,C1), (W2,A2), (W1,B2), (W2,C2)}
ordered_access = FALSE or access_scope = TOPIC or INSTANCE	The order across *DataWriters* will not be preserved. DDS samples may be delivered in multiple orders. For example: {(W1,A1), (W1,C1), (W1,B2), (W2,B1), (W2,A2), (W2,C2)} {(W1,A1), (W2,B1), (W1,B2), (W1,C1), (W2,A2), (W2,C2)}
ordered_access = TRUE access_scope = GROUP	DDS samples are delivered in the same order they were published: {(W1,A1), (W2,B1), (W1,C1), (W2,A2), (W1,B2), (W2,C2)}

7.4.6.4 Properties

This QosPolicy cannot be modified after the *Publisher* or *Subscriber* is enabled.

This QoS must be set compatibly between the *DataWriter*'s *Publisher* and the *DataReader*'s *Subscriber*. The compatible combinations are shown in Table 7.29 Valid Combinations of ordered_access and access_scope, with Subscriber's ordered_access = False and Table 7.30 Valid Combinations of ordered_access and access_scope, with Subscriber's ordered_access = True for *ordered_access* and Table 7.31 Valid Combinations of Presentation Coherent Access and Access Scope for *coherent_access*.

Table 7.29 Valid Combinations of ordered_access and access_scope, with Subscriber's ordered_access = False

{ordered_access/access_scope}		Subscriber Requests:			
		False/Instance	**False/Topic**	**False/Group**	**False/Highest**
Publisher offers:	False/Instance	compatible	incompatible	incompatible	compatible
	False/Topic	compatible	compatible	incompatible	compatible
	False/Group	compatible	compatible	compatible	compatible
	True/Instance	compatible	incompatible	incompatible	compatible
	True/Topic	compatible	compatible	incompatible	compatible
	True/Group	compatible	compatible	compatible	compatible

Table 7.30 Valid Combinations of ordered_access and access_scope, with Subscriber's ordered_access = True

{ordered_access/access_scope}		Subscriber Requests:			
		True/Instance	True/Topic	True/Group	True/Highest
Publisher offers:	False/Instance	incompatible	incompatible	incompatible	incompatible
	False/Topic	incompatible	incompatible	incompatible	incompatible
	False/Group	incompatible	incompatible	incompatible	incompatible
	True/Instance	compatible	incompatible	incompatible	compatible
	True/Topic	compatible	compatible	incompatible	compatible
	True/Group	compatible	compatible	compatible	compatible

Table 7.31 Valid Combinations of Presentation Coherent Access and Access Scope

{coherent_access/access_scope}		Subscriber requests:			
		False/Instance	False/Topic	True/Instance	True/Topic
Publisher offers:	False/Instance	compatible	incompatible	incompatible	incompatible
	False/Topic	compatible	compatible	incompatible	incompatible
	True/Instance	compatible	incompatible	compatible	incompatible
	True/Topic	compatible	compatible	compatible	compatible

7.4.6.5 Related QosPolicies

- The 7.5.8 DESTINATION_ORDER QosPolicy on page 406 is closely related and also affects the ordering of DDS data samples on a per-instance basis when there are multiple *DataWriters*.
- The 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565 may be used to configure the DDS sample ordering process in the Subscribers configured with *GROUP* or *HIGHEST_OFFERED access_scope*.

7.4.6.6 Applicable DDS Entities

- 7.2 Publishers on page 270
- 8.2 Subscribers on page 483

7.4.6.7 System Resource Considerations

The use of this policy does not significantly impact the usage of resources.

7.5 DataWriter QosPolicies

This section provides detailed information about the QosPolicies associated with a *DataWriter*. Table 7.18 DataWriter QosPolicies provides a quick reference. They are presented here in alphabetical order.

- 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on the next page
- 7.5.2 BATCH QosPolicy (DDS Extension) on page 373
- 7.5.3 DATA_REPRESENTATION QosPolicy on page 379
- 7.5.4 DATATAG QosPolicy on page 386
- 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388
- 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400
- 7.5.7 DEADLINE QosPolicy on page 404
- 7.5.8 DESTINATION_ORDER QosPolicy on page 406
- 7.5.9 DURABILITY QosPolicy on page 410
- 7.5.10 DURABILITY SERVICE QosPolicy on page 414
- 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416
- 7.5.12 HISTORY QosPolicy on page 418
- 7.5.13 LATENCYBUDGET QoS Policy on page 423
- 7.5.14 LIFESPAN QoS Policy on page 423
- 7.5.15 LIVELINESS QosPolicy on page 425
- 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429
- 7.5.17 OWNERSHIP QosPolicy on page 432
- 7.5.18 OWNERSHIP_STRENGTH QosPolicy on page 435
- 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436
- 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441
- 7.5.21 RELIABILITY QosPolicy on page 444
- 7.5.22 RESOURCE_LIMITS QosPolicy on page 449
- 7.5.23 SERVICE QosPolicy (DDS Extension) on page 452
- 7.5.24 TOPIC_QUERY_DISPATCH_QosPolicy (DDS Extension) on page 453
- 7.5.26 TRANSPORT_PRIORITY QosPolicy on page 455

- 7.5.27 TRANSPORT_SELECTION QosPolicy (DDS Extension) on page 456
- 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458
- 7.5.29 TYPESUPPORT QosPolicy (DDS Extension) on page 461
- 7.5.30 USER_DATA QosPolicy on page 462
- 7.5.31 WRITER_DATA_LIFECYCLE QoS Policy on page 464

7.5.1 AVAILABILITY QosPolicy (DDS Extension)

This QoS policy configures the availability of data and it is used in the context of two features:

- Collaborative DataWriters (7.5.1.1 Availability QoS Policy and Collaborative DataWriters on the next page)
- Required Subscriptions (7.5.1.2 Availability QoS Policy and Required Subscriptions on page 371)

It contains the members listed in Table 7.32 DDS_AvailabilityQosPolicy.

Table 7.32 DDS_AvailabilityQosPolicy

Type	Field Name	Description
DDS_Boolean	enable_required_subscriptions	Enables support for required subscriptions in a *DataWriter*. For Collaborative DataWriters: Not applicable. For Required Subscriptions: See Table 7.35 Configuring Required Subscriptions with DDS_AvailabilityQosPolicy.
struct DDS_Duration_t	max_data_availability_waiting_time	Defines how much time to wait before delivering a DDS sample to the application without having received some of the previous DDS samples. For Collaborative DataWriters: See Table 7.34 Configuring Collaborative DataWriters with DDS_AvailabilityQosPolicy. For Required Subscriptions: Not applicable.
struct DDS_Duration_t	max_endpoint_availability_waiting_time	Defines how much time to wait to discover *DataWriters* providing DDS samples for the same data source. For Collaborative DataWriters: See Table 7.34 Configuring Collaborative DataWriters with DDS_AvailabilityQosPolicy. For Required Subscriptions: Not applicable.
struct DDS_EndpointGroupSeq	required_matched_endpoint_groups	A sequence of endpoint groups, described in Table 7.33 struct DDS_EndpointGroup_t. For Collaborative DataWriters: See Table 7.34 Configuring Collaborative DataWriters with DDS_AvailabilityQosPolicy. For Required Subscriptions: See Table 7.35 Configuring Required Subscriptions with DDS_AvailabilityQosPolicy

Table 7.33 struct DDS_EndpointGroup_t

Type	Field Name	Description
char *	role_name	Defines the role name of the endpoint group. If used in the AvailabilityQosPolicy on a *DataWriter*, it specifies the name that identifies a Required Subscription.
int	quorum_count	Defines the minimum number of members that satisfies the endpoint group. If used in the AvailabilityQosPolicy on a *DataWriter*, it specifies the number of *DataReaders* with a specific role name that must acknowledge a DDS sample before the DDS sample is considered to be acknowledged by the Required Subscription.

7.5.1.1 Availability QoS Policy and Collaborative DataWriters

The *Collaborative DataWriters* feature allows you to have multiple *DataWriters* publishing DDS samples from a common logical data source. The *DataReaders* will combine the DDS samples coming from the *DataWriters* in order to reconstruct the correct order at the source. The Availability QosPolicy allows you to configure the DDS sample combination (synchronization) process in the *DataReader*.

Each DDS sample published in a DDS domain for a given logical data source is uniquely identified by a pair (virtual GUID, virtual sequence number). DDS samples from the same data source (same virtual GUID) can be published by different *DataWriters*.

A *DataReader* will deliver a DDS sample (VGUIDn, VSNm) to the application if one of the following conditions is satisfied:

- (GUIDn, SNm-1) has already been delivered to the application.
- All the known *DataWriters* publishing VGUIDn have announced that they do not have (VGUIDn, VSNm-1).
- None of the known *DataWriters* publishing VGUIDn have announced potential availability of (VGUIDn, VSNm-1) and both timeouts in this QoS policy have expired.

A *DataWriter* announces potential availability of DDS samples by using virtual heartbeats. The frequency at which virtual heartbeats are sent is controlled by the protocol parameters virtual_heartbeat_period on page 391 and samples_per_virtual_heartbeat on page 391 (see Table 7.44 DDS_RtpsReliableWriterProtocol_t).

Table 7.34 Configuring Collaborative DataWriters with DDS_AvailabilityQosPolicy describes the fields of this policy when used for a Collaborative DataWriter.

For further information, see Collaborative DataWriters (Chapter 12 on page 721).

Table 7.34 Configuring Collaborative DataWriters with DDS_AvailabilityQosPolicy

Field Name	Description for Collaborative DataWriters
max_data_availability_waiting_time	Defines how much time to wait before delivering a DDS sample to the application without having received some of the previous DDS samples. A DDS sample identified by (VGUIDn, VSNm) will be delivered to the application if this timeout expires for the DDS sample and the following two conditions are satisfied: None of the known *DataWriters* publishing VGUIDn have announced potential availability of (VGUIDn, VSNm-1). The *DataWriters* for all the endpoint groups specified in required_matched_endpoint_groups on page 369 have been discovered or max_endpoint_availability_waiting_time on the next page has expired.
max_endpoint_availability_waiting_time	Defines how much time to wait to discover *DataWriters* providing DDS samples for the same data source. The set of endpoint groups that are required to provide DDS samples for a data source can be configured using required_matched_endpoint_groups on page 369. A non-consecutive DDS sample identified by (GUIDn, SNm) cannot be delivered to the application unless the *DataWriters* for all the endpoint groups in required_matched_endpoint_groups on page 369 are discovered or this timeout expires.
required_matched_endpoint_groups	Specifies the set of endpoint groups that are expected to provide DDS samples for the same data source. The quorum count in a group represents the number of *DataWriters* that must be discovered for that group before the *DataReader* is allowed to provide non consecutive DDS samples to the application. A *DataWriter* becomes a member of an endpoint group by configuring the **role_name** in the *DataWriter's* 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416. The *DataWriters* created by *RTI Persistence Service* have a predefined **role_name** of 'PERSISTENCE_SERVICE'. For other *DataWriters*, the **role_name** is not set by default.

7.5.1.2 Availability QoS Policy and Required Subscriptions

In the context of Required Subscriptions, the Availability QosPolicy can be used to configure a set of required subscriptions on a *DataWriter*.

Required Subscriptions are preconfigured, named subscriptions that may leave and subsequently rejoin the network from time to time, at the same or different physical locations. Any time a required subscription is disconnected, any DDS samples that would have been delivered to it are stored for delivery if and when the subscription rejoins the network.

Table 7.35 Configuring Required Subscriptions with DDS_AvailabilityQosPolicy describes the fields of this policy when used for a Required Subscription.

For further information, see 7.3.13 Required Subscriptions on page 322.

Table 7.35 Configuring Required Subscriptions with DDS_AvailabilityQosPolicy

Field Name	Description for Required Subscriptions
enable_required_ subscriptions	Enables support for Required Subscriptions in a *DataWriter*.
max_data_avail- ability_ waiting_time	Not applicable to Required Subscriptions.
max_endpoint_avail- ability_ waiting_time	
required_matched_ endpoint_groups	A sequence of endpoint groups that specify the Required Subscriptions on a *DataWriter*. Each Required Subscription is specified by a name and a quorum count. The quorum count represents the number of *DataReaders* that have to acknowledge the DDS sample before it can be considered fully acknowledged for that Required Subscription. A *DataReader* is associated with a Required Subscription by configuring the **role_name** in the *DataReader's* 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416.

7.5.1.3 Properties

For *DataWriters*, all the members in this QosPolicy can be changed after the *DataWriter* is created except for the member **enable_required_subscriptions**.

For *DataReaders*, this QosPolicy cannot be changed after the *DataReader* is created.

There are no compatibility restrictions for how it is set on the publishing and subscribing sides.

7.5.1.4 Related QosPolicies

- 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416
- 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649
- 7.5.9 DURABILITY QosPolicy on page 410

7.5.1.5 Applicable DDS Entities

- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.1.6 System Resource Considerations

The resource limits for the endpoint groups in **required_matched_endpoint_groups** are determined by two values in the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension)

on page 649:

- **max_endpoint_groups**
- **max_endpoint_group_cumulative_characters**

The maximum number of virtual writers (identified by a virtual GUID) that can be managed by a *DataReader* is determined by the **max_remote_virtual_writers** in 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571. When the *Subscriber's* **access_scope** is GROUP, **max_remote_virtual_writers** determines the maximum number of *DataWriter* groups supported by the *Subscriber*. Since the *Subscriber* may contain more than one *DataReader*, only the setting of the first applies.

7.5.2 BATCH QosPolicy (DDS Extension)

This QosPolicy can be used to decrease the amount of communication overhead associated with the transmission and (in the case of reliable communication) acknowledgment of small DDS samples, in order to increase throughput.

It specifies and configures the mechanism that allows *Connext DDS* to collect multiple user data DDS samples to be sent in a single network packet, to take advantage of the efficiency of sending larger packets and thus increase effective throughput.

This QosPolicy can be used to increase effective throughput dramatically for small data DDS samples. Throughput for small DDS samples (size < 2048 bytes) is typically limited by CPU capacity and not by network bandwidth. Batching many smaller DDS samples to be sent in a single large packet will increase network utilization and thus throughput in terms of DDS samples per second.

It contains the members listed in Table 7.36 DDS_BatchQosPolicy.

Table 7.36 DDS_BatchQosPolicy

Type	Field Name	Description
DDS_Boolean	enable	Enables/disables batching.
DDS_Long	max_data_bytes	Sets the maximum cumulative length of all serialized DDS samples in a batch. Before or when this limit is reached, the batch is automatically flushed. The size does not include the meta-data associated with the batch DDS samples.
DDS_Long	max_samples	Sets the maximum number of DDS samples in a batch. When this limit is reached, the batch is automatically flushed.

Table 7.36 DDS_BatchQosPolicy

Type	Field Name	Description
struct DDS_ Duration_t	max_flush_ delay	Sets the maximum flush delay. When this duration is reached, the batch is automatically flushed. The delay is measured from the time the first DDS sample in the batch is written by the application.
struct DDS_ Duration_t	source_ timestamp_ resolution	Sets the batch source timestamp resolution. The value of this field determines how the source timestamp is associated with the DDS samples in a batch. A DDS sample written with timestamp 't' inherits the source timestamp 't2' associated with the previous DDS sample, unless ('t' - 't2') is greater than **source_timestamp_resolution**. If **source_timestamp_resolution** is DURATION_INFINITE, every DDS sample in the batch will share the source timestamp associated with the first DDS sample. If **source_timestamp_resolution** is zero, every DDS sample in the batch will contain its own source timestamp corresponding to the moment when the DDS sample was written. The performance of the batching process is better when **source_timestamp_resolution** is set to DURATION_ INFINITE.
DDS_ Boolean	thread_ safe_write	Determines whether or not the write operation is thread-safe. If TRUE, multiple threads can call write on the *DataWriter* concurrently. A setting of FALSE can be used to increase batching throughput for batches with many small DDS samples.

If batching is enabled (not the default), DDS samples are not immediately sent when they are written. Instead, they get collected into a "batch." A batch always contains whole number of DDS samples—a DDS sample will never be fragmented into multiple batches.

A batch is sent on the network ("flushed") when one of the following things happens:

- User-configurable flushing conditions
  - A batch size limit (**max_data_bytes**) is reached.
  - A number of DDS samples are in the batch (**max_samples**).
  - A time-limit (**max_flush_delay**) is reached, as measured from the time the first DDS sample in the batch is written by the application.
  - The application explicitly calls a *DataWriter's* **flush()** operation.
- Non-user configurable flushing conditions:
  - A coherent set starts or ends.
  - The number of DDS samples in the batch is equal to **max_samples** in RESOURCE_LIMITS for unkeyed topics or **max_samples_per_instance** in RESOURCE_LIMITS for keyed topics.

Additional batching configuration takes place in the *Publisher's* 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344.

The **flush()** operation is described in 7.3.9 Flushing Batches of DDS Data Samples on page 314.

7.5.2.1 Synchronous and Asynchronous Flushing

Usually, a batch is flushed synchronously:

- When a batch reaches its application-defined size limit (**max_data_bytes** or **max_samples**) because the application called **write()**, the batch is flushed immediately in the context of the writing thread.
- When an application manually flushes a batch, the batch is flushed immediately in the context of the calling thread.
- When the first DDS sample in a coherent set is written, the batch in progress (without including the DDS sample in the coherent set) is immediately flushed in the context of the writing thread.
- When a coherent set ends, the batch in progress is immediately flushed in the context of the calling thread.
- When the number of DDS samples in a batch is equal to **max_samples** in RESOURCE_LIMITS for unkeyed topics or **max_samples_per_instance** in RESOURCE_LIMITS for keyed topics, the batch is flushed immediately in the context of the writing thread.

However, some behavior is asynchronous:

- To flush batches based on a time limit (**max_flush_delay**), enable asynchronous batch flushing in the 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344 of the *DataWriter's Publisher*. This will cause the *Publisher* to create an additional thread that will be used to flush batches of that *Publisher's DataWriters*. This behavior is analogous to the way asynchronous publishing works.
- You may also use batching alongside asynchronous publication with 7.6 FlowControllers (DDS Extension) on page 467. These features are independent of one another. Flushing a batch on an asynchronous *DataWriter* makes it available for sending to the *DataWriter's* FlowController. From the point of view of the FlowController, a batch is treated like one large DDS sample.

7.5.2.2 Batching vs. Coalescing

Even when batching is disabled, *Connext DDS* will sometimes coalesce multiple DDS samples into a single network datagram. For example, DDS samples buffered by a FlowController or sent in response to a negative acknowledgement (NACK) may be coalesced. This behavior is distinct from DDS sample batching.

DDS samples that are sent individually (not part of a batch) are always treated as separate DDS samples by *Connext DDS*. Each DDS sample is accompanied by a complete RTPS header on the network

(although DDS samples may share UDP and IP headers) and (in the case of reliable communication) a unique physical sequence number that must be positively or negatively acknowledged.

In contrast, batched DDS samples share an RTPS header and an entire batch is acknowledged —positively or negatively—as a unit, potentially reducing the amount of meta-traffic on the network and the amount of processing per individual DDS sample.

Batching can also improve latency relative to simply coalescing. Consider two use cases:

1. A *DataWriter* is configured to write asynchronously with a FlowController. Even if the FlowController's rules would allow it to publish a new DDS sample immediately, the send will always happen in the context of the asynchronous publishing thread. This context switch can add latency to the send path.
2. A *DataWriter* is configured to write synchronously but with batching turned on. When the batch is full, it will be sent on the wire immediately, eliminating a thread context switch from the send path.

7.5.2.3 Batching and ContentFilteredTopics

When batching is enabled, content filtering is always done on the reader side.

7.5.2.4 Turbo Mode: Automatically Adjusting the Number of Bytes in a Batch—Experimental Feature

Turbo Mode is an experimental feature that uses an intelligent algorithm that automatically adjusts the number of bytes in a batch at run time according to current system conditions, such as write speed (or write frequency) and DDS sample size. This intelligence is what gives it the ability to increase throughput at high message rates and avoid negatively impacting message latency at low message rates.

To enable Turbo mode, set the *DataWriter's* property **dds.data_writer.enable_turbo_mode** to true. Turbo mode is not enabled by default.

Note: If you explicitly enable batching by setting enable to TRUE in BatchQosPolicy, the value of the turbo mode property is ignored and turbo mode is not used.

7.5.2.5 Performance Considerations

The purpose of batching is to increase throughput when writing small DDS samples at a high rate. In such cases, throughput can be increased several-fold, approaching much more closely the physical limitations of the underlying network transport.

However, collecting DDS samples into a batch implies that they are not sent on the network immediately when the application writes them; this can potentially increase latency. However, if the application sends data faster than the network can support, an increased proportion of the network's available bandwidth will be spent on acknowledgements and DDS sample resends. In this case, reducing that overhead by turning on batching could decrease latency while increasing throughput.

As a general rule, to improve batching throughput:

- Set **thread_safe_write** to FALSE when the batch contains a big number of small DDS samples. If you do not use a thread-safe write configuration, asynchronous batch flushing must be disabled.
- Set **source_timestamp_resolution** to DURATION_INFINITE. Note that you set this value, every DDS sample in the batch will share the same source timestamp.

Batching affects how often piggyback heartbeats are sent; see **heartbeats_per_max_samples** in Table 7.44 DDS_RtpsReliableWriterProtocol_t.

7.5.2.6 Maximum Transport Datagram Size

Batches cannot be fragmented. As a result, the maximum batch size (**max_data_bytes**) must be set no larger than the maximum transport datagram size. For example, a UDP datagram is limited to 64 KB, so any batches sent over UDP must be less than or equal to that size.

7.5.2.7 Bandwidth Considerations

A minimum overhead of 8-bytes is added to each sample in a batch; however, the overhead may be bigger in some cases. For example:

- When you add a source timestamp per sample instead of per batch, there will be 8 more bytes for the source timestamp. You can control this behavior with **writer_qos.batch.source_timestamp_resolution**.
- By default, for keyed topics, *Connext DDS* adds the key hash for the instance, adding an extra overhead of 20 bytes. If you don't want to add the key hash and instead get it from the serialized data on the *DataReader* side, set **writer_qos.protocol.disable_inline_keyhash** to true.
- Disposed/unregistered samples also need an additional 8-byte overhead to mark the status as disposed or unregistered.
- There are other scenarios in which overhead may increase—for example, when using collaborative *DataWriters* or group order access.

To summarize:

- For a data sample for a keyed topic, by default, the overhead will be 32-bytes (8 (minimum) + 20 (for the key hash) + 4 (for the sentinel)). You can reduce this to 8 bytes by not sending the key hash (in which case, the sentinel goes away, too).
- For disposed/unregistered samples for a keyed topic, by default, the overhead will be 40-bytes (8 (minimum) + 20 (for the key hash) + 8 (for the status information) + 4 (for the sentinel)). You can

reduce this to 20 bytes by not sending the key hash (the sentinel remains for the status information).

- For an unkeyed topic, the overhead is typically 8 bytes.

7.5.2.8 Properties

This QosPolicy cannot be modified after the *DataWriter* is enabled.

Since it is only for *DataWriters*, there are no compatibility restrictions for how it is set on the publishing and subscribing sides.

All batching configuration occurs on the publishing side. A subscribing application does not configure anything specific to receive batched DDS samples, and in many cases, it will be oblivious to whether the DDS samples it processes were received individually or as part of a batch.

Consistency rules:

- **max_samples** must be consistent with **max_data_bytes**: they cannot both be set to LENGTH_UNLIMITED.
- If **max_flush_delay** is not DURATION_INFINITE, **disable_asynchronous_batch** in the 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344 must be FALSE.
- If **thread_safe_write** is FALSE, **source_timestamp_resolution** must be DURATION_INFINITE.

7.5.2.9 Related QosPolicies

To flush batches based on a time limit, enable batching in the 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344 of the *DataWriter's Publisher*.

Be careful when configuring a *DataWriter's* 7.5.14 LIFESPAN QoS Policy on page 423 with a **duration** shorter than the batch flush period (**max_flush_delay**). If the batch does not fill up before the flush period elapses, by default the short **duration** will cause the DDS samples to be dropped without being sent. (You can, however, change this default behavior. See the last paragraph in this section.)

Do not configure the *DataReader's* or *DataWriter's* 7.5.12 HISTORY QosPolicy on page 418 to be shallower than the *DataWriter's* maximum batch size (**max_samples**). When the HISTORY QosPolicy is shallower on the *DataWriter*, by default some DDS samples may not be sent. (You can, however, change this default behavior. See the last paragraph in this section.) When the HISTORY QosPolicy is shallower on the *DataReader*, DDS samples may be lost before being provided to the application.

The initial and maximum numbers of batches that a *DataWriter* will manage is set in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400.

The maximum number of DDS samples that a *DataWriter* can store is determined by the value **max_samples** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 and **max_batches** in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400. The limit that is reached first is applied.

The amount of resources required for batching depends on the configuration of the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 and the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400. See 7.5.2.11 System Resource Considerations below.

By default, samples marked as removed in a batch are dropped. Examples of removed samples in a batch are samples that were replaced due to KEEP_LAST_HISTORY_QOS on the *DataWriter* (see 7.5.12 HISTORY QosPolicy on page 418) or samples that outlived the *DataWriter's* 7.5.14 LIFESPAN QoS Policy on page 423 duration. You can keep track of the number of these dropped samples via **writer_removed_batch_sample_dropped_sample_count** in the 8.3.7.2 DATA_READER_CACHE_STATUS on page 514. You can also choose not to drop these samples at all by setting the property **dds.data_reader.accept_writer_removed_batch_samples** to TRUE (by default it is set to FALSE); you can set this property via the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.

> **Note:** When the *DataWriter* history depth is shallower than the *DataWriter's* maximum batch size (**max_samples**), the excess samples are marked as removed, but you can choose *not* to drop these removed samples using the **accept_writer_removed_batch_samples** property. But when the *DataReader* history depth is shallower than the *DataWriter's* maximum batch size (**max_samples**), the excess samples are lost. (These are not affected by the property or included in the dropped sample count.)

7.5.2.10 Applicable DDS Entities

- 7.3 DataWriters on page 286

7.5.2.11 System Resource Considerations

- Batching requires additional resources to store the meta-data associated with the DDS samples in the batch.
  - For unkeyed topics, the meta-data will be at least 8 bytes, with a maximum of 20 bytes.
  - For keyed topics, the meta-data will be at least 8 bytes, with a maximum of 52 bytes.
- Other resource considerations are described in 7.5.2.9 Related QosPolicies on the previous page.

7.5.3 DATA_REPRESENTATION QosPolicy

The DATA_REPRESENTATION QosPolicy is used to configure what form data is represented or expected in on the wire. It indicates which versions (version 1 and version 2) of the Extended Common Data Representation (CDR) are offered and requested as well as if and how the data may be compressed, including which compression algorithm is offered and requested.

A *DataWriter* might also offer a single representation, which indicates the CDR version the *DataWriter* uses to serialize its data. A *DataReader* requests one or more representations, which indicate the CDR versions the *DataReader* accepts. If a *DataWriter*'s offered representation is contained within a reader's

sequence of requested representations, then the offer satisfies the request, and the policies are compatible. Otherwise, they are incompatible.

A *DataWriter* also offers a single **compression_id**, which is the compression algorithm the *DataWriter* uses to compress data it sends to matching *DataReaders*. A *DataReader* requests zero or more compression algorithms. If a *DataWriter* offers a compression algorithm that is contained within the algorithms requested by the *DataReader*, the offer satisfies the request and the policies are compatible. Otherwise, they are incompatible.

The DATA_REPRESENTATION QosPolicy includes the members in Table 7.37 DDS_DataRepresentationQosPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 7.37 DDS_DataRepresentationQosPolicy

Type	Field Name	Description
DDS_DataRepresentationIdSeq	value	A sequence of two-byte signed integers corresponding to representation identifiers. The supported identifiers are DDS_XCDR_DATA_REPRESENTATION (Extensible CDR version 1), DDS_XCDR2_DATA_REPRESENTATION (Extensible CDR version 2), and DDS_AUTO_DATA_REPRESENTATION. An empty sequence is equivalent to a sequence with one DDS_XCDR_DATA_REPRESENTATION element. The default value, however, is a sequence with one DDS_AUTO_DATA_REPRESENTATION element. For plain language binding, the value DDS_AUTO_DATA_REPRESENTATION translates to DDS_XCDR_DATA_REPRESENTATION if the @allowed_data_representation annotation either is not specified or contains the value XCDR. Otherwise, it translates to DDS_XCDR2_DATA_REPRESENTATION. For FlatData language binding, DDS_AUTO_DATA_REPRESENTATION translates to XCDR2_DATA_REPRESENTATION. (See 7.5.3.1 Data Representation on the next page for further explanation.) For additional information on the @allowed_data_representation annotation, see *Data Representation*, in the RTI Connext DDS Core Libraries Extensible Types Guide.

Table 7.37 DDS_DataRepresentationQosPolicy

Type	Field Name	Description
DDS_CompressionSettings_t	compression_settings	Settings related to compressing user data: • compression_ids: A bitmap that represents the compression algorithm IDs supported by the *DataWriter* or *DataReader*. The possible values are: COMPRESSION_ID_ZLIB, COMPRESSION_ID_BZIP2, COMPRESSION_ID_LZ4, COMPRESSION_ID_MASK_NONE, and COMPRESSION_ID_MASK_ALL. Only COMPRESSION_ID_ZLIB is supported if the *DataWriter* is using both compression and batching. Compression is not supported if also using batching and data protection (via *RTI Security Plugins*). See 7.5.3.2 Data Compression on the next page. *DataWriter* creation will fail if more than one algorithm is provided on the *DataWriter* side (meaning that COMPRESSION_ID_MASK_ALL is only supported for *DataReaderQos* and *TopicQos*). Default: COMPRESSION_ID_MASK_NONE (for *DataWriterQoS* and *TopicQoS*), COMPRESSION_ID_MASK_ALL (for *DataReaderQoS)* • writer_compression_level: The level of compression to use when compressing data. The value is a range between 0 and 10. It can be set only for the *DataWriterQoS* or *TopicQoS*. A lower compression level results in a faster compression speed, but lower compression ratio. A higher compression level results in a better compression ratio, but slower compression speed. Default: COMPRESSION_LEVEL_BEST_COMPRESSION (10) • writer_compression_threshold: The threshold, in bytes, above which a serialized sample is eligible to be compressed. The value is a range between 0 and LENGTH_UNLIMITED. It can be set only for the *DataWriterQoS* or *TopicQoS*. Any sample with a serialized size equal to or greater than the threshold will be eligible to be compressed. Only if the compressed size is smaller than the serialized size will the sample be stored and sent compressed on the wire. Setting the threshold to LENGTH_UNLIMITED disables compression. Default: COMPRESSION_THRESHOLD_DEFAULT (8192 bytes) See 7.5.3.2 Data Compression on the next page for more details.

7.5.3.1 Data Representation

You can view data representation as a two-step process:

1. As described above, DDS_AUTO_DATA_REPRESENTATION translates to the value DDS_XCDR_DATA_REPRESENTATION or DDS_XCDR2_DATA_REPRESENTATION depending on a few factors. Or you can explicitly set the value to DDS_XCDR_DATA_REPRESENTATION or DDS_XCDR2_DATA_REPRESENTATION. If you let DDS_AUTO_DATA_REPRESENTATION set the value, the following table shows how it will be set, depending on your IDL:

Table 7.38 How DDS_AUTO_DATA_REPRESENTATION Sets the Value

IDL looks like ...	AUTO value translates to ...

`Struct Point {`
`}`
which is equivalent to:
`@allowed_data_representation(XCDR | XCDR2)`
`Struct Point {`
`}`
	XCDR

`@allowed_data_representation(XCDR2)`
`Struct Point {`
`}`
	XCDR2

`@language_binding(FLAT_DATA)`
`Struct Point {`
`}`
	XCDR2

2. Once the value is set (either by DDS_AUTO_DATA_REPRESENTATION or explicitly by you), that value determines what the *DataWriter* writes or the *DataReader* reads. (Recall that the *DataWriter* offers one representation; the *DataReader* requests one or more representations.) The next step is how the *DataWriter* and *DataReader* match based on the QoS value. The QoS must be compatible between the *DataWriter* and the *DataReader*. The compatible combinations are shown in Table 7.37 DDS_DataRepresentationQosPolicy.

Table 7.39 Valid Reader/Writer Combinations of DataRepresentation

DataWriter-offered DataRepresentation value	DataReader-requested DataRepresentation values
XCDR	XCDR
XCDR	XCDR and XCDR2
XCDR2	XCDR2
XCDR2	XCDR and XCDR2

If this QosPolicy is set incompatibly, the ON_OFFERED_INCOMPATIBLE_QOS and ON_REQUESTED_INCOMPATIBLE_QOS statuses will be modified and the corresponding *Listeners* called for the *DataWriter* and *DataReader* respectively.

7.5.3.2 Data Compression

A *DataReader* with compression enabled can receive samples from *DataWriters* with or without compression as well as from multiple *DataWriters* with different compression algorithms. *DataWriters* cannot optionally send compressed samples to some *DataReaders* and the same samples, but uncompressed, to other *DataReaders* that do not support compression.

7.5.3.2.1 compression_ids

You can compare the compression algorithms (LZ4, zlib, and bzip2) by checking their compression ratios against their compression speeds. The compression ratio defines how much the data size is reduced. For example, a ratio of 2 means that the size of the data is reduced by half. The compression speed has a direct impact on the latency of the compressed data; the slower the speed, the higher the latency. Generally, the higher the compression ratio, the lower the speed; the higher the speed, the lower the compression ratio.

Table 7.40 Compression Algorithm References

compression_ids	Information
COMPRESSION_ID_MASK_NONE	Default for *DataWriterQoS* and *TopicQoS*
COMPRESSION_ID_LZ4	See https://github.com/lz4/lz4
COMPRESSION_ID_ZLIB	See https://zlib.net/
COMPRESSION_ID_BZIP2	See https://www.sourceware.org/bzip2/
COMPRESSION_ID_MASK_ALL	Default for *DataReaderQoS*

There are many benchmarking resources comparing various compression algorithms. One such resource is https://github.com/inikep/lzbench. LZ4 is considered the fastest of the three builtin algorithms, while zlib and bzip2 give the best compression ratios. Use LZ4 if you want to keep latency as low as possible while maintaining a decent compression ratio. Use zlib or bzip2 if latency is less important in your system than a high compression ratio to reduce bandwidth usage. The choice of which of the three builtin compression algorithms to use depends on the type of data, the rate at which the data is being sent, and latency and bandwidth considerations. It is a good idea for you to understand the strengths and weaknesses of each of the builtin algorithms, and perform benchmarking in your own system so that you can choose the algorithm that is best suited to your system.

When you specify compression settings for a *Topic*, all *DataWriters* and *DataReaders* for that *Topic* inherit the *Topic's* compression settings. If you specify multiple compression algorithms for a *Topic*, the *DataReader* will use all of them, but since the *DataWriter* can have only one algorithm enabled, it will choose one of them, in the following order: COMPRESSION_ID_ZLIB, COMPRESSION_ID_BZIP2, and COMPRESSION_ID_LZ4.

Notes:

- When the **serialize_key_with_dispose** field in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388 is enabled and a dispose message is sent, the serialized key is not compressed.
- The only algorithm supported when compression and batching are enabled on the same *DataWriter* is COMPRESSION_ID_ZLIB, because zlib is the only builtin algorithm that supports stream-based

compression with acceptable performance. Stream-based compression allows *Connext DDS* to compress and build the batch as samples are written into the batch. (LZ4 also supports stream-based compression, but with a high performance penalty, so RTI has decided not to support this mode in *Connext DDS*.)

- **If you are using *Security Plugins* and batching:** The combination of compression, batching, and data protection (via *Security Plugins*) is not supported and will result in a *DataWriter* creation error. Consider using RTPS protection instead of data protection if compression and batching are also required. The reason for this restriction is that when using batching, compression is applied to the entire batch, while data protection is applied to each of the batch samples individually. Compressing already encrypted data results in an expansion of the data instead of a reduction of it because encrypted data does not lend itself to compression.

7.5.3.2.2 writer_compression_level

Each level between 0 and 10 has trade-offs between compression ratio and compression speed, with 1 representing the fastest speed and lowest compression ratio and 10 representing the slowest speed and highest compression ratio. (0 disables compression.)

Connext DDS also provides the following **writer_compression_level** values:

- COMPRESSION_LEVEL_BEST_COMPRESSION. This value is the same as 10. With this value, *Connext DDS* chooses the best compression level for the given algorithm.
- COMPRESSION_LEVEL_BEST_SPEED. This value is the same as 1. With this value, *Connext DDS* chooses the fastest compression speed for whatever algorithm is chosen.

COMPRESSION_LEVEL_BEST_COMPRESSION and COMPRESSION_LEVEL_BEST_SPEED do not vary dynamically depending on the algorithm and the size of the data. They have a strict one-to-one mapping to the algorithms' compression ratios/speeds as follows:

- zlib

writer_compression_level	zlib mapped value
COMPRESSION_LEVEL_BEST_COMPRESSION = 10	level = 9
COMPRESSION_LEVEL_BEST_SPEED = 1	level = 1

For the rest of the values, a linear normalization is applied, so any **writer_compression_level** value you enter in the range of 1 to 10 is translated to the range used by ZLIB between 1 and 9. See the zlib documentation for the **compress2** function for more details on how the level parameter is used.

- LZ4

writer_compression_level	LZ4 mapped value
COMPRESSION_LEVEL_BEST_COMPRESSION = 10	acceleration = 0
COMPRESSION_LEVEL_BEST_SPEED = 1	acceleration = 30

  For the rest of the values, a linear normalization is applied, so any **writer_compression_level** value you enter in the range of 1 to 10 is translated to the range used by LZ4 between 30 and 0. Although technically the acceleration value is unbounded, *Connext DDS* sets the limit at 30; beyond that, no compression occurs in most cases. See the LZ4 documentation for the **LZ4_compress_fast** function for more details on how the acceleration parameter is used.

- bzip2

writer_compression_level	bzip2 mapped value
COMPRESSION_LEVEL_BEST_COMPRESSION = 10	blockSize100k = 9
COMPRESSION_LEVEL_BEST_SPEED = 1	blockSize100k = 1

  For the rest of the values, a linear normalization is applied, so any **writer_compression_level** value you enter in the range of 1 to 10 is translated to the range used by bzip2 between 1 and 9. See the bzip2 documentation for the **BZ2_bzBuffToBuffCompress** function for more details on how the blockSize100k parameter is used.

7.5.3.2.3 writer_compression_threshold

Any sample with a serialized size equal to or greater than this threshold (see Table 7.37 DDS_DataRepresentationQosPolicy) is eligible to be compressed.

There are two scenarios where a sample, even with compression enabled on the *DataWriter*, is not compressed:

- Any sample with a serialized size lower than the writer_compression_threshold will not be compressed.

  If batching is enabled: a batch will not be compressed if the maximum serialized size of the batch (**max_sample_serialized_size** as returned by the type-plugin **get_serialized_sample_max_size()**) * **max_samples in the batch**) is smaller than the writer_compression_threshold. See information about **max_samples** in 7.5.2 BATCH QosPolicy (DDS Extension) on page 373.

- If the compressed size is bigger than the sample's serialized size, the compressed sample will be discarded and the original sample will be sent instead.

7.5.3.2.4 Connext DDS Micro

Connext DDS Micro does not interoperate with *DataWriters* that send compressed data.

7.5.3.2.5 Performance Considerations when Using Content Filtering and Compression

Samples are stored compressed in the *DataWriter's* queue. When a sample is being written and there are matching *DataReaders* using ContentFilteredTopics, the *DataWriter* will apply the filter and then compress the sample. In some cases, a sample needs to be filtered again after it has already been compressed. This can happen, for example, when a non-VOLATILE, late-joining *DataReader* with a ContentFilteredTopic is discovered by the *DataWriter* or a TopicQuery is issued by an existing *DataReader*. If a filtering operation occurs on the *DataWriter* side after the sample is already compressed, the sample must be decompressed to apply the filter, increasing the latency for these requested samples. Note that in these scenarios the original compressed sample is kept around, so a sample is never compressed twice. In other words, *Connext DDS* decompresses the sample into a separate buffer, performs the filtering, and then either sends or doesn't send the compressed sample.

7.5.3.2.6 Using Compression with FlatData language binding and Zero Copy Transfer over Shared Memory

See FlatData's section 23.5.2.4 Interactions with RTI Security Plugins and Compression on page 952 for notes about interactions with the FlatData language binding.

See Zero Copy's section 23.6.1.5 Interactions with RTI Security Plugins and Compression on page 958 for information about interactions with Zero Copy transfer over shared memory.

7.5.3.3 Properties

This QosPolicy cannot be modified after the Entity has been enabled.

7.5.3.4 Applicable Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.4 DATATAG QosPolicy

The DATATAG QosPolicy can be used to associate a set of tags in the form of (name, value) pairs with a *DataReader* or *DataWriter*. The Access Control plugin may use the tags to determine publish and subscribe permissions.

The DATATAG QosPolicy is similar to the PropertyQosPolicy, except you cannot select whether or not a particular pair should be propagated (included in the built-in topic); data tags are always propagated. For example, with the Property QoS, it would be possible for a *DomainParticipant* to allow its own endpoint (*DataReader* or *DataWriter*) based on some required properties, and for a remote *DomainParticipant* to deny that same endpoint because the endpoint chose not to propagate the required properties to the remote *DomainParticipant*. To avoid such inconsistencies—and because other participants *must* know about a *DomainParticipant*'s security credentials—data tags in the DATATAG QosPolicy are always propagated.

This policy includes the member listed in Table 7.41 DDS_DataTagQosPolicy.

Table 7.41 DDS_DataTagQosPolicy

Type	Field Name	Description
DDS_TagSeq	tags	A sequence of (name, value) string pairs.

You can manipulate the sequence of tags (name, value pairs) with the standard methods available for sequences. You can also use the helper class, DataTagQosPolicyHelper, which provides another way to work with a DataTagQosPolicy object. The DataTagQosPolicyHelper operations are described in the following table. For more information, see the API Reference HTML documentation.

Table 7.42 DDS_DataTagQosPolicyHelper Operations

Operation	Description
get_number_of_tags	Gets the number of data tags in the input policy.
assert_tag	Asserts the data tag identified by name in the input policy. (Either adds it, or replaces an existing one.)
add_tag	Adds a new data tag to the input policy.
lookup_tag	Searches for a data tag in the input policy given its name.
remove_tag	Removes a data tag from the input policy.

7.5.4.1 Properties

This QosPolicy cannot be modified after the Entity has been created. There is no requirement that the publishing and subscribing sides use compatible values.

7.5.4.2 Related QosPolicies

9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649

7.5.4.3 Applicable Entities

- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.4.4 System Resource Considerations

9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649 contains several fields for configuring the resources associated with the data tags stored in this QosPolicy.

7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension)

Connext DDS uses a standard protocol for packet (user and meta data) exchange between applications. The DataWriterProtocol QosPolicy gives you control over configurable portions of the protocol, including the configuration of the reliable data delivery mechanism of the protocol on a per *DataWriter* basis.

These configuration parameters control timing and timeouts, and give you the ability to trade off between speed of data loss detection and repair, versus network and CPU bandwidth used to maintain reliability.

It is important to tune the reliability protocol on a per *DataWriter* basis to meet the requirements of the end-user application so that data can be sent between *DataWriters* and *DataReaders* in an efficient and optimal manner in the presence of data loss. You can also use this QosPolicy to control how *Connext DDS* responds to "slow" reliable *DataReaders* or ones that disconnect or are otherwise lost.

This policy includes the members presented in Table 7.43 DDS_DataWriterProtocolQosPolicy and Table 7.44 DDS_RtpsReliableWriterProtocol_t. For defaults and valid ranges, please refer to the API Reference HTML documentation.

For details on the reliability protocol used by *Connext DDS*, see Reliable Communications (Chapter 11 on page 682). See the 7.5.21 RELIABILITY QosPolicy on page 444 for more information on per-*DataReader/DataWriter* reliability configuration. The 7.5.12 HISTORY QosPolicy on page 418 and 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 also play important roles in the DDS reliability protocol.

Table 7.43 DDS_DataWriterProtocolQosPolicy

Type	Field Name	Description
DDS_GUID_t	virtual_guid	The virtual GUID (Global Unique Identifier) is used to uniquely identify the same *DataWriter* across multiple incarnations. In other words, this value allows *Connext DDS* to remember information about a *DataWriter* that may be deleted and then recreated. *Connext DDS* uses the virtual GUID to associate a durable writer history to a *DataWriter*. *Persistence Service* uses the virtual GUID to send DDS samples on behalf of the original *DataWriter*. A *DataReader* persists its state based on the virtual GUIDs of matching remote *DataWriters*. For more information, see 13.2 Durability and Persistence Based on Virtual GUIDs on page 731. By default, *Connext DDS* will assign a virtual GUID automatically. If you want to restore the state of the durable writer history after a restart, you can retrieve the value of the writer's virtual GUID using the *DataWriter's* **get_qos()** operation, and set the virtual GUID of the restarted *DataWriter* to the same value.
DDS_ Unsigned-Long	rtps_object_id	Determines the *DataWriter's* RTPS object ID, according to the DDS-RTPS Interoperability Wire Protocol. Only the last 3 bytes are used; the most significant byte is ignored. The **rtps_host_id**, **rtps_app_id**, and **rtps_instance_id** in the 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664, together with the 3 least significant bytes in **rtps_object_id**, and another byte assigned by *Connext DDS* to identify the entity type, forms the BuiltinTopicKey in PublicationBuiltinTopicData.
DDS_Boolean	push_on_write	Controls when a DDS sample is sent after **write()** is called on a *DataWriter*. If TRUE, the DDS sample is sent immediately; if FALSE, the DDS sample is put in a queue until an ACK/NACK is received from a reliable *DataReader*.
DDS_Boolean	disable_positive_acks	Determines whether matching *DataReaders* send positive acknowledgements (ACKs) to the *DataWriter*. When TRUE, the *DataWriter* will keep DDS samples in its queue for ACK-disabled readers for a minimum keep duration (see 7.5.5.3 Disabling Positive Acknowledgements on page 395). When strict reliability is not required, setting this to TRUE reduces overhead network traffic.
DDS_Boolean	disable_inline_keyhash	Controls whether or not the key-hash is propagated on the wire with DDS samples. This field only applies to keyed writers. *Connext DDS* associates a key-hash (an internal 16-byte representation) with each key. When FALSE, the key-hash is sent on the wire with every data instance. When TRUE, the key-hash is not sent on the wire (so the readers must compute the value using the received data). If the *reader* is CPU bound, sending the key-hash on the wire may increase performance, because the reader does not have to get the key-hash from the data. If the writer is CPU bound, sending the key-hash on the wire may decrease performance, because it requires more bandwidth (16 more bytes per DDS sample). Setting **disable_inline_keyhash** to TRUE is not compatible with using RTI Database Integration Service or RTI Recording Service.

Table 7.43 DDS_DataWriterProtocolQosPolicy

Type	Field Name	Description
DDS_Boolean	serialize_key_with_dispose	Controls whether or not the serialized key is propagated on the wire with dispose notifications. This field only applies to keyed writers. RTI recommends setting this field to TRUE if there are *DataReaders* with **propagate_dispose_of_unregistered_instances** (in the 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565) also set to TRUE. Important: When this field TRUE, batching will not be compatible with *RTI Data Distribution Service* 4.3e, 4.4b, or 4.4c–the *DataReaders* will receive incorrect data and/or encounter deserialization errors.
DDS_Boolean	propagate_app_ack_with_no_response	Controls whether or not a *DataWriter* receives **on_application_acknowledgment()** notifications with an empty or invalid response. When FALSE, **on_application_acknowledgment()** will not be invoked if the DDS sample being acknowledged has an empty or invalid response.
DDS_RtpsReliableWriterProtocol_t	rtps_reliable_writer	This structure includes the fields in Table 7.44 DDS_RtpsReliableWriterProtocol_t.
DDS_Sequence_t	initial_virtual_sequence_number	Determines the initial virtual sequence number for this *DataWriter*. By default, the virtual sequence number of the first sample published by a *DataWriter* is 1 for *DataWriters* that do not use durable writer history. For durable writers, the default virtual sequence number is the last sequence number they published in a previous execution, plus one. So, when a non-durable *DataWriter* is restarted and must continue communicating with the same *DataReaders*, its samples start over with sequence number 1. Durable *DataWriters* start over where the last sequence number left off, plus one. This QoS setting allows overwriting the default initial virtual sequence number. Normally, this parameter is not expected to be modified; however, in some scenarios when continuing communication after restarting, applications may require the *DataWriter's* virtual sequence number to start at something other than the value described above. An example would be to enable non-durable *DataWriters* to start at the last sequence number published, plus one, similar to the durable *DataWriter*. This property enables you to make such a configuration, if desired. The virtual sequence number can be overwritten as well on a per sample basis by updating **DDS_WriteParams_t::identity** in FooDataWriter_write_w_params.

Table 7.44 DDS_RtpsReliableWriterProtocol_t

Type	Field Name	Description
DDS_Long	low_watermark	Queue levels that control when to switch between the regular and fast heartbeat rates (heartbeat_period on the next page and fast_heartbeat_period on the next page). See 7.5.5.1 High and Low Watermarks on page 393.
	high_watermark	

Table 7.44 DDS_RtpsReliableWriterProtocol_t

Type	Field Name	Description
DDS_Duration_t	heartbeat_period fast_heartbeat_period late_joiner_heartbeat_period	Rates at which to send heartbeats to *DataReaders* with unacknowledged DDS samples. See 7.5.5.2 Normal, Fast, and Late-Joiner Heartbeat Periods on page 394 and 11.3.4.1 How Often Heartbeats are Resent (heartbeat_period) on page 698.
DDS_Duration_t	virtual_heartbeat_period	The rate at which a reliable *DataWriter* will send virtual heartbeats. Virtual heartbeat informs the reliable *DataReader* about the range of DDS samples currently present for each virtual GUID in the reliable writer's queue. See 7.5.5.6 Virtual Heartbeats on page 398.
DDS_Long	samples_per_virtual_heartbeat	The number of DDS samples that a reliable *DataWriter* must publish before sending a virtual heartbeat. See 7.5.5.6 Virtual Heartbeats on page 398.
DDS_Long	max_heartbeat_retries	Maximum number of *periodic* heartbeats sent without receiving an ACK/NACK packet before marking a *DataReader* 'inactive.' When a *DataReader* has not acknowledged all the DDS samples the reliable *DataWriter* has sent to it, and **max_heartbeat_retries** number of periodic heartbeats have been sent without receiving any ACK/NACK packets in return, the *DataReader* will be marked as inactive (not alive) and be ignored until it resumes sending ACK/NACKs. Note that *piggyback* heartbeats do *not* count towards this value. See 11.3.4.4 Controlling How Many Times Heartbeats are Resent (max_heartbeat_retries) on page 703.
DDS_Boolean	inactivate_nonprogressing_readers	Allows the *DataWriter* to treat *DataReaders* that send successive non-progressing NACK packets as inactive. See 11.3.4.5 Treating Non-Progressing Readers as Inactive Readers (inactivate_nonprogressing_readers) on page 703.
DDS_Long	heartbeats_per_max_samples	A piggyback heartbeat is sent every [current send-window size/heartbeats_per_max_samples] number of DDS samples written. If set to zero, no piggyback heartbeat will be sent. If the current send-window size is LENGTH_UNLIMITED, 100 million is assumed as the value in the calculation. See 7.5.5.4 Configuring the Send Window Size on page 396.
DDS_Boolean	disable_repair_piggyback_heartbeat	When samples are repaired, the *DataWriter* resends the number of bytes indicated in max_bytes_per_nack_response and a piggyback heartbeat with each message. You can configure the *DataWriter* to not send the piggyback heartbeat, by setting this field to TRUE, and instead rely on the late_joiner_heartbeat_period to control the throughput used to repair samples. This field is only mutable for the *DataWriter* QoS and not for the Discovery Config QoS of the *DomainParticipant*.
DDS_Duration_t	min_nack_response_delay	Minimum delay to respond to an ACK/NACK. When a reliable *DataWriter* receives an ACK/NACK from a *DataReader*, the *DataWriter* can choose to delay a while before it sends repair DDS samples or a heartbeat. This set the value of the minimum delay. See 11.3.4.6 Coping with Redundant Requests for Missing DDS Samples (max_nack_response_delay) on page 703.

Table 7.44 DDS_RtpsReliableWriterProtocol_t

Type	Field Name	Description
DDS_Duration_t	max_nack_response_delay	Maximum delay to respond to a ACK/NACK. This sets the value of maximum delay between receiving an ACK/NACK and sending repair DDS samples or a heartbeat. A longer wait can help prevent storms of repair packets if many *DataReaders* send NACKs at the same time. However, it delays the repair, and hence increases the latency of the communication. See 11.3.4.6 Coping with Redundant Requests for Missing DDS Samples (max_nack_response_delay) on page 703.
DDS_Duration_t	nack_suppression_duration	How long consecutive NACKs are suppressed. When a reliable *DataWriter* receives consecutive NACKs within a short duration, this may trigger the *DataWriter* to send redundant repair messages. This value sets the duration during which consecutive NACKs are ignored, thus preventing redundant repairs from being sent.
DDS_Long	max_bytes_per_nack_response	Maximum bytes in a repair package. When a reliable *DataWriter* resends DDS samples, the total package size is limited to this value. Note: The reliable *DataWriter* will always send at least one sample. See 11.3.4.3 Controlling Packet Size for Resent DDS Samples (max_bytes_per_nack_response) on page 702.
DDS_Duration_t	disable_positive_acks_min_sample_keep_duration	Minimum duration that a DDS sample will be kept in the *DataWriter's* queue for ACK-disabled *DataReaders*. See 7.5.5.3 Disabling Positive Acknowledgements on page 395 and 11.3.4.7 Disabling Positive Acknowledgements (disable_positive_acks_min_sample_keep_duration) on page 705.
	disable_positive_acks_max_sample_keep_duration	Maximum duration that a DDS sample will be kept in the *DataWriter's* queue for ACK-disabled readers.
DDS_Boolean	disable_positive_acks_enable_adaptive_sample_keep_duration	Enables automatic dynamic adjustment of the 'keep duration' in response to network congestion.
DDS_Long	disable_positive_acks_increase_sample_keep_duration_factor	When the 'keep duration' is dynamically controlled, the lengthening of the 'keep duration' is controlled by this factor, which is expressed as a percentage. When the adaptive algorithm determines that the keep duration should be increased, this factor is multiplied with the current keep duration to get the new longer keep duration. For example, if the current keep duration is 20 milliseconds, using the default factor of 150% would result in a new keep duration of 30 milliseconds.
	disable_positive_acks_decrease_sample_keep_duration_factor	When the 'keep duration' is dynamically controlled, the shortening of the 'keep duration' is controlled by this factor, which is expressed as a percentage. When the adaptive algorithm determines that the keep duration should be decreased, this factor is multiplied with the current keep duration to get the new shorter keep duration. For example, if the current keep duration is 20 milliseconds, using the default factor of 95% would result in a new keep duration of 19 milliseconds.

Table 7.44 DDS_RtpsReliableWriterProtocol_t

Type	Field Name	Description
DDS_Long	min_send_window_size	Minimum and maximum size for the window of outstanding DDS samples. See 7.5.5.4 Configuring the Send Window Size on page 396.
	max_send_window_size	
DDS_Long	send_window_decrease_factor	Scales the current send-window size down by this percentage to decrease the effective send-rate in response to received negative acknowledgement. See 7.5.5.4 Configuring the Send Window Size on page 396.
DDS_Boolean	enable_multicast_periodic_heartbeat	Controls whether or not periodic heartbeat messages are sent over multicast. When enabled, if a reader has a multicast destination, the writer will send its periodic HEARTBEAT messages to that destination. Otherwise, if not enabled or the reader does not have a multicast destination, the writer will send its periodic HEARTBEATs over unicast.
DDS_Long	multicast_resend_threshold	Sets the minimum number of requesting readers needed to trigger a multicast resend. See 7.5.5.7 Resending Over Multicast on page 398.
DDS_Long	send_window_increase_factor	Scales the current send-window size up by this percentage to increase the effective send-rate when a duration has passed without any received negative acknowledgements. See 7.5.5.4 Configuring the Send Window Size on page 396
DDS_Duration	send_window_update_period	Period in which *DataWriter* checks for received negative acknowledgements and conditionally increases the send-window size when none are received. See 7.5.5.4 Configuring the Send Window Size on page 396

7.5.5.1 High and Low Watermarks

When the number of unacknowledged DDS samples in the current send-window of a reliable *DataWriter* meets or exceeds high_watermark on page 390, the 7.3.6.8 RELIABLE_WRITER_CACHE_CHANGED Status (DDS Extension) on page 304 will be changed appropriately, a listener callback will be triggered, and the *DataWriter* will start heartbeating its matched *DataReaders* at fast_heartbeat_period on page 391

When the number of DDS samples meets or falls below low_watermark on page 390, the 7.3.6.8 RELIABLE_WRITER_CACHE_CHANGED Status (DDS Extension) on page 304 will be changed appropriately, a listener callback will be triggered, and the heartbeat rate will return to the "normal" rate (heartbeat_period on page 391).

Having both high and low watermarks (instead of one) helps prevent rapid flickering between the rates, which could happen if the number of DDS samples hovers near the cut-off point.

Increasing the high and low watermarks will make the *DataWriters* less aggressive about seeking acknowledgments for sent data, decreasing the size of traffic spikes but slowing performance.

Decreasing the watermarks will make the *DataWriters* more aggressive, increasing both network utilization and performance.

If batching is used, high_watermark on page 390 and low_watermark on page 390 refer to batches, not DDS samples.

When min_send_window_size on the previous page and max_send_window_size on the previous page are not equal, the low and high watermarks are scaled down linearly to stay within the current send-window size. The value provided by configuration corresponds to the high and low watermarks for the max_send_window_size on the previous page.

7.5.5.2 Normal, Fast, and Late-Joiner Heartbeat Periods

The normal heartbeat_period on page 391 is used until the number of DDS samples in the reliable *DataWriter*'s queue meets or exceeds high_watermark on page 390; then fast_heartbeat_period on page 391 is used. Once the number of DDS samples meets or drops below low_watermark on page 390, the normal rate (heartbeat_period on page 391) is used again.

- fast_heartbeat_period on page 391 must be <= heartbeat_period on page 391

Increasing fast_heartbeat_period on page 391 increases the speed of discovery, but results in a larger surge of traffic when the *DataWriter* is waiting for acknowledgments.

Decreasing heartbeat_period on page 391 decreases the steady state traffic on the wire, but may increase latency by decreasing the speed of repairs for lost packets when the writer does not have very many outstanding unacknowledged DDS samples.

Having two periodic heartbeat rates, and switching between them based on watermarks:

- Ensures that all *DataReaders* receive all their data as quickly as possible (the sooner they receive a heartbeat, the sooner they can send a NACK, and the sooner the *DataWriter* can send repair DDS samples);
- Helps prevent the *DataWriter* from overflowing its resource limits (as its queue starts the fill, the *DataWriter* sends heartbeats faster, prompting the *DataReaders* to acknowledge sooner, allowing the *DataWriter* to purge these acknowledged DDS samples from its queue);
- Tunes the amount of network traffic. (Heartbeats and NACKs use up network bandwidth like any other traffic; decreasing the heartbeat rates, or increasing the threshold before the fast rate starts, can smooth network traffic—at the expense of discovery performance).

The late_joiner_heartbeat_period on page 391 is used when a reliable *DataReader* joins after a reliable *DataWriter* (with non-volatile Durability) has begun publishing DDS samples. Once the late-joining *DataReader* has received all cached DDS samples, it will be serviced at the same rate as other reliable *DataReaders*.

- late_joiner_heartbeat_period on page 391 must be <= heartbeat_period on page 391

7.5.5.3 Disabling Positive Acknowledgements

When strict reliable communication is not required, you can configure *Connext DDS* so that it does *not* send positive acknowledgements (ACKs). In this case, reliability is maintained solely based on negative acknowledgements (NACKs). The removal of ACK traffic may improve middleware performance. For example, when sending DDS samples over multicast, ACK-storms that previously may have hindered *DataWriters* and consumed overhead network bandwidth are now precluded.

By default, *DataWriters* and *DataReaders* are configured with positive ACKS enabled. To disable ACKs, either:

- Configure the *DataWriter* to disable positive ACKs for all matching *DataReaders* (by setting **disable_positive_acks** to TRUE in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388).
- Disable ACKs for individual *DataReaders* (by setting **disable_positive_acks** to TRUE in the 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565*)*.

If ACKs are disabled, instead of the *DataWriter* holding a DDS sample in its send queue until all of its *DataReaders* have ACKed it, the *DataWriter* will hold a DDS sample for a configurable duration. This "keep-duration" starts when a DDS sample is written. When this time elapses, the DDS sample is logically considered as acknowledged by its ACK-disabled readers.

The length of the "keep-duration" can be static or dynamic, depending on how **rtps_reliable_writer.disable_positive_acks_enable_adaptive_sample_keep_duration** is set.

- When the length is static, the "keep-duration" is set to the minimum (**rtps_reliable_writer.disable_positive_acks_min_sample_keep_duration**).
- When the length is dynamic, the "keep-duration" is dynamically adjusted between the minimum and maximum durations (**rtps_reliable_writer.disable_positive_acks_min_sample_keep_duration** and **rtps_reliable_writer.disable_positive_acks_max_sample_keep_duration**).

Dynamic adjustment maximizes throughput and reliability in response to current network conditions: when the network is congested, durations are increased to decrease the effective send rate and relieve the congestion; when the network is not congested, durations are decreased to increase the send rate and maximize throughput.

You should configure the minimum "keep-duration" to allow at least enough time for a possible NACK to be received and processed. When a *DataWriter* has both matching ACK-disabled and ACK-enabled *DataReaders*, it holds a DDS sample in its queue until all ACK-enabled *DataReaders* have ACKed it and the "keep-duration" has elapsed.

See also: 11.3.4.7 Disabling Positive Acknowledgements (disable_positive_acks_min_sample_keep_duration) on page 705.

7.5.5.4 Configuring the Send Window Size

When a reliable *DataWriter* writes a DDS sample, it keeps the DDS sample in its queue until it has received acknowledgements from all of its subscribing *DataReaders*. The number of these outstanding DDS samples is referred to as the *DataWriter's* "send window." Once the number of outstanding DDS samples has reached the send window size, subsequent writes will block until an outstanding DDS sample is acknowledged.

Configuration of the send window sets a minimum and maximum size, which may be unlimited. The min and max send windows can be the same. When set differently, the send window will dynamically change in response to detected network congestion, as signaled by received negative acknowledgements. When NACKs are received, the DataWriter responds to the slowed reader by decreasing the send window by the **send_window_decrease_factor** to throttle down its effective send rate. The send window will not be decreased to less than the **min_send_window_size**. After a period (**send_window_update_period**) during which no NACKs are received, indicating that the reader is catching up, the *DataWriter* will increase the send window size to increase the effective send rate by the percentage specified by **send_window_increase_factor**. The send window will increase to no greater than the **max_send_window_size**.

When both **min_send_window_size** and **max_send_window_size** are unlimited, either the resource limits **max_samples** in 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 (for non-batching) or **max_batches** in 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400 (for batching) serves as the effective **max_send_window_size**.

When either **max_samples** (for non-batching) or **max_batches** (for batching) is less than **max_send_window_size**, it serves as the effective **max_send_window_size**. If it is also less than **min_send_window_size**, then effectively both min and max send-window sizes are equal to **max_samples** or **max_batches**.

7.5.5.5 Propagating Serialized Keys with Disposed-Instance Notifications

This section describes the interaction between these two fields:

- **serialize_key_with_dispose** in 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388
- **propagate_dispose_of_unregistered_inst**ances in 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565

RTI recommends setting **serialize_key_with_dispose** to TRUE if there are *DataReaders* with **propagate_dispose_of_unregistered_instances** also set to TRUE. However, it is permissible to set one to TRUE and the other to FALSE. The following examples will help you understand how these fields work.

See also: 7.3.14.3 Disposing Instances on page 327.

Example 1

1. *DataWriter's* **serialize_key_with_dispose** = FALSE
2. *DataReader's* **propagate_dispose_of_unregistered_instances** = TRUE
3. *DataWriter* calls **dispose()** before writing any DDS samples
4. *DataReader* calls **take()** and receives a disposed-instance notification (without a key)
5. *DataReader* calls **get_key_value()**, which returns an error because there is no key associated with the disposed-instance notification

Example 2

1. *DataWriter's* **serialize_key_with_dispose** = TRUE
2. *DataReader's* **propagate_dispose_of_unregistered_instances** = FALSE
3. *DataWriter* calls **dispose()** before writing any DDS samples
4. *DataReader* calls **take()**, which does not return any DDS samples because none were written, and it does not receive any disposed-instance notifications because **propagate_dispose_of_unregistered_instances** = FALSE

Example 3

1. *DataWriter's* **serialize_key_with_dispose** = TRUE
2. *DataReader's* **propagate_dispose_of_unregistered_instances** = TRUE
3. *DataWriter* calls **dispose()** before writing any DDS samples
4. *DataReader* calls **take()** and receives the disposed-instance notification
5. *DataReader* calls **get_key_value()** and receives the key for the disposed-instance notification

Example 4

1. *DataWriter's* **serialize_key_with_dispose** = TRUE
2. *DataReader's* **propagate_dispose_of_unregistered_instances** = TRUE
3. *DataWriter* calls **write(),** which writes a DDS sample with a key
4. *DataWriter* calls **dispose()**, which writes a disposed-instance notification with a key
5. *DataReader* calls **take()** and receives a DDS sample and a disposed-instance notification; both have keys
6. *DataReader* calls **get_key_value()** with no errors

7.5.5.6 Virtual Heartbeats

Virtual heartbeats announce the availability of DDS samples with the Collaborative DataWriters feature described in 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565, where multiple *DataWriters* publish DDS samples from a common logical data-source (identified by a virtual GUID).

When 7.4.6 PRESENTATION QosPolicy on page 361 **access_scope** is set to TOPIC or INSTANCE on the *Publisher*, the virtual heartbeat contains information about the DDS samples contained in the *DataWriter* queue.

When presentation **access_scope** is set to GROUP on the *Publisher*, the virtual heartbeat contains information about the DDS samples in the queues of all *DataWriters* that belong to the *Publisher*.

7.5.5.7 Resending Over Multicast

Given *DataReaders* with multicast destinations, when a *DataReader* sends a NACK to request for DDS samples to be resent, the *DataWriter* can either resend them over unicast or multicast. Though resending over multicast would save bandwidth and processing for the *DataWriter*, the potential problem is that there could be *DataReaders* of the multicast group that did not request for any resends, yet they would have to process, and drop, the resent DDS samples.

Thus, to make each multicast resend more efficient, the **multicast_resend_threshold** is set as the minimum number of *DataReaders* of the same multicast group that the *DataWriter* must receive NACKs from within a single response-delay duration. This allows the *DataWriter* to coalesce near-simultaneous unicast resends into a multicast resend, and it allows a "vote" from *DataReaders* of a multicast group to exceed a threshold before resending over multicast.

The **multicast_resend_threshold** must be set to a positive value. Note that a threshold of 1 means that all resends will be sent over multicast. Also, note that a *DataWriter* with a zero NACK response-delay (i.e., both **min_nack_response_delay** and **max_nack_response_delay** are zero) will resend over multicast only if the threshold is 1.

7.5.5.8 Example

For information on how to use the fields in Table 7.44 DDS_RtpsReliableWriterProtocol_t, see 11.3.4 Controlling Heartbeats and Retries with DataWriterProtocol QosPolicy on page 698.

The following describes a use case for when to change **push_on_write** to **DDS_BOOLEAN_FALSE**. Suppose you have a system in which the data packets being sent is very small. However, you want the data to be sent reliably, and the latency between the time that data is sent to the time that data is received is not an issue. However, the total network bandwidth between the *DataWriter* and *DataReader* applications is limited.

If the *DataWriter* sends a burst of data a a high rate, it is possible that it will overwhelm the limited bandwidth of the network. If you allocate enough space for the *DataWriter* to store the data burst being sent

(see 7.5.22 RESOURCE_LIMITS QosPolicy on page 449), then you can use the **push_on_write** parameter of the DATA_WRITER_PROTOCOL QosPolicy to delay sending the data until the reliable *DataReader* asks for it.

By setting **push_on_write** to **DDS_BOOLEAN_FALSE**, when **write()** is called on the *DataWriter*, no data is actually sent. Instead data is stored in the *DataWriter*'s send queue. Periodically, *Connext DDS* will be sending heartbeats informing the DataReader about the data that is available. So every heartbeat period, the *DataReader* will realize that the *DataWriter* has new data, and it will send an ACK/NACK, asking for them.

When *DataWriter* receives the ACK/NACK packet, it will put together a package of data, up to the size set by the parameter **max_bytes_per_nack_response**, to be sent to the *DataReader*. This method not only self-throttles the send rate, but also uses network bandwidth more efficiently by eliminating redundant packet headers when combining several small packets into one larger one. Please note that the *DataWriter* will always send at least one sample.

7.5.5.9 Properties

This QosPolicy cannot be modified after the *DataWriter* is created.

Since it is only for *DataWriter*s, there are no compatibility restrictions for how it is set on the publishing and subscribing sides.

When setting the fields in this policy, the following rules apply. If any of these are false, *Connext DDS* returns **DDS_RETCODE_INCONSISTENT_POLICY**:

- **min_nack_response_delay** <= **max_nack_response_delay**
- **fast_heartbeat_period** <= **heartbeat_period**
- **late_joiner_heartbeat_period** <= **heartbeat_period**
- **low_watermark** < **high_watermark**
- If batching is disabled:
  - **heartbeats_per_max_samples** <= **writer_qos.resource_limits.max_samples**
- If batching is enabled:
  - **heartbeats_per_max_samples** <= **writer_qos.resource_limits.max_batches**

7.5.5.10 Related QosPolicies

- 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565
- 7.5.12 HISTORY QosPolicy on page 418
- 7.5.21 RELIABILITY QosPolicy on page 444

7.5.5.11 Applicable DDS Entities

- 7.3 DataWriters on page 286

7.5.5.12 System Resource Considerations

A high **max_bytes_per_nack_response** may increase the instantaneous network bandwidth required to send a single burst of traffic for resending dropped packets.

7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension)

This QosPolicy defines various settings that configure how *DataWriters* allocate and use physical memory for internal resources.

It includes the members in Table 7.45 DDS_DataWriterResourceLimitsQosPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 7.45 DDS_DataWriterResourceLimitsQosPolicy

Type	Field Name	Description
DDS_Long	initial_concurrent_blocking_threads	Initial number of threads that are allowed to concurrently block on the **write()**call on the same *DataWriter*.
DDS_Long	max_concurrent_blocking_threads	Maximum number of threads that are allowed to concurrently block on write() call on the same *DataWriter*.
DDS_Long	max_remote_reader_filters	Maximum number of remote *DataReaders* for which this *DataWriter* will perform content-based filtering.
DDS_Long	initial_batches	Initial number of batches that a *DataWriter* will manage if batching is enabled.
DDS_Long	max_batches	Maximum number of batches that a DataWriter will manage if batching is enabled. When batching is enabled, the maximum number of DDS samples that a *DataWriter* can store is limited by this value and **max_samples** in 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.
DDS_DataWriterResourceLimitsInstanceReplacementKind	instance_replacement	Sets the kinds of instances allowed to be replaced when a *DataWriter* reaches **max_instances** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449. (See 7.5.6.1 Configuring DataWriter Instance Replacement on page 402.)
DDS_Boolean	replace_empty_instances	Whether to replace empty instances during instance replacement. (See 7.5.6.1 Configuring DataWriter Instance Replacement on page 402.)

Table 7.45 DDS_DataWriterResourceLimitsQosPolicy

Type	Field Name	Description
DDS_Boolean	autoregister_instances	Whether to register automatically instances written with non-NIL handle that are not yet registered, which will otherwise return an error. This can be especially useful if the instance has been replaced.
DDS_Long	initial_virtual_writers	Initial number of virtual writers supported by a *DataWriter*.
DDS_Long	max_virtual_writers	Maximum number of virtual writers supported by a *DataWriter*. Sets the maximum number of unique virtual writers supported by a *DataWriter*, where virtual writers are added when DDS samples are written with the virtual writer GUID. This field is especially relevant in the configuration of *Persistence Service DataWriters,* since they publish information on behalf of multiple virtual writers.
DDS_Long	max_remote_readers	The maximum number of remote readers supported by a *DataWriter*.
DDS_Long	max_app_ack_remote_readers	The maximum number of application-level acknowledging remote readers supported by a *DataWriter*.
DDS_Long	initial_active_topic_queries	Initial number of active topic queries a *DataWriter* will manage.
DDS_Long	max_active_topic_queries	Maximum number of active topic queries a *DataWriter* will manage. When topic queries are enabled, the maximum number of topic queries that a *DataWriter* can process at the same time is limited by this value.
DDS_AllocationSettings_t	writer_loaned_sample_allocation	Sets the allocation settings of the *DataWriter*-managed sample pool, when using Zero Copy transfer over shared memory or FlatData language binding. The number of samples loaned by a *DataWriter* via FooDataWriter's **get_loan()** operation is limited by the max_count in **writer_loaned_sample_allocation**. See Chapter 23 Sending Large Data on page 934.
DDS_Boolean	initialize_writer_loaned_sample	Determines whether or not to initialize members to default values in loaned samples returned by FooDataWriter's **get_loan()** operation, when using Zero Copy transfer over shared memory or FlatData language binding. See Chapter 23 Sending Large Data on page 934.

DataWriters must allocate internal structures to handle the simultaneous blocking of threads trying to call **write()** on the same *DataWriter*, for the storage used to batch small DDS samples, and for content-based filters specified by *DataReaders*.

Most of these internal structures start at an initial size and by default, will grow as needed by dynamically allocating additional memory. You may set fixed, maximum sizes for these internal structures if you want to bound the amount of memory that a *DataWriter* can use. By setting the initial size to the maximum size, you will prevent *Connext DDS* from dynamically allocating any memory after the creation of the *DataWriter*.

When setting the fields in this policy, the following rule applies. If this is false, *Connext DDS* returns **DDS_RETCODE_INCONSISTENT_POLICY**:

- **max_concurrent_blocking_threads** >= **initial_concurrent_blocking_threads**

The **initial_concurrent_blocking_threads** is used to allocate necessary initial system resources. If necessary, it will be increased automatically up to the **max_concurrent_blocking_threads** limit.

Every user thread calling **write()** on a *DataWriter* may use a semaphore that will block the thread when the *DataWriter*'s send queue is full. Because user code may set a timeout, each thread must use a different semaphore. See the **max_blocking_time** parameter of the 7.5.21 RELIABILITY QosPolicy on page 444. This QoS is offered so that the user application can control the dynamic allocation of system resources by *Connext DDS*.

If you do not mind if *Connext DDS* dynamically allocates semaphores when needed, then you can set the **max_concurrent_blocking_threads** parameter to some large value like **MAX_INT**. However, if you know exactly how many threads will be calling **write()** on the same *DataWriter*, and you do not want *Connext DDS* to allocate any system resources or memory after initialization, then you should set:

```
max_concurrent_blocking_threads = initial_concurrent_blocking_threads = NUM
```

(where *NUM* is the number of threads that could possibly block concurrently).

Each *DataWriter* can perform content-based data filtering for up to **max_remote_reader_filters** number of *DataReaders*.

Values for **max_remote_reader_filters** may be.

- **0**: The *DataWriter* will not perform filtering for any *DataReader*, which means the *DataReader* will have to filter the data itself.
- **1 to (2^{31}-2)**: The *DataWriter* will filter for up to the specified number of *DataReaders*. In addition, the *Datawriter* will store the result of the filtering per DDS sample per *DataReader*.
- **DDS_LENGTH_UNLIMITED** (default): The *DataWriter* will filter for up to (2^{31})-2 *DataReaders*. However, in this case, the *DataWriter* will not store the filtering result per DDS sample per *DataReader*. Thus, if a DDS sample is resent (such as due to a loss of reliable communication), the DDS sample will be filtered again.

For more information, see 5.4 ContentFilteredTopics on page 227.

7.5.6.1 Configuring DataWriter Instance Replacement

When the **max_instances** limit (in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400) is reached, a *DataWriter* will try to make space for a new instance by replacing an existing instance according to the instance replacement kind set in **instance_replacement** in the 7.5.6

DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400. For the sake of instance replacement, an instance is considered to be unregistered, disposed, or alive. The oldest instance of the specified kind, if such an instance exists, would be replaced with the new instance. Also, all DDS samples of a replaced instance must already have been acknowledged, such that removing the instance would not deprive any existing reader from receiving them.

Since an unregistered instance is one that a *DataWriter* will not update any further, unregistered instances are replaced before any other instance kinds. This applies for all **instance_replacement** kinds; for example, the ALIVE_THEN_DISPOSED kind would first replace unregistered, then alive, and then disposed instances. The rest of the kinds specify one or two kinds (e.g DISPOSED and ALIVE_OR_DISPOSED). For the single kind, if no unregistered instances are replaceable, and no instances of the specified kind are replaceable, then the instance replacement will fail. For the others specifying multiple kinds, it either specifies to look for one kind first and then another kind (e.g. ALIVE_THEN_DISPOSED), meaning if the first kind is found then that instance will be replaced, or it will replace either of the kinds specified (e.g. ALIVE_OR_DISPOSED), whichever is older as determined by the time of instance registering, writing, or disposing.

If an acknowledged instance of the specified kind is found, the *DataWriter* will reclaim its resources for the new instance. It will also invoke the DataWriterListener's **on_instance_replaced()** callback (if installed) and notify the user with the handle of the replaced instance, which can then be used to retrieve the instance key from within the callback. If no replaceable instances are found, the new instance will fail to be registered; the *DataWriter* may block, if the instance registration was done in the context of a write, or it may return with an out-of-resources return code.

In addition, **replace_empty_instances** (in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400) configures whether instances with no DDS samples are eligible to be replaced. If this is set, then a *DataWriter* will first try to replace empty instances, even before replacing unregistered instances.

7.5.6.2 Example

If there are multiple threads that can write on the same *DataWriter*, and the **write()** operation may block (based on **reliability_qos**.**max_blocking_time** and HISTORY settings), you may want to set **initial_concurrent_blocking_threads** to the most likely number of threads that will block on the same *DataWriter* at the same time, and set **max_concurrent_blocking_threads** to the maximum number of threads that could potentially block in the worst case.

7.5.6.3 Properties

This QosPolicy cannot be modified after the *DataWriter* is created.

Since it is only for *DataWriter*s, there are no compatibility restrictions for how it is set on the publishing and subscribing sides.

7.5.6.4 Related QosPolicies

- 7.5.2 BATCH QosPolicy (DDS Extension) on page 373
- 7.5.21 RELIABILITY QosPolicy on page 444
- 7.5.12 HISTORY QosPolicy on page 418

7.5.6.5 Applicable DDS Entities

- 7.3 DataWriters on page 286

7.5.6.6 System Resource Considerations

Increasing the values in this QosPolicy will cause more memory usage and more system resource usage.

7.5.7 DEADLINE QosPolicy

On a *DataWriter*, this QosPolicy states the maximum period in which the application expects to call **write()** on the *DataWriter*, thus publishing a new DDS sample. The application may call **write()** faster than the rate set by this QosPolicy.

On a *DataReader*, this QosPolicy states the maximum period in which the application expects to receive new values for the *Topic*. The application may receive data faster than the rate set by this QosPolicy.

The DEADLINE QosPolicy has a single member, shown in Table 7.46 DDS_DeadlineQosPolicy. For the default and valid range, please refer to the API Reference HTML documentation.

Table 7.46 DDS_DeadlineQosPolicy

Type	Field Name	Description
DDS_Duration_t	period	For *DataWriters*: maximum time between writing a new value of an instance. For *DataReaders*: maximum time between receiving new values for an instance.

You can use this QosPolicy during system integration to ensure that applications have been coded to meet design specifications. You can also use it during run time to detect when systems are performing outside of design specifications. Receiving applications can take appropriate actions to prevent total system failure when data is not received in time. For topics on which data is not expected to be periodic, the deadline period should be set to an infinite value.

For keyed topics, the DEADLINE QoS applies on a per-instance basis. An application must call **write()** for each known instance of the *Topic* within the **period** specified by the DEADLINE on the *DataWriter* or receive a new value for each known instance within the **period** specified by the DEADLINE on the *DataReader*. For a *DataWriter*, the deadline period begins when the instance is first written or registered. For a *DataReader*, the deadline period begins when the first DDS sample is received.

Connext DDS will modify the *OFFERED_DEADLINE_MISSED_STATUS* and call the associated method in the **DataWriterListener** (see 7.3.6.5 OFFERED_DEADLINE_MISSED Status on page 302) if the application fails to **write()** a value for an instance within the period set by the DEADLINE QosPolicy of the *DataWriter*.

Similarly, *Connext DDS* will modify the *REQUESTED_DEADLINE_MISSED_STATUS* and call the associated method in the *DataReaderListener* (see 8.3.7.5 REQUESTED_DEADLINE_MISSED Status on page 523) if the application fails to receive a value for an instance within the period set by the DEADLINE QosPolicy of the *DataReader*.

For *DataReaders*, the DEADLINE QosPolicy and the 8.6.4 TIME_BASED_FILTER QosPolicy on page 583 may interact such that even though the *DataWriter* writes DDS samples fast enough to fulfill its commitment to its own DEADLINE QosPolicy, the *DataReader* may see violations of *its* DEADLINE QosPolicy. This happens because *Connext DDS* will drop any packets received within the **minimum_separation** set by the TIME_BASED_FILTER—packets that could satisfy the *DataReader's* deadline.

To avoid triggering the *DataReader's* deadline even though the matched *DataWriter* is meeting its own deadline, set your QoS parameters to meet the following relationship:

```
reader deadline period >= reader minimum_separation + writer deadline period
```

Although you can set the DEADLINE QosPolicy on *Topics*, its value can only be used to initialize the DEADLINE QosPolicies of either a *DataWriter* or *DataReader*. It does not directly affect the operation of *Connext DDS*, see 5.1.3 Setting Topic QosPolicies on page 219.

7.5.7.1 Example

Suppose you have a time-critical piece of data that should be updated at least once every second. You can set the DEADLINE **period** to 1 second on both the *DataWriter* and *DataReader*. If there is no update within that time, the *DataWriter* will get an **on_offered_deadline_missed** *Listener* callback, and the *DataReader* will get **on_requested_deadline_missed**, so that both sides can handle the error situation properly.

Note that in practice, there will be latency and jitter in the time between when data is send and when data is received. Thus even if the *DataWriter* is sending data at exactly 1 second intervals, the *DataReader* may not receive the data at exactly 1 second intervals. More likely, it will *DataReader* will receive the data at 1 second plus a small variable quantity of time. Thus you should accommodate this practical reality in choosing the DEADLINE **period** as well as the actual update period of the *DataWriter* or your application may receive false indications of failure.

The DEADLINE QosPolicy also interacts with the OWNERSHIP QosPolicy when OWNERSHIP is set to **EXCLUSIVE**. If a *DataReader* fails to receive data from the highest strength *DataWriter* within its requested DEADLINE, then the *DataReaders* can fail-over to lower strength *DataWriters*, see the 7.5.17 OWNERSHIP QosPolicy on page 432.

7.5.7.2 Properties

This QosPolicy can be changed at any time.

The deadlines on the two sides must be compatible.

DataWriter's DEADLINE **period** <= the *DataReader*'s DEADLINE **period**.

That is, the *DataReader* cannot expect to receive DDS samples more often than the *DataWriter* commits to sending them.

If the *DataReader* and *DataWriter* have compatible deadlines, *Connext DDS* monitors this "contract" and informs the application of any violations. If the deadlines are incompatible, both sides are informed and communication does not occur. The **ON_OFFERED_INCOMPATIBLE_QOS** and the **ON_REQUESTED_INCOMPATIBLE_QOS** statuses will be modified and the corresponding *Listeners* called for the *DataWriter* and *DataReader* respectively.

7.5.7.3 Related QosPolicies

- 7.5.15 LIVELINESS QosPolicy on page 425
- 7.5.17 OWNERSHIP QosPolicy on page 432
- 8.6.4 TIME_BASED_FILTER QosPolicy on page 583

7.5.7.4 Applicable DDS Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.7.5 System Resource Considerations

A *Connext DDS*-internal thread will wake up at least by the DEADLINE **period** to check to see if the deadline was missed. It may wake up faster if the last DDS sample that was published or sent was close to the last time that the deadline was checked. Therefore a short **period** will use more CPU to wake and execute the thread checking the deadline.

7.5.8 DESTINATION_ORDER QosPolicy

When multiple *DataWriters* send data for the same topic, the order in which data from different *DataWriters* are received by the applications of different *DataReaders* may be different. Thus different *DataReaders* may not receive the same "last" value when *DataWriters* stop sending data.

This policy controls how each subscriber resolves the final value of a data instance that is written by multiple *DataWriters* (which may be associated with different *Publishers*) running on different nodes.

This QosPolicy can be used to create systems that have the property of "eventual consistency." Thus intermediate states across multiple applications may be inconsistent, but when *DataWriters* stop sending changes to the same topic, all applications will end up having the same state.

Each DDS sample includes two timestamps: a source timestamp and a reception timestamp. The source timestamp is recorded by the *DataWriter* application when the data was written. The reception timestamp is recorded by the *DataReader* application when the data was received.

This QoS includes the members in Table 7.47 DDS_DestinationOrderQosPolicy.

Table 7.47 DDS_DestinationOrderQosPolicy

Type	Field Name	Description
DDS_DestinationOrderQosPolicyKind	kind	Can be either: DDS_BY_RECEPTION_TIMESTAMP_DESTINATIONORDER_QOS DDS_BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS
DDS_DestinationOrderQosPolicyScopeKind	kind	Can be either: DDS_INSTANCE_SCOPE_DESTINATIONORDER_QOS - Indicates that data is ordered on a per instance basis if used along with DDS_BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS. The source timestamp of the current sample is compared to the source timestamp of the previously received sample for the same instance. The tolerance check is also applied per instance. DDS_TOPIC_SCOPE_DESTINATIONORDER_QOS - Indicates that data is ordered on a per topic basis if used along with DDS_BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS. The source timestamp of the current sample is compared to the source timestamp of the previously received sample for the same topic. The tolerance check is also applied per topic.
DDS_Duration_t	source_timestamp_tolerance	Allowed tolerance between source timestamps of consecutive DDS samples. Only applies when **kind** (above) is DDS_BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS. • For a *DataWriter*: The write operation will fail if the source timestamp of the sample is older than the timestamp of the previously written DDS sample by more than the **source_timestamp_tolerance**. • For a *DataReader*: A DataReader will accept a sample only if the source timestamp is no farther in the future from the reception timestamp than the **source_timestamp_tolerance**.

This QoS policy can be set for both *DataWriters* and *DataReaders*. See 7.5.8.1 Properties on page 409 for compatibility rules.

For a *DataReader*:

- DDS_BY_RECEPTION_TIMESTAMP_DESTINATIONORDER_QOS

Assuming the OWNERSHIP_STRENGTH allows it, the latest received value for the instance should be the one whose value is kept. Data will be delivered by a *DataReader* in the order in which it was received (which may lead to inconsistent final values).

- DDS_BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS

  If scope is set to DDS_INSTANCE_SCOPE_DESTINATIONORDER_QOS (default), within each instance, the sample's source timestamp shall be used to determine the most recent information. *This is the only setting that*, in the case of concurrent same-strength *DataWriters* updating the same instance, *ensures that all DataReaders end up with the same final value for the instance*. If a *DataReader* receives a sample for an instance with a source timestamp that is older than the last source timestamp received for the instance, the sample is dropped. You can keep track of the total number of dropped samples for this reason with the **old_source_timestamp_dropped_sample_count** field in the 8.3.7.2 DATA_READER_CACHE_STATUS on page 514. The SAMPLE_REJECTED status or the SAMPLE_LOST status will not be updated.

  If scope is set to DDS_TOPIC_SCOPE_DESTINATIONORDER_QOS, the ordering is enforced per topic across all instances.

  In addition, a *DataReader* will accept a sample only if the source timestamp is no farther in the future from the reception timestamp than the **source_timestamp_tolerance**. Otherwise, the DDS sample is dropped. You can keep track of the total number of dropped samples for this reason with the **tolerance_source_timestamp_dropped_sample_count** field in the 8.3.7.2 DATA_READER_CACHE_STATUS on page 514. The SAMPLE_REJECTED status or the SAMPLE_LOST status will not be updated.

For the *DataWriter*:

- DDS_BY_RECEPTION_TIMESTAMP_DESTINATIONORDER_QOS

  The *DataWriter* will not enforce source timestamp ordering when writing samples using the **DataWriter::write_w_timestamp** or **DataWriter::write_w_params** API. The source timestamp of a new sample can be older than the source timestamp of the previous samples.

- DDS_BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS

  If scope is set to DDS_INSTANCE_SCOPE_DESTINATIONORDER_QOS (default), when writing a sample, the sample's timestamp must not be older than the timestamp of the previously written DDS sample for the same instance. If, however, the timestamp is older than the timestamp of the previously written DDS sample—but the difference is less than the **source_timestamp_tolerance**—the DDS sample will use the previously written DDS sample's timestamp as its timestamp. Otherwise, if the difference is greater than the tolerance, the write will fail with retcode DDS_RETCODE_BAD_PARAMETER.

If scope is set to DDS_TOPIC_SCOPE_DESTINATIONORDER_QOS, a new sample timestamp must not be older than the timestamp of the previously written DDS sample, across all instances. (The ordering is enforced across all instances.)

Although you can set the DESTINATION_ORDER QosPolicy on *Topics*, its value can only be used to initialize the DESTINATION_ORDER QosPolicies of either a *DataWriter* or *DataReader*. It does not directly affect the operation of *Connext DDS*, see 5.1.3 Setting Topic QosPolicies on page 219.

7.5.8.1 Properties

This QosPolicy *cannot* be modified after the *Entity* is enabled.

This QoS must be set compatibly between the *DataWriter* and the *DataReader*. The compatible combinations are shown in Table 7.48 Valid Reader/Writer Combinations of DestinationOrder.

Table 7.48 Valid Reader/Writer Combinations of DestinationOrder

Destination Order		DataReader requests:	
		BY_SOURCE	BY_RECEPTION
DataWriter offers:	BY_SOURCE	compatible	compatible
	BY_RECEPTION	incompatible	compatible

If this QosPolicy is set incompatibly, the **ON_OFFERED_INCOMPATIBLE_QOS** and **ON_REQUESTED_INCOMPATIBLE_QOS** statuses will be modified and the corresponding *Listeners* called for the *DataWriter* and *DataReader* respectively.

7.5.8.2 Related QosPolicies

- 7.5.17 OWNERSHIP QosPolicy on page 432
- 7.5.12 HISTORY QosPolicy on page 418

7.5.8.3 Applicable DDS Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.8.4 System Resource Considerations

The use of this policy does not significantly impact the use of resources.

7.5.9 DURABILITY QosPolicy

Because the publish-subscribe paradigm is connectionless, applications can create publications and subscriptions in any way they choose. As soon as a matching pair of *DataWriters* and *DataReaders* exist, the data published by the *DataWriter* will be delivered to the *DataReader*. However, a *DataWriter* may publish data before a *DataReader* has been created. For example, before you subscribe to a magazine, there have been past issues that were published.

The DURABILITY QosPolicy controls whether or not, and how, published DDS samples are stored by the *DataWriter* application for *DataReaders* that are found after the DDS samples were initially written. *DataReaders* use this QoS to request DDS samples that were published before they were created. The analogy is for a new subscriber to a magazine to ask for issues that were published in the past. These are known as 'historical' DDS data samples. (Reliable *DataReaders* may wait for these historical DDS samples, see 8.3.5 Checking DataReader Status and StatusConditions on page 511.)

This QosPolicy can be used to help ensure that *DataReaders* get all data that was sent by *DataWriters*, regardless of when it was sent. This QosPolicy can increase system tolerance to failure conditions.

The 7.5.12 HISTORY QosPolicy on page 418 controls how many samples the *DataWriter* stores for repair to currently matched *DataReaders*. The DURABILITY QosPolicy controls how many samples the *DataWriter* stores for sending to late-joining *DataReaders* (*DataReaders* that are found after the samples were initially written). See Figure 7.30: History Depth and Durability Depth on page 422.

See also Mechanisms for Achieving Information Durability and Persistence (Chapter 13 on page 726).

The possible settings for this QoS are:

- **DDS_VOLATILE_DURABILITY_QOS**

  Connext DDS is not required to send and will not deliver any DDS data samples to *DataReaders* that are discovered after the DDS samples were initially published.

- **DDS_TRANSIENT_LOCAL_DURABILITY_QOS**

  Connext DDS will store and send previously published DDS samples for delivery to newly discovered *DataReader*s as long as the *DataWriter* still exists. For this setting to be effective, you must also set the 7.5.21 RELIABILITY QosPolicy on page 444 **kind** to Reliable (not Best Effort). Which particular DDS samples are kept depends on other QoS settings such as 7.5.12 HISTORY QosPolicy on page 418 and 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.

- **DDS_TRANSIENT_DURABILITY_QOS**

  Connext DDS will store previously published DDS samples in memory using *Persistence Service*, which will send the stored data to newly discovered *DataReader*s. Which particular DDS samples are kept and sent by *Persistence Service* depends on the 7.5.12 HISTORY QosPolicy on page 418

and 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 of the *Persistence Service DataWriters*. These QosPolicies can be configured in the *Persistence Service* configuration file or through the 7.5.10 DURABILITY SERVICE QosPolicy on page 414 of the *DataWriters* configured with DDS_TRANSIENT_DURABILITY_QOS.

- **DDS_PERSISTENT_DURABILITY_QOS**

  Connext DDS will store previously published DDS samples in permanent storage, like a disk, using *Persistence Service*, which will send the stored data to newly discovered *DataReader*s. Which particular DDS samples are kept and sent by *Persistence Service* depends on the 7.5.12 HISTORY QosPolicy on page 418 and 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 in the *Persistence Service DataWriters*. These QosPolicies can be configured in the *Persistence Service* configuration file or through the 7.5.10 DURABILITY SERVICE QosPolicy on page 414 of the *DataWriters* configured with DDS_PERSISTENT_DURABILITY_QOS.

This QosPolicy includes the members in Table 7.49 DDS_DurabilityQosPolicy. For default settings, please refer to the API Reference HTML documentation.

Table 7.49 DDS_DurabilityQosPolicy

Type	Field Name	Description
DDS_DurabilityQosPolicyKind	kind	*DDS_VOLATILE_DURABILITY_QOS*: Do not save or deliver historical DDS samples. *DDS_TRANSIENT_LOCAL_DURABILITY_QOS*: Save and deliver historical DDS samples if the *DataWriter* still exists. *DDS_TRANSIENT_DURABILITY_QOS*: Save and deliver historical DDS samples using *Persistence Service* to store samples in volatile memory. *DDS_PERSISTENCE_DURABILITY_QOS*: Save and deliver historical DDS samples using *Persistence Service* to store samples in non-volatile memory.
DDS_Long	writer_depth	How many DDS samples are stored per instance by the *DataWriter* application for sending to late-joining *DataReaders* (*DataReaders* that are found after the DDS samples were initially written). The default value, AUTO, makes this parameter equal to the following: • History **depth** in the 7.5.12 HISTORY QosPolicy on page 418 if the History **kind** is KEEP_LAST. • **max_samples_per_instance** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 if the History **kind** is KEEP_ALL. The **writer_depth** must be <= to the History **depth** in the HISTORY QosPolicy if the History **kind** is KEEP_LAST. **writer_depth** applies only to non-volatile *DataWriters* (those for which the **kind** is DDS_TRANSIENT_LOCAL_DURABILITY_QOS, DDS_TRANSIENT_DURABILITY_QOS, or DDS_PERSISTENCE_DURABILITY_QOS). **writer_depth** set on the *DataReader* side will be ignored.

Table 7.49 DDS_DurabilityQosPolicy

Type	Field Name	Description
DDS_Boolean	direct_ communication	Whether or not a TRANSIENT or PERSISTENT *DataReader* should receive DDS samples directly from a TRANSIENT or PERSISTENT *DataWriter*. When TRUE, a TRANSIENT or PERSISTENT *DataReader* will receive DDS samples directly from the original *DataWriter*. The *DataReader* may also receive DDS samples from *Persistence Service*, but the duplicates will be filtered by the middleware. When FALSE, a TRANSIENT or PERSISTENT *DataReader will receive DDS samples only from the DataWriter created by* Persistence Service. This 'relay communication' pattern provides a way to guarantee eventual consistency. See 13.5.1 RTI Persistence Service on page 743. This field only applies to *DataReaders*.

With this QoS policy alone, there is no way to specify or characterize the intended consumers of the information. With TRANSIENT_LOCAL, TRANSIENT, or PERSISTENT durability a *DataWriter* can be configured to keep DDS samples around for late-joiners. However, there is no way to know when the information has been consumed by all the intended recipients.

Information durability can be combined with required subscriptions in order to guarantee that DDS samples are delivered to a set of required subscriptions. For additional details on required subscriptions see 7.3.13 Required Subscriptions on page 322 and 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369.

A *DataWriter* will keep at most **History.depth** samples per instance until they are fully acknowledged. Samples outside of the **Durability.writer_depth** for an instance will be removed once they are fully acknowledged. Only the most recent **Durability.writer_depth** samples per instance will be kept by the *DataWriter* for delivery to late-joining non-volatile *DataReaders*.

When **writer_depth** is used in combination with batching, it acts as a minimum number of samples that will be kept per instance, rather than a maximum. Any batch that contains a sample that falls within the **writer_depth** of the instance to which it belongs will be sent to late-joining *DataReaders*. This means that batches may be sent that contain samples from other instances, or the same instance, that fall outside of the **writer_depth** for the instance to which they belong. For example, if the **writer_depth** is set to 1 and a batch with two samples for the same instance is written, then when a late-joining *DataReader* is discovered, the *DataWriter* will send the batch containing two samples for the same instance to the *DataReader*.

7.5.9.1 Example

Suppose you have a *DataWriter* that sends data sporadically and its DURABILITY **kind** is set to **VOLATILE**. If a new *DataReader* joins the system, it won't see any data until the next time that **write()** is called on the *DataWriter*. If you want the *DataReader* to receive any data that is valid, old or new, both

sides should set their DURABILITY *kind* to **TRANSIENT_LOCAL**. This will ensure that the *DataReader* gets some of the previous DDS samples immediately after it is enabled.

7.5.9.2 Properties

This QosPolicy cannot be modified after the Entity has been created.

The *DataWriter* and *DataReader* must use compatible settings for this QosPolicy. To be compatible, the *DataWriter* and *DataReader* must use one of the valid combinations shown in Table 7.50 Valid Combinations of Durability 'kind'.

If this QosPolicy is found to be incompatible, the **ON_OFFERED_INCOMPATIBLE_QOS** and **ON_REQUESTED_INCOMPATIBLE_QOS** statuses will be modified and the corresponding *Listeners* called for the *DataWriter* and *DataReader* respectively.

Table 7.50 Valid Combinations of Durability 'kind'

		DataReader requests:			
		VOLATILE	TRANSIENT_LOCAL	TRANSIENT	PERSISTENT
DataWriter offers:	VOLATILE	compatible	incompatible	incompatible	incompatible
	TRANSIENT_LOCAL	compatible	compatible	incompatible	incompatible
	TRANSIENT	compatible	compatible	compatible	incompatible
	PERSISTENT	compatible	compatible	compatible	compatible

7.5.9.3 Related QosPolicies

- 7.5.12 HISTORY QosPolicy on page 418
- 7.5.21 RELIABILITY QosPolicy on page 444
- 7.5.10 DURABILITY SERVICE QosPolicy on the next page
- 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369

7.5.9.4 Applicable Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.9.5 System Resource Considerations

Using this policy with a setting other than **VOLATILE** will cause *Connext DDS* to use CPU and network bandwidth to send old DDS samples to matching, newly discovered *DataReaders*. The actual amount of resources depends on the total size of data that needs to be sent.

The maximum number of DDS samples that will be kept on the *DataWriter's* queue for late-joiners and/or required subscriptions is determined by **max_samples** in RESOURCE_LIMITS Qos Policy.

System Resource Considerations With Required Subscriptions

By default, when TRANSIENT_LOCAL durability is used in combination with required subscriptions, a *DataWriter* configured with KEEP_ALL in the 7.5.12 HISTORY QosPolicy on page 418 will keep the DDS samples in its cache until they are acknowledged by all the required subscriptions. (For additional details, see 7.3.13 Required Subscriptions on page 322.) After the DDS samples are acknowledged by the required subscriptions they will be marked as reclaimable, but they will not be purged from the *DataWriter's* queue until the *DataWriter* needs these resources for new DDS samples. This may lead to a non efficient resource utilization, specially when **max_samples** is high or even UNLIMITED.

The *DataWriter's* behavior can be changed to purge DDS samples after they have been acknowledged by all the active/matching *DataReaders* and all the required subscriptions configured on the DataWriter. To do so, set the **dds.data_writer.history.purge_samples_after_acknowledgment** property to 1 (see 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436).

See 7.3.13 Required Subscriptions on page 322.

7.5.10 DURABILITY SERVICE QosPolicy

This QosPolicy is only used if the 7.5.9 DURABILITY QosPolicy on page 410 is PERSISTENT or TRANSIENT *and* you are using *Persistence Service*. It is used to store and possibly forward the data sent by the *DataWriter* to *DataReaders* that are created after the data was initially sent.

This QosPolicy configures certain parameters of *Persistence Service* when it operates on the behalf of the *DataWriter*, such as how much data to store. Specifically, this QosPolicy configures the HISTORY and RESOURCE_LIMITS used by the fictitious *DataReader* and *DataWriter* used by *Persistence Service*.

Note however, that by default, *Persistence Service* will ignore the values in the 7.5.10 DURABILITY SERVICE QosPolicy above and must be configured to use those values.

For more information, please see:

- Mechanisms for Achieving Information Durability and Persistence (Chapter 13 on page 726)
- Introduction to RTI Persistence Service (Chapter 45 on page 1160)
- Configuring Persistence Service (Chapter 46 on page 1161)

This QosPolicy includes the members in Table 7.51 DDS_DurabilityServiceQosPolicy. For default values, please refer to the API Reference HTML documentation.

Table 7.51 DDS_DurabilityServiceQosPolicy

Type	Field Name	Description
DDS_Duration_t	service_cleanup_delay	How long to keep all information regarding an instance. Can be: Zero (default): Purge disposed instances from Persistence Service immediately. However, this will only happen if use_durability_service = 1. INFINITE: Do not purge disposed instances.
DDS_HistoryQosPolicyKind	kind	Setting to use for the 7.5.12 HISTORY QosPolicy on page 418 **kind** when recouping durable data.
DDS_Long	depth	Setting to use for the 7.5.9 DURABILITY QosPolicy on page 410 **writer_depth** when recouping durable data. If the 7.5.12 HISTORY QosPolicy on page 418 **depth** is set to a value lower than this value, then the HISTORY **depth** will be set equal to the value of this field.
DDS_Long	max_samples	Settings to use for the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 when feeding data to a late joiner.
	max_instances	
	max_samples_per_instance	

The **service_cleanup_delay** in this QosPolicy controls when *Persistence Service* may remove all information regarding a data-instances. Information on a data-instance is maintained until all of the following conditions are met:

1. The instance has been explicitly disposed (**instance_state** = NOT_ALIVE_DISPOSED).
2. All samples for the disposed instance have been acknowledged, including the dispose sample itself.
3. A time interval longer that DurabilityService QosPolicy's **service_cleanup_delay** has elapsed since the time that *Connext DDS* detected that the previous two conditions were met. (Note: Only values of zero or INFINITE are currently supported for **service_cleanup_delay**.)

The **service_cleanup_delay** field is useful in the situation where your application disposes an instance and it crashes before it has a chance to complete additional tasks related to the disposition. Upon restart, your application may ask for initial data to regain its state and the delay introduced by **service_cleanup_delay**

will allow your restarted application to receive the information about the disposed instance and complete any interrupted tasks.

Although you can set the DURABILITY_SERVICE QosPolicy on a *Topic*, this is only useful as a means to initialize the DURABILITY_SERVICE QosPolicy of a *DataWriter*. A Topic's DURABILITY_SERVICE setting does not directly affect the operation of *Connext DDS*, see 5.1.3 Setting Topic QosPolicies on page 219.

7.5.10.1 Properties

This QosPolicy cannot be modified after the Entity has been enabled.

It does not apply to *DataReaders*, so there is no requirement for setting it compatibly on the sending and receiving sides.

7.5.10.2 Related QosPolicies

- 7.5.9 DURABILITY QosPolicy on page 410
- 7.5.12 HISTORY QosPolicy on page 418
- 7.5.22 RESOURCE_LIMITS QosPolicy on page 449

7.5.10.3 Applicable Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286

7.5.10.4 System Resource Considerations

Since this QosPolicy configures the HISTORY and RESOURCE_LIMITS used by the fictitious *DataReader* and *DataWriter* used by *Persistence Service*, it does have some impact on resource usage.

7.5.11 ENTITY_NAME QosPolicy (DDS Extension)

The ENTITY_NAME QosPolicy assigns a name and role name to a *DomainParticipant*, *Publisher, Subscriber, DataReader*, or *DataWriter*.

How the **name** is used is strictly application-dependent.

It is useful to attach names that are meaningful to the user. These names (except for *Publishers* and *Subscribers*) are propagated during discovery so that applications can use these names to identify, in a user-context, the entities that it discovers. Also, *RTI Connext* tools will print the names of discovered entities (except for *Publishers* and *Subscribers*).

The **role_name** identifies the role of the entity. It is used by the Collaborative DataWriter feature (see 7.5.1.1 Availability QoS Policy and Collaborative DataWriters on page 370). With Durable

Subscriptions, **role_name** is used to specify to which Durable Subscription the *DataReader* belongs. (see 7.5.1.2 Availability QoS Policy and Required Subscriptions on page 371.

This QosPolicy contains the members listed in Table 7.52 DDS_EntityNameQoSPolicy.

Table 7.52 DDS_EntityNameQoSPolicy

Type	Field Name	Description
char*	name	A null-terminated string up to 255 characters in length. To set this in XML, see 19.4.8 Entity Names on page 875.
char*	role_name	A null-terminated string up to 255 characters in length. To set this in XML, see 19.4.8 Entity Names on page 875. For Collaborative DataWriters, this name is used to specify to which endpoint group the *DataWriter* belongs. See. 7.5.1.1 Availability QoS Policy and Collaborative DataWriters on page 370. For Required and Durable Subscriptions this name is used to specify to which Subscription the *DataReader* belongs. See 7.3.13 Required Subscriptions on page 322.

These names will appear in the built-in topic for the entity (see the tables in 18.2 Built-in DataReaders on page 826).

Prior to **get_qos()**, if the **name** and/or **role_name** field in this QosPolicy is not null, *Connext DDS* assumes the memory to be valid and big enough and may write to it. If that is not desired, set **name** and/or **role_name** to NULL before calling **get_qos()** and *Connext DDS* will allocate adequate memory for name.

When you call the destructor of entity's QoS structure (DomainParticipantQos, DataReaderQos, or DataWriterQos) (in C++, C++/CLI, and C#) or **<entity>Qos_finalize()** (in C), *Connext DDS* will attempt to free the memory used for **name** and **role_name** if it is not NULL. If this behavior is not desired, set **name** and/or **role_name** to NULL before you call the destructor of entity's QoS structure or **DomainParticipantQos_finalize()**.

7.5.11.1 Properties

This QosPolicy cannot be modified after the entity is enabled.

7.5.11.2 Related QosPolicies

- None

7.5.11.3 Applicable Entities

- 9.3 DomainParticipants on page 604
- 7.2 Publishers on page 270

- 8.2 Subscribers on page 483
- 8.3 DataReaders on page 501
- 7.3 DataWriters on page 286

7.5.11.4 System Resource Considerations

If the value of **name** in this QosPolicy is not NULL, some memory will be consumed in storing the information in the database, but should not significantly impact the use of resource.

7.5.12 HISTORY QosPolicy

This QosPolicy configures the number of DDS samples that *Connext DDS* will store locally for *DataWriters* and *DataReaders*. For reliable *DataWriters*, the HISTORY QosPolicy configures the reliability window, or the number of samples that are kept until all matching *DataReaders* have fully-acknowledged the samples. For keyed *Topics*, this QosPolicy applies on a per instance basis, so that *Connext DDS* will attempt to store the configured value of DDS samples for every instance (see 2.4 DDS Samples, Instances, and Keys on page 18 for a discussion of keys and instances).

This QoS policy includes the members seen in Table 7.53 DDS_HistoryQosPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 7.53 DDS_HistoryQosPolicy

Type	Field Name	Description
DDS_HistoryQosPolicyKind	kind	DDS_KEEP_LAST_HISTORY_QOS: keep the last *depth* number of DDS samples per instance. DDS_KEEP_ALL_HISTORY_QOS: keep all DDS samples. *Connext DDS* will store up to the value of the **max_samples_per_instance** parameter in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449. For *DataWriters*, the samples are kept only until either they are fully acknowledged by all matching *DataReaders* or they are replaced. See 7.3.8.2 write() behavior with KEEP_LAST and KEEP_ALL on page 311 for more information about when a sample may be replaced in the *DataWriter* queue.
DDS_Long	depth	If *kind* = DDS_KEEP_LAST_HISTORY_QOS, this is how many DDS samples to keep per instance. **depth** must be <= **max_samples_per_instance** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449. if *kind* = DDS_KEEP_ALL_HISTORY_QOS, this value is ignored.

The **kind** determines whether or not to save a configured number of DDS samples or *all* DDS samples. In either case, when using a Reliable 7.5.21 RELIABILITY QosPolicy on page 444, the samples are kept until they are fully acknowledged by all matching *DataReaders*. Once a sample is fully acknowledged, it is removed from the *DataWriter's* queue, unless it needs to be kept for durability purposes. (See 7.5.9 DURABILITY QosPolicy on page 410). The HISTORY QoS Policy **kind** can be set to either of the following:

- **DDS_KEEP_LAST_HISTORY_QOS.** *Connext DDS* attempts to keep the latest values of the data-instance and discard the oldest ones when the limit as set by the depth parameter is reached; new data will overwrite the oldest data in the queue. Thus the queue acts like a circular buffer of length **depth**. Invalid samples are samples representing the disposal or unregistration of an instance. There is only ever one invalid sample per-instance and that one sample can be in different states depending on whether the instance has been disposed, unregistered, or both. How invalid samples affect the history depth differs for *DataReaders* and *DataWriters:*
  - For a *DataWriter*: *Connext DDS* attempts to keep the most recent **depth** DDS samples of each instance (identified by a unique key) managed by the *DataWriter*. Invalid samples count towards the depth and may replace other DDS samples currently in the *DataWriter* queue.
  - For a *DataReader*: *Connext DDS* attempts to keep the most recent **depth** DDS samples received for each instance (identified by a unique key) until the application takes them via the *DataReader's* **take()** operation. See 8.4.3 Accessing DDS Data Samples with Read or Take on page 550 for a discussion of the difference between **read()** and **take()**. Invalid samples do not count towards the **depth** and will not replace other DDS samples currently in the *DataReader* queue.
- **DDS_KEEP_ALL_HISTORY_QOS.** *Connext DDS* attempts to keep all of the DDS samples of a *Topic*.
  - For a *DataWriter*: *Connext DDS* attempts to keep all DDS samples published by the *DataWriter*.
  - For a *DataReader*: *Connext DDS* attempts to keep all DDS samples received by the *DataReader* for a Topic (both keyed and non-keyed) until the application takes them via the *DataReader*'s **take()** operation. See 8.4.3 Accessing DDS Data Samples with Read or Take on page 550 for a discussion of the difference between **read()** and **take()**.
  - The value of the **depth** parameter is ignored.

The above descriptions say "attempts to keep" because the actual number of DDS samples kept is subject to the limitations imposed by the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449. All of the DDS samples of all instances of a *Topic* share a single physical queue that is allocated for a *DataWriter* or *DataReader*. The size of this queue is configured by the RESOURCE_LIMITS QosPolicy. If there are many different instances for a *Topic*, it is possible that the physical queue may run out of space before the number of DDS samples reaches the **depth** for all instances.

In the **KEEP_ALL** case, *Connext DDS* can only keep as many DDS samples for a *Topic* (independent of instances) as the size of the allocated queue. *Connext DDS* may or may not allocate more memory when the queue is filled, depending on the settings in the RESOURCE_LIMITS QoSPolicy of the *DataWriter* or *DataReader*.

This QosPolicy interacts with the 7.5.21 RELIABILITY QosPolicy on page 444 by controlling whether or not *Connext DDS* guarantees that ALL of the data sent is received or if only the last N data values sent are guaranteed to be received (a reduced level of reliability using the KEEP_LAST setting). However, the

physical sizes of the send and receive queues are *not* controlled by the History QosPolicy. The memory allocation for the queues is controlled by the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.

What happens when the physical queue is filled depends both on the setting for the HISTORY QosPolicy as well as the RELIABILITY QosPolicy.

- **DDS_KEEP_LAST_HISTORY_QOS**
  - If RELIABILITY is **BEST_EFFORT**: When the number of DDS samples for an instance in the queue reaches the value of **depth**, a new DDS sample for the instance will replace the oldest DDS sample for the instance in the queue.
  - If RELIABILITY is **RELIABLE**: When the number of DDS samples for an instance in the queue reaches the value of **depth**, a new DDS sample for the instance will replace the oldest DDS sample for the instance in the queue—even if the DDS sample being overwritten has not been fully acknowledged as being received by all reliable *DataReaders*. This implies that the discarded DDS sample may be lost (with the reason LOST_BY_WRITER) by some reliable *DataReaders*. Thus, when using the **KEEP_LAST** setting, strict reliability is not guaranteed. See Reliable Communications (Chapter 11 on page 682) for a complete discussion on *Connext DDS*'s reliable protocol.
- **DDS_KEEP_ALL_HISTORY_QOS**
  - If RELIABILITY is **BEST_EFFORT**: For a *DataWriter*, if the number of DDS samples for an instance in the queue reaches the value of the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449's **max_samples_per_instance** field, a new DDS sample for the instance will replace the oldest DDS sample for the instance in the queue (regardless of instance). For a *DataReader*, a new DDS sample received by the *DataReader* when this resource limit is exceeded will be lost with the reason DDS_LOST_BY_SAMPLES_PER_INSTANCE_LIMIT.
  - If RELIABILITY is **RELIABLE**: When the number of DDS samples for an instance in the queue reaches the value of the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449's **max_samples_per_instance** field, then:
    - For a *DataWriter*: A new DDS sample for the instance will replace the oldest DDS sample for the instance in the sending queue—*only* if the DDS sample being overwritten has been fully acknowledged as being received by all reliable *DataReaders*. If the oldest DDS sample for the instance has not been fully acknowledged, the **write()** operation trying to enter a new DDS sample for the instance into the sending queue will block (for the **max_blocking_time** specified in the RELIABLE QosPolicy).
    - For a *DataReader:* **max_samples_per_instance** represents the maximum number of DDS samples of any one instance that are stored in the *DataReader* output queue—that is, the queue from which the application takes/reads samples. Therefore, when **max_samples_per_instance** is hit, the *DataWriter* samples will be rejected. They will not be

moved to the *DataReader* output queue. They will stay in the *DataWriter's* remote writer queue until there is space for them in the *DataReader* output queue (until the samples in the *DataReader* output queue are taken). On a reliable *DataReader*, there is one remote writer queue for each *DataWriter* that matches the *DataReader*. The remote writer queue size is configurable with the resource limit **reader_qos.reader_resource_limit.max_samples_per_remote_writer** (see 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571).

Although you can set the HISTORY QosPolicy on *Topics*, its value can only be used to initialize the HISTORY QosPolicies of either a *DataWriter* or *DataReader*. It does not directly affect the operation of *Connext DDS*, see 5.1.3 Setting Topic QosPolicies on page 219.

7.5.12.1 Example

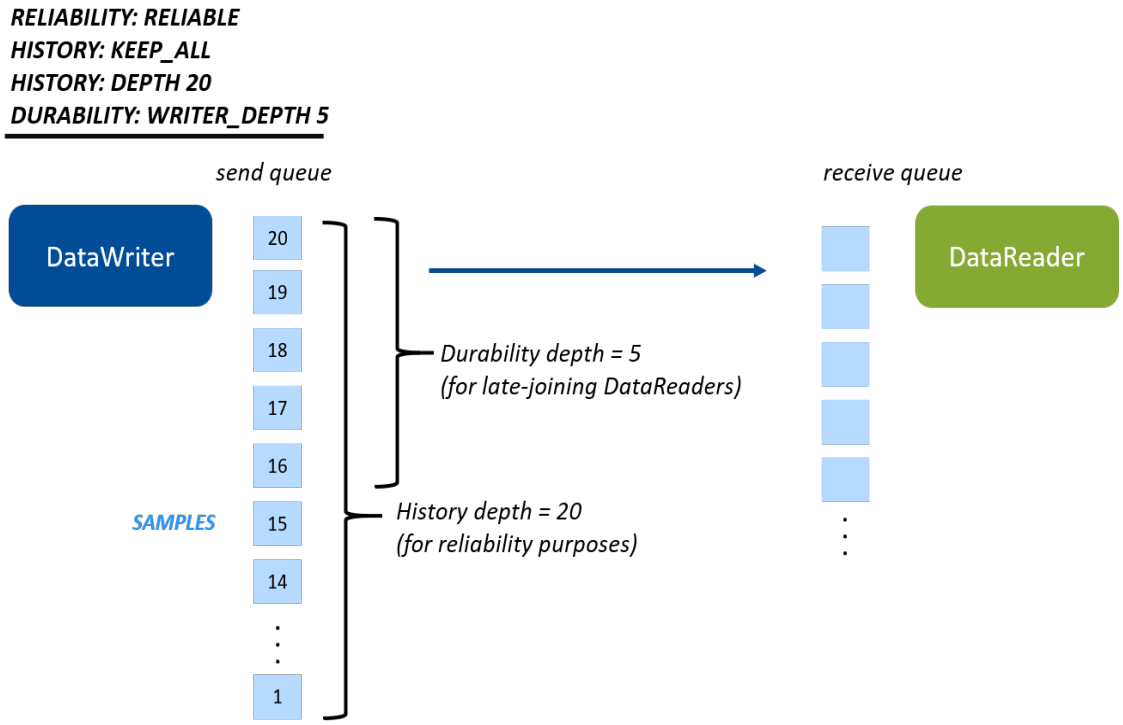
To achieve strict reliability, you must (1) set the *DataWriter's* and *DataReader's* HISTORY QosPolicy to **KEEP_ALL**, and (2) set the *DataWriter's* and *DataReader's* RELIABILITY QosPolicy to **RELIABLE**.

See Reliable Communications (Chapter 11 on page 682) for a complete discussion on *Connext DDS*'s reliable protocol.

See 11.3.3 Controlling Queue Depth with the History QosPolicy on page 697.

It is possible to configure the reliability window (the number of samples kept in the queue for reliability purposes) separately from the durability window (the number of samples kept in the *DataWriter* queue for late-joining *DataReaders*). This allows an application to achieve the level of reliability that is required and still only deliver a subset of data to late-joining *DataReaders* when using a non-VOLATILE 7.5.9 DURABILITY QosPolicy on page 410. Figure 7.30: History Depth and Durability Depth on the next page shows the relationship between History **depth** and Durability **writer_depth**.

Figure 7.30: History Depth and Durability Depth



*The History **depth** determines how many samples to keep for reliability purposes (for example, for redelivering to DataReaders that haven't acknowledged them yet). The 7.5.9 DURABILITY QosPolicy on page 410 **writer_depth** determines what subset of those samples to deliver to late-joining DataReaders.*

7.5.12.2 Properties

This QosPolicy cannot be modified after the *Entity* has been enabled.

There is no requirement that the publishing and subscribing sides use compatible values.

7.5.12.3 Related QosPolicies

- 7.5.2 BATCH QosPolicy (DDS Extension) on page 373 Do not configure the *DataReader's* **depth** to be shallower than the *DataWriter's* maximum batch size (**batch_max_data_size**). Because batches are acknowledged as a group, a *DataReader* that cannot process an entire batch will lose the remaining DDS samples in it.
- 7.5.21 RELIABILITY QosPolicy on page 444
- 7.5.22 RESOURCE_LIMITS QosPolicy on page 449

7.5.12.4 Applicable Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.12.5 System Resource Considerations

While this QosPolicy does not directly affect the system resources used by *Connext DDS*, the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 that must be used in conjunction with the 7.5.12 HISTORY QosPolicy on page 418 will affect the amount of memory that *Connext DDS* will allocate for a *DataWriter* or *DataReader*.

7.5.13 LATENCYBUDGET QoS Policy

This QosPolicy can be used by a DDS implementation to change how it processes and sends data that has low latency requirements. The DDS specification does not mandate whether or how this parameter is used. *Connext DDS* uses it to prioritize the sending of asynchronously published data; see 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344.

This QosPolicy also applies to *Topics*. The *Topic's* setting for the policy is ignored unless you explicitly make the *DataWriter* use it.

It contains the single member listed in Table 7.54 DDS_LatencyBudgetQosPolicy.

Table 7.54 DDS_LatencyBudgetQosPolicy

Type	Field Name	Description
DDS_Duration_t	duration	Provides a hint as to the maximum acceptable delay from the time the data is written to the time it is received by the subscribing applications.

7.5.13.1 Applicable Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.14 LIFESPAN QoS Policy

The purpose of this QoS is to avoid delivering stale data to the application by specifying how long the data written by a *DataWriter* is considered valid.

Each data sample written by a *DataWriter* has an associated expiration time beyond which the data should not be delivered to any application. Once the sample expires, the data will be removed from the *DataWriter* and *DataReader* caches.

The expiration time of each sample from the *DataWriter's* cache is computed by adding the duration specified by this QoS policy to the time when the sample is added to the *DataWriter's* cache. This timestamp is not necessarily equal to the sample's source timestamp that can be provided by the user using the *DataWriter's* **write_w_timestamp()** or **write_w_params()** APIs.

The expiration time of each sample from the *DataReader's* cache is computed by adding the duration to the reception timestamp.

The Lifespan QosPolicy can be used to control how much data is stored by *Connext DDS*. Even if it is configured to store "all" of the data sent or received for a topic (see the 7.5.12 HISTORY QosPolicy on page 418), the total amount of data it stores may be limited by the Lifespan QosPolicy.

You may also use the Lifespan QosPolicy to ensure that applications do not receive or act on data, commands or messages that are too old and have "expired."

It includes the single member listed in Table 7.55 DDS_LifespanQosPolicy. For the default and valid range, please refer to the API Reference HTML documentation.

Table 7.55 DDS_LifespanQosPolicy

Type	Field Name	Description
DDS_Duration_t	duration	Maximum duration for the data's validity.

Although you can set the LIFESPAN QosPolicy on *Topics*, its value can only be used to initialize the LIFESPAN QosPolicies of *DataWriters*. The Topic's setting for this QosPolicy does not directly affect the operation of *Connext DDS*, see 5.1.3 Setting Topic QosPolicies on page 219.

7.5.14.1 Properties

This QoS policy can be modified after the entity is enabled.

It does not apply to *DataReaders*, so there is no requirement that the publishing and subscribing sides use compatible values.

7.5.14.2 Related QoS Policies

- 7.5.2 BATCH QosPolicy (DDS Extension) on page 373 Be careful when configuring a *DataWriter* with a Lifespan **duration** shorter than the batch flush period (**batch_flush_delay**). If the batch does not fill up before the flush period elapses, the short **duration** by default will cause the DDS samples to be dropped without being sent. (You can, however, keep track of the number of

these dropped samples via **writer_removed_batch_sample_dropped_sample_count** in the 8.3.7.2 DATA_READER_CACHE_STATUS on page 514. You can also choose not to drop these samples at all by setting the property **dds.data_reader.accept_writer_removed_batch_samples** to TRUE (by default it is set to FALSE); you can set this property via the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.)

- 7.5.9 DURABILITY QosPolicy on page 410

7.5.14.3 Applicable Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286

7.5.14.4 System Resource Considerations

The use of this policy does not significantly impact the use of resources.

7.5.15 LIVELINESS QosPolicy

The LIVELINESS QosPolicy specifies how *Connext DDS* determines whether a *DataWriter* is "alive." A *DataWriter*'s liveliness is used in combination with the 7.5.17 OWNERSHIP QosPolicy on page 432 to maintain ownership of an instance (note that the 7.5.7 DEADLINE QosPolicy on page 404 is also used to change ownership when a *DataWriter* is still alive). That is, for a *DataWriter* to own an instance, the *DataWriter* must still be alive as well as honoring its DEADLINE contract.

It includes the members in Table 7.56 DDS_LivelinessQosPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 7.56 DDS_LivelinessQosPolicy

Type	Field Name	Description
DDS_LivelinessQosPolicyKind	kind	DDS_AUTOMATIC_LIVELINESS_QOS: *Connext DDS* will automatically assert liveliness for the *DataWriter* at least as often as the **lease_duration**. DDS_MANUAL_BY_PARTICIPANT_LIVELINESS_QOS: The *DataWriter* is assumed to be alive if any Entity within the same *DomainParticipant* has asserted its liveliness. DDS_MANUAL_BY_TOPIC_LIVELINESS_QOS: Your application must explicitly assert the liveliness of the *DataWriter* within the **lease_duration**.

Table 7.56 DDS_LivelinessQosPolicy

Type	Field Name	Description
DDS_Duration_t	lease_duration	The timeout by which liveliness must be asserted for the *DataWriter* or the *DataWriter* will be considered inactive or not alive. Additionally, for *DataReaders*, the lease_duration also specifies the maximum period at which *Connext DDS* will check to see if the matching DataWriter is still alive. A *DataReader* will consider a *DataWriter* not alive if the *DataWriter* does not assert its liveliness within the *DataWriter's* **lease_duration**, not the *DataReader's* **lease_duration**.
DDS_Long	assertions_per_lease_duration	The number of assertions a *DataWriter* will send during a **lease_duration** period. This field only applies to *DataWriters* using DDS_AUTOMATIC_LIVELINESS_QOS kind and it is not considered during QoS compatibility checks. The default value is 3. A higher value will make the liveliness mechanism more robust against packet losses, but it will also increase the network traffic.

Setting a *DataWriter*'s **kind** of LIVELINESS specifies the mechanism that will be used to assert liveliness for the *DataWriter*. The *DataWriter's* **lease_duration** then specifies the maximum period at which packets that indicate that the *DataWriter* is still alive are sent to matching *DataReaders*.

The various mechanisms are:

- **DDS_AUTOMATIC_LIVELINESS_QOS:**

  The *DomainParticipant* is responsible for automatically sending packets to indicate that the *DataWriter is* alive; this will be done at the rate determined by the **assertions_per_lease_duration** and **lease_duration** values. This setting is appropriate when the primary failure mode is that the publishing application itself dies. It does not cover the case in which the application is still alive but in an erroneous state–allowing the *DomainParticipant* to continue to assert liveliness for the *DataWriter* but preventing threads from calling **write()** on the *DataWriter*.

  As long as the internal threads spawned by *Connext DDS* for a *DomainParticipant* are running, then the liveliness of the *DataWriter* will be asserted regardless of the state of the rest of the application.

  This setting is certainly the most convenient, if the least accurate, method of asserting liveliness for a *DataWriter*.

- **DDS_MANUAL_BY_PARTICIPANT_LIVELINESS_QOS:**

  Connext DDS will assume that as long as the user application has asserted the liveliness of at least one *DataWriter* belonging to the same *DomainParticipant* or the liveliness of the *DomainParticipant* itself, then this *DataWriter* is also alive.

This setting allows the user code to control the assertion of liveliness for an entire group of *DataWriters* with a single operation on any of the *DataWriters* or their *DomainParticipant*. Its a good balance between control and convenience.

- **DDS_MANUAL_BY_TOPIC_LIVELINESS_QOS:**

  The *DataWriter* is considered alive only if the user application has explicitly called operations that assert the liveliness for that particular *DataWriter*.

  This setting forces the user application to assert the liveliness for a *DataWriter* which gives the user application great control over when other applications can consider the *DataWriter* to be inactive, but at the cost of convenience.

With the *MANUAL_BY_[TOPIC,PARTICIPANT]* settings, user application code can assert the liveliness of *DataWriters* either explicitly by calling the **assert_liveliness()** operation on the *DataWriter* (as well as the *DomainParticipant* for the *MANUAL_BY_PARTICIPANT* setting) or implicitly by calling **write()** on the *DataWriter*. If the application does not use either of the methods mentioned at least once every **lease_duration**, then the subscribing application may assume that the *DataWriter* is no longer alive. Sending data MANUAL_BY_TOPIC will cause an assert message to be sent between the *DataWriter* and its matched *DataReaders.*

Publishing applications will monitor their *DataWriters* to make sure that they are honoring their LIVELINESS QosPolicy by asserting their liveliness at least at the period set by the **lease_duration**. If *Connext DDS* finds that a *DataWriter* has failed to have its liveliness asserted by its **lease_duration**, an internal thread will modify the *DataWriter*'s *LIVELINESS_LOST_STATUS* and trigger its **on_liveliness_lost()** *DataWriterListener* callback if a listener exists, see 4.4 Listeners on page 189.

Setting the *DataReader*'s **kind** of LIVELINESS requests a specific mechanism for the publishing application to maintain the liveliness of *DataWriter*s. The subscribing application may want to know that the publishing application is explicitly asserting the liveliness of the matching *DataWriter* rather than inferring its liveliness through the liveliness of its *DomainParticipant* or its sibling *DataWriters*.

The *DataReader's* **lease_duration** specifies the maximum period at which matching *DataWriters* must have their liveliness asserted. In addition, in the subscribing application *Connext DDS* uses an internal thread that wakes up at the period set by the *DataReader's* **lease_duration** *to* see if the *DataWriter's* **lease_duration** has been violated.

When a matching *DataWriter* is determined to be dead (inactive), *Connext DDS* will modify the *LIVELINESS_CHANGED_STATUS* of each matching *DataReader* and trigger that *DataReader's* **on_liveliness_changed()** *DataReaderListener* callback (if a listener exists).

Although you can set the LIVELINESS QosPolicy on *Topics*, its value can only be used to initialize the LIVELINESS QosPolicies of either a *DataWriter* or *DataReader*. It does not directly affect the operation of *Connext DDS*, see 5.1.3 Setting Topic QosPolicies on page 219.

For more information on Liveliness, see 15.3.1.2 Maintaining DataWriter Liveliness for kinds AUTOMATIC and MANUAL_BY_PARTICIPANT on page 773.

7.5.15.1 Example

You can use LIVELINESS QosPolicy during system integration to ensure that applications have been coded to meet design specifications. You can also use it during run time to detect when systems are performing outside of design specifications. Receiving applications can take appropriate actions in response to disconnected *DataWriters*.

The LIVELINESS QosPolicy can be used to manage fail-over when the 7.5.17 OWNERSHIP QosPolicy on page 432 is set to **EXCLUSIVE**. This implies that the *DataReader* will only receive data from the highest strength *DataWriter* that is alive (active). When that *DataWriter*'s liveliness expires, then Connext DDS will start delivering data from the next highest strength *DataWriter* that is still alive.

7.5.15.2 Properties

This QosPolicy cannot be modified after the Entity has been enabled.

The *DataWriter* and *DataReader* must use compatible settings for this QosPolicy. To be compatible, *both* of the following conditions must be true:

The *DataWriter* and *DataReader* must use one of the valid combinations shown in Table 7.57 Valid Combinations of Liveliness 'kind'.

DataWriter's **lease_duration** <= *DataReader's* **lease_duration**.

If this QosPolicy is found to be incompatible, the **ON_OFFERED_INCOMPATIBLE_QOS** and **ON_REQUESTED_INCOMPATIBLE_QOS** statuses will be modified and the corresponding *Listeners* called for the *DataWriter* and *DataReader* respectively.

Table 7.57 Valid Combinations of Liveliness 'kind'

		DataReader requests:		
		MANUAL_BY_TOPIC	MANUAL_BY_PARTICIPANT	AUTOMATIC
DataWriter offers:	MANUAL_BY_TOPIC	compatible	compatible	compatible
	MANUAL_BY_PARTICIPANT	incompatible	compatible	compatible
	AUTOMATIC	incompatible	incompatible	compatible

7.5.15.3 Related QosPolicies

- 7.5.7 DEADLINE QosPolicy on page 404
- 7.5.17 OWNERSHIP QosPolicy on page 432
- 7.5.18 OWNERSHIP_STRENGTH QosPolicy on page 435

7.5.15.4 Applicable Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.15.5 System Resource Considerations

An internal thread in *Connext DDS* will wake up periodically to check the liveliness of all the *DataWriters*. This happens both in the application that contains the *DataWriters* at the **lease_duration** set on the *DataWriters* as well as the applications that contain the *DataReaders* at the **lease_duration** set on the *DataReaders*. Therefore, as **lease_duration** becomes smaller, more CPU will be used to wake up threads and perform checks. A short **lease_duration** (or a high **assertions_per_lease_duration**) set on *DataWriters* may also use more network bandwidth because liveliness packets are being sent at a higher rate—this is especially true when LIVELINESS kind is set to AUTOMATIC.

7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension)

This QosPolicy is used to partition the data published by a *DataWriter* across multiple *channels*. A *channel* is defined by a filter expression and a sequence of multicast locators.

By using this QosPolicy, a *DataWriter* can be configured to send data to different multicast groups based on the content of the data. Using syntax similar to those used in Content-Based Filters, you can associate different multicast addresses with filter expressions that operate on the values of the fields within the data. When your application's code calls **write()**, data is sent to any multicast address for which the data passes the filter.

See Multi-channel DataWriters (Chapter 20 on page 888) for complete documentation on multi-channel *DataWriters*.

Note: Durable writer history is not supported for multi-channel *DataWriters*; an error is reported if a multi-channel *DataWriter* tries to configure Durable Writer History.

This QosPolicy includes the members presented in Table 7.58 DDS_MultiChannelQosPolicy, Table 7.59 DDS_ChannelSettings_t, and Table 7.60 DDS_TransportMulticastSettings_t. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 7.58 DDS_MultiChannelQosPolicy

Type	Field Name	Description
DDS_ChannelSettingsSeq	channels	A sequence of channel settings used to configure the channels' properties. If the length of the sequence is zero, the QosPolicy will be ignored. See Table 7.59 DDS_ChannelSettings_t.
char*	filter_name	Name of the filter class used to describe the filter expressions[1]. The following values are supported: DDS_SQLFILTER_NAME (see 5.4.6 SQL Filter Expression Notation on page 235) DDS_STRINGMATCHFILTER_NAME (see 5.4.7 STRINGMATCH Filter Expression Notation on page 244) More details are described in the API Reference HTML documentation.

Table 7.59 DDS_ChannelSettings_t

Type	Field Name	Description
DDS_TransportMulticastSettingsSeq	multicast_settings	A sequence of multicast settings used to configure the multicast addresses associated with a channel. **The sequence cannot be empty.** The maximum number of multicast locators in a channel is limited by default to 16. This is a hard limit that cannot be increased. However, this limit can be *decreased* by configuring the *DomainParticipant* property **dds.domain_participant.max_announced_locator_list_size**. See Table 7.60 DDS_TransportMulticastSettings_t.
char*	filter_expression	A logical expression used to determine the data that will be published in the channel. **This string cannot be NULL.** An empty string always evaluates to TRUE. See 5.4.6 SQL Filter Expression Notation on page 235 and 5.4.7 STRINGMATCH Filter Expression Notation on page 244 for expression syntax.
DDS_Long	priority	A positive integer designating the relative priority of the channel, used to determine the transmission order of pending transmissions. Larger numbers have higher priority. To use publication priorities, the *DataWriter's* 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441 must be set for asynchronous publishing and the *DataWriter* must use a FlowController that is configured for highest-priority-first (HPF) scheduling. See 7.6.4 Prioritized DDS Samples on page 473.

[1] In Java and C#, you can access the names of the built-in filters by using DomainParticipant.SQLFILTER_NAME and DomainParticipant.STRINGMATCHFILTER_NAME.

Table 7.60 DDS_TransportMulticastSettings_t

Type	Field Name	Description
DDS_StringSeq	transports	A sequence of transport aliases that specifies which transport should be used to publish multicast messages for this channel.
char*	receive_address	A multicast group address on which *DataReaders* subscribing to this channel will receive data.
DDS_Long	receive_port	The multicast port on which *DataReaders* subscribing to this channel will receive data.

The format of the **filter_expression** should correspond to one of the following filter classes:

- DDS_SQLFILTER_NAME *(see 5.4.6 SQL Filter Expression Notation on page 235)*
- DDS_STRINGMATCHFILTER_NAME (see 5.4.7 STRINGMATCH Filter Expression Notation on page 244

A *DataReader* can use the ContentFilteredTopic API (see 5.4.5 Using a ContentFilteredTopic on page 233) to subscribe to a subset of the channels used by a *DataWriter*.

7.5.16.1 Example

See Multi-channel DataWriters (Chapter 20 on page 888).

7.5.16.2 Properties

This QosPolicy cannot be modified after the *DataWriter* is created.

It does not apply to *DataReaders*, so there is no requirement that the publishing and subscribing sides use compatible values.

7.5.16.3 Related Qos Policies

- 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649

7.5.16.4 Applicable Entities

- 7.3 DataWriters on page 286

7.5.16.5 System Resource Considerations

The following fields in the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649 configure the resources associated with the channels stored in the MULTI_CHANNEL QosPolicy:

- **channel_seq_max_length**
- **channel_filter_expression_max_length**

For information about partitioning topic data across multiple channels, please refer to Multi-channel DataWriters (Chapter 20 on page 888).

7.5.17 OWNERSHIP QosPolicy

The OWNERSHIP QosPolicy specifies whether a *DataReader* receives data for an instance of a *Topic* sent by multiple *DataWriters*.

For non-keyed *Topics*, there is only one instance of the *Topic*.

This policy includes the single member shown in Table 7.61 DDS_OwnershipQosPolicy.

Table 7.61 DDS_OwnershipQosPolicy

Type	Field Name	Description
DDS_OwnershipQosPolicyKind	kind	(**default**) DDS_SHARED_OWNERSHIP_QOS or DDS_EXCLUSIVE_OWNERSHIP_QOS

The **kind** of OWNERSHIP can be set to one of two values:

- **SHARED Ownership**

  When OWNERSHIP is **SHARED**, and multiple *DataWriters* for the *Topic* publishes the value of the same instance, all the updates are delivered to subscribing *DataReaders*. So in effect, there is no "owner;" no single *DataWriter* is responsible for updating the value of an instance. The subscribing application will receive modifications from all *DataWriters*.

- **EXCLUSIVE Ownership**

  When OWNERSHIP is **EXCLUSIVE**, each instance can only be owned by one *DataWriter* at a time. This means that a single *DataWriter* is identified as the exclusive owner whose updates are allowed to modify the value of the instance for matching *DataReaders*. Other *DataWriters* may submit modifications for the instance, but only those made by the current owner are passed on to the *DataReaders*. If a non-owner *DataWriter* modifies an instance, no error or notification is made; the modification is simply ignored. The owner of the instance can change dynamically.

  Note for non-keyed *Topics*, **EXCLUSIVE** ownership implies that *DataReaders* will pay attention to only one *DataWriter* at a time because there is only a single instance. For keyed *Topics*, *DataReaders* may actually receive data from multiple *DataWriters* when different *DataWriters* own different instances of the *Topic*.

This QosPolicy is often used to help users build systems that have redundant elements to safeguard against component or application failures. When systems have active and hot standby components, the Ownership QosPolicy can be used to ensure that data from standby applications are only delivered in the case of the failure of the primary.

The Ownership QosPolicy can also be used to create data channels or topics that are designed to be taken over by external applications for testing or maintenance purposes.

Although you can set the OWNERSHIP QosPolicy on *Topics*, its value can only be used to initialize the OWNERSHIP QosPolicies of either a *DataWriter* or *DataReader*. It does not directly affect the operation of *Connext DDS*, see 5.1.3 Setting Topic QosPolicies on page 219.

7.5.17.1 How Connext DDS Selects which DataWriter is the Exclusive Owner

When OWNERSHIP is **EXCLUSIVE**, the owner of an instance at any given time is the *DataWriter* with the highest 7.5.18 OWNERSHIP_STRENGTH QosPolicy on page 435 that is "alive" as defined by the 7.5.15 LIVELINESS QosPolicy on page 425) and has not violated the 7.5.7 DEADLINE QosPolicy on page 404 of the *DataReader*. OWNERSHIP_STRENGTH is simply an integer set by the *DataWriter*.

If the *Topic*'s data type is keyed (see 2.4 DDS Samples, Instances, and Keys on page 18), **EXCLUSIVE** ownership is determined on a per-instance basis. That is, the *DataWriter* owner of each instance is considered separately. A *DataReader* can receive values written by a lower strength *DataWriter* as long as those values are for instances that are not being written by a higher-strength *DataWriter*.

If there are multiple *DataWriters* with the same OWNERSHIP_STRENGTH writing to the same instance, *Connext DDS* resolves the tie by choosing the *DataWriter* with the smallest GUID (Globally Unique Identifier, see 15.1.1 Simple Participant Discovery on page 759.). This means that different *DataReaders* (in different applications) of the same *Topic* will all choose the same *DataWriter* as the owner when there are multiple *DataWriters* with the same strength.

The owner of an instance can change when:

- A *DataWriter* with a higher OWNERSHIP_STRENGTH publishes a value for the instance.
- The OWNERSHIP_STRENGTH of the owning *DataWriter* is dynamically changed to be less than the strength of an existing *DataWriter* of the instance.
- The owning *DataWriter* stops asserting its LIVELINESS (the *DataWriter* dies).
- The owning *DataWriter* violates the DEADLINE QosPolicy by not updating the value of the instance within the period set by the DEADLINE.

Note however, the change of ownership is not synchronous across different *DataReaders* in different participants. That is, *DataReaders* in different applications may not determine that the ownership of an instance has changed at exactly the same time.

7.5.17.2 Example

OWNERSHIP is really a property that is shared between *DataReaders* and *DataWriters* of a *Topic*. However, in a system, some *Topics* will be exclusively owned and others will be shared. System requirements will determine which are which.

An example of a *Topic* that may be shared is one that is used by applications to publish alarm messages. If the application detects an anomalous condition, it will use a *DataWriter* to write a *Topic* "Alarm." Another application that records alarms into a system log file will have a *DataReader* that subscribes to "Alarm." In this example, any number of applications can publish the "Alarm" message. There is no concept that only one application at a time is allowed to publish the "Alarm" message, so in this case, the OWNERSHIP of the *DataWriters* and *DataReaders* should be set to **SHARED**.

In a different part of the system, **EXCLUSIVE** OWNERSHIP may be used to implement redundancy in support of fault tolerance. Say, the distributed system controls a traffic system. It monitors traffic and changes the information posted on signs, the operation of metering lights, and the timing of traffic lights. This system must be tolerant to failure of any part of the system including the application that actually issues commands to change the lights at a particular intersection.

One way to implement fault tolerance is to create the system redundantly both in hardware and software. So if a piece of the running system fails, a backup can take over. In systems where failover from the primary to backup system must be seamless and transparent, the actual mechanics of failover must be fast, and the redundant component must immediately pickup where the failed component left off. For the network connections of the component, Connext DDS can provided redundant *DataWriter* and *DataReaders*.

In this case, you would not want the *DataReaders* to receive redundant messages from the redundant *DataWriters*. Instead you will want the *DataReaders* to only receive messages from the primary application and only from a backup application when a failure occurs. To continue our example, if we have redundant applications that all try to control the lights at an intersection, we would want the *DataReaders* on the light to receive messages only from the primary application. To do so, we should configure the *DataWriters* and *DataReaders* to have **EXCLUSIVE** OWNERSHIP and set the OWNERSHIP_STRENGTH differently on different redundant applications to distinguish between primary and backup systems.

7.5.17.3 Properties

This QosPolicy cannot be modified after the *Entity* is enabled.

It must be set to the same **kind** on both the publishing and subscribing sides. If a *DataWriter* and *DataReader* of the same topic are found to have different **kinds** set for the OWNERSHIP QoS, the **ON_OFFERED_INCOMPATIBLE_QOS** and **ON_REQUESTED_INCOMPATIBLE_QOS** statuses will be modified and the corresponding *Listeners* called for the *DataWriter* and *DataReader* respectively.

7.5.17.4 Related QosPolicies

- 7.5.7 DEADLINE QosPolicy on page 404
- 7.5.15 LIVELINESS QosPolicy on page 425
- 7.5.18 OWNERSHIP_STRENGTH QosPolicy below

7.5.17.5 Applicable Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.17.6 System Resource Considerations

This QosPolicy does not significantly impact the use of system resources.

7.5.18 OWNERSHIP_STRENGTH QosPolicy

The OWNERSHIP_STRENGTH QosPolicy is used to rank *DataWriters* of the same instance of a *Topic*, so that *Connext DDS* can decide which *DataWriter* will have ownership of the instance when the 7.5.17 OWNERSHIP QosPolicy on page 432 is set to **EXCLUSIVE**.

It includes the member in Table 7.62 DDS_OwnershipStrengthQosPolicy. For the default and valid range, please refer to the API Reference HTML documentation.

Table 7.62 DDS_OwnershipStrengthQosPolicy

Type	Field Name	Description
DDS_Long	value	The strength value used to arbitrate among multiple *DataWriters*.

This QosPolicy only applies to *DataWriters* when **EXCLUSIVE** OWNERSHIP is used. The strength is simply an integer value, and the *DataWriter* with the largest value is the owner. A deterministic method is used to decide which *DataWriter* is the owner when there are multiple *DataWriters* that have equal strengths. See 7.5.17.1 How Connext DDS Selects which DataWriter is the Exclusive Owner on page 433 for more details.

7.5.18.1 Example

Suppose there are two *DataWriters* sending DDS samples of the same *Topic* instance, one as the main *DataWriter*, and the other as a backup. If you want to make sure the *DataReader* always receive from the main one whenever possible, then set the main *DataWriter* to use a higher **ownership_strength** value than the one used by the backup *DataWriter*.

7.5.18.2 Properties

This QosPolicy can be changed at any time.

It does not apply to *DataReaders*, so there is no requirement that the publishing and subscribing sides use compatible values.

7.5.18.3 Related QosPolicies

- 7.5.17 OWNERSHIP QosPolicy on page 432

7.5.18.4 Applicable Entities

- 7.3 DataWriters on page 286

7.5.18.5 System Resource Considerations

The use of this policy does not significantly impact the use of resources.

7.5.19 PROPERTY QosPolicy (DDS Extension)

The PROPERTY QosPolicy stores name/value (string) pairs that can be used to configure certain parameters of *Connext DDS* that are not exposed through formal QoS policies.

It can also be used to store and propagate application-specific name/value pairs that can be retrieved by user code during discovery. This is similar to the USER_DATA QosPolicy, except this policy uses (name, value) pairs, and you can select whether or not a particular pair should be propagated (included in the built-in topic). By default, properties are not propagated during discovery.

It includes the member in Table 7.63 DDS_PropertyQosPolicy.

Table 7.63 DDS_PropertyQosPolicy

Type	Field Name	Description
DDS_PropertySeq	value	A sequence of: (name, value) pairs and booleans that indicate whether the pair should be propagated (included in the entity's built-in topic upon discovery).

The Property QoS stores name/value pairs for an Entity. Both the name and value are strings. Certain configurable parameters for Entities that do not have a formal DDS QoS definition may be configured via this QoS by using a predefined name and the desired setting in string form.

You can find a complete list of predefined properties in the Property Reference Guide.

You can manipulate the sequence of properties (name, value pairs) with the standard methods available for sequences. You can also use the helper class, DDSPropertyQosPolicyHelper, which provides another way to work with a PropertyQosPolicy object.

The PropertyQosPolicy may be used to configure:

- Durable writer history (see 13.3.2 How To Configure Durable Writer History on page 735)
- Durable reader state (see 13.4.4 How To Configure a DataReader for Durable Reader State on page 741)
- Built-in and extension Transport Plugins (see 16.6 Setting Builtin Transport Properties with the PropertyQosPolicy on page 795, 42.2 Setting Up a Transport with the Property QoS on page 1103, Configuring the TCP Transport (Chapter 44 on page 1128)).
- Automatic registration of built-in types (see 3.2.1 Registering Built-in Types on page 39)
- 9.6 Clock Selection on page 671
- 7.3.18 Turbo Mode and Automatic Throttling for DataWriter Performance—Experimental Features on page 343
- Location or content of your license from RTI (see License Management, in the Installation Guide)

In addition, you can add your own name/value pairs to the Property QoS of an Entity. Start them with a prefix other than **dds.**, **com.rti.**, or **rti.**, so that they do not fail validation. (See 7.5.19.1 Property Validation on page 439.) You may also use this QosPolicy to direct *Connext DDS* to propagate these name/-value pairs with the discovery information for the Entity. Applications that discover the Entity can then access the user-specific name/value pairs in the discovery information of the remote Entity. This allows you to add meta-information about an Entity for application-specific use, for example, authentication/authorization certificates (which can also be done using the User or Group Data QoS).

Reasons for using the PropertyQosPolicy include:

- Some features can only be configured through the PropertyQosPolicy, not through other QoS or APIs (for example, Durable Reader State, Durable Writer History, Built-in Types, Monotonic Clock).
- Alternative way to configure built-in transports settings. For example, to use non-default values for the built-in transports without using the PropertyQosPolicy, you would have to create a *DomainParticipant* disabled, change the built-in transport property settings, then enable the *DomainParticipant*. Using the PropertyQosPolicy to configure built-in transport settings will save you the work of enabling and disabling the *DomainParticipant*. Also, transport settings are not a QoS and therefore cannot be configured through an XML file. By configuring built-in transport settings through the PropertyQosPolicy instead, XML files can be used.

When using the Java or .NET APIs, transport configuration must take place through the PropertyQosPolicy (not through the transport property structures).

- Alternative way to support multiple instances of built-in transports (without using Transport API).
- Alternative way to dynamically load extension transports (such as *RTI Secure WAN Transport*[1] or *RTI TCP Transport*[2]) or user-created transport plugins in C/C++ language bindings. If the extension or user-created transport plugin is installed using the transport API instead, the library that extra transport library/code will need to be linked into your application and may require recompilation.
- Allows full pluggable transport configuration for non-C/C++ language bindings (Java, C++/CLI, C#, etc.) The pluggable transport API is not available in those languages. Without using PropertyQosPolicy, you cannot use extension transports (such as *RTI Secure WAN Transport*) and you cannot create your own custom transport.
- Alternative way to provide a license for platforms that do not support a file system, or if a default license location is not feasible and environment variables are not supported.

The PropertyQosPolicyHelper operations are described in Table 7.64 PropertyQoSPolicyHelper Operations. For more information, see the API Reference HTML documentation.

Table 7.64 PropertyQoSPolicyHelper Operations

Operation	Description
get_number_of_properties	Gets the number of properties in the input policy.
assert_property	Asserts the property identified by name in the input policy. (Either adds it, or replaces an existing one.)
add_property	Adds a new property to the input policy.
assert_pointer_property	Asserts the property identified by name in the input policy. Used when the property to store is a pointer.
add_pointer_property	Adds a new property to the input policy. Used when the property to store is a pointer.
lookup_property	Searches for a property in the input policy given its name.
remove_property	Removes a property from the input policy.
get_properties	Retrieves a list of properties whose names match the input prefix.

[1] *RTI Secure WAN Transport* is an optional component that is installed separately.

[2] *RTI TCP Transport* is included with your*Connext DDS* distribution but is not a built-in transport and therefore not enabled by default.

7.5.19.1 Property Validation

All the properties that *Connext DDS* provides (which begin with **dds.**, **com.rti.**, or **rti.**) are validated when the entity or the plugin is created. This validation is done to avoid using an unknown or incorrect property name (for example, due to a typo). Without this validation, *Connext DDS* ignores the unknown property name, and you might not know why the property's configuration isn't being applied.

By default, at the creation of an entity or a plugin, if you specify an incorrect property name, *Connext DDS* logs an exception similar to the following:

- Entity:

```
DDS_PropertyQosPolicy_validatePropertyNames:Unexpected property: dds.type_
consistnecy.ignore_sequence_bounds. Closest valid property: dds.type_consistency.ignore_
sequence_bounds
DDS_DataReaderQos_is_consistentI:inconsistent QoS property
DDS_Subscriber_create_datareader_disabledI:ERROR: Inconsistent QoS
```

- Plugin, such as TCPv4:

```
DDS_PropertyQosPolicy_validate_plugin_property_suffixes:Unexpected property:
dds.transport.TCPv4.tcp1.invalidPropertyTest. Closest valid property:
dds.transport.TCPv4.tcp1.aliases
NDDS_Transport_TCPv4_Property_parseDDSProperties:Inconsistent QoS property:
dds.transport.TCPv4.
NDDS_Transport_TCPv4_create:!get transport TCPv4 plugin property from DDS Property
```

You can configure the behavior of this validation by setting a property at the *DomainParticipant* level. The *DomainParticipant's DataWriters* and *DataReaders* use the participant's setting. Or you can set the property at the plugin level.

- At the entity-level setting, you can set the property **dds.participant.property_validation_action** to any of the following options:
  - (default) VALIDATION_ACTION_EXCEPTION: validate properties. Upon failure, log errors and fail.
  - VALIDATION_ACTION_SKIP: skip validation.
  - VALIDATION_ACTION_WARNING: validate properties. Upon failure, log warnings and do not fail.
- At the plugin level setting, you can set the property **<plugin_name>.property_validation_action**:
  - Options:
    - VALIDATION_ACTION_EXCEPTION: validate properties. Upon failure, log errors and fail.
    - VALIDATION_ACTION_SKIP: skip validation.

    - VALIDATION_ACTION_WARNING: validate properties. Upon failure, log warnings and do not fail.
- If the property is not set, the plugin property validation behavior will be the same as that of the *DomainParticipant*, which by default is VALIDATION_ACTION_EXCEPTION.
- For example, to set the **property_validation_action** for the **dds.transport.TCPv4.tcp1** transport plugin via XML:

```
<domain_participant_qos>
    <property>
        <value>
            <element>
                <name>dds.transport.load_plugins</name>
                <value>dds.transport.TCPv4.tcp1</value>
            </element>
            <element>
                <name>dds.transport.TCPv4.tcp1.property_validation_action</name>
                <value>VALIDATION_ACTION_WARNING</value>
            </element>
        </value>
    </property>
</domain_participant_qos>
```

In general, it is recommended that you use **dds.participant.property_validation_action** to control the validation of the properties for both the *Connext DDS* core libraries and any plugins you might use. However, there are cases where you might want to configure different behaviors for the core libraries and the plugins. For example, if you are running a customized version of the plugins that supports a new, experimental property, you will need to disable the *DomainParticipant* validation via **dds.participant.property_validation_action**, but still keep the plugin validation (for example, **dds.transport.TCPv4.tcp1.property_validation_action**). Here's an example of disabling the *DomainParticipant* level validation and enabling a plugin level validation:

```
<domain_participant_qos>
    <property>
        <value>
            <element>
                <name>dds.participant.property_validation_action</name>
                <value>VALIDATION_ACTION_SKIP</value>
            </element>
            <element>
                <name>dds.transport.TCPv4.tcp1.property_validation_action</name>
                <value>VALIDATION_ACTION_EXCEPTION</value>
            </element>
        </value>
    </property>
</domain_participant_qos>
```

Note that the validation is sequential: first the property is validated when the *DomainParticipant* is created, then it is validated when the plugin is created. For example, consider that the *DomainParticipant* sets the

property **dds.participant.property_validation_action** to VALIDATION_ACTION_EXCEPTION, but the plugin is configured to skip the unknown property. In this case, *DomainParticipant* creation will fail, and the plugin will never get created. As described above, if you are customizing the plugin, set the validation to VALIDATION_ACTION_SKIP at the *DomainParticipant* level, then set the plugin property validation to VALIDATION_ACTION_EXCEPTION. By doing that, the properties will be validated just at the plugin level.

You can find a complete list of the *Connext DDS* predefined properties in the Property Reference Guide.

7.5.19.2 Properties

This QosPolicy can be changed at any time.

There is no requirement that the publishing and subscribing sides use compatible values.

7.5.19.3 Related QosPolicies

- 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649

7.5.19.4 Applicable Entities

- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501
- 9.3 DomainParticipants on page 604

7.5.19.5 System Resource Considerations

The 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649 contains several fields for configuring the resources associated with the properties stored in this QosPolicy.

7.5.20 PUBLISH_MODE QosPolicy (DDS Extension)

This QosPolicy determines the *DataWriter's* publishing mode, either asynchronous or synchronous.

The publishing mode controls whether data is written synchronously—in the context of the user thread when calling **write()**, or asynchronously—in the context of a separate thread internal to *Connext DDS*.

Note: For information on asynchronous *DataWriters* and sender-side filtering, see 5.4.2 Where Filtering is Applied—Publishing vs. Subscribing Side on page 228.

Each *Publisher* spawns a single asynchronous publishing thread (set in its 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344) to serve all its asynchronous *DataWriters*.

When data is written asynchronously, a FlowController (7.6 FlowControllers (DDS Extension) on page 467), identified by **flow_controller_name**, can be used to shape the network traffic. The

FlowController's properties determine when the asynchronous publishing thread is allowed to send data and how much.

The fastest way for *Connext DDS* to send data is for the user thread to execute the middleware code that actually sends the data itself. However, there are times when user applications may need or want an internal middleware thread to send the data instead. For instance, for sending large data reliably, an asynchronous thread must be used (see 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344).

This QosPolicy can select a FlowController to prioritize or shape the data flow sent by a *DataWriter* to *DataReaders*. Shaping a data flow usually means limiting the maximum data rates with which the middleware will send data for a *DataWriter*. The FlowController will buffer data sent faster than the maximum rate by the *DataWriter*, and then only send the excess data when the user send rate drops below the maximum rate.

If **kind** is set to DDS_ASYNCHRONOUS_PUBLISH_MODE_QOS, the flow controller referred to by **flow_controller_name** must exist. Otherwise, the setting will be considered inconsistent.

This QosPolicy includes the members in Table 7.65 DDS_PublishModeQosPolicy. For the defaults, please refer to the API Reference HTML documentation.

Table 7.65 DDS_PublishModeQosPolicy

Type	Field Name	Description
DDS_PublishModeQosPolicyKind	kind	Either: • DDS_ASYNCHRONOUS_PUBLISH_MODE_QOS • DDS_SYNCHRONOUS_PUBLISH_MODE_QOS
char*	flow_controller_name	Name of the associated flow controller. There are three built-in FlowControllers: • DDS_DEFAULT_FLOW_CONTROLLER_NAME • DDS_FIXED_RATE_FLOW_CONTROLLER_NAME • DDS_ON_DEMAND_FLOW_CONTROLLER_NAME You may also create your own FlowControllers. See 7.6 FlowControllers (DDS Extension) on page 467.
DDS_Long	priority	A positive integer designating the relative priority of the *DataWriter*, used to determine the transmission order of pending writes. To use publication priorities, this QosPolicy's **kind** must be DDS_ASYNCHRONOUS_PUBLISH_MODE_QOS and the *DataWriter* must use a FlowController with a highest-priority first (HPF) **scheduling_policy**. See 7.6.4 Prioritized DDS Samples on page 473.

The maximum number of DDS samples that will be coalesced depends on **NDDS_Transport_Property_t::gather_send_buffer_count_max** (each DDS sample requires at least 2-4 gather-send buffers). Performance can be improved by increasing **NDDS_Transport_Property_t::gather_send_buffer_count_max**. Note that the maximum value is operating system dependent.

Connext DDS queues DDS samples until they can be sent by the asynchronous publishing thread (as determined by the corresponding FlowController).

The number of DDS samples that will be queued is determined by the 7.5.12 HISTORY QosPolicy on page 418: when using **KEEP_LAST**, the most recent **depth** DDS samples are kept in the queue.

Once unsent DDS samples are removed from the queue, they are no longer available to the asynchronous publishing thread and will therefore never be sent.

Unless **flow_controller_name** points to one of the built-in FlowControllers, finalizing the DataWriterQos will also free the string pointed to by **flow_controller_name**. Therefore, you should use **DDS_String_dup()** before passing the string to **flow_controller_name**, or reset **flow_controller_name** to NULL before the destructing /finalizing the QoS.

Advantages of Asynchronous Publishing:

Asynchronous publishing may increase latency, but offers the following advantages:

- The **write()** call does not make any network calls and is therefore faster and more deterministic. This becomes important when the user thread is executing time-critical code.
- When data is written in bursts or when sending large data types as multiple fragments, a flow controller can throttle the send rate of the asynchronous publishing thread to avoid flooding the network.
- Asynchronously written DDS samples for the same destination will be coalesced into a single network packet which reduces bandwidth consumption.

7.5.20.1 Properties

This QosPolicy cannot be modified after the *DataWriter* is created.

Since it is only for *DataWriters*, there are no compatibility restrictions for how it is set on the publishing and subscribing sides.

7.5.20.2 Related QosPolicies

- 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344
- 7.5.12 HISTORY QosPolicy on page 418

7.5.20.3 Applicable Entities

- 7.3 DataWriters on page 286

7.5.20.4 System Resource Considerations

See 7.5.22.1 Configuring Resource Limits for Asynchronous DataWriters on page 450.

System resource usage depends on the settings in the corresponding FlowController (see 7.6 FlowControllers (DDS Extension) on page 467).

7.5.21 RELIABILITY QosPolicy

This RELIABILITY QosPolicy determines whether or not data published by a *DataWriter* will be reliably delivered by *Connext DDS* to matching *DataReaders*. The reliability protocol used by *Connext DDS* is discussed in Reliable Communications (Chapter 11 on page 682).

The reliability of a connection between a *DataWriter* and *DataReader* is entirely user configurable. It can be done on a per *DataWriter*/*DataReader* connection. A connection may be configured to be "best effort" which means that *Connext DDS* will not use any resources to monitor or guarantee that the data sent by a *DataWriter* is received by a *DataReader*.

For some use cases, such as the periodic update of sensor values to a GUI displaying the value to a person, "best effort" delivery is often good enough. It is certainly the fastest, most efficient, and least resource-intensive (CPU and network bandwidth) method of getting the newest/latest value for a topic from *DataWriters* to *DataReaders*. But there is no guarantee that the data sent will be received. It may be lost due to a variety of factors, including data loss by the physical transport such as wireless RF or even Ethernet. Packets received out of order are dropped and reported as lost with the reason LOST_BY_WRITER (see 8.3.7.7 SAMPLE_LOST Status on page 524).

However, there are data streams (topics) in which you want an absolute guarantee that all data sent by a *DataWriter* is received reliably by *DataReaders*. This means that *Connext DDS* must check whether or not data was received, and repair any data that was lost by resending a copy of the data as many times as it takes for the *DataReader* to receive the data.

Connext DDS uses a reliability protocol configured and tuned by these QoS policies:

- 7.5.12 HISTORY QosPolicy on page 418
- 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388
- 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565
- 7.5.22 RESOURCE_LIMITS QosPolicy on page 449

The Reliability QoS policy is simply a switch to turn on the reliability protocol for a *DataWriter*/*DataReader* connection. The level of reliability provided by *Connext DDS* is determined by the configuration of the aforementioned QoS policies.

You can configure *Connext DDS* to deliver ALL data in the order they were sent (also known as absolute or strict reliability). Or, as a trade-off for less memory, CPU, and network usage, you can choose a reduced level of reliability where only the last N values are guaranteed to be delivered reliably to *DataReaders* (where N is user-configurable). With the reduced level of reliability, there are no guarantees that the data sent before the last N are received. Only the last N data packets are monitored and repaired if necessary.

It includes the members in Table 7.66 DDS_ReliabilityQosPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 7.66 DDS_ReliabilityQosPolicy

Type	Field Name	Description
DDS_ReliabilityQosPolicyKind	kind	Can be either: • DDS_BEST_EFFORT_RELIABILITY_QOS: DDS data samples are sent once and missed samples are acceptable. • DDS_RELIABLE_RELIABILITY_QOS: *Connext DDS* will make sure that data sent is received and missed DDS samples are resent.
DDS_Duration_t	max_blocking_time	How long a *DataWriter* can block on a write() when the send queue is full due to unacknowledged messages. (Has no meaning for *DataReaders*.)
DDS_ReliabilityQosPolicyAcknowledgmentModeKind	acknowledgment_kind	Kind of reliable acknowledgment. Only applies when **kind** is RELIABLE. Sets the kind of acknowledgments supported by a *DataWriter* and sent by *DataReader*. Possible values: • DDS_PROTOCOL_ACKNOWLEDGMENT_MODE • DDS_APPLICATION_AUTO_ACKNOWLEDGMENT_MODE • DDS_APPLICATION_EXPLICIT_ACKNOWLEDGMENT_MODE See 7.3.12.1 Application Acknowledgment Kinds on page 317

The **kind** of RELIABILITY can be either:

- **BEST_EFFORT**

  Connext DDS will send DDS data samples only once to *DataReaders*. No effort or resources are spent to track whether or not sent DDS samples are received. Minimal resources are used. This is the most deterministic method of sending data since there is no indeterministic delay that can be introduced by buffering or resending data. DDS data samples may be lost. This setting is good for

periodic data.

- **RELIABLE**

  Connext DDS will send DDS samples reliably to *DataReaders*–buffering sent data until they have been acknowledged as being received by *DataReaders* and resending any DDS samples that may have been lost during transport. Additional resources configured by the HISTORY and RESOURCE_LIMITS QosPolicies may be used. Extra packets will be sent on the network to query (heartbeat) and acknowledge the receipt of DDS samples by the *DataReader*. This setting is a good choice when guaranteed data delivery is required; for example, sending events or commands.

To send *large* data reliably, you will also need to set the 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441 **kind** to DDS_ASYNCHRONOUS_PUBLISH_MODE_QOS. *Large* in this context means that the data cannot be sent as a single packet by a transport (for example, data larger than 63K when using UDP/IP).

While a *DataWriter* sends data reliably, the 7.5.12 HISTORY QosPolicy on page 418 and 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 determine how many DDS samples can be stored while waiting for acknowledgements from *DataReaders*. A DDS sample that is sent reliably is entered in the *DataWriter*'s send queue awaiting acknowledgement from *DataReaders*. How many DDS samples that the *DataWriter* is allowed to store in the send queue for a data-instance depends on the **kind** of the HISTORY QoS as well as the **max_samples_per_instance** and **max_samples** parameter of the RESOURCE_LIMITS QoS.

If the HISTORY **kind** is **KEEP_LAST**, then the *DataWriter* is allowed to have the HISTORY **depth** number of DDS samples per instance of the *Topic* in the send queue. Should the number of unacknowledge DDS samples in the send queue for a data-instance reach the HISTORY **depth**, then the next DDS sample written by the *DataWriter* for the instance will overwrite the oldest DDS sample for the instance in the queue. This implies that an unacknowledged DDS sample may be overwritten and thus lost. So even if the RELIABILITY **kind** is **RELIABLE**, if the HISTORY **kind** is **KEEP_LAST**, it is possible that some data sent by the *DataWriter* will not be delivered to the *DataReader*. What is guaranteed is that if the *DataWriter* stops writing, the last *N* DDS samples that the *DataWriter* wrote will be delivered reliably; where n is the value of the HISTORY **depth**.

However, if the HISTORY **kind** is **KEEP_ALL**, then when the send queue is filled with unacknowledged DDS samples (either due to the number of unacknowledged DDS samples for an instance reaching the RESOURCE_LIMITS **max_samples_per_instance** value or the total number of unacknowledged DDS samples have reached the size of the send queue as specified by RESOURCE_LIMITS **max_samples**), the next **write()** operation on the *DataWriter* will block until either a DDS sample in the queue has been fully acknowledged by *DataReaders* and thus can be overwritten or a timeout of RELIABILITY **max_blocking_period** has been reached.

If there is still no space in the queue when **max_blocking_time** is reached, the **write()** call will return a failure with the error code **DDS_RETCODE_TIMEOUT**.

Thus for strict reliability—a guarantee that all DDS data samples sent by a *DataWriter* are received by *DataReaders*—you must use a RELIABILITY **kind** of **RELIABLE** and a HISTORY **kind** of **KEEP_ALL** for both the *DataWriter* and the *DataReader*.

Although you can set the RELIABILITY QosPolicy on *Topics*, its value can only be used to initialize the RELIABILITY QosPolicies of either a *DataWriter* or *DataReader*. It does not directly affect the operation of *Connext DDS*, see 5.1.3 Setting Topic QosPolicies on page 219.

7.5.21.1 Example

This QosPolicy is used to achieve reliable communications, which is discussed in Reliable Communications (Chapter 11 on page 682) and 11.3.1 Enabling Reliability on page 690.

7.5.21.2 Properties

This QosPolicy *cannot* be modified after the Entity has been enabled.

The *DataWriter* and *DataReader* must use compatible settings for this QosPolicy. To be compatible, the *DataWriter* and *DataReader* must use one of the valid combinations for the Reliability **kind** (see Table 7.67 Valid Combinations of Reliability 'kind'), and one of the valid combinations for the **acknowledgment_kind** (see Table 7.68 Valid Combinations of Reliability 'acknowledgment_kind'):

Table 7.67 Valid Combinations of Reliability 'kind'

		DataReader requests:	
		BEST_EFFORT	RELIABLE
DataWriter offers:	BEST_EFFORT	compatible	incompatible
	RELIABLE	compatible	compatible

Table 7.68 Valid Combinations of Reliability 'acknowledgment_kind'

		DataReader requests:		
		PROTOCOL	APPLICATION_AUTO	APPLICATION_EXPLICIT
DataWriter offers:	PROTOCOL	compatible	incompatible	incompatible
	APPLICATION_AUTO	compatible	compatible	compatible
	APPLICATION_EXPLICIT	compatible	compatible	compatible

If this QosPolicy is found to be incompatible, statuses **ON_OFFERED_INCOMPATIBLE_QOS** and **ON_REQUESTED_INCOMPATIBLE_QOS** will be modified and the corresponding *Listeners* called for the *DataWriter* and *DataReader,* respectively.

There are no compatibility issues regarding the value of **max_blocking_wait**, since it does not apply to *DataReaders*.

7.5.21.3 Related QosPolicies

- 7.5.12 HISTORY QosPolicy on page 418
- 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441
- 7.5.22 RESOURCE_LIMITS QosPolicy on the next page

7.5.21.4 Applicable Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.21.5 System Resource Considerations

Setting the **kind** to **RELIABLE** will cause *Connext DDS* to use up more resources to monitor and maintain a reliable connection between a *DataWriter* and all of its reliable *DataReaders*. This includes the use of extra CPU and network bandwidth to send and process heartbeat, ACK/NACK, and repair packets (see Reliable Communications (Chapter 11 on page 682)).

Setting **max_blocking_time** to a non-zero number may block the sending thread when the RELIABILITY kind is **RELIABLE**.

7.5.22 RESOURCE_LIMITS QosPolicy

For the reliability protocol (and the 7.5.9 DURABILITY QosPolicy on page 410), this QosPolicy determines the actual maximum queue size when the 7.5.12 HISTORY QosPolicy on page 418 is set to KEEP_ALL.

In general, this QosPolicy is used to limit the amount of system memory that *Connext DDS* can allocate. For embedded real-time systems and safety-critical systems, pre-determination of maximum memory usage is often required. In addition, dynamic memory allocation could introduce non-deterministic latencies in time-critical paths.

It includes the members in Table 7.69 DDS_ResourceLimitsQosPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 7.69 DDS_ResourceLimitsQosPolicy

Type	Field Name	Description
DDS_Long	max_samples	Maximum number of live DDS samples that *Connext DDS* can store for a *DataWriter*/*DataReader*. This is a physical limit.
DDS_Long	max_instances	Maximum number of active instances that can be managed by a *DataWriter*/*DataReader*. (See 8.3.8.6.1 Active State and Minimum State on page 535.) For *DataReaders*, **max_instances** must be <= **max_total_instances** in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571. See also: 7.5.22.2 Example on page 451.
DDS_Long	max_samples_per_instance	On a *DataWriter*, this resource limit represents the maximum number of DDS samples of any one instance that *Connext DDS* will store for a *DataWriter*. On a *DataReader*, this resource limit represents the maximum number of DDS samples of any one instance that are stored in the *DataReader* output queue–that is, the queue from which the application takes/reads samples. For keyed types and *DataReaders*, this value only applies to DDS samples with an instance state of DDS_ALIVE_INSTANCE_STATE. If a keyed *Topic* is not used, then **max_samples_per_instance** must equal **max_samples**. How this property behaves depends on your HISTORY and RELIABILITY QoS configurations. See 7.5.12 HISTORY QosPolicy on page 418.
DDS_Long	initial_samples	Initial number of DDS samples that *Connext DDS* will store for a *DataWriter*/*DataReader*. (DDS extension)
DDS_Long	initial_instances	Initial number of instances that can be managed by a *DataWriter*/*DataReader*. (DDS extension)
DDS_Long	instance_hash_buckets	Number of hash buckets, which are used by *Connext DDS* to facilitate instance lookup. (DDS extension).

One of the most important fields is **max_samples**, which sets the size and causes memory to be allocated for the send or receive queues. For information on how this policy affects reliability, see 11.3.2 Tuning Queue Sizes and Other Resource Limits on page 690.

When a *DataWriter* or *DataReader* is created, the **initial_instances** and **initial_samples** parameters determine the amount of memory first allocated for the those Entities. As the application executes, if more space is needed in the send/receive queues to store DDS samples or as more instances are created, then *Connext DDS* will automatically allocate memory until the limits of **max_instances** and **max_samples** are reached.

You may set **initial_instances** = **max_instances** and **initial_samples** = **max_samples** if you do not want *Connext DDS* to dynamically allocate memory after initialization.

For keyed *Topics*, the **max_samples_per_instance** field in this policy represents the maximum number of DDS samples with the same key that are allowed to be stored by a *DataWriter* (in the *DataWriter's* queue) or by the *DataReader* (in the *DataReader's* output queue—that is, the queue from which the application takes/reads samples). The **max_samples_per_instance** field is a logical limit. The hard physical limit is determined by **max_samples**. However, because the theoretical number of instances may be quite large (as set by **max_instances**), you may not want *Connext DDS* to allocate the total memory needed to hold the maximum number of DDS samples per instance for all possible instances (**max_samples_per_instance * max_instances**) because during normal operations, the application will never have to hold that much data for the Entity.

So it is possible that an Entity will hit the physical limit **max_samples** before it hits the **max_samples_per_instance** limit for a particular instance. However, *Connext DDS* must be able to store **max_samples_per_instance** for at least one instance. Therefore, **max_samples_per_instance must be <= max_samples.**

> If a keyed data type is not used, there is only a single instance of the *Topic*, so **max_samples_per_instance must equal max_samples**.

Once a physical or logical limit is hit, then how *Connext DDS* deals with new DDS data samples being sent or received for a *DataWriter* or *DataReader* is described in the 7.5.12 HISTORY QosPolicy on page 418 setting of **DDS_KEEP_ALL_HISTORY_QOS**. It is closely tied to whether or not a reliable connection is being maintained.

Although you can set the RESOURCE_LIMITS QosPolicy on *Topics*, its value can only be used to initialize the RESOURCE_LIMITS QosPolicies of either a *DataWriter* or *DataReader*. It does not directly affect the operation of *Connext DDS*, see 5.1.3 Setting Topic QosPolicies on page 219.

7.5.22.1 Configuring Resource Limits for Asynchronous DataWriters

When using an asynchronous *Publisher*, if a call to **write()** is blocked due to a resource limit, the block will last until the timeout period expires, which will prevent others from freeing the resource. To avoid this situation, make sure that the *DomainParticipant's* **outstanding_asynchronous_sample_allocation** in the

9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649 is always greater than the sum of all asynchronous *DataWriters*' **max_samples**.

7.5.22.2 Example

If you want to be able to store **max_samples_per_instance** for every instance, then you should set

```
max_samples >= max_instances * max_samples_per_instance
```

But if you want to save memory and you do not expect that the running application will ever reach the case where it will see **max_instances** of instances, then you may use a smaller value for **max_samples** to save memory.

In any case, there is a lower limit for **max_samples**:

```
max_samples >= max_samples_per_instance
```

If the 7.5.12 HISTORY QosPolicy on page 418's **kind** is set to **KEEP_LAST**, then you should set:

```
max_samples_per_instance = HISTORY.depth
```

7.5.22.3 Properties

This QosPolicy cannot be modified after the Entity is enabled.

There are no requirements that the publishing and subscribing sides use compatible values.

7.5.22.4 Related QosPolicies

- 7.5.12 HISTORY QosPolicy on page 418
- 7.5.21 RELIABILITY QosPolicy on page 444
- For *DataReaders*, **max_instances** must be <= **max_total_instances** in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571

7.5.22.5 Applicable Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.22.6 System Resource Considerations

Larger **initial_*** numbers will increase the initial system memory usage. Larger **max_*** numbers will increase the worst-case system memory usage.

Increasing **instance_hash_buckets** speeds up instance-lookup time but also increases memory usage.

7.5.23 SERVICE QosPolicy (DDS Extension)

The SERVICE QosPolicy is intended for use by RTI infrastructure services. User applications should not modify its value. It includes the member in Table 7.70 DDS_ServiceQosPolicy.

Table 7.70 DDS_ServiceQosPolicy

Type	Field Name	Description
DDS_ServiceQosPolicyKind	kind	Kind of service associated with the entity. Possible values: • DDS_NO_SERVICE_QOS, • DDS_PERSISTENCE_SERVICE_QOS, • DDS_QUEUING_SERVICE_QOS, • DDS_ROUTING_SERVICE_QOS, • DDS_RECORDING_SERVICE_QOS, • DDS_REPLAY_SERVICE_QOS, • DDS_DATABASE_INTEGRATION_SERVICE_QOS • DDS_WEB_INTEGRATION_SERVICE_QOS

An application can determine the kind of service associated with a discovered *DataWriter* and *DataReader* by looking at the **service** field in the PublicationBuiltinTopicData and SubscriptionBuiltinTopicData structures (see Chapter 18 Built-In Topics on page 825).

7.5.23.1 Properties

This QosPolicy cannot be modified after the Entity is enabled.

There are no requirements that the publishing and subscribing sides use compatible values.

7.5.23.2 Related QosPolicies

None

7.5.23.3 Applicable Entities

- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501
- 9.3 DomainParticipants on page 604

7.5.23.4 System Resource Considerations

None.

7.5.24 TOPIC_QUERY_DISPATCH_QosPolicy (DDS Extension)

The TOPIC_QUERY_DISPATCH QosPolicy configures the ability of a *DataWriter* to publish historical samples in response to a TopicQuery (see Topic Queries (Chapter 24 on page 962)).

It contains the members listed in Table 7.71 DDS_TopicQueryDispatchQosPolicy.

Table 7.71 DDS_TopicQueryDispatchQosPolicy

Type	Field Name	Description
DDS_Boolean	enable	Allows this writer to dispatch TopicQueries.
struct DDS_Duration_t	publication_period	Sets the periodic interval at which samples are published.
DDS_Long	samples_per_period	Sets the maximum number of samples to publish in each publication_period

This QoS policy configures the ability of a *DataWriter* to publish samples in response to a TopicQuery.

It enables the ability of a *DataWriter* to publish historical samples upon reception of a TopicQuery and how often they are published.

Since a TopicQuery selects previously written samples, the *DataWriter* must have a DurabilityQosPolicy **kind** different from DDS_VOLATILE_DURABILITY_QOS. Also, the ReliabilityQosPolicy **kind** must be set to DDS_RELIABLE_RELIABILITY_QOS.

A TopicQuery may select multiple samples at once. The writer will publish them periodically, independently from newly written samples. TopicQueryDispatchQosPolicy's **publication_period** configures the frequency of that period and its **samples_per_period** configures the maximum number of samples to publish each period.

If the *DataWriter* blocks during the publication of one of these samples, it will stop and try again the next period. (See 7.3.8 Writing Data on page 308 (**FooDataWriter::write()**) for the conditions that may cause the write operation to block.)

All the *DataWriters* that belong to a single *Publisher* and enable TopicQueries share the same event thread, but each *DataWriter* schedules separate events. To configure that thread, see the AsynchronousPublisherQosPolicy's **topic_query_publication_thread**.

If the *DataWriter* is dispatching more than one TopicQuery at the same time, the configuration of this periodic event applies to all of them. For example, if a *DataWriter* receives two TopicQueries around the same time, the period is 1 second, the number of samples per period is 10, the first TopicQuery selects five samples, and the second one selects 8, the *DataWriter* will immediately attempt to publish all five for the first TopicQuery and five for the second one. After one second, it will publish the remaining three samples.

7.5.24.1 Properties

This QosPolicy cannot be modified after the *Entity* is enabled.

There are no requirements that the publishing and subscribing sides use compatible values.

7.5.24.2 Related QosPolicies

7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344

7.5.24.3 Applicable Entities

- 7.3 DataWriters on page 286

7.5.24.4 System Resource Considerations

None.

7.5.25 TRANSFER_MODE QosPolicy

The TRANSFER_MODE QosPolicy configures the properties of a Zero Copy *DataWriter*. It contains the member listed in the following table.

Table 7.72 DDS_TransferModeQosPolicy

Type	Field Name	Description
DDS_Boolean	enable_data_consistency_check	Enables a Zero Copy *DataWriter* to send a special sequence number as a part of its inline Qos. This sequence number is used by a Zero Copy *DataReader* to check for sample consistency in the **is_data_consistent()** operation . For more details, see 23.6.1.3 Checking data consistency with Zero Copy transfer over shared memory on page 957. Default: true

7.5.25.1 Properties

This QosPolicy cannot be modified after the *DataWriter* is created.

Since it is only for *DataWriters*, there are no compatibility restrictions for how it is set on the publishing and subscribing sides.

7.5.25.2 Related QosPolicies

None.

7.5.25.3 Applicable Entities

7.3 DataWriters on page 286

7.5.25.4 System Resource Considerations

With **enable_data_consistency_check** set to true, a Zero Copy *DataWriter* sends an additional sequence number as part of its inline Qos with every write operation. The use of this inline QoS creates a small additional wire-payload, consuming extra bandwidth and serialization/deserialization time.

7.5.26 TRANSPORT_PRIORITY QosPolicy

The TRANSPORT_PRIORITY QosPolicy is optional and only partially supported on certain OSs and transports by RTI. However, its intention is to allow you to specify on a per-*DataWriter* or per-*DataReader* basis that the data sent by a *DataWriter* or *DataReader* is of a different priority.

DDS does not specify how a DDS implementation shall treat data of different priorities. It is often difficult or impossible for DDS implementations to treat data of higher priority differently than data of lower priority, especially when data is being sent (delivered to a physical transport) directly by the thread that called *DataWriter's* **write()** operation. Also, many physical network transports themselves do not have an end-user controllable level of data packet priority.

In *Connext DDS*, for the UDPv4 built-in transport, the value set in the TRANSPORT_PRIORITY QosPolicy is used in a setsockopt call to set the TOS (type of service) bits of the IPv4 header for datagrams sent by a *DataWriter* or *DataReader*. It is platform dependent on how and whether or not the setsockopt has an effect. On some platforms such as Windows and Linux, external permissions must be given to the user application in order to set the TOS bits.

It is incorrect to assume that using the TRANSPORT_PRIORITY QosPolicy will have any effect at all on the end-to-end delivery of data between a *DataWriter* and *DataReader*. All network elements such as switches and routers must have the capability and be enabled to actually use the TOS bits to treat higher-priority packets differently. Thus the ability to use the TRANSPORT_PRIORITY QosPolicy must be designed and configured at a system level; just turning it on in an application may have no effect at all.

It includes the member in Table 7.73 DDS_TransportPriorityQosPolicy. For the default and valid range, please refer to the API Reference HTML documentation.

Table 7.73 DDS_TransportPriorityQosPolicy

Type	Field Name	Description
DDS_Long	value	Hint as to how to set the priority.

Connext DDS will propagate the **value** set on a per-*DataWriter* or per-*DataReader* basis to the transport when the *DataWriter* publishes data. It is up to the implementation of the transport to do something with the **value**, if anything.

You can set the TRANSPORT_PRIORITY QosPolicy on a *Topic* and use its **value** to initialize the TRANSPORT_PRIORITY QosPolicies of *DataWriters* and *DataReaders*. The TRANSPORT_

PRIORITY QosPolicy of a *Topic* does not directly affect the operation of *Connext DDS*, see 5.1.3 Setting Topic QosPolicies on page 219.

7.5.26.1 Example

Should *Connext DDS* be configured with a transport that can use and will honor the concept of a prioritized message, then you would be able to create a *DataWriter* of a *Topic* whose DDS data samples, when published, will be sent at a higher priority than other *DataWriters* that use the same transport.

7.5.26.2 Properties

This QosPolicy cannot be modified after the entity is created.

7.5.26.3 Related QosPolicies

This QosPolicy does not interact with any other policies.

7.5.26.4 Applicable Entities

- 5.1 Topics on page 215
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.26.5 System Resource Considerations

The use of this policy does not significantly impact the use of resources. However, if a transport is implemented to use the value set by this policy, then there may be transport-specific issues regarding the resources that the transport implementation itself uses.

7.5.27 TRANSPORT_SELECTION QosPolicy (DDS Extension)

The TRANSPORT_SELECTION QosPolicy allows you to select the transports that have been installed with the *DomainParticipant* to be used by the *DataWriter* or *DataReader*.

An application may be simultaneously connected to many different physical transports, e.g., Ethernet, Infiniband, shared memory, VME backplane, and wireless. By default, the middleware will use up to 16 transports to deliver data from a *DataWriter* to a *DataReader*.

This QosPolicy can be used to both limit and control which of the application's available transports may be used by a *DataWriter* to send data or by a *DataReader* to receive data.

It includes the member in Table 7.74 DDS_TransportSelectionQosPolicy. For more information, please refer to the API Reference HTML documentation.

Table 7.74 DDS_TransportSelectionQosPolicy

Type	Field Name	Description
DDS_StringSeq	enabled_transports	A sequence of aliases for the transports that may be used by the *DataWriter* or *DataReader*.

Connext DDS allows you to configure the transports that it uses to send and receive messages. A number of built-in transports, such as UDPv4 and shared memory, are available as well as custom ones that you may implement and install. Each transport will be installed in the *DomainParticipant* with one or more *aliases*.

To enable a *DataWriter* or *DataReader* to use a particular transport, add the *alias* to the **enabled_transports** sequence of this QosPolicy. An empty sequence is a special case, and indicates that all transports installed in the *DomainParticipant* can be used by the *DataWriter* or *DataReader*.

For more information on configuring and installing transports, please see the API Reference HTML documentation (from the **Modules** page, select **RTI DDS API Reference, Pluggable Transports**).

7.5.27.1 Example

Suppose a *DomainParticipant* has both UDPv4 and shared memory transports installed. If you want a particular *DataWriter* to publish its data only over shared memory, then you should use this QosPolicy to specify that restriction.

7.5.27.2 Properties

This QosPolicy cannot be modified after the *Entity* is created.

It can be set differently for the *DataWriter* and the *DataReader*.

7.5.27.3 Related QosPolicies

- 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on the next page
- 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586
- 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660

7.5.27.4 Applicable Entities

- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.27.5 System Resource Considerations

By restricting *DataWriters* from sending or *DataReaders* from receiving over certain transports, you may decrease the load on those transports.

7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension)

The TRANSPORT_UNICAST QosPolicy allows you to specify unicast network addresses to be used by *DomainParticipant*, *DataWriters* and *DataReaders* for receiving messages.

Connext DDS may send data to a variety of *Entities*, not just *DataReaders*. *DomainParticipants* receive messages to support the discovery process discussed in Discovery (Chapter 15 on page 758). *DataWriters* may receive ACK/NACK messages to support the reliable protocol discussed in Reliable Communications (Chapter 11 on page 682).

During discovery, each Entity announces to remote applications a list of (up to 16) unicast addresses to which the remote application should send data (either user-data packets or reliable protocol meta-data such as ACK/NACK and Heartbeats).

By default, the list of addresses is populated automatically with values obtained from the enabled transport plugins allowed to be used by the Entity (see the 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660 and 7.5.27 TRANSPORT_SELECTION QosPolicy (DDS Extension) on page 456). Also, the associated ports are automatically determined (see 15.5.2 Inbound Ports for User Traffic on page 787).

Use TRANSPORT_UNICAST QosPolicy to manually set the receive address list for an Entity. You may optionally set a port to use a non-default receive port as well. Only the first 16 addresses will be used. *Connext DDS* will create a receive thread for every unique port number that it encounters (on a per transport basis).

The QosPolicy structure includes the members in Table 7.75 DDS_TransportUnicastQosPolicy. For more information and default values, please refer to the API Reference HTML documentation.

Table 7.75 DDS_TransportUnicastQosPolicy

Type	Field Name	Description
DDS_TransportUnicastSettingsSeq (see Table 7.76 DDS_TransportUnicastSettings_t)	value	A sequence of up to 16 unicast settings that should be used by remote entities to address messages to be sent to this Entity. This is a hard limit that cannot be increased. However, this limit can be *decreased* by configuring the *DomainParticipant* property **dds.domain_participant.max_announced_locator_list_size** (whose default size is 8).

Table 7.76 DDS_TransportUnicastSettings_t

Type	Field Name	Description
DDS_StringSeq	transports	A sequence of transport aliases that specifies which transports should be used to receive unicast messages for this *Entity*.
DDS_Long	receive_port	The port that should be used in the addressing of unicast messages destined for this *Entity*. A value of 0 will cause *Connext DDS* to use a default port number based on *domain* and participant ids. See 15.5 Ports Used for Discovery on page 785.

A message sent to a unicast address will be received by a single node on the network (as opposed to a multicast address where a single message may be received by multiple nodes). This policy sets the unicast addresses and ports that remote entities should use when sending messages to the Entity on which the TRANSPORT_UNICAST QosPolicy is set.

Up to 16 "return" unicast addresses may be configured for an *Entity*. This is a hard limit that cannot be increased. However, this limit can be *decreased* by configuring the *DomainParticipant* **property dds.domain_participant.max_announced_locator_list_size**. Instead of specifying addresses directly, you use the **transports** field of the DDS_TransportUnicastSetting_t to select the transports (using their aliases) on which remote entities should send messages destined for this Entity. The addresses of the selected transports will be the "return" addresses. See the API Reference HTML documentation about configuring transports and aliases (from the **Modules** page, select **RTI Connext DDS API Reference**, **Pluggable Transports**).

Note, a single transport may have more than one unicast address. For example, if a node has multiple network interface cards (NICs), then the UDPv4 transport will have an address for each NIC. When using the TRANSPORT_UNICAST QosPolicy to set the return addresses, a single **value** for the **DDS_TransportUnicastSettingsSeq** may provide more than the maximum number of return addresses that *Connext DDS* accepts (8 by default, changeable to 16).

Whether or not you are able to configure the network interfaces that are allowed to be used by a transport is up to the implementation of the transport. For the built-in UDPv4 transport, you may restrict an instance of the transport to use a subset of the available network interfaces. See the API Reference HTML documentation for the built-in UDPv4 transport for more information.

For a *DomainParticipant*, this QoS policy sets the default list of addresses used by other applications to send user data for local *DataReaders*.

For a reliable *DataWriter*, if set, the other applications will use the specified list of addresses to send reliable protocol packets (ACKS/NACKS) on the behalf of reliable *DataReaders*. Otherwise, if not set, the other applications will use the addresses set by the *DomainParticipant*.

For a *DataReader*, if set, then other applications will use the specified list of addresses to send user data (and reliable protocol packets for reliable *DataReaders*). Otherwise, if not set, the other applications will use the addresses set by the *DomainParticipant*.

For a *DataReader*, if the port number specified by this QoS is the same as a port number specified by a TRANSPORT_MULTICAST QoS, then the transport may choose to process data received both via multicast and unicast with a single thread. Whether or not a transport must use different threads to process data received via multicast or unicast for the same port number depends on the implementation of the transport.

To use this QosPolicy, you also need to specify a port number. A port number of 0 will cause *Connext DDS* to automatically use a default value. As explained in 15.5 Ports Used for Discovery on page 785, the default port number for unicast addresses is based on the domain and participant IDs. Should you choose to use a different port number, then for every unique port number used by Entities in your application, depending on the transport, *Connext DDS* may create a thread to process messages received for that port on that transport. See Connext DDS Threading Model (Chapter 21 on page 900) for more about threads.

Threads are created on a per-transport basis, so if this QosPolicy specifies multiple **transports** for a **receive_port**, then a thread may be created for each transport for that unique port. Some transports may be able to share a single thread for different ports, others can not. Different *Entities* can share the same port number, and thus, the same thread will process all of the data for all of the *Entities* sharing the same port number for a transport.

Note: If a *DataWriter* is using the 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429, the unicast addresses specified in the TRANSPORT_UNICAST QosPolicy are ignored by that *DataWriter*. The *DataWriter* will not publish DDS samples on those locators.

7.5.28.1 Example

You may use this QosPolicy to restrict an *Entity* from receiving data through a particular transport. For example, on a multi-NIC (network interface card) system, you may install different transports for different NICs. Then you can balance the network load between network cards by using different values for the TRANSPORT_UNICAST QosPolicy for different *DataReaders*. Thus some *DataReaders* will receive their data from one NIC and other *DataReaders* will receive their data from another.

7.5.28.2 Properties

This QosPolicy cannot be modified after the Entity is created.

It can be set differently for the *DomainParticipant*, the *DataWriter* and the *DataReader*.

7.5.28.3 Related QosPolicies

- 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429
- 7.5.27 TRANSPORT_SELECTION QosPolicy (DDS Extension) on page 456
- 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586
- 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660

7.5.28.4 Applicable Entities

- 9.3 DomainParticipants on page 604
- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501

7.5.28.5 System Resource Considerations

Because this QosPolicy changes the transports on which messages are received for different Entities, the bandwidth used on the different transports may be affected.

Depending on the implementation of a transport, *Connext DDS* may need to create threads to receive and process data on a unique-port-number basis. Some transports can share the same thread to process data received for different ports; others like UDPv4 must have different threads for different ports. In addition, if the same port is used for both unicast and multicast, the transport implementation will determine whether or not the same thread can be used to process both unicast and multicast data. For UDPv4, only one thread is needed per port–independent of whether the data was received via unicast or multicast data. See 21.3 Receive Threads on page 903 for more information.

7.5.29 TYPESUPPORT QosPolicy (DDS Extension)

This policy can be used to modify the code generated by *RTI Code Generator* so that the [de]serialization routines act differently depending on the information passed in via the object pointer. This policy also determines if padding bytes are set to zero during serialization.

It includes the members in Table 7.77 DDS_TypeSupportQosPolicy.

Table 7.77 DDS_TypeSupportQosPolicy

Type	Field Name	Description
void *	plugin_data	Value to pass into the type plug-in's serialization/deserialization function. See Note below.
DDS_CdrPaddingKind	cdr_padding_kind	Determines whether or not the padding bytes will be set to zero during CDR serialization. For a *DomainParticipant*: Configures how padding bytes are set when serializing data for the builtin topic *DataWriters* and *DataReaders*. For *DataWriters* and *DataReaders*: Configures how padding bytes are set when serializing data for that entity. May be: • ZERO_CDR_PADDING (Padding bytes will be set to zero during CDR serialization) • NOT_SET_CDR_PADDING (Padding bytes will not be set to any value during CDR serialization) • AUTO_CDR_PADDING (For a *DomainParticipant*, the default behavior is NOT_SET_CDR_PADDING. For a *DataWriter* or *DataReader*, the behavior is to inherit the value from the *DomainParticipant*.)

Note: RTI generally recommends that you treat generated source files as compiler outputs (analogous to object files) and that you do not modify them. RTI cannot support user changes to generated source files. Furthermore, such changes would make upgrading to newer versions of *Connext DDS* more difficult, as this generated code is considered to be a part of the middleware implementation and consequently does change from version to version. *The plugin_data field in this QoS policy should be considered a back door, only to be used after careful design consideration, testing, and consultation with your RTI representative.*

7.5.29.1 Properties

This QoS policy may be modified after the *DataWriter* or *DataReader* is enabled.

It can be set differently for the *DataWriter* and *DataReader*.

7.5.29.2 Related QoS Policies

None.

7.5.29.3 Applicable Entities

- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501
- 9.3 DomainParticipants on page 604

7.5.29.4 System Resource Considerations

None.

7.5.30 USER_DATA QosPolicy

This QosPolicy provides an area where your application can store additional information related to a *DomainParticipant*, *DataWriter*, or *DataReader*. This information is passed between applications during discovery (see Discovery (Chapter 15 on page 758)) using built-in-topics (see Built-In Topics (Chapter 18 on page 825)). How this information is used will be up to user code. *Connext DDS* does not do anything with the information stored as USER_DATA except to pass it to other applications.

Use cases are usually for application-to-application identification, authentication, authorization, and encryption purposes. For example, applications can use Group or User Data to send security certificates to each other for RSA-type security.

The value of the USER_DATA QosPolicy is sent to remote applications when they are first discovered, as well as when the *DomainParticipant*, *DataWriter* or *DataReader*'s **set_qos()** methods are called after changing the value of the USER_DATA. User code can set listeners on the built-in *DataReaders* of the built-in *Topics* used by *Connext DDS* to propagate discovery information. Methods in the built-in topic

listeners will be called whenever new *DomainParticipants*, *DataReaders*, and *DataWriters* are found. Within the user callback, you will have access to the USER_DATA that was set for the associated *Entity*.

Currently, USER_DATA of the associated *Entity* is only propagated with the information that declares a *DomainParticipant*, *DataWriter* or *DataReader*. Thus, you will need to access the value of USER_DATA through **DDS_ParticipantBuiltinTopicData, DDS_PublicationBuiltinTopicData** or **DDS_SubscriptionBuiltinTopicData** (see Built-In Topics (Chapter 18 on page 825)).

The structure for the USER_DATA QosPolicy includes just one field, as seen in Table 7.78 DDS_UserDataQosPolicy. The field is a sequence of octets that translates to a contiguous buffer of bytes whose contents and length is set by the user. The maximum size for the data are set in the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649.

Table 7.78 DDS_UserDataQosPolicy

Type	Field Name	Description
DDS_OctetSeq	value	Default: empty

This policy is similar to the 7.4.4 GROUP_DATA QosPolicy on page 352 and 5.2.1 TOPIC_DATA QosPolicy on page 224 that apply to other types of Entities.

7.5.30.1 Example

One possible use of USER_DATA is to pass some credential or certificate that your subscriber application can use to accept or reject communication with the *DataWriter*s (or vice versa, where the publisher application can validate the permission of *DataReaders* to receive its data). Using the same method, an application (*DomainParticipant*) can accept or reject all connections from another application. The value of the USER_DATA of the *DomainParticipant* is propagated in the '**user_data**' field of the **DDS_ParticipantBuiltinTopicData** that is sent with the declaration of each *DomainParticipant*. Similarly, the value of the USER_DATA of the *DataWriter* is propagated in the '**user_data**' field of the **DDS_PublicationBuiltinTopicData** that is sent with the declaration of each *DataWriter*, and the value of the USER_DATA of the *DataReader* is propagated in the '**user_data**' field of the **DDS_SubscriptionBuiltinTopicData** that is sent with the declaration of each *DataReader*.

When *Connext DDS* discovers a *DomainParticipant/DataWriter/DataReader,* the application can be notified of the discovery of the new entity and retrieve information about the *Entity*'s QoS by reading the **DCPSParticipant, DCPSPublication** or **DCPSSubscription** built-in topics (see Built-In Topics (Chapter 18 on page 825)). The user application can then examine the USER_DATA field in the built-in *Topic* and decide whether or not the remote *Entity* should be allowed to communicate with the local *Entity*. If communication is not allowed, the application can use the *DomainParticipant's* **ignore_participant()**, **ignore_publication()** or **ignore_subscription()** operation to reject the newly discovered remote entity as one with which the application allows *Connext DDS* to communicate. See 18.2 Built-in DataReaders on page 826 for an example of how to do this.

7.5.30.2 Properties

This QosPolicy can be modified at any time. A change in the QosPolicy will cause *Connext DDS* to send packets containing the new USER_DATA to all of the other applications in the DDS domain.

It can be set differently on the publishing and subscribing sides.

7.5.30.3 Related QosPolicies

- 5.2.1 TOPIC_DATA QosPolicy on page 224
- 7.4.4 GROUP_DATA QosPolicy on page 352
- 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649

7.5.30.4 Applicable Entities

- 7.3 DataWriters on page 286
- 8.3 DataReaders on page 501
- 9.3 DomainParticipants on page 604

7.5.30.5 System Resource Considerations

The maximum size of the USER_DATA is set in the **participant_user_data_max_length, writer_user_data_max_length**, and **reader_user_data_max_length** fields of the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649. Because *Connext DDS* will allocated memory based on this value, you should only increase this value if you need to. If your system does not use USER_DATA, then you can set this value to 0 to save memory. Setting the value of the USER_DATA QosPolicy to hold data longer than the value set in the **[participant,writer,reader]_user_data_max_length** field will result in failure and an **INCONSISTENT_QOS_POLICY** return code.

However, should you decide to change the maximum size of USER_DATA, you *must* make certain that all applications in the DDS domain have changed the value of **[participant,writer,reader]_user_data_max_length** to be the same. If two applications have different limits on the size of USER_DATA, and one application sets the USER_DATA QosPolicy to hold data that is greater than the maximum size set by another application, then the *DataWriters* and *DataReaders* between the two applications will *not* connect. The *DomainParticipants* may also reject connections from each other entirely. This is also true for the GROUP_DATA (7.4.4 GROUP_DATA QosPolicy on page 352) and TOPIC_DATA (5.2.1 TOPIC_DATA QosPolicy on page 224) QosPolicies.

7.5.31 WRITER_DATA_LIFECYCLE QoS Policy

This QoS policy controls how a *DataWriter* handles the lifecycle of the instances (keys) that the *DataWriter* is registered to manage. This QoS policy includes the members in Table 7.79 DDS_WriterDataLifecycleQosPolicy.

Table 7.79 DDS_WriterDataLifecycleQosPolicy

Type	Field Name	Description
DDS_ Boolean	autodispose_ unregistered_ instances	Controls what happens when the *DataWriter* unregisters an instance by means of the unregister operations. This setting has no impact on the *DataWriter* deletion operation. When a *DataWriter* is deleted, and it was the last known *DataWriter* for any of the instances that it was writing, the instance will automatically be transitioned to NOT_ALIVE_ NO_WRITERS by all matching *DataReaders*. No unregister messages are sent in this scenario, and therefore no dispose messages are sent, either, regardless of the value of this setting. RTI_TRUE: The *DataWriter* first disposes of the instance each time it unregisters from the instance. This behavior is identical to explicitly calling one of the dispose operations on the instance prior to calling the unregister operation. **Note:** It is recommended that you keep this QoS setting at FALSE. See 7.5.31.2 Autodisposing Unregistered Instances on the next page. RTI_FALSE (default): The *DataWriter* does not dispose of the instance each time it is unregistered. The application can still call one of the dispose operations prior to unregistering the instance and dispose of the instance that way. When a *DataWriter* is deleted, no extra messages are sent. *DataReaders* will automatically unregister this *DataWriter* from all instances when they recognize that the *DataWriter* has been deleted.
struct DDS_Duration_t	autopurge_ unregistered_ instances_ delay	Determines how long the *DataWriter* will maintain information regarding an instance that has been unregistered. By default, the *DataWriter* resources associated with an instance (e.g., the space needed to remember the Instance Key or KeyHash) are released lazily. This means the resources are only reclaimed when the space is needed for another instance because max_instances (7.5.22 RESOURCE_LIMITS QosPolicy on page 449) is exceeded. This behavior can be changedby setting **autopurge_unregistered_instances_delay** to a value other than **INFINITE.** After this time elapses, the *DataWriter* will purge all internal information regarding the instance, including historical DDS samples even if max_instances has not been reached. The purging of unregistered instances can be done based on the source timestamp of the unregister sample or the time when the unregister sample was added to the *DataWriter* queue, by setting the following property to 1 or 0 respectively (default: 0): **dds.data_writer.history.source_timestamp_based_autopurge_instances_delay**. The source timestamp can differ from the time that the sample was added to the queue if a timestamp was provided along with the sample when it was written (using the **write_with_timestamp()** or **write_with_params()** operations). This is the case, for example, in *RTI Routing Service* when samples are routed with the original publisher information. **autopurge_unregistered_instances_delay** is not supported with durable *DataWriter* history or VOLATILE durability. With VOLATILE durability, instances are always removed as soon as all samples for the instance are fully acknowledged. Default: INFINITE (except for builtin *DataWriters*, in which case 0)
struct DDS_Duration_t	autopurge_ disposed_in- stances_ delay	Determines the maximum duration for which the *DataWriter* will maintain information regarding an instance once it has disposed of the instance. By default, disposing of an instance does not make it eligible to be purged. By setting **autopurge_disposed_instances_delay** to a value other than DDS_DURATION_INFINITE, the *DataWriter* will reclaim the resources associated with an instance (including historical samples) once the time has elapsed and all matching *DataReaders* have acknowledged all the samples for this instance, including the dispose sample. The purging of the disposed instances can be done based on the dispose sample source timestamp or the time when the dispose sample was added to the *DataWriter* queue, by setting the following property to 1 or 0 respectively (default: 0): **dds.data_writer.history.source_timestamp_based_autopurge_instances_delay**. The source timestamp can differ from the time that the sample was added to the queue if a timestamp was provided along with the sample when it was written (using the **write_with_timestamp()** or **write_with_params()** operations). This is the case, for example, in *Routing Service* when samples are routed with the original publisher information. **autopurge_disposed_instances_delay** is supported with durable *DataWriter* queues only for 0 and INFINITE values (finite values are not supported). Default: INFINITE

7.5.31.1 Unregistering vs. Disposing

- Disposing an instance conveys an explicit state about an instance: for example, disposing a flight because it has landed. You can decide what dispose means for your system. See 7.3.14.3 Disposing Instances on page 327.
- Unregistering an instance can be thought of as a *DataWriter* unregistering itself from the instance, indicating that the *DataWriter* has no more information/data on the instance. An example is when radar is no longer tracking a flight. In this example, the flight is still a valid, alive instance in the system, with the same location and trajectory, but this specific radar is simply no longer tracking it. Unregistering tells *Connext DDS* that the *DataWriter* does not intend to modify that instance anymore, allowing *Connext DDS* to recover any resources it allocated for the instance. See 7.3.14.4 Unregistering Instances on page 327.

7.5.31.2 Autodisposing Unregistered Instances

The **autodispose_unregistered_instances** QoS setting determines whether explicit calls to an unregister operation also automatically first dispose the instance that it is being unregistered from.

It is recommended to keep the default setting of FALSE for **autodispose_unregistered_instances** and manage all instance state transitions through explicit calls to **dispose()** and **unregister_instance()** in your application. The reasons for this recommendation are as follows:

- In many cases where the ownership of a Topic is EXCLUSIVE (see the 7.5.17 OWNERSHIP QosPolicy on page 432), *DataWriters* may want to relinquish ownership of a particular instance of the Topic to allow other *DataWriters* to send updates for the value of that instance. In this case, you may want a *DataWriter* to just unregister an instance—without disposing it (since there are other writers). Unregistering an instance implies that the *DataWriter* no longer owns that instance, but it is a stronger statement to say that instance no longer exists.
- User applications may be coded to trigger on the disposal of instances, thus the ability to unregister without disposing may be useful to properly maintain the semantic of disposal.

7.5.31.3 Properties

The WRITER_DATA_LIFECYCLE QoS Policy does not apply to *DataReaders*, so there is no requirement that the publishing and subscribing sides use compatible values.

This QoS policy may be modified after the *DataWriter* is enabled.

7.5.31.4 Related QoS Policies

- None.

7.5.31.5 Applicable Entities

- 7.3 DataWriters on page 286

7.5.31.6 System Resource Considerations

None.

7.6 FlowControllers (DDS Extension)

This section does not apply when using the separate add-on product, *Ada Language Support*, which does not support FlowControllers.

A FlowController is the object responsible for shaping the network traffic by determining when attached asynchronous *DataWriters* are allowed to write data. To configure a *DataWriter* to be asynchronous, see 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441.

You can use one of the built-in FlowControllers (and optionally modify their properties), create a custom FlowController by using the *DomainParticipant's* **create_flowcontroller()** operation (see 7.6.6 Creating and Deleting FlowControllers on page 478), or create a custom FlowController by using the *DomainParticipant's* 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436; see 7.6.5 Creating and Configuring Custom FlowControllers with Property QoS on page 476.

To use a FlowController, you provide its name in the *DataWriter's* 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441.

- **DDS_DEFAULT_FLOW_CONTROLLER_NAME**

  By default, flow control is disabled. That is, the built-in DDS_DEFAULT_FLOW_CONTROLLER_NAME flow controller does not apply any flow control. Instead, it allows data to be sent asynchronously as soon as it is written by the *DataWriter*.

- **DDS_FIXED_RATE_FLOW_CONTROLLER_NAME**

  The FIXED_RATE flow controller shapes the network traffic by allowing data to be sent only once every second. Any accumulated DDS samples destined for the same destination are coalesced into as few network packets as possible.

- **DDS_ON_DEMAND_FLOW_CONTROLLER_NAME**

  The ON_DEMAND flow controller allows data to be sent only when you call the FlowController's **trigger_flow()** operation. With each trigger, all accumulated data since the previous trigger is sent (across all *Publishers* or *DataWriters*). In other words, the network traffic shape is fully controlled by the user. Any accumulated DDS samples destined for the same destination are coalesced into as

few network packets as possible.

This external trigger source is ideal for users who want to implement some form of closed-loop flow control or who want to only put data on the wire every so many DDS samples (e.g., with the number of DDS samples based on NDDS_Transport_Property_t's **gather_send_buffer_count_max**).

The default property settings for the built-in FlowControllers are described in the API Reference HTML documentation.

DDS samples written by an asynchronous *DataWriter* are not sent in the context of the **write()** call. Instead, *Connext DDS* puts the DDS samples in a queue for future processing and they are sent in the asynchronous publishing thread. (See 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344.) The FlowController associated with each asynchronous *DataWriter* determines when the DDS samples are actually sent.

Each FlowController maintains a separate FIFO queue for each unique destination (remote application). DDS samples written by asynchronous *DataWriters* associated with the FlowController are placed in the queues that correspond to the intended destinations of the DDS sample.

When tokens become available, a FlowController must decide which queue(s) to grant tokens first. This is determined by the FlowController's **scheduling_policy** property (see Table 7.80 DDS_FlowControllerProperty_t). Once a queue has been granted tokens, it is serviced by the asynchronous publishing thread. The queued up DDS samples will be coalesced and sent to the corresponding destination. The number of DDS samples sent depends on the data size and the number of tokens granted.

Table 7.80 DDS_FlowControllerProperty_t lists the properties for a FlowController.

Table 7.80 DDS_FlowControllerProperty_t

Type	Field Name	Description
DDS_FlowControllerSchedulingPolicy	scheduling_policy	Round robin, earliest deadline first, or highest priority first. See 7.6.1 Flow Controller Scheduling Policies on the next page.
DDS_FlowControllerTokenBucketProperty_t	token_bucket	See 7.6.3 Token Bucket Properties on page 471.

Table 7.81 FlowController Operations lists the operations available for a FlowController.

Table 7.81 FlowController Operations

Operation	Description	Reference
get_property set_property	Get and Set the FlowController properties.	7.6.8 Getting/Setting Properties for a Specific FlowController on page 479
trigger_flow	Provides an external trigger to the FlowController.	7.6.9 Adding an External Trigger on page 479
get_name	Returns the name of the FlowController.	7.6.10 Other FlowController Operations on page 480
get_participant	Returns the *DomainParticipant* to which the FlowController belongs.	

7.6.1 Flow Controller Scheduling Policies

- **Round Robin**

  (DDS_RR_FLOW_CONTROLLER_SCHED_POLICY) Perform flow control in a round-robin (RR) fashion.

  Whenever tokens become available, the FlowController distributes the tokens uniformly across all of its (non-empty) destination queues. No destinations are prioritized. Instead, all destinations are treated equally and are serviced in a round-robin fashion.

- **Earliest Deadline First**

  (DDS_EDF_FLOW_CONTROLLER_SCHED_POLICY) Perform flow control in an earliest-deadline-first (EDF) fashion.

  A DDS sample's deadline is determined by the time it was written plus the latency budget of the *DataWriter* at the time of the write call (as specified in the DDS_LatencyBudgetQosPolicy). The relative priority of a flow controller's destination queue is determined by the earliest deadline across all DDS samples it contains.

  When tokens become available, the FlowController distributes tokens to the destination queues in order of their priority. In other words, the queue containing the DDS sample with the earliest deadline is serviced first. The number of tokens granted equals the number of tokens required to send the first DDS sample in the queue. Note that the priority of a queue may change as DDS samples are sent (i.e., removed from the queue). If a DDS sample must be sent to multiple destinations or two DDS samples have an equal deadline value, the corresponding destination queues are serviced in a round-robin fashion.

  With the default **duration** of 0 in the LatencyBudgetQosPolicy, using an EDF_FLOW_CONTROLLER_SCHED_POLICY FlowController preserves the order in which you call **write()** across the *DataWriters* associated with the FlowController.

Since the LatencyBudgetQosPolicy is mutable, a DDS sample written second may contain an earlier deadline than the DDS sample written first if the DDS_LatencyBudgetQosPolicy's **duration** is sufficiently decreased in between writing the two DDS samples. In that case, if the first DDS sample is not yet written (still in queue waiting for its turn), it inherits the priority corresponding to the (earlier) deadline from the second DDS sample.

In other words, the priority of a destination queue is always determined by the earliest deadline among all DDS samples contained in the queue. This priority inheritance approach is required in order to both honor the updated **duration** and to adhere to the *DataWriter* in-order data delivery guarantee.

- **Highest Priority First**

  (DDS_HPF_FLOW_CONTROLLER_SCHED_POLICY) Perform flow control in an highest-priority-first (HPF) fashion.

  Note: Prioritized DDS samples are not supported when using the Ada API. Therefore, the Highest Priority First scheduling policy is not supported when using this API.

  The next destination queue to service is determined by the publication priority of the *DataWriter*, the channel of a multi-channel *DataWriter*, or individual DDS sample.

  The relative priority of a flow controller's destination queue is determined by the highest publication priority of all the DDS samples it contains.

  When tokens become available, the FlowController distributes tokens to the destination queues in order of their publication priority. The queue containing the DDS sample with the highest publication priority is serviced first. The number of tokens granted equals the number of tokens required to send the first DDS sample in the queue. Note that a queue's priority may change as DDS samples are sent (i.e., as they are removed from the queue). If a DDS sample must be sent to multiple destinations or two DDS samples have the same publication priority, the corresponding destination queues are serviced in a round-robin fashion.

  This priority inheritance approach is required to both honor the designated publication priority and adhere to the *DataWriter's* in-order data delivery guarantee.

  See also: 7.6.4 Prioritized DDS Samples on page 473.

7.6.2 Managing Fast DataWriters When Using a FlowController

If a *DataWriter* is writing DDS samples faster than its attached FlowController can throttle, *Connext DDS* may drop DDS samples on the writer's side. This happens because the DDS samples may be removed from the queue before the asynchronous publisher's thread has a chance to send them. To work around this problem, either:

- Use reliable communication to block the **write()** call and thereby throttle your application.
- Do not allow the queue to fill up in the first place.

  The queue should be sized large enough to handle expected write bursts, so that no DDS samples are dropped. Then in steady state, the FlowController will smooth out these bursts and the queue will ideally have only one entry.

7.6.3 Token Bucket Properties

FlowControllers use a token-bucket approach for open-loop network flow control. The flow control characteristics are determined by the token bucket properties. The properties are listed in Table 7.82 DDS_FlowControllerTokenBucketProperty_t ; see the API Reference HTML documentation for their defaults and valid ranges.

Table 7.82 DDS_FlowControllerTokenBucketProperty_t

Type	Field Name	Description
DDS_Long	max_tokens	Maximum number of tokens than can accumulate in the token bucket. See 7.6.3.1 max_tokens on the next page.
DDS_Long	tokens_added_per_period	The number of tokens added to the token bucket per specified period. See 7.6.3.2 tokens_added_per_period on the next page.
DDS_Long	tokens_leaked_per_period	The number of tokens removed from the token bucket per specified period. See 7.6.3.3 tokens_leaked_per_period on the next page.
DDS_Duration_t	period	Period for adding tokens to and removing tokens from the bucket. See 7.6.3.4 period on the next page.
DDS_Long	bytes_per_token	Maximum number of bytes allowed to send for each token available. See 7.6.3.5 bytes_per_token on the next page.

Asynchronously published DDS samples are queued up and transmitted based on the token bucket flow control scheme. The token bucket contains tokens, each of which represents a number of bytes. DDS samples can be sent only when there are sufficient tokens in the bucket. As DDS samples are sent, tokens are consumed. The number of tokens consumed is proportional to the size of the data being sent. Tokens are replenished on a periodic basis.

The rate at which tokens become available and other token bucket properties determine the network traffic flow.

Note that if the same DDS sample must be sent to multiple destinations, separate tokens are required for each destination. Only when multiple DDS samples are destined to the same destination will they be coalesced and sent using the same token(s). In other words, each token can only contribute to a single network packet.

7.6.3.1 max_tokens

The maximum number of tokens in the bucket will never exceed this value. Any excess tokens are discarded. This property value, combined with **bytes_per_token**, determines the maximum allowable data burst.

Use DDS_LENGTH_UNLIMITED to allow accumulation of an unlimited amount of tokens (and therefore potentially an unlimited burst size).

7.6.3.2 tokens_added_per_period

A FlowController transmits data only when tokens are available. Tokens are periodically replenished. This field determines the number of tokens added to the token bucket with each periodic replenishment.

Available tokens are distributed to associated *DataWriters* based on the **scheduling_policy**. Use DDS_LENGTH_UNLIMITED to add the maximum number of tokens allowed by **max_tokens**.

7.6.3.3 tokens_leaked_per_period

When tokens are replenished and there are sufficient tokens to send all DDS samples in the queue, this property determines whether any or all of the leftover tokens remain in the bucket.

Use DDS_LENGTH_UNLIMITED to remove all excess tokens from the token bucket once all DDS samples have been sent. In other words, no token accumulation is allowed. When new DDS samples are written after tokens were purged, the earliest point in time at which they can be sent is at the next periodic replenishment.

7.6.3.4 period

This field determines the period by which tokens are added or removed from the token bucket.

The special value DDS_DURATION_INFINITE can be used to create an on-demand FlowController, for which tokens are no longer replenished periodically. Instead, tokens must be added explicitly by calling the FlowController's **trigger_flow()** operation. This external trigger adds **tokens_added_per_period** tokens each time it is called (subject to the other property settings).

> Once **period** is set to DDS_DURATION_INFINITE, it can no longer be reverted to a finite period.

7.6.3.5 bytes_per_token

This field determines the number of bytes that can actually be transmitted based on the number of tokens.

Tokens are always consumed in whole by each *DataWriter*. That is, in cases where **bytes_per_token** is greater than the DDS sample size, multiple DDS samples may be sent to the same destination using a single token (regardless of the **scheduling_policy**).

Where fragmentation is required, the fragment size will be either (a) **bytes_per_token** or (b) the minimum of the largest message sizes across all transports installed with the *DataWriter*, whichever is less.

Use DDS_LENGTH_UNLIMITED to indicate that an unlimited number of bytes can be transmitted per token. In other words, a single token allows the recipient *DataWriter* to transmit all its queued DDS samples to a single destination. A separate token is required to send to each additional destination.

7.6.4 Prioritized DDS Samples

Note: This feature is not supported when using the Ada API.

The *Prioritized DDS Samples* feature allows you to prioritize traffic that is in competition for transmission resources. The granularity of this prioritization may be by *DataWriter*, by instance, or by individual DDS sample.

Prioritized DDS Samples can improve latency in the following cases:

- Low-Availability Links

  With low-availability communication, unsent DDS samples may accumulate while the link is unavailable. When the link is restored, a large number of DDS samples may be waiting for transmission. High priority DDS samples will be sent first.
- Low-Bandwidth Links

  With low-bandwidth communication, a temporary backlog may occur or the link may become congested with large DDS samples. High-priority DDS samples will be sent at the first available gap, between the fragments of a large low-priority DDS sample.

- Prioritized Topics

  With limited bandwidth communication, some topics may be deemed to be of higher priority than others on an ongoing basis, and DDS samples written to some topics should be given precedence over others on transmission.

- High Priority Events

  Due to external rules or content analysis (e.g., perimeter violation or identification as a threat), the priority of DDS samples is dynamically determined, and the priority assigned a given DDS sample will reflect the urgency of its delivery.

To configure a *DataWriter* to use prioritized DDS samples*:*

- Create a FlowController with the **scheduling_policy** property set to *DDS_HPF_FLOW_CONTROLLER_SCHED_POLICY.*

- Create a *DataWriter* with the 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441 **kind** set to *ASYNCHRONOUS* and **flow_controller_name** set to the name of the FlowController.

A single FlowController may perform traffic shaping for multiple *DataWriters* and multiple *DataWriter* channels. The FlowController's configuration determines how often publication resources are scheduled, how much data may be sent per period, and other transmission characteristics that determine the ultimate performance of prioritized DDS samples.

When working with prioritized DDS samples, you should use these operations, which allow you to specify priority:

- **write_w_params()** (see 7.3.8 Writing Data on page 308)
- **unregister_instance_w_params()** (see 7.3.14.4 Unregistering Instances on page 327)
- **dispose_w_params()** (see 7.3.14.3 Disposing Instances on page 327)

If you use **write()**, **unregister()**, or **dispose()** instead of the **_w_params()** versions, the affected DDS sample is assigned priority 0 (undefined priority). If you are using a multi-channel DataWriter with a priority filter, and you have no channel for priority 0, the DDS sample will be discarded.

7.6.4.1 Designating Priorities

For *DataWriters* and *DataWriter* channels, valid publication priority values are:

- DDS_PUBLICATION_PRIORITY_UNDEFINED
- DDS_PUBLICATION_PRIORITY_AUTOMATIC
- Positive integers excluding zero

For individual DDS samples, valid publication priority values are 0 and positive integers.

There are three ways to set the publication priority of a *DataWriter* or *DataWriter* channel:

1. For a *DataWriter,* publication priority is set in the **priority** field of its **7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441. For a multi-channel *DataWriter* (see 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429), this value will be the default publication priority for any member channel that has not been assigned a specific value.**
2. For a channel of a Multi-channel *DataWriter*, publication priority can be set in the *DataWriter's* 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429 in **channels[].priority**.
3. If a *DataWriter* or a channel of a Multi-channel *DataWriter* is configured for publication priority inheritance (DDS_PUBLICATION_PRIORITY_AUTOMATIC), its publication priority is the highest priority among all the DDS samples currently in the publication queue. When using

publication priority inheritance, the publication priorities of individual DDS samples are set by calling the **write_w_params()** operation, which takes a **priority** parameter.

The *effective* publication priority is determined from the interaction of the *DataWriter*, channel, and DDS sample publication priorities, as shown in Table 7.83 Effective Publication Priority of Samples.

Table 7.83 Effective Publication Priority of Samples

	Priority Setting Combinations				
Writer Priority	Undefined	Don't care	AUTOMATIC	Don't care	Designated positive integer > 0
Channel Priority	Undefined	AUTOMATIC	Undefined	Designated positive integer > 0	Undefined
DDS Sample Priority	Don't care	Designated positive integer > 0	Designated positive integer > 0	Don't care	Don't care
Effective Priority	Lowest Priority	DDS Sample Priority[1]	DDS Sample Priority[2]	Channel Priority	Writer Priority

7.6.4.2 Priority-Based Filtering

The configuration methods explained above are sufficient to create multiple *DataWriters*, each with its own assigned priority, all using the same *FlowController* configured for *publication priority*-based scheduling. Such a configuration is sufficient to assign different priorities to individual topics, but it does not allow different *publication priorities* to be assigned to published data *within* a *Topic*.

To assign different priorities to data within a *DataWriter*, you will need to use a Multi-channel *DataWriter* and configure the channels with different priorities. Configuring the publication priorities of *DataWriter* channels is explained above. To associate different priorities of data with different publication channels, configure the **channel[].filter_expression** in the *DataWriter's* 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429. The filtering criteria that is available for evaluation by each channel is determined by the filter type, which is configured with the *DataWriter's* **filter_name** (also in the 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429).

For example, using the built-in SQL-based content filter allows channel membership to be determined based on the content of each DDS sample.

If you do not want to embed priority criteria within each DDS sample, you can use a built-in filter named DDS_PRIFILTER_NAME that uses the publication priority that is provided when you call **write_w_params()** (see 7.3.8 Writing Data on page 308). The filter's expression syntax is:

[1]Highest sample priority among all DDS samples currently in the publication queue.

[2]Highest sample priority among all DDS samples currently in the publication queue.

```
@priority OP VAL
```

where OP can be < , <= , > , >= , = , or <> (standard relational operators), and VAL is a positive integer.

The filter supports multiple expressions, combined with the conjunctions AND and OR. You can use parentheses to disambiguate combinations of AND and OR in the same expression. For example:

```
@priority = 2 OR (@priority > 6 AND @priority < 10)
```

7.6.5 Creating and Configuring Custom FlowControllers with Property QoS

You can create and configure FlowControllers using the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436. The properties must have a prefix of "dds.flow_controller.token_bucket", followed by the name of the FlowController being created or configured. For example, if you want to create/configure a FlowController named **MyFC**, all the properties for **MyFC** should have the prefix "**dds.flow_controller.token_bucket.MyFC**".

Table 7.84 FlowController Properties lists the properties that can be set for FlowControllers in the *DomainParticipant's* 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436. A FlowController with the name "**dds.flow_controller.token_bucket.<*your flow controllername*>**" will be implicitly created when at least one property using that prefix is specified. Then, to link a *DataWriter* to your FlowController, use "dds.flow_controller.token_bucket.<*your flow controllername*>" in the *DataWriter's* **publish_mode.flow_controller_name**.

Table 7.84 FlowController Properties

Property Name prefix with 'dds.flow_controller.token_bucket.<*your flow controller name*>	Property Value Description
scheduling_policy	Specifies the scheduling policy to be used. (See 7.6.1 Flow Controller Scheduling Policies on page 469) May be: DDS_RR_FLOW_CONTROLLER_SCHED_POLICY DDS_EDF_FLOW_CONTROLLER_SCHED_POLICY DDS_HPF_FLOW_CONTROLLER_SCHED_POLICY
token_bucket.max_tokens	Maximum number of tokens than can accumulate in the token bucket. Use -1 for unlimited.
token_bucket.tokens_added_per_period	Number of tokens added to the token bucket per specified period. Use -1 for unlimited.
token_bucket.tokens_leaked_per_period	Number of tokens removed from the token bucket per specified period. Use -1 for unlimited.
token_bucket.period.sec	Period for adding tokens to and removing tokens from the bucket in seconds.
token_bucket.period.nanosec	Period for adding tokens to and removing tokens from the bucket in nanoseconds.

Table 7.84 FlowController Properties

Property Name prefix with 'dds.flow_ controller.token_bucket. *<your flow controller name>*	Property Value Description
token_bucket.bytes_per_token	Maximum number of bytes allowed to send for each token available.

7.6.5.1 Example

The following example shows how to set FlowController properties.

```
<domain_participant_qos>
       <property>
               <value>
                       <element>
                               <name>
       dds.flow_controller.token_bucket.MyFlowController.scheduling_policy
                               </name>
                               <value>DDS_RR_FLOW_CONTROLLER_SCHED_POLICY</value>
                       </element>
                       <element>
                               <name>
       dds.flow_controller.token_bucket.MyFlowController.token_bucket.period.sec
                               </name>
                               <value>100</value>
                       </element>
                       <element>
                               <name>
               dds.flow_controller.token_bucket.MyFlowController.token_bucket.period.nanosec
                               </name>
                               <value>0</value>
                       </element>
                       <element>
                               <name>
       dds.flow_controller.token_bucket.MyFlowController.token_bucket.tokens_added_per_period
                               </name>
                               <value>2</value>
                       </element>
                       <element>
                               <name>
       dds.flow_controller.token_bucket.MyFlowController.token_bucket.tokens_leaked_per_period
                               </name>
                               <value>2</value>
                       </element>
                       <element>
                               <name>
       dds.flow_controller.token_bucket.MyFlowController.token_bucket.bytes_per_token
                               </name>
                               <value>1024</value>
                       </element>
               </value>
       </property>
```

```
</domain_participant_qos>
<datawriter_qos>
       <publish_mode>
              <flow_controller_name>
                     dds.flow_controller.token_bucket.MyFlowController
              </flow_controller_name>
              <kind>ASYNCHRONOUS_PUBLISH_MODE_QOS</kind>
       </publish_mode>
</datawriter_qos>
```

7.6.6 Creating and Deleting FlowControllers

(Note: in the Modern C++ API FlowControllers have reference semantics, see Creating and Deleting Entities)

If you do not want to use one of the three built-in FlowControllers described in 7.6 FlowControllers (DDS Extension) on page 467, you can create your own with the *DomainParticipant's* **create_flowcontroller()** operation:

```
DDSFlowController* create_flowcontroller
                (const char * name,
                const DDS_FlowControllerProperty_t & property)
```

To associate a FlowController with a *DataWriter*, you set the FlowController's name in the 7.5.20 PUBLISH_MODE QosPolicy (DDS Extension) on page 441 (**flow_controller_name**).

A single FlowController may service multiple *DataWriters*, even if they belong to a different *Publisher*. The FlowController's **property** structure determines how the FlowController shapes the network traffic.

name	Name of the FlowController to create. A *DataWriter* is associated with a DDSFlowController by name. Limited to 255 characters.
property	Properties to be used for creating the FlowController. The special value DDS_FLOW_CONTROLLER_PROPERTY_DEFAULT can be used to indicate that the FlowController should be created with the default DDS_FlowControllerProperty_t set in the *DomainParticipant*.

Note: If you use DDS_FLOW_CONTROLLER_PROPERTY_DEFAULT, it is *not* safe to create the FlowController while another thread may be simultaneously calling **set_default_flowcontroller_property ()** or looking for that FlowController with **lookup_flowcontroller()**.

To delete an existing FlowController, use the *DomainParticipant's* **delete_flowcontroller()** operation:

```
DDS_ReturnCode_t delete_flowcontroller (DDSFlowController *  fc)
```

The FlowController must belong this the *DomainParticipant* and not have any attached *DataWriters* or the delete call will return an error (PRECONDITION_NOT_MET).

7.6.7 Getting/Setting Default FlowController Properties

To get the default DDS_FlowControllerProperty_t values, use this operation on the *DomainParticipant*:

```
DDS_ReturnCode_t get_default_flowcontroller_property
        (DDS_FlowControllerProperty_t &  property)
```

The retrieved property will match the set of values specified on the last successful call to the *DomainParticipant's* **set_default_flowcontroller_property()**, or if the call was never made, the default values listed in DDS_FlowControllerProperty_t.

To change the default DDS_FlowControllerProperty_t values used when a new FlowController is created, use this operation on the *DomainParticipant*:

```
DDS_ReturnCode_t set_default_flowcontroller_property
        (const DDS_FlowControllerProperty_t &  property)
```

The special value DDS_FLOW_CONTROLLER_PROPERTY_DEFAULT may be passed for the **property** to indicate that the default property should be reset to the default values the factory would use if **set_default_flowcontroller_property()** had never been called.

Note: It is not safe to set the default FlowController properties while another thread may be simultaneously calling **get_default_flowcontroller_property(), set_default_flowcontroller_property(),** or **create_flowcontroller()** with DDS_FLOW_CONTROLLER_PROPERTY_DEFAULT as the **qos** parameter. It is also not safe to get the default FlowController properties while another thread may be simultaneously calling **get_default_flowcontroller_property().**

7.6.8 Getting/Setting Properties for a Specific FlowController

To get the properties of a FlowController, use the FlowController's **get_property()** operation:

```
DDS_ReturnCode_t DDSFlowController::get_property
        (struct DDS_FlowControllerProperty_t &  property)
```

To change the properties of a FlowController, use the FlowController's **set_property()** operation:

```
DDS_ReturnCode_t DDSFlowController::set_property
        (const struct DDS_FlowControllerProperty_t &  property)
```

Once a FlowController has been instantiated, only its **token_bucket** property can be changed. The **scheduling_policy** is immutable. A new **token.period** only takes effect at the next scheduled token distribution time (as determined by its previous value).

The special value DDS_FLOW_CONTROLLER_PROPERTY_DEFAULT can be used to match the current default properties set in the *DomainParticipant*.

7.6.9 Adding an External Trigger

Typically, a FlowController uses an internal trigger to periodically replenish its tokens. The period by which this trigger is called is determined by the **period** property setting.

The **trigger_flow()** function provides an additional, external trigger to the FlowController. This trigger adds **tokens_added_per_period** tokens each time it is called (subject to the other property settings of the FlowController).

```
DDS_ReturnCode_t trigger_flow ()
```

An on-demand FlowController can be created with a DDS_DURATION_INFINITE as **period**, in which case the only trigger source is external (i.e. the FlowController is solely triggered by the user on demand).

trigger_flow() can be called on both a strict on-demand FlowController and a hybrid FlowController (internally and externally triggered).

7.6.10 Other FlowController Operations

If you have the FlowController object and need its name, call the FlowController's **get_name()** operation:

```
const char* DDSFlowController::get_name( )
```

Conversely, if you have the name of the FlowController and need the FlowController object, call the *DomainPartipant's* **lookup_flowcontroller()** operation:

```
DDSFlowController* lookup_flowcontroller (const char *  name)
```

To get a FlowController's *DomainParticipant*, call the FlowController's **get_participant()** operation:

```
DDSDomainParticipant* get_participant ( )
```

Note: It is not safe to lookup a FlowController description while another thread is creating that FlowController

Chapter 8 Receiving Data

This section discusses how to create, configure, and use *Subscribers* and *DataReaders* to receive data. It describes how these objects interact, as well as the types of operations that are available for them.

The goal of this section is to help you become familiar with the Entities you need for receiving data. For up-to-date details such as formal parameters and return codes on any mentioned operations, please see the *Connext DDS* API Reference HTML documentation.

8.1 Preview: Steps to Receiving Data

There are three ways to receive data:

- Your application can explicitly check for new data by calling a *DataReader*'s **read()** or **take()** operation. This method is also known as *polling for data*.
- Your application can be notified asynchronously whenever new DDS data samples arrive—this is done with a *Listener* on either the *Subscriber* or the *DataReader*. *Connext DDS* will invoke the *Listener*'s callback routine when there is new data. Within the callback routine, user code can access the data by calling **read()** or t**ake()** on the *DataReader*. This method is the way for your application to receive data with the least amount of latency.
- Your application can wait for new data by using *Conditions* and a *WaitSet*, then calling **wait()**. *Connext DDS* will block your application's thread until the criteria (such as the arrival of DDS samples, or a specific status) set in the *Condition* becomes true. Then your application resumes and can access the data with **read()** or **take()**.

The *DataReader*'s **read()** operation gives your application a copy of the data and leaves the data in the *DataReader*'s receive queue. The *DataReader*'s **take()** operation removes data from the receive queue before giving it to your application.

See 8.4 Using DataReaders to Access Data (Read & Take) on page 548 for details on using *DataReaders* to access received data.

See 4.6 Conditions and WaitSets on page 202 for details on using *Conditions* and *WaitSets*.

To prepare to receive data, create and configure the required Entities:

1. Create a *DomainParticipant*.
2. Register user data types[1] with the *DomainParticipant*. For example, the '**FooDataType**'.
3. Use the *DomainParticipant* to create a *Topic* with the registered data type.
4. Optionally[2], use the *DomainParticipant* to create a *Subscriber*.
5. Use the *Subscriber* or *DomainParticipant* to create a *DataReader* for the *Topic*.
6. Use a type-safe method to cast the generic *DataReader* created by the *Subscriber* to a type-specific *DataReader*. For example, '**FooDataReader**'.

Then use one of the following mechanisms to receive data.

- To receive DDS data samples by polling for new data:
  - Using a **FooDataReader**, use the **read()** or **take()** operations to access the DDS data samples that have been received and stored for the *DataReader*. These operations can be invoked at any time, even if the receive queue is empty.
- To receive DDS data samples asynchronously:
  - Install a *Listener* on the *DataReader* or *Subscriber* that will be called back by an internal *Connext DDS* thread when new DDS data samples arrive for the *DataReader*.

1. Create a *DDSDataReaderListener* for the *FooDataReader* or a *DDSSubscriberListener* for *Subscriber*. In C++, C++/CLI, C# and Java, you must derive your own *Listener* class from those base classes. In C, you must create the individual functions and store them in a structure.

   If you created a *DDSDataReaderListener* with the **on_data_available()** callback enabled: **on_data_available()** will be called when new data arrives for that *DataReader*.

   If you created a *DDSSubscriberListener* with the **on_data_on_readers()** callback enabled: **on_data_on_readers()** will be called when data arrives for any *DataReader* created by the *Subscriber*.
2. Install the *Listener* on either the **FooDataReader** or *Subscriber*.

   For the *DataReader*, the *Listener* should be installed to handle changes in the **DATA_AVAILABLE** status.

[1] Type registration is not required for built-in types (see 3.2.1 Registering Built-in Types on page 39).

[2] You are not required to explicitly create a *Subscriber*; instead, you can use the 'implicit *Subscriber*' created from the *DomainParticipant*. See 8.2.1 Creating Subscribers Explicitly vs. Implicitly on page 487.

For the *Subscriber*, the *Listener* should be installed to handle changes in the **DATA_ON_READERS** status.

3. Only 1 *Listener* will be called back when new data arrives for a *DataReader*.

   Connext DDS will call the *Subscriber*'s *Listener* if it is installed. Otherwise, the *DataReader*'s *Listener* is called if it is installed. That is, the **on_data_on_readers()** operation takes precedence over the **on_data_available()** operation.

   If neither *Listeners* are installed or neither *Listeners* are enabled to handle their respective statuses, then *Connext DDS* will not call any user functions when new data arrives for the *DataReader*.
4. In the **on_data_available()** method of the *DDSDataReaderListener*, invoke **read()** or **take()** on the **FooDataReader** to access the data.

   If the **on_data_on_readers()** method of the *DDSSubscriberListener* is called, the code can invoke **read()** or **take()** directly on the *Subscriber*'s *DataReaders* that have received new data. Alternatively, the code can invoke the *Subscriber's* **notify_datareaders()** operation. This will in turn call the **on_data_available()** methods of the *DataReaderListeners* (if installed and enabled) for each of the *DataReaders* that have received new DDS data samples.

To wait (block) until DDS data samples arrive:

1. Use the *DataReader* to create a *ReadCondition* that describes the DDS samples for which you want to wait. For example, you can specify that you want to wait for never-before-seen DDS samples from *DataReaders* that are still considered to be 'alive.'

   Alternatively, you can create a *StatusCondition* that specifies you want to wait for the ON_DATA_AVAILABLE status.
2. Create a *WaitSet*.
3. Attach the *ReadCondition* or *StatusCondition* to the *WaitSet*.
4. Call the *WaitSet's* **wait()** operation, specifying how long you are willing to wait for the desired DDS samples. When **wait()** returns, it will indicate that it timed out, or that the attached *Condition* become true (and therefore the desired DDS samples are available).
5. Using a **FooDataReader**, use the **read()** or **take()** operations to access the DDS data samples that have been received and stored for the *DataReader*.

8.2 Subscribers

An application that intends to subscribe to information needs the following *Entities*: *DomainParticipant*, *Topic*, *Subscriber*, and *DataReader*. All *Entities* have a corresponding specialized *Listener* and a set of QosPolicies. The *Listener* is how *Connext DDS* notifies your application of status changes relevant to the *Entity*. The QosPolicies allow your application to configure the behavior and resources of the *Entity*.

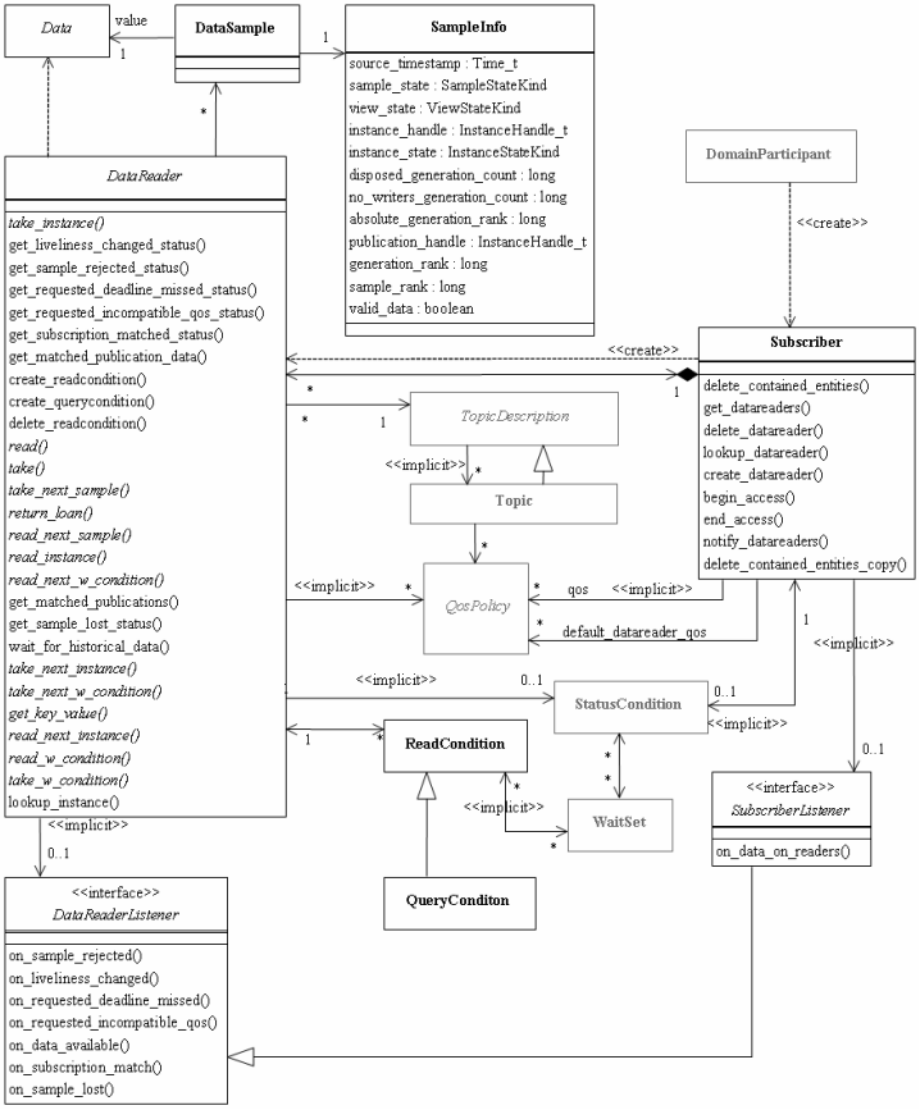
- The *DomainParticipant* defines the DDS domain on which the information will be available.
- The *Topic* defines the name of the data to be subscribed, as well as the type (format) of the data itself.
- The *DataReader* is the Entity used by the application to subscribe to updated values of the data. The *DataReader* is bound at creation time to a *Topic*, thus specifying the named and typed data stream to which it is subscribed. The application uses the *DataWriter*'s **read()** or **take()** operation to access DDS data samples received for the *Topic*.
- The *Subscriber* manages the activities of several *DataReader* entities. The application receives data using a *DataReader* that belongs to a *Subscriber*. However, the *Subscriber* will determine when the data received from applications is actually available for access through the *DataReader*. Depending on the settings of various QosPolicies of the *Subscriber* and *DataReader*, data may be buffered until DDS data samples for associated *DataReaders* are also received. By default, the data is available to the application as soon as it is received.

For more information, see 8.2.1 Creating Subscribers Explicitly vs. Implicitly on page 487.

The UML diagram in Figure 8.1: Subscription Module on the next page shows how these *Entities* are related as well as the methods defined for each Entity.

Subscribers are used to perform the operations listed in Table 8.1 Subscriber Operations. For details such as formal parameters and return codes, please see the API Reference HTML documentation. Otherwise, you can find more information about the operations by looking in the section listed under the Reference on page 486 column.

Figure 8.1: Subscription Module



Note: Some operations cannot be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

Table 8.1 Subscriber Operations

Working with ...	Operation	Description	Reference
DataReaders	begin_access	Indicates that the application is about to access the DDS data samples in the *DataReaders* of the *Subscriber*.	8.2.5 Beginning and Ending Group-Ordered Access on page 496
	create_datareader	Creates a *DataReader*.	8.3.1 Creating DataReaders on page 507
	create_datareader_with_profile	Creates a *DataReader* with QoS from a specified QoS profile.	
	copy_from_topic_qos	Copies relevant QosPolicies from a *Topic* into a DataReaderQoS structure.	8.2.4.6 Subscriber QoS-Related Operations on page 495
DataReaders cont'd	delete_contained_entities	Deletes all the *DataReaders* that were created by the *Subscriber*. Also deletes the corresponding *ReadConditions* created by the contained *DataReaders*.	8.2.3.1 Deleting Contained DataReaders on page 490
	delete_datareader	Deletes a specific *DataReader*.	8.3.3 Deleting DataReaders on page 509
	end_access	Indicates that the application is done accessing the DDS data samples in the *DataReaders* of the *Subscriber*.	8.2.5 Beginning and Ending Group-Ordered Access on page 496
	get_all_datareaders	Retrieves all the *DataReaders* created from this *Subscriber*.	8.3.2 Getting All DataReaders on page 509
	get_datareaders	Returns a list of *DataReaders* that contain DDS samples with the specified **sample_states**, **view_states** and instance_states.	8.2.7 Getting DataReaders with Specific DDS Samples on page 499
	get_default_datareader_qos	Copies the *Subscriber's* default DataReaderQos values into a DataReaderQos structure.	8.2.4 Setting Subscriber QosPolicies on page 490
DataReaders cont'd	get_status_changes	Gets all status changes.	4.1.4 Getting Status and Status Changes on page 171
	lookup_datareader	Retrieves a *DataReader* previously created for a specific *Topic*.	8.2.8 Finding a Subscriber's Related Entities on page 499
	notify_datareaders	Invokes the on_data_available() operation for attached *Listeners* of *DataReaders* that have new DDS data samples.	8.2.6 Setting Up SubscriberListeners on page 497
	set_default_datareader_qos	Sets or changes the *Subscriber's* default DataReaderQoS values.	8.2.4 Setting Subscriber QosPolicies on page 490

Table 8.1 Subscriber Operations

Working with ...	Operation	Description	Reference
Libraries and Profiles	get_default_library	Gets the *Subscriber's* default QoS profile library.	8.2.4.4 Getting and Settings Subscriber's Default QoS Profile and Library on page 494
	get_default_profile	Gets the *Subscriber's* default QoS profile.	
	get_default_profile_library	Gets the library that contains the *Subscriber's* default QoS profile.	
	set_default_library	Sets the default library for a *Subscriber*.	
	set_default_profile	Sets the default profile for a *Subscriber*.	
Participants	get_participant	Gets the *Subscriber's DomainParticipant*.	8.2.8 Finding a Subscriber's Related Entities on page 499
Subscribers	enable	Enables the *Subscriber*.	4.1.2 Enabling DDS Entities on page 168
	equals	Compares two *Subscriber's* QoS structures for equality.	8.2.4.2 Comparing QoS Values on page 493
	get_listener	Gets the currently installed *Listener*.	8.2.6 Setting Up SubscriberListeners on page 497
	get_qos	Gets the *Subscriber's* current QosPolicy settings. This is most often used in preparation for calling set_qos.	8.2.4.3 Changing QoS Settings After Subscriber Has Been Created on page 493
	set_listener	Sets the *Subscriber's Listener*. If you created the Subscriber without a *Listener*, you can use this operation to add one later.	8.2.6 Setting Up SubscriberListeners on page 497
	set_qos	Sets the *Subscriber's* QoS. You can use this operation to change the values for the *Subscriber's* QosPolicies. Note, however, that not all QosPolicies can be changed after the *Subscriber* has been created.	8.2.4.3 Changing QoS Settings After Subscriber Has Been Created on page 493
	set_qos_with_profile	Sets the *Subscriber's* QoS based on a QoS profile.	8.2.4.3 Changing QoS Settings After Subscriber Has Been Created on page 493

8.2.1 Creating Subscribers Explicitly vs. Implicitly

To receive data, your application must have a *Subscriber*. However, you are not required to explicitly create a *Subscriber*. If you do not create one, the middleware will implicitly create a *Subscriber* the first time you create a *DataReader* using the *DomainParticipant's* operations. It will be created with default QoS (DDS_SUBCRIBER_QOS_DEFAULT) and no Listener. The 'implicit *Subscriber*' can be

accessed using the *DomainParticipant's* **get_implicit_subscriber()** operation (see 9.3.10 Getting the Implicit Publisher or Subscriber on page 624).You can use this 'implicit *Subscriber*' just like any other *Subscriber* (it has the same operations, QosPolicies, etc.). So you can change the mutable QoS and set a Listener if desired.

A *Subscriber* (implicit or explicit) gets its own default QoS and the default QoS for its child *DataReaders* from the *DomainParticipant*. These default QoS are set when the *Subscriber* is created. (This is true for *Publishers* and *DataWriters*, too.)

DataReaders are created by calling **create_datareader()** or **create_datareader_with_profile()**—these operations exist for *DomainParticipants* and *Subscribers*[1]. If you use the *DomainParticipant* to create a *DataReader*, it will belong to the implicit *Subscriber*. If you use a *Subscriber* to create a *DataReader*, it will belong to that *Subscriber*.

The middleware will use the same implicit *Subscriber* for all *DataReaders* that are created using the *DomainParticipant's* operations.

Having the middleware implicitly create a Subscriber allows you to skip the step of creating a Subscriber. However, having all your *DataReaders* belong to the same Subscriber can reduce the concurrency of the system because all the read operations will be serialized.

8.2.2 Creating Subscribers

Before you can explicitly create a *Subscriber*, you need a *DomainParticipant* (9.3 DomainParticipants on page 604). To create a *Subscriber*, use the *DomainParticipant*'s **create_subscriber()** or **create_subscriber_with_profile()** operation.

A QoS profile is way to use QoS settings from an XML file or string. With this approach, you can change QoS settings without recompiling the application. For details, see Configuring QoS with XML (Chapter 19 on page 842).

Note: The Modern C++ API provides Subscriber constructors whose first, and only required argument is the *DomainParticipant*.

```
DDSSubscriber* create_subscriber(
    const DDS_SubscriberQos &qos,
    DDSSubscriberListener * listener,
    DDS_StatusMask mask)
DDSSubscriber* create_subscriber_with_profile (
    const char * library_name,
    const char * profile_name,
    DDSSubscriberListener * listener,
    DDS_StatusMask  mask )
```

Where:

[1]In the Modern C++ API, you always use a DataReader constructor.

qos	If you want the default QoS settings (described in the API Reference HTML documentation), use DDS_SUBSCRIBER_QOS_DEFAULT for this parameter (see Figure 8.2: Creating a Subscriber with Default QosPolicies below). If you want to customize any of the QosPolicies, supply a QoS structure (see Figure 8.3: Creating a Subscriber with Non-Default QosPolicies (not from a profile) on page 492). The QoS structure for a *Subscriber* is described in 8.5 Subscriber QosPolicies on page 565. **Note**: If you use DDS_SUBSCRIBER_QOS_DEFAULT, it is not safe to create the *Subscriber* while another thread may be simultaneously calling **set_default_subscriber_qos()**.
listener	*Listeners* are callback routines. *Connext DDS* uses them to notify your application when specific events (new DDS data samples arrive and status changes) occur with respect to the *Subscriber* or the *DataReaders* created by the *Subscriber*. The *listener* parameter may be set to NULL if you do not want to install a *Listener*. If you use NULL, the *Listener* of the *DomainParticipant* to which the *Subscriber* belongs will be used instead (if it is set). For more information on *SubscriberListeners*, see 8.2.6 Setting Up SubscriberListeners on page 497.
mask	This bit-mask indicates which status changes will cause the *Subscriber*'s *Listener* to be invoked. The bits set in the mask must have corresponding callbacks implemented in the *Listener*. If you use NULL for the *Listener*, use DDS_STATUS_MASK_NONE for this parameter. If the *Listener* implements all callbacks, use DDS_STATUS_MASK_ALL. For information on Status, see 4.4 Listeners on page 189. This bit-mask indicates which status changes will cause the *Subscriber*'s *Listener* to be invoked. The bits set in the mask must have corresponding callbacks implemented in the *Listener*. If you use NULL for the *Listener*, use DDS_STATUS_MASK_NONE for this parameter. If the *Listener* implements all callbacks, use DDS_STATUS_MASK_ALL. For information on Status, see 4.4 Listeners on page 189.
library_name	A QoS Library is a named set of QoS profiles. See 19.3 QoS Profiles on page 844.
profile_name	A QoS profile groups a set of related QoS, usually one per entity. See 19.3 QoS Profiles on page 844.

Figure 8.2: Creating a Subscriber with Default QosPolicies

```
// create the subscriber
DDSSubscriber* subscriber =
    participant->create_subscriber(
        DDS_SUBSCRIBER_QOS_DEFAULT,
        NULL, DDS_STATUS_MASK_NONE);
if (subscriber == NULL) {
// handle error
}
```

For more examples, see 8.2.4.1 Configuring QoS Settings when the Subscriber is Created on page 491.

After you create a *Subscriber*, the next step is to use the *Subscriber* to create a *DataReader* for each *Topic*, see 8.3.1 Creating DataReaders on page 507. For a list of operations you can perform with a *Subscriber*, see Table 8.1 Subscriber Operations.

8.2.3 Deleting Subscribers

(Note: in the Modern C++ API, *Entities* are automatically destroyed, see 4.1.1 Creating and Deleting DDS Entities on page 167)

This section applies to both implicitly and explicitly created *Subscribers*.

To delete a *Subscriber*:

1. You must first delete all *DataReaders* that were created with the *Subscriber*. Use the *Subscriber*'s **delete_datareader()** operation (8.3.1 Creating DataReaders on page 507) to delete them one at a time, or use the **delete_contained_entities()** operation (8.2.3.1 Deleting Contained DataReaders below) to delete them all at the same time.

```
DDS_ReturnCode_t delete_datareader (DDSDataReader *a_datareader)
```

2. Delete the *Subscriber* by using the *DomainParticipant's* **delete_subscriber()** operation ().

Note: A *Subscriber* cannot be deleted within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

8.2.3.1 Deleting Contained DataReaders

The *Subscriber's* **delete_contained_entities()** operation deletes all the *DataReaders* that were created by the *Subscriber*. It also deletes the *ReadConditions* created by each contained *DataReader*.

```
DDS_ReturnCode_t DDSSubscriber::delete_contained_entities ()
```

After this operation returns successfully, the application may delete the *Subscriber* (see 8.2.3 Deleting Subscribers on the previous page).

The operation will return **PRECONDITION_NOT_MET** if any of the contained entities cannot be deleted. This will occur, for example, if a contained *DataReader* cannot be deleted because the application has called **read()** but has not called the corresponding **return_loan()** operation to return the loaned DDS samples.

8.2.4 Setting Subscriber QosPolicies

A *Subscriber*'s QosPolicies control its behavior. Think of the policies as the configuration and behavior 'properties' for the *Subscriber*. The **DDS_SubscriberQos** structure has the following format:

```
struct DDS_SubscriberQos {
       DDS_PresentationQosPolicy   presentation;
       DDS_PartitionQosPolicy      partition;
       DDS_GroupDataQosPolicy      group_data;
       DDS_EntityFactoryQosPolicy  entity_factory;
       DDS_ExclusiveAreaQosPolicy  exclusive_area;
       DDS_EntityNameQosPolicy     subscriber_name;
};
```

Note: set_qos() cannot always be used by a *Listener*, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

Table 8.2 Subscriber QosPolicies summarizes the meaning of each policy. *Subscribers* have the same set of QosPolicies as Publishers; they are described in detail in 7.4 Publisher/Subscriber QosPolicies on page 344. For information on *why* you would want to change a particular QosPolicy, see the referenced

section. For defaults and valid ranges, please refer to the API Reference HTML documentation for each policy.

Table 8.2 Subscriber QosPolicies

QosPolicy	Description
7.4.2 ENTITYFACTORY QosPolicy on page 347	Whether or not new entities created from this entity will start out as 'enabled.'
7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416	Assigns a name and role_name to a *Subscriber*.
7.4.3 EXCLUSIVE_AREA QosPolicy (DDS Extension) on page 350	Whether or not the entity uses a multi-thread safe region with deadlock protection.
7.4.4 GROUP_DATA QosPolicy on page 352	A place to pass group-level information among applications. Usage is application-dependent.
7.4.5 PARTITION QosPolicy on page 355	Set of strings that introduces a logical partition among Topics visible by *Publisher*/*Subscriber*.
7.4.6 PRESENTATION QosPolicy on page 361	The order in which instance changes are presented to the Subscriber. By default, no order is used.

8.2.4.1 Configuring QoS Settings when the Subscriber is Created

As described in 8.2.2 Creating Subscribers on page 488, there are different ways to create a *Subscriber, depending on how you want to specify its QoS (with or without a QoS Profile).*

- In 8.2.2 Creating Subscribers on page 488 is an example of how to explicitly create a *Subscriber* with default QosPolicies. It used the special constant, **DDS_SUBSCRIBER_QOS_DEFAULT**, which indicates that the default QoS values for a *Subscriber* should be used. The default Subscriber QosPolicies are configured in the *DomainParticipant*; you can change them with the *DomainParticipant's* **set_default_subscriber_qos()** or **set_default_subscriber_qos_with_profile()** operation (see 9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622).
- To create a *Subscriber* with non-default QoS settings, without using a QoS profile, see Figure 8.3: Creating a Subscriber with Non-Default QosPolicies (not from a profile) on the next page. It uses the *DomainParticipant*'s **get_default_subscriber_qos()** method to initialize a **DDS_SubscriberQos** structure. Then the policies are modified from their default values before the QoS structure is passed to **create_subscriber()**.
- You can also create a *Subscriber* and specify its QoS settings via a QoS Profile. To do so, call **create_subscriber_with_profile()**, as seen in Figure 8.4: Creating a Subscriber with a QoS Profile on the next page.
- If you want to use a QoS profile, but then make some changes to the QoS before creating the *Subscriber*, call **get_subscriber_qos_from_profile()**, modify the QoS and use the modified QoS struc-

ture when calling **create_subscriber()**, as seen in Figure 8.5: Getting QoS Values from a Profile, Changing QoS Values, Creating a Subscriber with Modified QoS Values on the next page.

For more information, see 8.2.2 Creating Subscribers on page 488 and Configuring QoS with XML (Chapter 19 on page 842).

Figure 8.3: Creating a Subscriber with Non-Default QosPolicies (not from a profile)

```
DDS_SubscriberQos subscriber_qos;[1]
// get defaults
if (participant->get_default_subscriber_qos(subscriber_qos) !=
    DDS_RETCODE_OK){
// handle error
}
// make QoS changes here. for example, this changes the ENTITY_FACTORY QoS
subscriber_qos.entity_factory.autoenable_created_entities=DDS_BOOLEAN_FALSE;
// create the subscriber
DDSSubscriber * subscriber = participant->create_subscriber(subscriber_qos,
    NULL, DDS_STATUS_MASK_NONE);
if (subscriber == NULL) {
    // handle error
}
```

Figure 8.4: Creating a Subscriber with a QoS Profile

```
// create the subscriber with QoS profile
DDSSubscriber * subscriber = participant->create_subscriber_with_profile(
    "MySubscriberLibary", "MySubscriberProfile", NULL, DDS_STATUS_MASK_NONE);
if (subscriber == NULL) {
    // handle error
}
```

[1]Note: In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 8.5: Getting QoS Values from a Profile, Changing QoS Values, Creating a Subscriber with Modified QoS Values

```
DDS_SubscriberQos subscriber_qos;[1]
// Get subscriber QoS from profile
retcode = factory->get_subscriber_qos_from_profile(subscriber_qos,
    "SubscriberLibrary", "SubscriberProfile");
if (retcode != DDS_RETCODE_OK) {
    // handle error
}
// Makes QoS changes here
// for example, this changes the ENTITY_FACTORY QoS
subscriber_qos.entity_factory.autoenable_created_entities = DDS_BOOLEAN_TRUE;
// create the subscriber with modified QoS
DDSPublisher* subscriber = participant->create_subscriber(
    "Example Foo", type_name, subscriber_qos,
    NULL, DDS_STATUS_MASK_NONE);
if (subscriber == NULL) {
    // handle error
}
```

8.2.4.2 Comparing QoS Values

The **equals()** operation compares two *Subscriber's* DDS_SubscriberQoS structures for equality. It takes two parameters for the two *Subscriber's* QoS structures to be compared, then returns TRUE is they are equal (all values are the same) or FALSE if they are not equal.

8.2.4.3 Changing QoS Settings After Subscriber Has Been Created

There are 2 ways to change an existing *Subscriber's* QoS after it is has been created—again depending on whether or not you are using a QoS Profile.

- To change an existing *Subscriber's* QoS programmatically (that is, without using a QoS profile), **get_qos()** and **set_qos()**. See the example code in Figure 8.6: Changing the Qos of an Existing Subscriber on the next page. It retrieves the current values by calling the *Subscriber's* **get_qos()** operation. Then it modify the value and call **set_qos()** to apply the new value. Note, however, that some QosPolicies cannot be changed after the *Subscriber* has been enabled—this restriction is noted in the descriptions of the individual QosPolicies.
- You can also change a *Subscriber's* (and all other Entities') QoS by using a QoS Profile and calling **set_qos_with_profile()**. For an example, see Figure 8.7: Changing the QoS of an Existing Subscriber with a QoS Profile on the next page. For more information, see Configuring QoS with XML (Chapter 19 on page 842).

[1]Note: In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 8.6: Changing the Qos of an Existing Subscriber

```
DDS_SubscriberQos subscriber_qos;
// Get current QoS. subscriber points to an existing DDSSubscriber.
if (subscriber->get_qos(subscriber_qos) != DDS_RETCODE_OK) {
    // handle error
}
// make changes
// New entity_factory autoenable_created_entities will be true
subscriber_qos.entity_factory.autoenable_created_entities =
    DDS_BOOLEAN_TRUE;
// Set the new QoS
if (subscriber->set_qos(subscriber_qos) != DDS_RETCODE_OK ) {
    // handle error
}
```

Figure 8.7: Changing the QoS of an Existing Subscriber with a QoS Profile

```
retcode = subscriber->set_qos_with_profile(
         "SubscriberProfileLibrary","SubscriberProfile");
if (retcode != DDS_RETCODE_OK) {
    // handle error
}
```

8.2.4.4 Getting and Settings Subscriber's Default QoS Profile and Library

You can retrieve the default QoS profile used to create *Subscribers* with the **get_default_profile()** operation. You can also get the default library for *Subscribers*, as well as the library that contains the *Subscriber's* default profile (these are not necessarily the same library); these operations are called **get_default_library()** and **get_default_library_profile()**, respectively. These operations are for informational purposes only (that is, you do not need to use them as a precursor to setting a library or profile.) For more information, see Configuring QoS with XML (Chapter 19 on page 842).

```
virtual const char *  get_default_library ()
const char *  get_default_profile ()
const char *  get_default_profile_library ()
```

There are also operations for setting the *Subscriber's* default library and profile:

```
DDS_ReturnCode_t set_default_library (
    const char * library_name)
DDS_ReturnCode_t set_default_profile (
    const char * library_name,
    const char *  profile_name)
```

These operations only affect which library/profile will be used as the default the next time a default *Subscriber* library/profile is needed during a call to one of this *Subscriber's* operations.

When calling a *Subscriber* operation that requires a **profile_name** parameter, you can use NULL to refer to the default profile. (This same information applies to setting a default library.)

If the default library/profile is not set, the *Subscriber* inherits the default from the *DomainParticipant*.

set_default_profile() does not set the default QoS for *DataReaders* created by the *Subscriber;* for this functionality, use the *Subscriber's* **set_default_datareader_qos_with_profile()**, see 8.2.4.5 Getting and Setting Default QoS for DataReaders below (you may pass in NULL after having called the *Subscriber's* **set_default_profile()**).

set_default_profile() does not set the default QoS for newly created *Subscribers*; for this functionality, use the *DomainParticipant's* **set_default_subscriber_qos_with_profile()** operation, see 9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622.

8.2.4.5 Getting and Setting Default QoS for DataReaders

These operations *set* the default QoS that will be used for new *DataReaders* if **create_datareader()** is called with DDS_DATAREADER_QOS_DEFAULT as the 'qos' parameter:

```
DDS_ReturnCode_t set_default_datareader_qos (const DDS_DataReaderQos &qos)

DDS_ReturnCode_t set_default_datareader_qos_with_profile (
                 const char *library_name, const char *profile_name)
```

The above operations may potentially allocate memory, depending on the sequences contained in some QoS policies.

To *get* the default QoS that will be used for creating *DataReaders* if **create_datareader()** is called with DDS_DATAREADER_QOS_DEFAULT as the 'qos' parameter:

```
DDS_ReturnCode_t get_default_datareader_qos (DDS_DataReaderQos & qos)
```

The above operation gets the QoS settings that were specified on the last successful call to **set_default_datareader_qos()** or **set_default_datareader_qos_with_profile()**, or if the call was never made, the default values listed in DDS_DataReaderQos.

Note: It is not safe to set the default *DataReader* QoS values while another thread may be simultaneously calling **get_default_datareader_qos(), set_default_datareader_qos()** or **create_datareader()** with DDS_DATAREADER_QOS_DEFAULT as the **qos** parameter. It is also not safe to get the default *DataReader* QoS values while another thread may be simultaneously calling **set_default_datareader_qos()**.

8.2.4.6 Subscriber QoS-Related Operations

- **Copying a Topic's QoS into a DataReader's QoS**

  This method is provided as a convenience for setting the values in a *DataReaderQos* structure before using that structure to create a *DataReader*. As explained in 5.1.3 Setting Topic QosPolicies on page 219, most of the policies in a *TopicQos* structure do not apply directly to the *Topic* itself, but to the associated *DataWriters* and *DataReaders* of that *Topic*. The *TopicQos* serves as a single container where the values of QosPolicies that must be set compatibly across matching *DataWriters* and *DataReaders* can be stored.

Thus instead of setting the values of the individual QosPolicies that make up a *DataReaderQos* structure every time you need to create a *DataReader* for a *Topic*, you can use the *Subscriber*'s **copy_from_topic_qos()** operation to "import" the *Topic*'s QosPolicies into a *DataReaderQos* structure. This operation copies the relevant policies in the *TopicQos* to the corresponding policies in the *DataReaderQos*.

This copy operation will often be used in combination with the *Subscriber's* **get_default_datareader_qos()** and the *Topic*'s **get_qos()** operations. The *Topic*'s QoS values are merged on top of the *Subscriber's* default *DataReader* QosPolicies with the result used to create a new *DataReader*, or to set the QoS of an existing one (see 8.3.9 Setting DataReader QosPolicies on page 538).

- **Copying a Subscriber's QoS**

  In the C API users should use the **DDS_SubscriberQos_copy()** operation rather than using structure assignment when copying between two QoS structures. The **copy()** operation will perform a deep copy so that policies that allocate heap memory such as sequences are copied correctly. In C++, C++/CLI, C# and Java, a copy constructor is provided to take care of sequences automatically.

- **Clearing QoS-Related Memory**

  Some QosPolicies contain sequences that allocate memory dynamically as they grow or shrink. The C API's **DDS_SubscriberQos_finalize()** operation frees the memory used by sequences but otherwise leaves the QoS unchanged. C users should call **finalize()** on all **DDS_SubscriberQos** objects before they are freed, or for QoS structures allocated on the stack, before they go out of scope. In C++, C++/CLI, C# and Java, the memory used by sequences is freed in the destructor.

8.2.5 Beginning and Ending Group-Ordered Access

The *Subscriber's* **begin_access()** operation indicates that the application is about to access the DDS data samples in any of the *DataReaders* attached to the *Subscriber*.

If the *Subscriber's* **access_scope** (in the 7.4.6 PRESENTATION QosPolicy on page 361) is GROUP or HIGHEST_OFFERED and **ordered_access** (also in the 7.4.6 PRESENTATION QosPolicy on page 361) is TRUE, the application is required to use this operation to access the DDS samples in order across *DataWriters* of the same group (*Publisher* with **access_scope** GROUP).

In the above case, **begin_access()** must be called prior to calling any of the sample-accessing operations: **get_datareaders()** on the *Subscriber*, and **read()**, **take()**, **read_w_condition(),** and **take_w_condition()** on any *DataReader*.

Once the application has finished accessing the DDS data samples, it must call **end_access()**. To see how to read samples in order when the *Subscriber's* **begin_access()** operation is called, see 8.2.7 Getting DataReaders with Specific DDS Samples on page 499.

The application is not required to call **begin_access()** and **end_access()** to access the DDS samples in order if the *Publisher's* **access_scope** is something other than GROUP. In this case, calling **begin_access()** and **end_access()** is not considered an error and has no effect.

Calls to **begin_access()** and **end_access()** may be nested and must be balanced. That is, **end_access()** close a previous call to **begin_access()**.

8.2.6 Setting Up SubscriberListeners

Like all Entities, Su*bscribers* may optionally have *Listeners*. *Listeners* are user-defined objects that implement a DDS-defined interface (i.e. a pre-defined set of callback functions). *Listeners* provide the means for *Connext DDS* to notify applications of any changes in *Statuses* (events) that may be relevant to it. By writing the callback functions in the *Listener* and installing the *Listener* into the *Subscriber*, applications can be notified to handle the events of interest. For more general information on *Listeners* and *Statuses*, see 4.4 Listeners on page 189.

Note: Some operations cannot be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

As illustrated in Figure 8.1: Subscription Module on page 485, the S*ubscriberListener* interface extends the *DataReaderListener* interface. In other words, the *SubscriberListener* interface contains all the functions in the *DataReaderListener* interface. In addition, a *SubscriberListener* has an additional function: **on_data_on_readers()**, corresponding to the *Subscriber*'s **DATA_ON_READERS** status. This is the only status that is specific to a *Subscriber*. This status is closely tied to the **DATA_AVAILABLE** status (8.3.7.1 DATA_AVAILABLE Status on page 514) of *DataReaders*.

The *Subscriber*'s **DATA_ON_READERS** status is set whenever the **DATA_AVAILABLE** status is set for any of the *DataReaders* created by the *Subscriber*. This implies that one of its *DataReaders* has received new DDS data samples. When the **DATA_ON_READERS** status is set, the *SubscriberListener*'s **on_data_on_readers()** method will be invoked.

The **DATA_ON_READERS** status of a *Subscriber* takes precedence over the **DATA_AVAILABLE** status of any of its *DataReaders*. Thus, when data arrives for a *DataReader*, the **on_data_on_readers()** operation of the *SubscriberListener* will be called instead of the **on_data_available()** operation of the *DataReaderListener*—assuming that the *Subscriber* has a *Listener* installed that is enabled to handle changes in the **DATA_ON_READERS** status. (Note however, that in the *SubscriberListener's* **on_data_on_readers()** operation, you may choose to call **notify_datareaders()**, which in turn may cause the *DataReaderListener's* **on_data_available()** operation to be called.)

All of the other methods of a *SubscriberListener* will be called back for changes in the *Statuses* of *Subscriber*'s *DataReaders* only if the *DataReader* is not set up to handle the statuses itself.

If you want a *Subscriber* to handle status events for its *DataReaders*, you can set up a *SubscriberListener* during the *Subscriber's* creation or use the **set_listener()** method after the *Subscriber* is created. The last parameter is a bit-mask with which you should set which *Status* events that the *SubscriberListener* will handle. For example,

```
DDS_StatusMask mask =
    DDS_REQUESTED_DEADLINE_MISSED_STATUS |
    DDS_REQUESTED_INCOMPATIBLE_QOS_STATUS;
subscriber = participant->create_subscriber(
    DDS_SUBSCRIBER_QOS_DEFAULT, listener, mask);
```

or

```
DDS_StatusMask mask =
    DDS_REQUESTED_DEADLINE_MISSED_STATUS |
    DDS_REQUESTED_INCOMPATIBLE_QOS_STATUS;
subscriber->set_listener(listener, mask);
```

As previously mentioned, the callbacks in the *SubscriberListener* act as 'default' callbacks for all the *DataReader*s contained within. When *Connext DDS* wants to notify a *DataReader* of a relevant *Status* change (for example, **SUBSCRIPTION_MATCHED**), it first checks to see if the *DataReader* has the corresponding *DataReaderListener* callback enabled (such as the **on_subscription_matched()** operation). If so, *Connext DDS* dispatches the event to the *DataReaderListener* callback. Otherwise, *Connext DDS* dispatches the event to the corresponding *SubscriberListener* callback.

NOTE, the reverse is true for the **DATA_ON_READERS/DATA_AVAILABLE** status. When **DATA_AVAILABLE** changes for any *DataReaders* of a *Subscriber*, *Connext DDS* first checks to see if the *SubscriberListener* has **DATA_ON_READERS** enabled. If so, *Connext DDS* will invoke the **on_data_on_readers()** callback. Otherwise, *Connext DDS* dispatches the event to the *Listener* (**on_data_available()**) of the *DataReader* whose **DATA_AVAILABLE** status actually changed.

A particular callback in a *DataReader* is *not* enabled if either:

- The application installed a NULL *DataReaderListener* (meaning there are *no* callbacks for the *DataReader* at all).
- The application has disabled the callback for a *DataReaderListener*. This is done by turning off the associated status bit in the *mask* parameter passed to the **set_listener()** or **create_datareader()** call when installing the *DataReaderListener* on the *DataReader*. For more information on *DataReaderListener*, see 8.3.4 Setting Up DataReaderListeners on page 509.

Similarly, the callbacks in the *DomainParticipantListener* act as 'default' callbacks for all the *Subscribers* that belong to it. For more information on *DomainParticipantListeners*, see 9.3.6 Setting Up DomainParticipantListeners on page 615.

The *Subscriber* also provides an operation called **notify_datareaders()** that can be used to invoke the **on_data_available()** callbacks of *DataReaders* who have new DDS data samples in their receive queues. Often **notify_datareaders()** will be used in the **on_data_on_readers()** callback to pass off the real processing of data from the *SubscriberListener* to the individual *DataReaderListeners*.

Calling **notify_datareaders()** causes the **DATA_ON_READERS** status to be reset.

Figure 8.8: Simple SubscriberListener on the next page shows a *SubscriberListener* that simply notifies its *DataReaders* when new data arrives.

Figure 8.8: Simple SubscriberListener

```
class MySubscriberListener : public DDSSubscriberListener {
    public:
        void on_data_on_readers(DDSSubscriber *);
/* For this example we take no action other operations */
};
void MySubscriberListener::on_data_on_readers (DDSSubscriber *subscriber)
{
    // do global processing
    ...
    // now dispatch data arrival event to specific DataReaders
    subscriber->notify_datareaders();
}
```

8.2.7 Getting DataReaders with Specific DDS Samples

The *Subscriber's* **get_datareaders()** operation retrieves a list of *DataReaders* that have DDS samples with specific **sample_states**, **view_states**, and **instance_states**.

If the application is outside a **begin_access()/end_access()** block, or if the *Subscriber's* **access_scope** (in the 7.4.6 PRESENTATION QosPolicy on page 361) is INSTANCE or TOPIC, or **ordered_access** (also in the 7.4.6 PRESENTATION QosPolicy on page 361) is FALSE, the returned collection is a 'set' containing each *DataReader* at most once, in no specified order.

If the application is within a **begin_access()/end_access()** block, and the *Subscriber's* **access_scope** is GROUP or HIGHEST_OFFERED, and **ordered_access** is TRUE, the returned collection is a 'list' of *DataReaders*, where a *DataReader* may appear more than one time.

To retrieve the DDS samples in the order in which they were published across *DataWriters* of the same group (a *Publisher* configured with GROUP **access_scope**), the application should **read()/take()** from each *DataReader* in the same order as appears in the output sequence. The application will move to the next *DataReader* when the **read()/take()** operation fails with NO_DATA.

```
DDS_ReturnCode_t get_datareaders (DDSDataReaderSeq & readers,
    DDS_SampleStateMask    sample_states,
    DDS_ViewStateMask     view_states,
    DDS_InstanceStateMask  instance_states)
```

For more information, see 8.4.6 The SampleInfo Structure on page 560.

8.2.8 Finding a Subscriber's Related Entities

These *Subscriber* operations are useful for obtaining a handle to related entities:

- **get_participant()**: Gets the *DomainParticipant* with which a *Subscriber* was created.

- **lookup_datareader()**: Finds a *DataReader* created by the *Subscriber* with a *Topic* of a particular name. Note that if multiple *DataReaders* were created by the same *Subscriber* with the same *Topic*, any one of them may be returned by this method.

  You can use this operation on a built-in *Subscriber* to access the built-in *DataReaders* for the built-in topics. The built-in *DataReader* is created when this operation is called on a built-in topic for the first time.

  If you are going to modify the transport properties for the built-in *DataReaders*, do so *before* using this operation. Built-in transports are implicitly registered when the *DomainParticipant* is enabled or the first *DataWriter/DataReader* is created. To ensure that built-in *DataReaders* receive all the discovery traffic, you should lookup the *DataReader* before the *DomainParticipant* is enabled. Therefore the suggested sequence when looking up built-in *DataReaders* is:

  1. Create a disabled *DomainParticipant* (see 7.4.2 ENTITYFACTORY QosPolicy on page 347).
  2. If you want to use non-default values, modify the built-in transport properties (see 16.5 Setting Builtin Transport Properties of Default Transport Instance—get/set_builtin_transport_properties() on page 793).
  3. Call **get_builtin_subscriber()** (see 18.2 Built-in DataReaders on page 826).
  4. Call **lookup_datareader()**.
  5. Call **enable()** on the *DomainParticipant* (see 4.1.2 Enabling DDS Entities on page 168).

- **DDS_Subscriber_as_Entity()**: This method is provided for C applications and is necessary when invoking the parent class *Entity* methods on *Subscribers*. For example, to call the *Entity* method **get_status_changes()** on a *Subscriber,* **my_sub**, do the following:

```
DDS_Entity_get_status_changes(DDS_Subscriber_as_Entity(my_sub))
```

- **DDS_Subscriber_as_Entity()** is not provided in the C++, C++/CLI, C# and Java APIs because the object-oriented features of those languages make it unnecessary.

8.2.9 Statuses for Subscribers

The status indicators for a *Subscriber* are the same as those available for its *DataReaders*, with one additional status: **DATA_ON_READERS** (8.2.9.1 DATA_ON_READERS Status on the next page). The following statuses can be monitored by the *SubscriberListener*.

- 8.2.9.1 DATA_ON_READERS Status on the next page
- 8.3.7.1 DATA_AVAILABLE Status on page 514
- 8.3.7.4 LIVELINESS_CHANGED Status on page 521

- 8.3.7.5 REQUESTED_DEADLINE_MISSED Status on page 523
- 8.3.7.6 REQUESTED_INCOMPATIBLE_QOS Status on page 523
- 8.3.7.7 SAMPLE_LOST Status on page 524
- 8.3.7.8 SAMPLE_REJECTED Status on page 527
- 8.3.7.9 SUBSCRIPTION_MATCHED Status on page 528

You can access *Subscriber* status by using a *SubscriberListener* or its inherited **get_status_changes()** operation (see 4.1.4 Getting Status and Status Changes on page 171), which can be used to explicitly poll for the **DATA_ON_READERS** status of the *Subscriber*.

8.2.9.1 DATA_ON_READERS Status

The **DATA_ON_READERS** status, like the **DATA_AVAILABLE** status for *DataReaders*, is a *read* communication status, which makes it somewhat different from other *plain* communication statuses. (See 4.3.1 Types of Communication Status on page 183 for more information on statuses and the difference between *read* and *plain* statuses.) In particular, there is no status-specific data structure; the status is either changed or not, there is no additional associated information.

The **DATA_ON_READERS** status indicates that there is new data available for one or more *DataReaders* that belong to this *Subscriber*. The **DATA_AVAILABLE** status for each such *DataReader* will also be updated.

The **DATA_ON_READERS** status is reset (the corresponding bit in the bitmask is turned off) when you call **read()**, **take()**, or one of their variations on *any* of the *DataReaders* that belong to the *Subscriber*. This is true even if the *DataReader* on which you call read/take is not the same *DataReader* that caused the **DATA_ON_READERS** status to be set in the first place. This status is also reset when you call **notify_datareaders()** on the *Subscriber*, or after **on_data_on_readers()** is invoked.

If a *SubscriberListener* has both **on_data_on_readers()** and **on_data_available()** callbacks enabled (by turning on both status bits), only **on_data_on_readers()** is called.

8.3 DataReaders

To create a *DataReader*, you need a *DomainParticipant,* a *Topic,* and optionally, a *Subscriber*. You need at least one *DataReader* for each *Topic* whose DDS data samples you want to receive.

After you create a *DataReader*, you will be able to use the operations listed in Table 8.3 DataReader Operations. You are likely to use many of these operations from within your *DataReader's Listener*, which is invoked when there are status changes or new DDS data samples. For more details on all operations, see the API reference HTML documentation. The *DataReaderListener* is described in 8.3.4 Setting Up DataReaderListeners on page 509.

DataReaders are created by using operations on a *DomainParticipant* or a *Subscriber*, as described in 8.2.1 Creating Subscribers Explicitly vs. Implicitly on page 487. If you use the *DomainParticipant's*

operations, the *DataReader* will belong to an implicit *Subscriber* that is automatically created by the middleware. If you use a *Subscriber's* operations, the *DataReader* will belong to that *Subscriber*. So either way, the *DataReader* belongs to a *Subscriber*.

Note: Some operations cannot be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

Table 8.3 DataReader Operations

Purpose	Operation	Description	Reference
Configuring the DataReader	enable	Enables the *DataReader*.	4.1.2 Enabling DDS Entities on page 168
	equals	Compares two *DataReader's* QoS structures for equality.	8.3.9.2 Comparing QoS Values on page 543
	get_qos	Gets the QoS.	8.3.9 Setting DataReader QosPolicies on page 538
	set_qos	Modifies the QoS.	
	set_qos_with_profile	Modifies the QoS based on a QoS profile.	
	get_listener	Gets the currently installed *Listener*.	8.3.4 Setting Up DataReaderListeners on page 509
	set_listener	Replaces the *Listener*.	

Table 8.3 DataReader Operations

Purpose	Operation	Description	Reference
Accessing DDS Data Samples with "Read" (Use FooData-Reader, see 8.4.3 Accessing DDS Data Samples with Read or Take on page 550)	read	Reads (copies) a collection of DDS data samples from the *DataReader*.	8.4.3 Accessing DDS Data Samples with Read or Take on page 550
	read_instance	Identical to read, but all DDS samples returned belong to a single instance, which you specify as a parameter.	8.4.3.4 read_instance and take_instance on page 554
	read_instance_w_condition	Identical to read_instance, but all DDS samples returned belong to a single instance *and* satisfy a specific ReadCondition.	8.4.3.7 read_instance_w_condition and take_instance_w_condition on page 556
	read_next_instance	Similar to read_instance, but the actual instance is not directly specified as a parameter. Instead, the DDS samples will all belong to instance ordered after the one previously read.	8.4.3.5 read_next_instance and take_next_instance on page 554
	read_next_instance_w_condition	Accesses a collection of DDS data samples of the next instance that match a specific set of *ReadConditions*, from the *DataReader*.	8.4.3.8 read_next_instance_w_condition and take_next_instance_w_condition on page 557
	read_next_sample	Reads the next not-previously-accessed data value from the *DataReader*.	8.4.3.3 read_next_sample and take_next_sample on page 553
	read_w_condition	Accesses a collection of DDS data samples from the *DataReader* that match specific *ReadCondition* criteria.	8.4.3.6 read_w_condition and take_w_condition on page 556

Table 8.3 DataReader Operations

Purpose	Operation	Description	Reference
Accessing DDS Data Samples with "Take" (Use FooData-Reader, see 8.4.3 Accessing DDS Data Samples with Read or Take on page 550)	take	Like read, but the DDS samples are removed from the *DataReader's* receive queue.	8.4.3 Accessing DDS Data Samples with Read or Take on page 550
	take_instance	Identical to take, but all DDS samples returned belong to a single instance, which you specify as a parameter.	8.4.3.4 read_instance and take_instance on page 554
	take_instance_w_condition	Identical to take_instance, but all DDS samples returned belong to a single instance *and* satisfy a specific ReadCondition.	8.4.3.7 read_instance_w_condition and take_instance_w_condition on page 556
	take_next_instance	Like read_next_instance, but the DDS samples are removed from the *DataReader's* receive queue.	8.4.3.5 read_next_instance and take_next_instance on page 554
	take_next_instance_w_condition	Accesses (and removes) a collection of DDS data samples of the next instance that match a specific set of *ReadConditions*, from the *DataReader*.	8.4.3.8 read_next_instance_w_condition and take_next_instance_w_condition on page 557
	take_next_sample	Like read_next_sample, but the DDS samples are removed from the *DataReader's* receive queue.	8.4.3.3 read_next_sample and take_next_sample on page 553
Working with DDS Data Samples and FooData-Reader (Use FooData-Reader, see 8.4.3 Accessing DDS Data Samples with Read or Take on page 550)	take_w_condition	Accesses (and removes) a collection of DDS data samples from the *DataReader* that match specific *ReadCondition* criteria.	8.4.3.6 read_w_condition and take_w_condition on page 556
	narrow	A type-safe way to cast a pointer. This takes a DDSDataReader pointer and 'narrows' it to a 'FooDataReader' where 'Foo' is the related data type.	8.4.1 Using a Type-Specific DataReader (FooDataReader) on page 548
	return_loan	Returns buffers loaned in a previous read or take call.	8.4.2 Loaning and Returning Data and SampleInfo Sequences on page 548
	get_key_value	Gets the key for an instance handle.	8.3.10.5 Getting the Key Value for an Instance on page 548
	lookup_instance	Gets the instance handle that corresponds to an instance key.	8.3.10.4 Looking Up an Instance Handle on page 547
Acknowledging DDS Samples	acknowledge_all	Acknowledge all previously accessed DDS samples.	8.4.4 Acknowledging DDS Samples on page 558
	acknowledge_sample	Acknowledge a single DDS sample.	

Table 8.3 DataReader Operations

Purpose	Operation	Description	Reference
Checking Status	get_liveliness_changed_status	Gets LIVELINESS_CHANGED_STATUS status.	8.3.7 Statuses for DataReaders on page 513
	get_requested_deadline_missed_status	Gets REQUESTED_DEADLINE_MISSED_STATUS status.	
	get_requested_incompatible_qos_status	Gets REQUESTED_INCOMPATIBLE_QOS_STATUS status.	
	get_sample_lost_status	Gets SAMPLE_LOST_STATUS status.	
	get_sample_rejected_status	Gets SAMPLE_REJECTED_STATUS status.	
	get_subscription_matched_status	Gets SUBSCRIPTION_MATCHED_STATUS status.	
	get_status_changes	Gets a list of statuses that changed since last time the application read the status or the listeners were called.	4.1.4 Getting Status and Status Changes on page 171
	get_datareader_cache_status	Gets DATA_READER_CACHE_STATUS status.	8.3.5 Checking DataReader Status and StatusConditions on page 511 8.3.7 Statuses for DataReaders on page 513
	get_datareader_protocol_status	Gets DATA_READER_PROTOCOL_STATUS status.	
	get_matched_publication_datareader_protocol_status	Get the protocol status for this *DataReader*, per matched publication identified by the publication_handle.	

Table 8.3 DataReader Operations

Purpose	Operation	Description	Reference
Navigating Relationships	get_instance_handle	Returns the DDS_InstanceHandle_t associated with the Entity.	4.1.3 Getting an Entity's Instance Handle on page 171
	get_matched_publication_data	Gets information on a publication with a matching Topic and compatible QoS.	8.3.10.1 Finding Matching Publications on page 546
	get_matched_publications	Gets a list of publications that have a matching Topic and compatible QoS. These are the publications currently associated with the *DataReader*.	
	get_matched_publication_participant_data	Gets information on a DomainParticipant of a matching publication.	8.3.10.2 Finding the Matching Publication's ParticipantBuiltinTopicData on page 547
	get_subscriber	Gets the *Subscriber* that created the *DataReader*.	8.3.10.3 Finding a DataReader's Related Entities on page 547
	get_topicdescription	Gets the Topic associated with the *DataReader*.	
	is_matched_publication_alive	Enables you to query whether the matched *DataWriter* (using the instance handle returned by **get_matched_publications**) is alive. **get_matched_publications** returns all matching *DataWriters*, including those that are not alive. This operation enables you to see which matching *DataWriters* are alive.	8.3.10.1 Finding Matching Publications on page 546
Working with Conditions	create_querycondition	Creates a *QueryCondition*.	4.6.7 ReadConditions and QueryConditions on page 209
	create_readcondition	Creates a *ReadCondition*.	
	delete_readcondition	Deletes a *ReadCondition*/*QueryCondition* attached to the *DataReader*.	
	delete_contained_entities	Deletes all the *ReadConditions*/*QueryConditions* that were created by means of the "create" operations on the *DataReader*.	8.3.3.1 Deleting Contained ReadConditions on page 509
	get_statuscondition	Gets the StatusCondition associated with the Entity.	4.6.8 StatusConditions on page 212
	create_readcondition_w_params	Creates a ReadCondition with parameters.	4.6.7 ReadConditions and QueryConditions on page 209
	create_querycondition_w_params	Creates a QueryCondition with parameters.	4.6.7 ReadConditions and QueryConditions on page 209

Table 8.3 DataReader Operations

Purpose	Operation	Description	Reference
Working with TopicQueries	create_topic_query	Creates a TopicQuery. The returned TopicQuery will haven been issued if the *DataReader* is enabled. Otherwise, the TopicQuery will be issued once the DataReader is enabled.	Topic Queries (Chapter 24 on page 962)
	delete_topic_query	Deletes an active TopicQuery. After deleting a TopicQuery, new *DataWriters* won't discover it and existing *DataWriters* currently publishing cached samples may stop before delivering all of them.	
	lookup_topic_query	Retrieves the TopicQuery that corresponds to the input GUID. To get the GUID associated with a TopicQuery, use the TopicQuery's **get_guid()**.	
Waiting for Historical Data	wait_for_historical_data	Waits until all "historical" (previously sent) data is received. Only valid for Reliable *DataReaders* with non-VOLATILE DURABILITY.	8.3.6 Waiting for Historical Data on page 512

8.3.1 Creating DataReaders

Before you can create a *DataReader*, you need a *DomainParticipant* and a *Topic*.

DataReaders are created by calling **create_datareader()** or **create_datareader_with_profile()**—these operations exist for *DomainParticipants* and *Subscribers*. If you use the *DomainParticipant* to create a *DataReader*, it will belong to the implicit *Subscriber* described in 8.2.1 Creating Subscribers Explicitly vs. Implicitly on page 487. If you use a *Subscriber's* operations to create a *DataReader*, it will belong to that *Subscriber*.
A QoS profile is way to use QoS settings from an XML file or string. With this approach, you can change QoS settings without recompiling the application. For details, see Configuring QoS with XML (Chapter 19 on page 842).

Note: In the Modern C++ API, *DataReaders* provide constructors whose first argument is a *Subscriber*. The only required arguments are the subscriber and the topic.

```
DDSDataReader* create_datareader(
    DDSTopicDescription *topic,
    const DDS_DataReaderQos &qos,
    DDSDataReaderListener *listener,
    DDS_StatusMask mask);
DDSDataReader * create_datareader_with_profile (
    DDSTopicDescription * topic,
    const char * library_name,
    const char * profile_name,
    DDSDataReaderListener * listener,
    DDS_StatusMask mask)
```

Where:

topic The *Topic* to which the *DataReader* is subscribing. This must have been previously created by the same *DomainParticipant*.

qos	If you want the default QoS settings (described in the API Reference HTML documentation), use *DDS_DATAREADER_QOS_DEFAULT* for this parameter (see Figure 8.9: Creating a DataReader with Default QosPolicies below). If you want to customize any of the QosPolicies, supply a QoS structure (see 8.3.9 Setting DataReader QosPolicies on page 538). **Note:** If you use DDS_DATAREADER_QOS_DEFAULT for the **qos** parameter, it is not safe to create the *DataReader* while another thread may be simultaneously calling the *Subscriber's* **set_default_datareader_qos()** operation.
listener	A *DataReader'sListener* is where you define the callback routine that will be notified when new DDS data samples arrive. *Connext DDS* also uses this *Listener* to notify your application of specific events (status changes) that may occur with respect to the *DataReader*. For more information, see 8.3.4 Setting Up DataReaderListeners on the next page and 8.3.7 Statuses for DataReaders on page 513. The *listener* parameter is optional; you may use NULL instead. In that case, the *Subscriber's Listener* (or if that is NULL, the *DomainParticipant's Listener*) will receive the notifications instead. See 8.3.4 Setting Up DataReaderListeners on the next page for more on *DataReaderListeners*.
mask	This bit mask indicates which status changes will cause the *Listener* to be invoked. The bits set in the mask must have corresponding callbacks implemented in the *Listener.* If you use NULL for the *Listener*, use *DDS_STATUS_MASK_NONE* for this parameter. If the *Listener* implements all callbacks, use *DDS_STATUS_MASK_ALL*. For information on statuses, see 4.4 Listeners on page 189.
library_name	A QoS Library is a named set of QoS profiles. See 19.3 QoS Profiles on page 844.
profile_name	A QoS profile groups a set of related QoS, usually one per entity. See 19.3 QoS Profiles on page 844.

After you create a *DataReader*, you can use it to retrieve received data. See 8.4 Using DataReaders to Access Data (Read & Take) on page 548.

Note: When a *DataReader* is created, only those transports already registered are available to the *DataReader*. The built-in transports are implicitly registered when (a) the *DomainParticipant* is enabled, (b) the first *DataReader* is created, or (c) you lookup a built-in *DataReader*, whichever happens first.

Figure 8.9: Creating a DataReader with Default QosPolicies below shows an example of how to create a *DataReader* with default QosPolicies.

Figure 8.9: Creating a DataReader with Default QosPolicies

```
// MyReaderListener is user defined, extends DDSDataReaderListener
DDSDataReaderListener *reader_listener = new MyReaderListener();
DataReader* reader = subscriber->create_datareader(topic,
       DDS_DATAREADER_QOS_DEFAULT,
       reader_listener, DDS_STATUS_MASK_ALL);
if (reader == NULL) {
       // ... error
}
// narrow it into your specific data type
FooDataReader* foo_reader = FooDataReader::narrow(reader);
```

For more examples on how to create a *DataReader*, see 8.3.9.1 Configuring QoS Settings when the DataReader is Created on page 541.

8.3.2 Getting All DataReaders

To retrieve all the *DataReaders* created by the *Subscriber*, use the *Subscriber's* **get_all_datareaders()** operation:

```
DDS_ReturnCode_t get_all_datareaders(
                 DDS_Subscriber* self,
                 struct DDS_DataReaderSeq* readers);
```

In the Modern C++ API, use the freestanding function **rti::sub::find_datareaders()**.

8.3.3 Deleting DataReaders

(Note: in the Modern C++ API, *Entities* are automatically destroyed, see 4.1.1 Creating and Deleting DDS Entities on page 167)

To delete a *DataReader*:

Delete any *ReadConditions* and *QueryConditions* that were created with the *DataReader*. Use the *DataReader*'s **delete_readcondition()** operation to delete them one at a time, or use the **delete_contained_entities()** operation (8.3.3.1 Deleting Contained ReadConditions below) to delete them all at the same time.

```
DDS_ReturnCode_t delete_readcondition (DDSReadCondition *condition)
```

Delete the *DataReader* by using the *Subscriber's* **delete_datareader()** operation (8.2.3 Deleting Subscribers on page 489).

Note: A *DataReader* cannot be deleted within its own reader listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

To delete all of a *Subscriber's DataReaders,* use the *Subscriber's* **delete_contained_entities()** operation (see 8.2.3.1 Deleting Contained DataReaders on page 490).

8.3.3.1 Deleting Contained ReadConditions

The *DataReader's* **delete_contained_entities()** operation deletes all the *ReadConditions* and *QueryConditions* (4.6.7 ReadConditions and QueryConditions on page 209) that were created by the *DataReader*.

```
DDS_ReturnCode_t delete_contained_entities ()
```

After this operation returns successfully, the application may delete the *DataReader* (see 8.3.3 Deleting DataReaders above).

8.3.4 Setting Up DataReaderListeners

DataReaders may optionally have *Listeners.* A *DataReaderListener* is a collection of callback methods; these methods are invoked by *Connext DDS* when DDS data samples are received or when there are status changes for the *DataReader*.

Note: Some operations cannot be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

If you do not implement a *DataReaderListener*, the associated *Subscriber*'s *Listener* is used instead. If that *Subscriber* does not have a *Listener* either, then the *DomainParticipant*'s *Listener* is used if one exists (see 8.2.6 Setting Up SubscriberListeners on page 497 and 9.3.6 Setting Up DomainParticipantListeners on page 615).

If you do not require asynchronous notification of data availability or status changes, you do not need to set a *Listener* for the *DataReader*. In that case, you will need to periodically call one of the **read()** or **take()** operations described in 8.4 Using DataReaders to Access Data (Read & Take) on page 548 to access the data that has been received.

Listeners are typically set up when the *DataReader* is created (see 8.3.1 Creating DataReaders on page 507). You can also set one up after creation by using the *DataReader*'s **get_listener()** and **set_listener()** operations. *Connext DDS* will invoke a *DataReader*'s *Listener* to report the status changes listed in Table 8.4 DataReaderListener Callbacks (if the *Listener* is set up to handle the particular status, see 8.3.4 Setting Up DataReaderListeners on the previous page).

Table 8.4 DataReaderListener Callbacks

This DataReaderListener callback...	...is triggered by a change in this status:
on_data_available()	8.3.7.1 DATA_AVAILABLE Status on page 514
on_liveliness_changed()	8.3.7.4 LIVELINESS_CHANGED Status on page 521
on_requested_deadline_missed()	8.3.7.5 REQUESTED_DEADLINE_MISSED Status on page 523
on_requested_incompatible_qos()	8.3.7.6 REQUESTED_INCOMPATIBLE_QOS Status on page 523
on_sample_lost()	8.3.7.7 SAMPLE_LOST Status on page 524
on_sample_rejected()	8.3.7.8 SAMPLE_REJECTED Status on page 527
on_subscription_matched()	8.3.7.9 SUBSCRIPTION_MATCHED Status on page 528

Note that the same callbacks can be implemented in the *SubscriberListener* or *DomainParticipantListener* instead. There is only one *SubscriberListener* callback that takes precedence over a *DataReaderListener's*. An **on_data_on_readers()** callback in the *SubscriberListener* (or *DomainParticipantListener*) takes precedence over the **on_data_available()** callback of a *DataReaderListener*.

If the *SubscriberListener* implements an **on_data_on_readers()** callback, it will be invoked instead of the *DataReaderListener's* **on_data_available()** callback when new data arrives. The **on_data_on_readers()** operation can in turn cause the **on_data_available()** method of the appropriate *DataReaderListener* to be invoked by calling the *Subscriber's* **notify_datareaders()** operation. For more information on status and *Listeners*, see 4.4 Listeners on page 189.

Figure 8.10: Simple DataReaderListener below shows a *DataReaderListener* that simply prints the data it receives.

Figure 8.10: Simple DataReaderListener

```
class MyReaderListener : public DDSDataReaderListener {
    public:
        virtual void on_data_available(DDSDataReader* reader);
    // don't do anything for the other callbacks
};
void MyReaderListener::on_data_available(DDSDataReader* reader)
{
    FooDataReader *Foo_reader = NULL;
    FooSeq data_seq; // In C, sequences have to be initialized
    DDS_SampleInfoSeq info_seq; // before use, see 8.4.5   The Sequence Data Structure on
page 558
    DDS_ReturnCode_t retcode;
    int i;
    // Must cast generic reader into reader of specific type
    Foo_reader = FooDataReader::narrow(reader);
    if (Foo_reader == NULL) {
        printf("DataReader narrow error\n");
        return;
    }
    retcode = Foo_reader->take(data_seq, info_seq,
        DDS_LENGTH_UNLIMITED, DDS_ANY_SAMPLE_STATE,
        DDS_ANY_VIEW_STATE, DDS_ANY_INSTANCE_STATE);
    if (retcode == DDS_RETCODE_NO_DATA) {
        return;
    } else if (retcode != DDS_RETCODE_OK) {
        printf("take error %d\n", retcode);
        return;
    }
    for (i = 0; i < data_seq.length(); ++i) {
        // the data may not be valid if the DDS sample is
        // meta information about the creation or deletion
        // of an instance
        if (info_seq[i].valid_data) {
           FooTypeSupport::print_data(&data_seq[i]);
        }
    }
    // Connext DDS gave a pointer to internal memory via
    // take(), must return the memory when finished processing the data
    retcode = Foo_reader->return_loan(data_seq, info_seq);
    if (retcode != DDS_RETCODE_OK) {
        printf("return loan error %d\n", retcode);
    }
}
```

8.3.5 Checking DataReader Status and StatusConditions

You can access individual communication status for a *DataReader* with the operations shown in Table 1 DataReader Status Operations.

Table 1 DataReader Status Operations

Use this operation...	...to retrieve this status:
get_datareader_cache_status	8.3.7.2 DATA_READER_CACHE_STATUS on page 514
get_datareader_protocol_status	8.3.7.3 DATA_READER_PROTOCOL_STATUS on page 517
get_matched_publication_ datareader_protocol_status	
get_liveliness_changed_status	8.3.7.4 LIVELINESS_CHANGED Status on page 521
get_sample_lost_status	8.3.7.7 SAMPLE_LOST Status on page 524
get_sample_rejected_status	8.3.7.8 SAMPLE_REJECTED Status on page 527
get_requested_deadline_missed_status	8.3.7.5 REQUESTED_DEADLINE_MISSED Status on page 523
get_requested_incompatible_qos_status	8.3.7.6 REQUESTED_INCOMPATIBLE_QOS Status on page 523
get_subscription_match_status	8.3.7.9 SUBSCRIPTION_MATCHED Status on page 528
get_status_changes	All of the above
get_statuscondition	See 4.6.8 StatusConditions on page 212

These methods are useful in the event that no *Listener* callback is set to receive notifications of status changes. If a *Listener is* used, the callback will contain the new status information, in which case calling these methods is unlikely to be necessary.

The **get_status_changes()** operation provides a list of statuses that have changed since the last time the status changes were 'reset.' A status change is reset each time the application calls the corresponding **get_*_status()**, as well as each time *Connext DDS* returns from calling the *Listener* callback associated with that status.

For more on status, see 8.3.4 Setting Up DataReaderListeners on page 509, 8.3.7 Statuses for DataReaders on the next page, and 4.4 Listeners on page 189.

8.3.6 Waiting for Historical Data

The **wait_for_historical_data()** operation waits (blocks) until all "historical" data is received from matched *DataWriters*. "Historical" data means DDS samples that were written before the *DataReader* joined the DDS domain.

This operation is intended only for *DataReaders* that have:

- 7.5.9 DURABILITY QosPolicy on page 410 **kind** set to *TRANSIENT_LOCAL (not VOLATILE)*
- 7.5.21 RELIABILITY QosPolicy on page 444 **kind** set to RELIABLE

Calling **wait_for_historical_data()** on a non-reliable *DataReader* will always return immediately, since *Connext DDS* will never deliver historical data to non-reliable *DataReaders*.

As soon as an application enables a non-VOLATILE *DataReader*, it will start receiving both "historical" data as well as any new data written by matching *DataWriters*. If you want the subscribing application to wait until all "historical" data is received, use this operation:

```
DDS_ReturnCode_t wait_for_historical_data (const DDS_Duration_t &  max_wait)
```

The **wait_for_historical_data()** operation blocks the calling thread until either all "historical" data is received or the duration specified by the **max_wait** parameter elapses, whichever happens first. A return value of OK indicates that all the "historical" data was received; a return value of TIMEOUT indicates that **max_wait** elapsed before all the data was received.

wait_for_historical_data() will return immediately if no *DataWriters* have been discovered at the time the operation is called. Therefore it is advisable to make sure at least one *DataWriter* has been discovered before calling this operation; one way to do this is to use **get_subscription_matched_status()**, like this:

```
while (1) {
   DDS_SubscriptionMatchedStatus status;
   MyType_reader->get_subscription_matched_status(status);
   if (status.current_count > 0) { break; }
   NDDSUtility::sleep(sleep_period);
}
```

8.3.7 Statuses for DataReaders

There are several types of statuses available for a *DataReader*. You can use the **get_*_status()** operations (8.3.5 Checking DataReader Status and StatusConditions on page 511) to access and reset them, use a *DataReaderListener* (8.3.4 Setting Up DataReaderListeners on page 509) to listen for changes in their values (for those statuses that have Listeners), or use a *StatusCondition* and a *WaitSet* (4.6.8 StatusConditions on page 212) to wait for changes. Each status has an associated data structure and is described in more detail in the following sections.

- 8.3.7.1 DATA_AVAILABLE Status on the next page
- 8.3.7.2 DATA_READER_CACHE_STATUS on the next page
- 8.3.7.3 DATA_READER_PROTOCOL_STATUS on page 517
- 8.3.7.4 LIVELINESS_CHANGED Status on page 521
- 8.3.7.5 REQUESTED_DEADLINE_MISSED Status on page 523
- 8.3.7.6 REQUESTED_INCOMPATIBLE_QOS Status on page 523
- 8.3.7.7 SAMPLE_LOST Status on page 524
- 8.3.7.8 SAMPLE_REJECTED Status on page 527
- 8.3.7.9 SUBSCRIPTION_MATCHED Status on page 528

8.3.7.1 DATA_AVAILABLE Status

This status indicates that new data is available for the *DataReader*. In most cases, this means that one new DDS sample has been received. However, there are situations in which more than one DDS samples for the *DataReader* may be received before the **DATA_AVAILABLE** status changes. For example, if the *DataReader* has the 7.5.9 DURABILITY QosPolicy on page 410 set to be non-**VOLATILE**, then the *DataReader* may receive a batch of old DDS data samples all at once. Or if data is being received reliably from *DataWriters*, *Connext DDS* may present several DDS samples of data simultaneously to the *DataReader* if they have been originally received out of order.

A change to this status also means that the **DATA_ON_READERS** status is changed for the *DataReader's Subscriber*. This status is reset when you call **read()**, **take()**, or one of their variations.

Unlike most other statuses, this status (as well as **DATA_ON_READERS** for *Subscribers*) is a *read communication status*. See 8.2.9 Statuses for Subscribers on page 500 and 4.3.1 Types of Communication Status on page 183 for more information on read communication statuses.

The *DataReaderListener's* **on_data_available()** callback is invoked when this status changes, unless the *SubscriberListener* (8.2.6 Setting Up SubscriberListeners on page 497) or *DomainParticipantListener* (9.3.6 Setting Up DomainParticipantListeners on page 615) has implemented an **on_data_on_readers()** callback. In that case, **on_data_on_readers()** will be invoked instead.

8.3.7.2 DATA_READER_CACHE_STATUS

This status keeps track of the number of DDS samples and instances in the reader's cache, including the number of samples that were dropped for different reasons. For information on the instance states described in the reader's cache, such as "alive," "no_writers," and "disposed," see 6.1 Instance States on page 257.

This status does not have an associated *Listener*. You can access this status by calling the *DataReader's* **get_datareader_cache_status()** operation, which will return the status structure described in Table 8.5 DDS_DataReaderCacheStatus.

Table 8.5 DDS_DataReaderCacheStatus

Type	Field Name	Description
DDS_ LongLong	sample_count_peak	Highest number of DDS samples in the *DataReader's* queue over the lifetime of the *DataReader*.
DDS_ LongLong	sample_count	Current number of DDS samples in the *DataReader's* queue. Includes DDS samples that may not yet be available to be read or taken by the user due to DDS samples being received out of order or settings in the 7.4.6 PRESENTATION QosPolicy on page 361.

Table 8.5 DDS_DataReaderCacheStatus

Type	Field Name	Description
DDS_ LongLong	writer_removed_batch_sample_ dropped_sample_count	The number of batched samples received by the *DataReader* that were marked as removed by the *DataWriter*. When the *DataReader* receives a batch, the batch can contain samples marked as removed by the *DataWriter*. Examples of removed samples in a batch are samples that were replaced due to KEEP_LAST_HISTORY_QOS on the *DataWriter* (see 7.5.12 HISTORY QosPolicy on page 418) or samples that outlived the *DataWriter's* 7.5.14 LIFESPAN QoS Policy on page 423 duration. By default, any sample marked as removed from a batch is dropped, unless you set the **dds.data_reader.accept_writer_removed_batch_samples** property in the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 to TRUE. (By default, it is set to FALSE.) **Note:** Historical data with removed batch samples written before the *DataReader* joined the DDS domain are also included in the count.
DDS_ LongLong	old_source_timestamp_ dropped_sample_count	The number of samples dropped as a result of receiving a sample older than the last one, using DDS_BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS. When the *DataReader* is using DDS_BY_SOURCE_TIMESTAMP_DESTINATIONORDER_ QOS: • If the *DataReader* receives a sample for an instance with a source timestamp that is older than the last source timestamp received for the instance, the sample is dropped and included in this count. • If the *DataReader* receives a sample for an instance with a source timestamp that is equal to the last source timestamp received for the instance and the writer has a higher virtual GUID, the sample is dropped and included in this count.
DDS_ LongLong	tolerance_source_timestamp_ dropped_sample_count	The number of samples dropped as a result of receiving a sample in the future, using DDS_BY_ SOURCE_TIMESTAMP_DESTINATIONORDER_QOS. When the *DataReader* is using DDS_BY_SOURCE_TIMESTAMP_DESTINATIONORDER_ QOS, the *DataReader* will accept a sample only if the source timestamp is no farther in the future from the reception timestamp than the **source_timestamp_tolerance**. Otherwise, the sample is dropped and included in this count.
DDS_ LongLong	ownership_dropped_sample_ count	The number of samples dropped as a result of receiving a sample from a *DataWriter* with a lower strength, using Exclusive Ownership. When using Exclusive Ownership, the *DataReader* receives data from multiple *DataWriters*. Each instance can only be owned by one *DataWriter*. If other *DataWriters* write samples belonging to this instance, the samples will be dropped.
DDS_ LongLong	content_filter_dropped_sample_ count	The number of samples filtered by the *DataReader* due to *ContentFilteredTopics*. When using a content filter on the *DataReader* side, if the sample received by the *DataReader* does not pass the filter, it will be dropped.
DDS_ LongLong	time_based_filter_dropped_ sample_count	The number of samples filtered by the *DataReader* due to the 8.6.4 TIME_BASED_FILTER QosPolicy on page 583. When using the 8.6.4 TIME_BASED_FILTER QosPolicy on page 583 on the *DataReader* side, if the sample received by the *DataReader* does not pass the **minimum_separation** filter, it will be dropped.

Table 8.5 DDS_DataReaderCacheStatus

Type	Field Name	Description
DDS_LongLong	expired_dropped_sample_count	The number of samples expired by the *DataReader* due to the 7.5.14 LIFESPAN QoS Policy on page 423 or the autopurge sample delays in the 8.6.3 READER_DATA_LIFECYCLE QoS Policy on page 581: • **DDS_LifespanQosPolicy:** When a sample expires due to the **DDS_LifespanQosPolicy**, the data is removed from the *DataReader* caches. This sample will be considered dropped if its DDS_SampleStateKind is DDS_NOT_READ_SAMPLE_STATE. • **DDS_ReaderDataLifecycleQosPolicy::autopurge_nowriter_samples_delay:** When a sample expires due to the **autopurge_nowriter_samples_delay**, this sample will be considered dropped if its DDS_SampleStateKind is DDS_NOT_READ_SAMPLE_STATE. • **DDS_ReaderDataLifecycleQosPolicy::autopurge_disposed_samples_delay:** When a sample expires due to the **autopurge_disposed_samples_delay**, this sample will be considered dropped if its DDS_SampleStateKind is DDS_NOT_READ_SAMPLE_STATE.
DDS_LongLong	virtual_duplicate_dropped_sample_count	The number of virtual duplicate samples dropped by the *DataReader*. A sample is a virtual duplicate if it has the same identity (Virtual Writer GUID and Virtual Sequence Number) as a previously received sample. When two *DataWriters* with the same logical data source publish a sample with the same **sequence_number**, one sample will be dropped and the other will be received by the *DataReader*. This can happen when multiple writers are writing on behalf of the same original *DataWriter*: for example, in systems with redundant *RTI Routing Service* applications or when a *DataReader* is receiving samples both directly from the original *DataWriter* and from an instance of *RTI Persistence Service*.
DDS_LongLong	replaced_dropped_sample_count	The number of samples replaced by the *DataReader* due to DDS_KEEP_LAST_HISTORY_QOS replacement in the 7.5.12 HISTORY QosPolicy on page 418. When the number of samples for an instance in the queue reaches the **depth** value in the HISTORY QosPolicy, a new sample for the instance will replace the oldest sample for the instance in the queue. The new sample will be accepted, and the old sample will be dropped. This counter will only be updated if the replaced sample's DDS_SampleStateKind is DDS_NOT_READ_SAMPLE_STATE.
DDS_LongLong	total_samples_dropped_by_instance_replacement	Number of samples of the state NOT_READ_SAMPLE_STATE that were dropped when removing an instance due to instance replacement via the **instance_replacement** field in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571.
DDS_LongLong	alive_instance_count	Number of instances currently in the *DataReader's* queue that have an **instance_state** of ALIVE.
DDS_LongLong	alive_instance_count_peak	Highest number of ALIVE instances in the *DataReader's* queue over the lifetime of the *DataReader*.
DDS_LongLong	no_writers_instance_count	Number of instances in the *DataReader's* queue that have an **instance_state** of NOT_ALIVE_NO_WRITERS.
DDS_LongLong	no_writers_instance_count_peak	Highest number of NOT_ALIVE_NO_WRITERS instances in the *DataReader's* queue over the lifetime of the *DataReader*.

Table 8.5 DDS_DataReaderCacheStatus

Type	Field Name	Description
DDS_ LongLong	disposed_instance_count	Number of instances in the *DataReader's* queue that have an **instance_state** of NOT_ALIVE_ DISPOSED.
DDS_ LongLong	disposed_instance_count_peak	Highest number of NOT_ALIVE_DISPOSED instances in the *DataReader's* queue over the lifetime of the *DataReader*.
DDS_ LongLong	detached_instance_count	Number of detached instances–which contain only the minimum instance state–currently being maintained in the *DataReader's* queue. If **keep_minimum_state_for_instances** in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571 is true (by default, it is), the *DataReader* will keep up to **max_total_instances** (in the DATA_READER_RESOURCE_LIMITS QosPolicy) of detached instances in its queue. See 8.3.8.6.1 Active State and Minimum State on page 535 for more information.
DDS_ LongLong	detached_instance_count_peak	Highest number of detached instances in the *DataReader's* queue over the lifetime of the *DataReader*.

8.3.7.3 DATA_READER_PROTOCOL_STATUS

The status of a *DataReader's* internal protocol related metrics (such as the number of DDS samples received, filtered, rejected) and the status of wire protocol traffic. The structure for this status appears in Table 8.6 DDS_DataReaderProtocolStatus.

This status does not have an associated Listener. You can access this status by calling the following operations on the *DataReader* (which return the status structure described in Table 8.6 DDS_DataReaderProtocolStatus):

get_datareader_protocol_status() returns the sum of the protocol status for all the matched publications for the *DataReader*.

get_matched_publication_datareader_protocol_status() returns the protocol status of a particular matched publication, identified by a **publication_handle**.

The **get_*_status()** operations also reset the related status so it is no longer considered "changed."

Note: Status/data for a matched publication is kept even if the *DataWriter* is not alive (that is, has lost liveliness based on the 7.5.15 LIVELINESS QosPolicy on page 425). The status/data will be removed only if the *DataWriter* is gone: that is, the *DataWriter* is destroyed and this change is propagated through a discovery update, or the *DataWriter's DomainParticipant* is gone (either gracefully or its liveliness expired and *Connext DDS* is configured to purge not-alive participants). Once a matched *DataWriter* is gone, its status is deleted. If you try to get the status/data for a matched publication that is gone, the 'get status' or ' get data' call will return an error.

Table 8.6 DDS_DataReaderProtocolStatus

Type	Field Name	Description
DDS_LongLong	received_sample_count	The number of samples received by a *DataReader*. **Note:** When data is fragmented, this count is updated when all of the fragments required to reassemble a sample are received, not when individual fragments are received. The fragment count is tracked in the received_fragment_count.
	received_sample_count_change	Change in the **received_sample_count** since the last time the status was read.
	received_sample_bytes	The number of bytes received by a *DataReader*. **Note:** When data is fragmented, this statistic is updated upon the receipt of each fragment, not when a sample is reassembled.
	received_sample_bytes_change	Change in **received_sample_bytes** since the last time the status was read.
DDS_LongLong	duplicate_sample_count	The number of DDS samples received from a *DataWriter*, not for the first time, by this *DataReader*.
	duplicate_sample_count_change	Change in **duplicate_sample_count** since the last time the status was read.
	duplicate_sample_bytes	The number of bytes of DDS samples received from a *DataWriter* received, not for the first time, by this *DataReader*.
	duplicate_sample_bytes_change	Change in the **duplicate_sample_bytes** since the last time the status was read.
DDS_LongLong	filtered_sample_count	The number of DDS samples filtered by this *DataReader* due to ContentFilteredTopics or Time-Based Filter.
	filtered_sample_count_change	Change in the **filtered_sample_count** since the last time the status was read.
	filtered_sample_bytes	The number of bytes of DDS samples filtered by this *DataReader* due to ContentFilteredTopics or Time-Based Filter.
	filtered_sample_bytes_change	Change in the **filtered_sample_bytes** since the last time the status was read.

Table 8.6 DDS_DataReaderProtocolStatus

Type	Field Name	Description
DDS_LongLong	received_heartbeat_count	The number of Heartbeats received from a *DataWriter* by this *DataReader*.
	received_heartbeat_count_change	Change in the **received_heartbeat_count** since the last time the status was read.
	received_heartbeat_bytes	The number of bytes of Heartbeats received from a *DataWriter* by this *DataReader*.
	received_heartbeat_bytes_change	Change in the **received_heartbeat_bytes** since the last time the status was read.
DDS_LongLong	sent_ack_count	The number of ACKs sent from this *DataReader* to a matching *DataWriter*.
	sent_ack_count_change	Change in the **sent_ack_count** since the last time the status was read.
	sent_ack_bytes	The number of bytes of ACKs sent from this *DataReader* to a matching *DataWriter*.
	sent_ack_bytes_change	Change in the **sent_ack_bytes** since the last time the status was read.
DDS_LongLong	sent_nack_count	The number of NACKs sent from this *DataReader* to a matching *DataWriter*.
	sent_nack_count_change	Change in the **sent_nack_count** since the last time the status was read.
	sent_nack_bytes	The number of bytes of NACKs sent from this *DataReader* to a matching *DataWriter*.
	sent_nack_bytes_change	Change in the **sent_nack_bytes** since the last time the status was read.

Table 8.6 DDS_DataReaderProtocolStatus

Type	Field Name	Description
DDS_LongLong	received_gap_count	The number of GAPs received from a *DataWriter* to this *DataReader*.
	received_gap_count_change	Change in the **received_gap_count** since the last time the status was read.
	received_gap_bytes	The number of bytes of GAPs received from a *DataWriter* to this *DataReader*.
	received_gap_bytes_change	Change in the **received_gap_bytes** since the last time the status was read.
DDS_LongLong	rejected_sample_count	The number of times a sample is rejected because it cannot be accepted by a reliable *DataReader*. Samples rejected by a reliable *DataReader* will be NACKed, and they will have to be resent by the *DataWriter* if they are still available in the *DataWriter* queue. **Note:** This count is a subset of the **total_count** in the 8.3.7.8 SAMPLE_REJECTED Status on page 527. For example, the DDS_REJECTED_BY_SAMPLES_PER_INSTANCE_LIMIT in the SAMPLE_REJECTED status is not part of this count.
	rejected_sample_count_change	Change in the **rejected_sample_count** since the last time the status was read.
DDS_LongLong	out_of_range_rejected_sample_count	The number of samples dropped by the *DataReader* due to the receive window being full and the sample received out-of-order. When using reliable 7.5.21 RELIABILITY QosPolicy on page 444, if the *DataReader* receives samples out-of-order, they are stored internally until the missing samples are received. The number of out-of-order samples that the *DataReader* can keep is set by the **receive_window_size** in the Table 8.19 DDS_RtpsReliableReaderProtocol_t on page 568. When the receive window is full, any out-of-order sample received will be dropped and included in this count (but not in the SampleRejectedStatus).
DDS_SequenceNumber_t	first_available_sample_sequence_number	Sequence number of the first available DDS sample in a matched *DataWriter's* reliability queue. Applicable only when retrieving matched *DataWriter* statuses.
	last_available_sample_sequence_number	Sequence number of the last available DDS sample in a matched *DataWriter's* reliability queue. Applicable only when retrieving matched *DataWriter* statuses.
	last_committed_sample_sequence_number	Sequence number of the last committed DDS sample (i.e. available to be read or taken) in a matched *DataWriter's* reliability queue. Applicable only when retrieving matched *DataWriter* statuses. For best-effort *DataReaders*, this is the sequence number of the latest DDS sample received. For reliable *DataReaders*, this is the sequence number of the latest DDS sample that is available to be read or taken from the *DataReader's* queue.

Table 8.6 DDS_DataReaderProtocolStatus

Type	Field Name	Description
DDS_Long	uncommitted_sample_count	Number of received DDS samples that are not yet available to be read or taken due to being received out of order. Applicable only when retrieving matched *DataWriter* statuses.
DDS_LongLong	received_fragment_count	The number of fragments (DATA_FRAG messages) that have been received by this *DataReader*. This count is incremented upon the receipt of each DATA_FRAG message. Fragments from duplicate samples do not count towards this number. Applicable only when data is fragmented.
DDS_LongLong	dropped_fragment_count	The number of DATA_FRAG messages that have been dropped by the *DataReader*. This count does not include malformed fragments. Applicable only when data is fragmented.
DDS_LongLong	reassembled_sample_count	The number of samples that have been reassembled by the *DataReader*. This statistic is incremented when all of the fragments that are required to reassemble an entire sample have been received. Applicable only when data is fragmented.
DDS_LongLong	sent_nack_fragment_count	The number of NACK FRAG RTPS messages that have been sent from the *DataReader* to a *DataWriter*. NACK FRAG RTPS messages are sent when large data is used in conjunction with reliable communication. They have the same properties as NACK messages, but instead of applying to samples, they apply to fragments. Applicable only when data is fragmented.
	sent_nack_fragment_bytes	The number of NACK FRAG RTPS message bytes that have been sent from the *DataReader* to a *DataWriter*. NACK FRAG RTPS messages are sent when large data is used in conjunction with reliable communication. They have the same properties as NACK messages, but instead of applying to samples, they apply to fragments. Applicable only when data is fragmented.

8.3.7.4 LIVELINESS_CHANGED Status

This status indicates that the liveliness of one or more matched *DataWriters* has changed (i.e., one or more *DataWriters* has become alive or not alive). The mechanics of determining liveliness between a *DataWriter* and a *DataReader* is specified in their 7.5.15 LIVELINESS QosPolicy on page 425.

The structure for this status appears in Table 8.7 DDS_LivelinessChangedStatus.

Table 8.7 DDS_LivelinessChangedStatus

Type	Field Name	Description
DDS_Long	alive_count	Number of matched *DataWriters* that are currently alive.
	not_alive_count	Number of matched *DataWriters* that are not currently alive.
	alive_count_change	The change in the **alive_count** since the last time the *Listener* was called or the status was read.
	not_alive_count_change	The change in the **not_alive_count** since the last time the *Listener* was called or the status was read. Note that a positive **not_alive_count_change** means one of the following: • The *DomainParticipant* containing the matched *DataWriter* has lost liveliness or has been deleted. • The matched *DataWriter* has lost liveliness or has been deleted.
DDS_InstanceHandle_t	last_publication_handle	This InstanceHandle can be used to look up which remote *DataWriter* was the last to cause this *DataReader*'s status to change, using the DataReader's **get_matched_publication_data()** method. It's possible that the *DataWriter* has been purged from the discovery database. If so, **get_matched_publication_data()** will not be able to return information about the *DataWriter*. In this case, the only way to get information about the lost *DataWriter* is if you cached the information previously.

The *DataReaderListener's* **on_liveliness_changed()** callback may be called for the following reasons:

- The liveliness of any *DataWriter* matching this *DataReader* (as defined by the 7.5.15 LIVELINESS QosPolicy on page 425) is lost.
- A *DataWriter's* liveliness is recovered after being lost.
- A new matching *DataWriter* has been discovered.
- A QoS Policy has changed such that a *DataWriter* that matched this *DataReader* before no longer matches (such as a change to the PartitionQosPolicy). In this case, *Connext DDS* will no longer keep track of the *DataWriter*'s liveliness. Furthermore:
  - If the *DataWriter* was alive when it and the *DataReader* stopped matching: **alive_count** will decrease (since there's one less matching alive *DataWriter*) and **not_alive_count** will remain the same (since the *DataWriter* is still alive).
  - If the *DataWriter* was not alive when it and the *DataReader* stopped matching: **alive_count** will remain the same (since the matching *DataWriter* was not alive) and **not_alive_count** will decrease (since there's one less not-alive matching *DataWriter*).

    Note: There are several ways that a *DataWriter* and *DataReader* can become incompatible after the *DataWriter* has lost liveliness. For example, when the 7.5.15 LIVELINESS QosPolicy on page 425 **kind** is set to MANUAL_BY_PARTICIPANT_LIVELINESS_QOS, it is possible that the *DataWriter* has not asserted its liveliness in a timely manner, and

then a QoS change occurs on the *DataWriter* or *DataReader* that makes the entities incompatible.

- A QoS Policy (such as the PartitionQosPolicy) has changed such that a *DataWriter* that was unmatched with the *DataReader* now matches.

You can also retrieve the value by calling the *DataReader's* **get_liveliness_changed_status()** operation; this will also reset the status so it is no longer considered "changed."

This status is reciprocal to the 7.3.6.9 RELIABLE_READER_ACTIVITY_CHANGED Status (DDS Extension) on page 306 for a *DataWriter*.

8.3.7.5 REQUESTED_DEADLINE_MISSED Status

This status indicates that the *DataReader* did not receive a new DDS sample for an data-instance within the time period set in the *DataReader's* 7.5.7 DEADLINE QosPolicy on page 404. For non-keyed Topics, this simply means that the *DataReader* did not receive data within the DEADLINE period. For keyed *Topics*, this means that for one of the data-instances that the *DataReader* was receiving, it has not received a new DDS sample within the DEADLINE period. For more information about keys and instances, see 2.4 DDS Samples, Instances, and Keys on page 18.

The structure for this status appears in Table 8.8 DDS_RequestedDeadlineMissedStatus.

Table 8.8 DDS_RequestedDeadlineMissedStatus

Type	Field Name	Description
DDS_Long	total_count	Cumulative number of times that the deadline was violated for any instance read by the *DataReader*.
	total_count_change	The change in total_count since the last time the *Listener* was called or the status was read.
DDS_InstanceHandle_t	last_instance_handle	Handle to the last data-instance in the *DataReader* for which a requested deadline was missed.

The *DataReaderListener's* **on_requested_deadline_missed()** callback is invoked when this status changes. You can also retrieve the value by calling the *DataReader's* **get_requested_deadline_missed_status()** operation; this will also reset the status so it is no longer considered "changed."

8.3.7.6 REQUESTED_INCOMPATIBLE_QOS Status

A change to this status indicates that the *DataReader* discovered a *DataWriter* for the same *Topic*, but that *DataReader* had requested QoS settings incompatible with this *DataWriter's* offered QoS.

The structure for this status appears in Table 8.9 DDS_RequestedIncompatibleQosStatus .

Table 8.9 DDS_RequestedIncompatibleQosStatus

Type	Field Name	Description
DDS_Long	total_ count	Cumulative number of times the *DataReader* discovered a *DataWriter* for the same Topic with an offered QoS that is incompatible with that requested by the *DataReader*.
DDS_Long	total_ count_ change	The change in total_count since the last time the *Listener* was called or the status was read.
DDS_QosPolicyId_t	last_ policy_id	The ID of the QosPolicy that was found to be incompatible the last time an incompatibility was detected. (Note: if there are multiple incompatible policies, only one of them is reported here.)
DDS_QosPolicyCountSeq	policies	A list containing–for each policy–the total number of times that the *DataReader* discovered a *DataWriter* for the same *Topic* with a offered QoS that is incompatible with that requested by the *DataReader*.

The *DataReaderListener's* **on_requested_incompatible_qos()** callback is invoked when this status changes. You can also retrieve the value by calling the *DataReader's* **get_requested_incompatible_qos_status()** operation; this will also reset the status so it is no longer considered "changed."

8.3.7.7 SAMPLE_LOST Status

This status indicates that one or more DDS samples written by a matched *DataWriter* have failed to be received and will never be received.

Some samples written by a *DataWriter* to its matching *DataReaders* may never be received by the *DataReaders*. This can happen because something went wrong while trying to add the sample to the *DataReader's* queue, like a decryption or deserialzation error, or because the sample was removed from the *DataWriter's* queue before it was received by the *DataReaders*. A sample can be removed from the *DataWriter's* queue before it is delivered to matching *DataReaders* for a number of reasons, including that *DataWriters* are limited in the number of published DDS data samples that they can store, so that if a *DataWriter* continues to publish DDS data samples, new data may overwrite old data that has not yet been received by the *DataReader*. The DDS samples that are overwritten can never be resent to the *DataReader* and thus are considered to be *lost*. *DataWriters* may also set the 7.5.14 LIFESPAN QoS Policy on page 423, and samples that expire due to lifespan may also be reported as lost by a *DataReader* that has not received those samples.

The *lost* status applies to reliable *and* best-effort *DataReaders*, see the 7.5.21 RELIABILITY QosPolicy on page 444. By reporting a sample as lost, the *DataReader* has declared that the sample will never be received, and will therefore not NACK it. It cannot be repaired by a *DataWriter* or resent to the *DataReader*.

Before a sample is received by a *DataReader* it may also be reported as rejected or dropped. (See 8.3.7.8 SAMPLE_REJECTED Status on page 527 and 8.3.7.2 DATA_READER_CACHE_STATUS on page 514.)

The structure for the *lost* status appears in Table 8.10 DDS_SampleLostStatus.

Table 8.10 DDS_SampleLostStatus

Type	Field Name	Description
DDS_Long	total_count	Cumulative count of all the DDS samples that have been lost, across all instances of data written for the *Topic*.
	total_count_change	The incremental number of DDS samples lost since the last time the *Listener* was called or the status was read.
DDS_SampleLostStatusKind	last_reason	The reason the last DDS sample was lost. See Table 8.11 DDS_SampleLostStatusKind.

The reason the DDS sample was lost appears in the **last_reason** field. The possible values are listed in Table 8.11 DDS_SampleLostStatusKind.

Table 8.11 DDS_SampleLostStatusKind

Reason Kind	Description
NOT_LOST	The sample was not lost.
LOST_BY_AVAILABILITY_WAITING_TIME	**max_data_availability_waiting_time** in the 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369 expired.
LOST_BY_DECODE_FAILURE	When using BEST_EFFORT in the 7.5.21 RELIABILITY QosPolicy on page 444, a sample was lost because it could not be decoded. When using RELIABLE in the RELIABILITY QosPolicy, the sample is rejected, not lost, with the reason REJECTED_BY_DECODE_FAILURE.
LOST_BY_DESERIALIZATION_FAILURE	A sample was lost because it could not be deserialized.
LOST_BY_INCOMPLETE_COHERENT_SET	A sample was lost because it is part of an incomplete coherent set. An incomplete coherent set is a coherent set for which some of the samples are missing. For example, consider a *DataWriter* using KEEP_LAST in the 7.5.12 HISTORY QosPolicy on page 418 with a **depth** of 1. The *DataWriter* publishes two samples of the same instance as part of a coherent set "CS1"; the first sample of "CS1" is replaced by a new sample before it can be successfully delivered to the *DataReader*. In this case, the coherent set containing the two samples is considered incomplete. The new sample, by default, will not be provided to the application, and will be reported as LOST_BY_INCOMPLETE_COHERENT_SET. (You can change this default behavior by setting **drop_incomplete_ coherent_set** to FALSE in the 7.4.6 PRESENTATION QosPolicy on page 361. If you do, the new sample will be provided to the application, but it will be marked as part of an incomplete coherent set in the 8.4.6 The SampleInfo Structure on page 560.)
LOST_BY_INSTANCES_LIMIT	**max_instances** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 was reached.

Table 8.11 DDS_SampleLostStatusKind

Reason Kind	Description
LOST_BY_LARGE_COHERENT_SET	A sample was lost because it was part of a large coherent set. A large coherent set is a coherent set that cannot fit all at once into the *DataReader* queue because resource limits are exceeded. For example, if **max_samples_per_instance** on the *DataReader* is 10 and the coherent set has 15 samples for a given instance, the coherent set is a large coherent set that will be considered incomplete. The resource limits that can lead to large coherent sets are: **max_samples**, **max_samples_per_instance**, **max_instances**, and **max_samples_per_remote_writer**.
LOST_BY_OUT_OF_MEMORY	A sample was lost because there was not enough memory to store the sample.
LOST_BY_REMOTE_WRITER_SAMPLES_PER_VIRTUAL_QUEUE_LIMIT	A resource limit on the number of samples published by a *DataWriter* on behalf of a virtual *DataWriter* that a *DataReader* may store was reached. (This field is currently not used.)
LOST_BY_REMOTE_WRITERS_PER_INSTANCE_LIMIT	**max_remote_writers_per_instance** in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571 was reached. (This limit is the number of *DataWriters* for a single instance from which a *DataReader* may read.)
LOST_BY_REMOTE_WRITERS_PER_SAMPLE_LIMIT	**max_remote_writers_per_sample** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 was reached. (This limit is the number of *DataWriters* that are allowed to write the same sample.)
LOST_BY_SAMPLES_LIMIT	When using BEST_EFFORT in the 7.5.21 RELIABILITY QosPolicy on page 444, **max_samples** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 was reached. When using RELIABLE in the RELIABILITY QosPolicy, reaching **max_samples** triggers a rejection, not a loss, with the reason REJECTED_BY_SAMPLES_LIMIT.
LOST_BY_SAMPLES_PER_INSTANCE_LIMIT	When using BEST_EFFORT in the 7.5.21 RELIABILITY QosPolicy on page 444, **max_samples_per_instance** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 was reached. When using RELIABLE in the RELIABILITY QosPolicy, reaching **max_samples_per_instance** triggers a rejection, not a loss, with the reason REJECTED_BY_SAMPLES_PER_INSTANCE_LIMIT.
LOST_BY_SAMPLES_PER_REMOTE_WRITER_LIMIT	When using BEST_EFFORT in the 7.5.21 RELIABILITY QosPolicy on page 444, **max_samples_per_remote_writer** in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571 was reached. (This limit is the number of samples from a given *DataWriter* that a *DataReader* may store.) When using RELIABLE in the RELIABILITY QosPolicy, reaching **max_samples_per_remote_writer** triggers a rejection, not a loss, with the reason REJECTED_BY_SAMPLES_PER_REMOTE_WRITER_LIMIT.
LOST_BY_UNKNOWN_INSTANCE	A sample was lost because it didn't contain enough information for the *DataReader* to know what instance it was associated with.
LOST_BY_VIRTUAL_WRITERS_LIMIT	**max_remote_virtual_writers** in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571 was reached. (This limit is the number of virtual *DataWriters* from which a *DataReader* may read.)
LOST_BY_WRITER	A *DataWriter* removed the DDS sample before being received by the *DataReader*.

The *DataReaderListener's* **on_sample_lost()** callback is invoked when this status changes. You can also retrieve the value by calling the *DataReader's* **get_sample_lost_status()** operation; this will also reset the status so it is no longer considered "changed."

8.3.7.8 SAMPLE_REJECTED Status

This status indicates that one or more DDS samples received from a matched *DataWriter* have been rejected by the *DataReader* because a resource limit would have been exceeded: for example, if the receive queue is full because the number of DDS samples in the queue is equal to the **max_samples** parameter of the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449. These rejected samples could be accepted later once the conditions for acceptance are met (e.g., once the number of samples in the queue becomes less than **max_samples**). A sample that is rejected can be resent any number of times until it is eventually reported as lost, dropped, or accepted.

Samples can be rejected only with reliable communication; see 7.5.21 RELIABILITY QosPolicy on page 444. In best-effort communication, samples cannot be rejected because samples cannot be received again and are not eligible for resending.

The structure for the *rejected* status appears in Table 8.12 DDS_SampleRejectedStatus. The reason the DDS sample was rejected appears in the **last_reason** field. The possible values are listed in Table 8.13 DDS_SampleRejectedStatusKind.

Table 8.12 DDS_SampleRejectedStatus

Type	Field Name	Description
DDS_Long	total_count	Cumulative count of all the DDS samples that have been rejected by the *DataReader*.
	total_count_change	The incremental number of DDS samples rejected since the last time the *Listener* was called or the status was read.
	current_count	The current number of writers with which the *DataReader* is matched.
	current_count_change	The change in **current_count** since the last time the *Listener* was called or the status was read.
DDS_SampleRejectedStatusKind	last_reason	Reason for rejecting the last DDS sample. See Table 8.13 DDS_SampleRejectedStatusKind.
DDS_InstanceHandle_t	last_instance_handle	Handle to the data-instance for which the last DDS sample was rejected.

Table 8.13 DDS_SampleRejectedStatusKind

Reason Kind	Description
DDS_NOT_REJECTED	DDS sample was accepted.
REJECTED_BY_DECODE_FAILURE	When using RELIABLE in the 7.5.21 RELIABILITY QosPolicy on page 444, a sample was rejected because it could not be decoded. When using BEST_EFFORT in the 7.5.21 RELIABILITY QosPolicy on page 444, the sample is lost, not rejected, with the reason LOST_BY_DECODE_FAILURE.
DDS_REJECTED_BY_ INSTANCES_LIMIT	This field is not currently used.
DDS_REJECTED_BY_ SAMPLES_LIMIT	When using RELIABLE in the 7.5.21 RELIABILITY QosPolicy on page 444, **max_samples** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 was reached. When using BEST_EFFORT in the RELIABILITY QosPolicy, reaching **max_samples** triggers a loss, not a rejection, with the reason LOST_BY_SAMPLES_LIMIT.
DDS_REJECTED_BY_ SAMPLES_PER_INSTANCE_LIMIT	When using RELIABLE in the 7.5.21 RELIABILITY QosPolicy on page 444, **max_samples_per_instance** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 was reached. When using BEST_EFFORT in the RELIABILITY QosPolicy, reaching **max_samples_per_instance** triggers a loss, not a rejection, with the reason LOST_BY_SAMPLES_PER_ INSTANCE_LIMIT.
DDS_REJECTED_BY_ SAMPLES_PER_REMOTE_WRITER_LIMIT	When using RELIABLE in the 7.5.21 RELIABILITY QosPolicy on page 444, **max_samples_per_remote_writer** in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571 was reached. (This limit is the number of samples that a *DataReader* may store from a specific *DataWriter*.) When using BEST_EFFORT in the RELIABILITY QosPolicy, reaching **max_samples_per_ remote_writer** triggers a loss, not a rejection, with the reason LOST_BY_SAMPLES_PER_ REMOTE_WRITER_LIMIT.
DDS_REJECTED_BY_ REMOTE_WRITER_SAMPLES_PER_VIRTUAL_ QUEUE_LIMIT	This field is currently not used.

The *DataReaderListener's* **on_sample_rejected()** callback is invoked when this status changes. You can also retrieve the value by calling the *DataReader's* **get_sample_rejected_status()** operation; this will also reset the status so it is no longer considered "changed."

8.3.7.9 SUBSCRIPTION_MATCHED Status

A change to this status indicates that the *DataReader* discovered a matching *DataWriter*. A 'match' occurs only if the *DataReader* and *DataWriter* have the same *Topic*, same or compatible data type, and compatible QosPolicies. (For more information on compatible data types, see the RTI Connext DDS Core Libraries Extensible Types Guide.) In addition, if user code has directed *Connext DDS* to ignore certain *DataWriters*, then those *DataWriters* will never be matched. See 18.4.2 Ignoring Publications and Subscriptions on page 837 for more on setting up a *DomainParticipant* to ignore specific *DataWriters*.

This status is also changed (and the listener, if any, called) when a match is ended. A *DataReader* will become unmatched from a *DataWriter* when that *DataWriter* goes away for any of the following reasons:

- The *DomainParticipant* containing the matched *DataWriter* has lost liveliness.
- The *DataReader* or the matched *DataWriter* has changed QoS such that the entities are now incompatible.
- The matched *DataWriter* has been deleted.

This status may reflect changes from multiple match or unmatch events, and the **current_count_change** can be used to determine the number of changes since the listener was called back or the status was checked.

The structure for this status appears in Table 8.14 DDS_SubscriptionMatchedStatus.

Table 8.14 DDS_SubscriptionMatchedStatus

Type	Field Name	Description
DDS_Long	total_count	Cumulative number of times the *DataReader* discovered a "match" with a *DataWriter*. This number increases whenever a new match is discovered. It does not decrease when an existing match goes away for any of the reasons listed above.
	total_count_change	The changes in **total_count** since the last time the listener was called or the status was read. Note that this number will never be negative (because it's the total number of times the *DataReader* ever matched with a *DataWriter*).
	current_count	The number of *DataWriters* currently matched to the concerned *DataReader*. This number increases when a new match is discovered and decreases when an existing match goes away for any of the reasons listed above.
	current_count_change	The change in **current_count** since the last time the listener was called or the status was read. Note that a negative **current_count_change** means that one or more *DataWriters* have become unmatched for one or more of the reasons listed above.
	current_count_peak	Greatest number of *DataWriters* that matched this *DataReader* simultaneously. That is, there was no moment in time when more than this many *DataWriters* matched this *DataReader*. (As a result, **total_count** can be higher than **current_count_peak**.)
DDS_InstanceHandle_t	last_publication_handle	This InstanceHandle can be used to look up which remote *DataWriter* was the last to cause this *DataReader*'s status to change, using the *DataReader*'s **get_matched_publication_data()** method. If the *DataWriter* no longer matches this *DataReader* due to any of the reasons listed above except incompatible QoS, then the *DataWriter* has been purged from this *DataReader*'s *DomainParticipant* discovery database. (See 15.1 What is Discovery? on page 759.) In that case, the *DataReader*'s **get_matched_publication_data** method will not be able to return information about the *DataWriter*. The only way to get information about the lost *DataWriter* is if you cached the information previously.

The *DataReaderListener's* **on_subscription_matched()** callback is invoked when this status changes. You can also retrieve the value by calling the *DataReader's* **get_subscription_match_status()** operation; this will also reset the status so it is no longer considered "changed."

8.3.8 Accessing and Managing Instances (Working with Keyed Data Types)

This section describes how instances work on *DataReaders*. This section applies only to data types that use keys; see 2.4 DDS Samples, Instances, and Keys on page 18. See also Chapter 6 Working with Instances on page 256.

A *DataReader* receives updates about instances and instance state changes as DATA_AVAILABLE statuses, the same way it receives data updates. (See 8.3.7.1 DATA_AVAILABLE Status on page 514.) *DataReaders* can access instance state as part of the **SampleInfo** that is returned when calling any variant of **read()** or **take()** (such as **read_instance()** or **take_instance()**).

8.3.8.1 Instance States

As seen in Figure 8.11: Instance States on the next page, *Connext DDS* keeps an **instance_state** for each instance:

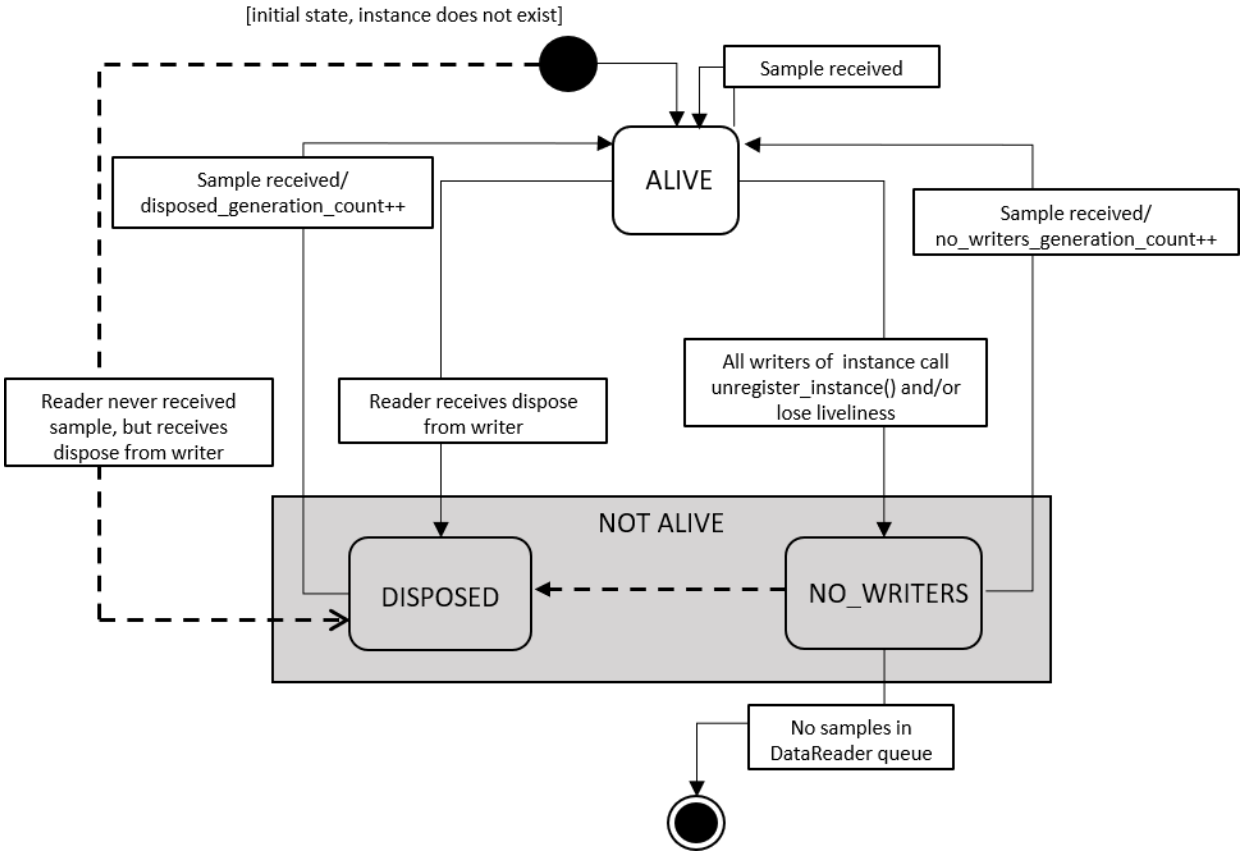
- **ALIVE**: The following are all true: (a) DDS samples have been received for the instance, (b) there are live *DataWriters* writing the instance, and (c) the instance has not been explicitly disposed (or more DDS samples have been received after it was disposed).
- **NOT_ALIVE_DISPOSED**: The instance was explicitly disposed by a *DataWriter* by means of the **dispose()** operation, or implicitly as a result of the **autodispose_unregistered_instances** QoS setting.
- **NOT_ALIVE_NO_WRITERS**: The instance has been declared as not-alive by the *DataReader* because it has determined that there are no live *DataWriter* entities that have previously written the instance.

Instances can cycle through these phases as seen in the state diagram below, becoming **NOT_ALIVE** and then becoming **ALIVE** again. To track these transitions, there is metadata the *DataReader* can query called generation counts. (See 8.3.8.2 Generation Counts and Ranks on page 532.)

The events that cause the **instance_state** to change can depend on the setting of the 7.5.17 OWNERSHIP QosPolicy on page 432:

- If OWNERSHIP QoS is set to **EXCLUSIVE**, the **instance_state** becomes **NOT_ALIVE_DISPOSED** only if the *DataWriter* that currently "owns" the instance explicitly disposes it. The **instance_state** will become **ALIVE** again only if the *DataWriter* that owns the instance writes it. Note that ownership of the instance is determined by a combination of the OWNERSHIP QoSPolicy and 7.5.18 OWNERSHIP_STRENGTH QosPolicy on page 435. Ownership of an instance can dynamically change.
- If OWNERSHIP QoS is set to **SHARED**, the **instance_state** becomes **NOT_ALIVE_DISPOSED** if any *DataWriter* explicitly disposes the instance. The **instance_state** becomes **ALIVE** as soon as any *DataWriter* writes the instance again.

Figure 8.11: Instance States

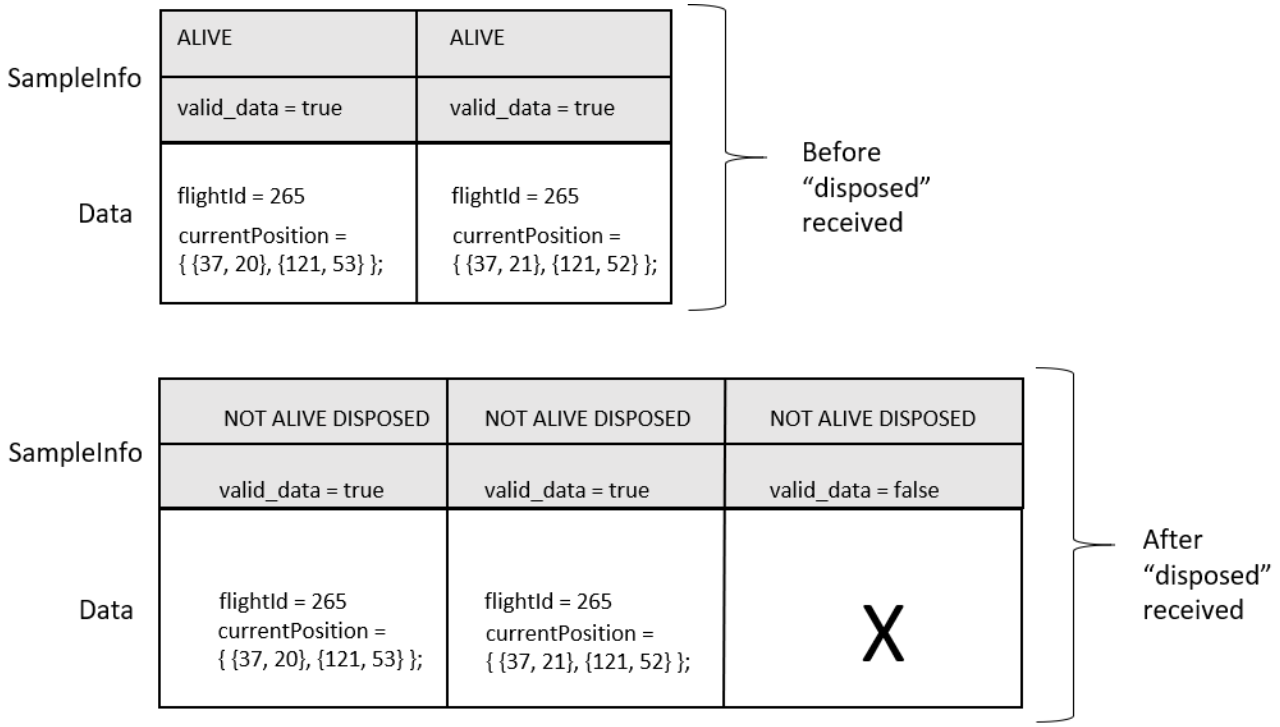


*Transitions shown with dashes are only available if **propagate_dispose_of_unregistered_instances** = true*

Since the **instance_state** in the **SampleInfo** structure is a per-instance concept, all DDS data samples related to the same instance that are returned by **read()** or **take()** will have the same value for **instance_state**. This means that if there are samples for that instance in the *DataReader's* queue that were received when the instance was **ALIVE**, and a subsequent dispose message is received, the samples' metadata will indicate that the instance's state is **NOT_ALIVE_DISPOSED** in all of them.

Note: The **instance_state** always reflects the current state of the instance at the time of reading.

Figure 8.12: Before and After Dispose Received



*When the dispose message is received (the box with the X, with **valid_data** = false), all samples for the flight 265 instance in the queue are marked as **NOT_ALIVE_DISPOSED**, even those that contain live data from when the instance was **ALIVE**.*

Note: If an instance transitions its state to **NOT_ALIVE_NO_WRITERS** due to one or more *DataWriters* losing liveliness, it will not transition back to **ALIVE** if the *DataWriter* regains liveliness. It only returns to the **ALIVE** state if a *DataWriter* writes a new sample of the instance.

8.3.8.2 Generation Counts and Ranks

Generation counts and ranks allow your application to distinguish DDS samples belonging to different ‘generations’ of the instance. It is possible for an instance to become alive, be disposed and become not-alive, and then cycle again from alive to not-alive states during the operation of an application. Each time an instance becomes alive defines a new generation for the instance.

It is possible that an instance may cycle through alive and not-alive states multiple times before the application accesses the DDS data samples for the instance. This means that the DDS data samples returned by **read()** and **take()** may cross generations. That is, some DDS samples were published when the instance was alive in one generation and other DDS samples were published when the instance transitioned through the non-alive state into the alive state again. It may be important to your application to distinguish the DDS data samples by the generation in which they were published.

Each *DataReader* keeps two counters for each instance it detects (recall that instances are distinguished by their key values):

- **disposed_generation_count**: Counts how many times the **instance_state** of the corresponding instance changes from **NOT_ALIVE_DISPOSED** to **ALIVE**.
- **no_writers_generation_count**: Counts how many times the **instance_state** of the corresponding instance changes from **NOT_ALIVE_NO_WRITERS** to **ALIVE**.

The **disposed_generation_count** and **no_writers_generation_count** fields in the **SampleInfo** structure capture a snapshot of the corresponding counters at the time the corresponding DDS sample was received.

The **sample_rank** and **generation_rank** in the **SampleInfo** structure are computed relative to the sequence of DDS samples returned by **read()** or **take()**:

- **sample_rank**: Indicates how many DDS samples of the same instance follow the current one in the sequence. The DDS samples are always time-ordered, thus the newest DDS sample of an instance will have a **sample_rank** of 0. Depending on what you have configured **read()** and **take()** to return (by passing in state masks and through the **max_samples_per_read** field in 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571), a **sample_rank** of 0 may or may not be the newest DDS sample that was ever received. It is just the newest DDS sample in the sequence that was returned. The **sample_rank** value could be used by an application to determine that there are newer samples in the sequence and that it might want to skip processing the older samples.
- **generation_rank**: Indicates the difference in 'generations' between the DDS sample and the newest DDS sample of the same instance as returned in the sequence. If a DDS sample belongs to the same generation as the newest DDS sample in the sequence returned by **read()** and **take()**, then **generation_rank** will be 0.
- **absolute_generation_rank**: Indicates the difference in 'generations' between the DDS sample and the newest DDS sample of the same instance ever received by the *DataReader*. Recall that the data sequence returned by **read()** and **take()** may not contain all of the data in the *DataReader*'s receive queue. Thus, a DDS sample that belongs to the newest generation of the instance will have an **absolute_generation_rank** of 0.

By using the **sample_rank**, **generation_rank** and **absolute_generation_rank** information in the **SampleInfo** structure, your application can determine exactly what happened to the instance and thus make appropriate decisions of what to do with the DDS data samples received for the instance. For example:

- A DDS sample with **sample_rank= 0** is the newest DDS sample of the instance in the returned sequence.

- DDS samples that belong to the same generation will have the same **generation_rank** (as well as **absolute_generation_rank**).
- DDS samples with **absolute_generation_rank = 0** belong to the newest generation for the instance received by the *DataReader*.

The 'generation count' and 'rank' values are statistics that are locally generated by each *DataReader* and maintained as part of the metadata for the instance that they refer to. Therefore, if the instance is reclaimed and then returns at a later point in time, these counters will all restart at 0.

8.3.8.3 Valid Data Flag

The **SampleInfo** structure's **valid_data** flag indicates whether the DDS sample contains data or is only used to communicate a change in the **instance_state** of the instance.

Normally, each DDS sample contains both a **SampleInfo** structure and some data. However, there are situations in which the DDS sample only contains the **SampleInfo** and does not have any associated data. This occurs when *Connext DDS* notifies the application of a change of state for an instance for which there is no associated data. An example is when *Connext DDS* detects that an instance has no writers and changes the corresponding **instance_state** to NOT_ALIVE_NO_WRITERS.

If the **valid_data** flag is TRUE, then the DDS sample contains valid data. If the flag is FALSE, the DDS sample contains no data.

To ensure correctness and portability, your application must check the **valid_data** flag prior to accessing the data associated with the DDS sample, and only access the data if it is TRUE. The value of data is undefined when the **valid_data** flag is false.

8.3.8.4 Looking up an Instance Handle

Some operations, such as **read_instance()**, require an **instance_handle** parameter. If you need to get such a handle, you can call the *FooDataReader's* **lookup_instance()** operation, which takes a sample with key fields specified as a parameter and returns a handle to that instance.

```
DDS_InstanceHandle_t lookup_instance (const Foo & key_holder)
```

The instance must have been received by the *DataReader* in order for the *DataReader* to look it up. If the instance is not known to the *DataReader*, this operation returns **DDS_HANDLE_NIL**.

8.3.8.5 Getting the Key Value for an Instance

Once you have an instance handle (using **lookup_instance()**, as part of a status change notification, or through the **SampleInfo**), you can use the *DataReader's* **get_key_value()** operation to retrieve the value of the key of the corresponding instance. The key fields of the data structure passed into **get_key_value()** will be filled out with the original values used to generate the instance handle. The key fields are defined

when the data type is defined; see 2.4 DDS Samples, Instances, and Keys on page 18 for more information.

If you set **propagate_dispose_of_unregistered_instances** to true and wish to call **get_key_value()** for instances for which only a dispose sample has been received, the **serialize_key_with_dispose** field in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388 must be set to true.

8.3.8.6 Instance Resource Limits and Memory Management

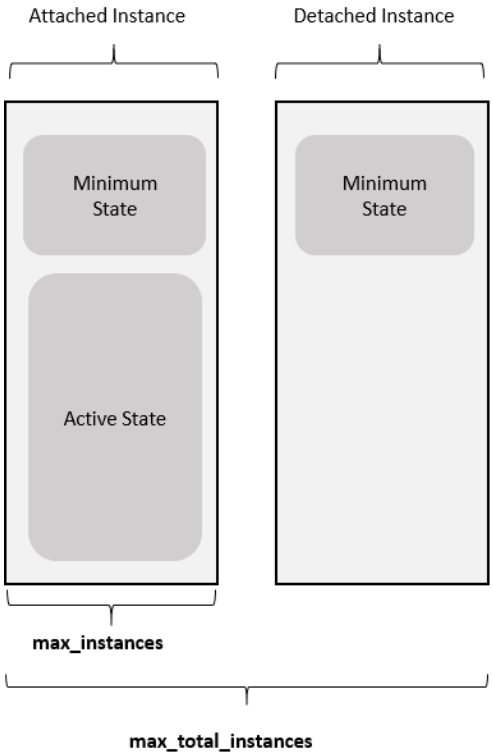
In *Connext DDS*, memory is primarily pre-allocated when creating entities. When data is keyed, the memory associated with each instance used for storing instance-specific metadata is allocated when the *DataReader* is created. Memory is not freed at runtime, unless you delete an entity. Instead, memory is made available to be reused by the *DataReader*, or "reclaimed".

The *DataReader* can receive a number of instances defined by the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 and 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571. It is also important to understand that an instance in the *DataReader* queue has two parts that make up the instance metadata: an active state and a minimum state. The resource limits control the amount of active state and minimum state that should be maintained. (Note: the concept of active and minimum state does not apply to instance metadata in the *DataWriter* queue.)

8.3.8.6.1 Active State and Minimum State

An instance is considered either *attached* or *detached* in the *DataReader* queue and is composed of two parts, which make up the instance metadata: an active state and a minimum state.

Figure 8.13: Active and Minimum Instance States



An instance is considered *attached* when the *DataReader* is actively managing all possible state that can be associated with an instance, including the associated samples, the instance and view states, generation and sample ranks, the list of remote writers that are known to be writing the instance, and so on. Only attached instances can have associated samples. A *DataReader* keeps both the active and the minimum state for attached instances. The sum of the **alive_instance_count**, **disposed_instance_count**, and **no_writers_instance_count** statistics in the 8.3.7.2 DATA_READER_CACHE_STATUS on page 514 reflects the total number of attached instances currently in the *DataReader* queue.

The following is applicable only if **keep_minimum_state_for_instances** in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571 is TRUE (by default, it is). See 8.6.2.2 keep_minimum_state_for_instances on page 577 for more on this QoS setting.

An instance is considered *detached* when the *DataReader* is only maintaining the minimum state for the instance. When instances are replaced or purged from the *DataReader* queue, by default only the active state of the instance is reclaimed. A minimum amount of state for the instance is kept even after the instance is removed in order to maintain system consistency without having to waste resources (memory and CPU) by keeping other information around that is no longer relevant (i.e., the active state). The minimum state is used when instances that have been removed re-enter the system. This can happen, for example, when a non-VOLATILE *DataReader* and *DataWriter* lose liveliness and then re-discover each other. The *DataWriter* will resend its history, but if the *DataReader* has the minimum state information for any instances that it removed during the disconnection, the previously received duplicate samples will be

filtered out and dropped before being accepted into the *DataReader's* queue again. The minimum state includes information such as the last source timestamp, the keyhash, and the list of virtual writers for the instance. In general, you should keep **keep_minimum_state_for_instances** set to true if you are using the Durable Reader State, MultiChannel DataWriters, or *RTI Persistence Service*, or in any system where instances may be removed and then re-enter the system either because the original *DataWriter* is re-discovered or writes the instance again or a new *DataWriter* begins writing the instance.

An instance transitions from what is considered an *attached* instance to a *detached* instance when the instance is removed from the *DataReader* queue (purged or replaced). This can happen under the following conditions:

- The instance is replaced due to the **instance_replacement** settings in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571.
- There are no more samples associated with the instance. Samples can be removed from the *DataReader* queue through the use of the **take()** operation, or various QoS configurations such as a finite lifespan or KEEP_LAST history configuration. In addition, at least one of the following must be true:
  - The instance was in the NOT_ALIVE_NO_WRITERS instance state and **autopurge_nowriter_instances_delay** has expired. (The default value for the **autopurge_nowriter_instances_delay** is 0, so by default instances are purged as soon as the instance is empty and transitions to NOT_ALIVE_NO_WRITERS.)
  - The instance was in the NOT_ALIVE_DISPOSED instance state and the **autopurge_disposed_instances_delay** has expired.

The **detached_instance_count** statistic in the 8.3.7.2 DATA_READER_CACHE_STATUS on page 514 counts the total number of detached instances currently in the *DataReader* queue.

8.3.8.6.2 Instance Resource Limit QoS Policies

The 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 and 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571 include the following fields that affect the number of instances that can be received:

- **max_instances** (7.5.22 RESOURCE_LIMITS QosPolicy on page 449): A resource limit on the number of attached instances that can be managed by *Connext DDS*. By default, **max_instances** is UNLIMITED, so you are bounded only by the physical resources of your system. If the **max_instances** limit has been hit, and a sample is received for a new instance, *Connext DDS* will first attempt to replace an instance according to what you have configured in the **instance_replacement** field in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571. If there are not any replaceable instances (by default empty NOT_ALIVE_DISPOSED and NOT_ALIVE_NO_WRITERS instances are replaceable, and ALIVE instances are not

replaceable), the sample will be lost with the reason LOST_BY_INSTANCES_LIMIT, and not resent by the *DataWriter*. The sum of the **alive_instance_count**, **disposed_instance_count**, and **no_writers_instance_count** statistics in the 8.3.7.2 DATA_READER_CACHE_STATUS on page 514 reflects the total number of attached instances currently in the *DataReader* queue.

- **max_total_instances** (8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571): A resource limit on the combined total number of attached+detached instances that can be managed by *Connext DDS*. This resource limit limits the number of minimum instance states that can be kept by the middleware, and both attached and detached instances require the minimum instance state to be kept. The **detached_instance_count** statistic in the 8.3.7.2 DATA_READER_CACHE_STATUS on page 514 counts the total number of detached instances currently in the *DataReader* queue.
    - When a *DataReader* receives a new instance, *Connext DDS* will check **max_instances**. If **max_instances** is not exceeded, *Connext DDS* will check **max_total_instances**. If **max_total_instances** is exceeded, *Connext DDS* will replace one of the detached instances with the new, attached one. The application could receive duplicate samples for the replaced instance if it becomes alive again.
    - **max_total_instances** should be equal to the number of attached instances you want to keep, plus the number of detached instances you want to keep.

- **keep_minimum_state_for_instances** (8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571): This QoS setting can be used to enable or disable *Connext DDS* from keeping minimum instance information for detached instances. By default, this setting is TRUE. This minimum instance information is useful for the features described earlier in this section. If this QoS setting is FALSE, minimum instance state will not be kept, and therefore detached instances will not be kept.

The **instance_replacement** field in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571 controls whether instances can be replaced to make room for new ones. See 8.6.2.3 Configuring DataReader Instance Replacement on page 578.

The 8.6.3 READER_DATA_LIFECYCLE QoS Policy on page 581 controls whether the *DataReader* can remove data from the queue if instance state becomes **NOT_ALIVE_NO_WRITERS** or **NOT_ALIVE_DISPOSED**.

8.3.9 Setting DataReader QosPolicies

A *DataReader*'s QosPolicies control its behavior. Think of QosPolicies as the 'properties' of a *DataReader*.

The **DDS_DataReaderQos** structure has the following format:

```
DDS_DataWriterQos struct  {
        DDS_DurabilityQosPolicy                 durability;
```

```
        DDS_DeadlineQosPolicy                   deadline;
        DDS_LatencyBudgetQosPolicy              latency_budget;
        DDS_LivelinessQosPolicy                 liveliness;
        DDS_ReliabilityQosPolicy                reliability;
        DDS_DestinationOrderQosPolicy           destination_order;
        DDS_HistoryQosPolicy                    history;
        DDS_ResourceLimitsQosPolicy             resource_limits;
        DDS_UserDataQosPolicy                   user_data;
        DDS_OwnershipQosPolicy                  ownership;
        DDS_TimeBasedFilterQosPolicy            time_based_filter;
        DDS_ReaderDataLifecycleQosPolicy        reader_data_lifecycle;
        DDS_DataRepresentationQosPolicy         representation;
        DDS_TypeConsistencyEnforcementQosPolicy type_consistency;
        DDS_DataTagQosPolicy                    data_tags;
        // extensions to the DDS standard:
        DDS_DataReaderResourceLimitsQosPolicy   reader_resource_limits;
        DDS_DataReaderProtocolQosPolicy         protocol;
        DDS_TransportSelectionQosPolicy         transport_selection;
        DDS_TransportUnicastQosPolicy           unicast;
        DDS_TransportMulticastQosPolicy         multicast;
        DDS_PropertyQosPolicy                   property;
        DDS_ServiceQosPolicy                    service;
        DDS_AvailabilityQosPolicy               availability;
        DDS_EntityNameQosPolicy                 subscription_name;
        DDS_TransportPriorotyQosPolicy          transport_priority;
        DDS_TypeSupportQosPolicy                type_support;
} DDS_DataReaderQos;
```

Note: set_qos() cannot always be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

Table 8.15 DataReader QosPolicies summarizes the meaning of each policy. (They appear alphabetically in the table.) For information on *why* you would want to change a particular QosPolicy, see the referenced section. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 8.15 DataReader QosPolicies

QosPolicy	Description
Availability	This QoS policy is used in the context of two features: • For a Collaborative DataWriter, specifies the group of DataWriters expected to collaboratively provide data and the timeouts that control when to allow data to be available that may skip DDS samples. • For a Durable Subscription, configures a set of Durable Subscriptions on a DataWriter. See 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369.
DataReaderProtocol	This QosPolicy configures the DDS on-the-network protocol, RTPS. See 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565.

Table 8.15 DataReader QosPolicies

QosPolicy	Description
DataReaderResourceLimits	Various settings that configure how *DataReaders* allocate and use physical memory for internal resources. See 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571.
DataRepresentation	Specifies which versions of the Extended Common Data Representation (CDR) are requested. See 7.5.3 DATA_REPRESENTATION QosPolicy on page 379.
DataTag	A sequence of (name, value) string pairs that may be used by the Access Control plugin. See 7.5.4 DATATAG QosPolicy on page 386.
Deadline	For a *DataReader*, it specifies the maximum expected elapsed time between arriving DDS data samples. For a *DataWriter*, it specifies a commitment to publish DDS samples with no greater elapsed time between them. See 7.5.7 DEADLINE QosPolicy on page 404.
DestinationOrder	Controls how *Connext DDS* will deal with data sent by multiple *DataWriters* for the same topic. Can be set to "by reception timestamp" or to "by source timestamp". See 7.5.8 DESTINATION_ORDER QosPolicy on page 406.
Durability	Specifies whether or not *Connext DDS* will store and deliver data that were previously published to new *DataReaders*. See 7.5.9 DURABILITY QosPolicy on page 410.
DurabilityService	Various settings to configure the external *Persistence Service* used by *Connext DDS* for *DataWriters* with a Durability QoS setting of Persistent Durability. See 7.5.10 DURABILITY SERVICE QosPolicy on page 414.
EntityName	Assigns a name to a *DataReader*. See 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416.
History	Specifies how much data must to stored by *Connext DDS* for the *DataWriter* or *DataReader*. This QosPolicy affects the 7.5.21 RELIABILITY QosPolicy on page 444 as well as the 7.5.9 DURABILITY QosPolicy on page 410. See 7.5.12 HISTORY QosPolicy on page 418.
LatencyBudget	Suggestion to *Connext DDS* on how much time is allowed to deliver data. See 7.5.13 LATENCYBUDGET QoS Policy on page 423.
Liveliness	Specifies and configures the mechanism that allows *DataReaders* to detect when *DataWriters* become disconnected or "dead." See 7.5.15 LIVELINESS QosPolicy on page 425.
Property	Stores name/value (string) pairs that can be used to configure certain parameters of *Connext DDS* that are not exposed through formal QoS policies. It can also be used to store and propagate application-specific name/value pairs, which can be retrieved by user code during discovery. See 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.
ReaderDataLifecycle	Controls how a DataReader manages the lifecycle of the data that it has received. See 8.6.3 READER_DATA_LIFECYCLE QoS Policy on page 581.
Reliability	Specifies whether or not *Connext DDS* will deliver data reliably. See 7.5.21 RELIABILITY QosPolicy on page 444.
ResourceLimits	Controls the amount of physical memory allocated for entities, if dynamic allocations are allowed, and how they occur. Also controls memory usage among different instance values for keyed topics. See 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.
Service	Intended for use by RTI infrastructure services. User applications should not modify its value. See 7.5.23 SERVICE QosPolicy (DDS Extension) on page 452.

Table 8.15 DataReader QosPolicies

QosPolicy	Description
TimeBasedFilter	Set by a DataReader to limit the number of new data values received over a period of time. See 8.6.4 TIME_BASED_FILTER QosPolicy on page 583.
TransportMulticast	Specifies the multicast address on which a *DataReader* wants to receive its data. Can specify a port number as well as a subset of the available transports with which to receive the multicast data. See 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586.
TransportPriority	Set by a *DataReader* to tell *Connext DDS* that the data being sent is a different "priority" than other data. See 7.5.26 TRANSPORT_PRIORITY QosPolicy on page 455.
TransportSelection	Allows you to select which physical transports a *DataWriter* or *DataReader* may use to send or receive its data. See 7.5.27 TRANSPORT_SELECTION QosPolicy (DDS Extension) on page 456.
TransportUnicast	Specifies a subset of transports and port number that can be used by an Entity to receive data. See 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458.
TypeConsistencyEnforcement	Defines rules that determine whether the type used to publish a given data stream is consistent with that used to subscribe to it. See 8.6.6 TYPE_CONSISTENCY_ENFORCEMENT QosPolicy on page 589.
TypeSupport	Used to attach application-specific value(s) to a *DataWriter* or *DataReader*. These values are passed to the serialization or deserialization routine of the associated data type. Also controls whether padding bytes are set to 0 during serialization. See 7.5.29 TYPESUPPORT QosPolicy (DDS Extension) on page 461.
UserData	Along with Topic Data QosPolicy and Group Data QosPolicy, used to attach a buffer of bytes to *Connext DDS*'s discovery meta-data. See 7.5.30 USER_DATA QosPolicy on page 462.

For a *DataReader* to communicate with a *DataWriter*, their corresponding QosPolicies must be compatible. For QosPolicies that apply both to the *DataWriter* and the *DataReader*, the setting in the *DataWriter* is considered what the *DataWriter* "offers" and the setting in the *DataReader* is what the DataReader "requests." Compatibility means that what is offered by the *DataWriter* equals or surpasses what is requested by the *DataReader*. See 4.2.1 QoS Requested vs. Offered Compatibility—the RxO Property on page 180.

Some of the policies may be changed after the *DataReader* has been created. This allows the application to modify the behavior of the *DataReader* while it is in use. To modify the QoS of an already-created *DataReader*, use the **get_qos()** and **set_qos()** operations on the *DataReader*. This is a general pattern for all *Entities*, described in 4.1.7.3 Changing the QoS for an Existing Entity on page 175.

8.3.9.1 Configuring QoS Settings when the DataReader is Created

As described in 8.3.1 Creating DataReaders on page 507, there are different ways to create a *DataReader, depending on how you want to specify its QoS (with or without a QoS Profile).*

- In Figure 8.9: Creating a DataReader with Default QosPolicies on page 508, there is an example of how to create a *DataReader* with default QosPolicies by using the special constant, **DDS_DATAREADER_QOS_DEFAULT**, which indicates that the default QoS values for a

DataReader should be used. The default *DataReader* QoS values are configured in the *Subscriber* or *DomainParticipant*; you can change them with **set_default_datareader_qos()** or **set_default_datareader_qos_with_profile()**. Then any *DataReaders* created with the *Subscriber* will use the new default values. As described in 4.1.7 Getting, Setting, and Comparing QosPolicies on page 172, this is a general pattern that applies to the construction of all *Entities*.

- *To create a DataReader with non-default QoS without using a QoS Profile,* see the example code in Figure 8.14: Creating a DataReader with Modified QosPolicies (not from a profile) below. It uses the *Subscriber's* **get_default_reader_qos()** method to initialize a **DDS_DataReaderQos** structure. Then the policies are modified from their default values before the structure is used in the **create_datareader()** method.
- You can also create a *DataReader* and specify its QoS settings via a QoS Profile. To do so, you will call **create_datareader_with_profile()**, as seen in Figure 8.15: Creating a DataReader with a QoS Profile on the next page.
- If you want to use a QoS profile, but then make some changes to the QoS before creating the *DataReader*, call **get_datawriter_qos_from_profile()** and **create_datawriter()** as seen in Figure 8.16: Getting QoS Values from Profile, Changing QoS Values, Creating DataReader with Modified QoS Values on the next page.

For more information, see 7.3.1 Creating DataWriters on page 291 and Configuring QoS with XML (Chapter 19 on page 842).

Notes:

- The examples in this section use the Traditional C++ API; for examples in the Modern C++ API, see the sections "DataReader Use Cases," "Qos Use Cases," and "Qos Provider Use Cases" in the API Reference HTML documentation, under "Programming How-To's."
- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 8.14: Creating a DataReader with Modified QosPolicies (not from a profile)

```
DDS_DataReaderQos reader_qos;
// initialize reader_qos with default values
subscriber->get_default_datareader_qos(reader_qos);
// make QoS changes
reader_qos.history.depth = 5;
// Create the reader with modified qos
DDSDataReader * reader = subscriber->create_datareader(
    topic, reader_qos, NULL, DDS_STATUS_MASK_NONE);
if (reader == NULL) {
    // ... error
}
// narrow it for your specific data type
FooDataReader* foo_reader = FooDataReader::narrow(reader);
```

Figure 8.15: Creating a DataReader with a QoS Profile

```
// Create the datareader
DDSDataReader * reader =
    subscriber->create_datareader_with_profile(
        topic, "MyReaderLibrary", "MyReaderProfile",
        NULL, DDS_STATUS_MASK_NONE);
if (reader == NULL) {
    // ... error
};
// narrow it for your specific data type
FooDataReader* foo_reader = FooDataReader::narrow(reader);
```

Figure 8.16: Getting QoS Values from Profile, Changing QoS Values, Creating DataReader with Modified QoS Values

```
DDS_DataReaderQos reader_qos;
// Get reader QoS from profile
retcode = factory->get_datareader_qos_from_profile(
    reader_qos, "ReaderProfileLibrary", "ReaderProfile");
if (retcode != DDS_RETCODE_OK) {
    // handle error
}
// Makes QoS changes
reader_qos.history.depth = 5;
DDSDataReader * reader = subscriber->create_datareader(
    topic, reader_qos, NULL, DDS_STATUS_MASK_NONE);
if (participant == NULL) {
    // handle error
}
```

8.3.9.2 Comparing QoS Values

The **equals()** operation compares two *DataReader's* DDS_DataReaderQoS structures for equality. It takes two parameters for the two *DataReader's* QoS structures to be compared, then returns TRUE is they are equal (all values are the same) or FALSE if they are not equal.

8.3.9.3 Changing QoS Settings After the DataReader has been Created

There are two ways to change an existing *DataReader's* QoS after it is has been created—again depending on whether or not you are using a QoS Profile.

- To change QoS programmatically (that is, without using a QoS Profile), use **get_qos()** and **set_qos()**. See the example code in Figure 8.17: Changing the QoS of Existing DataReader (without a QoS Profile) on the next page. It retrieves the current values by calling the *DataWriter's* **get_qos()** operation. Then it modifies the value and calls **set_qos()** to apply the new value. Note, however, that some QosPolicies cannot be changed after the *DataWriter* has been enabled—this restriction is

noted in the descriptions of the individual QosPolicies.

- You can also change a *DataReader's* (and all other *Entities*') QoS by using a QoS Profile and calling **set_qos_with_profile()**. For an example, see Figure 8.18: Changing the QoS of Existing DataReader with a QoS Profile below. For more information, see Configuring QoS with XML (Chapter 19 on page 842).

Note:

- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 8.17: Changing the QoS of Existing DataReader (without a QoS Profile)

```
DDS_DataReaderQos reader_qos;
// Get current QoS.
if (datareader->get_qos(reader_qos) != DDS_RETCODE_OK) {
    // handle error
}
// Makes QoS changes here
reader_qos.history.depth = 5;
// Set the new QoS
if (datareader->set_qos(reader_qos) != DDS_RETCODE_OK ) {
    // handle error
}
```

Figure 8.18: Changing the QoS of Existing DataReader with a QoS Profile

```
retcode = reader->set_qos_with_profile(
    "ReaderProfileLibrary","ReaderProfile");
if (retcode != DDS_RETCODE_OK) {
    // handle error
}
```

8.3.9.4 Using a Topic's QoS to Initialize a DataReader's QoS

Several *DataReader* QosPolicies can also be found in the QosPolicies for *Topics* (see 5.1.3 Setting Topic QosPolicies on page 219). The QosPolicies set in the Topic do not directly affect the *DataReaders* (or *DataWriters*) that use that *Topic*. In many ways, some QosPolicies are a *Topic*-level concept, even though the DDS standard allows you to set different values for those policies for different *DataWriters* and *DataReaders* of the same *Topic*. Thus, the policies in the **DDS_TopicQos** structure exist as a way to help centralize and annotate the intended or suggested values of those QosPolicies. *Connext DDS* does not check to see if the actual policies set for a *DataReader* is aligned with those set in the *Topic* to which it is bound.

There are many ways to use the QosPolicies' values set in the *Topic* when setting the QosPolicies' values in a *DataReader*. The most straightforward way is to get the values of policies directly from the *Topic* and

use them in the policies for the *DataReader*, as shown in Figure 8.19: Copying Selected QoS from a Topic when Creating a DataReader below.

Note:

- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 8.19: Copying Selected QoS from a Topic when Creating a DataReader

```
DDS_DataReaderQos reader_qos;
DDS_TopicQos topic_qos;
// topic and publisher already created
// get current QoS for the topic, default QoS for the reader
if (topic->get_qos(topic_qos) != DDS_RETCODE_OK) {
    // handle error
}
if (publisher->get_default_datareader_qos(reader_qos)
    != DDS_RETCODE_OK) {
    // handle error
}
// Copy specific policies from topic QoS to reader QoS
reader_qos.deadline = topic_qos.deadline;
reader_qos.reliability = topic_qos.reliability;
// Create the DataReader with the modified QoS
DDSDataReader* reader = publisher->create_datareader(topic,
   reader_qos,NULL, DDS_STATUS_MASK_NONE);
```

You can use the *Subscriber*'s **copy_from_topic_qos()** operation to copy all of the common policies from the *Topic* QoS to a *DataReader* QoS. This is illustrated in Figure 8.20: Copying all QoS from a Topic when Creating a DataReader below.

Figure 8.20: Copying all QoS from a Topic when Creating a DataReader

```
DDS_DataReaderQos reader_qos;
DDS_TopicQos topic_qos;
// topic, publisher, reader_listener already created
if (topic->get_qos(topic_qos) != DDS_RETCODE_OK) {
// handle error
}
if (publisher->get_default_datareader_qos(reader_qos)
    != DDS_RETCODE_OK)
{
    // handle error
}
// copy relevant QoS from topic into reader's qos
publisher->copy_from_topic_qos(reader_qos, topic_qos);
// Optionally, modify policies as desired
reader_qos.deadline.duration.sec = 1;
reader_qos.deadline.duration.nanosec = 0;
// Create the DataReader with the modified QoS
```

```
DDSDataReader* reader = publisher->create_datareader(topic,
    reader_qos, reader_listener, DDS_STATUS_MASK_ALL);
```

The special macro, DDS_DATAREADER_QOS_USE_TOPIC_QOS, can be used to indicate that the *DataReader* should be created with the QoS that results from modifying the default *DataReader* QoS with the values specified by the *Topic*. See Figure 7.23: Combining Default Topic and DataWriter QoS (Option 1) on page 340 and Figure 7.24: Combining Default Topic and DataWriter QoS (Option 2) on page 341 for examples involving DataWriters. The same pattern applies to *DataReaders*.

For more information on the general use and manipulation of QosPolicies, see 4.1.7 Getting, Setting, and Comparing QosPolicies on page 172.

8.3.10 Navigating Relationships Among Entities

8.3.10.1 Finding Matching Publications

The following *DataReader* operations can be used to get information about the *DataWriters* that will send data to this *DataReader*. A publication consists of information about the *DataWriter* and its associated *Publisher* and *Topic*.

- **get_matched_publications()**
- **get_matched_publication_data()**

The **get_matched_publications()** operation will return a sequence of handles to matched *DataWriters*. You can use these handles in the **get_matched_publication_data()** method to get information about the *DataWriter* such as the values of its QosPolicies, as well as information about its *Publisher* and *Topic*.

Note that *DataWriters* that have been ignored using the *DomainParticipant's* **ignore_publication()** operation are not considered to be matched even if the *DataWriter* has the same *Topic* and compatible QosPolicies. Thus, they will not be included in the list of *DataWriters* returned by **get_matched_publications()**. See 18.4.2 Ignoring Publications and Subscriptions on page 837 for more on **ignore_publication()**.

You can also get the DATA_READER PROTOCOL_STATUS for matching publications with **get_matched_publication_datareader_protocol_status()** (see 8.3.7.3 DATA_READER_PROTOCOL_STATUS on page 517).

Notes:

- The **get_matched_publications()** function includes the return of handles of matched *DataWriters* that are no longer alive. All of the handles returned by this function are valid inputs to the **get_matched_publication_data()** function.
- Status/data for a matched publication is kept even if the matched *DataWriter* is not alive. Status/data for a matched publication will be removed only if the *DataWriter* is gone: that is, the *DataWriter* is

destroyed and this change is propagated through a discovery update, or the *DataWriter's DomainParticipant* is gone (either gracefully or its liveliness expired and *Connext DDS* is configured to purge not-alive participants). Once a matched *DataWriter* is gone, its status is deleted. If you try to get the status/data for a matched *DataWriter* that is gone, the 'get status' or ' get data' call will return an error.

- If you want to know which matched *DataWriters* are not alive, use **is_matched_publication_alive()**. See Table 8.3 DataReader Operations on page 502.
- The **get_matched_publication_data()** operation does not retrieve the **type_code** information from built-in-topic data structures. This information is available through the **on_data_available()** callback (if a DataReaderListener is installed on the PublicationBuiltinTopicDataDataReader).

See also: 8.3.10.2 Finding the Matching Publication's ParticipantBuiltinTopicData below

8.3.10.2 Finding the Matching Publication's ParticipantBuiltinTopicData

get_matched_publication_participant_data() allows you to get the DDS_ParticipantBuiltinTopicData (see Table 18.1 Participant Built-in Topic's Data Type (DDS_ParticipantBuiltinTopicData)) of a matched publication using a publication handle.

This operation retrieves the information on a discovered *DomainParticipant* associated with the publication that is currently matching with the *DataReader*.

The publication handle passed into this operation must correspond to a publication currently associated with the *DataReader*. Otherwise, the operation will fail with RETCODE_BAD_PARAMETER. The operation may also fail with RETCODE_PRECONDITION_NOT_MET if the publication handle corresponds to the same *DomainParticipant* to which the *DataReader* belongs.

Use **get_matched_publications()** (see 8.3.10.1 Finding Matching Publications on the previous page) to find the publications that are currently matched with the *DataReader*.

8.3.10.3 Finding a DataReader's Related Entities

These *DataReader* operations are useful for obtaining a handle to various related entities:

- **get_subscriber()**
- **get_topicdescription()**

The **get_subscriber()** operation returns the *Subscriber* that created the *DataReader*. **get_topicdescription()** returns the *Topic* with which the *DataReader* is associated.

8.3.10.4 Looking Up an Instance Handle

Some operations, such as **read_instance()** and **take_instance()**, take an **instance_handle** parameter. If you need to get such as handle, you can call the **lookup_instance()** operation, which takes an instance as a

parameter and returns a handle to that instance.

8.3.10.5 Getting the Key Value for an Instance

If you have a handle to a data-instance, you can use the **FooDataReader**'s **get_key_value()** operation to retrieve the key for that instance. The value of the key is decomposed into its constituent fields and returned in a **Foo** structure. For information on keys and keyed data types, please see 2.4 DDS Samples, Instances, and Keys on page 18.

8.4 Using DataReaders to Access Data (Read & Take)

For user applications to access the data received for a *DataReader*, they must use the type-specific derived class or set of functions in the C API. Thus for a user data type '**Foo**', you must use methods of the **FooDataReader** class. The type-specific class or functions are automatically generated if you use *RTI Code Generator*. Else, you will have to create them yourself, see 3.2.8 Type Codes for Built-in Types on page 74 for more details.

8.4.1 Using a Type-Specific DataReader (FooDataReader)

> This section doesn't apply to the Modern C++ API, where a *DataReader*'s data type is part of its template definition: **DataReader<*Foo*>**.

Using a *Subscriber* you will create a *DataReader* associating it with a specific data type, for example '**Foo**'. Note that the *Subscriber*'s **create_datareader()** method returns a generic *DataReader*. When your code is ready to access *DDS* data samples received for the *DataReader*, you must use type-specific operations associated with the **FooDataReader,** such as **read()** and **take()**.

To cast the generic *DataReader* returned by **create_datareader()** into an object of type **FooDataReader**, you should use the type-safe **narrow()** method of the **FooDataReader** class. **narrow()** will make sure that the generic *DataReader* passed to it is indeed an object of the **FooDataReader** class before it makes the cast. Else, it will return NULL. Figure 8.8: Simple SubscriberListener on page 499 shows an example:

```
Foo_reader = FooDataReader::narrow(reader);
```

Table 8.3 DataReader Operations lists type-specific operations using a **FooDataReader**. Also listed are generic, non-type specific operations that can be performed using the base class object **DDSDataReader** (or **DDS_DataReader** in C). In C, you must pass a pointer to a **DDS_DataReader** to those generic functions.

8.4.2 Loaning and Returning Data and SampleInfo Sequences

8.4.2.1 C, Traditional C++, Java and .NET

The **read()** and **take()** operations (and their variations) return information to your application in two sequences:

- Received *DDS* data samples in a sequence of the data type
- Corresponding information about each DDS sample in a **SampleInfo** sequence

These sequences are parameters that are passed by your code into the **read()** and **take()** operations. If you use empty sequences (sequences that are initialized but have a maximum length of 0), *Connext DDS* will fill those sequences with memory directly loaned from the receive queue itself. There is no copying of the data or of **SampleInfo** when the contents of the sequences are loaned. This is certainly the most efficient way for your code to retrieve the data.

However when you do so, your code must return the loaned sequences back to *Connext DDS* so that they can be reused by the receive queue. If your code does not return the loan by calling the **FooDataReader**'s **return_loan()** method, then *Connext DDS* will eventually run out of memory to store *DDS* data samples received from the network for that *DataReader*. See Figure 8.21: Using Loaned Sequences in read() and take() below for an example of borrowing and returning loaned sequences.

```
DDS_ReturnCode_t return_loan(
    FooSeq &received_data, DDS_SampleInfoSeq &info_seq);
```

Figure 8.21: Using Loaned Sequences in read() and take()

```
// In C++ and Java, sequences are automatically initialized
// to be empty
FooSeq data_seq;
DDS_SampleInfoSeq info_seq;
DDS_ReturnCode_t retcode;
...
// with empty sequences, a take() or read() will return loaned
// sequence elements
retcode = Foo_reader->take(data_seq, info_seq,
       DDS_LENGTH_UNLIMITED, DDS_ANY_SAMPLE_STATE,
       DDS_ANY_VIEW_STATE, DDS_ANY_INSTANCE_STATE);
       ... // process the returned data
// must return the loaned sequences when done processing
Foo_reader->return_loan(data_seq, info_seq);
...
```

For the C API, you must use the **FooSeq_initialize()** and **DDS_SampleInfoSeq_initialize()** operations or the macro DDS_SEQUENCE_INITIALIZER to initialize the FooSeq and DDS_SampleInfoSeq to be empty. For example, DDS_SampleInfoSeq infoSeq; DDS_SampleInfoSeq_initialize(&infoSeq); or FooSeq fooSeq = DDS_SEQUENCE_INITIALIZER;

If your code provides its own sequences to the read/take operations, then *Connext DDS* will copy the data from the receive queue. In that case, you do not have to call **return_loan()** when you are finished with the data. However, you must make sure the following is true, or the read/take operation will fail with a return code of **DDS_RETCODE_PRECONDITION_NOT_MET**:

- The **received_data** of type **FooSeq** and **info_seq** of type **DDS_SampleInfoSeq** passed in as parameters have the same maximum size (length).
- The maximum size (length) of the sequences are less than or equal to the passed in parameter, **max_samples**.

8.4.2.2 Modern C++

The **read()** and **take()** operations (and their variations) return LoanedSamples, an iterable collection of loaned, read-only samples each containing the actual data and meta-information about the sample.
A LoanedSamples collection automatically returns the loan to the middleware in its destructor. You can also explicitly call **LoanedSamples::return_loan()**.

Figure 8.22: Using LoanedSamples to read data

```
dds::sub::LoanedSamples<Foo> samples = reader.take();
for (auto sample : samples) { // process the data
    if (sample.info().valid()) {
        std::cout << sample.data() << std::endl;
    }
}
```

8.4.3 Accessing DDS Data Samples with Read or Take

To access the *DDS* data samples that *Connext DDS* has received for a *DataReader*, you must invoke the **read()** or **take()** methods. These methods return a list (sequence) of *DDS* data samples and additional information about the DDS samples in a corresponding list (sequence) of **SampleInfo** structures. The contents of **SampleInfo** are described in 8.4.6 The SampleInfo Structure on page 560.

Calling **read()**, **take()**, or one of their variations resets the **DATA_AVAILABLE** status.

The way *Connext DDS* builds the collection of DDS samples depends on QoS policies set on the DataReader and Subscriber, the **source_timestamp** of the DDS samples, and the **sample_states**, **view_states**, and **instance_states** parameters passed to the read/take operation.

In **read()** and **take()**, you may enter parameters so that *Connext DDS* selectively returns *DDS* data samples currently stored in the *DataReader's* receive queue. You may want *Connext DDS* to return all of the data in a single list or only a subset of the available DDS samples as configured using the **sample_states**, **view_*Connext DDS*states**, and **instance_states** masks. 8.4.6 The SampleInfo Structure on page 560 describes how these masks are used to determine which *DDS* data samples should be returned.

8.4.3.1 Read vs. Take

The difference between **read()** and **take()** is how *Connext DDS* treats the data that is returned. With **take()**, *Connext DDS* will remove the data from the *DataReader*'s receive queue. The data returned by *Connext DDS* is no longer stored by *Connext DDS*. With **read()**, *Connext DDS* will continue to store the data in the *DataReader*'s receive queue. The same data may be read again until it is taken in subsequent **take()**

calls. Note that the data stored in the *DataReader*'s receive queue may be overwritten, even if it has not been read, depending on the setting of the 7.5.12 HISTORY QosPolicy on page 418.

The **read()** and **take()** operations are non-blocking calls, so that they may return no data (**DDS_RETCODE_NO_DATA**) if the receive queue is empty or has no data that matches the criteria specified by the **StateMasks**.

The **read_w_condition()** and **take_w_condition()** operations take a ReadCondition as a parameter instead of DDS sample, view or instance states. The only DDS samples returned will be those for which the ReadCondition is TRUE. These operations, in conjunction with ReadConditions and a WaitSet, allow you to perform 'waiting reads.' For more information, see 4.6.7 ReadConditions and QueryConditions on page 209.

As you will see, **read** and **take** have the same parameters:

```
DDS_ReturnCode_t read( FooSeq &received_data_seq,
                       DDS_SampleInfoSeq &info_seq,
                       DDS_Long max_samples,
                       DDS_SampleStateMask sample_states,
                       DDS_ViewStateMask view_states,
                       DDS_InstanceStateMask instance_states);

DDS_ReturnCode_t take( FooSeq &received_data_seq,
                       DDS_SampleInfoSeq &info_seq,
                       DDS_Long max_samples,
                       DDS_SampleStateMask sample_states,
                       DDS_ViewStateMask view_states,
                       DDS_InstanceStateMask instance_states);
```

Note: These operations may loan internal *Connext DDS* memory, which must be returned with **return_loan()**. See 8.4.2 Loaning and Returning Data and SampleInfo Sequences on page 548.

Both operations return an ordered collection of DDS data samples (in the **received_data_seq** parameter) and information about each DDS sample (in the **info_seq** parameter). Exactly how they are ordered depends on the setting of the 7.4.6 PRESENTATION QosPolicy on page 361 and the 7.5.8 DESTINATION_ORDER QosPolicy on page 406. For more details please see the API Reference HTML documentation for **read()** and **take()**.

In **read()** and **take()**, you can use the **sample_states**, **view_states**, and **instance_states** parameters to specify properties that are used to select the actual DDS samples that are returned by those methods. With different combinations of these three parameters, you can direct *Connext DDS* to return all DDS data samples, DDS data samples that you have not accessed before, the DDS data samples of instances that you have not seen before, DDS data samples of instances that have been disposed, etc. The possible values for the different states are described both in the API Reference HTML documentation and in 8.4.6 The SampleInfo Structure on page 560.

Table 8.16 Read and Take Operations lists the variations of the **read()** and **take()** operations.

Table 8.16 Read and Take Operations

Read Operations	Take Operations	Modern C++[1]	Description	Reference
read	take	reader.read() or reader.select() .state(...) .read()	Reads/takes a collection of DDS data samples from the *DataReader*. Can be used for both keyed and non-keyed data types.	8.4.3 Accessing DDS Data Samples with Read or Take on page 550
read_instance	take_instance	reader.select() .instance(...) .read()	Identical to **read()** and **take()**, but all returned DDS samples belong to a single instance, which you specify as a parameter. Can only be used with keyed data types.	8.4.3.4 read_instance and take_instance on page 554
read_instance_w_condition	take_instance_w_condition	reader.select() .instance() .condition(...) .read()	Identical to **read_instance()** and **take_instance()**, but all returned DDS samples belong to the single specified instance *and* satisfy the specified ReadCondition.	8.4.3.7 read_instance_w_condition and take_instance_w_condition on page 556
read_next_instance	take_next_instance	reader.select ().next_instance (...).read()	Similar to **read_instance()** and **take_instance()**, but the actual instance is not directly specified as a parameter. Instead, the DDS samples will all belong to instance ordered after the instance that is specified by the previous_handle parameter.	8.4.3.5 read_next_instance and take_next_instance on page 554
read_next_instance_w_condition	take_next_instance_w_condition	reader.select() .next_instance (...) .condition(...) .read()	Accesses a collection of DDS data samples of the next instance that match a specific set of ReadConditions, from the *DataReader*.	8.4.3.8 read_next_instance_w_condition and take_next_instance_w_condition on page 557
read_next_sample	take_next_sample	reader.select() .state (DataState::not_read())	Provides a convenient way to access the next DDS DDS sample in the receive queue that has not been accessed before.	8.4.3.3 read_next_sample and take_next_sample on the next page
read_w_condition	take_w_condition	reader.select() .condition(...)	Accesses a *collection* of DDS data samples from the *DataReader* that match specific ReadCondition criteria.	8.4.3.6 read_w_condition and take_w_condition on page 556

8.4.3.2 General Patterns for Accessing Data

Once the DDS data samples are available to the data readers, the DDS samples can be read or taken by the application. The basic rule is that the application may do this in any order it wishes. This approach is very flexible and allows the application ultimate control.

To access data coherently, or in order, the 7.4.6 PRESENTATION QosPolicy on page 361 must be set properly.

[1]For the Modern C++, only the read() operation is shown; the take() variant is parallel.

Accessing DDS samples If No Order or Coherence Is Required

Simply access the data by calling read/take on each *DataReader* in any order you want.

You do not have to call **begin_access()** and **end_access()**. However, doing so is not an error and it will have no effect.

You can call the *Subscriber's***get_datareaders()** operation to see which *DataReaders* have data to be read, but you do not need to read all of them or read them in a particular order. The **get_datareaders()** operation will return a logical 'set' in the sense that the same *DataReader* will not appear twice. The order of the *DataReaders* returned is not specified.

Accessing DDS samples within a SubscriberListener

This case describes how to access the data inside the listener's **on_data_on_readers()** operation (regardless of the PRESENTATION QoS policy settings).

To do so, you can call read/take on each *DataReader* in any order. You can also delegate accessing of the data to the DataReaderListeners by calling the *Subscriber's***notify_datareaders()** operation.

Similar to the previous case, you can still call the Subscriber's **get_datareaders()** operation to determine which *DataReaders* have data to be read, but you do not have to read all of them, or read them in a particular order. **get_datareaders()** will return a logical 'set.'

You do not have to call **begin_access()** and **end_access()**. However, doing so is not an error and it will have no effect.

8.4.3.3 read_next_sample and take_next_sample

The **read_next_sample()** or **take_next_sample()** operation is used to retrieve the next DDS sample that hasn't already been accessed. It is a simple way to 'read' DDS samples and frees your application from managing sequences and specifying DDS sample, instance or view states. It behaves the same as calling **read()** or **take()** with **max_samples** = **1**, **sample_states** = **NOT_READ**, **view_states** = **ANY_VIEW_STATE**, and **instance_states** = **ANY_INSTANCE_STATE**.

```
DDS_ReturnCode_t read_next_sample(
       Foo & received_data, DDS_SampleInfo & sample_info);
DDS_ReturnCode_t take_next_sample(
       Foo & received_data, DDS_SampleInfo & sample_info);
```

It copies the next, not-previously-accessed data value from the *DataReader*. It also copies the DDS sample's corresponding **DDS_SampleInfo** structure.

If there is no unread data in the *DataReader*, the operation will return **DDS_RETCODE_NO_DATA** and nothing is copied.

Since this operation copies both the DDS data sample and the **SampleInfo** into user-provided storage, it does not allocate nor loan memory. You do not have to call **return_loan()** after this operation.

Note: If the **received_data** parameter references a structure that contains a sequence and that sequence has not been initialized, the operation will return **DDS_RETCODE_ERROR**.

8.4.3.4 read_instance and take_instance

The **read_instance()** and **take_instance()** operations are identical to **read()** and **take()**, but they are used to access DDS samples for just a specific instance (key value). The parameters are the same, except you must also supply an instance handle. These functions can only be used when the *DataReader* is tied to a keyed type, see 2.4 DDS Samples, Instances, and Keys on page 18 for more about keyed data types.

These operations may return BAD_PARAMETER if the instance handle does not correspond to an existing data-object known to the *DataReader*.

The handle to a particular data instance could have been cached from a previous **read()** operation (value taken from the **SampleInfo** struct) or created by using the *DataReader*'s **lookup_instance()** operation.

```
DDS_ReturnCode_t read_instance(
       FooSeq &received_data,
       DDS_SampleInfoSeq &info_seq,
       DDS_Long max_samples,
        const DDS_InstanceHandle_t &a_handle,
       DDS_SampleStateMask sample_states,
       DDS_ViewStateMask view_states,
       DDS_InstanceStateMask instance_states);
```

Note: This operation may loan internal *Connext DDS* memory, which must be returned with **return_loan()**. See 8.4.2 Loaning and Returning Data and SampleInfo Sequences on page 548.

8.4.3.5 read_next_instance and take_next_instance

The **read_next_instance()** and **take_next_instance()** operations are similar to **read_instance()** and **take_instance()** in that they return DDS samples for a specific data instance (key value). The difference is that instead of passing the handle of the data instance for which you want DDS data samples, instead you pass the handle to a 'previous' instance. The returned DDS samples will all belong to the 'next' instance, where the ordering of instances is explained below.

```
DDS_ReturnCode_t read_next_instance(
       FooSeq &received_data,
       DDS_Long max_samples,
       const DDS_InstanceHandle_t &previous_handle
       DDS_SampleStateMask sample_states,
       DDS_ViewStateMask view_states,
       DDS_InstanceStateMask instance_states)
```

Connext DDS orders all instances relative to each other. This ordering depends on the value of the key as defined for the data type associated with the *Topic*. For the purposes of this discussion, it is 'as if' each

instance handle is represented by a unique integer and thus different instance handles can be ordered by their value. (The ordering of the instances is specific to each implementation of the DDS standard; to maximize the portability of your code, do not assume any particular order. In the case of Connext DDS, and likely other DDS implementations, the order is not likely to be meaningful to you as a developer; it is simply important that some ordering exists.)

This operation will return values for the *next* instance handle that has DDS data samples stored in the receive queue (that meet the criteria specified by the **StateMasks**). The *next* instance handle will be ordered after the **previous_handle** that is passed in as a parameter.

The special value **DDS_HANDLE_NIL** can be passed in as the **previous_handle**. Doing so, you will receive values for the "smallest" instance handle that has DDS data samples stored in the receive queue that you have not yet accessed.

You can call the **read_next_instance()** operation with a **previous_handle** that does not correspond to an instance currently managed by the *DataReader*. For example, you could use this approach to iterate though all the instances, take all the DDS samples with a NOT_ALIVE_NO_WRITERS instance_state, return the loans (at which point the instance information may be removed, and thus the handle becomes invalid), and then try to read the next instance.

The example below shows how to use **take_next_instance()** iteratively to process all the data received for an instance, one instance at a time. We always pass in DDS_HANDLE_NIL as the value of **previous_handle**. Each time through the loop, we will receive DDS samples for a different instance, since the previous time through the loop, all of the DDS samples of the previous instance were returned (and thus accessed).

In the C API, you must use the **FooSeq_initialize()** and **DDS_SampleInfoSeq_initialize()** operations or the macro DDS_SEQUENCE_INITIALIZER to initialize the FooSeq and DDS_SampleInfoSeq to be empty. For example, DDS_SampleInfoSeq infoSeq; DDS_SampleInfoSeq_initialize(&infoSeq); or FooSeq fooSeq = DDS_SEQUENCE_INITIALIZER;

```
FooSeq received_data;
DDS_SampleInfoSeq info_seq;
while (retcode = reader->take_next_instance(received_data, info_seq,
                        DDS_LENGTH_UNLIMITED, DDS_HANDLE_NIL,
                        DDS_ANY_SAMPLE_STATE, DDS_ANY_VIEW_STATE,
                        DDS_ANY_INSTANCE_STATE)
                        != DDS_RETCODE_NO_DATA) {
       // the data samples returned in received_data will all
       // be for a single instance
       // process the data
       // now return the loaned sequences
       if (reader->return_loan(received_data, info_seq)
       != DDS_RETCODE_OK) {
              // handle error
       }
}
```

Note: This operation may loan internal *Connext DDS* memory, which must be returned with **return_loan ()**. See 8.4.2 Loaning and Returning Data and SampleInfo Sequences on page 548.

8.4.3.6 read_w_condition and take_w_condition

The **read_w_condition()** and **take_w_condition()** operations are identical to **read()** and **take()**, but instead of passing in the sample_states, view_states, and instance_states mask parameters directly, you pass in a ReadCondition (which specifies these masks).

```
DDS_ReturnCode_t read_w_condition (
               FooSeq &received_data,
               DDS_SampleInfoSeq &info_seq,
               DDS_Long max_samples,
                DDSReadCondition *condition)
```

Note: This operation may loan internal *Connext DDS* memory, which must be returned with **return_loan ()**. See 8.4.2 Loaning and Returning Data and SampleInfo Sequences on page 548.

8.4.3.7 read_instance_w_condition and take_instance_w_condition

The **read_instance_w_condition()** and **take_instance_w_condition()** operations are similar to **read_ instance()** and **take_instance()**, respectively, except that the returned DDS samples must also satisfy a specified ReadCondition.

```
DDS_ReturnCode_t read_instance_w_condition(
               FooSeq & received_data,
               DDS_SampleInfoSeq & info_seq,
               DDS_Long max_samples,
               const DDS_InstanceHandle_t & a_handle,
               DDSReadCondition * condition);
```

The behavior of **read_instance_w_condition()** and **take_instance_w_condition()** follows the same rules as **read()** and **take()** regarding pre-conditions and post-conditions for the **received_data** and **sample_info** parameters.

These functions can only be used when the *DataReader* is tied to a keyed type, see 2.4 DDS Samples, Instances, and Keys on page 18 for more about keyed data types.

Similar to **read()**, these operations must be provided on the specialized class that is generated for the particular application data-type that is being accessed.

Note: These operations may loan internal *Connext DDS* memory, which must be returned with **return_loan()**. See 8.4.2 Loaning and Returning Data and SampleInfo Sequences on page 548.

8.4.3.8 read_next_instance_w_condition and take_next_instance_w_condition

The **read_next_instance_w_condition()** and **take_next_instance_w_condition()** operations are identical to **read_next_instance()** and **take_next_instance()**, but instead of passing in the sample_states, view_states, and instance_states mask parameters directly, you pass in a ReadCondition (which specifies these masks).

```
DDS_ReturnCode_t read_next_instance_w_condition (
                FooSeq &received_data,
                 DDS_SampleInfoSeq &info_seq,
                DDS_Long max_samples,
                const DDS_InstanceHandle_t &previous_handle,
                DDSReadCondition *condition)
```

Note: This operation may loan internal *Connext DDS* memory, which must be returned with **return_loan()**. See 8.4.2 Loaning and Returning Data and SampleInfo Sequences on page 548.

8.4.3.9 The select() API (Modern C++)

The Modern C++ API combines all the previous ways to read data into a single operation: **reader.select()**.This call is followed by one or more calls to functions that configure the query and always ends in a call to **read()** or **take()**. These are the functions that configure a **select()**:

Function	Description	Default
max_samples()	Specifies the maximum number of samples to read or take in this call	Up to the value specified in max_samples_per_read on page 572
instance()	Specifies an instance to read or take	All instances
next_instance()	Indicates that read or take should return samples for the instance that follows the one being passed (Note: both next_instance() and instance() can't be specified at the same time)	All instances
state()	Specifies the sample state, view state and instance state	All samples
content()	Specifies a query on the data values to read	All samples
condition()	Specifies a condition (see read_w_condition()). If condition() is specified state() and content()cannot be specified. When running a query more than once on the same DataReader, it is more efficient to create a QueryCondition and pass it to condition() rather than using content().	All samples

To read or take using the default options, simply call **reader.read()** or **reader.take()** with no arguments.

The following example shows how to call **select()**:

```
dds::sub::LoanedSamples<Foo> samples =
    reader.select()
        .max_samples(20)
        .state(dds::sub::status::DataState::new_instance())
        .content(dds::sub::Query(reader, "x > 10"))
        .instance(my_instance_handle)
        .take();
```

8.4.4 Acknowledging DDS Samples

DDS samples can be acknowledged one at a time, or as a group.

To explicitly acknowledge a single DDS sample:

```
DDS_ReturnCode_t acknowledge_sample (
               const DDS_SampleInfo & sample_info);
DDS_ReturnCode_t acknowledge_sample (
               const DDS_SampleInfo & sample_info,
               const DDS_AckResponseData_t & response_data);
```

Or you may acknowledge all previously accessed DDS samples by calling:

```
DDS_ReturnCode_t DDSDataReader::acknowledge_all ()
DDS_ReturnCode_t DDSDataReader::acknowledge_all (
               const DDS_AckResponseData_t & response_data)
```

Where:

sample_info	is of type DDS_SampleInfo, identifying the DDS sample being acknowledged
response_data	is response data sent to the DataWriter upon acknowledgment

These operations can only be used when the *DataReader's* 7.5.21 RELIABILITY QosPolicy on page 444 has an **acknowledgment_kind** set to DDS_APPLICATION_EXPLICIT_ACKNOWLEDGMENT_MODE. You must also set **max_app_ack_response_length** (in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571) to a value greater than zero.

See also: 7.3.12 Application Acknowledgment on page 316 and Guaranteed Delivery of Data (Chapter 14 on page 746).

8.4.5 The Sequence Data Structure

(This section doesn't apply to the Modern C++ API)

The DDS specification uses sequences whenever a variable-length array of elements must be passed through the API. This includes passing QosPolicies into *Connext DDS*, as well as retrieving DDS data samples from *Connext DDS*. A sequence is an ordered collection of elements of the same type. The type

of a sequence containing elements of type "**Foo**" (whether "**Foo**" is one of your types or a built-in *Connext DDS* type) is typically called "**FooSeq**."

In all APIs except Java, **FooSeq** contains deep copies of **Foo** elements; in Java, which does not provide direct support for deep copy semantics, **FooSeq** contains references to **Foo** objects. In Java, sequences implement the **java.util.List** interface, and thus support all of the collection APIs and idioms familiar to Java programmers.

A sequence is logically composed of three things: an array of elements, a *maximum* number of elements that the array may contain (i.e. its allocated size), and a logical *length* indicating how many of the allocated elements are valid. The length may vary dynamically between 0 and the maximum (inclusive); it is not permissible to access an element at an index greater than or equal to the length.

A sequence may either "own" the memory associated with it, or it may "borrow" that memory. If a sequence owns its own memory, then the sequence itself will allocate the its memory and is permitted to grow and shrink that memory (i.e. change its maximum) dynamically.

You can also loan a sequence of memory using the sequence-specific operations **loan_contiguous()** or **loan_discontiguous()**. This is useful if you want *Connext DDS* to copy the received DDS data samples directly into data structures allocated in user space.

Please do not confuse (a) the user loaning memory to a sequence with (b) *Connext DDS* loaning internal memory from the receive queue to the user code via the **read()** or **take()** operations. For sequences of user data, these are complementary operations. **read()** and **take()** loan memory to the user, passing in a sequence that has been loaned memory with **loan_contiguous()** or **loan_discontinguous()**.

A sequence with loaned of memory may not change its maximum size.

For C developers:

In C, because there is no concept of a constructor, sequences must be initialized before they are used. You can either set a sequence equal to the macro **DDS_SEQUENCE_INITIALIZER** or use a sequence-specific method, **<*type*>Seq_initialize()**, to initialize sequences.

For Traditional C++, C++/CLI, and C# developers:

Traditional C++ sequence classes overload the **[ ]** operators to allow you to access their elements as if the sequence were a simple array. However, for code portability reasons, *Connext DDS*'s Traditional C++ implementation of sequences does not use the Standard Template Library (STL).

For Java developers:

In Java, sequences implement the **List** interface, and typically, a **List** must contain **Objects**; it cannot contain primitive types directly. This restriction makes **Lists** of primitives types less efficient because each type must be wrapped and unwrapped into and from an **Object** as it is added to and removed from the **List**.

Connext DDS provides a more efficient implementation for sequences of primitive types. In *Connext DDS*, primitive sequence types (e.g., **IntSeq, FloatSeq, etc.**) are implemented as wrappers around arrays of primitive types. The wrapper also provides the usual **List** APIs; however, these APIs manipulate **Objects** that store the primitive type.

More efficient APIs are also provided that manipulate the primitive types directly and thus avoid unnecessary memory allocations and type casts. These additional methods are named according to the pattern *<standard method><primitive type>*; for example, the **IntSeq** class defines methods **addInt()** and **getInt()** that correspond to the **List** APIs **add()** and **get()**. **addInt()** and **getInt()** directly manipulate **int** values while **add()** and **get()** manipulate **Objects** that contain a single **int**.

For more information on sequence APIs in all languages, please consult the API Reference HTML documentation (from the main page, select **Modules**, **RTI Connext DDS API Reference**, **Infrastructure Module**, **Sequence Support**).

8.4.6 The SampleInfo Structure

When you invoke the **read**/**take** operations, for every DDS data sample that is returned, a corresponding **SampleInfo** is also returned. **SampleInfo** structures provide you with additional information about the DDS data samples received by *Connext DDS*.

Table 8.17 DDS_SampleInfo Structure shows the format of the **SampleInfo** structure.

Table 8.17 DDS_SampleInfo Structure

Type	Field Name	Description
DDS_SampleStateKind	sample_state	See 8.4.6.2 Sample States on page 563
DDS_ViewStateKind	view_state	See 8.4.6.3 View States on page 564
DDS_InstanceStateKind	instance_state	See 8.3.8.1 Instance States on page 530
DDS_Time_t	source_timestamp	Time stored by the *DataWriter* when the DDS sample was written.
DDS_InstanceHandle_t	instance_handle	Handle to the data-instance corresponding to the DDS sample.
DDS_InstanceHandle_t	publication_handle	Local handle to the *DataWriter* that modified the instance. This is the same instance handle returned by **get_matched_publications()**. You can use this handle when calling **get_matched_publication_data()**.

Table 8.17 DDS_SampleInfo Structure

Type	Field Name	Description
DDS_Long	disposed_generation_count	See 8.3.8.2 Generation Counts and Ranks on page 532.
	no_writers_generation_count	
	sample_rank	
	generation_rank	
	absolute_generation_rank	
DDS_Boolean	valid_data	Indicates whether the DDS data sample includes valid data. See 8.3.8.3 Valid Data Flag on page 534.
DDS_Time_t	reception_timestamp	Time stored when the DDS sample was committed by the *DataReader*. See 8.4.6.1 Reception Timestamp on page 563.
DDS_SequenceNumber_t	publication_sequence_number	Publication sequence number assigned when the DDS sample was written by the *DataWriter*.
DDS_SequenceNumber_t	reception_sequence_number	Reception sequence number assigned when the DDS sample was committed by the *DataReader*. See 8.4.6.1 Reception Timestamp on page 563.
struct DDS_GUID_t	original_publication_virtual_guid	Original publication virtual GUID. If the *Publisher's* **access_scope** is GROUP, this field contains the *Publisher* virtual GUID that uniquely identifies the *DataWriter* group.
struct DDS_SequenceNumber_t	original_publication_virtual_sequence_number	Original publication virtual sequence number. If the *Publisher's* **access_scope** is GROUP, this field contains the *Publisher* virtual sequence number that uniquely identifies a DDS sample within the *DataWriter* group.
DDS_GUID_t	topic_query_guid	The GUID of the DDS_TopicQuery that is related to the sample. This GUID indicates whether a sample is part of the response to a DDS_TopicQuery or a regular ("live") sample: If the sample was written for the TopicQuery stream, this field contains the GUID of the target TopicQuery. If the sample was written for the live stream, this field will be set to DDS_GUID_UNKNOWN.

Table 8.17 DDS_SampleInfo Structure

Type	Field Name	Description
DDS_Long	flag	Flags associated with the DDS sample; set by using the **flag** field in DDS_WriteParams_t when writing a DDS sample with **FooDataWriter_write_w_params()** (see 7.3.8 Writing Data on page 308). RTI reserves least-significant bits [0-7] for middleware-specific usage. The application can use least significant bits [8-15]. The first bit, REDELIVERED_SAMPLE, is reserved to mark a DDS sample as redelivered when using RTI Queuing Service. The second bit, INTERMEDIATE_REPLY_SEQUENCE_SAMPLE, is used to indicate that a response DDS sample is not the last response DDS sample for a given request. This bit is usually set by Connext DDS Repliers sending multiple responses for a request. The third bit, REPLICATE_SAMPLE, indicates if a sample must be broadcast by one Queuing Service replica to other replicas. The fourth bit, LAST_SHARED_READER_QUEUE_SAMPLE, indicates that a sample is the last sample in a SharedReaderQueue for a QueueConsumer DataReader. The fifth bit, INTERMEDIATE_TOPIC_QUERY_SAMPLE, indicates that a sample for a TopicQuery will be followed by more samples. This flag only applies to samples that have been published as a response to a TopicQuery. When this bit is not set and topic_query_guid is different from GUID_UNKNOWN, this sample is the last sample for that TopicQuery coming from the *DataWriter* identified by original_publication_virtual_guid on the previous page. The sixth bit, WRITER_REMOVED_BATCH_SAMPLE, will be set if the sample was accepted into the *DataReader* queue even though it was marked by the *DataWriter* as removed. Examples of removed samples in a batch are samples that were replaced due to KEEP_LAST_HISTORY_QOS on the *DataWriter* (see 7.5.12 HISTORY QosPolicy on page 418) or samples that outlived the *DataWriter's* 7.5.14 LIFESPAN QoS Policy on page 423 duration. If the *DataReader* sets the property **dds.data_reader.accept_writer_removed_batch_samples** to true (in the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436), the removed sample will be accepted into the *DataReader* queue and this flag will be set.
struct DDS_GUID_t	source_guid	The application logical data source associated with the sample.
struct DDS_GUID_t	related_source_guid	The application logical data source that is related to the sample.
struct DDS_GUID_t	related_subscription_guid	The related_reader_guid associated with the sample.

Table 8.17 DDS_SampleInfo Structure

Type	Field Name	Description
struct DDS_CoherentSetInfo_t	coherent_set_info	Information about the coherent set that this sample is a part of. This field is set for all samples that are part of a coherent set. This field contains the following members: • group_guid identifies the *DataWriter* or the group of *DataWriters* publishing the coherent set, depending on the value of the *Subscriber's* **access_scope** in the 7.4.6 PRESENTATION QosPolicy on page 361. (If **access_scope** is TOPIC or INSTANCE, then group_guid identifies a single *DataWriter*; if **access_scope** is GROUP, then group_guid identifies all the *DataWriters* within a *Publisher*.) • coherent_set_sequence_number identifies a sample as part of a *DataWriter* coherent set. When the *Subscriber's* **access_scope** in the 7.4.6 PRESENTATION QosPolicy on page 361 is TOPIC or INSTANCE, the coherent set associated with a sample is identified by the pair (group_guid, coherent_set_sequence_number). • group_coherent_set_sequence_number identifies a sample as part of a group coherent set. When the *Subscriber's* **access_scope** in the 7.4.6 PRESENTATION QosPolicy on page 361 is GROUP, the coherent set associated with a sample is identified by the pair (group_guid, group_coherent_set_sequence_number). • incomplete_coherent_set indicates if a sample is part of an incomplete coherent set. An incomplete coherent set is a coherent set for which not all samples have been received. Note that a coherent set is also considered incomplete if some of its samples are filtered by content or time on the *DataWriter* side. By default, received samples from an incomplete coherent set are not provided to the application and they are reported as LOST_BY_INCOMPLETE_COHERENT_SET (see 8.3.7.7 SAMPLE_LOST Status on page 524). You can change this behavior by setting **drop_incomplete_coherent_set** to FALSE in the 7.4.6 PRESENTATION QosPolicy on page 361.

8.4.6.1 Reception Timestamp

In reliable communication, if DDS data samples are received out received of order, *Connext DDS* will not deliver them until all the previous DDS data samples have been received. For example, if DDS sample 2 arrives before DDS sample 1, DDS sample 2 cannot be delivered until DDS sample 1 is received. The **reception_timestamp** is the time when all previous DDS samples has been received—the time at which the DDS sample is *committed*. If DDS samples are all received in order, the committed time will be same as reception time. However, if DDS samples are lost on the wire, then the committed time will be later than the initial reception time.

8.4.6.2 Sample States

For each DDS sample received, *Connext DDS* keeps a **sample_state** relative to each *DataReader*. The **sample_state** can be either:

- READ: The *DataReader* has already accessed that DDS sample by means of **read()**.
- NOT_READ: The *DataReader* has never accessed that DDS sample before.

The DDS samples retrieved by a **read()** or **take()** need not all have the same **sample_state**.

8.4.6.3 View States

For each instance (identified by a unique key value), *Connext DDS* keeps a **view_state** relative to each *DataReader*. The **view_state** can be either:

- NEW: Either this is the first time the *DataReader* has ever accessed DDS samples of the instance, or the *DataReader* has accessed previous DDS samples of the instance, but the instance has since been reborn (i.e., become not-alive and then alive again). These two cases are distinguished by examining the **disposed_generation_count** and the **no_writers_generation_count** (see 8.3.8.2 Generation Counts and Ranks on page 532).
- NOT_NEW:The *DataReader* has already accessed DDS samples of the same instance and the instance has not been reborn since.

The **view_state** in the **SampleInfo** structure is really a per-instance concept (as opposed to the **sample_state** which is per DDS sample). Thus all DDS data samples related to the same instance that are returned by **read()** or **take()** will have the same value for **view_state**.

8.4.6.4 Instance States

Connext DDS keeps an **instance_state** for each instance; it can be:

- **ALIVE**
- **NOT_ALIVE_DISPOSED**
- **NOT_ALIVE_NO_WRITERS**

For more information, see 8.3.8.1 Instance States on page 530.

8.4.6.5 Generation Counts and Ranks

Each *DataReader* keeps two counters for each *new* instance it detects (recall that instances are distinguished by their key values):

- **disposed_generation_count**
- **no_writers_generation_count**

For more information, see 8.3.8.2 Generation Counts and Ranks on page 532.

8.4.6.6 Valid Data Flag

The **SampleInfo** structure's **valid_data** flag indicates whether the DDS sample contains data or is only used to communicate a change in the **instance_state** of the instance.

For more information, see 8.3.8.3 Valid Data Flag on page 534.

8.5 Subscriber QosPolicies

Subscribers have the same set of QosPolicies as *Publishers*; see 7.4 Publisher/Subscriber QosPolicies on page 344.

- 7.4.2 ENTITYFACTORY QosPolicy on page 347
- 7.4.3 EXCLUSIVE_AREA QosPolicy (DDS Extension) on page 350
- 7.4.4 GROUP_DATA QosPolicy on page 352
- 7.4.5 PARTITION QosPolicy on page 355
- 7.4.6 PRESENTATION QosPolicy on page 361

8.6 DataReader QosPolicies

This section describes the QosPolicies that are strictly for *DataReaders* (not for *DataWriters*). For a complete list of QosPolicies that apply to *DataReaders*, see Table 8.15 DataReader QosPolicies .

- 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) below
- 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571
- 8.6.3 READER_DATA_LIFECYCLE QoS Policy on page 581
- 8.6.4 TIME_BASED_FILTER QosPolicy on page 583
- 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586
- 8.6.6 TYPE_CONSISTENCY_ENFORCEMENT QosPolicy on page 589

8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension)

The DATA_READER_PROTOCOL QosPolicy applies only to *DataReaders* that are set up for reliable operation (see 7.5.21 RELIABILITY QosPolicy on page 444). This policy allows the application to fine-tune the reliability protocol separately for each *DataReader*. For details of the reliable protocol used by *Connext DDS*, see Reliable Communications (Chapter 11 on page 682).

Connext DDS uses a standard protocol for packet (user and meta data) exchange between applications. The DataReaderProtocol QosPolicy gives you control over configurable portions of the protocol, including the configuration of the reliable data delivery mechanism of the protocol on a per *DataReader* basis.

These configuration parameters control timing and timeouts, and give you the ability to trade off between speed of data loss detection and repair, versus network and CPU bandwidth used to maintain reliability.

It is important to tune the reliability protocol on a per *DataReader* basis to meet the requirements of the end-user application so that data can be sent between *DataWriters* and *DataReaders* in an efficient and optimal manner in the presence of data loss.

You can also use this QosPolicy to control how DDS responds to "slow" reliable *DataReaders* or ones that disconnect or are otherwise lost.

See the 7.5.21 RELIABILITY QosPolicy on page 444 for more information on the per-DataReader/DataWriter reliability configuration. The 7.5.12 HISTORY QosPolicy on page 418 and 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 also play an important role in the DDS reliability protocol.

This policy includes the members presented in Table 8.18 DDS_DataReaderProtocolQosPolicy and Table 8.19 DDS_RtpsReliableReaderProtocol_t. For defaults and valid ranges, please refer to the API Reference HTML documentation.

When setting the fields in this policy, the following rule applies. If this is false, *Connext DDS* returns **DDS_RETCODE_INCONSISTENT_POLICY** when setting the QoS:

max_heartbeat_response_delay >= min_heartbeat_response_delay

Table 8.18 DDS_DataReaderProtocolQosPolicy

Type	Field Name	Description
DDS_GUID_t	virtual_guid	The virtual GUID (Global Unique Identifier) is used to uniquely identify the same *DataReader* across multiple incarnations. In other words, this value allows *Connext DDS* to remember information about a *DataReader* that may be deleted and then recreated. This value is used to provide durable reader state. For more information, see 13.2 Durability and Persistence Based on Virtual GUIDs on page 731. By default, *Connext DDS* will assign a virtual GUID automatically. If you want to restore the *DataReader's* state after a restart, you can get the *DataReader's* virtual GUID using its **get_qos()** operation, then set the virtual GUID of the restarted *DataReader* to the same value.
DDS_UnsignedLong	rtps_object_id	Determines the *DataReader's* RTPS object ID, according to the DDS-RTPS Interoperability Wire Protocol. Only the last 3 bytes are used; the most significant byte is ignored. The **rtps_host_id**, **rtps_app_id**, **rtps_instance_id** in the 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664, together with the 3 least significant bytes in **rtps_object_id**, and another byte assigned by *Connext DDS* o identify the entity type, forms the BuiltinTopicKey in SubscriptionBuiltinTopicData.

Table 8.18 DDS_DataReaderProtocolQosPolicy

Type	Field Name	Description
DDS_Boolean	expects_inline_qos	Specifies whether this *DataReader* expects inline QoS with every DDS sample. *DataReaders* usually rely on the discovery process to propagate QoS changes for matched *DataWriters*. Another way to get QoS information is to have it sent inline with a DDS sample. With *Connext DDS*, *DataWriters* and *DataReaders* cache discovery information, so sending inline QoS is typically unnecessary. The use of inline QoS is only needed for stateless implementations of DDS in which *DataReaders* do not cache Discovery information. The complete set of QoS that a *DataWriter* may send inline is specified by the Real-Time Publish-Subscribe (RTPS) Wire Interoperability Protocol. Note: The use of inline QoS creates an additional wire-payload, consuming extra bandwidth and serialization/deserialization time.
DDS_Boolean	disable_positive_acks	Determines whether the *DataReader* sends positive acknowledgements (ACKs) to matching *DataWriters*. When TRUE. the matching *DataWriter* will keep DDS samples in its queue for this *DataReader* for a minimum keep duration (see 7.5.5.3 Disabling Positive Acknowledgements on page 395). When strict-reliability is not required and NACK-based reliability is sufficient, setting this field reduces overhead network traffic.
DDS_Boolean	propagate_dispose_of_unregistered_instances	Indicates whether or not an instance can move to the DDS_NOT_ALIVE_DISPOSED_INSTANCE_STATE state without being in the DDS_ALIVE_INSTANCE_STATE state. When set to TRUE, the *DataReader* will receive dispose notifications even if the instance is not alive. This field only applies to keyed *DataReaders*. To make sure the key is available to the FooDataReader's **get_key_value()** operation, use this option in combination with setting the *DataWriter's* **serialize_key_with_dispose** field (in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388) to TRUE. See 7.5.5.5 Propagating Serialized Keys with Disposed-Instance Notifications on page 396.
DDS_Boolean	propagate_unregister_of_disposed_instances	Indicates whether or not an instance can move to the DDS_NOT_ALIVE_NO_WRITERS_INSTANCE_STATE state without being in the DDS_ALIVE_INSTANCE_STATE state. When set to TRUE, the *DataReader* will receive unregister notifications even if the instance is not alive. This field only applies to keyed *DataReaders*.

Table 8.18 DDS_DataReaderProtocolQosPolicy

Type	Field Name	Description
DDS_RtpsReliableReaderProtocol_t	rtps_reliable_reader	See Table 8.19 DDS_RtpsReliableReaderProtocol_t

Table 8.19 DDS_RtpsReliableReaderProtocol_t

Type	Field Name	Description
DDS_Duration_t	min_heartbeat_response_delay	Minimum delay between when the *DataReader* receives a heartbeat and when it sends an ACK/NACK.
DDS_Duration_t	max_heartbeat_response_delay	Maximum delay between when the *DataReader* receives a heartbeat and when it sends an ACK/NACK. Increasing this value helps prevent NACK storms, but increases latency.
DDS_Duration_t	heartbeat_suppression_duration	How long additionally received heartbeats are suppressed. When a reliable *DataReader* receives consecutive heartbeats within a short duration, this may trigger redundant NACKs. To prevent the *DataReader* from sending redundant NACKs, the *DataReader* may ignore the latter heartbeat(s) for this amount of time. See 11.3.4.1 How Often Heartbeats are Resent (heartbeat_period) on page 698.
DDS_Duration_t	nack_period	Rate at which to send negative acknowledgements to new *DataWriters*. See 8.6.1.3 Example on page 570.
DDS_Long	receive_window_size	The number of received out-of-order DDS samples a reader can keep at a time. See 8.6.1.1 Receive Window Size on the next page
DDS_Duration_t	round_trip_time	The duration from sending a NACK to receiving a repair of a DDS sample. See 8.6.1.2 Round-Trip Time For Filtering Redundant NACKs on the next page
DDS_Duration_t	app_ack_period	The period at which application-level acknowledgment messages are sent. A *DataReader* sends application-level acknowledgment messages to a *DataWriter* at this periodic rate, and will continue sending until it receives a message from the *DataWriter* that it has received and processed the acknowledgment.
DDS_Duration_t	min_app_ack_response_keep_duration	Minimum duration for which application-level acknowledgment response data is kept. The user-specified response data of an explicit application-level acknowledgment (called by DataReader's **acknowledge_sample()** or **acknowledge_all()** operations) is cached by the *DataReader* for the purpose of reliably resending the data with the acknowledgment message. After this duration has passed from the time of the first acknowledgment, the response data is dropped from the cache and will not be resent with future acknowledgments for the corresponding DDS sample(s).

Table 8.19 DDS_RtpsReliableReaderProtocol_t

Type	Field Name	Description
DDS_Long	samples_per_app_ack	The minimum number of DDS samples acknowledged by one application-level acknowledgment message. This setting applies only when the 7.5.21 RELIABILITY QosPolicy on page 444 **acknowledgment_kind** is set to APPLICATION_EXPLICIT or APPLICATION_AUTO. A *DataReader* will immediately send an application-level acknowledgment message when it has at least this many DDS samples that have been acknowledged. It will not send an acknowledgment message until it has at least this many DDS samples pending acknowledgment. For example, calling the *DataReader's* **acknowledge_sample()** this many times consecutively will trigger the sending of an acknowledgment message. Calling the *DataReader's* **acknowledge_all()** may trigger the sending of an acknowledgment message, if at least this many DDS samples are being acknowledged at once. See 8.4.4 Acknowledging DDS Samples on page 558. This is independent of the DDS_RtpsReliableReaderProtocol_t's **app_ack_period**, where a *DataReader* will send acknowledgment messages at the periodic rate regardless. When this is set to DDS_LENGTH_UNLIMITED, acknowledgment messages are sent only periodically, at the rate set by DDS_RtpsReliableReaderProtocol_t's **app_ack_period**.

8.6.1.1 Receive Window Size

A reliable *DataReader* presents DDS samples it receives to the user in-order. If it receives DDS samples out-of-order, it stores them internally until the other missing DDS samples are received. For example, if the *DataWriter* sends DDS samples 1 and 2, if the *DataReader* receives 2 first, it will wait until it receives 1 before passing the DDS samples to the user.

The number of out-of-order DDS samples that a *DataReader* can keep is set by the **receive_window_size**. A larger window allows more out-of-order DDS samples to be kept. When the window is full, any subsequent out-of-order DDS samples received will be rejected, and such rejections would necessitate NACK repairs that would degrade throughput. So, in network environments where out-of-order samples are more probable or where NACK repairs are costly, this window likely should be increased.

By default, the window is set to 256, which is the maximum number of DDS samples a single NACK submessage can request.

Samples rejected for exceeding the **receive_window_size** are counted in **out_of_range_rejected_sample_count** in the 8.3.7.3 DATA_READER_PROTOCOL_STATUS on page 517, but not included in the 8.3.7.8 SAMPLE_REJECTED Status on page 527.

8.6.1.2 Round-Trip Time For Filtering Redundant NACKs

When a *DataReader* requests for a DDS sample to be resent, there is a delay from when the NACK is sent, to when it receives the resent DDS sample. During that delay, the *DataReader* may receive

HEARTBEATs that normally would trigger another NACK for the same DDS sample. Such redundant repairs waste bandwidth and degrade throughput.

The **round_trip_time** is a user-configured estimate of the delay between sending a NACK to receiving a repair. A *DataReader* keeps track of when a DDS sample has been NACK'd, and will prevent subsequent NACKs from redundantly requesting for the same DDS sample, until the round trip time has passed.

Note that the default value of 0 seconds means that the *DataReader* does not filter for redundant NACKs.

8.6.1.3 Example

For many applications, changing these values will not be necessary. However, the more nodes that your distributed application uses, and the greater the amount of network traffic it generates, the more likely it is that you will want to consider experimenting with these values.

When a reliable *DataReader* receives a heartbeat from a *DataWriter*, it will send an ACK/NACK packet back to the *DataWriter*. Instead of sending the packet out immediately, the *DataReader* can choose to send it after a delay. This policy sets the minimum and maximum time to delay; the actual delay will be a random value in between. (For more on heartbeats and ACK/NACK messages, see Discovery (Chapter 15 on page 758).)

Why is a delay useful? For *DataWriters* that have multiple reliable *DataReaders*, an efficient way of heartbeating all of the *DataReaders* is to send a single heartbeat via multicast. In that case, all of the *DataReaders* will receive the heartbeat (approximately) simultaneously. If all *DataReaders* immediately respond with a ACK/NACK packet, the network may be flooded. While the size of a ACK/NACK packet is relatively small, as the number of *DataReaders* increases, the chance of packet collision also increases. All of these conditions may lead to dropped packets which forces the *DataWriter* to send out additional heartbeats that cause more simultaneous heartbeats to be sent, ultimately resulting a network packet storm.

By forcing each *DataReader* to wait for a random amount of time, bounded by the minimum and maximum values in this policy, before sending an ACK/NACK response to a heartbeat, the use of the network is spread out over a period of time, decreasing the peak bandwidth required as well as the likelihood of dropped packets due to collisions. This can increase the overall performance of the reliable connection while avoiding a network storm.

When a reliable *DataReader* first matches a reliable *DataWriter*, the *DataReader* sends periodic NACK messages at the specified period to pull historical data from the *DataWriter*. The *DataReader* will stop sending periodic NACKs when it has received all historical data available at the time that it matched the *DataWriter*. The *DataReader* ensures that at least one NACK is sent per period; for example, if, within a NACK period, the *DataReader* responds to a HEARTBEAT message with a NACK, then the *DataReader* will not send another periodic NACK.

8.6.1.4 Properties

This QosPolicy cannot be modified after the *DataReader* is created.

It only applies to *DataReaders*, so there are no restrictions for setting it compatibly with respect to *DataWriters*.

8.6.1.5 Related QosPolicies

- 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388
- 7.5.21 RELIABILITY QosPolicy on page 444

8.6.1.6 Applicable DDS Entities

- 8.3 DataReaders on page 501

8.6.1.7 System Resource Considerations

Changing the values in this policy requires making tradeoffs between minimizing latency (decreasing **min_heartbeat_response_delay**), maximizing determinism (decreasing the difference between **min_heartbeat_response_delay** and **max_heartbeat_response_delay**), and minimizing network collisions/spreading out the ACK/NACK packets across a time interval (increasing the difference between **min_heartbeat_response_delay** and **max_heartbeat_response_delay** and/or shifting their values between different *DataReaders*).

If the values are poorly chosen with respect to the characteristics and requirements of a given application, the latency and/or throughput of the application may suffer.

8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension)

The DATA_READER_RESOURCE_LIMITS QosPolicy extends your control over the memory allocated by *Connext DDS* for *DataReaders* beyond what is offered by the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449. RESOURCE_LIMITS controls memory allocation with respect to the *DataReader* itself: the number of DDS samples that it can store in the receive queue and the number of instances that it can manage simultaneously. DATA_READER_RESOURCE_LIMITS controls memory allocation on a per matched-*DataWriter* basis. The two are orthogonal.

This policy includes the members in Table 8.20 DDS_DataReaderResourceLimitsQosPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 8.20 DDS_DataReaderResourceLimitsQosPolicy

Type	Field Name	Description
DDS_ Long	max_remote_ writers	Maximum number of *DataWriters* from which a *DataReader* may receive DDS data samples, among all instances. For unkeyed *Topics*: **max_remote_writers** must = **max_remote_ writers_per_instance**
	max_remote_ writers_ per_instance	Maximum number of *DataWriters* from which a *DataReader* may receive DDS data samples for a single instance. For unkeyed *Topics*: **max_remote_writers** must = **max_remote_ writers_per_instance**
	max_samples_ per_remote_ writer	Maximum number of DDS samples received out-of-order that a *DataReader* can store from a single reliable *DataWriter*. **max_samples_per_remote_writer** must be <= **RESOURCE_ LIMITS::max_samples**
	max_infos	Maximum number of DDS_SampleInfo structures that a *DataReader* can allocate. **max_infos** must be >= **RESOURCE_LIMITS::max_samples**
	initial_remote_ writers	Initial number of *DataWriters* from which a *DataReader* may receive DDS data samples, including all instances. For unkeyed Topics: **initial_remote_writers** must = **initial_remote_writers_per_instance**
	initial_remote_ writers_per_instance	Initial number of *DataWriters* from which a *DataReader* may receive DDS data samples for a single instance. For unkeyed *Topics*: **initial_remote_writers** must = **initial_remote_writers_per_instance**
	initial_infos	Initial number of DDS_SampleInfo structures that a *DataReader* will allocate.
	initial_out- standing_ reads	Initial number of times in which memory can be concurrently loaned via read/take calls without being returned with **return_loan()**.
	max_out- standing_ reads	Maximum number of times in which memory can be concurrently loaned via read/take calls without being returned with **return_loan ()**.
	max_samples_ per_ read	Maximum number of DDS samples that can be read/taken on a *DataReader*.
DDS_ Boolean	disable_frag- mentation_ support	Determines whether the *DataReader* can receive fragmented DDS samples. When fragmentation support is not needed, disabling fragmentation support will save some memory resources.

Table 8.20 DDS_DataReaderResourceLimitsQosPolicy

Type	Field Name	Description
DDS_ Long	max_fragmented_samples	The maximum number of DDS samples for which the *DataReader* may store fragments at a given point in time. At any given time, a *DataReader* may store fragments for up to **max_fragmented_samples** DDS samples while waiting for the remaining fragments. These DDS samples need not have consecutive sequence numbers and may have been sent by different *DataWriters*. Once all fragments of a DDS sample have been received, the DDS sample is treated as a regular DDS sample and becomes subject to standard QoS settings, such as max_samples. *Connext DDS* will drop fragments if the max_fragmented_samples limit has been reached. For best-effort communication, *Connext DDS* will accept a fragment for a new DDS sample, but drop the oldest fragmented DDS sample from the same remote writer. For reliable communication, *Connext DDS* will drop fragments for any new DDS samples until all fragments for at least one older DDS sample from that writer have been received. Only applies if **disable_fragmentation_support** is FALSE.
	initial_fragmented_samples	The initial number of DDS samples for which a *DataReader* may store fragments. Only applies if **disable_fragmentation_support** is FALSE.
	max_fragmented_samples_per_remote_writer	The maximum number of DDS samples per remote writer for which a *DataReader* may store fragments. This is a logical limit, so a single remote writer cannot consume all available resources. Only applies if **disable_fragmentation_support** is FALSE.
	max_fragments_per_sample	Maximum number of fragments for a single DDS sample. Only applies if **disable_fragmentation_support** is FALSE.
DDS_ Boolean	dynamically_allocate_fragmented_samples	By default, the middleware does not allocate memory upfront, but instead allocates memory from the heap upon receiving the first fragment of a new sample. The amount of memory allocated equals the amount of memory needed to store all fragments in the sample. Once all fragments of a sample have been received, the sample is deserialized and stored in the regular receive queue. At that time, the dynamically allocated memory is freed again. This QoS setting is useful for large, but variable-sized data types where up-front memory allocation for multiple samples based on the maximum possible sample size may be expensive. The main disadvantage of not pre-allocating memory is that one can no longer guarantee the middleware will have sufficient resources at run-time. If dynamically_allocate_fragmented_samples is FALSE, the middleware will allocate memory up-front for storing fragments for up to initial_fragmented_samples samples. This memory may grow up to max_fragmented_samples if needed. Only applies if disable_fragmentation_support is FALSE.

Table 8.20 DDS_DataReaderResourceLimitsQosPolicy

Type	Field Name	Description
DDS_ Long	max_total_instances	Maximum number of instances (attached + detached instances) for which a *DataReader* will keep state. Only applicable if **keep_minimum_state_for_intsances** is TRUE. See 8.6.2.1 max_total_instances and max_instances on page 577
DDS_DataReaderResourceLimitsInstanceReplacementSettings	instance_replacement	Sets the kinds of instances allowed to be replaced for each instance state when a *DataReader* reaches **max_instances** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449. See 8.6.2.3 Configuring DataReader Instance Replacement on page 578.
DDS_ Long	max_remote_virtual_writers	The maximum number of virtual writers (identified by a virtual GUID) from which a *DataReader* may read, including all instances. When the *Subscriber's* **access_scope** is GROUP, this value determines the maximum number of *DataWriter* groups supported by the *Subscriber*. Since the *Subscriber* may contain more than one *DataReader*, only the setting of the first applies.
DDS_ Long	initial_remote_virtual_writers	The initial number of virtual writers from which a *DataReader* may read, including all instances.
DDS_ Long	max_remote_virtual_writers_per_instance	Maximum number of virtual remote writers that can be associated with an instance. For unkeyed types, this value is ignored. The features of Durable Reader State and MultiChannel DataWriters, as well as *Persistence Service*, require *Connext DDS* to keep some internal state per virtual writer and instance that is used to filter duplicate DDS samples. These duplicate DDS samples could be coming from different *DataWriter* channels or from multiple executions of *Persistence Service*. Once an association between a remote virtual writer and an instance is established, it is permanent–it will not disappear even if the physical writer incarnating the virtual writer is destroyed. If **max_remote_virtual_writers_per_instance** is exceeded for an instance, *Connext DDS* will not associate this instance with new virtual writers. Duplicate DDS samples coming from these virtual writers will not be filtered on the reader. If you are not using Durable Reader State, MultiChannel *DataWriters* or *Persistence Service*, you can set this property to 1 to optimize resources. For additional information about the virtual writers see Mechanisms for Achieving Information Durability and Persistence (Chapter 13 on page 726).
DDS_ Long	initial_remote_virtual_writers_per_instance	Initial number of virtual remote writers per instance. For unkeyed types, this value is ignored.

Table 8.20 DDS_DataReaderResourceLimitsQosPolicy

Type	Field Name	Description
DDS_ Long	max_remote_ writers_ per_sample	Maximum number of remote writers that are allowed to write the same DDS sample. One scenario in which two DataWriters may write the same DDS sample is when using *Persistence Service*. The DataReader may receive the same DDS sample from the original DataWriter and from an *Persistence Service* DataWriter.
DDS_ Long	max_query_ condition_ filters	This value determines the maximum number of unique query condition content filters that a reader may create. Each query condition content filter is comprised of both its **query_expression** and **query_parameters**. Two query conditions that have the same **query_expression** will require unique query condition filters if their **query_parameters** differ. Query conditions that differ only in their state masks will share the same query condition filter.
DDS_ Long	max_app_ ack_response_ length	Maximum length of application-level acknowledgment response data. The maximum length of response data in an application-level acknowledgment. When set to zero, no response data is sent with application-level acknowledgments.
DDS_Boolean	keep_minimum_state_ for_instances	Determines whether the *DataReader* keeps a minimum instance state for up to **max_total_instances**. The minimum state is useful for filtering samples in certain scenarios. See 8.6.2.1 max_total_instances and max_instances on page 577
DDS_Long	initial_topic_ queries	The initial number of TopicQueries allocated by a *DataReader*.
DDS_Long	max_topic_ queries	The maximum number of active TopicQueries that a *DataReader* can create. Once this limit is reached, a *DataReader* can create more TopicQueries only if it deletes some of the previously created ones.
DDS_AllocationSettings_t	shmem_ref_ transfer_ mode_attached_segment_ allocation	Configures the allocation resource used to attach to different shared memory segments if you are using Zero Copy transfer over shared memory. See 23.6 Zero Copy Transfer Over Shared Memory on page 953.

DataReaders must allocate internal structures to handle: the maximum number of *DataWriters* that may connect to it; whether or not a *DataReader* handles data fragmentation and how many data fragments that it may handle (for *DDS* data samples larger than the MTU of the underlying network transport); how many simultaneous outstanding loans of internal memory holding DDS data samples can be provided to user code; as well as others.

Most of these internal structures start at an initial size and, by default, will grow as needed by dynamically allocating additional memory. You may set fixed, maximum sizes for these internal structures if you want

initial size to the maximum size will prevent *Connext DDS* from dynamically allocating any memory after the *DataReader* is created.

This policy also controls how the allocated internal data structure may be used. For example, *DataReaders* need data structures to keep track of all of the *DataWriters* that may be sending it DDS data samples. The total number of *DataWriters* that it can keep track of is set by the **initial_remote_writers** and **max_remote_writers** values. For keyed Topics, **initial_remote_writers_per_instance** and **max_remote_writers_per_instance** control the number of *DataWriters* allowed by the *DataReader* to modify the value of a single instance.

By setting the max value to be less than **max_remote_writers**, you can prevent instances with many *DataWriters* from using up the resources and starving other instances. Once the resources for keeping track of *DataWriters* are used up, the *DataReader* will not be able to accept "connections" from new *DataWriters*. The *DataReader* will not be able to receive data from new matching *DataWriters* which would be ignored.

In the reliable protocol used by *Connext DDS* to support a RELIABLE setting for the 7.5.21 RELIABILITY QosPolicy on page 444, the *DataReader* must temporarily store DDS data samples that have been received out-of-order from a reliable *DataWriter*. The storage of out-of-order DDS samples is allocated from the *DataReader*'s receive queue and shared among all reliable *DataWriters*. The parameter **max_samples_per_remote_writer** controls the maximum number of out-of-order data DDS samples that the *DataReader* is allowed to store for a single *DataWriter*. This value must be less than the **max_samples** value set in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.

max_samples_per_remote_writer allows *Connext DDS* to share the limited resources of the *DataReader* equitably so that a single *DataWriter* is unable to use up all of the storage of the *DataReader* while missing DDS data samples are being resent.

When setting the values of the members, the following rules apply:

- **max_remote_writers >= initial_remote_writers**
- **max_remote_writers_per_instance >= initial_remote_writers_per_instance**
  max_remote_writers_per_instance <= max_remote_writers
- **max_infos >= initial_infos**
  max_infos >= RESOURCE_LIMITS::max_samples
- **max_outstanding_reads >= initial_outstanding_reads**
- **max_remote_writers >= max_remote_writers_per_instance**
- **max_samples_per_remote_writer** <= RESOURCE_LIMITS::max_samples

If any of the above are false, *Connext DDS* returns the error code **DDS_RETCODE_INCONSISTENT_POLICY** when setting the *DataReader*'s QoS.

8.6.2.1 max_total_instances and max_instances

The features 13.4 Durable Reader State on page 738, Multi-channel DataWriters (Chapter 20 on page 888), and *Persistence Service* (Part 8: RTI Persistence Service on page 1159) require *Connext DDS* to keep some minimum internal state even for instances without *DataWriters* or DDS samples in the *DataReader's* queue or that have been purged due to a dispose. Instances for which only this minimum state is kept are called *detached* instances. The additional state is used to filter duplicate DDS samples that could be coming from different *DataWriter* channels or from multiple executions of *Persistence Service*. The total maximum number of instances that will be managed by the middleware, attached plus detached instances, is determined by **max_total_instances**. This additional state will only be kept for up to **max_total_instances** if **keep_minimum_state_for_instances** is TRUE, otherwise the additional state will not be kept for any instances. The minimum state includes information such as the source timestamp of the last sample received by the instance and the last sequence number received from a virtual GUID. See also 8.3.8.6.1 Active State and Minimum State on page 535.

8.6.2.2 keep_minimum_state_for_instances

There are important implications of the minimum state setting.

When a *DataReader* is exposed to an unbounded number of instances over its lifetime (for example, if the key for an instance is a UUID and the application cycles through unlimited numbers of such UUIDs over time) and the *DataReader* does keep its minimum state, the set of minimum state data will grow with the total number of instances (unique keys) the *DataReader* has been exposed to until **max_total_instances** is reached.

max_total_instances by default gets its value from **max_instances**. If **max_instances** is set to its default value, which is unbounded, the *DataReader's* memory will grow slowly but without bound until the *DataReader* itself is deleted. As a rule of thumb, when instances are used only once in a system and are never used again after being disposed or unregistered, set **max_instances** and **max_total_instances** to finite values or bound the lifetime of the *DataReader* (see 4.1.1 Creating and Deleting DDS Entities on page 167). If neither of these options is practical, it may help to set **keep_minimum_state_for_instances** to FALSE.

If a *DataReader* does not retain this minimum state, there may be correctness implications if the *DataReader* is exposed to an instance again after it has been removed from the *DataReader* cache. For example, because the last source timestamp is not preserved, eventual consistency cannot be assured (even if destination order is by source timestamp). Samples that had already been received by the *DataReader* may be re-delivered and provided to the application again as if for the first time (especially when using redundant *Routing Service* routes, *Persistence Service*, or *Collaborative DataWriters*). As a rule of thumb, when instances have complex lifecycles (especially involving multiple *DataWriters* modifying the instance), in which an instance can become not alive and later come alive again, set **keep_minimum_state_for_instances** to TRUE.

8.6.2.3 Configuring DataReader Instance Replacement

When the **max_instances** limit in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 is reached, a *DataReader* will try to make space for a new instance by replacing an existing instance according to the instance replacement kind set in **instance_replacement** in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571. If it cannot make space for the new instance, the sample for the new instance will be lost with the reason LOST_BY_INSTANCES_LIMIT (see 8.3.7.7 SAMPLE_LOST Status on page 524).

The **instance_replacement** field is useful for managing large volumes of instances that come and go. It is important to be able to set an upper limit on the resources that will be used by an application to avoid running into decreased performance and potentially running out of system resources. The **instance_replacement** QoS setting allows you to set an upper bound on the resources that will be used for instances. It allows *DataReaders* to make room for new instances by replacing older ones. For example, a hospital may have 100 beds. Many patients (instances) come and go, so at any given time you only need resources for 100 instances, but over time you will see an unbounded number of instances. An instance replacement policy can help manage this flow.

For each instance state (see 8.3.8.1 Instance States on page 530), you can set the following removal kinds:

- The alive_instance_removal kind sets a removal policy for ALIVE instances (default: DDS_NO_INSTANCE_REMOVAL).
- The disposed_instance_removal kind sets a removal policy for NOT_ALIVE_DISPOSED instances (default: DDS_EMPTY_INSTANCE_REMOVAL).
- The no_writers_instance_removal kind sets a removal policy for NOT_ALIVE_NO_WRITERS instances (default: DDS_EMPTY_INSTANCE_REMOVAL).

For each instance state, you can choose among the following replacement kinds:

- DDS_NO_INSTANCE_REMOVAL: Instances in the associated state cannot be replaced.
- DDS_EMPTY_INSTANCE_REMOVAL: Instances in the associated state can be replaced only if they are empty (all samples have been taken or removed from the *DataReader* queue due to QoS settings such as, but not limited to, the 7.5.14 LIFESPAN QoS Policy on page 423 or sample purging due to the 8.6.3 READER_DATA_LIFECYCLE QoS Policy on page 581), and there are no outstanding loans on any of the instance's samples.
- DDS_FULLY_PROCESSED_INSTANCE_REMOVAL: Instances in the associated state can be replaced only if every sample has been processed by the application. A sample is considered processed by the application based on the Reliability kind:
    - If the Reliability kind is RELIABLE, a sample is considered processed by the application based on the ApplicationAcknowledgementKind (see 7.3.12.1 Application

Acknowledgment Kinds on page 317):

- PROTOCOL_ACKNOWLEDGMENT_MODE or APPLICATION_AUTO_ACKNOWLEDGEMENT_MODE: The sample is considered processed when it has been read or taken by the application and **return_loan** has been called.
- APPLICATION_EXPLICIT_ACKNOWLEDGMENT_MODE: The sample is considered processed when the subscribing application has explicitly acknowledged the sample by calling either the *DataReader's* **acknowledge_sample()** or **acknowledge_all()** operations, the AppAckConf message has been received, and the application has called **return_loan**.

- If the Reliability kind is BEST_EFFORT, a sample is considered processed by the application when all samples have been read or taken by the application and **return_loan** has been called.

- DDS_ANY_INSTANCE_REMOVAL: Instances in the associated state can be replaced regardless of whether the subscribing application has processed all of the samples. Samples that have not been processed will be dropped and accounted for by the **total_samples_dropped_by_instance_replacement** statistic in the 8.3.7.2 DATA_READER_CACHE_STATUS on page 514.

For all kinds, instance replacement starts with the *least-recently-updated* (LRU) instance that matches the allowed criteria. For example, if **alive_instance_removal** is set to DDS_EMPTY_INSTANCE_REMOVAL: when the **max_instances** limit is reached, the least-recently-updated, empty, ALIVE instance will be replaced to make room for the new instance. An instance is considered updated when a valid sample or dispose sample for the instance is received and accepted by the *DataReader*. An instance is not considered updated in the following cases:

- When using EXCLUSIVE_OWNERSHIP, when samples that are received from *DataWriters* that do not own the instance. Only the owner of an instance can update the instance.
- A sample that is filtered out due to content filtering does not count as updating the instance.
- Unregister messages do not count as an update to the instance because the unregister message conveys information about the *DataWriter* (that it is finished updating the instance), as opposed to any change to the instance itself.

There is no preference among the instance states as far as which instance is replaced first; instance replacement relies only on the LRU. For example, imagine if *Connext DDS* were to prefer disposed_instance_removal over alive_instance_removal. It doesn't, but if it did, the application might never see disposed instances, yet have very old alive instances in its queue. The same is true for the replacement criteria options. If you choose DDS_FULLY_PROCESSED_INSTANCE_REMOVAL (for example), *Connext DDS* will not look for empty instances first and then fully processed instances; the LRU instance that is considered fully-processed will be replaced.

If no replaceable instance exists after the instance replacement kinds above have been applied, the sample for the new instance will be considered lost with the reason LOST_BY_INSTANCES_LIMIT in the 8.3.7.7 SAMPLE_LOST Status on page 524; the instance will not be inserted into the *DataReader* queue.

8.6.2.4 Example

The **max_samples_per_remote_writer** value affects sharing and starvation. **max_samples_per_remote_writer** can be set to less than the RESOURCE_LIMITS QosPolicy's **max_samples** to prevent a single *DataWriter* from starving others. This control is especially important for *Topics* that have their 7.5.17 OWNERSHIP QosPolicy on page 432 set to **SHARED**.

In the case of **EXCLUSIVE** ownership, a lower-strength remote *DataWriter* can "starve" a higher-strength remote *DataWriter* by making use of more of the *DataReader*'s resources, an undesirable condition. In the case of **SHARED** ownership, a remote *DataWriter* may starve another remote *DataWriter*, making the sharing not really equal.

8.6.2.5 Properties

This QosPolicy cannot be modified after the *DataReader* is created.

It only applies to *DataReaders*, so there are no restrictions for setting it compatibly on the *DataWriter*.

8.6.2.6 Related QosPolicies

- 7.5.22 RESOURCE_LIMITS QosPolicy on page 449
- 7.5.17 OWNERSHIP QosPolicy on page 432

8.6.2.7 Applicable DDS Entities

- 8.3 DataReaders on page 501

8.6.2.8 System Resource Considerations

Increasing any of the "initial" values in this policy will increase the amount of memory allocated by *Connext DDS* when a new *DataReader* is created. Increasing any of the "max" values will not affect the initial memory allocated for a new *DataReader*, but will affect how much additional memory may be allocated as needed over the *DataReader's* lifetime.

Setting a max value greater than an initial value thus allows your application to use memory more dynamically and efficiently in the event that the size of the application is not well-known ahead of time. However, *Connext DDS* may dynamically allocate memory in response to network communications.

8.6.3 READER_DATA_LIFECYCLE QoS Policy

This policy controls the behavior of the *DataReader* with regards to the lifecycle of the data instances it manages, that is, the data instances that have been received and for which the *DataReader* maintains some internal resources.

When a *DataReader* receives data, it is stored in a receive queue for the *DataReader*. The user application may either take the data from the queue or leave it there. This QoS controls whether or not *Connext DDS* will automatically remove data from the receive queue (so that user applications cannot access it afterward) when *Connext DDS* detects that there are no more *DataWriters* alive for that data.

DataWriters may also call **dispose()** on its data, informing *DataReaders* that the data no longer exists. This QosPolicy also controls whether or not *Connext DDS* automatically removes disposed data from the receive queue.

For keyed Topics, the consideration of removing DDS data samples from the receive queue is done on a per instance (key) basis. Thus when *Connext DDS* detects that there are no longer *DataWriters* alive for a certain key value for a *Topic* (an instance of the *Topic*), it can be configured to remove all DDS data samples for a certain instance (key). *DataWriters* also can dispose its data on a per instance basis. Only the DDS data samples of disposed instances would be removed by *Connext DDS* if so configured.

This policy helps purge untaken DDS samples from not-alive-instances and thus may prevent a *DataReader* from reclaiming resources. With this policy, the untaken DDS samples from not-alive-instances are purged and treated as if the DDS samples were taken after the specified amount of time.

The *DataReader* internally maintains the DDS samples that have not been taken by the application, subject to the constraints imposed by other QoS policies such as 7.5.12 HISTORY QosPolicy on page 418 and 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.

The *DataReader* also maintains information regarding the identity, view-state, and instance-state of data instances, even after all DDS samples have been 'taken' (see 8.4.3 Accessing DDS Data Samples with Read or Take on page 550). This is needed to properly compute the states when future DDS samples arrive.

Under normal circumstances, a *DataReader* can only reclaim all resources for instances for which there are no *DataWriters* and for which all DDS samples have been 'taken.' The last DDS sample taken by the *DataReader* for that instance will have an instance state of NOT_ALIVE_NO_WRITERS or NOT_ALIVE_DISPOSED_INSTANCE (depending on whether or not the instance was disposed by the last *DataWriter* that owned it.) If you are using the default (infinite) values for this QosPolicy, this behavior can cause problems if the application does not 'take' those DDS samples for some reason. The 'untaken' DDS samples will prevent the *DataReader* from reclaiming the resources and they would remain in the *DataReader* indefinitely.

A *DataReader* can also reclaim all resources for instances that have an instance state of NOT_ALIVE_DISPOSED and for which all DDS samples have been 'taken'. *DataReaders* will only reclaim resources in this situation when **autopurge_disposed_instances_delay** has been set to zero.

It includes the members in Table 8.21 DDS_ReaderDataLifecycleQosPolicy.

Table 8.21 DDS_ReaderDataLifecycleQosPolicy

Type	Field Name	Description
DDS_Duration_t	autopurge_nowriter_samples_delay	Minimum duration for which the *DataReader* will maintain samples regarding an instance once its **instance_state** becomes **NOT_ALIVE_NO_WRITERS**. An instance will transition to **NOT_ALIVE_NO_WRITERS** when all known writers for the instance have lost liveliness, been deleted, or unregistered from the instance. After this time elapses, the *DataReader* will purge all samples for the instance even if they have not been read by the application. These samples will be dropped. (See **expired_dropped_sample_count** in 8.3.7.2 DATA_READER_CACHE_STATUS on page 514.) This purge is done lazily when space is needed for other samples or instances (for example, when a resource limit such as max_samples on page 449 is hit). Default: INFINITE
DDS_Duration_t	autopurge_disposed_samples_delay	Minimum duration for which the *DataReader* will maintain samples for an instance once its **instance_state** becomes **NOT_ALIVE_DISPOSED**. After this time elapses, the *DataReader* will purge all samples for the instance even if they have not been read by the application. These samples will be dropped. (See **expired_dropped_sample_count** in 8.3.7.2 DATA_READER_CACHE_STATUS on page 514.) This purge is done lazily when space is needed for other samples or instances (for example, when a resource limit such as max_samples on page 449 is hit). Default: INFINITE
DDS_Duration_t	autopurge_disposed_instances_delay	Minimum duration for which the *DataReader* will maintain "active state" information about a received instance once its **instance_state** becomes **NOT_ALIVE_DISPOSED**, and there are no samples for the instance in the *DataReader* queue.(See 8.3.8.6.1 Active State and Minimum State on page 535.) Note: only values of 0 or INFINITE are currently supported. A value of 0 will purge an instance's state immediately after the instance state transitions to **NOT_ALIVE_DISPOSED**, as long as all samples, including the dispose sample, associated with that instance have been 'taken.' After this time elapses, when the last sample for the disposed instance is taken, the *DataReader* will keep only a minimum amount of state about the instance. To disable retention of even this minimum state after the delay period, also set **keep_minimum_state_for_instances** to FALSE in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571. See 8.6.2.2 keep_minimum_state_for_instances on page 577. Default: INFINITE
DDS_Duration_t	autopurge_nowriter_instances_delay	Minimum duration for which the *DataReader* will maintain "active state" information about a received instance once its **instance_state** becomes **NOT_ALIVE_NO_WRITERS** and there are no samples for the instance in the *DataReader* queue. (See 8.3.8.6.1 Active State and Minimum State on page 535.) An instance will transition to **NOT_ALIVE_NO_WRITERS** when all known writers for the instance have lost liveliness, been deleted, or unregistered from the instance. After this time elapses, when the last sample for the instance without writers is taken, the *DataReader* will keep only the minimum state about the instance. To disable retention of even this minimum state after the delay period, also set **keep_minimum_state_for_instances** to FALSE in the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571. See 8.6.2.2 keep_minimum_state_for_instances on page 577. (Note: only values of 0 or INFINITE are currently supported. A value of 0 will purge an instance's state immediately after the instance state transitions to **NOT_ALIVE_NO_WRITERS**, as long as all samples, including the no_writers sample, associated with that instance have been 'taken.') Default: 0

8.6.3.1 Properties

This QoS policy *can* be modified after the *DataReader* is enabled.

It only applies to *DataReaders*, so there are no RxO restrictions for setting it compatibly on the *DataWriter*.

8.6.3.2 Related QoS Policies

- 7.5.12 HISTORY QosPolicy on page 418
- 7.5.15 LIVELINESS QosPolicy on page 425
- 7.5.17 OWNERSHIP QosPolicy on page 432
- 7.5.22 RESOURCE_LIMITS QosPolicy on page 449
- 7.5.31 WRITER_DATA_LIFECYCLE QoS Policy on page 464

8.6.3.3 Applicable DDS Entities

- 8.3 DataReaders on page 501

8.6.3.4 System Resource Considerations

None.

8.6.4 TIME_BASED_FILTER QosPolicy

The TIME_BASED_FILTER QosPolicy allows you to specify that data should not be delivered more than once per specified period for data-instances of a *DataReader*—regardless of how fast *DataWriters* are publishing new DDS samples of the data-instance.

This QoS policy allows you to optimize resource usage (CPU and possibly network bandwidth) by only delivering the required amount of data to different *DataReaders*.

DataWriters may send data faster than needed by a *DataReader*. For example, a *DataReader* of sensor data that is displayed to a human operator in a GUI application does not need to receive data updates faster than a user can reasonably perceive changes in data values. This is often measure in tenths (0.1) of a second up to several seconds. However, a *DataWriter* of sensor information may have *DataReaders* that are processing the sensor information to control parts of the system and thus need new data updates in measures of hundredths (0.01) or thousandths (0.001) of a second.

With this QoS policy, different *DataReaders* can set their own time-based filters, so that data published faster than the period set by a *DataReader* will be dropped by the middleware and not delivered to the *DataReader*. Note that all filtering takes place on the reader side.

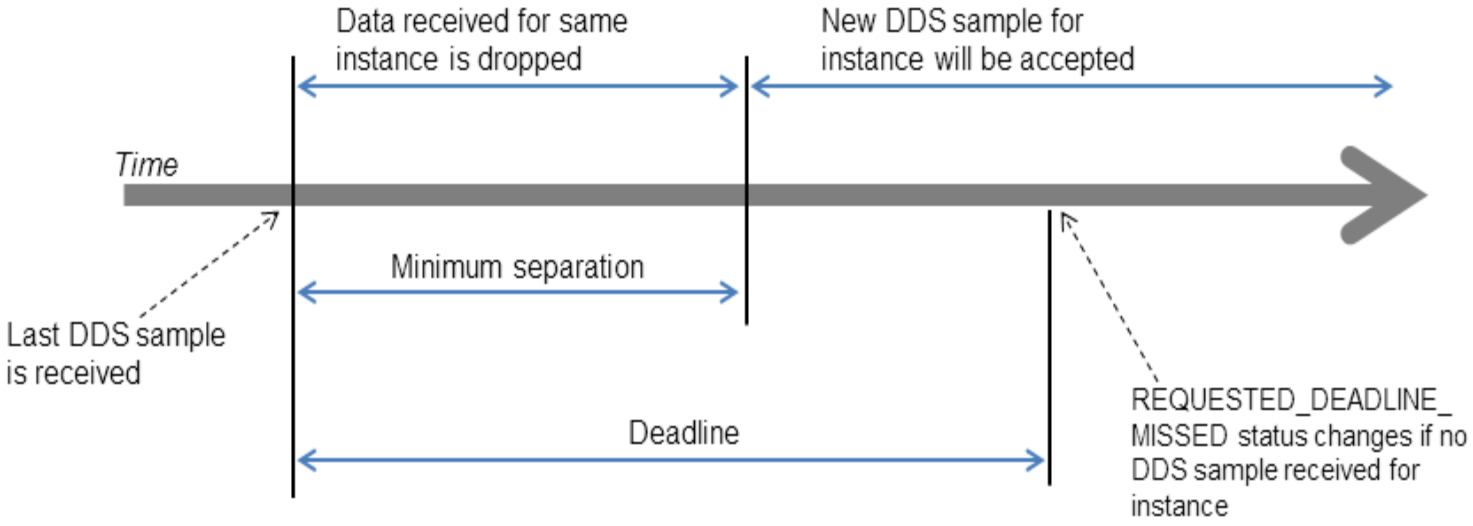
It includes the member in Table 8.22 DDS_TimeBasedFilterQosPolicy. For the default and valid range, please refer to the API Reference HTML documentation.

Table 8.22 DDS_TimeBasedFilterQosPolicy

Type	Field Name	Description
DDS_Duration_t	minimum_separation	Minimum separation time between DDS samples of the same instance. Must be <= **DEADLINE::period**

As seen in Figure 8.23: Accepting Data for DataReaders below, it is inconsistent to set a *DataReader's* **minimum_separation** longer than its 7.5.7 DEADLINE QosPolicy on page 404 **period**.

Figure 8.23: Accepting Data for DataReaders



DDS data samples for a DataReader can be filtered out using the TIME_BASED_FILTER QoS (minimum_separation). Once a DDS sample for an instance has been received, Connext DDS will accept but drop any new data samples for the same instance that arrives within the time specified by minimum_separation. After the minimum_separation, a new DDS sample that arrives is accepted and stored in the receive queue, and the timer starts again. If no DDS samples arrive by the DEADLINE, the REQUESTED_DEADLINE_MISSED status will be changed and Listeners called back if installed.

This QosPolicy allows a *DataReader* to subsample the data being published for a data instance by *DataWriters*. If a user application only needs new DDS samples for a data instance to be received at a specified period, then there is no need for *Connext DDS* to deliver data faster than that period. However, whether or not data being published by a *DataWriter* at a faster rate than set by the TIME_BASED_FILTER QoS is sent on the wire depends on several factors, including whether the *DataReader* is receiving the data reliably and if the data is being sent via multicast for multiple *DataReaders*.

For best effort data delivery, if the data type is unkeyed and the *DataWriter* has an infinite liveliness **lease_duration** (7.5.15 LIVELINESS QosPolicy on page 425), *Connext DDS* will only send as many packets to a *DataReader* as required by the TIME_BASED_FILTER, no matter how fast the *DataWriter*'s **write()** function is called.

For multicast data delivery to multiple *DataReaders*, the *DataReader* with the lowest TIME_BASED_FILTER **minimum_separation** determines the *DataWriter's* send rate. For example, if a *DataWriter* sends multicast to two *DataReaders*, one with **minimum_separation** of 2 seconds and one with **minimum_separation** of 1 second, the *DataWriter* will send every 1 second.

Other configurations (for example, when the *DataWriter* is reliable, or the data type is keyed, or the *DataWriter* has a finite liveliness **lease_duration**) must send all data published by the *DataWriter.* On reception, only the data that passes the TIME_BASED_FILTER will be stored in the *DataReader*'s receive queue. Extra data will be accepted but dropped. Note that filtering is only applied on 'alive' DDS samples (that is, DDS samples that have *not* been disposed/unregistered).

8.6.4.1 Example

The purpose of this QosPolicy is to prevent fast *DataWriters* from overwhelming a *DataReader* that cannot process the data at the rate the data is being published. In certain configurations, the number of packets sent by *Connext DDS* can also be reduced thus minimizing the consumption of network bandwidth.

You may want to change the **minimum_separation** between DDS data samples for one or more of the following reasons:

- The *DataReader* is connected to the network via a low-bandwidth connection that is unable to sustain the amount of traffic generated by the matched *DataWriter(s)*.
- The rate at which the matched *DataWriter(s)* can generate DDS samples is faster than the rate at which the *DataReader* can process them. Or faster than needed by the *DataReader*. For example, a graphical user interface seldom needs to be updated faster than 30 times a second, even if new data values are available much faster.
- The resource limits of the *DataReader* are constrained relative to the number of DDS samples that could be generated by the matched *DataWriter(s)*. Too many packets coming at once will cause them to be exhausted before the *DataReader* has time to process them.

8.6.4.2 Properties

This QosPolicy can be modified at any time.

It only applies to *DataReaders*, so there are no restrictions for setting it compatibly on the *DataWriter*.

8.6.4.3 Related QosPolicies

- 7.5.21 RELIABILITY QosPolicy on page 444
- 7.5.7 DEADLINE QosPolicy on page 404
- 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on the next page

8.6.4.4 Applicable DDS Entities

- 8.3 DataReaders on page 501

8.6.4.5 System Resource Considerations

Depending on the values of other QosPolicies such as RELIABILITY and TRANSPORT_MULTICAST, this policy may be able to decrease the usage of network bandwidth and CPU by preventing unneeded packets from being sent and processed.

8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension)

This QosPolicy specifies the multicast address on which a *DataReader* wants to receive its data. It can also specify a port number as well as a subset of the available transports with which to receive the multicast data.

By default, *DataWriters* will send individually addressed packets for each *DataReader* that subscribes to the topic of the *DataWriter*—this is known as unicast delivery. Thus, as many copies of the data will be sent over the network as there are *DataReaders* for the data. The network bandwidth used by a *DataWriter* will thus increase linearly with the number of *DataReaders*.

Multicast is a concept supported by some transports, most notably UDP/IP, so that a *single* packet on the network can be addressed such that it is received by multiple nodes. This is more efficient when the same data needs to be sent to multiple nodes. By using multicast, the network bandwidth usage will be constant, independent of the number of *DataReaders*.

Coordinating the multicast address specified by *DataReaders* can help optimize network bandwidth usage in systems where there are multiple *DataReaders* for the same *Topic*.

The QosPolicy structure includes the members in Table 8.23 DDS_TransportMulticastQosPolicy.

Table 8.23 DDS_TransportMulticastQosPolicy

Type	Field Name	Description
DDS_TransportMulticastSettingSeq (A sequence of the type shown in Table 8.24 DDS_TransportMulticastSetting_t)	value	A sequence of up to 16 multicast locators. This is a hard limit that cannot be increased. However, this limit can be *decreased* by configuring the *DomainParticipant* property **dds.domain_participant.max_announced_locator_list_size**. For more information on the locator format, see 15.2.1.1 Locator Format on page 763.

Table 8.23 DDS_TransportMulticastQosPolicy

Type	Field Name	Description
DDS_TransportMulticastKind	kind	This field can be set to one of the following two values: DDS_AUTOMATIC_TRANSPORT_MULTICAST_QOS or DDS_UNICAST_ONLY_TRANSPORT_MULTICAST_QOS. If it is set to DDS_AUTOMATIC_TRANSPORT_MULTICAST_QOS, the behavior depends on the content of DDS_TransportMulticastQosPolicy::value: If DDS_TransportMulticastQosPolicy::value does not have any elements, multicast will not be used. If DDS_TransportMulticastQosPolicy::value first element has an empty address, the address will be obtained from DDS_TransportMulticastMappingQosPolicy. If none of the elements in DDS_TransportMulticastQosPolicy::value are empty, and at least one element has a valid address, then that address will be used. If it is set to DDS_UNICAST_ONLY_TRANSPORT_MULTICAST_QOS, then multicast will not be used.

Table 8.24 DDS_TransportMulticastSetting_t

Type	Field Name	Description
DDS_StringSeq	transports	A sequence of transport aliases that specifies which transports should be used to receive multicast messages for this *DataReader*.
char *	receive_address	A multicast group address to which the *DataWriter* should send data for this *DataReader*.
DDS_Long	receive_port	The port that should be used in the addressing of multicast messages destined for this *DataReader*. A value of 0 will cause *Connext DDS* to use a default port number based on domain ID. See 15.5 Ports Used for Discovery on page 785.

To take advantage of multicast, the value of this QosPolicy must be coordinated among all of the applications on a network for *DataReaders* of the same *Topic*. For a *DataWriter* to send a single packet that will be received by all *DataReaders* simultaneously, the same multicast address must be used.

To use this QosPolicy, you will also need to specify a port number. A port number of 0 will cause *Connext DDS* to automatically use a default value. As explained in 15.5 Ports Used for Discovery on page 785, the default port number for multicast addresses is based on the domain ID. Should you choose to use a different port number, then for every unique port number used by Entities in your application, depending on the transport, *Connext DDS* may create a thread to process messages received for that port on that transport. See Connext DDS Threading Model (Chapter 21 on page 900) for more about threads.

Threads are created on a per-transport basis, so if this QosPolicy specifies multiple **transports** for a **receive_port**, then a thread may be created for each transport for that unique port. Some transports may be able to share a single thread for different ports, others can not. Note that different Entities can share the same port number, and thus, the same thread will process all of the data for all of the Entities sharing the same port number for a transport.

Also note that if the port number specified by this QoS is the same as a port number specified by a TRANSPORT_UNICAST QoS, then the transport may choose to process data received both via multicast and unicast with a single thread. Whether or not a transport must use different threads to process data received via multicast or unicast for the same port number depends on the implementation of the transport.

Notes:

- The same multicast address can be used by *DataReaders* of different *Topics*.
- Even though the TRANSPORT_MULTICAST QoS allows you to specify multiple multicast addresses for a *DataReader*, *Connext DDS* currently only uses one multicast address (the first in the sequence) per *DataReader*.
- If a *DataWriter* is using the 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429, the multicast addresses specified in the TRANSPORT_MULTICAST QosPolicy are ignored by that *DataWriter*. The *DataWriter* will not publish DDS samples on those locators.

8.6.5.1 Example

In an airport, there may be many different monitors that display current flight information. Assuming each monitor is controlled by a networked application, network bandwidth would be greatly reduced if flight information was published using multicast.

Figure 8.24: Setting Up a Multicast DataReader below shows an example of how to set this QosPolicy.

Figure 8.24: Setting Up a Multicast DataReader

```
...
DDS_DataReaderQos  reader_qos;
reader_listener = new HelloWorldListener();
if (reader_listener == NULL) {
       // handle error
}
// Get default data reader QoS to customize
retcode = subscriber->get_default_datareader_qos(reader_qos);
if (retcode != DDS_RETCODE_OK) {
       // handle error
}
// Set up multicast reader
reader_qos.multicast.value.ensure_length(1,1);
reader_qos.multicast.value[0].receive_address =
       DDS_String_dup("239.192.0.1");
reader = subscriber->create_datareader(
       topic,reader_qos,
       reader_listener, DDS_STATUS_MASK_ALL);
```

8.6.5.2 Properties

This QosPolicy cannot be modified after the *Entity* is created.

For compatibility between *DataWriters* and *DataReaders*, the *DataWriter* must be able to send to the multicast address that the *DataReader* has specified.

8.6.5.3 Related QosPolicies

- 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429
- 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458
- 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660

8.6.5.4 Applicable DDS Entities

- 9.3 DomainParticipants on page 604
- 8.3 DataReaders on page 501

8.6.5.5 System Resource Considerations

On Ethernet-based systems, the number of multicast addresses that can be "listened" to by the network interface card is usually limited. The exact number of multicast addresses that can be monitored simultaneously by a NIC depends on its manufacturer. Setting a multicast address for a *DataReader* will use up one of the multicast-address slots of the NIC.

What happens if the number of different multicast addresses used by different *DataReaders* across different applications on the same node exceeds the total number supported by a NIC depends on the specific operating system. Some will prevent you from configuring too many multicast addresses to be monitored.

Many operating systems will accommodate the extra multicast addresses by putting the NIC in promiscuous mode. This means that the NIC will pass every Ethernet packet to the operating system, and the operating system will pass the packets with the specified multicast addresses to the application(s). This results in extra CPU usage. We recommend that your applications do not use more multicast addresses on a single node than the NICs on that node can listen to simultaneously in hardware.

Depending on the implementation of a transport, *Connext DDS* may need to create threads to receive and process data on a unique-port-number basis. Some transports can share the same thread to process data received for different ports; others like UDPv4 must have different threads for different ports. In addition, if the same port is used for both unicast and multicast, the transport implementation will determine whether or not the same thread can be used to process both unicast and multicast data. For UDPv4, only one thread is needed per port–independent of whether the data was received via unicast or multicast data. See 21.3 Receive Threads on page 903 for more information.

8.6.6 TYPE_CONSISTENCY_ENFORCEMENT QosPolicy

The TypeConsistencyEnforcementQosPolicy defines the rules that determine whether the type used to publish a given topic is consistent with the type used to subscribe to it.

The QosPolicy structure includes the members in the following table.

Table 8.25 DDS_TypeConsistencyEnforcementQosPolicy

Type	Field Name	Description
DDS_TypeConsistencyKind	kind	Can be any of the following values: • AUTO_TYPE_COERCION (default) • ALLOW_TYPE_COERCION • DISALLOW_TYPE_COERCION See below for details.
DDS_Boolean	ignore_sequence_bounds	Controls whether sequence bounds are taken into consideration for type assignability. If false, a sequence with a larger maximum length may not be assigned to a sequence with a smaller maximum length. If true, sequences and strings in a *DataReader* type can have a maximum length smaller than that of the *DataWriter* type. When the length of the sequence in a particular sample is larger than the maximum length, that sample is discarded. Default: true
DDS_Boolean	ignore_string_bounds	Controls whether string bounds are taken into consideration for type assignability. If false, then a string with a larger maximum length may not be assigned to a string with a smaller maximum length. Default: true

DDS_Boolean	ignore_member_names	Controls whether member names are taken into consideration for type assignability.
		If false, members with the same ID and different names are not assignable to each other.
		If true, members of a type can change their name while keeping their member ID. For example, MyType and MyTypeSpanish are only assignable if ignore_member_names is true:
		`struct MyType {`
		`  @id(10) int32 x;`
		`  @id(20) int32 angle;`
		`};`
		`struct MyTypeSpanish {`
		`  @id(10) int32 x;`
		`  @id(20) int32 angulo;`
		`};`
		Default: false

DDS_Boolean	prevent_type_widening	Controls whether type widening is allowed. A type T2 widens a type T1 when T2 contains required members that are not present in T1. If a *DataReader* of T2 sets prevent_type_widening to true, then the *DataReader* will not be matched with a *DataWriter* of T1 because T1 is not assignable to T2. Default: false
DDS_Boolean	force_type_validation	Controls whether type information must be available in order to complete matching between a *DataWriter* and this *DataReader*. If false, matching may occur as long as the type names match. Note that if the types have the same name but are not assignable, *DataReaders* may fail to deserialize incoming data samples. Default: false

Table 8.25 DDS_TypeConsistencyEnforcementQosPolicy

Type	Field Name	Description
DDS_Boolean	ignore_enum_literal_names	Controls whether enumeration constant names are taken into consideration for type assignability. If the option is set to true, then enumeration constants may change their names, but not their values, and still maintain assignability. If the option is set to false, then in order for enumerations to be assignable, any constant that has the same value in both enumerations must also have the same name. For example, enum Color {RED = 0} and enum Color {ROJO = 0} are assignable if and only if ignore_enum_literal_names is true. Default: false

The type-consistency enforcement rules consist of two steps:

1. If both the *DataWriter* and *DataReader* specify a TypeObject, it is considered first. If the *DataReader* allows type coercion, then its type must be assignable from the *DataWriter's* type, taking into account the values of **prevent_type_widening**, **ignore_sequence_bounds**, **ignore_string_bounds**, **ignore_member_names**, and **ignore_enum_literal_names**. If the *DataReader* does not allow type coercion, then its type must be equivalent to the type of the *DataWriter*.
2. If either the *DataWriter* or the *DataReader* does not provide a TypeObject definition, then the registered type names are examined. The *DataReader's* and *DataWriter's* registered type names must match exactly, as was true in *Connext DDS* releases prior to 5.0. This step will fail if **force_type_validation** is true, regardless of the type names.

If either Step 1 or Step 2 fails, the *Topics* associated with the *DataReader* and *DataWriter* are considered to be inconsistent and the 5.3.1 INCONSISTENT_TOPIC Status on page 226 is updated.

The default enforcement kind is **DDS_AUTO_TYPE_COERCION**. This default kind translates to **DDS_ALLOW_TYPE_COERCION**, except in the following cases:

- When a Zero Copy *DataReader* is used, the kind is translated to **DDS_DISALLOW_TYPE_COERCION**.
- When the middleware is introspecting the built-in topic data declaration of a remote *DataReader* in order to determine whether it can match with a local *DataWriter*, if it observes that no TypeConsistencyEnforcementQosPolicy value is provided (as would be the case when communicating with a Service implementation not in conformance with this specification), it assumes a kind of **DDS_DISALLOW_TYPE_COERCION**.

8.6.6.1 Values for TypeConsistencyKind

- AUTO_TYPE_COERCION (default)

  For a regular *DataReader*, this default value is translated to ALLOW_TYPE_COERCION. For a Zero Copy *DataReader*, this default value is translated to DISALLOW_TYPE_COERCION. (See

23.6 Zero Copy Transfer Over Shared Memory on page 953 for information on why a Zero Copy *DataReader* requires the DISALLOW_TYPE_COERCION option.)

- DISALLOW_TYPE_COERCION

  With this setting, the *DataWriter* and *DataReader* must support the same data type in order for them to communicate. (This is the degree of enforcement required by the OMG DDS Specification prior to the OMG 'Extensible and Dynamic Topic Types for DDS' specification.)

  When *Connext DDS* is introspecting the built-in topic data declaration of a remote *DataWriter* or *DataReader*, if no TypeConsistencyEnforcementQosPolicy value is provided (as would be the case when communicating with an implementation not in conformance with the Extensible and Dynamic Topic Types for DDS" (DDS-XTypes) specification), *Connext DDS* shall assume a **kind** of DISALLOW_TYPE_COERCION.
- ALLOW_TYPE_COERCION

  With this setting, the *DataWriter* and the *DataReader* need not support the same data type in order for them to communicate, as long as the *DataReader's* type is assignable from the *DataWriter's* type.

  For example, the following two extensible types will be assignable to each other since MyDerivedType contains all the members of MyBaseType (**member_1**) plus an additional element (**member_2**).

```
struct MyBaseType {
       long member_1;
};
struct MyDerivedType: MyBaseType {
       long member_2;
};
```

  Even if MyDerivedType was not explicitly inherited from MyBaseType, the types would still be assignable. For example:

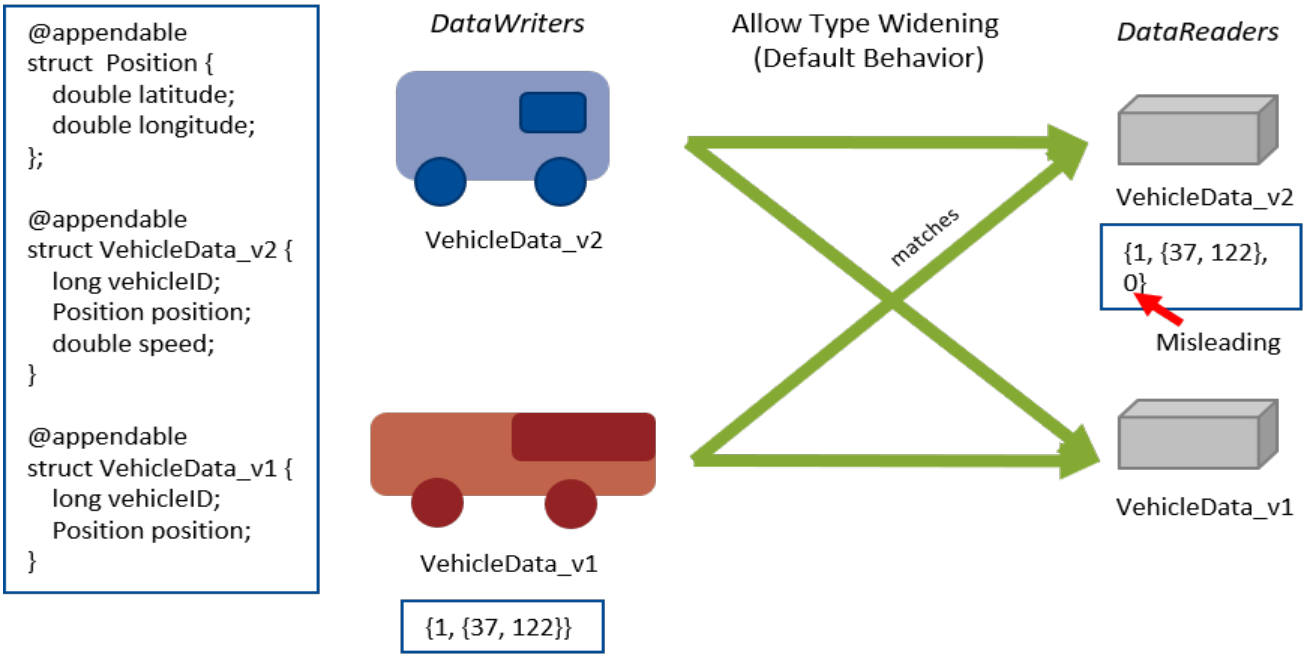
```
struct MyBaseType {
       long member_1;
};
struct MyDerivedType {
       long member_1;
       long member_2;
};
```

For more information, see the RTI Connext DDS Core Libraries Extensible Types Guide and the OMG 'Extensible and Dynamic Topic Types for DDS' Specification.

8.6.6.2 Prevent Type Widening

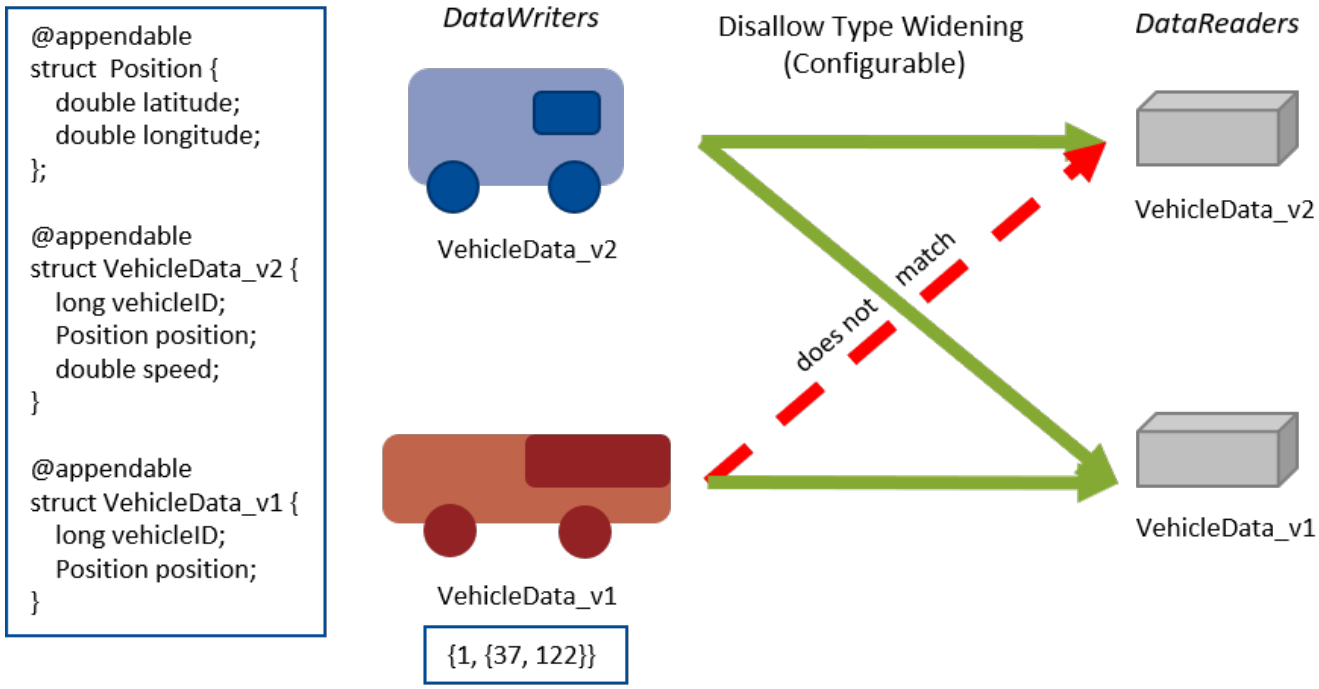
The **prevent_type_widening** field determines whether type widening is allowed. In Figure 8.25: prevent_type_widening = false below, VehicleData_v2 has three members and VehicleData_v1 two members. With type widening allowed, the narrower car (VehicleData_v1, with two members) can write to the wider car (VehicleData_v2), but notice that the *DataReader* assumes a value that might be misleading (in this case, a default speed of zero).

Figure 8.25: prevent_type_widening = false



If widening is not allowed (Figure 8.26: prevent_type_widening = true on the next page), VehicleData_v1 and VehicleData_v2 do not communicate with each other.

Figure 8.26: prevent_type_widening = true



8.6.6.3 Properties

This QosPolicy cannot be modified after the *DataReader* is enabled.

It only applies to *DataReaders*, so there is no requirement that the publishing and subscribing sides use compatible values.

8.6.6.4 Related QoS Policies

- None.

8.6.6.5 Applicable Entities

- 8.3 DataReaders on page 501

8.6.6.6 System Resource Considerations

- None.

Chapter 9 Working with DDS Domains

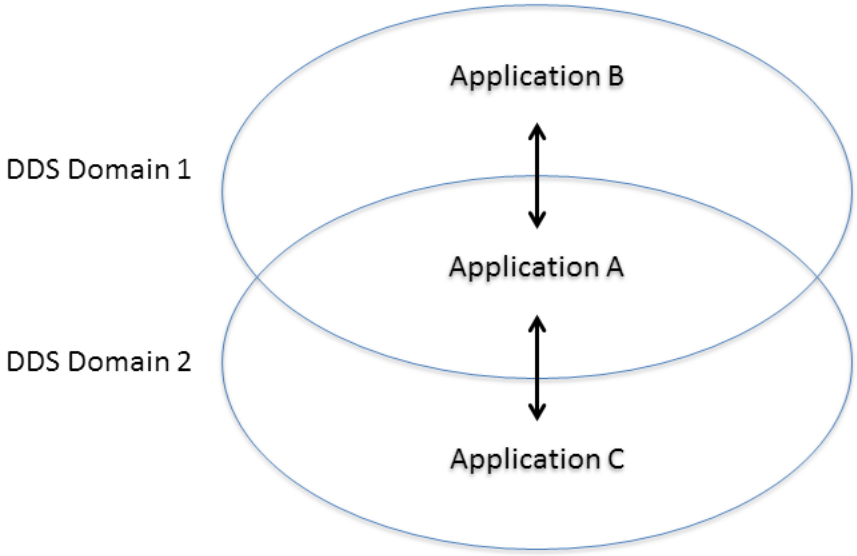
This section discusses how to use *DomainParticipant*s. It describes the types of operations that are available for them and their QosPolicies.

The goal of this section is to help you become familiar with the objects you need for setting up your *Connext DDS* application. For specific details on any mentioned operations, see the API Reference HTML documentation.

9.1 Fundamentals of DDS Domains and DomainParticipants

DomainParticipants are the focal point for creating, destroying, and managing other *Connext DDS* objects. A *DDS domain* is a logical network of applications: only applications that belong to the same DDS domain may communicate using *Connext DDS*. A DDS domain is identified by a unique integer value known as a domain ID. An application participates in a DDS domain by creating a *DomainParticipant* for that domain ID.

Figure 9.1: Relationship between Applications and DDS Domains



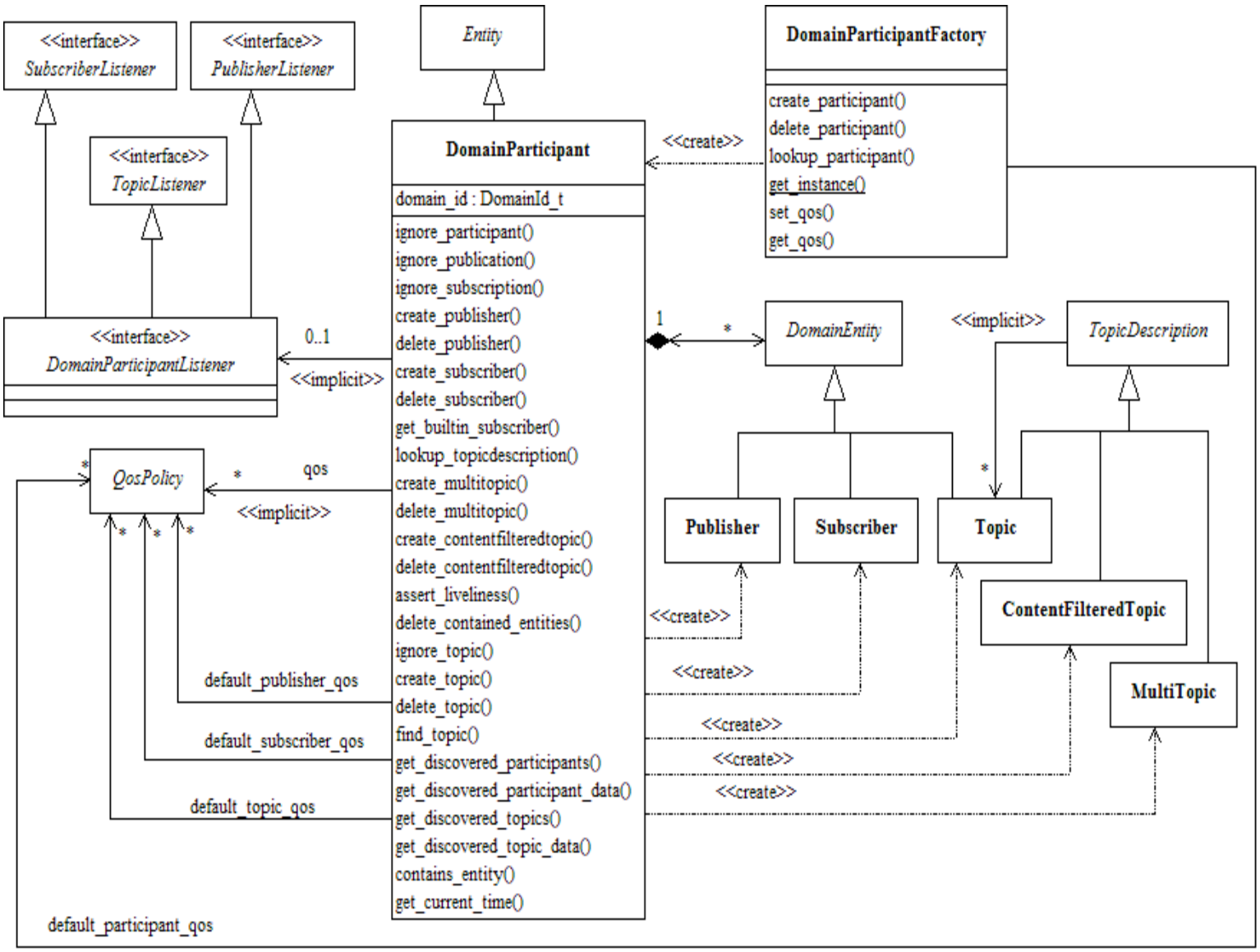
Applications can belong to multiple DDS domains—A belongs to DDS domains 1 and 2. Applications in the same DDS domain can communicate with each other, such as A and B, or A and C. Applications in different DDS domains, such as B and C, are not even aware of each other and will not exchange messages.

As seen in Figure 9.1: Relationship between Applications and DDS Domains above, a single application can participate in multiple DDS domains by creating multiple *DomainParticipants* with different domain IDs. *DomainParticipant*s in the same DDS domain form a logical network; they are isolated from *DomainParticipant*s of other DDS domains, even those running on the same set of physical computers sharing the same physical network. *DomainParticipants* in different DDS domains will never exchange messages with each other. Thus, a DDS domain establishes a "virtual network" linking all *DomainParticipant*s that share the same domain ID.

An application that wants to participate in a certain DDS domain will need to create a *DomainParticipant*. As seen in Figure 9.2: DDS Domain Module on the next page, a *DomainParticipant* object is a container for all other *Entities* that belong to the same DDS domain. It acts as factory for the *Publisher*, *Subscriber*, and *Topic* entities. (As seen in Sending Data (Chapter 7 on page 269) and Receiving Data (Chapter 8 on page 481), in turn, *Publishers* are factories for *DataWriters* and *Subscribers* are factories for *DataReaders*.) *DomainParticipants* cannot contain other *DomainParticipants*.

Like all *Entities*, *DomainParticipants* have QosPolicies and *Listeners*. The *DomainParticipant* entity also allows you to set 'default' values for the QosPolicies for all the entities created from it or from the entities that it creates (*Publishers*, *Subscribers*, *Topics*, *DataWriters*, and *DataReaders*).

Figure 9.2: DDS Domain Module



Note: MultiTopics are not supported.

9.2 DomainParticipantFactory

- C, Traditional C++, Java and .NET APIs:

  The main purpose of a *DomainParticipantFactory* is to create and destroy *DomainParticipant*s.

  In C++ terms, this is a singleton class; that is, you will only have a single *DomainParticipantFactory* in an application—no matter how many *DomainParticipants* the application may create. Figure 9.3: Instantiating a DomainParticipantFactory on the next page shows how to

instantiate a *DomainParticipantFactory*. Notice that there are no parameters to specify. Alternatively, in C++, C++/CLI, and C#, the predefined macro, **DDSTheParticipantFactory**,[1] can also be used to retrieve the singleton factory.

Unlike the other *Entities* that you create, the *DomainParticipantFactory* does not have an associated *Listener*. However, it does have associated QosPolicies, see 9.2.1 Setting DomainParticipantFactory QosPolicies on page 600. You can change them using the factory's **get_qos()** and **set_qos()** operations. The *DomainParticipantFactory* also stores the default QoS settings that can be used when a *DomainParticipant* is created. These default settings can be changed as well, see 9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622.

Figure 9.3: Instantiating a DomainParticipantFactory

```
DDSDomainParticipantFactory* factory = NULL;
factory = DDSDomainParticipantFactory::get_instance();
if (factory == NULL) {
        // ... error
}
```

- Modern C++ API:

  In the Modern C++ API, there isn't a explicit DomainParticipantFactory. *DomainParticipants* are created using their constructors andare automatically destroyed as a reference type (See 4.1.1 Creating and Deleting DDS Entities on page 167).

  The operations to set and get the default DomainParticipantQos are static functions in *DomainParticipant*: **DomainParticipant::default_participant_qos()**. The operations to look up participants are freestanding functions in the **dds::domain** and **rti::domain** namespaces: **dds::domain::find()**, **rti::domain::find_participant_by_name()**, and **rti::domain::find_participants()**. The class QosProvider is responsible for managing QoS profiles (see 19.5 How to Load XML-Specified QoS Settings on page 875).

  There is a DomainParticipantFactoryQos, but it only contains the ENTITY_FACTORY to indicate if a *DomainParticipant* should be enabled in its constructor or by calling **enable()**, and SYSTEM_RESOURCE_LIMITS. The DomainParticipantFactoryQos getter and setter are static functions in DomainParticipant: **DomainParticipant::participant_factory_qos()**.

  Another static function in DomainParticipant allows finalizing the implicit DomainParticipantFactory singleton: **DomainParticipant::finalize_participant_factory()**.

Once you have a *DomainParticipantFactory*, you can use it to perform the operations listed in Table 9.1 DomainParticipantFactory Operations. The most important one is **create_participant()**, described in 9.3.1

[1] In C, the macro is DDS_TheParticipantFactory. In Java, use the static class method DomainParticipantFactory.TheParticipantFactory.

Creating a DomainParticipant on page 610. For more details on all operations, see the API Reference HTML documentation as well as the section of the manual listed in the Reference column.

Table 9.1 DomainParticipantFactory Operations

Working with ...	Operation	Description	Reference
Domain-Participants	create_participant	Creates a *DomainParticipant*.	9.3.1 Creating a DomainParticipant on page 610
	create_participant_with_profile	Creates a *DomainParticipant* based on a QoS profile.	
	delete_participant	Deletes a *DomainParticipant*.	9.3.2 Deleting DomainParticipants on page 612
	get_default_participant_qos	Gets the default QoS for *DomainParticipants*.	9.2.2 Getting and Setting Default QoS for DomainParticipants on page 602
	get_participants	Returns a sequence of pointers to all the *DomainParticipants* within the DomainParticipantFactory.	9.2.4 Looking Up DomainParticipants on page 603
	lookup_participant	Finds a specific *DomainParticipant*, based on a domain ID.	
	lookup_participant_by_name	Finds a specific *DomainParticipant*, based on a domain name.	
	set_default_participant_qos	Sets the default QoS for *DomainParticipant*s.	9.2.2 Getting and Setting Default QoS for DomainParticipants on page 602
	set_default_participant_qos_with_profile	Sets the default QoS for *DomainParticipants* based on a QoS profile.	
The Factory's Instance	get_instance	Gets the singleton instance of this class.	9.2.3 Freeing Resources Used by the DomainParticipantFactory on page 602
	finalize_instance	Destroys the singleton instance of this class.	
The Factory's Own QoS	get_qos	Gets/sets the DomainParticipantFactory's QoS.	4.1.7 Getting, Setting, and Comparing QosPolicies on page 172
	set_qos		
	equals	Compares two DomainParticipantFactory's QoS structures for equality.	

Table 9.1 DomainParticipantFactory Operations

Working with ...	Operation	Description	Reference
Threads	set_thread_factory	Specifies a ThreadFactory implementation that DomainParticipants will use to create and delete all threads.	21.7 User-Managed Threads on page 907
	unregister_thread	Frees all resources related to a thread. This function is intended to be used at the end of any user-created threads that invoke *Connext DDS* APIs (not all users will have this situation). The best approach is to call it immediately before exiting such a thread, after all *Connext DDS* APIs have been called.	
Profiles & Libraries	get_default_library	Gets the default library for a DomainParticipantFactory.	9.2.1.1 Getting and Setting the DomainParticipantFactory's Default QoS Profile and Library on the next page
	get_default_profile	Gets the default QoS profile for a DomainParticipantFactory.	
	get_default_profile_library	Gets the library that contains the default QoS profile for a *DomainParticipantFactory*.	
	get_<*entity*>_qos_from_profile	Gets the <*entity*> QoS values associated with a specified QoS profile. <*entity*> may be *topic*, *datareader*, *datawriter*, *subscriber*, *publisher*, or *participant*.	9.2.5 Getting QoS Values from a QoS Profile on page 603
	get_<*entity*>_qos_from_profile_w_topic_name	Like get_<*entity*>_qos_from_profile(), but this operation allows you to specify a topic name associated with the entity. The topic filter expressions in the profile will be evaluated on the topic name. <*entity*> may be *topic*, *datareader*, or *datawriter*.	
	get_qos_profiles	Gets the names of all XML QoS profiles associated with a specified XML QoS profile library.	19.4 Tags for Configuring QoS with XML on page 868
	get_qos_profile_libraries	Gets the names of all XML QoS profile libraries associated with the DomainParticipantFactory.	19.10.1 Retrieving a List of Available Libraries on page 886
	load_profiles	Explicitly loads or reloads the QoS profiles.	19.5.1 Loading, Reloading and Unloading Profiles on page 877
	reload_profiles		
	set_default_profile	Sets the default QoS profile for a DomainParticipantFactory.	9.2.1.1 Getting and Setting the DomainParticipantFactory's Default QoS Profile and Library on the next page
	set_default_library	Sets the default library for a DomainParticipantFactory.	
	unload_profiles	Frees the resources associated with loading QoS profiles.	19.5.1 Loading, Reloading and Unloading Profiles on page 877

9.2.1 Setting DomainParticipantFactory QosPolicies

The DDS_DomainParticipantFactoryQos structure has the following format:

```
struct DDS_DomainParticipantFactoryQos {
       DDS_EntityFactoryQosPolicy              entity_factory;
       DDS_SystemResourceLimitsQosPolicy       resource_limits;
       DDS_ProfileQosPolicy                    profile;
       DDS_LoggingQosPolicy                    logging;
};
```

For information on *why* you would want to change a particular QosPolicy, see the section referenced in Table 9.2 DomainParticipantFactory QoS.

Table 9.2 DomainParticipantFactory QoS

QosPolicy	Description
EntityFactory	Controls whether or not child entities are created in the enabled state. See 7.4.2 ENTITYFACTORY QosPolicy on page 347.
Logging	Configures the properties associated with *Connext DDS* logging. See 9.4.1 LOGGING QosPolicy (DDS Extension) on page 627.
Profile	Configures the way that XML documents containing QoS profiles are loaded by RTI. See 9.4.2 PROFILE QosPolicy (DDS Extension) on page 628.
SystemResource-Limits	Configures *DomainParticipant*-independent resources used by *Connext DDS*. Mainly used to change the maximum number of *DomainParticipants* that can be created within a single process (address space). See 9.4.3 SYSTEM_RESOURCE_LIMITS QoS Policy (DDS Extension) on page 630.

9.2.1.1 Getting and Setting the DomainParticipantFactory's Default QoS Profile and Library

You can retrieve the default QoS profile for the DomainParticipantFactory with the **get_default_profile()** operation. You can also get the default library for the DomainParticipantFactory, as well as the library that contains the DomainParticipantFactory's default profile (these are not necessarily the same library); these operations are called **get_default_library()** and **get_default_library_profile()**, respectively. These operations are for informational purposes only (that is, you do not need to use them as a precursor to setting a library or profile.) For more information, see Configuring QoS with XML (Chapter 19 on page 842).

```
virtual const char *  get_default_library ()
const char *  get_default_profile ()
const char *  get_default_profile_library ()
```

There are also operations for setting the DomainParticipantFactory*'s* default library and profile:

```
DDS_ReturnCode_t set_default_library  (const char *  library_name)
DDS_ReturnCode_t set_default_profile (const char *  library_name,
                                      const char *  profile_name)
```

set_default_profile() specifies the profile that will be used as the default the next time a default DomainParticipantFactory profile is needed during a call to a DomainParticipantFactory operation.

When calling a DomainParticipantFactory operation that requires a **profile_name** parameter, you can use NULL to refer to the default profile. (This same information applies to setting a default library.)

set_default_profile() does not set the default QoS for the *DomainParticipant* that can be created by the DomainParticipantFactory. To set the default QoS using a profile, use the DomainParticipantFactory's **set_default_participant_qos_with_profile()** operation (see 9.2.2 Getting and Setting Default QoS for DomainParticipants below).

9.2.2 Getting and Setting Default QoS for DomainParticipants

To *get* the default QoS that will be used for creating *DomainParticipants* if **create_participant()** is called with DDS_PARTICIPANT_QOS_DEFAULT as the **qos** parameter, use this DomainParticipantFactory operation:

```
DDS_ReturnCode_t get_default_participant_qos (DDS_DomainParticipantQos & qos)
```

This operation gets the QoS settings that were specified on the last successful call to **set_default_participant_qos()** or **set_default_participant_qos_with_profile()**, or if the call was never made, the default values listed in DDS_DomainParticipantQos.

To *set* the default QoS that will be used for new *DomainParticipants*, use the following operations. Then these default QoS will be used if **create_participant()** is called with DDS_PARTICIPANT_QOS_ DEFAULT as the 'qos' parameter.

```
DDS_ReturnCode_t set_default_participant_qos (
       const DDS_DomainParticipantQos &qos)
```

or

```
DDS_ReturnCode_t set_default_participant_qos_with_profile (
       const char *library_name, const char *profile_name)
```

Notes:

- These operations may potentially allocate memory, depending on the sequences contained in some QoS policies.
- It is not safe to set the default *DomainParticipant* QoS values while another thread may be simultaneously calling **get_default_participant_qos(), set_default_participant_qos(),** or **create_participant()** with DDS_PARTICIPANT_QOS_DEFAULT as the **qos** parameter. It is also not safe to get the default *DomainParticipant* QoS values while another thread may be simultaneously calling **set_default_participant_qos().**

9.2.3 Freeing Resources Used by the DomainParticipantFactory

The **finalize_instance()** operation explicitly reclaims resources used by the participant factory singleton (including resources use for QoS profiles).

On many operating systems, these resources are automatically reclaimed by the OS when the program terminates. However, some memory-check tools will flag those resources as unreclaimed. This method provides a way to clean up all the memory used by the participant factory.

Before calling **finalize_instance()** on a *DomainParticipantFactory*, all of the participants created by the factory must have been deleted. For a *DomainParticipant* to be successfully deleted, all *Entities* created by the participant or by the *Entities* that the participant created must have been deleted. In essence, the *DomainParticipantFactory* cannot be deleted until all other Entities have been deleted in an application.

Except for Linux systems: **get_instance()** and **finalize_instance()** are UNSAFE on the FIRST call. It is not safe for two threads to simultaneously make the first call to get or finalize the factory instance. Subsequent calls are thread safe.

9.2.4 Looking Up DomainParticipants

The DomainParticipantFactory has these useful operations for retrieving its *DomainParticipants*:

- **get_participants()** returns a sequence of pointers to all the *DomainParticipants* within the DomainParticipantFactory.

```
DDS_ReturnCode_t
       get_participants (DDSDomainParticipantSeq & participants)
```

- **lookup_participant()** locates an existing *DomainParticipant* based on its domain ID.

```
DDSDomainParticipant *
       lookup_participant (DDS_DomainId_t domainId)
```

- **lookup_participant_by_name ()** locates an existing *DomainParticipant* based on its name.

```
DDSDomainParticipant *
       lookup_participant_by_name(const char * participant_name)
```

Note: in the Modern C++ API these operations are freestanding functions **rti::domain::find_participants ()**, **dds::domain::find()**, and **rti::domain::find_participant_by_name()**, respectively.

9.2.5 Getting QoS Values from a QoS Profile

A QoS Profile may include configuration settings for all types of Entities. If you just want the settings for a specific type of Entity, call **get_<*entity*>_qos_from_profile()** (where <*entity*> may be **participant**, **publisher**, **subscriber**, **datawriter**, **datareader**, or **topic**). This is useful if you want to get the QoS values from the profile in a structure, make some changes, and then use that structure to create an entity.

```
DDS_ReturnCode_t get_<entity>_qos_from_profile (
                                DDS_<Entity>Qos &qos,
                                const char *library_name,
                                const char *profile_name)
```

For an example, see Figure 7.5: Getting QoS Values from a Profile, Changing QoS Values, Creating a Publisher with Modified QoS Values on page 279.

The **get_<*entity*>_qos_from_profile()** operations do not take into account the **topic_filter** attributes that may be set for *DataWriter*, *DataReader*, or *Topic* QoSs in profiles (see 19.3.4 Topic Filters on page 864). If there is a topic name associated with an entity, you can call **get_<*entity*>_qos_from_profile_w_topic_name()** (where <*entity*> can be datawriter, datareader, or topic) and the topic filter expressions in the profile will be evaluated on the topic name.

```
DDS_ReturnCode_t get_<entity>_qos_from_profile_w_topic_name(
                                 DDS_<entity>Qos &qos,
                                 const char *library_name,
                                 const char *profile_name,
                                 const char *topic_name)
```

get_<*entity*>_qos_from_profile() and **get_<*entity*>_qos_from_profile_w_topic_name()** may allocate memory, depending on the sequences contained in some QoS policies.

Note: in the Modern C++ API, the class QosProvider provides the functionality described in thi section. Please see the API Reference HTML documentation: Modules, RTI Connext DDS API Reference, Configuring QoS Profiles with XML, QosProvider.

9.3 DomainParticipants

A *DomainParticipant* is a container for *Entity* objects that all belong to the same DDS domain. Each *DomainParticipant* has its own set of internal threads and internal data structures that maintain information about the *Entities* created by itself and other *DomainParticipants* in the same DDS domain. A *DomainParticipant* is used to create and destroy *Publishers, Subscribers* and *Topics*.

Once you have a *DomainParticipant*, you can use it to perform the operations listed in Table 9.3 DomainParticipant Operations. For more details on all operations, see the API Reference HTML documentation. Some of the first operations you'll be interested in are **create_topic()**, **create_subscriber()**, and **create_publisher()**.

Note: Some operations cannot be used within a listener callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

Table 9.3 DomainParticipant Operations

Working with ...	Operation	Description	Reference
Builtin Subscriber	get_builtin_subscriber	Returns the builtin Subscriber.	18.2 Built-in DataReaders on page 826

Table 9.3 DomainParticipant Operations

Working with ...	Operation	Description	Reference
Domain-Participants	add_peer	Adds an entry to the peer list.	9.5.2.3 Adding and Removing Peers List Entries on page 636
	enable	Enables the *DomainParticipant*.	4.1.2 Enabling DDS Entities on page 168
	equals	Compares two *DomainParticipant's* QoS structures for equality.	9.3.7.2 Comparing QoS Values on page 620
	get_discovered_participant_data	Provides the ParticipantBuiltinTopicData for a discovered *DomainParticipant*.	9.3.12 Learning about Discovered DomainParticipants on page 625
	get_discovered_participants	Provides a list of *DomainParticipants* that have been discovered.	
	get_domain_id	Gets the domain ID of the *DomainParticipant*.	9.3.4 Choosing a Domain ID and Creating Multiple DDS Domains on page 613
	get_listener	Gets the currently installed *DomainParticipantListener*.	9.3.6 Setting Up DomainParticipantListeners on page 615
	get_qos	Gets the *DomainParticipant* QoS.	9.3.7 Setting DomainParticipant QosPolicies on page 617
	ignore_participant	Rejects the connection to a remote *DomainParticipant*.	18.4 Restricting Communication–Ignoring Entities on page 835
	remove_peer	Removes an entry from the peer list.	9.5.2.3 Adding and Removing Peers List Entries on page 636
	set_listener	Replaces the *DomainParticipantListener*.	9.3.6 Setting Up DomainParticipantListeners on page 615
	set_qos	Sets the *DomainParticipant* QoS.	9.3.7 Setting DomainParticipant QosPolicies on page 617
	set_qos_with_profile	Sets the *DomainParticipant* QoS based on a QoS profile.	

Table 9.3 DomainParticipant Operations

Working with ...	Operation	Description	Reference
Content-Filtered-Topics	create_contentfilteredtopic	Creates a ContentFilteredTopic that can be used to process content-based subscriptions.	5.4.3 Creating ContentFilteredTopics on page 229
	create_contentfilteredtopic_with_filter		
	delete_contentfilteredtopic	Deletes a ContentFilteredTopic.	5.4.4 Deleting ContentFilteredTopics on page 232
	register_contentfilter	Registers a new content filter.	5.4.10.2 Registering a Custom Filter on page 248
	unregister_contentfilter	Unregisters a new content filter.	5.4.10.3 Unregistering a Custom Filter on page 251
	lookup_contentfilter	Gets a previously registered content filter.	5.4.10.4 Retrieving a ContentFilter on page 251
DataReaders	create_datareader	Creates a *DataReader* with a given DataReaderListener, and an implicit *Subscriber*.	8.3.1 Creating DataReaders on page 507
	create_datareader_with_profile	Creates a *DataReader* based on a QoS profile, with a given DataReaderListener, and an implicit *Subscriber*.	
	delete_datareader	Deletes a *DataReader* that belongs to the 'implicit *Subscriber*.'	8.3.3 Deleting DataReaders on page 509
	get_default_datareader_qos	Copies the default DataReaderQoS values into the provided structure.	9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622
	ignore_subscription	Rejects the connection to a *DataReader*	
	set_default_datareader_qos	Sets the default DataReaderQos values.	
	set_default_datareader_qos_with_profile	Sets the default DataReaderQos using values from a QoS profile.	

Table 9.3 DomainParticipant Operations

Working with ...	Operation	Description	Reference
DataWriters	create_datawriter	Creates a *DataWriter* with a given DataWriterListener, and an implicit *Publisher*.	7.2.2 Creating Publishers on page 275
	create_datawriter_with_profile	Creates a *DataWriter* based on a QoS profile, with a given DataWriterListener, and an implicit *Publisher*.	
	delete_datawriter	Deletes a *DataWriter* that belongs to the 'implicit *Publisher*.'	7.2.3 Deleting Publishers on page 276
	ignore_publication	Rejects the connection to a *DataWriter*.	18.4 Restricting Communication–Ignoring Entities on page 835
	get_default_datawriter_qos	Copies the default DataWriterQos values into the provided DataWriterQos structure.	9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622
	set_default_datawriter_qos	Sets the default DataWriterQoS values.	
	set_default_datawriter_qos _with_profile	Sets the default DataWriterQos using values from a profile.	
Publishers	create_publisher	Creates a *Publisher* and a PublisherListener.	7.2.2 Creating Publishers on page 275
	create_publisher_with_profile	Creates a *Publisher* based on a QoS profile, and a PublisherListener.	
	delete_publisher	Deletes a *Publisher*.	7.2.3 Deleting Publishers on page 276
	get_default_publisher_qos	Copies the default PublisherQos values into the provided PublisherQos structure.	9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622
	get_implicit_publisher	Gets the *Publisher* that is implicitly created by the *DomainParticipant*.	9.3.10 Getting the Implicit Publisher or Subscriber on page 624
	get_publishers	Provides a list of all *Publishers* owned by the *DomainParticipant*.	9.3.15.3 Getting All Publishers and Subscribers on page 627
	set_default_publisher_qos	Sets the default PublisherQos values.	9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622
	set_default_publisher_qos_with_profile	Sets the default PublisherQos using values from a QoS profile.	

Table 9.3 DomainParticipant Operations

Working with ...	Operation	Description	Reference
Subscribers	create_subscriber	Creates a *Subscriber* and a SubscriberListener.	8.2.2 Creating Subscribers on page 488
	create_subscriber_with_profile	Creates a *Subscriber* based on a QoS profile, and a SubscriberListener.	
	delete_subscriber	Deletes a *Subscriber*.	8.2.3 Deleting Subscribers on page 489
	get_default_subscriber_qos	Copies the default SubscriberQos values into the provided SubscriberQos structure.	9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622
	get_implicit_subscriber	Gets the *Subscriber* that is implicitly created by the *DomainParticipant*.	9.3.10 Getting the Implicit Publisher or Subscriber on page 624
	get_subscribers	Provides a list of all *Subscribers* owned by the *DomainParticipant*.	9.3.15.3 Getting All Publishers and Subscribers on page 627
	set_default_subscriber_qos	Sets the default SubscriberQos values.	9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622
	set_default_subscriber_qos_with_profile	Sets the default SubscriberQos values using values from a QoS profile.	
Durable Subscriptions	delete_durable_subscription	Deletes an existing Durable Subscription. The quorum of the existing DDS samples will be considered satisfied.	46.9 Configuring Durable Subscriptions in Persistence Service on page 1180
	register_durable_subscription	Creates a Durable Subscription that will receive all DDS samples published on a *Topic*, including those published while a *DataReader* is inactive or before it may be created. *RTI Persistence Service* will ensure that all the DDS samples on that *Topic* are retained until they are acknowledged by at least *N DataReaders* belonging to the Durable Subscription, where *N* is the quorum count. If the same Durable Subscription is created on a different *Topic*, *RTI Persistence Service* will implicitly delete the previous Durable Subscription and create a new one on the new *Topic*.	

Table 9.3 DomainParticipant Operations

Working with ...	Operation	Description	Reference
Topics	create_topic	Creates a *Topic* and a TopicListener.	5.1.1 Creating Topics on page 217
	create_topic _with_ profile	Creates a Topic based on a QoS profile, and a TopicListener.	
	delete_topic	Deletes a *Topic*.	
	get_default_topic_ qos	Copies the default TopicQos values into the provided TopicQos structure.	9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622
	get_discovered_ topic_data	Retrieves the BuiltinTopicData for a discovered *Topic*.	9.3.13 Learning about Discovered Topics on page 625
	get_discovered_topics	Returns a list of all (non-ignored) discovered *Topics*.	
	ignore_topic	Rejects a remote topic.	18.4 Restricting Communication–Ignoring Entities on page 835
	lookup_topicdescription	Gets an existing locally-created TopicDescription (Topic).	9.3.8 Looking up Topic Descriptions on page 623
	set_default_topic_ qos	Sets the default TopicQos values.	9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622
	set_default_topic_ qos_with_profile	Sets the default TopicQos values using values from a profile.	
	find_topic	Finds an existing Topic, based on its name.	9.3.9 Finding a Topic on page 623
Flow-Controllers	create_flow-controller	Creates a custom FlowController object.	7.6.6 Creating and Deleting FlowControllers on page 478
	delete_flow-controller	Deletes a custom FlowController object.	
	get_default_flow-controller_property	Gets the default properties used when a new FlowController is created.	7.6.7 Getting/Setting Default FlowController Properties on page 478
	set_default_flow-controller_property	Sets the default properties used when a new FlowController is created.	
	lookup_flow-controller	Finds a FlowController, based on its name.	7.6.10 Other FlowController Operations on page 480

Table 9.3 DomainParticipant Operations

Working with ...	Operation	Description	Reference
Libraries and Profiles	get_default_library	Gets the default library.	9.3.7.4 Getting and Setting DomainParticipant's Default QoS Profile and Library on page 621
	get_default_profile	Gets the default profile.	
	get_default_profile_library	Gets the library that contains the default profile.	
	set_default_profile	Sets the default QoS profile.	
	set_default_library	Sets the default library.	
MultiTopics	create_multitopic	Creates a *MultiTopic* that can be used to subscribe to multiple topics and combine/filter the received data into a resulting type.	Currently not supported.
	delete_multitopic	Deletes a *MultiTopic*.	
Other	assert_liveliness	Manually asserts the liveliness of this *DomainParticipant*.	9.3.10 Getting the Implicit Publisher or Subscriber on page 624
	delete_contained_entities	Recursively deletes all the entities that were created using the "create" operations on the *DomainParticipant* and its children.	9.3.3 Deleting Contained Entities on page 612
	contains_entity	Confirms if an entity belongs to the *DomainParticipant* or not.	9.3.15.1 Verifying Entity Containment on page 626
	get_current_time	Gets the current time used by *Connext DDS*.	9.3.15.2 Getting the Current Time on page 626
	get_status_changes	Gets a list of statuses that have changed since the last time the application read the status or the *Listeners* were called.	4.1.4 Getting Status and Status Changes on page 171

9.3.1 Creating a DomainParticipant

Typically, you will only need to create one *DomainParticipant* per DDS domain per application. (Although unusual, you can create multiple *DomainParticipants* for the same DDS domain in an application.)

To create a *DomainParticipant*, use the *DomainParticipantFactory's* **create_participant()** or **create_participant_with_profile()** operation:

A QoS profile is way to use QoS settings from an XML file or string. With this approach, you can change QoS settings without recompiling the application. For details, see Configuring QoS with XML (Chapter 19 on page 842).

Note: In the Modern C++ API, you will use the *DomainParticipant* constructors.

```
DDSDomainParticipant * create_participant(
                DDS_DomainId_t domainId,
                const DDS_DomainParticipantQos &qos,
```

```
                DDSDomainParticipantListener *listener,
                DDS_StatusMask mask)
DDSDomainParticipant * create_participant_with_profile (
               DDS_DomainId_t domainId,
                const char * library_name,
                const char *profile_name,
               DDSDomainParticipantListener *listener,
               DDS_StatusMask mask)
```

Where:

domainId The domain ID uniquely identifies the DDS domain that the *DomainParticipant* is in. It controls with which other *DomainParticipants* it will communicate. See 9.3.4 Choosing a Domain ID and Creating Multiple DDS Domains on page 613 for more information on domain IDs.

qos If you want the default QoS settings (described in the API Reference HTML documentation), use DDS_PARTICIPANT_QOS_DEFAULT for this parameter (see Figure 9.4: Creating a DomainParticipant with Default QosPolicies below). If you want to customize any of the QosPolicies, supply a DomainParticipantQos structure that is described in 9.3.7 Setting DomainParticipant QosPolicies on page 617.

Note: If you use **DDS_PARTICIPANT_QOS_DEFAULT**, it is not safe to create the *DomainParticipant* while another thread may simultaneously be calling the DomainParticipantFactory's **set_default_participant_qos()** operation.

listener Listeners are callback routines. *Connext DDS* uses them to notify your application of specific events (status changes) that may occur. The listener parameter may be set to NULL if you do not want to install a *Listener*. The *DomainParticipant*'s *Listener* is a catchall for all of the events of all of its *Entities*. If an event is not handled by an *Entity*'s *Listener*, then the *DomainParticipantListener* may be called in response to the event. For more information, see 9.3.6 Setting Up DomainParticipantListeners on page 615.

mask This bit mask indicates which status changes will cause the *Listener* to be invoked. The bits set in the mask must have corresponding callbacks implemented in the *Listener*. If you use NULL for the *Listener*, use DDS_STATUS_MASK_NONE for this parameter. If the *Listener* implements all callbacks, use DDS_STATUS_MASK_ALL. For information on statuses, see 4.4 Listeners on page 189.

library_name A QoS Library is a named set of QoS profiles. See 19.3 QoS Profiles on page 844.

profile_name A QoS profile groups a set of related QoS, usually one per entity. See 19.3 QoS Profiles on page 844.

After you create a *DomainParticipant*, the next step is to register the data types that will be used by the application, see 3.6 Using RTI Code Generator (rtiddsgen) on page 152. Then you will need to create the *Topics* that the application will publish and/or subscribe, see 5.1.1 Creating Topics on page 217. Finally, you will use the *DomainParticipant* to create *Publishers* and/or *Subscribers*, see 7.2.2 Creating Publishers on page 275 and 8.2.2 Creating Subscribers on page 488.

Note: It is not safe to create one *DomainParticipant* while another thread may simultaneously be looking up (9.2.4 Looking Up DomainParticipants on page 603) or deleting (9.3.2 Deleting DomainParticipants on the next page) the same *DomainParticipant*.

For more examples, see 9.3.7.1 Configuring QoS Settings when DomainParticipant is Created on page 618.

Figure 9.4: Creating a DomainParticipant with Default QosPolicies

```
DDS_DomainId_t domain_id = 10;
// MyDomainParticipantListener is user defined and
// extends DDSDomainParticipantListener
MyDomainParticipantListener* participant_listener =
```

```
        new MyDomainParticipantListener(); // or = NULL
// Create the participant
DDSDomainParticipant* participant = factory->create_participant(
        domain_id, DDS_PARTICIPANT_QOS_DEFAULT,
        participant_listener, DDS_STATUS_MASK_ALL);
if (participant == NULL) {
        // ... error
};
```

9.3.2 Deleting DomainParticipants

If the application is no longer interested in communicating in a certain DDS domain, the *DomainParticipant* can be deleted. A *DomainParticipant* can be deleted only after all the *Entities* that were created by the *DomainParticipant* have been deleted (see 9.3.3 Deleting Contained Entities below).

To delete a *DomainParticipant*:

You must first delete all *Entities (Publishers, Subscribers, ContentFilteredTopics,* and *Topics)* that were created with the *DomainParticipant*. Use the *DomainParticipant's* **delete_<entity>()** operations to delete them one at a time, or use the **delete_contained_entities()** operation (9.3.3 Deleting Contained Entities below) to delete them all at the same time.

```
DDS_ReturnCode_t delete_publisher  (DDSPublisher  *p)
DDS_ReturnCode_t delete_subscriber (DDSSubscriber *s)
DDS_ReturnCode_t delete_contentfilteredtopic
        (DDSContentFilteredTopic *a_contentfilteredtopic)
DDS_ReturnCode_t delete_topic (DDSTopic *topic)
```

Delete the *DomainParticipant* by using the *DomainParticipantFactory's* **delete_participant()** operation.

```
DDS_ReturnCode_t delete_participant
        (DDSDomainParticipant *a_participant)
```

Note: A *DomainParticipant* cannot be deleted within its *Listener* callback, see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

After a *DomainParticipant* has been deleted, all of the participant's internal *Connext DDS* threads and allocated memory will have been deleted. You should delete the *DomainParticipantListener* only after the *DomainParticipant* itself has been deleted.

Note: In the Modern C++ API, *Entities* are automatically destroyed.

9.3.3 Deleting Contained Entities

The *DomainParticipant's* **delete_contained_entities()** operation deletes all the *Publishers* (including an implicitly created one, if it exists)*, Subscribers* (including an implicitly created one, if it exists)*, ContentFilteredTopics,* and *Topics* that have been created by the *DomainParticipant*.

```
DDS_ReturnCode_t delete_contained_entities( )
```

Prior to deleting each contained entity, this operation recursively calls the corresponding **delete_contained_entities()** operation on each contained entity (if applicable). This pattern is applied recursively.

Therefore, **delete_contained_entities()** on the *DomainParticipant* will end up deleting all the entities recursively contained in the *DomainParticipant*, that is also the *DataWriter*, *DataReader*, as well as the *QueryCondition* and *ReadCondition* objects belonging to the contained *DataReader*.

If **delete_contained_entities()** returns successfully, the application may delete the **DomainParticipant** knowing that it has no contained entities (see 9.3.2 Deleting DomainParticipants on the previous page).

9.3.4 Choosing a Domain ID and Creating Multiple DDS Domains

A domain ID identifies the DDS domain in which the *DomainParticipant* is communicating. *DomainParticipants* with the same domain ID are on the same communication "channel". *DomainParticipants* with different domain IDs are completely isolated from each other.

The domain ID is a purely arbitrary value; you can use any integer 0 or higher, provided it does not violate the guidelines for the DDS_RtpsWellKnownPorts_t structure (9.5.9.2 Ports Used for Discovery on page 666). Domain IDs are typically between 0 and 232. Please see the API Reference HTML documentation for the DDS_RtpsWellKnownPorts_t structure and in particular, DDS_INTEROPERABLE_RTPS_WELL_KNOWN_PORTS.

> **Note:** On Windows, you should avoid using ports 49152 through 65535 for inbound traffic. *Connext DDS*'s ephemeral ports (see 15.5 Ports Used for Discovery on page 785) may be within that range (see https://msdn.microsoft.com/en-us/library/windows/desktop/ms737550(v=vs.85).aspx). With the default RtpsWellKnownPorts settings, port 49152 corresponds to domain ID 167, so using domain IDs 168 through 232 on Windows introduces the risk of a port collision and failure to create the *DomainParticipant* when using multicast discovery. You may see this error:

```
RTIOsapiSocket_bindWithIP:OS bind() failure, error 0X271D: An attempt was made to access a
socket in a way forbidden by its access permissions.
```

Most distributed systems can use a single DDS domain for all of its applications. Thus a single domain ID is sufficient. Some systems may need to logically partition nodes to prevent them from communicating with each other directly, and thus will need to use multiple DDS domains. However, even in systems that only use a single DDS domain, during the testing and development phases, one may want to assign different users/testers different domain IDs for running their applications so that their tests do not interfere with each other.

To run multiple applications on the same node with the same domain ID, *Connext DDS* uses a participant ID to distinguish between the different *DomainParticipants* in the different applications. The participant ID is simply an integer value that must be unique across all *DomainParticipants* created on the same node that use the same domain ID. The participant_id is part of the 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664.

Although usually those *DomainParticipants* have been created in different applications, the same application can also create multiple *DomainParticipants* with the same domain ID. For optimal results, the participant_id should be assigned sequentially to the different *DomainParticipants*, starting from the default value of 0.

Once you have a *DomainParticipant*, you can retrieve its domain ID with the **get_domain_id()** operation.

The domain ID and participant ID are mapped to port numbers that are used by transports for discovery traffic. For information on how port numbers are calculated, see 15.5 Ports Used for Discovery on page 785. How *DomainParticipants* discover each other is discussed in Discovery (Chapter 15 on page 758).

9.3.5 Choosing a Domain Tag

The Domain Tag is an intuitive way of subdividing domains. It consists of a string value (with a maximum of 255 characters). It allows *DomainParticipants* to drop Participant Discovery messages not belonging to the same Domain Tag they are using. The Domain Tag is immutable, and cannot be changed after creating the *DomainParticipant*.

Unlike Domain IDs, Domain Tags are not mapped to port numbers that are used by transports for discovery traffic. Consequently, a *DomainParticipant* may receive Participant Discovery traffic belonging to a different Domain Tag; however, this traffic will be dropped upon reception. Another consequence of Domain Tag having no impact on port mapping is that multiple *DomainParticipants* running on the same machine with the same Domain ID, but with different Domain Tags, will end up using different participant IDs to avoid port collision.

As an example, a system with six DomainParticipants could be configured as follows:

- Participant A: Domain ID = 24, Domain Tag = "ENG. DEPT"
- Participant B: Domain ID = 24, Domain Tag = "ENG. DEPT"
- Participant C: Domain ID = 24, Domain Tag = "SALES DEPT"
- Participant D: Domain ID = 24, Domain Tag = "SALES DEPT"
- Participant E: Domain ID = 42, Domain Tag = "ENG. DEPT"
- Participant F: Domain ID = 42, Domain Tag = "ENG. DEPT"

In this system, Participants A, B, C, and D are all on the same Domain ID, so all of them will receive the discovery traffic belonging to domain 24; however, only DomainParticipant pairs A-B and C-D will be able to discover each other, since they have a matching Domain Tag. (Any discovery message not matching the expected Domain Tag will be dropped.) Participants E and F are in a different domain (42), so they are completely isolated from the rest, not even receiving the discovery traffic from the rest of the DomainParticipants. For more information, see 15.1.1 Simple Participant Discovery on page 759.

By default, a *DomainParticipant* is in an empty ("", zero-length string) Domain Tag. To associate a Domain Tag with a *DomainParticipant*, use the following *DomainParticipant* PropertyQos property:

> **dds.domain_participant.domain_tag:** A string (with a maximum of 255 characters) defining the Domain Tag the *DomainParticipant* will propagate through Participant Discovery. Participants will drop any Participant discovery message that contains a Domain Tag that does not match the local

Domain Tag. This parameter is only propagated if it is set to a value different than the default. Default: "" (empty, zero-length string).

Note: While Domain ID is fully supported across the whole *Connext DDS* ecosystem, Domain Tag support is currently limited to the Core Libraries and infrastructure Services (by setting the aforementioned *DomainParticipant* PropertyQos property). Domain Tags are not well supported in *Connext* tools (such as *Admin Console*). *Connext* tools do not provide a tool-specific mechanism to configure Domain Tags. Consequently, if you configure an application to use Domain Tags, that application will not be able to communicate with *Connext* tools, unless you edit the tool's QoS configuration (if it has one—for instance, see *Admin Console's* Preferences dialog) to use Domain Tags.

9.3.6 Setting Up DomainParticipantListeners

DomainParticipants may optionally have *Listeners*. *Listeners* are essentially callback routines and are how *Connext DDS* will notify your application of specific events (changes in status) for entities *Topics, Publishers, Subscribers, DataWriters*, and *DataReaders*. Each *Entity* may have a *Listener* installed and enabled to process the events for itself and all of the sub-*Entities* created from it. If an *Entity* does not have a *Listener* installed or is not enabled to listen for a particular event, then *Connext DDS* will propagate the event to the *Entity*'s parent. If the parent *Entity* does not process the event, *Connext DDS* will continue to propagate the event up the object hierarchy until either a *Listener* is invoked or the event is dropped.

The *DomainParticipantListener* is the last chance that an event can be processed for the *Entities* descended from a *DomainParticipant*. The *DomainParticipantListener* is used only if an event is not handled by any of the *Entities* contained by the participant.

A *Listener* is typically set up when the *DomainParticipant* is created (see 9.3.1 Creating a DomainParticipant on page 610). You can also set one up after creation time by using the **set_listener()** operation, as illustrated in Figure 9.5: Setting up DomainParticipantListener below. The **get_listener()** operation can be used to retrieve the current *DomainParticipantListener*.

Figure 9.5: Setting up DomainParticipantListener

```
// MyDomainParticipantListener only handles PUBLICATION_MATCHED and
// SUBSCRIPTION_MATCHED status for DomainParticipant Entities
class MyDomainParticipantListener :
       public DDSDomainParticipantListener {
       public:
       virtual void on_publication_matched(DDSDataWriter *writer,
               const DDS_PublicationMatchedStatus &status);
       virtual void on_subscription_matched(DDSDataReader *reader,
               const DDS_SubscriptionMatchedStatus &status);
};
void MyDomainParticipantListener::on_publication_matched(
       DDSDataWriter *writer,
       const DDS_PublicationMatchedStatus &status)
{
       const char *name = writer->get_topic()->get_name();
       printf("Number of matching DataReaders for Topic %s is %d\n",
               name, status.current_count);
```

```
};
void MyDomainParticipantListener::on_subscription_matched(
       DDSDataReader *reader,
       const DDS_SubscriptionMatchedStatus &status)
{
       const char *name =
              reader->get_topicdescription()->get_name();
       printf("Number of matching DataWriters for Topic %s is %d\n",
              name, status.current_count);
};

// Set up participant listener
MyDomainParticipantListener* participant_listener =
       new MyDomainParticipantListener();
if (participant_listener == NULL) {
       // ... handle error
}
// Create the participant with a listener
DDSDomainParticipant* participant = factory->create_participant(
       domain_id, participant_qos, participant_listener,
       DDS_PUBLICATION_MATCHED_STATUS |
       DDS_SUBSCRIPTION_MATCHED_STATUS );
if (participant == NULL) {
       // ... handle error
}
```

If a *Listener* is set for a *DomainParticipant*, the *Listener* needs to exist as long as the *DomainParticipant* exists. It is unsafe to destroy the *Listener* while it is attached to a participant. However, you may remove the *DomainParticipantListener* from a *DomainParticipant* by calling **set_listener()** with a NULL value. Once the *Listener* has been removed from the participant, you may safely destroy it (see 4.4.1 Types of Listeners on page 190).

Notes:

- Due to a thread-safety issue, the destruction of a *DomainParticipantListener* from an enabled *DomainParticipant* should be avoided—even if the *DomainParticipantListener* has been removed from the *DomainParticipant*. (This limitation does not affect the Java API.)
- It is possible for multiple internal *Connext DDS* threads to call the same method of a *DomainParticipantListener* simultaneously. You must write the methods of a *DomainParticipantListener* to be multithread safe and reentrant. The methods of the *Listener* of other Entities do not have this constraint and are guaranteed to have single threaded access.

See also:

- 5.1.5 Setting Up TopicListeners on page 223
- 7.2.5 Setting Up PublisherListeners on page 283
- 7.3.4 Setting Up DataWriterListeners on page 293

- 8.2.6 Setting Up SubscriberListeners on page 497
- 8.3.4 Setting Up DataReaderListeners on page 509

9.3.7 Setting DomainParticipant QosPolicies

A *DomainParticipant*'s QosPolicies are used to configure discovery, database sizing, threads, information sent to other *DomainParticipant*s, and the behavior of the *DomainParticipant* when acting as a factory for other *Entities*.

Note: **set_qos()** cannot always be used in a listener callback; see 4.5.1 Restricted Operations in Listener Callbacks on page 200.

The DDS_DomainParticipantQos structure has the following format:

```
struct DDS_DomainParticipantQos {
       DDS_UserDataQosPolicy                    user_data;
       DDS_EntityFactoryQosPolicy               entity_factory;
       DDS_WireProtocolQosPolicy                wire_protocol;
       DDS_TransportBuiltinQosPolicy            transport_builtin;
       DDS_TransportUnicastQosPolicy            default_unicast;
       DDS_DiscoveryQosPolicy                   discovery;
       DDS_DomainParticipantResourceLimitsQosPolicy  resource_limits;
       DDS_EventQosPolicy                       event;
       DDS_ReceiverPoolQosPolicy                receiver_pool;
       DDS_DatabaseQosPolicy                    database;
       DDS_DiscoveryConfigQosPolicy             discovery_config;
       DDS_PropertyQosPolicy                    property;
       DDS_EntityNameQosPolicy                  participant_name;
       DDS_TransportMulticastMappingQosPolicy   multicast_mapping;
       DDS_ServiceQosPolicy                     service;
       DDS_TypeSupportQosPolicy                 type_support;
};
```

Table 9.4 DomainParticipant QosPolicies summarizes the meaning of each policy (listed alphabetically). For information on *why* you would want to change a particular QosPolicy, see the section referenced in the table.

Table 9.4 DomainParticipant QosPolicies

QosPolicy	Description
Database	Various settings and resource limits used by *Connext DDS* to control its internal database. See 9.5.1 DATABASE QosPolicy (DDS Extension) on page 632.
Discovery	Configures the mechanism used by *Connext DDS* to automatically discover and connect with new remote applications. See 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635.
DiscoveryConfig	Controls the amount of delay in discovering entities in the system and the amount of discovery traffic in the network. See 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639.

Table 9.4 DomainParticipant QosPolicies

QosPolicy	Description
DomainParticipantResourceLimits	Various settings that configure how *DomainParticipants* allocate and use physical memory for internal resources, including the maximum sizes of various properties. See 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649.
EntityFactory	Controls whether or not child entities are created in the enabled state. See 7.4.2 ENTITYFACTORY QosPolicy on page 347.
EntityName	Assigns a name to a *DomainParticipant*. See 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416.
Event	Configures the *DomainParticipant's* internal thread that handles timed events. See 9.5.5 EVENT QosPolicy (DDS Extension) on page 656.
Property	Stores name/value(string) pairs that can be used to configure certain parameters of *Connext DDS* that are not exposed through formal QoS policies. It can also be used to store and propagate application-specific name/-value pairs, which can be retrieved by user code during discovery. See 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.
ReceiverPool	Configures threads used by *Connext DDS* to receive and process data from transports (for example, UDP sockets). See 9.5.6 RECEIVER_POOL QosPolicy (DDS Extension) on page 658.
Service	Intended for use by RTI infrastructure services. User applications should not modify its value. See 7.5.23 SERVICE QosPolicy (DDS Extension) on page 452.
TransportBuiltin	Specifies which built-in transport plugins are used. See 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660.
TransportMulticastMapping	Specifies the automatic mapping between a list of topic expressions and multicast address that can be used by a *DataReader* to receive data for a specific topic. See 9.5.8 TRANSPORT_MULTICAST_MAPPING QosPolicy (DDS Extension) on page 661.
TransportUnicast	Specifies a subset of transports and port number that can be used by an Entity to receive data. See 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458.
TypeSupport	Used to attach application-specific value(s) to a *DataWriter* or *DataReader*. These values are passed to the serialization or deserialization routine of the associated data type. See 7.5.29 TYPESUPPORT QosPolicy (DDS Extension) on page 461.
UserData	Along with Topic Data QosPolicy and Group Data QosPolicy, used to attach a buffer of bytes to *Connext DDS*'s discovery meta-data. See 7.5.30 USER_DATA QosPolicy on page 462.
WireProtocol	Specifies IDs used by the RTPS wire protocol to create globally unique identifiers. See 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664.

9.3.7.1 Configuring QoS Settings when DomainParticipant is Created

As described in 9.3.1 Creating a DomainParticipant on page 610, there are different ways to create a DomainParticipant, depending on how you want to specify its QoS (with or without a QoS Profile).

- Figure 9.4: Creating a DomainParticipant with Default QosPolicies on page 611 has an example of how to create a DomainParticipant with default QosPolicies by using the special constant, DDS_PARTICIPANT_QOS_DEFAULT, which indicates that the default QoS values for a DomainParticipant should be used. The default DomainParticipant QoS values are configured in the DomainParticipantFactory; you can change them with **set_default_participant_qos()** or **set_default_participant_qos_with_profile()** (see 9.2.2 Getting and Setting Default QoS for DomainParticipants on page 602). Then any DomainParticipants created with the DomainParticipantFactory will use the new default values. As described in 4.1.7 Getting, Setting, and Comparing QosPolicies on page 172, this is a general pattern that applies to the construction of all Entities.
- To create a DomainParticipant with non-default QoS without using a QoS Profile, see the example code in Figure 9.6: Creating DomainParticipant with Modified QosPolicies (not from profile) below. It uses the *DomainParticipantFactory*'s **get_default_participant_qos()** method to initialize a DDS_ParticipantQos structure. Then, the policies are modified from their default values before the structure is used in the **create_participant()** method.
- You can also create a DomainParticipant and specify its QoS settings via a QoS Profile. To do so, you will call **create_participant_with_profile()**, as seen in Figure 9.7: Creating DomainParticipant with QoS Profile on the next page.
- If you want to use a QoS profile, but then make some changes to the QoS before creating the DomainParticipant, call **get_participant_qos_from_profile()** and **create_participant()** as seen in Figure 9.8: Getting QoS from Profile, Creating DomainParticipant with Modified QoS Values on the next page.

For more information, see 9.3.1 Creating a DomainParticipant on page 610 and Configuring QoS with XML (Chapter 19 on page 842).

Notes:

- The examples in this section use the Traditional C++ API; for examples in the Modern C++ API, see the sections "Participant Use Cases," "Qos Use Cases," and "Qos Provider Use Cases" in the API Reference HTML documentation, under "Programming How-To's."
- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 9.6: Creating DomainParticipant with Modified QosPolicies (not from profile)

```
DDS_DomainId_t domain_id = 10;
DDS_DomainParticipantQos participant_qos;
// initialize participant_qos with default values
factory->get_default_participant_qos(participant_qos);
// make QoS changes here
participant_qos.wire_protocol.participant_id = 2;
// Create the participant with modified qos
DDSDomainParticipant* participant = factory->create_participant(
```

```
        domain_id, participant_qos, NULL, DDS_STATUS_MASK_NONE);
if (participant == NULL) {
        // ... error
}
```

Figure 9.7: Creating DomainParticipant with QoS Profile

```
DDS_DomainId_t domain_id = 10;
// MyDomainParticipantListener is user defined and
// extends DDSDomainParticipantListener
MyDomainParticipantListener* participant_listener
        = new MyDomainParticipantListener(); // or = NULL
// Create the participant
DDSDomainParticipant* participant =
        factory->create_participant_with_profile(domain_id,
        "MyDomainLibrary", "MyDomainProfile",
        participant_listener, DDS_STATUS_MASK_ALL);
if (participant == NULL) {
        // ... error
};
```

Figure 9.8: Getting QoS from Profile, Creating DomainParticipant with Modified QoS Values

```
DDS_DomainParticipantQos participant_qos;
// Get DomainParticipant QoS from profile
retcode = factory->get_participant_qos_from_profile( participant_qos,
        "DomainParticipantProfileLibrary", "DomainParticipantProfile");
if (retcode != DDS_RETCODE_OK) {
        // handle error
}
// Makes QoS changes here
participant_qos.entity_factory.autoenable_created_entities = DDS_BOOLEAN_FALSE;
// create participant with modified QoS
DDSDomainParticipant* participant = factory->create_participant(domain_id,
        participant_qos, NULL, DDS_STATUS_MASK_NONE);
if (participant == NULL) {
        // handle error
}
```

9.3.7.2 Comparing QoS Values

The **equals()** operation compares two *DomainParticipant's* DDS_DomainParticipantQoS structures for equality. It takes two parameters for the two *DomainParticipant*'s QoS structures to be compared, then returns TRUE is they are equal (all values are the same) or FALSE if they are not equal.

9.3.7.3 Changing QoS Settings After DomainParticipant Has Been Created

There are two ways to change an existing *DomainParticipant*'s QoS after it is has been created—again depending on whether or not you are using a QoS Profile.

- To change QoS programmatically (that is, without using a QoS Profile), use **get_qos()** and **set_qos ()**. See the example code in Figure 9.9: Changing QoS of Existing Participant (without QoS Profile) on the next page. It retrieves the current values by calling the DomainParticipant's **get_qos()**

operation. Then it modifies the value and calls **set_qos()** to apply the new value. Note, however, that some QosPolicies cannot be changed after the DomainParticipant has been enabled—this restriction is noted in the descriptions of the individual QosPolicies.

- You can also change a *DomainParticipant's* (and all other Entities') QoS by using a QoS Profile and calling **set_qos_with_profile()**. For an example, see Figure 9.10: Changing QoS of Existing Participant with QoS Profile below. For more information, see Configuring QoS with XML (Chapter 19 on page 842).

Note:

- In C, you must initialize the QoS structures before they are used, see 4.2.2 Special QosPolicy Handling Considerations for C on page 182.

Figure 9.9: Changing QoS of Existing Participant (without QoS Profile)

```
DDS_DomainParticipantQos participant_qos;
// Get current QoS
//participant points to an existing DDSDomainParticipant
if (participant->get_qos(participant_qos) != DDS_RETCODE_OK) {
       // handle error
}
// Make QoS changes
participant_qos.entity_factory.autoenable_created_entities =
       DDS_BOOLEAN_FALSE;
// Set the new QoS
if (participant->set_qos(participant_qos) != DDS_RETCODE_OK ) {
       // handle error
}
```

Figure 9.10: Changing QoS of Existing Participant with QoS Profile

```
DDS_DomainParticipantQos participant_qos;
// Get current QoS
//participant points to an existing DDSDomainParticipant
if (participant->get_qos(participant_qos) != DDS_RETCODE_OK) {
       // handle error
}
// Make QoS changes
participant_qos.entity_factory.autoenable_created_entities =
       DDS_BOOLEAN_FALSE;
// Set the new QoS
if (participant->set_qos(participant_qos) != DDS_RETCODE_OK ) {
       // handle error
}
```

9.3.7.4 Getting and Setting DomainParticipant's Default QoS Profile and Library

You can get the default QoS profile for the *DomainParticipant* with the **get_default_profile()** operation. You can also get the default library for the *DomainParticipant*, as well as the library that contains the *DomainParticipant's* default profile (these are not necessarily the same library); these operations are called **get_default_library()** and **get_default_library_profile()**, respectively. These operations are for

informational purposes only (that is, you do not need to use them as a precursor to setting a library or profile.) For more information, see Configuring QoS with XML (Chapter 19 on page 842).

```
virtual const char *  get_default_library ()
const char *  get_default_profile ()
const char *  get_default_profile_library ()
```

There are also operations for *setting* the *DomainParticipant's* default library and profile:

```
DDS_ReturnCode_t set_default_library  (
    const char *  library_name)
DDS_ReturnCode_t set_default_profile (
    const char *  library_name,
    const char *  profile_name)
```

If the default profile/library is not set, the *DomainParticipant* inherits the default from the DomainParticipantFactory.

- **set_default_profile()** specifies the profile that will be used as the default the next time a default *DomainParticipant* profile is needed during a call to one of this *DomainParticipant's* operations. When calling a DomainParticipant operation that requires a **profile_name** parameter, you can use NULL to refer to the default profile. (This same information applies to setting a default library.)
- **set_default_profile()** does not set the default QoS for entities created by the *DomainParticipant*; for this functionality, use the *DomainParticipant's* **set_default_<*entity*>_qos_with_profile()** operation (you may pass in NULL after having called **set_default_profile(),** see 9.3.7.5 Getting and Setting Default QoS for Child Entities below).
- **set_default_profile()** does not set the default QoS for newly created *DomainParticipants*; for this functionality, use the DomainParticipantFactory's **set_default_participant_qos_with_profile(),** see 9.2.2 Getting and Setting Default QoS for DomainParticipants on page 602).

9.3.7.5 Getting and Setting Default QoS for Child Entities

The **set_default_<*entity*>_qos()** and **set_default_<*entity*>_qos_with_profile()** operations set the default QoS that will be used for newly created entities (where **<*entity*>** may be **publisher**, **subscriber**, **datawriter**, **datareader**, or **topic**). The new QoS settings will only be used if DDS_<entity>_QOS_DEFAULT is specified as the **qos** parameter when **create_<*entity*>()** is called. For example, for a *Publisher*, you can use either:

```
DDS_ReturnCode_t set_default_publisher_qos (
    const DDS_PublisherQos &qos)
DDS_ReturnCode_t set_default_publisher_qos_with_profile (
    const char *library_name,
    const char *profile_name)
```

The following operation gets the default QoS that will be used for creating *Publishers* if DDS_PUBLISHER_QOS_DEFAULT is specified as the 'qos' parameter when **create_publisher()** is called:

```
DDS_ReturnCode_t get_default_publisher_qos (
    DDS_PublisherQos & qos)
```

There are similar operations for *Subscribers, DataWriters, DataReaders* and *Topics*. These operations, **get_default_<*entity*>_qos()**, get the QoS settings that were specified on the last successful call to **set_default_<*entity*>_qos()** or **set_default_<*entity*>_qos_with_profile()**, or if the call was never made, the default values listed in **DDS_<*entity*>Qos**. They may potentially allocate memory depending on the sequences contained in some QoS policies.

Note: It is not safe to set default QoS values for an entity while another thread may be simultaneously getting or setting them, or using the QOS_DEFAULT constant to create the entity.

9.3.8 Looking up Topic Descriptions

The **lookup_topicdescription()** operation allows you to access a locally created DDSTopicDescription based on the *Topic's* name.

```
DDSTopicDescription* lookup_topicdescription(const char *topic_name)
```

DDSTopicDescription is the base class for *Topics*, *MultiTopics*[1] and *ContentFilteredTopics*. You can narrow the **DDSTopicDescription** returned from **lookup_topicdescription()** to a *Topic* or *ContentFilteredTopic* as appropriate.

Unlike **find_topic()** (see 9.3.9 Finding a Topic below), which logically returns a new *Topic* that must be independently deleted, *this* operation returns a reference to the original local object.

If no TopicDescription has been created yet with the given *Topic* name, this method will return a NULL value.

The *DomainParticipant* does not have to be enabled when you call **lookup_topicdescription()**.

Note: It is not safe to create or delete a topic while another thread is calling **lookup_topicdescription()** for that same topic.

9.3.9 Finding a Topic

The **find_topic()** operation finds an existing (or ready to exist) *Topic*, based on its name. This call can be used to block for a specified duration to wait for the *Topic* to be created.

```
DDSTopic* DDSDomainParticipant::find_topic (const char * topic_name,
                                            const DDS_Duration_t & timeout)
```

If the requested *Topic* already exists, it is returned. Otherwise, **find_topic()** waits until either another thread creates it, or returns when the specified timeout occurs.

find_topic() is useful when multiple threads are concurrently creating and looking up topics. In that case, one thread can call **find_topic()** and, if another thread has not yet created the topic being looked up, it can

[1] *Multitopics* are not supported.

wait for some period of time for it to do so. In almost all other cases, it is more straightforward to call **lookup_topicdescription()** (see 9.3.8 Looking up Topic Descriptions on the previous page).

The *DomainParticipant* must be enabled when you call **find_topic()**.

Note: Each DDSTopic obtained by **find_topic()** must also be deleted by calling the *DomainParticipant's* **delete_topic()** operation (see 5.1.2 Deleting Topics on page 219).

9.3.10 Getting the Implicit Publisher or Subscriber

The **get_implicit_publisher()** operation allows you to access the *DomainParticipant's* implicit *Publisher*. If one does not already exist, this operation creates an implicit *Publisher*.

There is a similar operation for implicit *Subscribers*:

```
DDSPublisher  * get_implicit_publisher ()
DDSSubscriber * get_implicit_subscriber()
```

There can only be one implicit *Publisher* and one implicit *Subscriber* per *DomainParticipant*. They are created with default QoS values (DDS_PUBLISHER_QOS_DEFAULT) and no Listener. For more information, see 7.2.1 Creating Publishers Explicitly vs. Implicitly on page 274. You can use an implicit *Publisher* or implicit *Subscriber* just like an explicitly created one.

An implicit *Publisher*/*Subscriber* is deleted automatically when **delete_contained_entities()** is called. It can also be deleted by calling **delete_publisher/subscriber()** with the implicit *Publisher*/*Subscriber* as a parameter.

When a *DomainParticipant* is deleted, if there are no attached *DataReaders* that belong to the implicit *Subscriber* or no attached *DataWriters* that belong to the implicit *Publisher*, any implicit *Publisher/Subscriber* will be deleted by the middleware implicitly.

Note: It is not safe to create an implicit *Publisher*/*Subscriber* while another thread may be simultaneously calling **set_default_[publisher/subscriber]_qos()**.

How to get the implicit *Publisher/Subscriber*. (For simplicity, error handling is not shown.)

```
using namespace DDS;
...
Publisher * publisher = NULL;
Subscriber * subscriber = NULL;
PublisherQos publisher_qos;
SubscriberQos subscriber_qos;
...
publisher = participant->get_implicit_publisher();
/* Change implicit publisher QoS */
publisher->get_qos(publisher_qos);
publisher_qos.partition.name.maximum(3);
publisher_qos.partition.name.length(3);
publisher_qos.partition.name[0] = DDS_String_dup("partition_A");
publisher_qos.partition.name[1] = DDS_String_dup("partition_B");
publisher_qos.partition.name[2] = DDS_String_dup("partition_C");
```

```
publisher->set_qos(publisher_qos);
/* Get implicit subscriber */
subscriber = participant->get_implicit_subscriber();
/* Change implicit subscriber QoS */
subscriber_qos.partition.name.maximum(3);
subscriber _qos.partition.name.length(3);
subscriber _qos.partition.name[0] = DDS_String_dup("partition_A");
subscriber _qos.partition.name[1] = DDS_String_dup("partition_B");
subscriber _qos.partition.name[2] = DDS_String_dup("partition_C");
subscriber->set_qos(subscriber_qos);
```

9.3.11 Asserting Liveliness

The **assert_liveliness()** operation manually asserts the liveliness of all the *DataWriters* created by this *DomainParticipant* that has 7.5.15 LIVELINESS QosPolicy on page 425 kind set to MANUAL_BY_PARTICIPANT. When **assert_liveliness()** is called, then for those *DataWriters* who have their LIVELINESS set to MANUAL_BY_PARTICIPANT, *Connext DDS* will send a packet to all matched *DataReaders* that indicates that the *DataWriter* is still alive.

However, the LIVELINESS contract of periodically sending liveliness packets to *DataReaders* is also fulfilled when the **write()**, **assert_liveliness()**, **unregister_instance()** and **dispose()** operations on a *DataWriter* itself is called. Those calls will also cause *Connext DDS* to send packets that indicate the liveliness of the *DataWriter*. Therefore, it is necessary for the application to call **assert_liveliness()** on the *DomainParticipant* only if those operations on a *DataWriter* are not being invoked within the period specified by the 7.5.15 LIVELINESS QosPolicy on page 425

9.3.12 Learning about Discovered DomainParticipants

The **get_discovered_participants()** operation provides you with a list of *DomainParticipants* that have been discovered in the DDS domain (except any that you have said to ignore via the **ignore_participant()** operation (see 18.4 Restricting Communication—Ignoring Entities on page 835)).

Once you have a list of discovered *DomainParticipants*, you can get more information about them by calling the **get_discovered_participant_data()** operation. This operation can only be used on *DomainParticipants* that are in the same DDS domain and have not been marked as 'ignored.' Otherwise, the operation will fail and return DDS_RETCODE_PRECONDITION_NOT_MET. The returned information is of type DDS_ParticipantBuiltinTopicData, described in Table 18.1 Participant Built-in Topic's Data Type (DDS_ParticipantBuiltinTopicData).

9.3.13 Learning about Discovered Topics

The **get_discovered_topics()** operation provides you with a list of *Topics* that have been discovered in the DDS domain (except any that you have said to ignore via the **ignore_topic()** operation (see 18.4 Restricting Communication—Ignoring Entities on page 835)).

Once you have a list of discovered *Topics*, you can get more information about them by calling the **get_discovered_topic_data()** operation. This operation can only be used on *Topics* that have been created by a

DomainParticipant in the same DDS domain as the participant on which this operation is invoked and must not have been "ignored" by means of the *DomainParticipant* **ignore_topic()** operation. Otherwise, the operation will fail and return DDS_RETCODE_PRECONDITION_NOT_MET. The returned information is of type DDS_TopicBuiltinTopicData, described in Table 18.4 Topic Built-in Topic's Data Type (DDS_TopicBuiltinTopicData) .

9.3.14 Getting Participant Protocol Status

Statistics about corrupted RTPS messages received by the participant can be obtained from the DomainParticipantProtocolStatus.

Table 9.5 DDS_DomainParticipantProtocolStatus

Type	Field Name	Description
DDS_ LongLong	corrupted_rtps_message_count	The number of corrupted RTPS messages detected by the participant.
DDS_ LongLong	corrupted_rtps_message_count_ change	The incremental change in the number of corrupted messages detected since the last time the status was read.
DDS_Time_t	last_corrupted_message_ timestamp	The timestamp of the last corrupted RTPS message detected by the participant.

You can get the DomainParticipantProtocolStatus by using the **get_participant_protocol_status()** operation. The WireProtocolQosPolicy's **compute_crc** and **check_crc** must be enabled in the publishing and subscribing applications, respectively, when the protocol status is obtained.

```
DDS_ReturnCode_t get_participant_protocol_status(DDS_DomainParticipantProtocolStatus &status)
```

9.3.15 Other DomainParticipant Operations

9.3.15.1 Verifying Entity Containment

If you have a handle to an *Entity*, and want to see if that *Entity* was created from your *DomainParticipant* (or any of its *Publishers* or *Subscribers*), use the **contains_entity()** operation, which returns a boolean.

An *Entity*'s instance handle may be obtained from built-in topic data (see Built-In Topics (Chapter 18 on page 825)), various statuses, or from the **get_instance_handle()** operation (see 4.1.3 Getting an Entity's Instance Handle on page 171).

9.3.15.2 Getting the Current Time

The **get_current_time()** operation returns the current time value from the same time-source (clock) that *Connext DDS* uses to timestamp the data published by *DataWriters* (source_timestamp of the SampleInfo structure, see 8.4.6 The SampleInfo Structure on page 560). The time-sources used by *Connext DDS* do not have to be synchronized nor are they synchronized by *Connext DDS*.

See also: 9.6 Clock Selection on page 671.

9.3.15.3 Getting All Publishers and Subscribers

The **get_publishers()** and **get_subscribers()** operations will provide you with a list of the *DomainParticipant's Publishers* and *Subscribers,* respectively.

9.4 DomainParticipantFactory QosPolicies

This section describes QosPolicies that are strictly for the *DomainParticipantFactory* (not the *DomainParticipant*). For a complete list of QosPolicies that apply to *DomainParticipantFactory*, see Table 9.2 DomainParticipantFactory QoS.

- 9.4.1 LOGGING QosPolicy (DDS Extension) below
- 9.4.2 PROFILE QosPolicy (DDS Extension) on the next page
- 9.4.3 SYSTEM_RESOURCE_LIMITS QoS Policy (DDS Extension) on page 630

9.4.1 LOGGING QosPolicy (DDS Extension)

This QosPolicy configures the properties associated with the *Connext DDS* logging facility.

This QosPolicy includes the members in Table 9.6 DDS_LoggingQosPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation.

See also: 25.2 Controlling Messages from Connext DDS on page 968 and 25.2.2 Configuring Logging via XML on page 976.

Table 9.6 DDS_LoggingQosPolicy

Type	Field Name	Description
NDDS_ConfigLogVerbosity	verbosity	Specifies the verbosity at which *Connext DDS* diagnostic information will be logged.
NDDS_Config_LogCategory	category	Specifies the category for which logging needs to be enabled.
NDDS_Config_LogPrintFormat	print_format	Specifies the format to be used to output *Connext DDS* diagnostic information.
char *	output_file	Specifies the file to which the logged output is redirected.
char *	output_file_suffix	Sets the file suffix when logging to a set of files.
DDS_Long	max_bytes_per_file	Specifies the maximum number of bytes a single file can contain.
DDS_Long	max_files	Specifices the maximum number of files to create before overwriting the previous ones.

9.4.1.1 Example

```
DSDomainParticipantFactory *factory =
    DDSDomainParticipantFactory::get_instance();
DDS_DomainParticipantFactoryQos factoryQos;
DDS_ReturnCode_t retcode = factory->get_qos(factoryQos);
if (retcode != DDS_RETCODE_OK) {
    // error
}
factoryQos.logging.output_file = DDS_String_dup("myOutput.txt");
factoryQos.logging.verbosity = NDDS_CONFIG_LOG_VERBOSITY_STATUS_LOCAL;
factory->set_qos(factoryQos);
```

9.4.1.2 Properties

This QosPolicy can be changed at any time.

Since it is only configuring logging, there are no compatibility restrictions for how it is set on the publishing and subscribing sides.

9.4.1.3 Related QosPolicies

- None

9.4.1.4 Applicable DDS Entities

- 9.2 DomainParticipantFactory on page 597

9.4.1.5 System Resource Considerations

Because the **output_file** will be freed by *Connext DDS*, you should use **DDS_String_dup()** to allocate the string.when providing an **output_file**.

9.4.2 PROFILE QosPolicy (DDS Extension)

This QosPolicy determines the way that XML documents containing QoS profiles are loaded.

All QoS values for *Entities* can be configured with QoS profiles defined in XML documents. XML documents can be passed to *Connext DDS* in string form, or more likely, through files found on a file system. This QoS configures how a *DomainParticipantFactory* loads the QoS profiles defined in XML. QoS profiles may be stored in this QoS as XML documents as a string. The location of XML files defining QoS profiles may be configured via this QoS. There are also default locations where the *DomainParticipantFactory* will look for files to load QoS profiles. You may disable any or all of these default locations using the Profile QoS. For more information about QoS profiles and libraries, please see Configuring QoS with XML (Chapter 19 on page 842).

This QosPolicy includes the members in Table 9.7 DDS_ProfileQosPolicy. For the defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 9.7 DDS_ProfileQosPolicy

Type	Field Name	Description
DDS_StringSeq	string_profile	Sequence of strings (empty by default) containing an XML document to load. The concatenation of the strings in this sequence must be a valid XML document according to the XML QoS profile schema.
	url_profile	A sequence of XML files (empty by default) containing a set of XML documents to load. See 19.5 How to Load XML-Specified QoS Settings on page 875.
DDS_Boolean	ignore_user_profile	When TRUE, the QoS profiles contained in the file **USER_QOS_PROFILES.xml** in the current working directory will be ignored.
	ignore_environment_profile	When TRUE, the value of the environment variable **NDDS_QOS_PROFILES** will be ignored.
	ignore_resource_profile	When TRUE, the QoS profiles in the file **$NDDSHOME/resource/xml/NDDS_QOS_PROFILES.xml** will be ignored. **NDDS_QOS_PROFILES.xml** does not exist by default. However, **NDDS_QOS_PROFILES.example.xml** is shipped with the host bundle of the product; you can copy it to **NDDS_QOS_PROFILES.xml** and modify it for your own use.

In the Modern C++ API, there is not a PROFILE QosPolicy, because the class that manages QoS profiles is dds::core::QosProvider—not the DomainParticipantFactory. A QosProvider can receive a QosProviderParams instance, which encapsulates the fields described before.

9.4.2.1 Example

Traditional C++:

```
DDSDomainParticipantFactory *factory =
       DDSDomainParticipantFactory::get_instance();
DDS_DomainParticipantFactoryQos factoryQos;

DDS_ReturnCode_t retcode = factory->get_qos(factoryQos);
if (retcode != DDS_RETCODE_OK) {
       // error
}
const char *url_profiles[2] = {
       "file://usr/local/default_dds.xml",
       "file://usr/local/alternative_default_dds.xml" };
factoryQos.profile.url_profile.from_array(url_profiles, 2);

factoryQos.profile.ignore_resource_profile = DDS_BOOLEAN_TRUE;
factory->set_qos(factoryQos);
```

Modern C++:

```
rti::core::QosProviderParams params =
       dds::core::QosProvider::Default()->default_provider_params();

std::vector<std::string> url_profiles = {
```

```
        "file://usr/local/default_dds.xml",
       "file://usr/local/alternative_default_dds.xml" };

params.url_profile(url_profiles);
params.ignore_resource_profile(true);

dds::core::QosProvider::Default()->default_provider_params(params);
```

9.4.2.2 Properties

This QosPolicy can be changed at any time.

Since it is only for the DomainParticipantFactory, there are no compatibility restrictions for how it is set on the publishing and subscribing sides.

9.4.2.3 Related QosPolicies

- None

9.4.2.4 Applicable Entities

- 9.2 DomainParticipantFactory on page 597

9.4.2.5 System Resource Considerations

Once the QoS profiles are loaded, the DomainParticipantFactory will keep one copy of each QoS in the QoS profiles in memory.

You can free the memory associated with the XML QoS profiles by calling the DomainParticipantFactory's **unload_profiles()** operation.

9.4.3 SYSTEM_RESOURCE_LIMITS QoS Policy (DDS Extension)

The SYSTEM_RESOURCE_LIMITS QosPolicy configures *DomainParticipant*-independent resources used by *Connext DDS*. Its main use is to change the maximum number of *DomainParticipants* that can be created within a single process (address space).

It contains the single member as shown in Table 9.8 DDS_SystemResourceLimitsQosPolicy. For the default and valid range, please refer to the API Reference HTML documentation.

Table 9.8 DDS_SystemResourceLimitsQosPolicy

Type	Field Name	Description
DDS_Long	max_objects_per_thread	Sizes the thread storage that is allocated on a per-thread basis when the thread calls *Connext DDS* APIs.

The only parameter that you can set, **max_objects_per_thread**, controls the size of thread-specific storage that is allocated by *Connext DDS* for every thread that invokes a *Connext DDS* API. This storage is used

to cache objects that have to be created on a per-thread basis when a thread traverses different portions of *Connext DDS* internal code.

Thus instead of dynamically creating and destroying the objects as a thread enters and leaves different parts of the code, *Connext DDS* caches the objects by storing them in thread-specific storage. We assume that a thread will repeatedly call *Connext DDS* APIs so that the objects cached will be needed again and again.

The number of objects that will be stored in the cache depends the number of APIs (sections of *Connext DDS* code) that a thread invokes. It also depends on the number of different *DomainParticipants* with which the thread interacts. For a single *DomainParticipant*, the maximum number of objects that could be stored is a constant–independent of the number of *Entities* created in or by the participant. A safe number to use is 200 objects per *DomainParticipant*.

A user thread that only interacts with a single *DomainParticipant* or the *Entities* thereof, would never have more than 200 objects stored in its cache. However, if the same thread invokes *Connext DDS* APIs on other *Entities* of other *DomainParticipants*, the maximum number of objects that may be stored will increase with the number of participants involved.

The default setting of this resource should work for most user applications. However, if your application uses more than 4 *DomainParticipants*, you may need to increase the value of max_objects_per_thread.

9.4.3.1 Example

Say an application uses 10 *DomainParticipants*. If a single thread was used to create all 10 *DomainParticipants*, or a single thread is used to call **write()** on *DataWriters* belonging to all 10 participants, it is possible to run out of thread-specific storage. Either the creation of the participant or the **write()** will fail.

In that case, you will need to increase the value of **max_objects_per_thread**.

9.4.3.2 Properties

This QoS policy cannot be modified after the DomainParticipantFactory is used to create the first *DomainParticipant* or WaitSet in an application.

This QoS can be set differently in different applications.

9.4.3.3 Related QoS Policies

There are no interactions with other QosPolicies.

9.4.3.4 Applicable DDS Entities

- 9.2 DomainParticipantFactory on page 597

9.4.3.5 System Resource Considerations

max_objects_per_thread is used to determine the size of an array of pointers to objects used in a thread. Increasing **max_objects_per_thread** will increase the amount of memory allocated by *Connext DDS* for every thread that access *Connext DDS* code. This includes internal *Connext DDS* threads as well as user threads.

9.5 DomainParticipant QosPolicies

This section describes the QosPolicies that are strictly for *DomainParticipants* (and no other types of Entities). For a complete list of QosPolicies that apply to *DomainParticipant*, see Table 9.4 DomainParticipant QosPolicies.

- 9.5.1 DATABASE QosPolicy (DDS Extension) below
- 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635
- 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639
- 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649
- 9.5.5 EVENT QosPolicy (DDS Extension) on page 656
- 9.5.6 RECEIVER_POOL QosPolicy (DDS Extension) on page 658
- 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660
- 9.5.8 TRANSPORT_MULTICAST_MAPPING QosPolicy (DDS Extension) on page 661
- 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664

9.5.1 DATABASE QosPolicy (DDS Extension)

The Database QosPolicy configures how *Connext DDS* manages its internal database, including how often it cleans up, the priority of the database thread, and limits on resources that may be allocated by the database. RTI uses an internal in-memory database to store information about entities created locally as well as remote entities found during the discovery process. This database uses a background thread to garbage-collect records related to deleted entities. When the *DomainParticipant* that maintains this database is deleted, it shuts down this thread..

It includes the members in Table 9.9 DDS_DatabaseQosPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 9.9 DDS_DatabaseQosPolicy

Type	Field Name	Description
DDS_ ThreadSettings_ t	thread.mask thread.priority thread.stack_ size	Thread settings for the database thread used by *Connext DDS* to periodically remove deleted records from the database. The values used for these settings are OS-dependent; see the RTI Connext DDS Core Libraries Platform Notes for details. Note: thread.cpu_list and thread.cpu_rotation are not relevant in this QoS policy.
DDS_Duration_t	shutdown_ timeout	The maximum time that the *DomainParticipant* will wait for the database thread to terminate when the participant is destroyed.
DDS_Duration_t	cleanup_ period	The period at which the database thread wakes up to removed deleted records.
DDS_Duration_t	shutdown_ cleanup_ period	The period at which the database thread wakes up to removed deleted records when the *DomainParticipant* is being destroyed.
DDS_Long	initial_records	The number of records that is initially created for the database. These records hold information for both local and remote entities that are dynamically created or discovered.
DDS_Long	max_skiplist_ level	This is a performance tuning parameter that optimizes the time it takes to search the database for a record. A 'Skip List' is an algorithm for maintaining a list that is faster to search than a binary tree. This value should be set to log2(N), where N is the maximum number of elements that will be stored in a single list. The list that stores the records for remote *DataReaders* or the one for remote *DataWriters* tend to have the most entries. So, the number of *DataWriters* or *DataReaders* in a system across all *DomainParticipants* in a single DDS domain, which ever is greater, can be used to set this parameter.
DDS_Long	max_weak_ references	This parameter sets the maximum number of entries in the weak reference table. Weak references are used as a technique for ensuring that unreferenced objects are deleted. The actual number of weak references is permitted to grow from the value set by initial_weak_references to this maximum. To prevent *Connext DDS* from allocating memory for weak references after initialization, you should set the initial and maximum weak references to the same value. However, it is difficult to calculate how many weak references an application will use. To allow *Connext DDS* to grow the weak reference table as needed, and thus dynamically allocate memory, you should set the value of this field to DDS_LENGTH_UNLIMITED, the default setting.
DDS_Long	initial_weak_ references	The initial number of entries in the weak reference table. See max_weak_references. *Connext DDS* may decide to use a larger initial value if initial_weak_references is set too small. If you access this parameter after a *DomainParticipant* has been created, you will see the actual value used.

You may be interested in modifying the **shutdown_timeout** and **shutdown_cleanup_period** parameters to decrease the time it takes to delete a *DomainParticipant* when your application is shutting down.

The 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649 controls the memory allocation for elements stored in the database.

Real-time programmers will probably want to adjust the priorities of all of the threads created by *Connext DDS* relative to each other as well as relative to non-*Connext DDS* threads in their applications. Connext

DDS Threading Model (Chapter 21 on page 900), 9.5.5 EVENT QosPolicy (DDS Extension) on page 656, and 9.5.6 RECEIVER_POOL QosPolicy (DDS Extension) on page 658 discuss the other threads that are created by *Connext DDS*.

A record in the database can be deleted only when no threads are using it. *Connext DDS* uses a thread that periodically checks the database if records that have been marked for deletion can be removed. This period is set by **cleanup_period**. When a *DomainParticipant* is being destroyed, the thread will wake up faster at the **shutdown_cleanup_period** as other threads delete and release records in preparation for shutting down.

On Windows and VxWorks® systems, the thread that is destroying the *DomainParticipant* may block up to **shutdown_timeout** seconds while waiting for the database thread to finish removing all records and terminating. On other operating systems, the thread destroying the *DomainParticipant* will block as long as required for the database thread to terminate.

The default values for those and the rest of the parameters in this QosPolicy should be sufficient for most applications.

9.5.1.1 Example

The priority of the database thread should be set to the lowest priority among all threads in a real-time system. Although, the database thread should not be permitted to starve, the work that it performs is non-time-critical.

9.5.1.2 Properties

This QosPolicy cannot be modified after the *DomainParticipant* is created.

It can be set differently on the publishing and subscribing sides.

9.5.1.3 Related QosPolicies

- 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649
- 9.5.5 EVENT QosPolicy (DDS Extension) on page 656
- 9.5.6 RECEIVER_POOL QosPolicy (DDS Extension) on page 658

9.5.1.4 Applicable DDS Entities

- 9.3 DomainParticipants on page 604

9.5.1.5 System Resource Considerations

Setting the thread parameters correctly on a real-time operating system is usually critical to the proper overall functionality of the applications on that system. Larger values for the thread.stack_size parameter will

use up more memory.

Smaller values for the cleanup_period and shutdown_cleanup_period will cause the database thread to wake up more frequently using more CPU.

Connext DDS is permitted to use up more memory for larger values of **max_skiplist_level** and **max_weak_references**. Whether or not more memory is actually used depends on actual operating conditions.

9.5.2 DISCOVERY QosPolicy (DDS Extension)

The DISCOVERY QoS configures how *DomainParticipants* discover each other on the network. It identifies where on the network this application can potentially discover other applications with which to communicate. The middleware will periodically send network packets to these locations, announcing itself to any remote applications that may be present, and will listen for announcements from those applications. The discovery process is described in detail in Discovery (Chapter 15 on page 758).

This QosPolicy includes the members in Table 9.10 DDS_DiscoveryQosPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 9.10 DDS_DiscoveryQosPolicy

Type	Field Name	Description
DDS_StringSeq	enabled_transports	Transports available for use by the discovery process. See 9.5.2.1 Transports Used for Discovery below.
DDS_StringSeq	initial_peers	Unicast locators (address/indices) of potential participants with which this *DomainParticipant* will attempt to establish communications. See 9.5.2.2 Setting the 'Initial Peers' List on the next page.
DDS_StringSeq	multicast_receive_addresses	List of multicast addresses on which Discovery-related messages can be received by the *DomainParticipant*. See 9.5.2.4 Configuring Multicast Receive Addresses on page 637.
DDS_Long	metatraffic_transport_priority	Transport priority to be used for sending Discovery messages. See 9.5.2.5 Meta-Traffic Transport Priority on page 637.
DDS_Boolean	accept_unknown_peers	Whether to accept a participant discovered via unicast that is not in the **initial_peers** list. See 9.5.2.6 Controlling Acceptance of Unknown Peers on page 638.
DDS_Boolean	enable_endpoint_discovery	Whether endpoint discovery will automatically occur with discovered *DomainParticipants*. See 18.4.5 Supervising Endpoint Discovery on page 839.

9.5.2.1 Transports Used for Discovery

The enabled_transports field allows you to specify the set of installed and enabled transports that can be used to discover other *DomainParticipants*. This field is a sequence of strings where each string specifies an alias of a registered (and thus installed and enabled) transport. Please see the API Reference HTML doc-

umentation (select **Modules, RTI Connext DDS API Reference**, **Pluggable Transports**) for more information.

9.5.2.2 Setting the 'Initial Peers' List

When a *DomainParticipant* is created, it needs to find other participants in the same DDS domain—this is known as the 'discovery process' which is discussed in Discovery (Chapter 15 on page 758). One way to do so is to use this QosPolicy to specify a list of potential participants. This is the role of the parameter initial_peers. The strings containing peer descriptors are stored in the initial_peers string sequence. The format of a string discussed in 15.2.1 Peer Descriptor Format on page 762.

The peers stored in initial_peers are merely *potential* peers—there is no requirement that the peer *DomainParticipants* are actually up and running or even will eventually exist. The *Connext DDS* discovery process will try to contact all potential peer participants in the list periodically using unicast transports (as configured by the 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639).

The initial_peers parameter can be modified in source code or it can be initialized from an environment variable, NDDS_DISCOVERY_PEERS or from a text file, see 15.2 Configuring the Peers List Used in Discovery on page 761.

Some transports accept the use of hostnames to specify the initial peers. By default, *Connext DDS* only resolves those hostnames when the *DomainParticipant* is created, but the DNS tracker can be used to keep the IP addresses of these hostnames updated. See 17.3 Using DNS Tracker to Keep Peer List Updated on page 823.

9.5.2.3 Adding and Removing Peers List Entries

The *DomainParticipant*'s **add_peer()** operation adds a peer description to the internal peer list that was initialized by the initial_peer field of the DISCOVERY QosPolicy.

```
DDS_ReturnCode_t DDSDomainParticipant::add_peer (
       const char* peer_desc)
```

The peer_desc string must be formatted as specified in 15.2.1 Peer Descriptor Format on page 762.

You can call this operation any time after the *DomainParticipant* has been enabled. An attempt will be made to contact the new peer immediately.

Adding peers with this operation has no effect on the initial_peers list. After a *DomainParticipant* has been created, the contents of the initial_peers field merely shows what the internal peer list was initialized to be. Therefore, initial_peers may not reflect the actual potential peer list used by a *DomainParticipant*. Furthermore, if you call **get_qos()**, the returned list of peers will not include the added peer—**get_qos()** will only show you what is set in the **initial_peers** list.

A peer added with **add_peer()** is *not* considered to be "unknown." (That is, you may have **accept_unknown_peers** (9.5.2.6 Controlling Acceptance of Unknown Peers on page 638) set to FALSE and still use **add_peer()**.)

This behavior may change depending on the DNS tracker configuration; see 17.3 Using DNS Tracker to Keep Peer List Updated on page 823. Adding a peer with a hostname that cannot be resolved into an IP address will produce an error if the DNS Tracker has not been enabled for that *DomainParticipant*.

You can remove an entry from the list with **remove_peer()**. Note that **remove_peer()** is only supported if Simple Participant Discovery (see 15.1.1 Simple Participant Discovery on page 759) is enabled for the Participant.

You can ignore data from a participant by using the **ignore_participant()** operation described in 18.4 Restricting Communication—Ignoring Entities on page 835.

9.5.2.4 Configuring Multicast Receive Addresses

The multicast_receive_addresses field in the DISCOVERY QosPolicy is a sequence of strings that specifies a set of multicast group addresses on which the *DomainParticipant* will listen for discovery meta-traffic. Each string must have a valid multicast address in either IPv4 dot notation or IPv6 presentation format. Please look at publicly available documentation of the IPv4 and IPv6 standards for the definition and valid address ranges for multicast.

The multicast_receive_addresses field can be initialized from multicast addresses that appear in the NDDS_DISCOVERY_PEERS environment variable or text file, see 15.2 Configuring the Peers List Used in Discovery on page 761. A multicast address found in the environment variable or text file will be added both to the initial_peers and multicast_receive_addresses fields. Note that the addresses in initial_peers are ones in which the *DomainParticipant* will *send* discovery meta-traffic, and the ones in multicast_receive_addresses are used for *receiving* discovery meta-traffic.

If **NDDS_DISCOVERY_PEERS** does *not* contain a multicast address, then **multicast_receive_addresses** is cleared and the RTI discovery process will not listen for discovery messages via multicast.

If **NDDS_DISCOVERY_PEERS** contains one or more multicast addresses, the addresses are stored in **multicast_receive_addresses**, starting at element 0. They will be stored in the order in which they appear in **NDDS_DISCOVERY_PEERS**.

Note: Currently, *Connext DDS* will only listen for discovery traffic on the first multicast address (element 0) in **multicast_receive_addresses**.

If you want to send discovery meta-traffic on a different set of multicast addresses than you want to receive discovery meta-traffic, set initial_peers and multicast_receive_addresses via the QosPolicy API.

9.5.2.5 Meta-Traffic Transport Priority

The metatraffic_transport_priority field is used to specify the transport priority to be used for sending all discovery meta-traffic. See the 7.5.26 TRANSPORT_PRIORITY QosPolicy on page 455 for details on how transport priorities may be used.

9.5.2.6 Controlling Acceptance of Unknown Peers

The accept_unknown_peers field controls whether or not a *DomainParticipant* is allowed to communicate with other *DomainParticipants* found via unicast transport that are not in its peers list (which is the combination of the **initial_peers** list and any peers added with the **add_peer()** operation described in 9.5.2.3 Adding and Removing Peers List Entries on page 636).

Suppose Participant A is included in Participant B's initial peers list, but Participant B is not in Participant A's list. When Participant B contacts Participant A by sending it a unicast discovery packet, then Participant A has a choice:

- If **accept_unknown_peers** is DDS_BOOLEAN_TRUE, then Participant A will reply to Participant B, and communications will be established.
- If **accept_unknown_peers** is DDS_BOOLEAN_FALSE, then Participant A will ignore Participant B, and A and B will never talk.

Note that Participants do not exchange peer lists. So if Participant A knows about Participant B, and Participant B knows about Participant C, Participant A will not discover Participant C.

Note: If **accept_unknown_peers** is false and shared memory is disabled, applications on the same node will not communicate if only 'localhost' is specified in the peer list. If shared memory is disabled or 'shmem://' is not specified in the peer list, if you want to communicate with other applications on the same node through the loopback interface, you must put the actual node address or hostname in **NDDS_DISCOVERY_PEERS**.

9.5.2.7 Example

You will always use this policy to set the participant_id when you want to run more than one *DomainParticipant* in the same DDS domain on the same host.

The easiest way to set the initial peers list is to use the NDDS_DISCOVERY_PEERS environment variable. However, should you want asymmetric multicast addresses for sending or receiving meta-traffic, you will need to use this QosPolicy directly.

A reason to use asymmetric multicast addresses is to take advantage of the efficiency provided by using multicast, while at the same time preventing all participants from discovering each other. For example, suppose you have a system in which you have a single server node and a hundred client nodes. The client nodes do not publish or subscribe to each other's data and thus never need to know about each others existence.

If we did not use multicast, we would have to populate the server application's peer list with 100 peer descriptors for each of the client nodes. Each client application would only need to have the server application in its peer list. The maintenance of the list is unwieldy, especially if nodes are constantly reconfigured and addresses changed. In addition, the server will send out discovery packets on a per client basis since the peer list essentially holds 100 unicast addresses.

Instead, if we used a single multicast address in the NDDS_DISCOVERY_PEERS environment variable, the server and all of the clients would discover each other. Certainly, the list is easier to maintain, but the total amount of traffic has actually increased since the clients are now exchanging packets with each other uselessly.

To keep the list maintainable, as well as to minimize discovery traffic, we can have the server send out packets on a multicast address by modifying its *initial_peer* field. The clients would have their **multicast_receive_addresses** field set to the same address used by the server. The **initial_peers** of the clients would only need the single unicast peer descriptor of the server as before.

Now, the server can send a single packet that will be received by all of the clients, but the clients will not discover each other because they never send out a multicast packet themselves.

9.5.2.8 Properties

This QosPolicy cannot be modified after the *DomainParticipant* is created.

It can be set differently on the publishing and subscribing sides.

9.5.2.9 Related QosPolicies

- 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) below
- 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660

9.5.2.10 Applicable Entities

- 9.3 DomainParticipants on page 604

9.5.2.11 System Resource Considerations

For every entry in the **initial_peers** list, *Connext DDS* will periodically send a discovery packet to see if that participant exists. If the list has many potential participants that are never started, then CPU and network bandwidth may be wasted in sending out packets that will never be received.

9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension)

The DISCOVERY_CONFIG QosPolicy is used to tune the discovery process. It controls how often to send discovery packets, how to determine when participants are alive or dead, and resources used by the discovery mechanism.

The amount of network traffic required by the discovery process can vary widely based on how your application has chosen to configure the middleware's network addressing (unicast vs. multicast, multicast TTL, etc.), the size of the system, whether all applications are started at the same time or whether start times are staggered, and other factors. Your application can use this policy to make trade-offs between discovery completion time and network bandwidth utilization. In addition, you can introduce random back-

off periods into the discovery process to decrease the probability of network contention when many applications start simultaneously.

This QosPolicy includes the members in Table 9.11 DDS_DiscoveryConfigQosPolicy. Many of these members are described in Discovery (Chapter 15 on page 758). For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 9.11 DDS_DiscoveryConfigQosPolicy

Type	Field Name	Description
DDS_Duration_t	participant_liveliness_lease_duration	The time period after which other DomainParticipants can consider this one dead if they do not receive a liveliness packet from this DomainParticipant.
DDS_Duration_t	participant_liveliness_assert_period	The period of time at which this DomainParticipant will send out packets asserting that it is alive.
DDS_RemoteParticipantPurgeKind	remote_participant_purge_kind	Controls the DomainParticipant's behavior for purging records of remote participants (and their contained entities) with which discovery communication has been lost. See 9.5.3.2 Controlling Purging of Remote Participants on page 646.
DDS_Duration_t	max_liveliness_loss_detection_period	The maximum amount of time between when a remote entity stops maintaining its liveliness and when the matched local entity realizes that fact.
DDS_Long	initial_participant_announcements	Sets how many initial liveliness announcements the DomainParticipant will send when it is first enabled, or after discovering a new remote participant.
DDS_Duration_t	min_initial_participant_announcement_period	Sets the minimum and maximum times between liveliness announcements. When a participant is first enabled, or after discovering a new remote participant, *Connext DDS* sends initial_paricipant_annoucements number of discovery messages. These messages are sent with a sleep period between them that is a random duration between min_initial_participant_announcement_period and max_initial_participant_announcement_period.
DDS_Duration_t	max_initial_participant_announcement_period	
DDS_Boolean	disable_repair_piggyback_heartbeat	When samples are repaired, the *DataWriter* resends the number of bytes indicated in **max_bytes_per_nack_response** (see 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension)) and a piggyback heartbeat with each message. You can configure the *DataWriter* to not send the piggyback heartbeat, by setting this field to TRUE, and instead rely on the **late_joiner_heartbeat_period** to control the throughput used to repair samples. This field is not mutable in the Discovery Config QoS of the *DomainParticipant*. It is mutable only for the *DataWriter* QoS. See Table 7.44 DDS_RtpsReliableWriterProtocol_t.
Table 9.12 DDS_BuiltinTopicReaderResourceLimits_t	participant_reader_resource_limits	Configures the resource for the built-in DataReaders used to access discovery information; see 9.5.3.1 Resource Limits for Builtin-Topic DataReaders on page 645 and Built-In Topics (Chapter 18 on page 825).

Table 9.11 DDS_DiscoveryConfigQosPolicy

Type	Field Name	Description
Table 8.19 DDS_RtpsReliableReaderProtocol_t	publication_reader	Configures the RTPS reliable protocol parameters for a built-in publication reader.
Table 9.12 DDS_BuiltinTopicReaderResourceLimits_t	publication_reader_resource_limits	Configures the resource for the built-in DataReaders used to access discovery information; see 9.5.3.1 Resource Limits for Builtin-Topic DataReaders on page 645 and Built-In Topics (Chapter 18 on page 825).
Table 8.19 DDS_RtpsReliableReaderProtocol_t	subscription_reader	Configures the RTPS reliable protocol parameters for a built-in subscription reader. Built-in subscription readers receive discovery information reliably from DomainParticipants that were dynamically discovered (see Discovery (Chapter 15 on page 758)).
Table 9.12 DDS_BuiltinTopicReaderResourceLimits_t	subscription_reader_resource_limits	Configures the resource for the built-in DataReaders used to access discovery information; see 9.5.3.1 Resource Limits for Builtin-Topic DataReaders on page 645 and Built-In Topics (Chapter 18 on page 825).
Table 7.44 DDS_RtpsReliableWriterProtocol_t	publication_writer	Configures the RTPS reliable protocol parameters for the writer side of a reliable connection. Built-in DataWriters send reliable discovery information to DomainParticipants that were dynamically discovered (see Discovery (Chapter 15 on page 758)).
Table 7.79 DDS_WriterDataLifecycleQosPolicy	publication_writer_data_lifecycle	Configures writer data-lifecycle settings for a built-in publication writer. (DDS_WriterDataLifecycleQosPolicy::autodispose_unregistered_instances will always be TRUE.)
Table 7.44 DDS_RtpsReliableWriterProtocol_t	subscription_writer	Configures the RTPS reliable protocol parameters for the writer side of a reliable connection. Built-in DataWriters send reliable discovery information to DomainParticipants that were dynamically discovered (see Discovery (Chapter 15 on page 758)).
Table 7.79 DDS_WriterDataLifecycleQosPolicy	subscription_writer_data_lifecycle	Configures writer data-lifecycle settings for a built-in subscription writer. (DDS_WriterDataLifecycleQosPolicy::autodispose_unregistered_instances will always be TRUE.)
DDS_DiscoveryConfigBuiltinPluginKindMask	builtin_discovery_plugins	The kind mask for selecting built-in discovery plugins: Simple Discovery Protocol: DDS_DISCOVERYCONFIG_BUILTIN_SDP
DDS_ReliabilityQosPolicyKind	participant_message_reader_reliability_kind	Reliability kind configuration setting for a built-in participant message reader (default: best-effort). See Table 7.66 DDS_ReliabilityQosPolicy
Table 8.19 DDS_RtpsReliableReaderProtocol_t	participant_message_reader	RTPS protocol-related configuration settings for a built-in participant message reader.
Table 7.44 DDS_RtpsReliableWriterProtocol_t	participant_message_writer	RTPS protocol-related configuration settings for a built-in participant message writer.

Table 9.11 DDS_DiscoveryConfigQosPolicy

Type	Field Name	Description
Table 7.65 DDS_PublishModeQosPolicy	publication_writer_publish_mode	Determines whether the Discovery built-in publication DataWriter publishes data synchronously or asynchronously and how.
Table 7.65 DDS_PublishModeQosPolicy	subscription_writer_publish_mode	Determines whether the Discovery built-in subscription DataWriter publishes data synchronously or asynchronously and how.
Table 7.19 DDS_AsynchronousPublisherQosPolicy	asynchronous_publisher	Asynchronous publishing settings for the Discovery Publisher and all entities that are created by it.
DDS_Duration_t	default_domain_announcement_period	The period at which a participant will announce itself to the default DDS domain 0 using the default UDPv4 multicast group address for discovery traffic on that DDS domain. For DDS domain 0, the default discovery multicast address is 239.255.0.1:7400. To disable announcement to the default DDS domain, set this to DURATION_INFINITE. When this period is set to a value other than DURATION_INFINITE and **ignore_default_domain_announcements** (see below) is FALSE, you can get information about participants running in different DDS domains by creating a participant in DDS domain 0 and implementing the **on_data_available** callback (see 8.3.7.1 DATA_AVAILABLE Status on page 514) in the ParticipantBuiltinTopicData built-in DataReader's listener (see 18.2 Built-in DataReaders on page 826). You can learn the domain ID associated with a participant by looking at the domain_id on page 827 in the ParticipantBuiltinTopicData.
DDS_Boolean	ignore_default_domain_announcements	When TRUE, ignores the announcements received by a participant on the default DDS domain 0 corresponding to participants running on domains IDs other than 0. This setting only applies to participants running on the default DDS domain 0 and using the default port mapping. When TRUE, a participant running on the default DDS domain 0 will ignore announcements from participants running on different DDS domain IDs. When FALSE, a participant running on the default DDS domain 0 will provide announcements from participants running on different DDS domain IDs to the application via the ParticipantBuiltinTopicData built-in DataReader (see 18.2 Built-in DataReaders on page 826).
Table 7.44 DDS_RtpsReliableWriterProtocol_t	service_request_writer	RTPS protocol-related configuration settings for the built-in service request writer.
Table 7.79 DDS_WriterDataLifecycleQosPolicy	service_request_writer_data_lifecycle	Configures writer data-lifecycle settings for the built-in service request writer.
Table 7.65 DDS_PublishModeQosPolicy)	service_request_writer_publish_mode	Determines whether the Discovery built-in service request DataWriter publishes data synchronously or asynchronously and how.
Table 8.18 DDS_DataReaderProtocolQosPolicy	service_request_reader	RTPS protocol-related configuration settings for the built-in service request reader.

Table 9.11 DDS_DiscoveryConfigQosPolicy

Type	Field Name	Description
DDS_Duration_t	locator_reachability_assert_period	Configures the period at which this *DomainParticipant* will ping all the locators that it has discovered from other *DomainParticipants*. This period should be strictly less than locator_reachability_lease_duration below. If locator_reachability_lease_duration below is INFINITE, this parameter is ignored. The *DomainParticipant* will not assert remote locators.
DDS_Duration_t	locator_reachability_lease_duration	For the purpose of this explanation, we use 'local' to refer to the *DomainParticipant* in which we configure locator_reachability_lease_duration above and 'remote' to refer to the other *DomainParticipants* communicating with the local *DomainParticipant*. This setting configures a timeout announced to the remote *DomainParticipants*. This timeout is used by the remote *DomainParticipants* as the maximum period by which a remote locator must be asserted by the local *DomainParticipant* (through a REACHABILITY PING message) before considering this locator as "unreachable" from the local *DomainParticipant*. When a remote *DomainParticipant* detects that one of its locators is not reachable from the local *DomainParticipant*, it will notify the local *DomainParticipant* of this event. From that moment on, and until notified otherwise, the local *DomainParticipant* will not send RTPS messages to remote *DomainParticipants* using this locator. If this value is set to INFINITE, the local *DomainParticipant* will send RTPS messages to a remote *DomainParticipant* on the locators announced by the remote *DomainParticipant*, regardless of whether or not the remote *DomainParticipant* can be reached using these locators.
DDS_Duration_t	locator_reachability_change_detection_period	Determines the maximum period at which this *DomainParticipant* will check to see if its locators are reachable from other DomainParticipants according to the other *DomainParticipants*' locator_reachability_lease_duration above. If locator_reachability_lease_duration above is INFINITE, this parameter is ignored. The *DomainParticipant* will not schedule an event to see if its locators are reachable from other *DomainParticipants*.
Table 7.44 DDS_RtpsReliableWriterProtocol_t	secure_volatile_writer	RTPS protocol-related configuration settings for the builtin Key Exchange writer.
Table 7.65 DDS_PublishModeQosPolicy	secure_volatile_writer_publish_mode	Publish mode policy for the builtin secure volatile writer. Determines whether the builtin secure volatile *DataWriter* publishes data synchronously or asynchronously and how.
Table 8.19 DDS_RtpsReliableReaderProtocol_t	secure_volatile_reader	RTPS protocol-related configuration settings for the builtin Key Exchange reader.

Table 9.11 DDS_DiscoveryConfigQosPolicy

Type	Field Name	Description
DDS_Long	endpoint_type_object_lb_serialization_threshold	Minimum size (in bytes) of the serialized TypeObject that will trigger the serialization of a TypeObjectLb instead of the regular TypeObject. TypeObjectLb is a compressed version of the serialized TypeObject. This compressed version reduces the size needed to propagate a TypeObject as part of Simple Endpoint Discovery. For example, setting this policy to 1000 will trigger the serialization of the TypeObjectLb for TypeObjects whose serialized size is greater than 1000 Bytes. Range: [-1, 2147483647]. The sentinel value -1 disables TypeObject compression (by never sending TypeObjectLb). Any non-valid values will behave as 0. Default: 0 (TypeObjectLb is enabled by default)
DDS_Duration_t	dns_tracker_polling_period	Configures the frequency used by the DNS Tracker thread to query the DNS service. If this parameter is set to INFINITE, the DNS tracker is disabled and changes in hostnames will not be tracked. See 17.3 Using DNS Tracker to Keep Peer List Updated on page 823 for more information.

A *DomainParticipant* needs to send a message periodically to other *DomainParticipants* to let the other participants know that it is still alive. These liveliness messages are sent to all peers in the peer list that was initialized by the **initial_peers** parameter of the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635. Peer participants on the peer list may or may not be alive themselves. The peer *DomainParticipants* that already know about this *DomainParticipant* will use the **participant_liveliness_lease_duration** provided by *this* participant to declare the participant dead, if they have not received a liveliness message for the specified time.

The **participant_liveliness_assert_period** is the periodic rate at which this *DomainParticipant* will be sending liveliness messages. Since these liveliness messages are not sent reliably and can get dropped by the transport, it is important to set:

participant_liveliness_assert_period < **participant_liveliness_lease_duration**/N

where N is the number of liveliness messages that other *DomainParticipants* must miss before they decide that this *DomainParticipant* is dead.

DomainParticipants that receive a liveliness message from a participant that they did not know about previously will have "discovered" the participant. When one *DomainParticipant* discovers another, the discoverer will immediately send its own liveliness packets back. **initial_participant_announcements** controls how many of these initial liveliness messages are sent, and **max_initial_participant_announcement_period** controls the time period in between each message.

After the initial set of liveliness messages are sent (when the *DomainParticipant* is first enabled or discovers a new remote participant), the *DomainParticipant* will return to sending liveliness packets to all peers in its peer list at the rate governed by **participant_liveliness_assert_period**.

For more information on the discovery process, see Discovery (Chapter 15 on page 758).

9.5.3.1 Resource Limits for Builtin-Topic DataReaders

The DDS_BuiltinTopicReaderResourceLimits_t structure is shown in Table 9.12 DDS_BuiltinTopicReaderResourceLimits_t. This structure contains several fields that are used to configure the resource limits of the builtin-topic *DataReaders* used to receive discovery meta-traffic from other *DomainParticipants*.

Table 9.12 DDS_BuiltinTopicReaderResourceLimits_t

Type	Field Name	Description
DDS_Long	initial_samples	Initial number of meta-traffic DDS data samples that can be stored by a builtin-topic *DataReader*.
	max_samples	Maximum number of meta-*traffic* DDS data samples that can be stored by a builtin-topic *DataReader*.
	initial_infos	Initial number of DDS_SampleInfo structures allocated for the builtin-topic *DataReader*.
	max_infos	Maximum number of DDS_SampleInfo structures that can be allocated for the built-in topic *DataReader*. **max_infos** must be >= **max_samples**
	initial_outstanding_reads	Initial number of times in which memory can be concurrently loaned via read/take calls on the builtin-topic *DataReader* without being returned with **return_loan()**.
	max_outstanding_reads	Maximum number of times in which memory can be concurrently loaned via read/take calls on the builtin-topic *DataReader* without being returned with **return_loan()**.
	max_samples_per_read	Maximum number of DDS samples that can be read/taken on a same built-in topic *DataReader*.
DDS_Boolean	disable_fragmentation_support	Determines whether the builtin-topic *DataReader* can receive fragmented DDS samples. When fragmentation support is not needed, disabling fragmentation support will save some memory resources.
DDS_Long	max_fragmented_samples	The maximum number of DDS samples for which the *DataReader* may store fragments at a given point in time. At any given time, a *DataReader* may store fragments for up to **max_fragmented_samples** DDS samples while waiting for the remaining fragments. These DDS samples need not have consecutive sequence numbers and may have been sent by different *DataWriters*. Once all fragments of a DDS sample have been received, the DDS sample is treated as a regular DDS sample and becomes subject to standard QoS settings, such as max_samples. *Connext DDS* will drop fragments if the max_fragmented_samples limit has been reached. For best-effort communication, *Connext DDS* will accept a fragment for a new DDS sample, but drop the oldest fragmented DDS sample from the same remote writer. For reliable communication, *Connext DDS* will drop fragments for any new DDS samples until all fragments for at least one older DDS sample from that writer have been received. Only applies if **disable_fragmentation_support** is FALSE.
DDS_Long	initial_fragmented_samples	The initial number of DDS samples for which a builtin-topic *DataReader* may store fragments. Only applies if disable_fragmentation_support above is FALSE.

Table 9.12 DDS_BuiltinTopicReaderResourceLimits_t

Type	Field Name	Description
DDS_Long	max_fragmented_samples_per_remote_writer	The maximum number of DDS samples per remote writer for which a builtin-topic *DataReader* may store fragments. Logical limit so a single remote writer cannot consume all available resources. Only applies if disable_fragmentation_support on the previous page is FALSE.
DDS_Long	max_fragments_per_sample	Maximum number of fragments for a single DDS sample. Only applies if disable_fragmentation_support on the previous page is FALSE.
DDS_Boolean	dynamically_allocate_fragmented_samples	By default, the middleware does not allocate memory upfront, but instead allocates memory from the heap upon receiving the first fragment of a new sample. The amount of memory allocated equals the amount of memory needed to store all fragments in the sample. Once all fragments of a sample have been received, the sample is deserialized and stored in the regular receive queue. At that time, the dynamically allocated memory is freed again. This QoS setting is useful for large, but variable-sized data types where up-front memory allocation for multiple samples based on the maximum possible sample size may be expensive. The main disadvantage of not pre-allocating memory is that one can no longer guarantee the middleware will have sufficient resources at run-time. If dynamically_allocate_fragmented_samples is FALSE, the middleware will allocate memory up-front for storing fragments for up to initial_fragmented_samples samples. This memory may grow up to max_fragmented_samples if needed. Only applies if disable_fragmentation_support on the previous page is FALSE.

There are builtin-topics for exchanging data about *DomainParticipants*, for publications (*Publisher*/*DataWriter* combination) and for subscriptions (*Subscriber*/*DataReader* combination). The *DataReaders* for the publication and subscription builtin-topics are reliable. The *DataReader* for the participant builtin-topic is best effort.

You can set listeners on these *DataReaders* that are created automatically when a *DomainParticipant* is created. With these listeners, your code can be notified when remote *DomainParticipants*, *Publishers*/*DataWriters*, and *Subscriber*/*DataReaders* are discovered. You can always check the receive queues of those DataReaders for the same information about discovered entities at any time. Please see Built-In Topics (Chapter 18 on page 825) for more details.

The **initial_samples** and **max_samples**, and related **initial_infos** and **max_infos**, fields size the amount of declaration messages can be stored in each builtin-topic *DataReader*.

9.5.3.2 Controlling Purging of Remote Participants

When discovery communication with a remote participant has been lost, the local participant must make a decision about whether to continue attempting to communicate with that participant and its contained entities. The **remote_participant_purge_kind** is used to select the desired behavior.

This does not pertain to the situation in which a remote participant has been gracefully deleted and notification of that deletion has been successfully received by its peers. In that case, the local participant will

immediately stop attempting to communicate with those entities and will remove the associated remote entity records from its internal database.

The **remote_participant_purge_kind** can be set to the following values:

DDS_LIVELINESS_BASED_REMOTE_PARTICIPANT_PURGE

This value causes *Connext DDS* to keep the state of a remote participant and its contained entities for as long as the participant maintains its liveliness contract (as specified by its **participant_liveliness_lease_duration** in the 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639).

A participant will maintain its own liveliness to any remote participant via inter-participant liveliness traffic (see 7.5.15 LIVELINESS QosPolicy on page 425).

The default Simple Discovery Protocol described in Discovery (Chapter 15 on page 758) automatically maintains this liveliness, whereas other discovery mechanisms may or may not.

DDS_NO_REMOTE_PARTICIPANT_PURGE

With this value, *Connext DDS* will never purge the records of a remote participant with which discovery communication has been lost.

- If the remote participant is later rediscovered, the records that remain in the database will be re-used.
- If the remote participant is not rediscovered, the records will continue to take up space in the database for as long as the local participant remains in existence.

In most cases, you will *not* need to change this value from its default, DDS_LIVELINESS_BASED_REMOTE_PARTICIPANT_PURGE.

However, DDS_NO_REMOTE_PARTICIPANT_PURGE may be a good choice if the following conditions apply:

Discovery communication with a remote participant may be lost while data communication remains intact. This will not be the typical case if discovery takes place over the Simple Discovery Protocol.

Extensive and prolonged lack of discovery communication between participants is not expected to be common, either because loss of the participant will be rare, or because participants may be lost sporadically but will typically return again.

Maintaining inter-participant liveliness is problematic, perhaps because a participant has no writers with the appropriate 7.5.15 LIVELINESS QosPolicy on page 425 **kind**.

9.5.3.3 Controlling the Reliable Protocol Used by Builtin-Topic DataWriters/DataReaders

The connection between the *DataWriters* and *DataReaders* for the publication and subscription builtin-topics are reliable. The publication_writer, subscription_writer, publication_reader, and subscription_reader parameters of the 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639 configure the

reliable messaging protocol used by *Connext DDS* for those topics. *Connext DDS*'s reliable messaging protocol is discussed in Reliable Communications (Chapter 11 on page 682).

See also:

- 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388
- 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565.

9.5.3.4 Example

Users will be most interested in setting the participant_liveliness_lease_duration and participant_liveliness_assert_period values for their *DomainParticipants*. Basically, the lease duration governs how fast an application realizes another application dies unexpectedly. The shorter the periods, the quicker a *DomainParticipant* can determine that a remote participant is dead and act accordingly by declaring all of the remote *DataWriters* and *DataReaders* of that participant dead as well.

However, you should realize that the shorter the period the more liveliness packets will sent by the *DomainParticipant*. How many packets is also determined by the number of peers in the peer list of the participant–whether or not the peers on the list are actually alive.

9.5.3.5 Properties

This QosPolicy cannot be modified after the *DomainParticipant* is created.

It can be set differently on the publishing and subscribing sides.

9.5.3.6 Related QosPolicies

- 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635
- 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on the next page
- 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664
- 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388
- 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565
- 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571

9.5.3.7 Applicable DDS Entities

- 9.3 DomainParticipants on page 604

9.5.3.8 System Resource Considerations

Setting smaller values for time periods can increase the CPU and network bandwidth usage. Setting larger values for maximum limits can increase the maximum memory that *Connext DDS* may allocate for a *DomainParticipant* while increasing the initial values will increase the initial memory allocated for a *DomainParticipant*.

9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension)

The DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy includes various settings that configure how *DomainParticipants* allocate and use physical memory for internal resources, including the maximum sizes of various properties.

This QosPolicy sets maximum size limits on variable-length parameters used by the participant and its contained *Entities*. It also controls the initial and maximum sizes of data structures used by the participant to store information about locally-created and remotely-discovered entities (such as *DataWriters*/*DataReaders*), as well as parameters used by the internal database to size the hash tables used by the data structures.

By default, a *DomainParticipant* is allowed to dynamically allocate memory as needed as users create local *Entities* such as *DataWriters* and *DataReaders* or as the participant discovers new applications to store their information. By setting fixed values for the maximum parameters in this QosPolicy, you can bound the memory that can be allocated by a *DomainParticipant*. In addition, by setting the initial values to the maximum values, you can reduce the amount of memory allocated by *DomainParticipants* after the initialization period. Notice that memory can still be allocated dynamically after the initialization period. For example, when a new local *DataWriter or DataReader* is created, the initial memory required for its queue is allocated dynamically.

The maximum sizes of several variable-length parameters—such as the number of partitions that can be stored in the 7.4.5 PARTITION QosPolicy on page 355, the maximum length of data store in the 7.5.30 USER_DATA QosPolicy on page 462 and 7.4.4 GROUP_DATA QosPolicy on page 352, and many others—can be changed from their defaults using this QoS. However, it is important that all *DomainParticipants* that need to communicate with each other use the same set of maximum values. Otherwise, when these parameters are propagated from one *DomainParticipant* to another, a *DomainParticipant* with a smaller maximum length may reject the parameter resulting in an error.

This QosPolicy includes the members in Table 9.13 DDS_DomainParticipantResourceLimitsQosPolicy . For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 9.13 DDS_DomainParticipantResourceLimitsQosPolicy

Type	Field Name	Description

DDS_Allocation-Settings_t
(see description column)
	local_writer_allocation	Each allocation structure configures how many objects of each type, <object>_allocation, will be allocated by the *DomainParticipant*.
		See 9.5.4.1 Configuring Resource Limits for Asynchronous DataWriters on page 655.
		`DDS_AllocationSettings_t`
		`{`
		`  DDS_Long initial_count;`
		`  DDS_Long max_count;`
		`  DDS_Long incremental_count;`
		`};`

See above row	local_reader_allocation	See above row
See above row	local_publisher_allocation	See above row
See above row	local_subscriber_allocation	See above row
See above row	local_topic_allocation	See above row
See above row	remote_writer_allocation	See above row
See above row	remote_reader_allocation	See above row
See above row	remote_participant_allocation	See above row
See above row	matching_writer_reader_pair_allocation	See above row
See above row	matching_reader_writer_pair_allocation	See above row
See above row	ignored_entity_allocation	See above row
See above row	content_filtered_topic_allocation	See above row
See above row	content_filter_allocation	See above row
See above row	read_condition_allocation	See above row
See above row	query_condition_allocation	See above row
See above row	outstanding_asynchronous_sample_allocation	See above row
See above row	flow_controller_allocation	See above row
DDS_DomainParticipantResourceLimitsIgnoredEntityReplacementKind	ignored_entity_replacement_kind	Sets the kinds of entities allowed to be replaced when a *DomainParticipant* reaches **ignored_entity_allocation.max_count.** See 18.4.4 Resource Limits Considerations for Ignored Entities on page 839.

Table 9.13 DDS_DomainParticipantResourceLimitsQosPolicy

Type	Field Name	Description
DDS_Long	local_writer_hash_buckets	Used to configure the hash tables used for database searches. If these numbers are too large then memory is wasted. If these number are too small, searching for an object will be less efficient.
DDS_Long	local_reader_hash_buckets	See above row
DDS_Long	local_publisher_hash_buckets	See above row
DDS_Long	local_subscriber_hash_buckets	See above row
DDS_Long	local_topic_hash_buckets	See above row
DDS_Long	remote_writer_hash_buckets	See above row
DDS_Long	remote_reader_hash_buckets	See above row
DDS_Long	remote_participant_hash_buckets	See above row
DDS_Long	matching_writer_reader_pair_hash_buckets	See above row
DDS_Long	matching_reader_writer_pair_hash_buckets	See above row
DDS_Long	ignored_entity_hash_buckets	See above row
DDS_Long	content_filtered_topic_hash_buckets	See above row
DDS_Long	content_filter_hash_buckets	See above row
DDS_Long	flow_controller_hash_buckets	See above row
DDS_Long	max_gather_destinations	Configures the maximum number of destinations that a message can be addressed in a single network send operation. Can improve efficiency if the underlying transport support can send to multiple destinations.
DDS_Long	participant_user_data_max_length	Controls the maximum lengths of 7.5.30 USER_DATA QosPolicy on page 462, 5.2.1 TOPIC_DATA QosPolicy on page 224 and 7.4.4 GROUP_DATA QosPolicy on page 352 for different entities. Must be configured to be the same values on all *DomainParticipants* in the same DDS domain.
DDS_Long	topic_data_max_length	See above row
DDS_Long	publisher_group_data_max_length	See above row
DDS_Long	subscriber_group_data_max_length	See above row
DDS_Long	writer_user_data_max_length	See above row
DDS_Long	reader_user_data_max_length	See above row

Table 9.13 DDS_DomainParticipantResourceLimitsQosPolicy

Type	Field Name	Description
DDS_Long	max_partitions	Controls the maximum number of partitions that can be assigned to a Publisher or Subscriber with the 7.4.5 PARTITION QosPolicy on page 355. Must be configured to be the same value on all *DomainParticipants* in the same DDS domain.
DDS_Long	max_partition_cumulative_characters	Controls the maximum number of combined characters among all partition names in the 7.4.5 PARTITION QosPolicy on page 355. Must be configured to be the same value on all *DomainParticipants* in the same DDS domain.
DDS_Long	type_code_max_serialized_length	Maximum size of serialized string for type code. If your data type has an especially complex type code, you may need to increase this value. See 3.7 Using Generated Types without Connext DDS (Standalone) on page 152. **Note:** TypeObject is now the standard method of exchanging type information in *Connext DDS*, so **type_code_max_serialized_length** defaults to 0 bytes. It is recommended to use **type_object_max_serialized_length** to configure the maximum serialized size for the TypeObject describing the type.
DDS_Long	type_object_max_serialized_length	Maximum length, in bytes, that the buffer to serialize TypeObject can consume. This parameter limits the size of the TypeObject that a *DomainParticipant* is able to propagate. Since TypeObjects contain all of the information of a data structure, including the strings that define the names of the members of a structure, complex data-structures can result in TypeObjects larger than the default maximum. This field allows you to specify a larger value. Cannot be unlimited.
DDS_Long	type_object_max_deserialized_length	Maximum number of bytes that a deserialized TypeObject can consume. This parameter limits the size of the TypeObject that a *DomainParticipant* is able to store.
DDS_Long	serialized_type_object_dynamic_allocation_threshold	Threshold, in bytes, for dynamic memory allocation for the serialized typeObject. Above this threshold, the memory for a TypeObject is allocated dynamically. Below it, the memory is obtained from a pool of fixed-size buffers. If **type_object_max_serialized_length** is not LENGTH_UNLIMITED and is smaller than **serialized_type_object_dynamic_allocation_threshold**, then **serialized_type_object_dynamic_allocation_threshold** will be adjusted to **type_object_max_serialized_length** and a warning will be logged. By default, **serialized_type_object_dynamic_allocation_threshold** is the same value as **type_object_max_serialized_length**, 8192. This means that the typeObject memory is obtained from a pool of fixed-size buffers.
DDS_Long	deserialized_type_object_dynamic_allocation_threshold	Threshold, in bytes, for dynamic memory allocation for the deserialized TypeObject. Above this threshold, the memory for a TypeObject is allocated dynamically. Below it, the memory is obtained from a pool of fixed-size buffers. The size of the buffers is equal to this threshold. If **type_object_max_deserialized_length** is not LENGTH_UNLIMITED and is smaller than **deserialized_type_object_dynamic_allocation_threshold**, then **deserialized_type_object_dynamic_allocation_threshold** will be adjusted to **type_object_max_deserialized_length** and a warning will be logged.

Table 9.13 DDS_DomainParticipantResourceLimitsQosPolicy

Type	Field Name	Description
DDS_Long	contentfilter_property_max_length	Maximum length of all data related to 5.4 ContentFilteredTopics on page 227.
DDS_Long	channel_seq_max_length	Maximum number of channels that can be specified in a *DataWriter's* 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429.
DDS_Long	channel_filter_expression_max_length	Maximum length of a channel filter_expression in a *DataWriter's* 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429.
DDS_Long	participant_property_list_max_length	Maximum number of properties ((name, value) pairs) that can be stored in the *DomainParticipant's* 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.
DDS_Long	participant_property_string_max_length	Maximum cumulative length (in bytes, including the null terminating characters) of all the (name, value) pairs in a *DomainParticipant's* Property QosPolicy.
DDS_Long	writer_property_list_max_length	Maximum number of properties ((name, value) pairs) that can be stored in a *DataWriter's* Property QosPolicy.
DDS_Long	writer_property_string_max_length	Maximum cumulative length (in bytes, including the null terminating characters) of all the (name, value) pairs in a *DataWriter's* Property QosPolicy.
DDS_Long	reader_property_list_max_length	Maximum number of properties ((name, value) pairs) that can be stored in a *DataReader's* Property QosPolicy.
DDS_Long	reader_property_string_max_length	Maximum cumulative length (in bytes, including the null terminating characters) of all the (name, value) pairs in a *DataReader's* Property QosPolicy.
DDS_Long	max_endpoint_groups	Maximum number of endpoint groups allowed in an 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565 .
	max_endpoint_group_cumulative_characters	Maximum number of combined **role_name** characters allowed in all endpoint groups in an 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369. The maximum number of combined characters should account for a terminating NULL (") character for each **role_name** string.
DDS_Long	transport_info_list_max_length	When sending *DomainParticipant* discovery information, this value defines the maximum number of transports whose properties will be announced to other *DomainParticipants*. If a *DomainParticipant* has three transports installed and this value is two, the *DomainParticipant* will only announce information about the first two transports. When receiving *DomainParticipant* information, this value defines the maximum size of the list containing information about the transports installed in a remote *DomainParticipant*. The information about the transports installed in a *DomainParticipant* is made available to remote *DomainParticipants* through the sequence field transport_info in the Participant Built-in Topic's Data (see Table 18.1 Participant Built-in Topic's Data Type (DDS_ParticipantBuiltinTopicData) Setting this value to 0 disables the capability of *Connext DDS* to detect and report transport misconfigurations. However, it does not affect the capability of reaching a given *DomainParticipant* in all transports available on that *DomainParticipant*.

Table 9.13 DDS_DomainParticipantResourceLimitsQosPolicy

Type	Field Name	Description
DDS_AllocationSettings_t	remote_topic_query_allocation	Allocation settings applied to remote TopicQueries. These settings are applied to the allocation of information about TopicQueries created by other participants and discovered by this participant. When the participant receives a new topic query that would make the current count go above **max_count**, it is not processed until the current count drops (i.e. another topic query is canceled). The topic query stays in the Built-in ServiceRequest DataReader queue until it can be processed or it is canceled.
DDS_Long	remote_topic_query_hash_buckets	Number of hash buckets for remote TopicQueries.
DDS_Long	writer_data_tag_list_max_length	Maximum number of data tags ((name, value) pairs) that can be stored in a *DataWriter*'s DataTag QosPolicy.
DDS_Long	writer_data_tag_string_max_length	Maximum cumulative length (in bytes, including the null terminating characters) of all the (name, value) pairs in a *DataWriter*'s DataTag QosPolicy.
DDS_Long	reader_data_tag_list_max_length	Maximum number of data tags ((name, value) pairs) that can be stored in a *DataReader*'s DataTag QosPolicy.
DDS_Long	reader_data_tag_string_max_length	Maximum cumulative length (in bytes, including the null terminating characters) of all the (name, value) pairs in a *DataReader*'s DataTag QosPolicy.
DDS_UnsignedLong	shmem_ref_transfer_mode_max_segments	Sets the maximum number of shared memory segments that can be created by all *DataWriters* belonging to this participant if you are using Zero Copy transfer over shared memory. See 23.6 Zero Copy Transfer Over Shared Memory on page 953.

Most of the parameters for this QosPolicy are described in the Description column of the table. However, you may need to refer to the sections listed in the column to fully understand the context in which the parameter is used.

An important parameter in this QosPolicy that is often changed by users is the **type_object_max_serialized_length**. This parameter limits the size of the TypeObject that a *DomainParticipant* is able to store and propagate for user data types. TypeObjects are the wire representation for a type code. Type codes can be used by external applications to understand user data types without having the data type predefined in compiled form. However, since type codes contain all of the information of a data structure, including the strings that define the names of the members of a structure, complex data structures can result in TypeObjects larger than the default maximum of 8192 bytes. Thus it is common for users to set this parameter to a larger value. However, as with all parameters in this QosPolicy defining maximum sizes for variable-length elements, all *DomainParticipants* should set the same value for **type_object_max_serialized_length**.

The <object type> hash_buckets configure the hash-table data structure that is used to efficiently search the database. The optimal number of buckets depend on the actual number of objects that will be stored in the hash table. So if you know how many *DataWriters* will be created in a *DomainParticipant*, you may change the value of local_writer_hash_buckets to balance memory usage against search efficiency. A smal-

ler value will use up less memory, but a larger value will make database lookups for the object more efficient.

If you modify any of the <entity type>_data_max_length, max_partitions, or max_partition_cummulative_characters parameters, then you must make sure that they are modified to be the same value for all *DomainParticipants* in the same DDS domain for all applications. If they are different and an application sends data that is larger than another application is configure to hold, then the two *Entities*, whether a matching *DataWriter*/*DataReader* pair or even two *DomainParticipants* will fail to connect.

9.5.4.1 Configuring Resource Limits for Asynchronous DataWriters

When using an asynchronous *Publisher*, if a call to **write()** is blocked due to a resource limit, the block will last until the timeout period expires, which will prevent others from freeing the resource. To avoid this situation, make sure that the *DomainParticipant's* **resource_limits.outstanding_asynchronous_sample_allocation** is always greater than the sum of all asynchronous *DataWriters*' **resource_limits.max_samples** (see 7.5.22 RESOURCE_LIMITS QosPolicy on page 449).

9.5.4.2 Configuring Memory Allocation

The <object type>_allocation configures the number of <object type>'s that can be stored in the internal *Connext DDS* database. For example, local_writer_allocation configures how many local *DataWriters* can be created for the *DomainParticipant*.

The DDS_AllocationSettings_t structure sets the initial and maximum number of each object type that can be stored. The **initial_count** will determine how many objects are initially allocated, and **max_count** will determine the maximum amount of objects that *Connext DDS* is allowed to allocate. The **incremental_count** is used to allocate more objects in chunks when the number of objects created exceed the **initial_count**. You can used fixed-size increments or -1 to double the amount of extra memory allocated each time memory is needed.

Notice that the memory pre-allocated for an object using the DDS_AllocationSettings_t structure is not the full memory that will be required by the object during its lifecycle. Memory can still be allocated dynamically when the object is actually used. For example, when a new local *DataWriter* or *DataReader* is created, the memory required for its queue is allocated from the heap dynamically at the moment of creation, independently of the DDS_AllocationSettings_t value. The memory pre-allocated for the object by using the DDS_AllocationSettings_t structure only accounts for the memory required to store the object in the internal in-memory database, not its full state.

You should only modify these parameters if you want to decrease the initial memory used by *Connext DDS* when a *DomainParticipant* is created or you want to increase the maximum number of local and remote *Entities* that can be stored in a *DomainParticipant*.

9.5.4.3 Example

For most applications, the default values for this QosPolicy may be sufficient. However, if an application uses the PARTITION, USER_DATA, TOPIC_DATA, or GROUP_DATA QosPolicies, the default maximum sizes of the data associated with those policies may need to be adjusted as required by the application. As noted previously, you must make sure that all *DomainParticipants* in the same DDS domain use the same sets of values or it is possible that *Connext DDS* will not successfully connect two *Entities*.

9.5.4.4 Properties

This QosPolicy cannot be modified after the *DomainParticipant* is created.

It can be set differently on the publishing and subscribing sides.

9.5.4.5 Related QosPolicies

- 9.5.1 DATABASE QosPolicy (DDS Extension) on page 632
- 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639
- 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429
- 7.5.30 USER_DATA QosPolicy on page 462
- 5.2.1 TOPIC_DATA QosPolicy on page 224
- 7.4.4 GROUP_DATA QosPolicy on page 352
- 7.4.5 PARTITION QosPolicy on page 355
- 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436

9.5.4.6 Applicable DDS Entities

- 9.3 DomainParticipants on page 604

9.5.4.7 System Resource Considerations

Memory and CPU usage are directly affected by the values set for parameters of this QosPolicy. See the detailed descriptions above for specifics.

9.5.5 EVENT QosPolicy (DDS Extension)

The EVENT QosPolicy configures the internal *Connext DDS* Event thread.

This QoS allows the you to configure thread properties such as priority level and stack size. You can also configure the maximum number of events that can be posted to the event thread. It contains the members in Table 9.14 DDS_EventQoSPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 9.14 DDS_EventQoSPolicy

Type	Field Name	Description
DDS_ThreadSettings_t	thread.mask thread.priority thread.stack_size	Thread settings for the event thread used by *Connext DDS* to wake up for a timed event and possibly execute listener callbacks. The values used for these settings are OS-dependent; see the RTI Connext DDS Core Libraries Platform Notes for details. Note: thread.cpu_list and thread.cpu_rotation are not relevant in this QoS policy.
DDS_Long	initial_count	Initial number of events that can be stored simultaneously.
DDS_Long	max_count	Maximum number of events that can be stored simultaneously.

The Event thread is used to wake up and execute timed events posted to the event queue. In a *DomainParticipant*, different Entities may have constraints that have to be checked at periodic intervals or at specific times. If the constraint is violated, a callback function may need to be executed. Timed events include checking for timeouts and deadlines, and executing internal and user timeout or exception handling routines/callbacks. A combination of a time, constraint, and callback can be considered to be an event. For more information, see 21.2 Event Thread on page 902.

For example, a *DataReader* may have a constraint that requires data to be received within a period of time specified by the 7.5.7 DEADLINE QosPolicy on page 404. For that *DataReader*, an event is stored by the Event thread so that it will wake up periodically to check to see if data has arrived in time. If not, the Event thread will execute the **on_requested_deadline_missed()** *Listener* callback of the *DataReader* (if it was installed and enabled).

A reliable connection between a *DataWriter* and *DataReader* will also post events for sending heartbeats used in the reliable protocol discussed in Reliable Communications (Chapter 11 on page 682).

This QoS configures the parameters associated with thread creation as well as the number of events that can be simultaneously stored by the Event thread.

9.5.5.1 Example

In a real-time operating system, the priority of the Event thread should be set relative to the priority of the events that it must handle. For example, you may want the Event thread to have a high priority if the deadlines and callbacks that it handles are time or safety critical. It may be critical that the data of a particular *DataReader* arrives on time or if not, alternative action is taken with minimal latency.

If you create many *Entities* in a *DomainParticipant* with QosPolicies that will post events that check deadlines, liveliness or send heartbeats, then you may need to increase the maximum number of events that can be stored by the Event thread.

If your application is sending a lot of reliable data, you should increase the event thread priority to be higher than the sending thread priority.

9.5.5.2 Properties

This QosPolicy cannot be modified after the *DomainParticipant* is created.

It can be set differently on the publishing and subscribing sides.

9.5.5.3 Related QosPolicies

- 9.5.1 DATABASE QosPolicy (DDS Extension) on page 632
- 9.5.6 RECEIVER_POOL QosPolicy (DDS Extension) below

9.5.5.4 Applicable DDS Entities

- 9.3 DomainParticipants on page 604

9.5.5.5 System Resource Considerations

Increasing **initial_count** and **max_count** will increase initial and maximum memory used for storing events.

Setting the thread parameters correctly on a real-time operating system is usually critical to the proper overall functionality of the applications on that system. Larger values for the thread.**stack_size** parameter will use up more memory.

By default, a *DomainParticipant* will dynamically allocate memory as needed for events posted to the event thread. However, by setting a maximum value or setting the initial and maximum value to be the same, you can either bound the amount of memory allocated for the event thread or prevent a *DomainParticipant* from dynamically allocating memory for the event thread after initialization.

9.5.6 RECEIVER_POOL QosPolicy (DDS Extension)

The RECEIVER_POOL QosPolicy configures the internal *Connext DDS* thread used to process the data received from a transport. The Receive thread is described in detail in 21.3 Receive Threads on page 903.

This QosPolicy contains the members in Table 9.15 DDS_ReceiverPoolQoSPolicy.

Table 9.15 DDS_ReceiverPoolQoSPolicy

Type	Field Name	Description
struct DDS_ThreadSettings_t	thread.mask thread.priority thread.stack_size hread.cpu_list thread.cpu_rotation	Thread settings for the receive thread(s) used by *Connext DDS* to process data received from a transport. The values used for these settings are OS-dependent; see the RTI Connext DDS Core Libraries Platform Notes for details. See also: 21.5 Controlling CPU Core Affinity for RTI Threads on page 905.
DDS_Long	buffer_size	Size of the receive buffer in bytes. For the default and valid range, see the API Reference HTML documentation. **buffer_size** must always be at least as large as the maximum **message_size_max** of any installed non-zero copy transport. (A "receive zero-copy transport" does not use the receive buffer. It just provides the transport buffer where data is received directly to the middleware. A transport is zero-copy if the **properties_bitmap** in the DDS_Transport_Property_t is NDDS_TRANSPORT_PROPERTY_BIT_BUFFER_ALWAYS_LOANED. The only built-in transport that supports zero-copy is the shared memory transport, in all platforms.) The **buffer_size** can be adjusted automatically by the middleware by configuring its value to DDS_LENGTH_AUTO (in C/C++) or ReceiverPoolQosPolicy.LENGTH_AUTO (in .NET and Java). When set to this AUTO default value, the effective value will automatically be set to the largest **message_size_max** of all installed transports, without needing any other configuration. Therefore you should not need to change this value.
DDS_Long	buffer_alignment	Byte-alignment of the receive buffer. For the default and valid range, see the API Reference HTML documentation.

This QosPolicy sets the thread properties, like priority level and stack size, for the threads used to receive and process data from transports. *Connext DDS* uses a separate receive thread per port per transport plugin. To force *Connext DDS* to use a separate thread to process the data for a *DataReader*, you should set a unique port for the 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458 or 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586 for the *DataReader*.

Connext DDS creates at least one thread for every transport that is installed and enabled for use by the *DomainParticipant* for receiving data. These threads are used to process data DDS samples received for the participant's *DataReaders,* as well as messages used by *Connext DDS* itself in support of the application discovery process discussed in Discovery (Chapter 15 on page 758).

The user application may configure *Connext DDS* to create many more threads for receiving data sent via multicast or even to dedicate a thread to process the DDS data samples of a single *DataReader* received on a particular transport. This QosPolicy is used in the creation of all receive threads.

9.5.6.1 Example

When new data arrives on a transport, the receive thread may invoke the **on_data_available()** of the *Listener* callback of a *DataReader*. Thus, you may want to adjust the priority of the receive threads with

respect to the other threads in the application as appropriate for the proper operation of the system.

9.5.6.2 Properties

This QosPolicy cannot be modified after the *DomainParticipant* is created.

It can be set differently on the publishing and subscribing sides.

9.5.6.3 Related QosPolicies

- 9.5.1 DATABASE QosPolicy (DDS Extension) on page 632
- 9.5.5 EVENT QosPolicy (DDS Extension) on page 656

9.5.6.4 Applicable DDS Entities

- 9.3 DomainParticipants on page 604

9.5.6.5 System Resource Considerations

Increasing the buffer_size will increase memory used by a receive thread.

Setting the thread parameters correctly on a real-time operating system is usually critical to the proper overall functionality of the applications on that system. Larger values for the thread.stack_size parameter will use up more memory.

9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension)

Connext DDS comes with three different transport plugins built into the core libraries (for most supported target platforms). These are plugins for UDPv4, shared memory, and UDPv6.

This QosPolicy allows you to control which built-in transport plugins are used by a *DomainParticipant*. By default, only the UDPv4 and shared memory plugins are enabled (for most platforms; on some platforms, the shared memory plugin is not available). You can disable one or all of the builtin transports.

In some cases, users will disable the shared memory transport when they do not want applications to use shared memory to communicate when running on the same node.

It contains the member in Table 9.16 DDS_TransportBuiltinQosPolicy. For the default and valid values, please refer to the API Reference HTML documentation.

Table 9.16 DDS_TransportBuiltinQosPolicy

Type	Field Name	Description
DDS_TransportBuiltinKindMask	mask	A mask with bits that indicate which built-in transports will be installed.

Please see the API Reference HTML documentation (select **Modules, RTI Connext DDS API Reference**, **Pluggable Transports, Using Transport Plugins** and **Built-in Transport Plugins**) for more information.

Note: Currently, *Connext DDS* will only listen for discovery traffic on the first multicast address (element 0) in **multicast_receive_addresses**.

9.5.7.1 Example

See 9.5.7.5 System Resource Considerations below for an example of why you may want to use this QosPolicy.

In addition, customers may wish to install and use their own custom transport plugins instead of any of the builtin transports. In that case, this QosPolicy may be used to disable all builtin transports.

9.5.7.2 Properties

This QosPolicy cannot be modified after the *DomainParticipant* is created.

It can be set differently on the publishing and subscribing sides.

9.5.7.3 Related QosPolicies

- 7.5.27 TRANSPORT_SELECTION QosPolicy (DDS Extension) on page 456
- 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458
- 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586

9.5.7.4 Applicable DDS Entities

- 9.3 DomainParticipants on page 604

9.5.7.5 System Resource Considerations

You can save memory and other system resources if you disable the built-in transports that your application will not use. For example, if you only run a single application with a single *DomainParticipant* on each machine in your network, then you can disable the shared memory transport since your applications will never use it to send or receive messages.

9.5.8 TRANSPORT_MULTICAST_MAPPING QosPolicy (DDS Extension)

The multicast address on which a *DataReader* wants to receive its data can be explicitly configured using the 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586. However in systems with many multicast addresses, managing the multicast configuration can become cumbersome. The TransportMulticastMapping QosPolicy is designed to make configuration and assignment of the *DataReader's*

multicast addresses more manageable. When using this QosPolicy, the middleware will automatically assign a multicast receive address for a *DataReader* from a range by using configurable mapping rules.

DataReaders can be assigned a single multicast receive address using the rules defined in this QosPolicy on the *DomainParticipant*. This multicast receive address is exchanged during simple discovery in the same manner used when the multicast receive address is defined explicitly. No additional configuration on the writer side is needed.

Mapping within a range is done through a mapping function. The middleware provides a default hash (md5) mapping function. This interface is also pluggable, so you can specify a custom mapping function to minimize collisions.

> To use this QosPolicy, you must set the **kind** in the 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586 to AUTOMATIC.

This QosPolicy contains the member in Table 9.17 DDS_TransportMulticastMappingQosPolicy.

Table 9.17 DDS_TransportMulticastMappingQosPolicy

Type	Field Name	Description
DDS_TransportMappingSettingsSeq	value	A sequence of multicast communication settings, each of which has the format shown in Table 9.18 DDS_TransportMulticastSettings_t.

Table 9.18 DDS_TransportMulticastSettings_t

Type	Field Name	Description
char*	addresses	A string containing a comma-separated list of IP addresses or IP address ranges to be used to receive multicast traffic for the entity with a topic that matches the **topic_expression**. See 9.5.8.1 Formatting Rules for Addresses on the next page.
char*	topic_expression	A regular expression used to map topic names to corresponding addresses. See 5.4.6.5 SQL Extension: Regular Expression Matching on page 241.
DDS_TransportMulticastMappingFunction_t	mapping_function	*Optional.* Defines a user-provided pluggable mapping function. See Table 9.19 DDS_TransportMulticastMappingFunction_t.

Table 9.19 DDS_TransportMulticastMappingFunction_t

Type	Field Name	Description
char*	dll	Specifies a dynamic library that contains a mapping function. You may specify a relative or absolute path. If the name is specified as "foo", the library name on Linux systems will be **libfoo.so**; on Windows systems it will be **foo.dll**.
char*	function_name	Specifies the name of a mapping function in the library specified in the above **dll**. The function must implement the following interface: `int function(const char* topic_name, int numberOfAddresses);` The function must return an integer that indicates the *index* of the address to use for the given **topic_name**. For example, if the first address in the list should be used, it must return 0; if the second address in the list should be used, it must return 1, etc.

9.5.8.1 Formatting Rules for Addresses

- The string must contain IPv4 or IPv6 addresses separated by commas. For example: "239.255.100.1,239.255.100.2,239.255.100.3"
- You may specify ranges of addresses by enclosing the start and end addresses in square brackets. For example: "[239.255.100.1,239.255.100.3]".
- You may combine the two approaches.
  For example: "239.255.200.1,[239.255.100.1,239.255.100.3], 239.255.200.3"
- IPv4 addresses must be specified in Dot-decimal notation.
- IPv6 addresses must be specified using 8 groups of 16-bit hexadecimal values separated by colons. For example: FF00:0000:0000:0000:0202:B3FF:FE1E:8329.
- Leading zeroes can be skipped. For example: FF00:0:0:0:202:B3FF:FE1E:8329.
- You may replace a consecutive number of zeroes with a double colon, but only once within an address. For example: FF00::202:B3FF:FE1E:8329.

9.5.8.2 Example

This QoS policy configures the multicast ranges and mapping rules at the *DomainParticipant* level. You can configure a large set of multicast addresses on the *DomainParticipant*.

In addition, you can configure a mapping between topic names and multicast addresses. For example, topic "A" can be assigned to address 239.255.1.1 and topic "B" can be assigned to address 239.255.1.2.

This configuration is quite flexible. For example, you can specify mappings between a subset of topics to a range of multicast addresses. For example, topics "X", "Y" and Z" can be mapped to [239.255.1.1, 239.255.1.255], or using regular expressions, "X*" and "B-Z" can be mapped to a sub-range of addresses. See 5.4.6.5 SQL Extension: Regular Expression Matching on page 241.

9.5.8.3 Properties

This QosPolicy cannot be modified after the *DomainParticipant* is created.

9.5.8.4 Related QosPolicies

- 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586

9.5.8.5 Applicable DDS Entities

- 9.3 DomainParticipants on page 604

9.5.8.6 System Resource Considerations

See 8.6.5.5 System Resource Considerations on page 589.

9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension)

The WIRE_PROTOCOL QosPolicy configures some global Real-Time Publish Subscribe (RTPS) protocol-related properties for the *DomainParticipant*. The RTPS OMG-standard, interoperability protocol is used by *Connext DDS* to format and interpret messages between *DomainParticipants*.

It includes the members in Table 9.20 DDS_WireProtocolQosPolicy. For defaults and valid ranges, please refer to the API Reference HTML documentation. (The default values contain the correctly initialized wire protocol attributes. They should not be modified without an understanding of the underlying Real-Time Publish Subscribe (RTPS) wire protocol.)

Table 9.20 DDS_WireProtocolQosPolicy

Type	Field Name	Description
DDS_Long	participant_id	Unique identifier for participants that belong to the same DDS domain on the same host. See 9.5.9.1 Choosing Participant IDs on the next page.
DDS_UnsignedLong	rtps_host_id	A machine/OS-specific host ID, unique in the DDS domain. See 9.5.9.3 Controlling How the GUID is Set (rtps_auto_id_kind) on page 667.
	rtps_app_id	A participant-specific ID, unique within the scope of the rtps_host_id. See 9.5.9.3 Controlling How the GUID is Set (rtps_auto_id_kind) on page 667.
	rtps_instance_id	An instance-specific ID of the *DomainParticipant* that, together with the **rtps_app_id**, is unique within the scope of the **rtps_host_id**. See 9.5.9.3 Controlling How the GUID is Set (rtps_auto_id_kind) on page 667.
DDS_RtpsWellKnownPorts_t	rtps_well_known_ports	Determines the well-known multicast and unicast ports for discovery and user traffic. See 9.5.9.2 Ports Used for Discovery on page 666.

Table 9.20 DDS_WireProtocolQosPolicy

Type	Field Name	Description
DDS_ RtpsReservedPortKindMask	rtps_ reserved_ ports _mask	Specifies which well-known multicast and unicast ports to reserve when enabling the *DomainParticipant*.
DDS_WirePro- tocolQosPolicyAutoKind	rtps_auto_ id_kind	Kind of auto mechanism used to calculate the GUID prefix.
DDS_Boolean	compute_ crc	Adds an RTPS CRC submessage to every message.
DDS_Boolean	check_crc	Checks if the received RTPS message is valid by comparing the computed CRC with the received RTPS CRC submessage.

Note that 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388 and 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565 configure RTPS and reliability properties on a per *DataWriter* and *DataReader* basis.

9.5.9.1 Choosing Participant IDs

When you create a *DomainParticipant*, you must specify a domain ID, which identifies the communication channel across the whole system. Each *DomainParticipant* in the same DDS domain on the same host also needs a unique integer, known as the **participant_id**.

The **participant_id** uniquely identifies a *DomainParticipant* from other *DomainParticipants* in the same DDS domain on the same host. You can use the same **participant_id** value for *DomainParticipants* in the same DDS domain but running on different hosts.

The **participant_id** is also used to calculate the default unicast user-traffic and the unicast meta-traffic port numbers, as described in 15.5 Ports Used for Discovery on page 785. If you only have one *DomainParticipant* in the same DDS domain on the same host, you will not need to modify this value.

You can either allow *Connext DDS* to select a participant ID automatically (by setting **participant_id** to -1), or choose a specific participant ID (by setting **participant_id** to the desired value).

- **Automatic Participant ID Selection**

  The default value of participant_id is -1, which means *Connext DDS* will select a participant ID for you.

  Connext DDS will pick the smallest participant ID, based on the unicast ports available on the transports enabled for discovery, based on the unicast and/or multicast ports available on the transports enabled for discovery and/or user traffic.

The **rtps_reserved_ports_mask** field determines which ports to check when picking the next available participant ID. The reserved ports are calculated based on the formula specified in 15.5.1 Inbound Ports for Meta-Traffic on page 786 an 15.5.2 Inbound Ports for User Traffic on page 787. By default, *Connext DDS* will reserve the meta-traffic unicast port, the meta-traffic multicast port, and the user traffic unicast port.

Connext DDS will attempt to resolve an automatic port ID either when a *DomainParticipant* is enabled, or when a *DataReader* or a *DataWriter* is created. Therefore, all the transports enabled for discovery must have been registered by this time. Otherwise, the discovery transports registered after resolving the automatic port index may produce port conflicts when the *DomainParticipant* is enabled.

To see what value *Connext DDS* has selected, either:

- Change the verbosity level of the NDDS_CONFIG_LOG_CATEGORY_API category to NDDS_CONFIG_LOG_VERBOSITY_STATUS_LOCAL (see 25.2 Controlling Messages from Connext DDS on page 968).
- Call **get_qos()** and look at the **participant_id** value in the 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664 after the *DomainParticipant* is enabled.

- **Manual Participant ID Selection**

  If you do have multiple *DomainParticipants* on the same host, you should use consecutively numbered participant indices start from 0. This will make it easier to specify the discovery peers using the **initial_peers** parameter of this QosPolicy or the NDDS_DISCOVERY_PEERS environment variable. See 15.2 Configuring the Peers List Used in Discovery on page 761 for more information.

  Do not use random participant indices since this would make DISCOVERY incredibly difficult to configure. In addition, the **participant_id** has a maximum value of 120 (and will be less for domain IDs other than 0) when using an IP-based transport since the **participant_id** is used to create the port number (see 15.5 Ports Used for Discovery on page 785), and for IP, a port number cannot be larger than 65536.

For details, see 15.5 Ports Used for Discovery on page 785.

9.5.9.2 Ports Used for Discovery

The **rtps_well_known_ports** structure allows you to configure the ports that are used for discovery of inbound meta-traffic (discovery data internal to *Connext DDS*) and user traffic (from your application).

It includes the members in Table 9.21 DDS_RtpsWellKnownPorts_t. For defaults and valid ranges, please refer to the API Reference HTML documentation.

Table 9.21 DDS_RtpsWellKnownPorts_t

Type	Field Name	Description
DDS_Long	port_base	The base port offset. All mapped well-known ports are offset by this value. Resulting ports must be within the range imposed by the underlying transport.
	domain_id_gain	Tunable gain parameters. See 15.5 Ports Used for Discovery on page 785.
	participant_id_gain	
	builtin_multicast_port_offset	Additional offset for meta-traffic port. See 15.5.1 Inbound Ports for Meta-Traffic on page 786.
	builtin_unicast_port_offset	
	user_multicast_port_offset	Additional offset for user traffic port. See 15.5.2 Inbound Ports for User Traffic on page 787.
	user_unicast_port_offset	

9.5.9.3 Controlling How the GUID is Set (rtps_auto_id_kind)

In order for the discovery process to work correctly, each *DomainParticipant* must have a unique identifier. This QoS policy specifies how that identifier should be generated.

RTPS defines a 96-bit prefix to this identifier; each *DomainParticipant* must have a unique value of this prefix relative to all other participants in its DDS domain.

If an application dies unexpectedly and is restarted, the IDs used by the new instance of *DomainParticipants* should be different than the ones used by the previous instances. A change in these values allows other *DomainParticipants* to know that they are communicating with a new instance of an application, and not the previous instance.

For legacy reasons, *Connext DDS* divides the 96-bit prefix into three integers:

- The first integer is called **host ID**. The original purpose of this integer was to contain the identity of the machine on which the *DomainParticipant* is executing.
- The second integer is called an **application ID**. The original purpose of this integer was to contain a value that identifies the process or task in which the *DomainParticipant* is contained.
- The third integer is called **instance ID**. The original purpose was to contain a value that uniquely identifies a *DomainParticipant* within a task or process.

The **rtps_auto_id_kind** field can be used to configure the algorithm that *Connext DDS* uses to populate the 96-bit prefix. Then you can optionally overwrite specific parts of the 96-bit prefix by explicitly configuring the **rtps_host_id** (first integer), **rtps_app_id** (second integer), and **rtps_instance_id** (third integer).

The **rtps_auto_id_kind** field supports three different prefix generation algorithms:

1. In the default and most common scenario, **rtps_auto_id_kind** is set to RTPS_AUTO_ID_FROM_UUID. As the name suggests, this mechanism uses a unique, randomly generated UUID to fill the **rtps_host_id**, **rtps_app_id**, or **rtps_instance_id** fields. The first two bytes of the **rtps_host_id** are replaced with the RTI vendor ID (0x0101).
2. (Legacy) When **rtps_auto_id_kind** is set to DDS_RTPS_AUTO_ID_FROM_IP, the 96-bit prefix is generated as follows:
   - **rtps_host_id**: the 32 bit value of the IPv4 of the first up and running interface of the host machine is assigned. If the host does not have an IPv4 address, the host-id will be automatically set to 0x7F000001.
   - **rtps_app_id**: the process (or task) ID is assigned.
   - **rtps_instance_id**: A counter is assigned that is incremented per new participant within a process.

   DDS_RTPS_AUTO_ID_FROM_IP is not a good algorithm to guarantee prefix uniqueness, because the process ID can be recycled by the OSs. See 9.5.9.3.2 Uniqueness Problem with DDS_RTPS_AUTO_ID_FROM_IP and DDS_RTPS_AUTO_ID_FROM_MAC on page 670 for additional information.
3. (Legacy) When **rtps_auto_id_kind** is set to DDS_RTPS_AUTO_ID_FROM_MAC, the 96-bit prefix is generated as follows:
   - **rtps_host_id**: the first 32 bits of the MAC address of the first up and running interface of the host machine are assigned.
   - **rtps_app_id**: the last 32 bits of the MAC address of the first up and running interface of the host machine are assigned.
   - **rtps_instance_id**: this field is split into two different parts. The process (or task) ID is assigned to the first 24 bits. A counter is assigned to the last 8 bits. This counter is incremented per new participant. In both scenarios, you can change the value of each field independently.

   DDS_RTPS_AUTO_ID_FROM_IP is not a good algorithm to guarantee prefix uniqueness because the process ID can be recycled by the OSs. See 9.5.9.3.2 Uniqueness Problem with DDS_RTPS_AUTO_ID_FROM_IP and DDS_RTPS_AUTO_ID_FROM_MAC on page 670 for additional information.

9.5.9.3.1 Overwriting the Default RTPS 96-bit Prefix

Some examples are provided to better explain the behavior of this QoSPolicy in case you want to change the default behavior with DDS_RTPS_AUTO_ID_FROM_MAC.

1. Get the *DomainParticipant* QoS from the DomainParticipantFactory:

```
DDS_DomainParticipantFactory_get_default_participant_qos(
              DDS_DomainParticipantFactory_get_instance(),
              &participant_qos);
```

2. Change the WireProtocolQosPolicy using one of the following options.

   - Use DDS_RTPS_AUTO_ID_FROM_MAC to explicitly set just the application/task identifier portion of the **rtps_instance_id** field:

```
participant_qos.wire_protocol.rtps_auto_id_kind =
        DDS_RTPS_AUTO_ID_FROM_MAC;
participant_qos.wire_protocol.rtps_host_id =
       DDS_RTPS_AUTO_ID;
participant_qos.wire_protocol.rtps_app_id =
       DDS_RTPS_AUTO_ID;
participant_qos.wire_protocol.rtps_instance_id  =
        (/* App ID */ (12 << 8) |
         /* Instance ID*/ (DDS_RTPS_AUTO_ID));
```

   - Only set the per participant counter and let *Connext DDS* handle the application/task identifier:

```
participant_qos.wire_protocol.rtps_auto_id_kind =
       DDS_RTPS_AUTO_ID_FROM_MAC;
participant_qos.wire_protocol.rtps_host_id =
       DDS_RTPS_AUTO_ID;
participant_qos.wire_protocol.rtps_app_id =
       DDS_RTPS_AUTO_ID;
participant_qos.wire_protocol.rtps_instance_id =
        (/* App ID */ (DDS_RTPS_AUTO_ID) |
         /* Instance ID*/ (12));
```

   - Set the entire **rtps_instance_id** field yourself:

```
participant_qos.wire_protocol.rtps_auto_id_kind =
       DDS_RTPS_AUTO_ID_FROM_MAC;
participant_qos.wire_protocol.rtps_host_id =
       DDS_RTPS_AUTO_ID;
participant_qos.wire_protocol.rtps_app_id =
       DDS_RTPS_AUTO_ID;
participant_qos.wire_protocol.rtps_instance_id  =
        ( /* App ID */ (12 << 8)) |
          /* Instance ID */ (9) )
```

     Note: If you are using DDS_RTPS_AUTO_ID_FROM_MAC as **rtps_auto_id_kind** and you decide to manually handle the **rtps_instance_id** field, you must ensure that both parts are non-zero (otherwise *Connext DDS* will take responsibility for them).

     RTI recommends that you always specify the two parts separately in order to avoid errors.

   - Let *Connext DDS* handle the entire **rtps_instance_id** field:

```
participant_qos.wire_protocol.rtps_auto_id_kind =
       DDS_RTPS_AUTO_ID_FROM_MAC;
participant_qos.wire_protocol.rtps_host_id  =
       DDS_RTPS_AUTO_ID;
participant_qos.wire_protocol.rtps_app_id =
       DDS_RTPS_AUTO_ID;
participant_qos.wire_protocol.rtps_instance_id =
       DDS_RTPS_AUTO_ID;
```

Note: If you are using DDS_RTPS_AUTO_ID_FROM_MAC as **rtps_auto_id_kind** and you decide to manually set the **rtps_instance_id** field, you must ensure that both parts are non-zero (otherwise *Connext DDS* will take responsibility for them). RTI recommends that you always specify the two parts separately in order to clearly show the difference.

3. Create the *DomainParticipant* as usual using the modified QoS structure instead of the default one.

9.5.9.3.2 Uniqueness Problem with DDS_RTPS_AUTO_ID_FROM_IP and DDS_RTPS_AUTO_ID_FROM_MAC

This section applies only when **rtps_auto_id_kind** is set to DDS_RTPS_AUTO_ID_FROM_IP or DDS_RTPS_AUTO_ID_FROM_MAC.

On many real-time operating systems, and even on some non-real-time operating systems, when a node is rebooted, and applications are automatically started, process IDs are deterministically assigned. That is, when the system restarts or if an application dies and is restarted, the application will be reassigned the same process or task ID.

This means that *Connext DDS*'s automatic algorithm for creating unique **rtps_app_id**'s will produce the same value between sequential instances of the same application. This will confuse the other *DomainParticipants* on the network into thinking that they are communicating with the previous instance of the application instead of a new instance. Errors usually resulting in a failure to communicate will ensue.

Thus, for applications running on nodes that may be rebooted without letting the application shutdown appropriately (destroying the *DomainParticipant*), especially on nodes running real-time operating systems like VxWorks, you will want to set the **rtps_app_id** manually. We suggest that a strictly incrementing counter is stored either on a file system or in non-volatile RAM for the **rtps_app_id**.

Whatever method you use, you should make sure that the **rtps_app_id** is unique across all *DomainParticipants* running on a host as well as *DomainParticipants* that were recently running on the host. After a period configured through the 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639, existing applications will eventually flush old *DomainParticipants* that did not properly shutdown from their databases. When that is done, then r**tps_app_id** may be reused.

9.5.9.4 Properties

This QosPolicy cannot be modified after the *DomainParticipant* is created.

If manually set, it must be set differently for every *DomainParticipant* in the same DDS domain across all applications. The value of **rtps_app_id** should also change between different invocations of the same application (for example, when an application is restarted).

9.5.9.5 Related QosPolicies

- 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639

9.5.9.6 Applicable DDS Entities

- 9.3 DomainParticipants on page 604

9.5.9.7 System Resource Considerations

The use of this policy does not significantly impact the use of resources.

9.6 Clock Selection

Connext DDS uses clocks to measure time and generate timestamps.

The middleware uses two clocks: an internal clock and an external clock.

- The internal clock measures time and handles all timing in the middleware.
- The external clock is used solely to generate timestamps (such as the source timestamp and the reception timestamp), in addition to providing the time given by the *DomainParticipant's* **get_current_time()** operation (see 9.3.15.2 Getting the Current Time on page 626).

9.6.1 Available Clocks

Two clock implementations are generally available: the *real-time* clock and the *monotonic* clock.

The real-time clock provides the real time of the system. This clock may generally be monotonic, but may not be guaranteed to be so. It is adjustable and may be subject to small and large changes in time. The time obtained from this clock is generally a meaningful time, in that it is the amount of time from a known epoch. For the purposes of clock selection, this clock can be referenced by the names "**realtime**" or "**system**"—*both names map to the same real-time clock.*

The monotonic clock provides times that are monotonic from a clock that is not adjustable. This clock is not subject to changes in the system or realtime clock, which may be adjusted by the user or via time synchronization protocols. However, this clock's time generally starts from an arbitrary point in time, such as system start-up. Note that the monotonic clock is not available for all architectures. Please see the RTI Connext DDS Core Libraries Platform Notes for the architectures on which it is supported. For the purposes of clock selection, this clock can be referenced by the name "**monotonic**".

9.6.2 Clock Selection Strategy

To configure the clock selection, use the *DomainParticipant's* 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436. Table 9.22 Clock Selection Properties lists the supported properties.

Table 9.22 Clock Selection Properties

Property	Description
dds.clock.external_clock	Comma-delimited list of clocks to use for the external clock, in the order of preference. Valid clock names are "realtime", "system", or "monotonic".
dds.clock.internal_clock	Comma-delimited list of clocks to use for the internal clock, in the order of preference. Valid clock names are "realtime", "system", or "monotonic".

By default, both the internal and external clocks use the realtime clock.

If you want your application to be robust to changes in the system time, you may use the monotonic clock as the internal clock, and leave the system clock as the external clock. However, note that this may slightly diminish performance, in that both the send and receive paths may need to get times from both clocks.

Since the monotonic clock is not available on all architectures, you may want to specify "monotonic, realtime" for the **internal_clock** property (see Table 9.22 Clock Selection Properties). By doing so, the middleware will attempt to use the monotonic clock if it is available, and will fall back to the realtime clock if the monotonic clock is not available.

If you want the application to be robust to changes in the system time, you are not relying on source timestamps, and you want to avoid obtaining times from both clocks, you may use the monotonic clock for both the internal and external clocks.

9.7 System Properties

Connext DDS uses the *DomainParticipant's* PropertyQosPolicy to maintain a set of properties that provide system information, such as the hostname.

Unless the default the DDS_DomainParticipantQos structure (see 9.3.7 Setting DomainParticipant QosPolicies on page 617) is overwritten, the system properties are automatically set in the DDS_DomainParticipantQos structure that is obtained by calling the DomainParticipantFactory's **get_default_participant_qos()** operation or by using the constant DDS_PARTICIPANT_QOS_DEFAULT.

System properties are also automatically set in the DDS_DomainParticipantQos structure loaded from an XML QoS profile unless you disable property inheritance using the attribute **inherit** in the XML tag <property>.

By default, the system properties are propagated to other *DomainParticipants* in the system and can be accessed through the **property** field in the Table 18.1 Participant Built-in Topic's Data Type (DDS_ParticipantBuiltinTopicData).

You can disable propagation of individual properties by setting the property's **propagate** flag to FALSE or by removing the property using the PropertyQosPolicyHelper operation, **remove_property()** (see Table 7.64 PropertyQoSPolicyHelper Operations).

The number of system properties that are initialized for a *DomainParticipant* is platform specific: only **process_id** and **os_arch** are supported on all platforms.

These properties will only be created if *Connext DDS* can obtain the information for them; see Table 9.23 System Properties.

System properties are affected by the DomainParticipantResourceLimitsQosPolicy's **participant_property_list_max_length** and **participant_property_string_max_length**.

Table 9.23 System Properties

Property Name	Description
dds.sys_info.creation_timestamp	Time when the executable was created.[1]
dds.sys_info.executable_filepath	Name and full path of the executable.[2]
dds.sys_info.execution_timestamp	Time when the execution started.[3]
dds.sys_info.hostname	Hostname[4]
dds.sys_info.target	Architecture for which the library was compiled (for example, x64Darwin10gcc4.2.1).
dds.sys_info.process_id	Process ID
dds.sys_info.username	Username that is running the process.[5]

[1]Only supported on Windows, INtime®, and Linux architectures.

[2]Only supported on Windows and Linux architectures.

[3]Only supported on Windows, INtime, and Linux architectures.

[4]Supported on Windows, Linux, macOS, INtime, and QNX architectures.

[5]Only supported on Windows, INtime, and Linux architectures.

Chapter 10 Building Applications

This chapter provides instructions on how to build *Connext DDS* applications for the following platforms:

- 10.4 Linux Platforms on page 677
- 10.5 Windows Platforms on page 678
- 10.6 Java Platforms on page 679

While you can create applications for other operating systems, the platforms presented in this chapter are a good starting point. We recommend that you first build and test your application on one of these systems.

Instructions for other supported target platforms are provided in the RTI Connext DDS Core Libraries Platform Notes.

To build a non-Java application using *Connext DDS*, you must specify the following items:

- NDDSHOME environment variable
- *Connext DDS* header files
- *Connext DDS* libraries to link
- Compatible system libraries
- Compiler options

To build Java applications using *Connext DDS*, you must specify the following items:

- NDDSHOME environment variable
- *Connext DDS* JAR file

- Compatible Java virtual machine (JVM)
- Compiler options

This chapter describes the basic steps you will take to build an application on the above-mentioned platforms. Specific details, such as exactly which libraries to link, compiler flags, etc. are in the RTI Connext DDS Core Libraries Platform Notes.

10.1 Running on a Computer Not Connected to a Network

If you want to run *Connext DDS* applications on the same computer, *and* that computer is not connected to a network, you must set NDDS_DISCOVERY_PEERS so that it will only use shared memory. For example:

```
set NDDS_DISCOVERY_PEERS=4@shmem://
```

(The number 4 is only an example. This is the maximum participant ID.)

10.2 Connext DDS Header Files – All Architectures

You must include the appropriate *Connext DDS* header files, which are listed in Table 10.1 Header Files to Include for Connext DDS (All Architectures). The header files that need to be included depend on the API being used.

Table 10.1 Header Files to Include for Connext DDS (All Architectures)

Connext DDS API	Header Files
C	#include “ndds/ndds_c.h”
C++	#include “ndds/ndds_cpp.h”
C++/CLI, C#, Java	none

For the compiler to find the included files, the path to the appropriate include directories must be provided. Table 10.2 Include Paths for Compilation (All Architectures) lists the appropriate include path for use with the compiler. The exact path depends on where you installed *Connext DDS*. See Paths Mentioned in Documentation on page 1.

Table 10.2 Include Paths for Compilation (All Architectures)

Connext DDS API	Include Path Directories
C and C++	<NDDSHOME>/include <NDDSHOME>/include/ndds
C++/CLI, C#, Java	none

The header files that define the data types you want to use within the application also need to be included. For example, Table 10.3 Header Files to Include for Data Types (All Architectures) lists the files to be include for type "Foo" (these are the filenames generated by *RTI Code Generator*, described in Data Types and DDS Data Samples (Chapter 3 on page 27)).

Table 10.3 Header Files to Include for Data Types (All Architectures)

Connext DDS API	User Data Type Header Files
C and C++	#include "Foo.h" #include "FooSupport.h"
C++/CLI, C#, Java	none

10.3 Choosing the Right Libraries

10.3.1 Required Libraries

All required system and *Connext DDS* libraries are listed in the RTI Connext DDS Core Libraries Platform Notes.

You must choose between dynamic (shared) and static libraries. Do not mix the different types of libraries during linking. The benefit of linking against the dynamic libraries is that your final executables' sizes will be significantly smaller. You will also use less memory when you are running several *Connext DDS* applications on the same node. However, shared libraries require more setup and maintenance during upgrades and installations.

To see if dynamic libraries are supported for your target architecture, see the RTI Connext DDS Core Libraries Platform Notes[1].

10.3.2 Mixing Static and Dynamic Libraries not Supported

You must choose *either* static or dynamic linking. Mixing static and dynamic RTI libraries—for example, using RTI static core libraries and dynamic TCP Transport—is not supported.

The examples in this section are for Linux systems, but except for small differences in names, the same concepts apply to Windows and macOS systems.

Suppose you have a *Connext DDS*-based application **myApp**, and you want to use the TCP Transport plugin. The library dependency looks something like that in Figure 10.1: Library Dependency on the next page.

[1] In the *Platform Notes*, see the "Building Instructions..." table for your target architecture.

Figure 10.1: Library Dependency

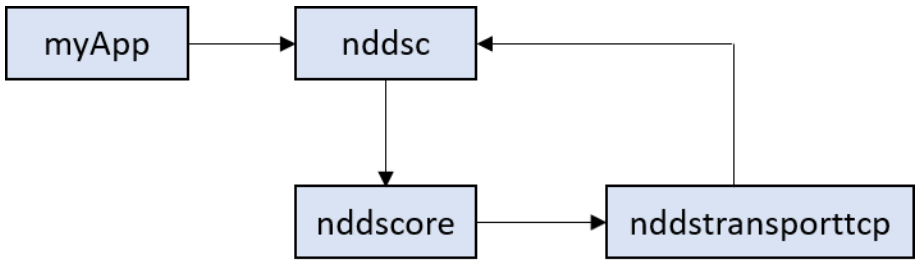


Figure 10.1: Library Dependency above is a simple and common situation, but make sure that the core libraries that your application uses are the same kinds of libraries that the TCP Transport plugin uses. For example, if **myApp** links statically with **nddsc**, but you load **nddstransporttcp** dynamically, there will be a mismatch between the libraries, potentially creating a dangerous situation. You must use static *or* dynamic linking, but not both.

Important: Even if a combination of static and dynamic libraries seems to work, RTI cannot guarantee there won't be issues when running the *Connext DDS* application.

10.4 Linux Platforms

Before building a *Connext DDS* application for a Linux platform (including QNX® systems), make sure that:

- A supported version of your architecture is installed. See the RTI Connext DDS Core Libraries Platform Notes for supported architectures.
- *Connext DDS* 6.x.y is installed (where 6.x.y stands for the version number of the current release). For installation instructions, refer to the RTI Connext DDS Installation Guide.
- A "make" tool is installed. RTI recommends GNU Make. If you do not have it, you may be able to download it from your operating system vendor. Learn more at www.gnu.org/software/make/ or download from ftpmirror.gnu.org/make as source code.
- The **NDDSHOME** environment variable is set to the root directory of the *Connext DDS* installation (such as **/home/user/rti_connext_dds-6.x.y**).
  - To confirm, type this at a command prompt:

    ```
    echo $NDDSHOME
    env | grep NDDSHOME
    ```

  - If it is not set or is set incorrectly, type:

    ```
    setenv NDDSHOME <correct directory>
    ```

To compile a *Connext DDS* application of any complexity, either modify the auto-generated makefile created by running *RTI Code Generator* or write your own makefile. See the RTI Connext DDS Core Libraries Platform Notes for information on compiler flags.

10.5 Windows Platforms

Before building an application for a Microsoft Windows® platform, make sure that:

- Supported versions of Windows and Visual Studio are installed. See the Windows section of the RTI Connext DDS Core Libraries Platform Notes.
- *Connext DDS* 6.x.y is installed (where 6.x.y stands for the version numbers of the current release). For installation instructions, refer to the RTI Connext DDS Installation Guide.
- The **NDDSHOME** environment variable is set to the root directory of the *Connext DDS* installation (such as **C:\Program Files\rti_connext_dds-6.x.y**). To confirm, type this at a command prompt:

  ```
  echo %NDDSHOME%
  ```

- You use the *dynamic* MFC Library (not static).

  To avoid communication problems in your *Connext DDS* application, use the dynamic MFC library, not the static version. (If you use the static version, your *Connext DDS* application may stop receiving DDS samples once the Windows sockets are initialized.)

To compile a *Connext DDS* application of any complexity, use a project file in Microsoft Visual Studio. The project settings are described below. The Windows section of the RTI Connext DDS Core Libraries Platform Notes contains more information.

10.5.1 Using Visual Studio

1. Select the multi-threaded project setting:
   a. From the **Project** menu, select **Properties**.
   b. Select the C/C++ folder.
   c. Select Code Generation.
   d. Set the **Runtime Library** field to one of the options from Table 10.4 Runtime Library Settings for Visual Studio.

2. Link against the *Connext DDS* libraries:
   a. Select the Linker folder on the Project, Properties dialog box.
   b. Select the Input properties.
   c. See the Windows section of the RTI Connext DDS Core Libraries Platform Notes for a list of required libraries. You have a choice of whether to link with *Connext DDS*'s static or

dynamic libraries. Decide whether or not you want debugging symbols on. In either case, be sure to use a *space* as a delimiter between libraries, *not* a comma. Add the libraries to the *beginning* of the Additional Dependencies field.

d. Select the **General** properties.

e. Add the following to the Additional library path field (replace <*architecture*> to match your installed system):

```
$(NDDSHOME)\lib\<architecture>
```

3. Specify the path to *Connext DDS's* header file:
   a. Select the C/C++ folder.
   b. Select the **General** properties.
   c. In the Additional include directories: field, add paths to the "include" and "include\ndds" directories.
   For example: (your paths may differ, depending on where you installed *Connext DDS*).

```
c:\Program Files\rti_connext_dds-6.x.y\include\
c:\Program Files\rti_connext_dds-6.x.y\include\ndds
```

Table 10.4 Runtime Library Settings for Visual Studio

If you are using this Library Format...	Set the Runtime Library field to...
Release version of static libraries	Multi-threaded DLL (/MD)
Debug version of static libraries	Multi-threaded Debug DLL (/MDd)
Release version of dynamic libraries	Multi-threaded DLL (/MD)
Debug version of dynamic libraries	Multi-threaded Debug DLL (/MDd)

10.6 Java Platforms

Before building an application for a Windows or Linux Java platform, make sure that:

- *Connext DDS* 6.x.y is installed (where 6.x.y stands for the version numbers of the current release).
- A supported version of a JDK is installed. See the appropriate section of the RTI Connext DDS Core Libraries Platform Notes.

10.6.1 Java Libraries

Connext DDS requires that certain Java archive (JAR) files be on your classpath when running *Connext DDS* applications. See the RTI Connext DDS Core Libraries Platform Notes for more details.

10.6.2 Native Libraries

Connext DDS for Java is implemented using Java Native Interface (JNI), so it is necessary to provide your *Connext DDS* distributed applications access to certain native shared libraries. See the RTI Connext DDS Core Libraries Platform Notes for more details.

10.7 Building Applications Using CMake

Connext DDS allows you to integrate the *RTI Connext DDS* libraries with build systems implemented using CMake®. A "Find Package" CMake script is provided as part of the *Connext DDS* installation. That script helps the build system find all the *RTI Connext DDS* libraries and include directories needed by your application. So, instead of setting the variables manually in your CMake scripts, you can call the *Connext DDS* "Find Package CMake" script to set all the variables needed by your application.

You can find the script (FindRTIConnextDDS.cmake) in **<NDDSHOME>/resource/cmake**. To know more about the input and output variables, see the documentation included in the script.

See the RTI Connext DDS Core Libraries Platform Notes for the platforms that support this script.

Part 3: Advanced Concepts

This part of the manual will guide you through some of the more advanced concepts:

- Reliable Communications (Chapter 11 on page 682)
- Collaborative DataWriters (Chapter 12 on page 721)
- Mechanisms for Achieving Information Durability and Persistence (Chapter 13 on page 726)
- Guaranteed Delivery of Data (Chapter 14 on page 746)
- Discovery (Chapter 15 on page 758)
- Transport Plugins (Chapter 16 on page 790)
- RTPS Locators and IP Mobility (Chapter 17 on page 821)
- Built-In Topics (Chapter 18 on page 825)
- Configuring QoS with XML (Chapter 19 on page 842)
- Multi-channel DataWriters (Chapter 20 on page 888)
- Connext DDS Threading Model (Chapter 21 on page 900)
- DDS Sample and Instance Memory Management (Chapter 22 on page 918)
- Sending Large Data (Chapter 23 on page 934)
- Topic Queries (Chapter 24 on page 962)
- Troubleshooting (Chapter 25 on page 965)

Chapter 11 Reliable Communications

Connext DDS uses *best-effort* delivery by default. The other type of delivery that *Connext DDS* supports is called *reliable*. This chapter provides instructions on how to set up and use reliable communication.

This chapter includes the following sections:

- 11.1 Sending Data Reliably below
- 11.2 Overview of the Reliable Protocol on page 684
- 11.3 Using QosPolicies to Tune the Reliable Protocol on page 688

11.1 Sending Data Reliably

The DCPS reliability model recognizes that the optimal balance between time-determinism and data-delivery reliability varies widely among applications and can vary among different publications within the same application. For example, individual DDS samples of *signal* data can often be dropped because their value disappears when the next DDS sample is sent. However, each DDS sample of *command* data must be received and it must be received in the order sent.

The QosPolicies provide a way to customize the determinism/reliability trade-off on a per *Topic* basis, or even on a per *DataWriter*/*DataReader* basis.

There are two delivery models:

- Best-effort delivery mode“I’m not concerned about missed or unordered DDS samples.”
- Reliable delivery model“Make sure all DDS samples get there, in order.”

11.1.1 Best-effort Delivery Model

By default, *Connext DDS* uses the best-effort delivery model: there is no effort spent ensuring in-order delivery or resending lost DDS samples. Best-effort *DataReaders* ignore lost DDS samples

in favor of the latest DDS sample. Your application is only notified if it does not receive a new DDS sample within a certain time period (set in the 7.5.7 DEADLINE QosPolicy on page 404).

The best-effort delivery model is best for time-critical information that is sent continuously. For instance, consider a *DataWriter* for the value of a sensor device (such as a the pressure inside a tank), and assume the *DataWriter* sends DDS samples continuously. In this situation, a *DataReader* for this *Topic* is only interested in having the latest pressure reading available—older DDS samples are obsolete.

11.1.2 Reliable Delivery Model

Reliable delivery means the DDS samples are guaranteed to arrive, in the order published.

The *DataWriter* maintains a *send queue* with space to hold the last *X* number of DDS samples sent. Similarly, a *DataReader* maintains a *receive queue* with space for consecutive *X* expected DDS samples.

The *send* and *receive queues* are used to temporarily cache DDS samples until *Connext DDS* is sure the DDS samples have been delivered and are not needed anymore. *Connext DDS* removes DDS samples from a publication's *send queue* after the DDS sample has been acknowledged by all reliable subscriptions. When positive acknowledgements are disabled (see 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388 and 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565), DDS samples are removed from the send queue after the corresponding keep-duration has elapsed (see Table 7.44 DDS_RtpsReliableWriterProtocol_t).

If an out-of-order DDS sample arrives, *Connext DDS* speculatively caches it in the *DataReader's receive queue* (provided there is space in the queue). Only consecutive DDS samples are passed on to the *DataReader*.

DataWriters can be set up to wait for available queue space when sending DDS samples. This will cause the sending thread to block until there is space in the *send queue*. (Or, you can decide to sacrifice sending DDS samples reliably so that the sending rate is not compromised.) If the *DataWriter* is set up to ignore the full queue and sends anyway, then older cached DDS samples will be pushed out of the queue before all *DataReaders* have received them. In this case, the *DataReader* (or its *Subscriber*) is notified of the missing DDS samples through its *Listener* and/or *Conditions*.

Connext DDS automatically sends acknowledgments (ACKNACKs) as necessary to maintain reliable communications. The *DataWriter* may choose to block for a specified duration to wait for these acknowledgments (see 7.3.11 Waiting for Acknowledgments in a DataWriter on page 316).

Connext DDS establishes a virtual reliable channel between the matching *DataWriter* and all *DataReaders*. This mechanism isolates *DataReaders* from each other, allows the application to control memory usage, and provides mechanisms for the *DataWriter* to balance reliability and determinism. Moreover, the use of *send* and *receive queues* allows *Connext DDS* to be implemented efficiently without introducing unnecessary delays in the stream.

Note that a successful return code (DDS_RETCODE_OK) from **write()** does not necessarily mean that all *DataReaders* have received the data. It only means that the DDS sample has been added to the

DataWriter's queue. To see if all *DataReaders* have received the data, look at the 7.3.6.8 RELIABLE_WRITER_CACHE_CHANGED Status (DDS Extension) on page 304 to see if any DDS samples are unacknowledged.

Suppose *DataWriter* A reliably publishes a *Topic* to which *DataReader*s B and C reliably subscribe. B has space in its queue, but C does not. Will *DataWriter* A be notified? Will *DataReader* C receive any error messages or callbacks? The exact behavior depends on the QoS settings:

- If HISTORY_KEEP_ALL is specified for C, C will reject DDS samples that cannot be put into the queue and request A to resend missing DDS samples. The *Listener* is notified with the on_sample_rejected() callback (see 8.3.7.8 SAMPLE_REJECTED Status on page 527). If A has a queue large enough, or A is no longer writing new DDS samples, A won't notice unless it checks the 7.3.6.8 RELIABLE_WRITER_CACHE_CHANGED Status (DDS Extension) on page 304.
- If HISTORY_KEEP_LAST is specified for C, C will drop old DDS samples and accept new ones. To A, it is as if all DDS samples have been received by C (that is, they have all been acknowledged).

11.2 Overview of the Reliable Protocol

An important advantage of *Connext DDS* is that it can offer the reliability and other QoS guarantees mandated by DDS on top of a very wide variety of transports, including packet-based transports, unreliable networks, multicast-capable transports, bursty or high-latency transports, etc. *Connext DDS* is also capable of maintaining liveliness and application-level QoS even in the presence of sporadic connectivity loss at the transport level, an important benefit in mobile networks. *Connext DDS* accomplishes this by implementing a reliable protocol that sequences and acknowledges application-level messages and monitors the liveliness of the link. This is called the Real-Time Publish-Subscribe (RTPS) protocol; it is an open, international standard.[1]

In order to work in this wide range of environments, the reliable protocol defined by RTPS is highly configurable with a set of parameters that let the application fine-tune its behavior to trade-off latency, responsiveness, liveliness, throughput, and resource utilization. This section describes the most important features to the extent needed to understand how the configuration parameters affect its operation.

The most important features of the RTPS protocol are:

- Support for both push and pull operating modes
- Support for both positive and negative acknowledgments
- Support for high data-rate *DataWriters*

[1]For a link to the RTPS specification, see the RTI website, www.rti.com.

- Support for multicast *DataReaders*
- Support for high-latency environments

In order to support these features, RTPS uses several types of messages: Data messages (DATA), acknowledgments (ACKNACKs), and heartbeats (HBs).

- **DATA** messages contain snapshots of the value of data-objects and associate the snapshot with a sequence number that *Connext DDS* uses to identify them within the *DataWriter*'s history. These snapshots are stored in the history as a direct result of the application calling **write()** on the *DataWriter*. Incremental sequence numbers are automatically assigned by the *DataWriter* each time **write()** is called. In Figure 11.1: Basic RTPS Reliable Protocol on the next page through 11.3 Using QosPolicies to Tune the Reliable Protocol on page 688, these messages are represented using the notation DATA(<value>, <sequenceNum>). For example, DATA(A,1) represents a message that communicates the value 'A' and associates the sequence number '1' with this message. A DATA is used for both keyed and non-keyed data types.
- **HB** messages announce to the *DataReader* that it should have received all snapshots up to the one tagged with a range of sequence numbers and can also request the *DataReader* to send an acknowledgement back. For example, HB(1-3) indicates to the *DataReader* that it should have received snapshots tagged with sequence numbers 1, 2, and 3 and asks the *DataReader* to confirm this.
- **ACKNACK** messages communicate to the *DataWrite*r that particular snapshots have been successfully stored in the *DataReader's* history. ACKNACKs also tell the *DataWriter* which snapshots are missing on the *DataReader* side. The ACKNACK message includes a set of sequence numbers represented as a bit map. The sequence numbers indicate which ones the *DataReader* is missing. (The bit map contains the base sequence number that has not been received, followed by the number of bits in bit map and the optional bit map. The maximum size of the bit map is 256.) All numbers up to (not including) those in the set are considered positively acknowledged. They are represented in Figure 11.1: Basic RTPS Reliable Protocol on the next page through Figure 11.7: Use of heartbeat_period on page 700 as ACKNACK(<first-missing>) or ACKNACK(<first-missing>-<last-missing>). For example, ACKNACK(4) indicates that the snapshots with sequence numbers 1, 2, and 3 have been successfully stored in the *DataReader* history, and that 4 has not been received.

It is important to note that *Connext DDS* can bundle multiple of the above messages within a single network packet. This 'submessage bundling' provides for higher performance communications.

Figure 11.1: Basic RTPS Reliable Protocol

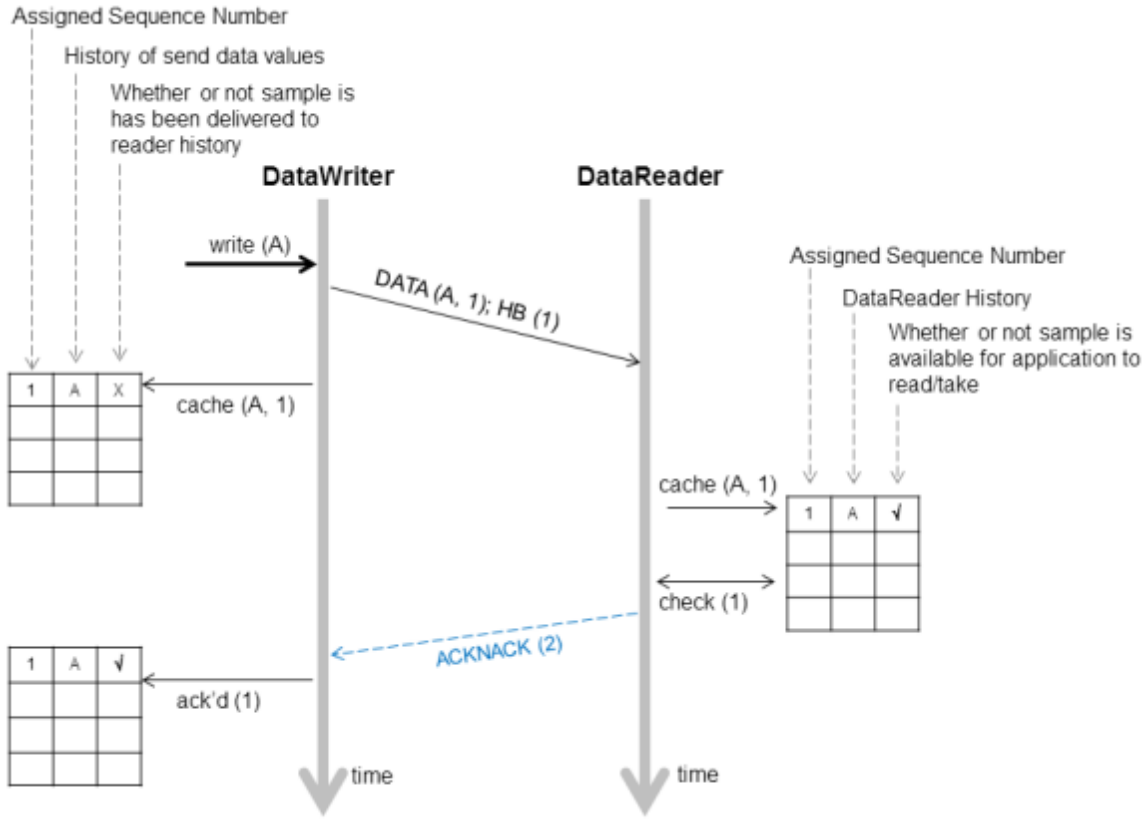


Figure 11.1: Basic RTPS Reliable Protocol above illustrates the basic behavior of the protocol when an application calls the write() operation on a *DataWriter* that is associated with a *DataReader*. As mentioned, the RTPS protocol can bundle multiple submessages into a single network packet. In Figure 11.1: Basic RTPS Reliable Protocol above this feature is used to piggyback a HB message to the DATA message. Note that before the message is sent, the data is given a sequence number (1 in this case) which is stored in the *DataWriter's* send queue. As soon as the message is received by the *DataReader*, it places it into the *DataReader's* receive queue. From the sequence number the *DataReader* can tell that it has not missed any messages and therefore it can make the data available immediately to the user (and call the *DataReaderListener*). This is indicated by the "✓" symbol. The reception of the HB(1) causes the *DataReader* to check that it has indeed received all updates up to and including the one with sequenceNumber=1. Since this is true, it replies with an ACKNACK(2) to positively acknowledge all messages up to (but not including) sequence number 2. The *DataWrite*r notes that the update has been acknowledged, so it no longer needs to be retained in its send queue. This is indicated by the "✓" symbol.

Figure 11.2: RTPS Reliable Protocol in the Presence of Message Loss

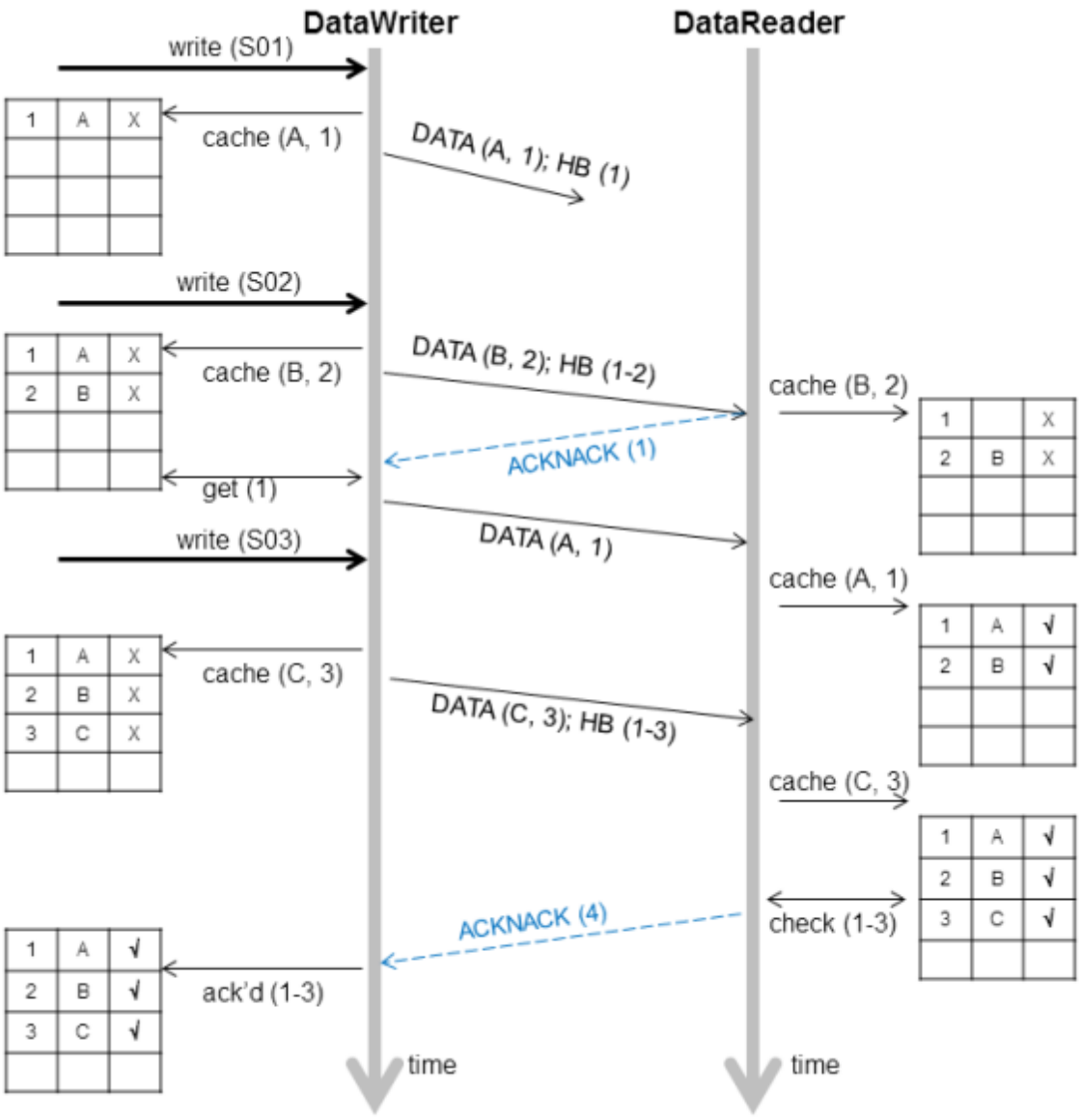


Figure 11.2: RTPS Reliable Protocol in the Presence of Message Loss above illustrates the behavior of the protocol in the presence of lost messages. Assume that the message containing DATA(A,1) is dropped by the network. When the *DataReader* receives the next message (DATA(B,2); HB(1-2)) the *DataReader* will notice that the data associated with sequence number 1 was never received. It realizes this because the heartbeat HB(1-2) tells the *DataReader* that it should have received all messages up to and including the one with sequence number 2. This realization has two consequences:

- The data associated with sequence number 2 (B) is tagged with 'X' to indicate that it is not deliverable to the application (that is, it should not be made available to the application, because the

application needs to receive the data associated with DDS sample 1 (A) first).

- An ACKNACK(1) is sent to the *DataWriter* to request that the data tagged with sequence number 1 be resent.

Reception of the ACKNACK(1) causes the *DataWriter* to resend DATA(A,1). Once the *DataReader* receives it, it can 'commit' both A and B such that the application can now access both (indicated by the "✓") and call the *DataReaderListener*. From there on, the protocol proceeds as before for the next data message (C) and so forth.

A subtle but important feature of the RTPS protocol is that ACKNACK messages are only sent as a direct response to HB messages. This allows the *DataWriter* to better control the overhead of these 'administrative' messages. For example, if the *DataWriter* knows that it is about to send a chain of DATA messages, it can bundle them all and include a single HB at the end, which minimizes ACKNACK traffic.

11.3 Using QosPolicies to Tune the Reliable Protocol

Reliability is controlled by the QosPolicies in Table 11.1 QosPolicies for Reliable Communications. To enable reliable delivery, read the following sections to learn how to change the QoS for the *DataWriter* and *DataReader*:

- 11.3.1 Enabling Reliability on page 690
- 11.3.2 Tuning Queue Sizes and Other Resource Limits on page 690
- 11.3.4 Controlling Heartbeats and Retries with DataWriterProtocol QosPolicy on page 698
- 11.3.5 Avoiding Message Storms with DataReaderProtocol QosPolicy on page 706
- 11.3.6 Resending DDS Samples to Late-Joiners with the Durability QosPolicy on page 706

Then see 11.3.7 Use Cases on page 707 to explore example use cases:

Table 11.1 QosPolicies for Reliable Communications

QosPolicy	Description	Related Entities [1]	Reference
Reliability	To establish reliable communication, this QoS must be set to **DDS_RELIABLE_RELIABILITY_QOS** for the *DataWriter* and its *DataReaders*.	DW, DR	11.3.1 Enabling Reliability on page 690, 7.5.21 RELIABILITY QosPolicy on page 444

[1] DW = DataWriter, DR = DataReader

Table 11.1 QosPolicies for Reliable Communications

QosPolicy	Description	Related Entities [1]	Reference
ResourceLimits	This QoS determines the amount of resources each side can use to manage instances and DDS samples of instances. Therefore it controls the size of the *DataWriter's* send queue and the *DataReader's* receive queue. The send queue stores DDS samples until they have been ACKed by all *DataReaders*. The *DataReader's* receive queue stores DDS samples for the user's application to access.	DW, DR	11.3.2 Tuning Queue Sizes and Other Resource Limits on the next page, 7.5.22 RESOURCE_LIMITS QosPolicy on page 449
History	This QoS affects how a *DataWriter*/*DataReader* behaves when its send/receive queue fills up.	DW, DR	11.3.3 Controlling Queue Depth with the History QosPolicy on page 697, 7.5.12 HISTORY QosPolicy on page 418
DataWriterProtocol	This QoS configures *DataWriter*-specific protocol. The QoS can disable positive ACKs for its *DataReaders*.	DW	11.3.4 Controlling Heartbeats and Retries with DataWriterProtocol QosPolicy on page 698, 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388
DataReaderProtocol	When a reliable *DataReader* receives a heartbeat from a *DataWriter* and needs to return an ACKNACK, the *DataReader* can choose to delay a while. This QoS sets the minimum and maximum delay. It can also disable positive ACKs for the *DataReader*.	DR	11.3.5 Avoiding Message Storms with DataReaderProtocol QosPolicy on page 706, 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565
DataReaderResourceLimits	This QoS determines additional amounts of resources that the *DataReader* can use to manage DDS samples (namely, the size of the *DataReader's* internal queues, which cache DDS samples until they are ordered for reliability and can be moved to the *DataReader's* receive queue for access by the user's application).	DR	11.3.2 Tuning Queue Sizes and Other Resource Limits on the next page,8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571
Durability	This QoS affects whether late-joining *DataReaders* will receive all previously-sent data or not.	DW, DR	11.3.6 Resending DDS Samples to Late-Joiners with the Durability QosPolicy on page 706, 7.5.9 DURABILITY QosPolicy on page 410

[1] DW = DataWriter, DR = DataReader

11.3.1 Enabling Reliability

You must modify the 7.5.21 RELIABILITY QosPolicy on page 444 of the *DataWriter* and each of its reliable *DataReaders*. Set the **kind** field to DDS_RELIABLE_RELIABILITY_QOS:

- *DataWriter*

```
writer_qos.reliability.kind = DDS_RELIABLE_RELIABILITY_QOS;
```

- *DataReader*

```
reader_qos.reliability.kind = DDS_RELIABLE_RELIABILITY_QOS;
```

11.3.1.1 Blocking until the Send Queue Has Space Available

The **max_blocking_time** property in the 7.5.21 RELIABILITY QosPolicy on page 444 indicates how long a *DataWriter* can be blocked during a **write()**.

If **max_blocking_time** is non-zero and the reliability send queue is full, the write is blocked (the DDS sample is not sent). If **max_blocking_time** has passed and the DDS sample is still *not* sent, **write()** returns DDS_RETCODE_TIMEOUT and the DDS sample is not sent.

If the number of unacknowledged DDS samples in the reliability send queue drops below **max_samples** (set in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449) before **max_blocking_time**, the DDS sample is sent and **write()** returns DDS_RETCODE_OK.

If **max_blocking_time** is zero and the reliability send queue is full, **write()** returns DDS_RETCODE_TIMEOUT and the DDS sample is not sent.

11.3.2 Tuning Queue Sizes and Other Resource Limits

Set the 7.5.12 HISTORY QosPolicy on page 418 appropriately to accommodate however many DDS samples should be saved in the *DataWriter*'s send queue or the *DataReader*'s receive queue. *The defaults may suit your needs;* if so, you do not have to modify this QosPolicy.

Set the DDS_RtpsReliableWriterProtocol_t in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388 appropriately to accommodate the number of unacknowledged DDS samples that can be in-flight at a time from a *DataWriter*.

For more information, see the following sections:

- 11.3.2.1 Understanding the Send Queue and Setting its Size on the next page
- 11.3.2.2 Understanding the Receive Queue and Setting Its Size on page 694

Note: The HistoryQosPolicy's **depth** must be less than or equal to the ResourceLimitsQosPolicy's **max_samples_per_instance**; **max_samples_per_instance** must be less than or equal to the

ResourceLimitsQosPolicy's **max_samples** (see 7.5.22 RESOURCE_LIMITS QosPolicy on page 449), and **max_samples_per_remote_writer** (see 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571) must be less than or equal to **max_samples**.

- **depth** <= **max_samples_per_instance** <= **max_samples**
- **max_samples_per_remote_writer** <= **max_samples**

Examples:

DataWriter

```
writer_qos.resource_limits.initial_instances = 10;
writer_qos.resource_limits.initial_samples = 200;
writer_qos.resource_limits.max_instances = 100;
writer_qos.resource_limits.max_samples = 2000;
writer_qos.resource_limits.max_samples_per_instance = 20;
writer_qos.history.depth = 20;
```

DataReader

```
reader_qos.resource_limits.initial_instances = 10;
reader_qos.resource_limits.initial_samples = 200;
reader_qos.resource_limits.max_instances = 100;
reader_qos.resource_limits.max_samples = 2000;
reader_qos.resource_limits.max_samples_per_instance = 20;
reader_qos.history.depth = 20;
reader_qos.reader_resource_limits.max_samples_per_remote_writer = 20;
```

11.3.2.1 Understanding the Send Queue and Setting its Size

A *DataWriter*'s send queue is used to store each DDS sample it writes. A DDS sample will be removed from the send queue after it has been acknowledged (through an ACKNACK) by all the reliable *DataReaders*. A *DataReader* can request that the *DataWriter* resend a missing DDS sample (through an ACKNACK). If that DDS sample is still available in the send queue, it will be resent. To elicit timely ACKNACKs, the *DataWriter* will regularly send heartbeats to its reliable *DataReaders*.

A *DataWriter*'s send queue size is determined by its 7.5.22 RESOURCE_LIMITS QosPolicy on page 449, specifically the **max_samples** field. The appropriate value depends on application parameters such as how fast the publication calls **write()**.

A *DataWriter* has a "send window" that is the maximum number of unacknowledged DDS samples allowed in the send queue at a time. The send window enables configuration of the number of DDS samples queued for reliability to be done independently from the number of DDS samples queued for history. This is of great benefit when the size of the history queue is much different than the size of the reliability queue. For example, you may want to resend a large history to late-joining *DataReaders*, so the send queue size is large. However, you do not want performance to suffer due to a large send queue; this can happen when the send rate is greater than the read rate, and the *DataWriter* has to resend many DDS samples from its large historical send queue. If the send queue size was both the historical and reliability

queue size, then both these goals could not be met. Now, with the send window, having a large history with good live reliability performance is possible.

The send window is determined by the DataWriterProtocolQosPolicy, specifically the fields **min_send_window_size** and **max_send_window_size** within the **rtps_reliable_writer** field of type DDS_RtpsReliableWriterProtocol_t. Other fields control a dynamic send window, where the send window size changes in response to network congestion to maximize the effective send rate. Like for **max_samples**, the appropriate values depend on application parameters.

Strict reliability:If a *DataWriter* does not receive ACKNACKs from one or more reliable *DataReader*s, it is possible for the reliability send queue—either its finite send window, or **max_samples** if its send window is infinite—to fill up. If you want to achieve strict reliability, the **kind** field in the 7.5.12 HISTORY QosPolicy on page 418 for both the *DataReader* and *DataWriter* must be set to KEEP_ALL, positive acknowledgments must be enabled for both the *DataReader* and *DataWriter*, and your publishing application should wait until space is available in the reliability queue before writing any more DDS samples. *Connext DDS* provides two mechanisms to do this:

- Allow the **write()** operation to block until there is space in the reliability queue again to store the DDS sample. The maximum time this call blocks is determined by the **max_blocking_time** field in the 7.5.21 RELIABILITY QosPolicy on page 444 (also discussed in 11.3.1.1 Blocking until the Send Queue Has Space Available on page 690).
- Use the *DataWriter*'s *Listener* to be notified when the reliability queue fills up or empties again.

When the 7.5.12 HISTORY QosPolicy on page 418 on the *DataWriter* is set to KEEP_LAST, strict reliability is not guaranteed. When there are **depth** number of DDS samples in the queue (set in the 7.5.12 HISTORY QosPolicy on page 418, see 11.3.3 Controlling Queue Depth with the History QosPolicy on page 697) the oldest DDS sample will be dropped from the queue when a new DDS sample is written. *Note that in such a reliable mode, when the send window is larger than **max_samples**, the DataWriter will never block, but strict reliability is no longer guaranteed.* If there is a request for the purged DDS sample from any *DataReaders,* the *DataWriter* will send a heartbeat that no longer contains the sequence number of the dropped DDS sample (it will not be able to send the DDS sample).

Alternatively, a *DataWriter* with KEEP_LAST may block on **write()** when its send window is smaller than its send queue. The *DataWriter* will block when its send window is full. Only after the blocking time has elapsed, the *DataWriter* will purge a DDS sample, and then strict reliability is no longer guaranteed.

The send queue size is set in the **max_samples** field of the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449. The appropriate size for the send queue depends on application parameters (such as the send rate), channel parameters (such as end-to-end delay and probability of packet loss), and quality of service requirements (such as maximum acceptable probability of DDS sample loss).

The *DataReader's* receive queue size should generally be larger than the *DataWriter's* send queue size. Receive queue size is discussed in 11.3.2.2 Understanding the Receive Queue and Setting Its Size on page 694.

A good rule of thumb, based on a simple model that assumes individual packet drops are not correlated and time-independent, is that the size of the reliability send queue, N, is as shown in Figure 11.3: Calculating Minimum Send Queue Size for a Desired Level of Reliability below.

Figure 11.3: Calculating Minimum Send Queue Size for a Desired Level of Reliability

$$N = 2RT(\log(1-Q))/\log(p))$$

Simple formula for determining the minimum size of the send queue required for strict reliability

In the above equation, *R* is the rate of sending DDS samples, *T* is the round-trip transmission time, *p* is the probability of a packet loss in a round trip, and *Q* is the required probability that a DDS sample is eventually successfully delivered. Of course, network-transport dropouts must also be taken into account and may influence or dominate this calculation.

Table 11.2 Required Size of the Send Queue for Different Network Parameters gives the required size of the send queue for several common scenarios.

Table 11.2 Required Size of the Send Queue for Different Network Parameters

Q[1]	p[2]	T[3]	R[4]	N[5]
99%	1%	0.001[6] sec	100 Hz	1
99%	1%	0.001 sec	2000 Hz	2
99%	5%	0.001 sec	100 Hz	1
99%	5%	0.001 sec	2000 Hz	4
99.99%	1%	0.001 sec	100 Hz	1
99.99%	1%	0.001 sec	2000 Hz	6
99.99%	5%	0.001 sec	100 Hz	1
99.99%	5%	0.001 sec	2000 Hz	8

[1] "Q" is the desired level of reliability measured as the probability that any data update will eventually be delivered successfully. In other words, percentage of DDS samples that will be successfully delivered.

[2] "p" is the probability that any single packet gets lost in the network.

[3] "T" is the round-trip transport delay in the network

[4] "R" is the rate at which the publisher is sending updates.

[5] "N" is the minimum required size of the send queue to accomplish the desired level of reliability "Q".

[6] The typical round-trip delay for a dedicated 100 Mbit/second ethernet is about 0.001 seconds.

Note: Packet loss on a network frequently happens in bursts, and the packet loss events are correlated. This means that the probability of a packet being lost is much higher if the previous packet was lost because it indicates a congested network or busy receiver. For this situation, it may be better to use a queue size that can accommodate the longest period of network congestion, as illustrated in Figure 11.4: Calculating Minimum Send Queue Size for Networks with Dropouts below.

Figure 11.4: Calculating Minimum Send Queue Size for Networks with Dropouts

$$N = RD\ (Q)$$

Send queue size as a function of send rate "R" and maximum dropout time D

In the above equation R is the rate of sending DDS samples, D(Q) is a time such that Q percent of the dropouts are of equal or lesser length, and Q is the required probability that a DDS sample is eventually successfully delivered. The problem with the above formula is that it is hard to determine the value of D(Q) for different values of Q.

For example, if we want to ensure that 99.9% of the DDS samples are eventually delivered successfully, and we know that the 99.9% of the network dropouts are shorter than 0.1 seconds, then we would use N = 0.1*R. So for a rate of 100Hz, we would use a send queue of N = 10; for a rate of 2000Hz, we would use N = 200.

11.3.2.2 Understanding the Receive Queue and Setting Its Size

DDS samples are stored in the *DataReader's* receive queue, which is accessible to the user's application.

A DDS sample is removed from the receive queue after it has been accessed by take(), as described in 8.4.3 Accessing DDS Data Samples with Read or Take on page 550. Note that read() does not remove DDS samples from the queue.

A *DataReader's* receive queue size is limited by its 7.5.22 RESOURCE_LIMITS QosPolicy on page 449, specifically the max_samples field. The storage of out-of-order DDS samples for each *DataWriter* is also allocated from the *DataReader's* receive queue; this DDS sample resource is shared among all reliable *DataWriters*. That is, **max_samples** includes both ordered and out-of-order DDS samples.

A *DataReader* can maintain reliable communications with multiple *DataWriters* (e.g., in the case of the 7.5.18 OWNERSHIP_STRENGTH QosPolicy on page 435 setting of SHARED). The maximum number of out-of-order DDS samples from any one *DataWriter* that can occupy in the receive queue is set in the max_samples_per_remote_writer field of the 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571; this value can be used to prevent a single *DataWriter* from using all the space in the receive queue. **max_samples_per_remote_writer** must be set to be <= **max_samples**.

The *DataReader* will cache DDS samples that arrive out of order while waiting for missing DDS samples to be resent. (Up to 256 DDS samples can be resent; this limitation is imposed by the wire protocol.) If

there is no room, the *DataReader* has to reject out-of-order DDS samples and request them again later after the missing DDS samples have arrived.

The appropriate size of the receive queue depends on application parameters, such as the *DataWriter's* sending rate and the probability of a dropped DDS sample. However, the receive queue size should generally be larger than the send queue size. Send queue size is discussed in 11.3.2.1 Understanding the Send Queue and Setting its Size on page 691.

Figure 11.5: Effect of Receive-Queue Size on Performance: Large Queue Size on the next page and Figure 11.6: Effect of Receive Queue Size on Performance: Small Queue Size on page 697 compare two hypothetical *DataReaders*, both interacting with the same *DataWriter*. The queue on the left represents an ordering cache, allocated from receive queue—DDS samples are held here if they arrive out of order. The *DataReader* in Figure 11.5: Effect of Receive-Queue Size on Performance: Large Queue Size on the next page has a sufficiently large receive queue (**max_samples**) for the given send rate of the *DataWriter* and other operational parameters. In both cases, we assume that all DDS samples are *taken* from the *DataReader* in the *Listener* callback. (See 8.4.3 Accessing DDS Data Samples with Read or Take on page 550 for information on take() and related operations.)

In Figure 11.6: Effect of Receive Queue Size on Performance: Small Queue Size on page 697, **max_samples** is too small to cache out-of-order DDS samples for the same operational parameters. In both cases, the *DataReaders* eventually receive all the DDS samples in order. However, the *DataReader* with the larger **max_samples** will get the DDS samples earlier and with fewer transactions. In particular, DDS sample "4" is never resent for the *DataReader* with the larger queue size.

Figure 11.5: Effect of Receive-Queue Size on Performance: Large Queue Size

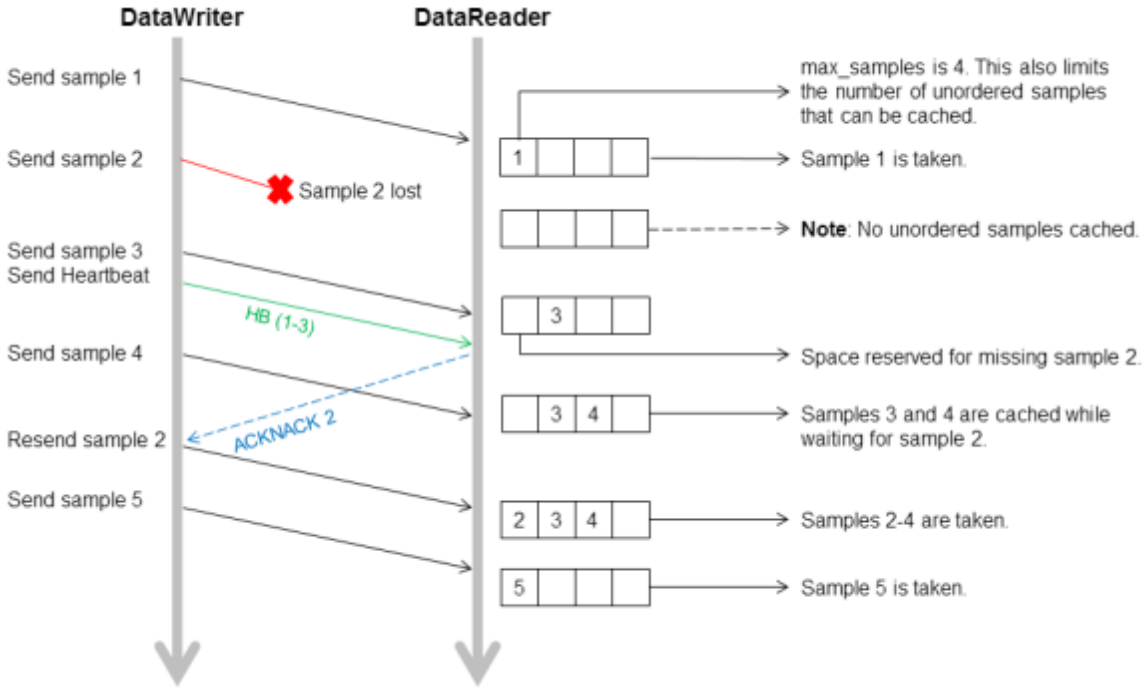
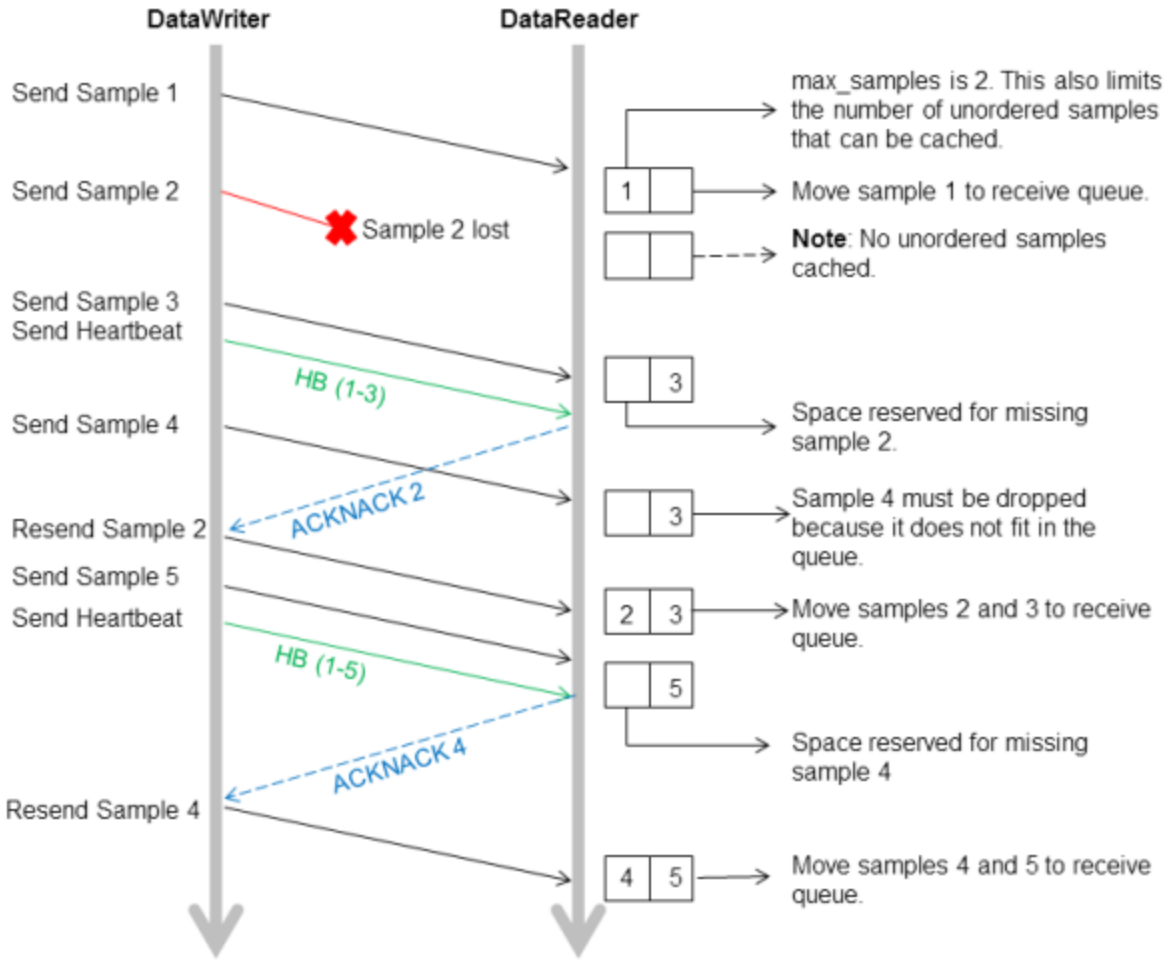


Figure 11.6: Effect of Receive Queue Size on Performance: Small Queue Size



11.3.3 Controlling Queue Depth with the History QosPolicy

If you want to achieve strict reliability, set the *kind* field in the 7.5.12 HISTORY QosPolicy on page 418 for both the *DataReader* and *DataWriter* to KEEP_ALL; in this case, the *depth* does not matter.

Or, for non-strict reliability, you can leave the **kind** set to KEEP_LAST (the default). This will provide non-strict reliability; some DDS samples may not be delivered if the resource limit is reached.

The **depth** field in the 7.5.12 HISTORY QosPolicy on page 418 controls how many DDS samples *Connext DDS* will attempt to keep on the *DataWriter*'s send queue or the *DataReader*'s receive queue. For reliable communications, depth should be >= 1. The depth can be set to 1, but cannot be more than the max_samples_per_instance in 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.

Example:

- *DataWriter*

```
writer_qos.history.depth = <number of DDS samples to keep in send queue>;
```

- *DataReader*

```
reader_qos.history.depth = <number of DDS samples to keep in receive queue>;
```

11.3.4 Controlling Heartbeats and Retries with DataWriterProtocol QosPolicy

In the *Connext DDS* reliability model, the *DataWriter* sends DDS data samples and heartbeats to reliable *DataReaders*. A *DataReader* responds to a heartbeat by sending an ACKNACK, which tells the *DataWriter* what the *DataReader* has received so far.

In addition, the *DataReader* can request missing DDS samples (by sending an ACKNACK) and the *DataWriter* will respond by resending the missing DDS samples. This section describes some advanced timing parameters that control the behavior of this mechanism. Many applications do not need to change these settings. These parameters are contained in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.

The protocol described in 11.2 Overview of the Reliable Protocol on page 684 uses very simple rules such as piggybacking HB messages to each DATA message and responding immediately to ACKNACKs with the requested repair messages. While correct, this protocol would not be capable of accommodating optimum performance in more advanced use cases.

This section describes some of the parameters configurable by means of the **rtps_reliable_writer** structure in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388 and how they affect the behavior of the RTPS protocol.

11.3.4.1 How Often Heartbeats are Resent (heartbeat_period)

If a *DataReader* does not acknowledge a DDS sample that has been sent, the *DataWriter* resends the heartbeat. These heartbeats are resent at the rate set in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388, specifically its heartbeat_period field.

For example, a **heartbeat_period** of 3 seconds means that if a *DataReader* does not receive the latest DDS sample (for example, it gets dropped by the network), it might take up to 3 seconds before the *DataReader* realizes it is missing data. The application can lower this value when it is important that recovery from packet loss is very fast.

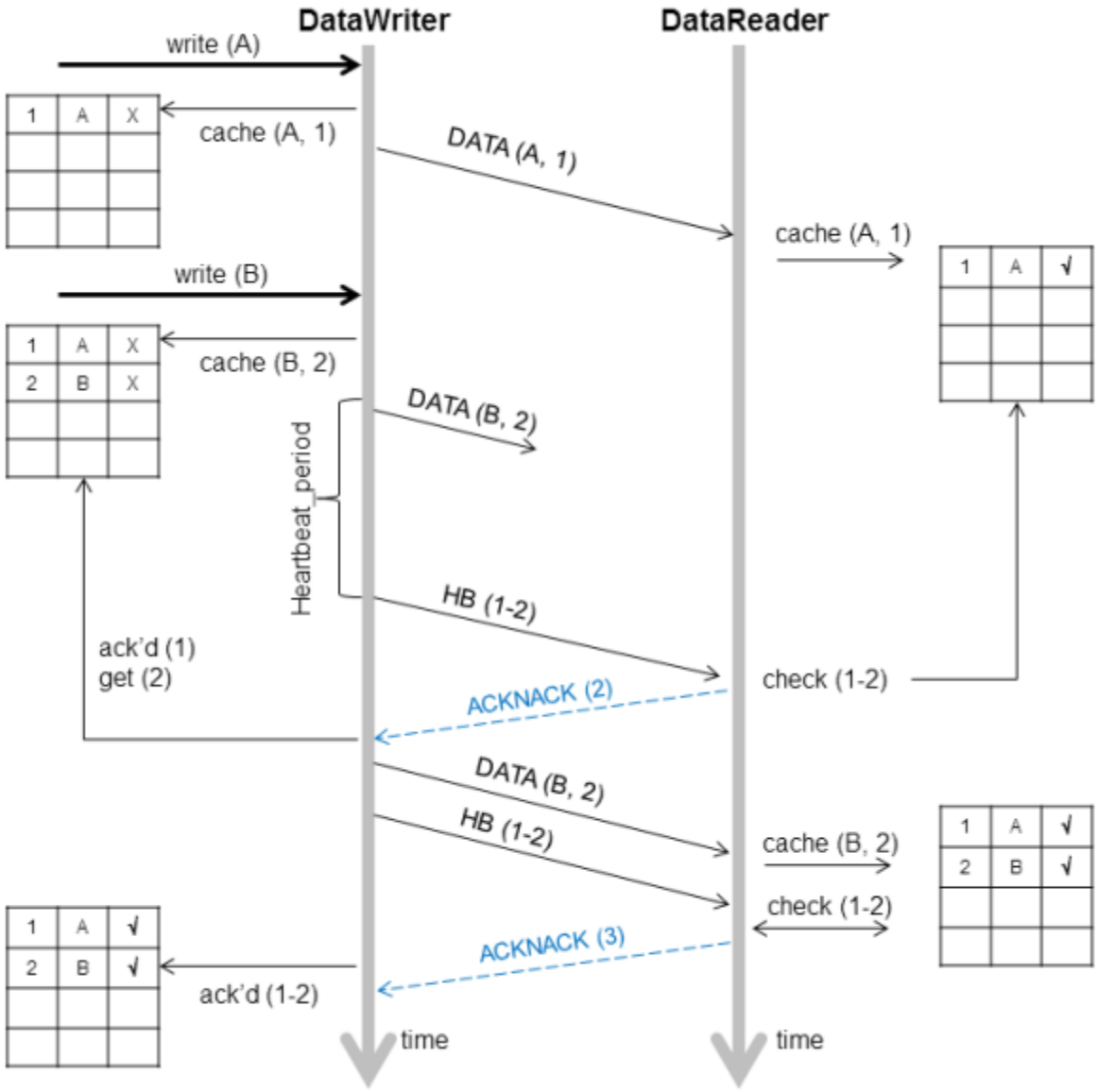
The basic approach of sending HB messages as a piggyback to DATA messages has the advantage of minimizing network traffic. However, there is a situation where this approach, by itself, may result in large latencies. Suppose there is a *DataWriter* that writes bursts of data, separated by relatively long periods of silence. Furthermore assume that the last message in one of the bursts is lost by the network. This is the

case shown for message DATA(B, 2) in Figure 11.7: Use of heartbeat_period on the next page. If HBs were only sent piggybacked to DATA messages, the *DataReader* would not realize it missed the 'B' DATA message with sequence number '2' until the *DataWriter* wrote the next message. This may be a long time if data is written sporadically. To avoid this situation, *Connext DDS* can be configured so that HBs are sent periodically as long as there are DDS samples that have not been acknowledged even if no data is being sent. The period at which these HBs are sent is configurable by setting the **rtps_reliable_writer.heartbeat_perio**d field in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.

Note that a small value for the **heartbeat_period** will result in a small worst-case latency if the last message in a burst is lost. This comes at the expense of the higher overhead introduced by more frequent HB messages.

Also note that the heartbeat_period should not be less than the **rtps_reliable_reader**.**heartbeat_suppression_duration** in the 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565; otherwise those HBs will be lost.

Figure 11.7: Use of heartbeat_period



11.3.4.2 How Often Piggyback Heartbeats are Sent (heartbeats_per_max_samples)

A *DataWriter* will automatically send heartbeats with new DDS samples to request regular ACKNACKs from the *DataReader*. These are called "piggyback" heartbeats.

A piggyback heartbeat is sent every [(*current send-window size*/**heartbeats_per_max_samples**)] number of DDS samples written.

The **heartbeats_per_max_samples** field is part of the **rtps_reliable_writer** structure in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388. If **heartbeats_per_max_**

samples is set equal to **max_send_window_size**, this means that a heartbeat will be sent with each DDS sample. A value of 8 means that a heartbeat will be sent with every 'current send-window size/8' DDS samples. Say current send window is 1024, then a heartbeat will be sent once every 128 DDS samples. If you set this to zero, DDS samples are sent without any piggyback heartbeat. The **max_send_window_size** field is part of the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.

Figure 11.1: Basic RTPS Reliable Protocol and Figure 11.2: RTPS Reliable Protocol in the Presence of Message Loss seem to imply that a heartbeat (HB) is sent as a piggyback to each DATA message. However, in situations where data is sent continuously at high rates, piggybacking a HB to each message may result in too much overhead; not so much on the HB itself, but on the ACKNACKs that would be sent back as replies by the *DataReader*.

There are two reasons to send a HB:

- To request that a *DataReader* confirm the receipt of data via an ACKNACK, so that the *DataWriter* can remove it from its send queue and therefore prevent the *DataWriter*'s history from filling up (which could cause the **write()** operation to temporarily block[1]).
- To inform the *DataReader* of what data it should have received, so that the *DataReader* can send a request for missing data via an ACKNACK.

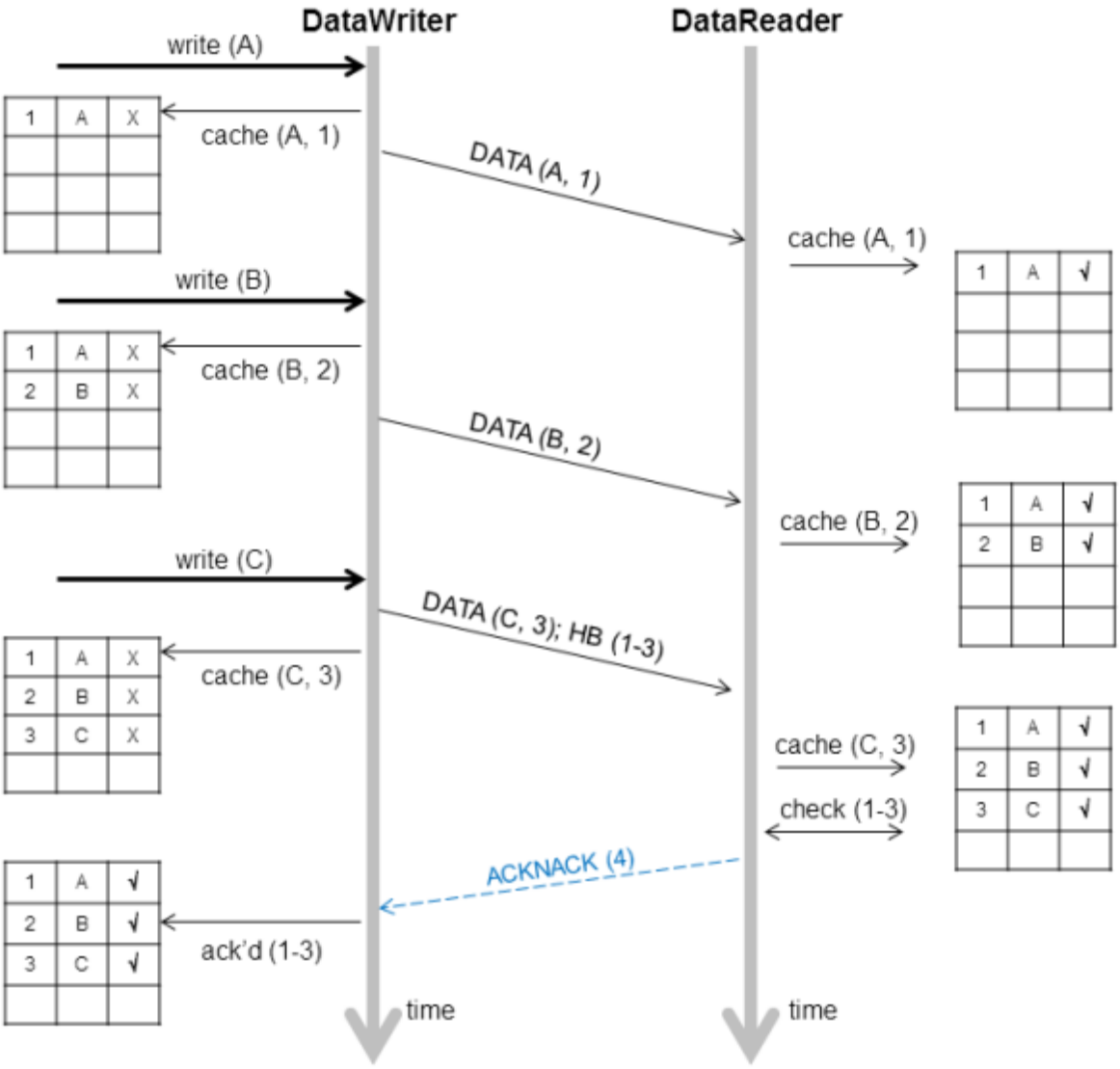
The *DataWriter's* send queue can buffer many DDS data samples while it waits for ACKNACKs, and the *DataReader*'s receive queue can store out-of-order DDS samples while it waits for missing ones. So it is possible to send HB messages much less frequently than DATA messages. The ratio of piggyback HB messages to DATA messages is controlled by the **rtps_reliable_writer.heartbeats_per_max_samples** field in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.

A HB is used to get confirmation from *DataReaders* so that the *DataWriter* can remove acknowledged DDS samples from the queue to make space for new DDS samples. Therefore, if the queue size is large, or new DDS samples are added slowly, HBs can be sent less frequently.

In Figure 11.8: Use of heartbeats_per_max_samples on the next page, the *DataWriter* sets the **heartbeats_per_max_samples** to certain value so that a piggyback HB will be sent for every three DDS samples. The *DataWriter* first writes DDS sample A and B. The *DataReader* receives both. However, since no HB has been received, the *DataReader* won't send back an ACKNACK. The *DataWriter* will still keep all the DDS samples in its queue. When the *DataWriter* sends DDS sample C, it will send a piggyback HB along with the DDS sample. Once the *DataReader* receives the HB, it will send back an ACKNACK for DDS samples up to sequence number 3, such that the *DataWriter* can remove all three DDS samples from its queue.

[1]Note that data could also be removed from the *DataWriter's* send queue if it is no longer relevant due to some other QoS such a HISTORY KEEP_LAST (7.5.12 HISTORY QosPolicy on page 418) or LIFESPAN (7.5.14 LIFESPAN QoS Policy on page 423).

Figure 11.8: Use of heartbeats_per_max_samples



11.3.4.3 Controlling Packet Size for Resent DDS Samples (max_bytes_per_nack_response)

A DataWriter may resend multiple missed DDS samples in the same packet. The **max_bytes_per_nack_response** field in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388 limits the size of this 'repair' packet. The reliable *DataWriter* will include at least one sample in the repair packet.

For example, if the *DataReader* requests 20 DDS samples, each 10K, and the **max_bytes_per_nack_response** is set to 100K, the *DataWriter* will only send the first 10 DDS samples at most. The *DataReader* will have to ACKNACK again to receive the other DDS samples.

Regardless of this setting, the maximum number of samples that can be part of a repair packet is limited to 32. This limit cannot be changed by configuration. In addition, the number of samples is limited by the value of NDDS_Transport_Property_t's **gather_send_buffer_count_max** (see 16.6.1 Setting the Maximum Gather-Send Buffer Count for UDP Transports on page 812).

11.3.4.4 Controlling How Many Times Heartbeats are Resent (max_heartbeat_retries)

If a *DataReader* does not respond within **max_heartbeat_retries** number of heartbeats, it will be dropped by the *DataWriter* and the reliable *DataWriter*'s *Listener* will be called with a 7.3.6.9 RELIABLE_READER_ACTIVITY_CHANGED Status (DDS Extension) on page 306.

If the dropped *DataReader* becomes available again (perhaps its network connection was down temporarily), it will be added back to the *DataWriter* the next time the *DataWriter* receives some message (ACKNACK) from the *DataReader*.

When a *DataReader* is 'dropped' by a *DataWriter*, the *DataWriter* will not wait for the *DataReader* to send an ACKNACK before any DDS samples are removed. However, the *DataWriter* will still send data and HBs to this *DataReader* as normal.

The **max_heartbeat_retries** field is part of the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.

11.3.4.5 Treating Non-Progressing Readers as Inactive Readers (inactivate_nonprogressing_readers)

In addition to **max_heartbeat_retries**, if **inactivate_nonprogressing_readers** is set, then not only are non-responsive *DataReaders* considered inactive, but *DataReaders* sending non-progressing NACKs can also be considered inactive. A *non-progressing NACK* is one which requests the same oldest DDS sample as the previously received NACK. In this case, the *DataWriter* will not consider a non-progressing NACK as coming from an active reader, and hence will inactivate the *DataReader* if no new NACKs are received before **max_heartbeat_retries** number of heartbeat periods has passed.

One example for which it could be useful to turn on **inactivate_nonprogressing_readers** is when a *DataReader's* (keep-all) queue is full of untaken historical DDS samples. Each subsequent heartbeat would trigger the same NACK, and nominally the *DataReader* would not be inactivated. A user not requiring strict-reliability could consider setting **inactivate_nonprogressing_readers** to allow the *DataWriter* to progress rather than being held up by this non-progressing *DataReader*.

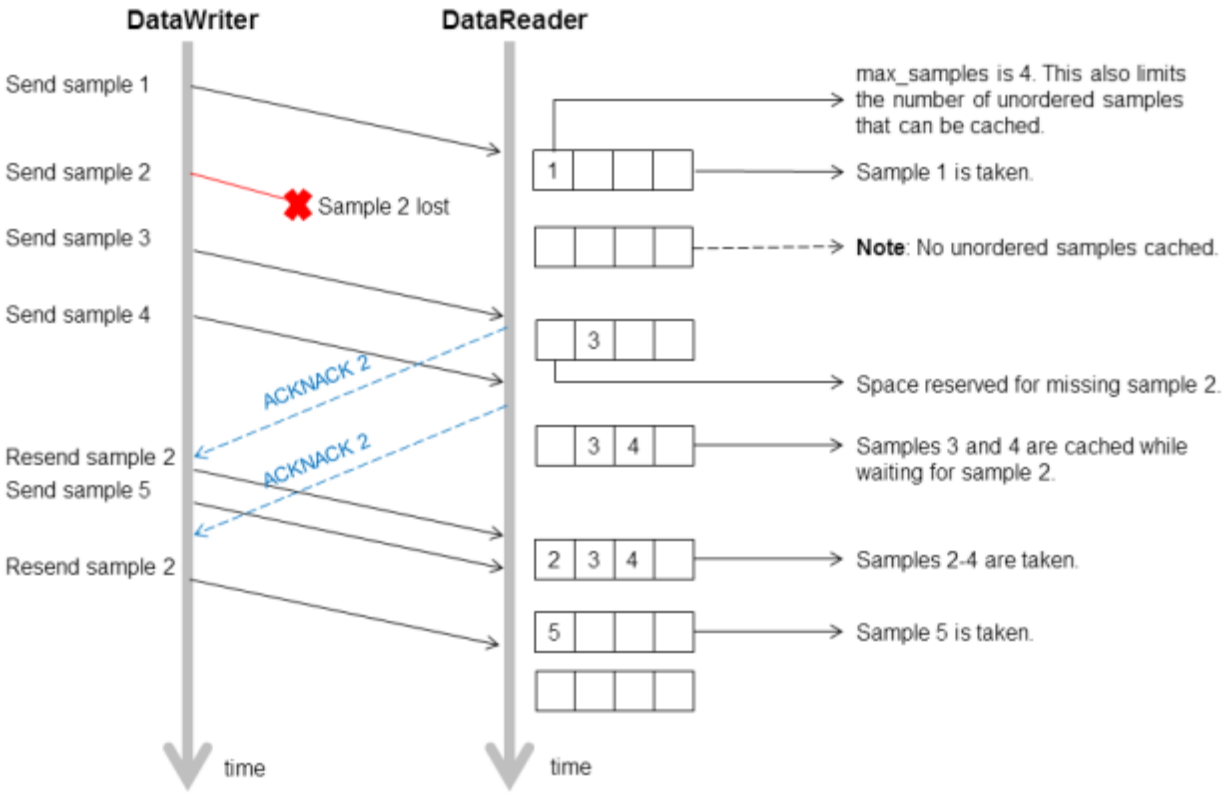
11.3.4.6 Coping with Redundant Requests for Missing DDS Samples (max_nack_response_delay)

When a *DataWriter* receives a request for missing DDS samples from a *DataReader* and responds by resending the requested DDS samples, it will ignore additional requests for the same DDS samples during the time period max_nack_response_delay.

The **rtps_reliable_writer.max_nack_response_delay** field is part of the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.

If your send period is smaller than the round-trip delay of a message, this can cause unnecessary DDS sample retransmissions due to redundant ACKNACKs. In this situation, an ACKNACK triggered by an out-of-order DDS sample is not received before the next DDS sample is sent. When a *DataReader* receives the next message, it will send another ACKNACK for the missing DDS sample. As illustrated in Figure 11.9: Resending Missing Samples due to Duplicate ACKNACKs below, duplicate ACKNACK messages cause another resending of missing DDS sample "2" and lead to wasted CPU usage on both the publication and the subscription sides.

Figure 11.9: Resending Missing Samples due to Duplicate ACKNACKs



While these redundant messages provide an extra cushion for the level of reliability desired, you can conserve the CPU and network bandwidth usage by limiting how often the same ACKNACK messages are sent; this is controlled by **min_nack_response_delay**.

Reliable subscriptions are prevented from resending an ACKNACK within **min_nack_response_delay** seconds from the last time an ACKNACK was sent for the same DDS sample. Our testing shows that the

default **min_nack_response_delay** of 0 seconds achieves an optimal balance for most applications on typical Ethernet LANs.

However, if your system has very slow computers and/or a slow network, you may want to consider increasing min_nack_response_delay. Sending an ACKNACK and resending a missing DDS sample inherently takes a long time in this system. So you should allow a longer time for recovery of the lost DDS sample before sending another ACKNACK. In this situation, you should increase **min_nack_response_delay**.

If your system consists of a fast network or computers, *and* the receive queue size is very small, then you should keep min_nack_response_delay very small (such as the default value of 0). If the queue size is small, recovering a missing DDS sample is more important than conserving CPU and network bandwidth (new DDS samples that are too far ahead of the missing DDS sample are thrown away). A fast system can cope with a smaller **min_nack_response_delay** value, and the reliable DDS sample stream can normalize more quickly.

11.3.4.7 Disabling Positive Acknowledgements (disable_positive_acks_min_sample_keep_duration)

When ACKNACK storms are a primary concern in a system, an alternative to tuning heartbeat and ACKNACK response delays is to disable positive acknowledgments (ACKs) and rely just on NACKs to maintain reliability. Systems with non-strict reliability requirements can disable ACKs to reduce network traffic and directly solve the problem of ACK storms. ACKs can be disabled for the *DataWriter* and the *DataReader*; when disabled for the *DataWriter*, none of its *DataReaders* will send ACKs, whereas disabling it at the *DataReader* allows per-*DataReader* configuration.

Normally when ACKs are enabled, strict reliability is maintained by the *DataWriter*, guaranteeing that a DDS sample stays in its send queue until all *DataReaders* have positively acknowledged it (aside from relevant DURABILITY, HISTORY, and LIFESPAN QoS policies). When ACKs are disabled, strict reliability is no longer guaranteed, but the *DataWriter* should still keep the DDS sample for a sufficient duration for ACK-disabled *DataReaders* to have a chance to NACK it. Thus, a configurable "keep-duration" (**disable_postive_acks_min_sample_keep_duration**) applies for DDS samples written for ACK-disabled *DataReaders*, where DDS samples are kept in the queue for at least that keep-duration. After the keep-duration has elapsed for a DDS sample, the DDS sample is considered to be "acknowledged" by its ACK-disabled *DataReaders*.

The keep duration should be configured for the expected worst-case from when the DDS sample is written to when a NACK for the DDS sample could be received. If set too short, the DDS sample may no longer be queued when a NACK requests it, which is the cost of not enforcing strict reliability.

If the peak send rate is known and writer resources are available, the writer queue can be sized so that writes will not block. For this case, the queue size must be greater than the send rate multiplied by the keep duration.

11.3.5 Avoiding Message Storms with DataReaderProtocol QosPolicy

DataWriters send DDS data samples and heartbeats to *DataReaders*. A *DataReader* responds to a heartbeat by sending an acknowledgement that tells the *DataWriter* what the *DataReader* has received so far and what it is missing. If there are many *DataReaders*, all sending ACKNACKs to the same *DataWriter* at the same time, a message storm can result. To prevent this, you can set a delay for each *DataReader*, so they don't all send ACKNACKs at the same time. This delay is set in the 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565.

If you have several *DataReaders* per *DataWriter*, varying this delay for each one can avoid ACKNACK message storms to the *DataWriter*. If you are not concerned about message storms, you do not need to change this QosPolicy.

Example:

```
reader_qos.protocol.rtps_reliable_reader.min_heartbeat_response_delay.sec = 0;
reader_qos.protocol.rtps_reliable_reader.min_heartbeat_response_delay.nanosec = 0;
reader_qos.protocol.rtps_reliable_reader.max_heartbeat_response_delay.sec = 0;
reader_qos.protocol.rtps_reliable_reader.max_heartbeat_response_delay.nanosec =
                                                    0.5 * 1000000000UL; // 0.5 sec
```

As the name suggests, the minimum and maximum response delay bounds the random wait time before the response. Setting both to zero will force immediate response, which may be necessary for the fastest recovery in case of lost DDS samples.

11.3.6 Resending DDS Samples to Late-Joiners with the Durability QosPolicy

The 7.5.9 DURABILITY QosPolicy on page 410 is also somewhat related to Reliability. *Connext DDS* requires a finite time to "discover" or match *DataReaders* to *DataWriters*. If an application attempts to send data before the *DataReader* and *DataWriter* "discover" one another, then the DDS sample will not actually get sent. Whether or not DDS samples are resent when the *DataReader* and *DataWriter* eventually "discover" one another depends on how the DURABILITY and 7.5.12 HISTORY QosPolicy on page 418 are set. The default setting for the Durability QosPolicy is VOLATILE, which means that the *DataWriter* will not store DDS samples for redelivery to late-joining DataReaders.

Connext DDS also supports the TRANSIENT_LOCAL setting for the Durability, which means that the DDS samples will be kept stored for redelivery to late-joining *DataReaders*, as long as the *DataWriter* is around. The DDS samples are not stored beyond the lifecycle of the *DataWriter*.

How many samples are sent to late-joining *DataReaders* is determined by the **writer_depth** in the DURABILITY QosPolicy.

See also: 8.3.6 Waiting for Historical Data on page 512.

11.3.7 Use Cases

This section contains advanced material that discusses practical applications of the reliability related QoS.

11.3.7.1 Importance of Relative Thread Priorities

For high throughput, the *Connext DDS* Event thread's priority must be sufficiently high on the sending application. Unlike an unreliable writer, a reliable writer relies on internal *Connext DDS* threads: the Receive thread processes ACKNACKs from the *DataReaders*, and the Event thread schedules the events necessary to maintain reliable data flow.

- When DDS samples are sent to the same or another application on the same host, the Receive thread priority should be higher than the writing thread priority (priority of the thread calling **write()** on the *DataWriter*). This will allow the Receive thread to process the messages as they are sent by the writing thread. A sustained reliable flow requires the reader to be able to process the DDS samples from the writer at a speed equal to or faster than the writer emits.
- The default Event thread priority is low. This is adequate if your reliable transfer is not sustained; queued up events will eventually be processed when the writing thread yields the CPU. The *Connext DDS* can automatically grow the event queue to store all pending events. But if the reliable communication is sustained, reliable events will continue to be scheduled, and the event queue will eventually reach its limit. The default Event thread priority is unsuitable for maintaining a fast and sustained reliable communication and should be increased through the **participant_qos.event.thread.priority**. This value maps directly to the OS thread priority, see 9.5.5 EVENT QosPolicy (DDS Extension) on page 656).

The Event thread should also be increased to minimize the reliable latency. If events are processed at a higher priority, dropped packets will be resent sooner.

Now we consider some practical applications of the reliability related QoS:

- 11.3.7.2 Aperiodic Use Case: One-at-a-Time below
- 11.3.7.3 Aperiodic, Bursty on page 712
- 11.3.7.4 Periodic on page 715

11.3.7.2 Aperiodic Use Case: One-at-a-Time

Suppose you have aperiodically generated data that needs to be delivered reliably, with minimum latency, such as a series of commands ("Ready," "Aim," "Fire"). If a writing thread may block between each DDS sample to guarantee reception of the just-sent DDS sample on the reader's middleware end, a smaller queue will provide a smaller upper bound on the DDS sample delivery time. Adequate writer QoS for this use case are presented in Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer on the next page.

Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer

```
1. qos->reliability.kind = DDS_RELIABLE_RELIABILITY_QOS;
2.  qos->history.kind = DDS_KEEP_ALL_HISTORY_QOS;
3.  qos->protocol.push_on_write = DDS_BOOLEAN_TRUE;
4.
5.  //use these hard coded value unless you use a key
6.  qos->resource_limits.initial_samples = qos->resource_limits.max_samples = 1;
7.  qos->resource_limits.max_samples_per_instance =
8.  qos->resource_limits.max_samples;
9.  qos->resource_limits.initial_instances =
10.  qos->resource_limits.max_instances = 1;
11.
12.  // want to piggyback HB w/ every sample.
13.  qos->protocol.rtps_reliable_writer.heartbeats_per_max_samples =
14.  qos->resource_limits.max_samples;
15.
16.  qos->protocol.rtps_reliable_writer.high_watermark = 1;
17.  qos->protocol.rtps_reliable_writer.low_watermark = 0;
18.  qos->protocol.rtps_reliable_writer.min_nack_response_delay.sec = 0;
19.  qos->protocol.rtps_reliable_writer.min_nack_response_delay.nanosec = 0;
20.  //consider making non-zero for reliable multicast
21.  qos->protocol.rtps_reliable_writer.max_nack_response_delay.sec = 0;
22.  qos->protocol.rtps_reliable_writer.max_nack_response_delay.nanosec = 0;
23.
24.  // should be faster than the send rate, but be mindful of OS resolution
25.  25 qos->protocol.rtps_reliable_writer.fast_heartbeat_period.sec = 0;
26.  26 qos->protocol.rtps_reliable_writer.fast_heartbeat_period.nanosec =
27.  alertReaderWithinThisMs * 1000000;
28.
29.  qos->reliability.max_blocking_time = blockingTime;
30.  qos->protocol.rtps_reliable_writer.max_heartbeat_retries = 7;
31.
32.  // essentially turn off slow HB period
33.  qos->protocol.rtps_reliable_writer.heartbeat_period.sec = 3600 * 24 * 7;
```

Line 1 (Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer above): This is the default setting for a writer, shown here strictly for clarity.

Line 2 (Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer above): Setting the History kind to KEEP_ALL guarantees that no DDS sample is ever lost.

Line 3 (Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer above): This is the default setting for a writer, shown here strictly for clarity. 'Push' mode reliability will yield lower latency than 'pull' mode reliability in normal situations where there is no DDS sample loss. (See 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.) Furthermore, it does not matter that each packet sent in response to a command will be small, because our data sent with each command is likely to be small, so that maximizing throughput for this data is not a concern.

Line 5 - Line 10 (Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer above): For this example, we assume a single writer is writing DDS samples one at a time. If we are not using keys (see 2.4 DDS Samples, Instances, and Keys on page 18), there is no reason to use a queue with room for more than one DDS sample, because we want to resolve a DDS sample completely before moving on to the next. While this negatively impacts throughput, it minimizes memory usage. In this example, a written

DDS sample will remain in the queue until it is acknowledged by all active readers (only 1 for this example).

Line 12 - Line 14 (Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer on the previous page): The fastest way for a writer to ensure that a reader is up-to-date is to force an acknowledgment with every DDS sample. We do this by appending a Heartbeat with every DDS sample. This is akin to a certified mail; the writer learns—as soon as the system will allow—whether a reader has received the letter, and can take corrective action if the reader has not. As with certified mail, this model has significant overhead compared to the unreliable case, trading off lower packet efficiency in favor of latency and fast recovery.

Line 16-Line 17 (Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer on the previous page): Since the writer takes responsibility for pushing the DDS samples out to the reader, a writer will go into a "heightened alert" mode as soon as the high water mark is reached (which is when any DDS sample is written for this writer) and only come out of this mode when the low water mark is reached (when all DDS samples have been acknowledged for this writer). Note that the selected high and low watermarks are actually the default values.

Line 18-Line 22 (Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer on the previous page): When a reader requests a lost DDS sample, we respond to the reader immediately in the interest of faster recovery. If the readers receive packets on unicast, there is no reason to wait, since the writer will eventually have to feed individual readers separately anyway. In case of multicast readers, it makes sense to consider further. If the writer delayed its response enough so that all or most of the readers have had a chance to NACK a DDS sample, the writer may coalesce the requests and send just one packet to all the multicast readers. Suppose that all multicast readers do indeed NACK within approximately 100 µsec. Setting the minimum and maximum delays at 100 µsec will allow the writer to collect all these NACKs and send a single response over multicast. (See 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388 for information on setting **min_nack_response_delay** and **max_nack_response_delay**.) Note that *Connext DDS* relies on the OS to wait for this 100 µsec. Unfortunately, not all operating systems can sleep for such a fine duration. On Windows systems, for example, the minimum achievable sleep time is somewhere between 1 to 20 milliseconds, depending on the version. On VxWorks systems, the minimum resolution of the wait time is based on the tick resolution, which is 1/system clock rate (thus, if the system clock rate is 100 Hz, the tick resolution is 10 millisecond). On such systems, the achievable minimum wait is actually far larger than the desired wait time. This could have an unintended consequence due to the delay caused by the OS; at a minimum, the time to repair a packet may be longer than you specified.

Line 24-Line 27 (Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer on the previous page): If a reader drops a DDS sample, the writer recovers by notifying the reader of what it has sent, so that the reader may request resending of the rejected DDS sample. Therefore, the recovery time depends primarily on how quickly the writer pings the reader that has fallen behind. If commands will not be generated faster than one every few seconds, it may be acceptable for the writer to ping the reader several hundred milliseconds after the DDS sample is sent.

- Suppose that the round-trip time of fairly small packets between the writer and the reader application is 50 microseconds, and that the reader does not delay response to a Heartbeat from the writer (see 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565 for how to change this). If a DDS sample is dropped by the network, the writer will ping the reader after a maximum of the OS delay resolution discussed above and **alertReaderWithinThisMs** (let's say 10 ms for this example). The reader will request the missing DDS sample immediately, and with the code set as above, the writer will feed the missing DDS sample immediately. Neglecting the processing time on the writer or the reader end, and assuming that this retry succeeds, the time to recover the DDS sample from the original publication time is: **alertReaderWithinThisMs + 50 µsec + 25 µsec**.

  If the OS is capable of micro-sleep, the recovery time can be within 100 µsec, barely noticeable to a human operator. If the OS minimum wait resolution is much larger, the recovery time is dominated by the wait resolution of the OS. Since ergonomic studies suggest that delays in excess of a 0.25 seconds start hampering operations that require low latency data, even a 10 ms limitation seems to be acceptable.

- What if two packets are dropped in a row? Then the recovery time would be **2 * alertReaderWithinThisMs + 2 * 50 µsec + 25 µsec**. If **alertReaderWithinThisMs** is 100 ms, the recovery time now exceeds 200 ms, and can perhaps degrade user experience.

Line 29-Line 30 (Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer on page 708): What if another command (like another button press) is issued before the recovery? Since we must not drop this new DDS sample, we block the writer until the recovery completes. If **alertReaderWithinThisMs** is 10 ms, and we assume no more than 7 consecutive drops, the longest time for recovery will be just above (**alertReaderWithinThisMs * max_heartbeat_retries**), or 70 ms.

So if we set **blockingTime** to about 80 ms, we will have given enough chance for recovery. Of course, in a dynamic system, a reader may drop out at any time, in which case **max_heartbeat_retries** will be exceeded, and the unresponsive reader will be dropped by the writer. In either case, the writer can continue writing. Inappropriate values will cause a writer to prematurely drop a temporarily unresponsive (but otherwise healthy) reader, or be stuck trying unsuccessfully to feed a crashed reader. In the unfortunate case where a reader becomes temporarily unresponsive for a duration exceeding (**alertReaderWithinThisMs * max_heartbeat_retries**), the writer may issue gaps to that reader when it becomes active again; the dropped DDS samples are irrecoverable. So estimating the worst case unresponsive time of all potential readers is critical if DDS sample drop is unacceptable.

Line 33 (Figure 11.10: QoS for an Aperiodic, One-at-a-time Reliable Writer on page 708): Since the command may not be issued for hours or even days on end, there is no reason to keep announcing the writer's state to the readers.

Figure 11.11: QoS for an Aperiodic, One-at-a-time Reliable Reader on the next page shows how to set the QoS for the reader side, followed by a line-by-line explanation.

Figure 11.11: QoS for an Aperiodic, One-at-a-time Reliable Reader

```
1. qos->reliability.kind = DDS_RELIABLE_RELIABILITY_QOS;
2.  qos->history.kind = DDS_KEEP_ALL_HISTORY_QOS;
3.
4.  // 1 is ok for normal use. 2 allows fast infinite loop
5.  qos->reader_resource_limits.max_samples_per_remote_writer = 2;
6.  qos->resource_limits.initial_samples = 2;
7.  qos->resource_limits.initial_instances = 1;
8.
9.  qos->protocol.rtps_reliable_reader.max_heartbeat_response_delay.sec = 0;
10.  qos->protocol.rtps_reliable_reader.max_heartbeat_response_delay.nanosec = 0;
11.  qos->protocol.rtps_reliable_reader.min_heartbeat_response_delay.sec = 0;
12.  qos->protocol.rtps_reliable_reader.min_heartbeat_response_delay.nanosec = 0;
```

Line 1-Line 2 (Figure 11.11: QoS for an Aperiodic, One-at-a-time Reliable Reader above): Unlike a writer, the reader's default reliability setting is best-effort, so reliability must be turned on. Since we don't want to drop anything, we choose KEEP_ALL history.

Line 4-Line 6 (Figure 11.11: QoS for an Aperiodic, One-at-a-time Reliable Reader above): Since we enforce reliability on each DDS sample, it would be sufficient to keep the queue size at 1, except in the following case: suppose that the reader takes some action in response to the command received, which in turn causes the writer to issue another command right away. Because *Connext DDS* passes the user data up to the application even before acknowledging the DDS sample to the writer (for minimum latency), the first DDS sample is still pending for acknowledgement in the writer's queue when the writer attempts to write the second DDS sample, and will cause the writing thread to block until the reader completes processing the first DDS sample and acknowledges it to the writer; all are as they should be. But if you want to run this infinite loop at full throttle, the reader should buffer one more DDS sample. Let's follow the packets flow under a normal circumstance:

1. The sender application writes DDS sample 1 to the reader. The receiver application processes it and sends a user-level response 1 to the sender application, but has not yet ACK'd DDS sample 1.
2. The sender application writes DDS sample 2 to the receiving application in response to response 1. Because the reader's queue is 2, it can accept DDS sample 2 even though it may not yet have acknowledged DDS sample 1. Otherwise, the reader may drop DDS sample 2, and would have to recover it later.
3. At the same time, the receiver application acknowledges DDS sample 1, and frees up one slot in the queue, so that it can accept DDS sample 3, which it on its way.

The above steps can be repeated ad-infinitum in a continuous traffic.

Line 7 (Figure 11.11: QoS for an Aperiodic, One-at-a-time Reliable Reader above): Since we are not using keys, there is just one instance.

Line 9-Line 12 (11.3.7 Use Cases on page 707): We choose immediate response in the interest of fastest recovery. In high throughput, multicast scenario, delaying the response (with event thread priority set high

of course) may decrease the likelihood of NACK storm causing a writer to drop some NACKs. This random delay reduces this chance by staggering the NACK response. But the minimum delay achievable once again depends on the OS.

11.3.7.3 Aperiodic, Bursty

Suppose you have aperiodically generated bursts of data, as in the case of a new aircraft approaching an airport. The data may be the same or different, but if they are written by a single writer, the challenge to this writer is to feed all readers as quickly and efficiently as possible when this burst of hundreds or thousands of DDS samples hits the system.

If you use an unreliable writer to push this burst of data, some of them may be dropped over an unreliable transport such as UDP.

If you try to shape the burst according to however much the slowest reader can process, the system throughput may suffer, and places an additional burden of queueing the DDS samples on the sender application.

If you push the data reliably as fast they are generated, this may cost dearly in repair packets, especially to the slowest reader, which is already burdened with application chores.

Connext DDS pull mode reliability offers an alternative in this case by letting each reader pace its own data stream. It works by notifying the reader what it is missing, then waiting for it to request only as much as it can handle. As in the aperiodic one-at-a-time case (11.3.7.2 Aperiodic Use Case: One-at-a-Time on page 707), multicast is supported, but its performance depends on the resolution of the minimum delay supported by the OS. At the cost of greater latency, this model can deliver reliability while using far fewer packets than in the push mode. The writer QoS is given in Figure 11.12: QoS for an Aperiodic, Bursty Writer below, with a line-by-line explanation below.

Figure 11.12: QoS for an Aperiodic, Bursty Writer

```
1. qos->reliability.kind = DDS_RELIABLE_RELIABILITY_QOS;
2.  qos->history.kind = DDS_KEEP_ALL_HISTORY_QOS;
3.  qos->protocol.push_on_write = DDS_BOOLEAN_FALSE;
4.
5.  //use these hard coded value until you use key
6.  qos->resource_limits.initial_instances =
7.  qos->resource_limits.max_instances = 1;
8.  qos->resource_limits.initial_samples = qos->resource_limits.max_samples
9.                      = worstBurstInSample;
10.  qos->resource_limits.max_samples_per_instance =
11.  qos->resource_limits.max_samples;
12.
13.  // piggyback HB not used
14.  qos->protocol.rtps_reliable_writer.heartbeats_per_max_samples = 0;
15.
16.  qos->protocol.rtps_reliable_writer.high_watermark = 1;
17.  qos->protocol.rtps_reliable_writer.low_watermark = 0;
18.
19.  qos->protocol.rtps_reliable_writer.min_nack_response_delay.sec = 0;
20.  qos->protocol.rtps_reliable_writer.min_nack_response_delay.nanosec = 0;
```

```
21.  qos->protocol.rtps_reliable_writer.max_nack_response_delay.sec = 0;
22.  qos->protocol.rtps_reliable_writer.max_nack_response_delay.nanosec = 0;
23.  qos->reliability.max_blocking_time = blockingTime;
24.
25.  // should be faster than the send rate, but be mindful of OS resolution
26.  qos->protocol.rtps_reliable_writer.fast_heartbeat_period.sec = 0;
27.  qos->protocol.rtps_reliable_writer.fast_heartbeat_period.nanosec =
28.                              alertReaderWithinThisMs * 1000000;
29.  qos->protocol.rtps_reliable_writer.max_heartbeat_retries = 5;
30.
31.  // essentially turn off slow HB period
32.   qos->protocol.rtps_reliable_writer.heartbeat_period.sec = 3600 * 24 * 7;
```

Line 1 (Figure 11.12: QoS for an Aperiodic, Bursty Writer on the previous page): This is the default setting for a writer, shown here strictly for clarity.

Line 2 (Figure 11.12: QoS for an Aperiodic, Bursty Writer on the previous page): Since we do not want any data lost, we want the History kind set to KEEP_ALL.

Line 3 (Figure 11.12: QoS for an Aperiodic, Bursty Writer on the previous page): The default *Connext DDS* reliable writer will push, but we want the reader to pull instead.

Line 5-Line 11 (Figure 11.12: QoS for an Aperiodic, Bursty Writer on the previous page): We assume a single instance, in which case the maximum DDS sample count will be the same as the maximum DDS sample count per writer. In contrast to the one-at-a-time case discussed in 11.3.7.2 Aperiodic Use Case: One-at-a-Time on page 707, the writer's queue is large; as big as the burst size in fact, but no more because this model tries to resolve a burst within a reasonable period, to be computed shortly. Of course, we could block the writing thread in the middle of the burst, but that might complicate the design of the sending application.

Line 13-Line 14 (Figure 11.12: QoS for an Aperiodic, Bursty Writer on the previous page): By a 'piggy-back' Heartbeat, we mean only a Heartbeat that is appended to data being pushed from the writer. Strictly speaking, the writer will also append a Heartbeat with each reply to a reader's lost DDS sample request, but we call that a 'framing' Heartbeat. Since data is pulled, **heartbeats_per_max_samples** is ignored.

Line 16-Line 17 (Figure 11.12: QoS for an Aperiodic, Bursty Writer on the previous page): Similar to the previous aperiodic writer, this writer spends most of its time idle. But as the name suggests, even a single new DDS sample implies more DDS sample to follow in a burst. Putting the writer into a fast mode quickly will allow readers to be notified soon. Only when all DDS samples have been delivered, the writer can rest.

Line 19- Line 23 (Figure 11.12: QoS for an Aperiodic, Bursty Writer on the previous page): Similar to the one-at-a-time case, there is no reason to delay response with only one reader. In this case, we can estimate the time to resolve a burst with only a few parameters. Let's say that the reader figures it can safely receive and process 20 DDS samples at a time without being overwhelmed, and that the time it takes a writer to fetch these 20 DDS samples and send a single packet containing these 20 DDS samples, plus the time it takes a reader to receive and process these DDS samples, and send another request back to the writer for the next 20 DDS samples is 11 ms. Even on the same hardware, if the reader's processing time can be

reduced, this time will decrease; other factors such as the traversal time through *Connext DDS* and the transport are typically in microseconds range (depending on machines of course).

For example, let's also say that the worst case burst is 1000 DDS samples. The writing thread will of course not block because it is merely copying each of the 1000 DDS samples to the *Connext DDS* queue on the writer side; on a typical modern machine, the act of writing these 1000 DDS samples will probably take no more than a few ms. But it would take at least 1000/20 = 50 resend packets for the reader to catch up to the writer, or 50 times 11 ms = 550 ms. Since the burst model deals with one burst at a time, we would expect that another burst would not come within this time, and that we are allowed to block for at least this period. Including a safety margin, it would appear that we can comfortably handle a burst of 1000 every second or so.

But what if there are multiple readers? The writer would then take more time to feed multiple readers, but with a fast transport, a few more readers may only increase the 11 ms to only 12 ms or so. Eventually, however, the number of readers will justify the use of multicast. Even in pull mode, *Connext DDS* supports multicast by measuring how many multicast readers have requested DDS sample repair. If the writer does not delay response to NACK, then repairs will be sent in unicast. But a suitable NACK delay allows the writer to collect potentially NACKs from multiple readers, and feed a single multicast packet. But as discussed in 11.3.7.2 Aperiodic Use Case: One-at-a-Time on page 707, by delaying reply to coalesce response, we may end up waiting much longer than desired. On a Windows system with 10 ms minimum sleep achievable, the delay would add at least 10 ms to the 11 ms delay, so that the time to push 1000 DDS samples now increases to 50 times 21 ms = 1.05 seconds. It would appear that we will not be able to keep up with incoming burst if it came at roughly 1 second, although we put fewer packets on the wire by taking advantage of multicast.

Line 25-Line 28 (11.3.7 Use Cases on page 707): We now understand how the writer feeds the reader in response to the NACKs. But how does the reader realize that it is behind? The writer notifies the reader with a Heartbeat to kick-start the exchange. Therefore, the latency will be lower bound by the writer's fast heartbeat period. If the application is not particularly sensitive to latency, the minimum wait time supported by the OS (10 ms on Windows systems, for example) might be a reasonable value.

Line 29 (Figure 11.12: QoS for an Aperiodic, Bursty Writer on page 712): With a fast heartbeat period of 50 ms, a writer will take 500 ms (50 ms times the default **max_heartbeat_retries** of 10) to write-off an unresponsive reader. If a reader crashes while we are writing a lot of DDS samples per second, the writer queue may completely fill up before the writer has a chance to drop the crashed reader. Lowering **max_heartbeat_retries** will prevent that scenario.

Line 31-Line 32 (Figure 11.12: QoS for an Aperiodic, Bursty Writer on page 712): For an aperiodic writer, turning off slow periodic Heartbeats will remove unwanted traffic from the network.

Figure 11.13: QoS for an Aperiodic, Bursty Reader on the next page shows example code for a corresponding aperiodic, bursty reader.

Figure 11.13: QoS for an Aperiodic, Bursty Reader

```
1. qos->reliability.kind = DDS_RELIABLE_RELIABILITY_QOS;
2.  qos->history.kind = DDS_KEEP_ALL_HISTORY_QOS;
3.  qos->resource_limits.initial_samples =
4.  qos->resource_limits.max_samples =
5.  qos->reader_resource_limits.max_samples_per_remote_writer = 32;
6.
7.  //use these hard coded value until you use key
8.  qos->resource_limits.max_samples_per_instance =
9.  qos->resource_limits.max_samples;
10.  qos->resource_limits.initial_instances =
11.  qos->resource_limits.max_instances = 1;
12.
13.  // the writer probably has more for the reader; ask right away
14.  qos->protocol.rtps_reliable_reader.min_heartbeat_response_delay.sec = 0;
15.  qos->protocol.rtps_reliable_reader.min_heartbeat_response_delay.nanosec = 0;
16.  qos->protocol.rtps_reliable_reader.max_heartbeat_response_delay.sec = 0;
17.  qos->protocol.rtps_reliable_reader.max_heartbeat_response_delay.nanosec = 0;
```

Line 1-Line 2 (Figure 11.13: QoS for an Aperiodic, Bursty Reader above): Unlike a writer, the reader's default reliability setting is best-effort, so reliability must be turned on. Since we don't want to drop anything, we choose KEEP_ALL for the History QoS kind.

Line 3-Line 5 (Figure 11.13: QoS for an Aperiodic, Bursty Reader above): Unlike the writer, the reader's queue can be kept small, since the reader is free to send ACKs for as much as it wants anyway. In general, the larger the queue, the larger the packet needs to be, and the higher the throughput will be. When the reader NACKs for lost DDS sample, it will only ask for this much.

Line 7-Line 11 (Figure 11.13: QoS for an Aperiodic, Bursty Reader above): We do not use keys in this example.

Line 13-Line 17 (Figure 11.13: QoS for an Aperiodic, Bursty Reader above): We respond immediately to catch up as soon as possible. When there are many readers, this may cause a NACK storm, as discussed in the reader code for one-at-a-time reliable reader.

11.3.7.4 Periodic

In a periodic reliable model, we can use the writer and the reader queue to keep the data flowing at a smooth rate. The data flows from the sending application to the writer queue, then to the transport, then to the reader queue, and finally to the receiving application. Unless the sending application or any one of the receiving applications becomes unresponsive (including a crash) for a noticeable duration, this flow should continue uninterrupted.

The latency will be low in most cases, but will be several times higher for the recovered and many subsequent DDS samples. In the event of a disruption (e.g., loss in transport, or one of the readers becoming temporarily unresponsive), the writer's queue level will rise, and may even block in the worst case. If the writing thread must not block, the writer's queue must be sized sufficiently large to deal with any fluctuation in the system. Figure 11.14: QoS for a Periodic Reliable Writer on the next page shows an example, with line-by-line analysis below.

Figure 11.14: QoS for a Periodic Reliable Writer

```
1. qos->reliability.kind = DDS_RELIABLE_RELIABILITY_QOS;
2.  qos->history.kind = DDS_KEEP_ALL_HISTORY_QOS;
3.  qos->protocol.push_on_write = DDS_BOOLEAN_TRUE;
4.
5.  //use these hard coded value until you use key
6.  qos->resource_limits.initial_instances =
7.  qos->resource_limits.max_instances = 1;
8.
9.  int unresolvedSamplePerRemoteWriterMax =
10.     worstCaseApplicationDelayTimeInMs * dataRateInHz / 1000;
11.  qos->resource_limits.max_samples = unresolvedSamplePerRemoteWriterMax;
12.  qos->resource_limits.initial_samples = qos->resource_limits.max_samples/2;
13.  qos->resource_limits.max_samples_per_instance =
14.     qos->resource_limits.max_samples;
15.
16.  int piggybackEvery = 8;
17.  qos->protocol.rtps_reliable_writer.heartbeats_per_max_samples =
18.     qos->resource_limits.max_samples / piggybackEvery;
19.
20.  qos->protocol.rtps_reliable_writer.high_watermark = piggybackEvery * 4;
21.  qos->protocol.rtps_reliable_writer.low_watermark = piggybackEvery * 2;
22.  qos->reliability.max_blocking_time = blockingTime;
23.
24.  qos->protocol.rtps_reliable_writer.min_nack_response_delay.sec = 0;
25.  qos->protocol.rtps_reliable_writer.min_nack_response_delay.nanosec = 0;
26.
27.  qos->protocol.rtps_reliable_writer.max_nack_response_delay.sec = 0;
28.  qos->protocol.rtps_reliable_writer.max_nack_response_delay.nanosec = 0;
29.
30.  qos->protocol.rtps_reliable_writer.fast_heartbeat_period.sec = 0;
31.  qos->protocol.rtps_reliable_writer.fast_heartbeat_period.nanosec =
32.  `   alertReaderWithinThisMs * 1000000;
33.  qos->protocol.rtps_reliable_writer.max_heartbeat_retries = 7;
34.
35.  // essentially turn off slow HB period
36.  qos->protocol.rtps_reliable_writer.heartbeat_period.sec = 3600 * 24 * 7;
```

Line 1 (Figure 11.14: QoS for a Periodic Reliable Writer above): This is the default setting for a writer, shown here strictly for clarity.

Line 2 (Figure 11.14: QoS for a Periodic Reliable Writer above): Since we do not want any data lost, we set the History kind to KEEP_ALL.

Line 3 (Figure 11.14: QoS for a Periodic Reliable Writer above): This is the default setting for a writer, shown here strictly for clarity. Pushing will yield lower latency than pulling.

Line 5-Line 7 (Figure 11.14: QoS for a Periodic Reliable Writer above): We do not use keys in this example, so there is only one instance.

Line 9-Line 11 (Figure 11.14: QoS for a Periodic Reliable Writer above): Though a simplistic model of queue, this is consistent with the idea that the queue size should be proportional to the data rate and the wort case jitter in communication.

Line 12 (Figure 11.14: QoS for a Periodic Reliable Writer on the previous page): Even though we have sized the queue according to the worst case, there is a possibility for saving some memory in the normal case. Here, we initially size the queue to be only half of the worst case, hoping that the worst case will not occur. When it does, *Connext DDS* will keep increasing the queue size as necessary to accommodate new DDS samples, until the maximum is reached. So when our optimistic initial queue size is breached, we will incur the penalty of dynamic memory allocation. Furthermore, you will wind up using more memory, as the initially allocated memory will be orphaned (note: does not mean a memory leak or dangling pointer); if the initial queue size is M_i and the maximal queue size is M_m, where M_m = M_i * 2^n, the memory wasted in the worst case will be (M_m - 1) * sizeof(DDS sample) bytes. Note that the memory allocation can be avoided by setting the initial queue size equal to its max value.

Line 13-Line 14 (Figure 11.14: QoS for a Periodic Reliable Writer on the previous page): If there is only one instance, maximum DDS samples per instance is the same as maximum DDS samples allowed.

Line 16-Line 18 (Figure 11.14: QoS for a Periodic Reliable Writer on the previous page): Since we are pushing out the data at a potentially rapid rate, the piggyback heartbeat will be useful in letting the reader know about any missing DDS samples. The **piggybackEvery** can be increased if the writer is writing at a fast rate, with the cost that more DDS samples will need to queue up for possible resend. That is, you can consider the piggyback heartbeat to be taking over one of the roles of the periodic heartbeat in the case of a push. So sending fewer DDS samples between piggyback heartbeats is akin to decreasing the fast heartbeat period seen in previous sections. Please note that we cannot express **piggybackEvery** directly as its own QoS, but indirectly through the maximum DDS samples.

Line 20-Line 22 (Figure 11.14: QoS for a Periodic Reliable Writer on the previous page): If **piggybackEvery** was exactly identical to the fast heartbeat, there would be no need for fast heartbeat or the high watermark. But one of the important roles for the fast heartbeat period is to allow a writer to abandon inactive readers before the queue fills. If the high watermark is set equal to the queue size, the writer would not doubt the status of an unresponsive reader until the queue completely fills—blocking on the next write (up to **blockingTime**). By lowering the high watermark, you can control how vigilant a writer is about checking the status of unresponsive readers. By scaling the high watermark to **piggybackEvery**, the writer is expressing confidence that an alive reader will respond promptly within the time it would take a writer to send 4 times **piggybackEvery** DDS samples. If the reader does not delay the response too long, this would be a good assumption. Even if the writer estimated on the low side and does go into fast mode (suspecting that the reader has crashed) when a reader is temporarily unresponsive (e.g., when it is performing heavy computation for a few milliseconds), a response from the reader in question will resolve any doubt, and data delivery can continue uninterrupted. As the reader catches up to the writer and the queue level falls below the low watermark, the writer will pop out to the normal, relaxed mode.

Line 24-Line 28 (Figure 11.14: QoS for a Periodic Reliable Writer on the previous page): When a reader is behind (including a reader whose Durability QoS is non-VOLATILE and therefore needs to catch up to the writer as soon as it is created), how quickly the writer responds to the reader's request will determine the catch-up rate. While a multicast writer (that is, a writer with multicast readers) may consider delaying for some time to take advantage of coalesced multicast packets. Keep in mind the OS delay resolution issue discussed in the previous section.

Line 30-Line 33 (Figure 11.14: QoS for a Periodic Reliable Writer on page 716): The fast heartbeat mechanism allows a writer to detect a crashed reader and move along with the remaining readers when a reader does not respond to any of the **max_heartbeat_retries** number of heartbeats sent at the **fast_heartbeat_period** rate. So if you want a more cautious writer, decrease either numbers; conversely, increasing either number will result in a writer that is more reluctant to write-off an unresponsive reader.

Line 35-Line 36 (Figure 11.14: QoS for a Periodic Reliable Writer on page 716): Since this a periodic model, a separate periodic heartbeat to notify the writer's status would seem unwarranted; the piggyback heartbeat sent with DDS samples takes over that role.

Figure 11.15: QoS for a Periodic Reliable Reader below shows how to set the QoS for a matching reader, followed by a line-by-line explanation.

Figure 11.15: QoS for a Periodic Reliable Reader

```
1. qos->reliability.kind = DDS_RELIABLE_RELIABILITY_QOS;
2.  qos->history.kind = DDS_KEEP_ALL_HISTORY_QOS;
3.  qos->resource_limits.initial_samples =
4.  qos->resource_limits.max_samples =
5.  qos->reader_resource_limits.max_samples_per_remote_writer =
6.   ((2*piggybackEvery - 1) + dataRateInHz * delayInMs / 1000);
7.
8.  //use these hard coded value until you use key
9.  qos->resource_limits.max_samples_per_instance =
10.       qos->resource_limits.max_samples;
11.  qos->resource_limits.initial_instances =
12.       qos->resource_limits.max_instances = 1;
13.
14.  qos->protocol.rtps_reliable_reader.min_heartbeat_response_delay.sec = 0;
15.  qos->protocol.rtps_reliable_reader.min_heartbeat_response_delay.nanosec = 0;
16.  qos->protocol.rtps_reliable_reader.max_heartbeat_response_delay.sec = 0;
17.  qos->protocol.rtps_reliable_reader.max_heartbeat_response_delay.nanosec = 0;
```

Line 1-Line 2 (Figure 11.15: QoS for a Periodic Reliable Reader above): Unlike a writer, the reader's default reliability setting is best-effort, so reliability must be turned on. Since we don't want to drop anything, we choose KEEP_ALL for the History QoS.

Line 3-Line 6 (Figure 11.15: QoS for a Periodic Reliable Reader above) Unlike the writer, the reader queue is sized not according to the jitter of the reader, but rather how many DDS samples you want to cache speculatively in case of a gap in sequence of DDS samples that the reader must recover. Remember that a reader will stop giving a sequence of DDS samples as soon as an unintended gap appears, because the definition of strict reliability includes in-order delivery. If the queue size were 1, the reader would have no choice but to drop all subsequent DDS samples received until the one being sought is recovered. *Connext DDS* uses speculative caching, which minimizes the disruption caused by a few dropped DDS samples. Even for the same duration of disruption, the demand on reader queue size is greater if the writer will send more rapidly. In sizing the reader queue, we consider two factors that comprise the DDS sample recovery time:

- How long it takes a reader to request a resend to the writer.

  The piggyback heartbeat tells a reader about the writer's state. If only DDS samples between two piggybacked DDS samples are dropped, the reader must cache **piggybackEvery** DDS samples before asking the writer for resend. But if a piggybacked DDS sample is also lost, the reader will not get around to asking the writer until the next piggybacked DDS sample is received. Note that in this worst case calculation, we are ignoring stand-alone heartbeats (i.e., not piggybacked heartbeat from the writer). Of course, the reader may drop any number of heartbeats, including the stand-alone heartbeat; in this sense, there is no such thing as the absolute worst case—just reasonable worst case, where the probability of consecutive drops is acceptably low. For the majority of applications, even two consecutive drops is unlikely, in which case we need to cache at most (**2*piggybackEvery - 1**) DDS samples before the reader will ask the writer to resend, assuming no delay (Line 14-Line 17, Figure 11.15: QoS for a Periodic Reliable Reader on the previous page).

- How long it takes for the writer to respond to the request.

  Even ignoring the flight time of the resend request through the transport, the writer takes a finite time to respond to the repair request--mostly if the writer delays reply for multicast readers. In case of immediate response, the processing time on the writer end, as well as the flight time of the messages to and from the writer do not matter unless very larger data rate; that is, it is the product term that matters. In case the delay for multicast is random (that is, the minimum and the maximum delay are not equal), one would have to use the maximum delay to be conservative.

Line 8-Line 12 (Figure 11.15: QoS for a Periodic Reliable Reader on the previous page): Since we are not using keys, there is just one instance.

Line 14-Line 17 (Figure 11.15: QoS for a Periodic Reliable Reader on the previous page): If we are not using multicast, or the number of readers being fed by the writer, there is no reason to delay.

11.4 Auto Throttling for DataWriter Performance—Experimental Feature

Auto Throttling is an experimental feature that allows you to configure a *DataWriter* to automatically adjust its writing rate and send window size to provide the best latency/throughput tradeoff as system conditions change.

When *DataWriters* and *DataReaders* are configured to be reliable, DDS samples that did not reach the matched *DataReaders* for any reason (such as network drops or sample rejection by the *DataReader*) are repaired automatically by *Connext DDS*. However, the repair path consumes bandwidth and increases latency. A high number of repaired DDS samples can reduce the throughput and increase the communication latency. With Auto Throttling, the number of repair DDS samples is reduced by using feedback provided by *DataReaders* in terms of ACK and NACK messages to adjust the *DataWriter's* write rate and send window size.

To configure Auto Throttling, use the following properties:

dds.domain_participant.auto_throttle.enable: Configures the *DomainParticipant* to gather internal measurements (during *DomainParticipant* creation) that are required for the Auto Throttle feature. This allows *DataWriters* belonging to this *DomainParticipant* to use the Auto Throttle feature. Default: false.

dds.data_writer.auto_throttle.enable: Enables automatic throttling in the *DataWriter* so it can automatically adjust the writing rate and the send window size; this minimizes the need for repair DDS samples and improves latency. Default: false.

Note: This property takes effect only in *DataWriters* that belong to a *DomainParticipant* that has set the property **dds.domain_participant.auto_throttle.enable** (described above) to true.

When Auto throttling is enabled, the size of the send window size is adjusted within the interval [**min_send_window_size**, **max_send_window_size**] configured in 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.

Chapter 12 Collaborative DataWriters

The *Collaborative DataWriters* feature allows you to have multiple *DataWriters* publishing DDS samples from a common logical data source. The *DataReaders* will combine the DDS samples coming from these *DataWriters* in order to reconstruct the correct order in which they were produced at the source. This combination process for the *DataReaders* can be configured using the 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369. It requires the middleware to provide a way to uniquely identify every DDS sample published in a DDS domain independently of the actual *DataWriter* that published the DDS sample.

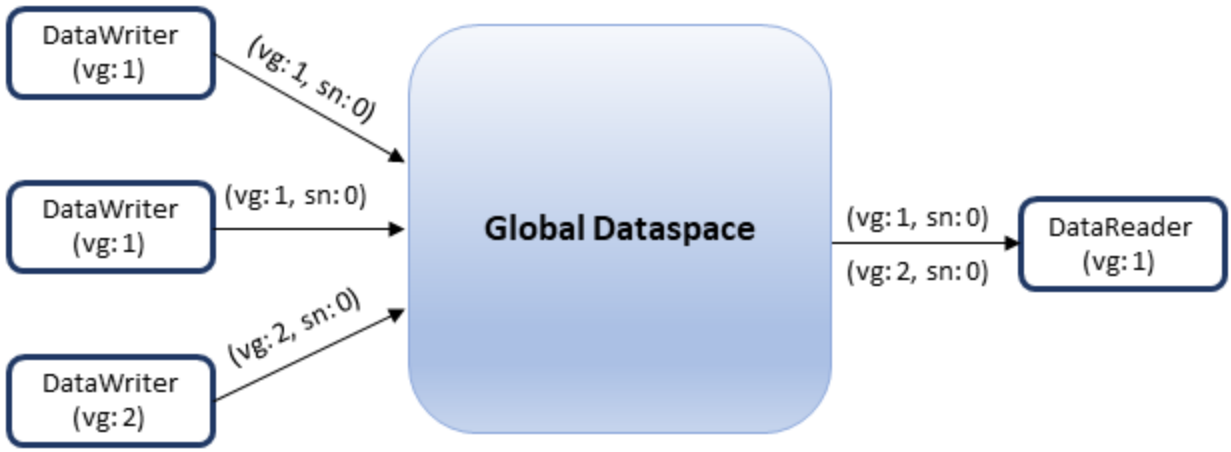
In *Connext DDS*, every modification (DDS sample) to the global dataspace made by a *DataWriter* within a DDS domain is identified by a pair (virtual GUID, sequence number).

The virtual GUID (Global Unique Identifier) is a 16-byte character identifier associated with the logical data source. *DataWriters* can be assigned a virtual GUID using **virtual_guid** in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.

The virtual sequence number is a 64-bit integer that identifies changes within the logical data source.

Several *DataWriters* can be configured with the same virtual GUID. If each of these *DataWriters* publishes a DDS sample with sequence number '0', the DDS sample will only be received once by the *DataReaders* subscribing to the content published by the *DataWriters* (see Figure 12.1: Global Dataspace Changes on the next page).

Figure 12.1: Global Dataspace Changes



12.1 Collaborative DataWriters Use Cases

- Ordered delivery of DDS samples in high availability scenarios

  One example of this is *RTI Persistence Service*[1]. When a late-joining *DataReader* configured with 7.5.9 DURABILITY QosPolicy on page 410 set to PERSISTENT or TRANSIENT joins a DDS domain, it will start receiving DDS samples from multiple *DataWriters*. For example, if the original *DataWriter* is still alive, the newly created *DataReader* will receive DDS samples from the original DataWriter and one or more *RTI Persistence Service DataWriters* (PRSTDataWriters).

- Ordered delivery of DDS samples in load-balanced scenarios

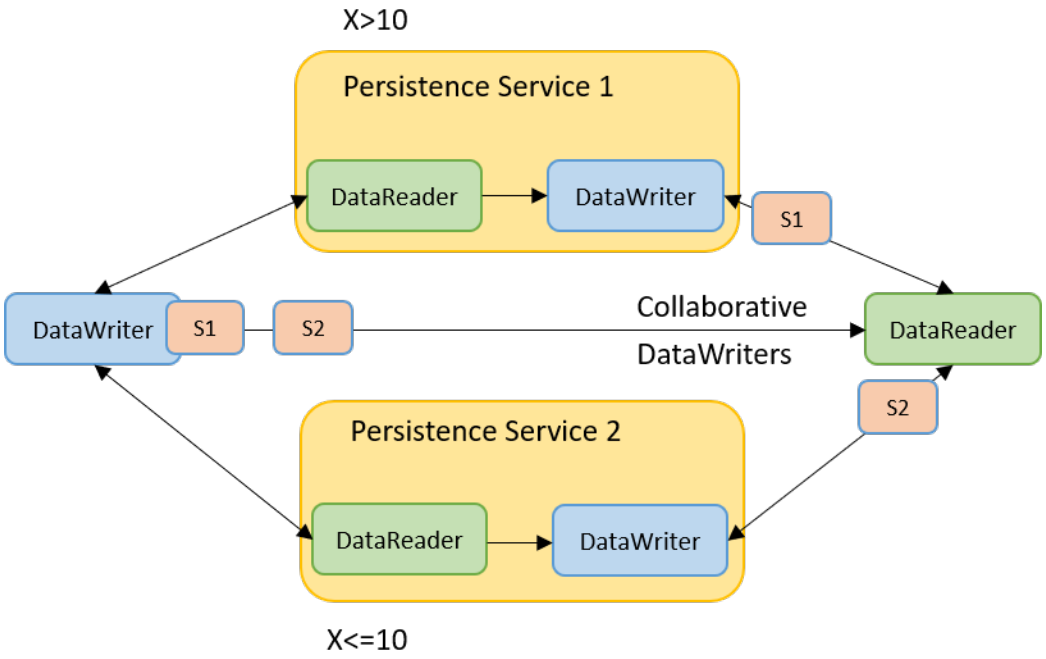
  Multiple instances of the same application can work together to process and deliver DDS samples. When the DDS samples arrive through different data-paths out of order, the DataReader will be able to reconstruct the order at the source. An example of this is when multiple instances of *RTI Persistence Service* are used to persist the data. Persisting data to a database on disk can impact performance. By dividing the workload (e.g., DDS samples larger than 10 are persisted by Persistence Service 1, DDS samples smaller or equal to 10 are persisted by Persistence Service 2) across different instances of *RTI Persistence Service* using different databases the user can improve scalability and performance.
- Ordered delivery of DDS samples with Group Ordered Access

  The Collaborative DataWriters feature can also be used to configure the DDS sample ordering process when the *Subscriber* is configured with 7.4.6 PRESENTATION QosPolicy on page 361

[1]For more information on *Persistence Service*, see Part 8: RTI Persistence Service on page 1159.

access_scope set to GROUP. In this case, the *Subscriber* must deliver in order the DDS samples published by a group of *DataWriters* that belong to the same *Publisher* and have **access_scope** set to GROUP.

Figure 12.2: Load-Balancing with Persistence Service



12.2 DDS Sample Combination (Synchronization) Process in a DataReader

A *DataReader* will deliver a DDS sample (VGUIDn, VSNm) to the application only when if one of the following conditions is satisfied:

- (VGUIDn, VSNm-1) has already been delivered to the application.
- All the known *DataWriters* publishing VGUIDn have announced that they do not have (VGUIDn, VSNm-1).
- None of the known *DataWriters* publishing VGUIDn have announced potential availability of (VGUIDn, VSNm-1) and a configurable timeout (**max_data_availability_waiting_time**) expires.

For additional details on how the reconstruction process works see the 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369.

12.3 Configuring Collaborative DataWriters

12.3.1 Associating Virtual GUIDs with DDS Data Samples

There are two ways to associate a virtual GUID with the DDS samples published by a *DataWriter*.

- Per *DataWriter*: Using **virtual_guid** in 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.
- Per DDS Sample: By setting the **writer_guid** in the identity field of the WriteParams_t structure provided to the **write_w_params** operation (see 7.3.8 Writing Data on page 308). Since the **writer_guid** can be set per DDS sample, the same *DataWriter* can potentially write DDS samples from independent logical data sources. One example of this is *RTI Persistence Service* where a single persistence service *DataWriter* can write DDS samples on behalf of multiple original *DataWriters*.

12.3.2 Associating Virtual Sequence Numbers with DDS Data Samples

You can associate a virtual sequence number with a DDS sample published by a *DataWriter* by setting the **sequence_number** in the **identity** field of the WriteParams_t structure provided to the **write_w_params** operation (see 7.3.8 Writing Data on page 308). Virtual sequence numbers for a given virtual GUID must be strictly monotonically increasing. If you try to write a DDS sample with a sequence number less than or equal to the last sequence number, the write operation will fail.

12.3.3 Specifying which DataWriters will Deliver DDS Samples to the DataReader from a Logical Data Source

The **required_matched_endpoint_groups** field in the 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369 can be used to specify the set of *DataWriter* groups that are expected to provide DDS samples for the same data source (virtual GUID). The quorum count in a group represents the number of *DataWriters* that must be discovered for that group before the *DataReader* is allowed to provide non-consecutive DDS samples to the application.

A *DataWriter* becomes a member of an endpoint group by configuring the **role_name** in 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416.

12.3.4 Specifying How Long to Wait for a Missing DDS Sample

A *DataReader's* 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369 specifies how long to wait for a missing DDS sample. For example, this is important when the first DDS sample is received: how long do you wait to determine the lowest sequence number available in the system?

- The **max_data_availability_waiting_time** defines how much time to wait before delivering a DDS sample to the application without having received some of the previous DDS samples.

- The **max_endpoint_availability_waiting_time** defines how much time to wait to discover *DataWriters* providing DDS samples for the same data source (virtual GUID).

12.4 Collaborative DataWriters and Persistence Service

The *DataWriters* created by persistence service are automatically configured to do collaboration:

- Every DDS sample published by the *Persistence Service DataWriter* keeps its original identity.
- *Persistence Service* associates the role name PERSISTENCE_SERVICE with all the *DataWriters* that it creates. You can overwrite that setting by changing the *DataWriter* QoS configuration in persistence service.

For more information, see Part 8: RTI Persistence Service on page 1159.

Chapter 13 Mechanisms for Achieving Information Durability and Persistence

13.1 Introduction

Connext DDS offers the following mechanisms for achieving durability and persistence:

- **Durable Writer History** This feature allows a *DataWriter* to persist its historical cache, perhaps locally, so that it can survive shutdowns, crashes and restarts. When an application restarts, each *DataWriter* that has been configured to have durable writer history automatically load all of the data in this cache from disk and can carry on sending data as if it had never stopped executing. To the rest of the system, it will appear as if the *DataWriter* had been temporarily disconnected from the network and then reappeared.
- **Durable Reader State** This feature allows a *DataReader* to persist its state and remember which data it has already received. When an application restarts, each *DataReader* that has been configured to have durable reader state automatically loads its state from disk and can carry on receiving data as if it had never stopped executing. Data that had already been received by the *DataReader* before the restart will be suppressed so that it is not even sent over the network.
- **Data Durability** This feature is a full implementation of the OMG DDS Persistence Profile. The 7.5.9 DURABILITY QosPolicy on page 410 allows an application to configure a *DataWriter* so that the information written by the *DataWriter* survives beyond the lifetime of the *DataWriter*. In this manner, a late-joining *DataReader* can subscribe to and receive the information even after the *DataWriter* application is no longer executing. To use this feature, you need *Persistence Service*, a separate application described in Introduction to RTI Persistence Service (Chapter 45 on page 1160).

These features can be configured separately or in combination. To use Durable Writer State and Durable Reader State, you need a relational database, which is not included with *Connext DDS*. *Persistence Service* does not require a database when used in TRANSIENT mode (see 13.5.1 RTI Persistence Service on page 743) or in PERSISTENT mode with file-system storage (see 13.5.1 RTI Persistence Service on page 743 and 46.5 Configuring Remote Administration on page 1168). See RTI Connext DDS Core Libraries Database Setup for a list of supported relational databases and setup instructions.

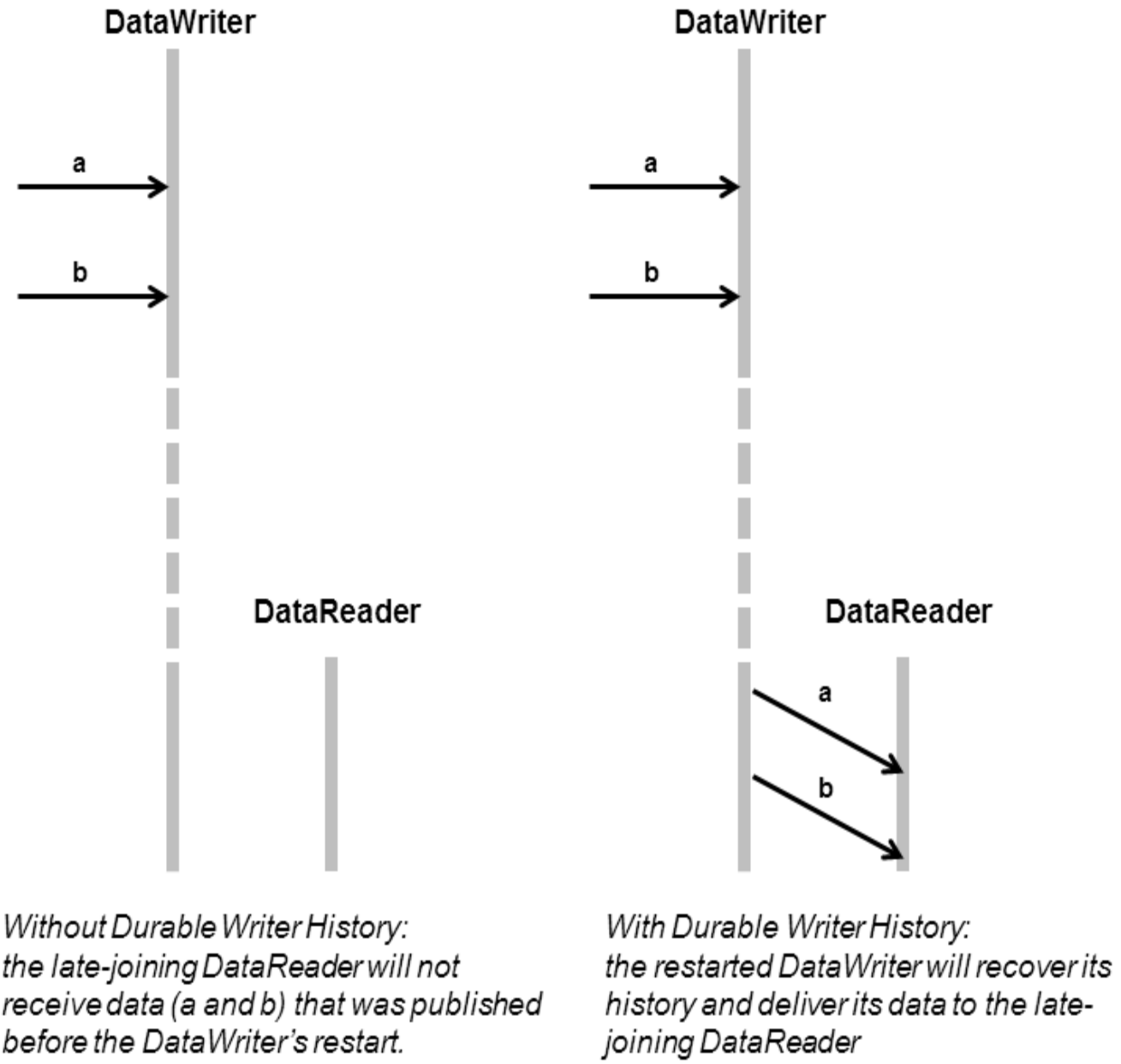
To understand how these features interact we will examine the behavior of the system using the following scenarios:

- 13.1.1 Scenario 1. DataReader Joins after DataWriter Restarts (Durable Writer History) below
- 13.1.2 Scenario 2: DataReader Restarts While DataWriter Stays Up (Durable Reader State) on page 729
- 13.1.3 Scenario 3. DataReader Joins after DataWriter Leaves Domain (Durable Data) on page 730

13.1.1 Scenario 1. DataReader Joins after DataWriter Restarts (Durable Writer History)

In this scenario, a *DomainParticipant* joins the domain, creates a *DataWriter* and writes some data, then the *DataWriter* shuts down (gracefully or due to a fault). The *DataWriter* restarts and a *DataReader* joins the domain. Depending on whether the *DataWriter* is configured with durable history, the late-joining *DataReader* may or may not receive the data published already by the *DataWriter* before it restarted. This is illustrated in Figure 13.1: Durable Writer History on the next page. For more information, see 13.3 Durable Writer History on page 733.

Figure 13.1: Durable Writer History



Without Durable Writer History: the late-joining DataReader will not receive data (a and b) that was published before the DataWriter's restart.

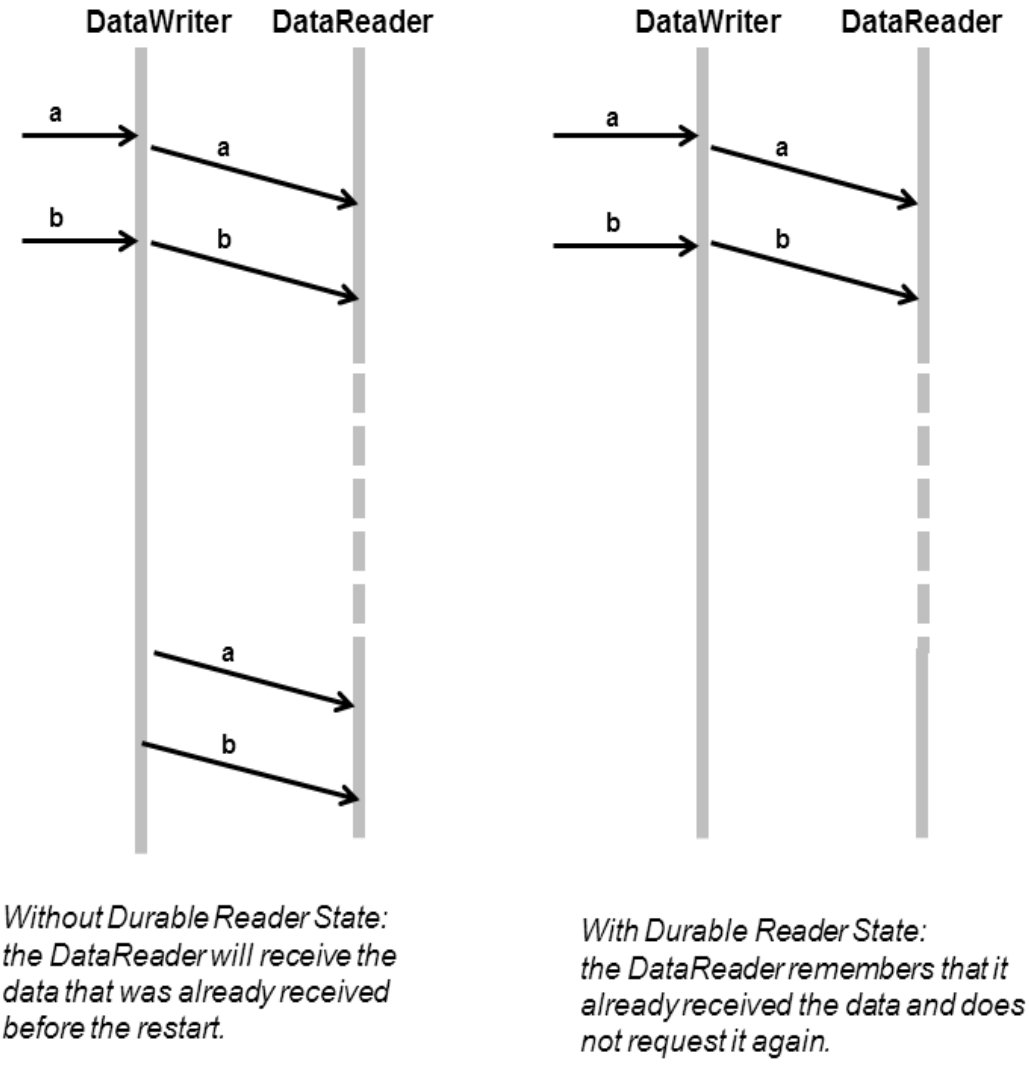
With Durable Writer History: the restarted DataWriter will recover its history and deliver its data to the late-joining DataReader

13.1.2 Scenario 2: DataReader Restarts While DataWriter Stays Up (Durable Reader State)

In this scenario, two *DomainParticipants* join a domain; one creates a *DataWriter* and the other a *DataReader* on the same Topic. The *DataWriter* publishes some data ("a" and "b") that is received by the *DataReader*. After this, the *DataReader* shuts down (gracefully or due to a fault) and then restarts—all while the *DataWriter* remains present in the domain.

Depending on whether the *DataReader* is configured with Durable Reader State, the *DataReader* may or may not receive a duplicate copy of the data it received before it restarted. This is illustrated in Figure 13.2: Durable Reader State below. For more information, see 13.4 Durable Reader State on page 738.

Figure 13.2: Durable Reader State

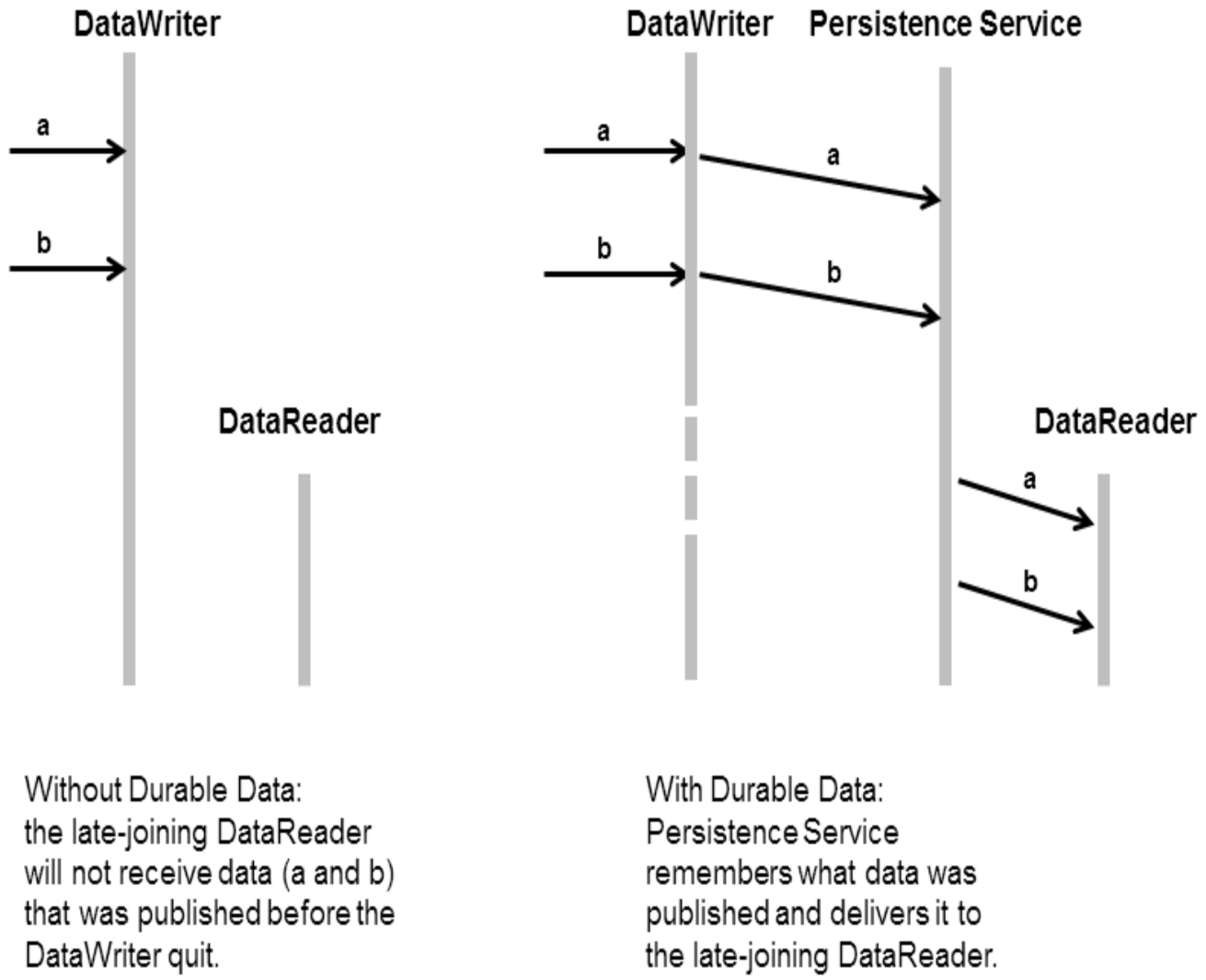


13.1.3 Scenario 3. DataReader Joins after DataWriter Leaves Domain (Durable Data)

In this scenario, a *DomainParticipant* joins a domain, creates a *DataWriter*, publishes some data on a Topic and then shuts down (gracefully or due to a fault). Later, a *DataReader* joins the domain and subscribes to the data. *Persistence Service* is running.

Depending on whether Durable Data is enabled for the Topic, the *DataReader* may or may not receive the data previous published by the *DataWriter*. This is illustrated in Figure 13.3: Durable Data on the next page. For more information, see 13.5 Data Durability on page 743

Figure 13.3: Durable Data



This third scenario is similar to 13.1.1 Scenario 1. DataReader Joins after DataWriter Restarts (Durable Writer History) on page 727 except that in this case the *DataWriter* does not need to restart for the *DataReader* to get the data previously written by the *DataWriter*. This is because *Persistence Service* acts as an intermediary that stores the data so it can be given to late-joining *DataReaders*.

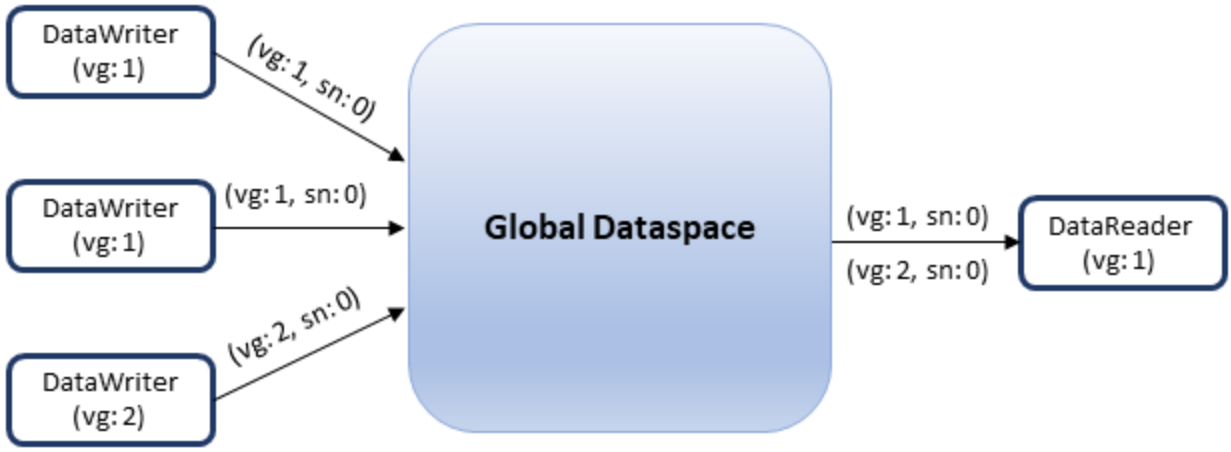
13.2 Durability and Persistence Based on Virtual GUIDs

Every modification to the global dataspace made by a *DataWriter* is identified by a pair (virtual GUID, sequence number).

- The virtual GUID (Global Unique Identifier) is a 16-byte character identifier associated with a *DataWriter* or *DataReader*; it is used to uniquely identify this entity in the global data space.
- The sequence number is a 64-bit identifier that identifies changes published by a specific *DataWriter*.

Several *DataWriters* can be configured with the same virtual GUID. If each of these *DataWriters* publishes a sample with sequence number '0', the sample will only be received once by the *DataReaders* subscribing to the content published by the *DataWriters* (see Figure 13.4: Global Dataspace Changes below).

Figure 13.4: Global Dataspace Changes

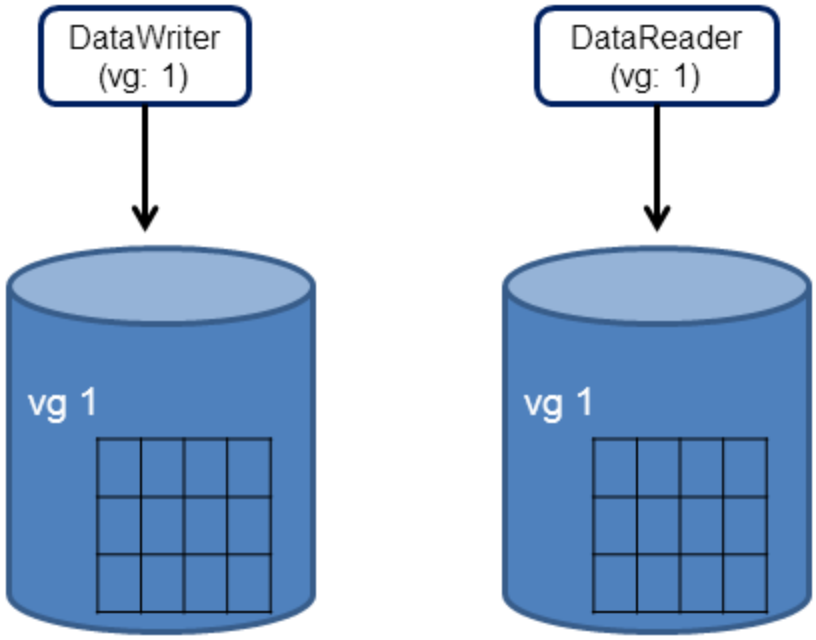


Additionally, *Connext DDS* uses the virtual GUID to associate a persisted state (state in permanent storage) to the corresponding *Entity*.

For example, the history of a *DataWriter* will be persisted in a database table with a name generated from the virtual GUID of the *DataWriter*. If the *DataWriter* is restarted, it must have associated the same virtual GUID to restore its previous history.

Likewise, the state of a *DataReader* will be persisted in a database table whose name is generated from the *DataReader* virtual GUID (see Figure 13.5: History/State Persistence Based on Virtual GUID on the next page).

Figure 13.5: History/State Persistence Based on Virtual GUID



- A *DataWriter*'s virtual GUID can be configured using the member **virtual_guid** in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388.
- A *DataReader's* virtual GUID can be configured using the member **virtual_guid** in the 8.6.1 DATA_READER_PROTOCOL QosPolicy (DDS Extension) on page 565.

The DDS_PublicationBuiltinTopicData and DDS_SubscriptionBuiltinTopicData structures include the virtual GUID associated with the discovered publication or subscription (see 18.2 Built-in DataReaders on page 826).

13.3 Durable Writer History

The 7.5.9 DURABILITY QosPolicy on page 410 controls whether or not, and how, published samples are stored by the *DataWriter* application for *DataReaders* that are found after the samples were initially written. The samples stored by the *DataWriter* constitute the *DataWriter's* history.

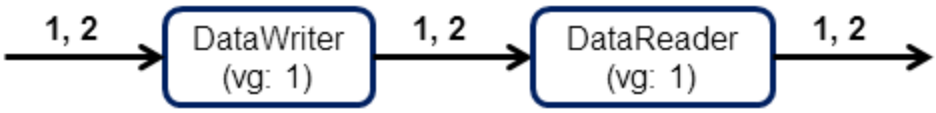
Connext DDS provides the capability to make the *DataWriter* history durable, by persisting its content in a relational database. This makes it possible for the history to be restored when the *DataWriter* restarts. See RTI Connext DDS Core Libraries Database Setup for a list of supported relational databases and setup instructions.

The association between the history stored in the database and the *DataWriter* is done using the virtual GUID.

13.3.1 Durable Writer History Use Case

The following use case describes the durable writer history functionality:

1. A *DataReader* receives two samples with sequence number 1 and 2 published by a *DataWriter* with virtual GUID 1.

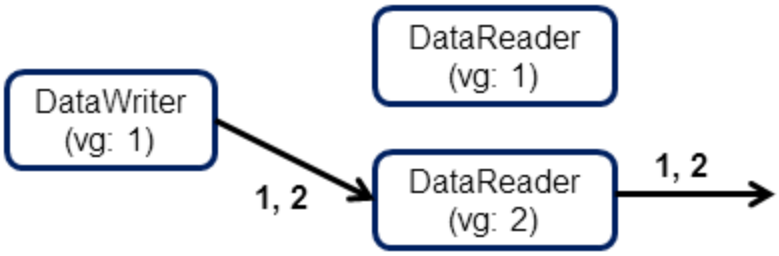


2. The process running the *DataWriter* is stopped and a new late-joining *DataReader* is created.

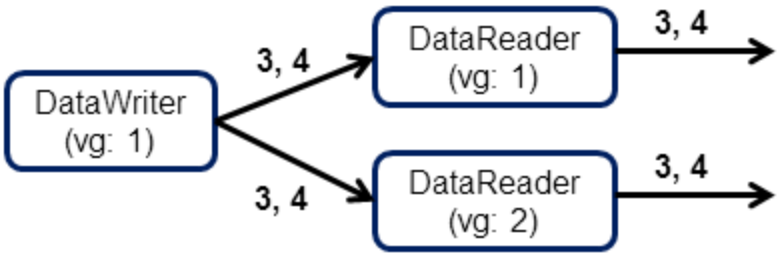
   The new *DataReader* with virtual GUID 2 does not receive samples 1 and 2 because the original *DataWriter* has been destroyed. If the samples must be available to late-joining *DataReaders* after the *DataWriter* deletion, you can use *Persistence Service*, described in Introduction to RTI Persistence Service (Chapter 45 on page 1160).

3. The *DataWriter* is restarted using the same virtual GUID.

   After being restarted, the *DataWriter* restores its history. The late-joining *DataReader* will receive samples 1 and 2 because they were not received previously. The *DataReader* with virtual GUID 1 will not receive samples 1 and 2 because it already received them



4. The *DataWriter* publishes two new samples.



The two new samples with sequence numbers 3 and 4 will be received by both *DataReaders*.

13.3.2 How To Configure Durable Writer History

Connext DDS allows a *DataWriter*'s history to be stored in a relational database that provides an ODBC driver.

For each *DataWriter* history that is configured to be durable, *Connext DDS* will create a maximum of two tables:

- The first table is used to store the samples associated with the writer history. The name of that table is WS<32 uuencoding of the writer virtual GUID>.
- The second table is only created for keyed-topic and it is used to store the instances associated with the writer history. The name of the second table is WI<32 uuencoding of the writer virtual GUID>.

To configure durable writer history, use the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 associated with *DataWriters* and *DomainParticipants*.

A 'durable writer history' property defined in the *DomainParticipant* will be applicable to all the *DataWriters* belonging to the *DomainParticipant* unless it is overwritten by the *DataWriter*. Table 13.1 Durable Writer History Properties lists the supported 'durable writer history' properties.

Table 13.1 Durable Writer History Properties

Property	Description
dds.data_writer-.history.plugin_name	Required. Must be set to **"dds.data_writer.history.odbc_plugin.builtin"** to enable durable writer history in the *DataWriter*.

Table 13.1 Durable Writer History Properties

Property	Description
dds.data_writer-.history.odbc_plugin.dsn	Required. The ODBC DSN (Data Source Name) associated with the database where the writer history must be persisted.
dds.data_writer-.history.odbc_plugin.driver	Tells *Connext DDS* which ODBC driver to load. If the property is not specified, *Connext DDS* will try to use the standard ODBC driver manager library (UnixOdbc on Linux systems, the Windows ODBC driver manager on Windows systems).
dds.data_writer-.history.odbc_plugin.username dds.data_writer-.history.odbc_plugin.password	Configures the username/password used to connect to the database. Default: No password or username
dds.data_writer-.history.odbc_plugin.shared	When set to 1, *Connext DDS* will create a single connection per DSN that will be shared across *DataWriters* within the same *Publisher*. A *DataWriter* can be configured to create its own database connection by setting this property to 0 (the default).
dds.data_writer-.history.odbc_plugin.instance_cache_max_size dds.data_writer-.history.odbc_plugin.instance_cache_init_size dds.data_writer-.history.odbc_plugin.sample_cache_max_size dds.data_writer-.history.odbc_plugin.sample_cache_init_size	These properties configure the resource limits associated with the ODBC writer history caches. To minimize the number of accesses to the database, *Connext DDS* uses two caches, one for samples and one for instances. The initial size and the maximum size of these caches are configured using these properties. The resource limits, **initial_instances**, **max_instances**, **initial_samples**, **max_samples**, and **max_samples_per_instance** defined in 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 are used to configure the maximum number of samples and instances that can be stored in the relational database. Defaults: **instance_cache_max_size**: **max_instances** in 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 **instance_cache_init_size**: **initial_instances** in 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 **sample_cache_max_size**: 32 **sample_cache_init_size**: 32 If **in_memory_state** (see below in this table) is 1, **instance_cache_max_size** is always equal to **max_instances** in 7.5.22 RESOURCE_LIMITS QosPolicy on page 449–it cannot be changed.
dds.data_writer-.history.odbc_plugin.restore	This property indicates whether or not the persisted writer history must be restored once the *DataWriter* is restarted. If this property is 0, the content of the database associated with the *DataWriter* being restarted will be deleted. If it is 1, the *DataWriter* will restore its previous state from the database content. Default: 1

Table 13.1 Durable Writer History Properties

Property	Description
dds.data_writer- .history.odbc_plu- gin. in_memory_state	This property determines how much state will be kept in memory by the ODBC writer history in order to avoid accessing the database. If this property is 1, then the property **instance_cache_max_size** (see above in this table) is always equal to **max_in-stances** in 7.5.22 RESOURCE_LIMITS QosPolicy on page 449–it cannot be changed. In addition, the ODBC writer his-tory will keep in memory a fixed state overhead of 24 bytes per sample. This mode provides the best ODBC writer history performance. However, the restore operation will be slower and the maximum number of samples that the writer history can manage is limited by the available physical memory. If it is 0, all the state will be kept in the underlying database. In this mode, the maximum number of samples in the writer his-tory is not limited by the physical memory available. Default: 1

Durable Writer History is not supported for Multi-channel *DataWriters* (see Multi-channel DataWriters (Chapter 20 on page 888)) or when Batching is enabled (see 7.5.2 BATCH QosPolicy (DDS Extension) on page 373); an error is reported if this type of *DataWriter* tries to configure Durable Writer History.

See also: 13.4 Durable Reader State on the next page.

Example C++ Code

```
/* Get default QoS */
...
retcode = DDSPropertyQosPolicyHelper::add_property (writerQos.property,
                        "dds.data_writer.history.plugin_name",
                        "dds.data_writer.history.odbc_plugin.builtin",
                        DDS_BOOLEAN_FALSE);
if (retcode != DDS_RETCODE_OK) {
       /* Report error */
}
retcode = DDSPropertyQosPolicyHelper::add_property (writerQos.property,
                        "dds.data_writer.history.odbc_plugin.dsn",
                        "<user DSN>",
                        DDS_BOOLEAN_FALSE);
if (retcode != DDS_RETCODE_OK) {
               /* Report error */
}
retcode = DDSPropertyQosPolicyHelper::add_property (writerQos.property,
                        "dds.data_writer.history.odbc_plugin.driver",
                        "<ODBC library>",
                        DDS_BOOLEAN_FALSE);
if (retcode != DDS_RETCODE_OK) {
               /* Report error */
}
retcode = DDSPropertyQosPolicyHelper::add_property (writerQos.property,
                        "dds.data_writer.history.odbc_plugin.shared",
                        "<0|1>",
                        DDS_BOOLEAN_FALSE);
if (retcode != DDS_RETCODE_OK) {
       /* Report error */
```

```
}
/* Create Data Writer */
...
```

13.4 Durable Reader State

Durable reader state allows a *DataReader* to locally store its state in disk and remember the data that has already been processed by the application[1]. When an application restarts, each *DataReader* configured to have durable reader state automatically reads its state from disk. Data that has already been processed by the application before the restart will not be provided to the application again.

Important: The *DataReader* does not persist the full contents of the data in its historical cache; it only persists an identification (e.g. sequence numbers) of the data the application has processed. This distinction is not meaningful if your application always uses the 'take' methods to access your data, since these methods remove the data from the cache at the same time they deliver it to your application. (See 8.4.3.1 Read vs. Take on page 550) However, if your application uses the 'read' methods, leaving the data in the *DataReader's* cache after you've accessed it for the first time, those previously viewed samples will not be restored to the *DataReader's* cache in the event of a restart.

Connext DDS requires a relational database to persist the state of a *DataReader*. This database is accessed using ODBC. See RTI Connext DDS Core Libraries Database Setup for a list of supported relational databases and setup instructions.

13.4.1 Durable Reader State With Protocol Acknowledgment

For each *DataReader* configured to have durable state, *Connext DDS* will create one database table with the following naming convention: **RS<32 uuencoding of the reader virtual GUID>**. This table will store the last sequence number processed from each virtual *GUID*. For *DataReaders* on keyed topics requesting instance-ordering (see 7.4.6 PRESENTATION QosPolicy on page 361), this state will be stored per instance per virtual *GUID*..

Criteria to consider a sample "processed by the application"

- For the read/take methods that require calling **return_loan()**, a sample 's1' with sequence number 's1_seq_num' and virtual GUID 'vg1' is considered processed by the application when the *DataReader's* **return_loan()** operation is called for sample 's1' or any other sample with the same virtual GUID and a sequence number greater than 's1_seq_num'. For example:

[1]The circumstances under which a data sample is considered "processed by the application" are described in the sections that follow.

```
retcode = Foo_reader->take(data_seq, info_seq,
       DDS_LENGTH_UNLIMITED, DDS_ANY_SAMPLE_STATE,
       DDS_ANY_VIEW_STATE, DDS_ANY_INSTANCE_STATE);
if (retcode == DDS_RETCODE_NO_DATA) {
       return;
} else if (retcode != DDS_RETCODE_OK) {
  /* report error */
       return;
}
for (i = 0; i < data_seq.length(); ++i) {
    /* Operate with the data */
}
/* Return the loan */
retcode = Foo_reader->return_loan(data_seq, info_seq);
if (retcode != DDS_RETCODE_OK) {
    /* Report and error */
}
/* At this point the samples contained in data_seq
  will be considered as received. If the DataReader
  restarts, the samples will not be received again */
```

- For the read/take methods that do not require calling **return_loan()**, a sample 's1' with sequence number 's1_seq_num' and virtual GUID ‘vg1’ will be considered processed after the application reads or takes the sample 's1' or any other sample with the same virtual GUID *and* with a sequence number greater than 's1_seq_num'. For example:

```
retcode = Foo_reader->take_next_sample(data,info);
/* At this point the sample contained in data will be
  considered as received. All the samples with a sequence
  number smaller than the sequence number associated with
  data will also be considered as received.
  If the DataReader restarts, these sample will not
  be received again */
```

If you access the samples in the *DataReader* cache out of order—for example via QueryCondition, specifying an instance state, or reading by instance when the PRESENTATION QoS is not set to INSTANCE_PRESENTATION_QOS—then the samples that have not yet been taken or read by the application may still be considered as ”processed by the application”.

13.4.1.1 Bandwidth Utilization

To optimize network usage, if a *DataReader* configured with durable reader state is restarted and it discovers a *DataWriter* with a virtual GUID ‘vg’, the *DataReader* will ACK all the samples with a sequence number smaller than ‘sn’, where ‘sn’ is the first sequence number that has not been being processed by the application for ‘vg’.

Notice that the previous algorithm can significantly reduce the number of duplicates on the wire. However, it does not suppress them completely in the case of keyed *DataReaders* where the durable state is kept per (instance, virtual GUID). In this case, and assuming that the application has read samples out of order (e.g., by reading different instances), the ACK is sent for the lowest sequence number processed across all

instances and may cause samples already processed to flow on the network again. These redundant samples waste bandwidth, but they will be dropped by the *DataReader* and not be delivered to the application.

13.4.2 Durable Reader State with Application Acknowledgment

This section assumes you are familiar with the concept of *Application Acknowledgment* as described in 7.3.12 Application Acknowledgment on page 316.

For each *DataReader* configured to be durable and that uses application acknowledgement (see 7.3.12 Application Acknowledgment on page 316), *Connext DDS* will create one database table with the following naming convention: **RS<32 uuencoding of the reader virtual GUID>**. This table will store the list of sequence number *intervals* that have been acknowledged for each virtual GUID. The size of the column that stores the sequence number intervals is limited to 32767 bytes. If this size is exceeded for a given virtual GUID, the operation that persists the *DataReader* state into the database will fail.

13.4.2.1 Bandwidth Utilization

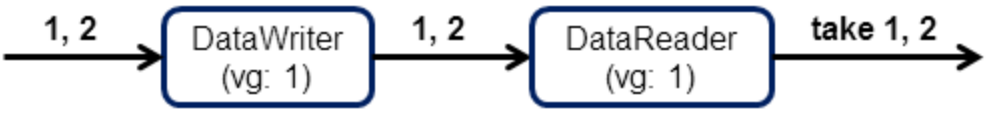
To optimize network usage, if a *DataReader* configured with durable reader state is restarted and it discovers a *DataWriter* with a virtual GUID 'vg', the *DataReader* will send an APP_ACK message with all the samples that were auto-acknowledged or explicitly acknowledged in previous executions.

Notice that this algorithm can significantly reduce the number of duplicates on the wire. However, it does not suppress them completely since the *DataReader* may send a NACK and receive some samples from the *DataWriter* before the *DataWriter* receives the APP_ACK message.

13.4.3 Durable Reader State Use Case

The following use case describes the durable reader state functionality:

1. A *DataReader* receives two samples with sequence number 1 and 2 published by a *DataWriter* with virtual GUID 1. The application takes those samples.

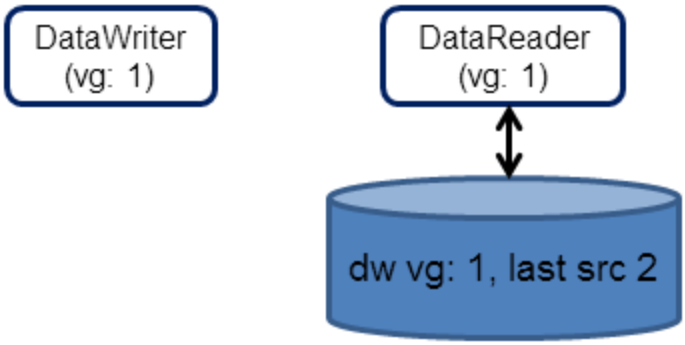


2. After the application returns the loan on samples 1 and 2, the *DataReader* considers them as processed and it persists the state change.

3. The process running the *DataReader* is stopped.

4. The *DataReader* is restarted.

   Because all the samples with sequence number smaller or equal than 2 were considered received, the reader will not ask for these samples from the *DataWriter*.



13.4.4 How To Configure a DataReader for Durable Reader State

To configure a *DataReader* with durable reader state, use the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 associated with *DataReaders* and *DomainParticipants*.

A property defined in the *DomainParticipant* will be applicable to all the *DataReaders* contained in the participant unless it is overwritten by the *DataReaders*. Table 13.2 Durable Reader State Properties lists the supported properties.

Table 13.2 Durable Reader State Properties

Property	Description
dds.data_reader.state.odbc.dsn	Required. The ODBC DSN (Data Source Name) associated with the database where the *DataReader* state must be persisted.
dds.data_reader.state.filter_redundant_samples	To enable durable reader state, this property must be set to 1. When set to 0, the reader state is not maintained and *Connext DDS* does not filter duplicate samples that may be coming from the same virtual writer. Default: 1
dds.data_reader.state.odbc.driver	This property indicates which ODBC driver to load. If the property is not specified, *Connext DDS* will try to use the standard ODBC driver manager library (UnixOdbc on Linux systems, the Windows ODBC driver manager on Windows systems).
dds.data_reader.state.odbc.username	These two properties configure the username and password used to connect to the database. Default: No password or username
dds.data_reader.state.odbc.password	
dds.data_reader.state.restore	This property indicates if the persisted *DataReader* state must be restored or not once the *DataReader* is restarted. If this property is 0, the previous state will be deleted from the database. If it is 1, the *DataReader* will restore its previous state from the database content. Default: 1
dds.data_reader.state.checkpoint_frequency	This property controls how often the reader state is stored into the database. A value of *N* means store the state once every *N* samples. A high frequency will provide better performance. However, if the reader is restarted it may receive some duplicate samples. These samples will be filtered by *Connext DDS* and they will not be propagated to the application. Default: 1
dds.data_reader.state.persistence_service.request_depth	This property indicates how many of the most recent historical samples the persisted *DataReader* wants to receive upon start-up. Default: 0

Example (C++ code):

```
/* Get default QoS */
...
retcode = DDSPropertyQosPolicyHelper::add_property(
               readerQos.property,
               "dds.data_reader.state.odbc.dsn",
               "<user DSN>", DDS_BOOLEAN_FALSE);

if (retcode != DDS_RETCODE_OK) {
       /* Report error */
}
retcode = DDSPropertyQosPolicyHelper::add_property(readerQos.property,
       "dds.data_reader.state.odbc.driver",
       "<ODBC library>", DDS_BOOLEAN_FALSE);
if (retcode != DDS_RETCODE_OK) {
       /* Report error */
```

```
}
retcode = DDSPropertyQosPolicyHelper::add_property(readerQos.property,
               "dds.data_reader.state.restore", "<0|1>",
               DDS_BOOLEAN_FALSE);
if (retcode != DDS_RETCODE_OK) {
       /* Report error */
}
/* Create Data Reader */
...
```

13.5 Data Durability

The data durability feature is an implementation of the OMG DDS Persistence Profile. The 7.5.9 DURABILITY QosPolicy on page 410 allows an application to configure a *DataWriter* so that the information written by the *DataWriter* survives beyond the lifetime of the *DataWriter*.

Connext DDS implements TRANSIENT and PERSISTENT durability using an external service called *RTI Persistence Service*, available for purchase as a separate RTI product.

Persistence Service receives information from *DataWriters* configured with TRANSIENT or PERSISTENT durability and makes that information available to late-joining *DataReaders*—even if the original *DataWriter* is not running.

The samples published by a *DataWriter* can be made durable by setting the **kind** field of the 7.5.9 DURABILITY QosPolicy on page 410 to one of the following values:

- DDS_TRANSIENT_DURABILITY_QOS:*Connext DDS* will store previously published samples in memory using *Persistence Service*, which will send the stored data to newly discovered *DataReaders*.
- DDS_PERSISTENT_DURABILITY_QOS: *Connext DDS* will store previously published samples in permanent storage, like a disk, using *Persistence Service*, which will send the stored data to newly discovered *DataReaders*.

A *DataReader* can request TRANSIENT or PERSISTENT data by setting the **kind** field of the corresponding 7.5.9 DURABILITY QosPolicy on page 410. A *DataReader* requesting PERSISTENT data will not receive data from *DataWriters* or *Persistence Service* applications that are configured with TRANSIENT durability.

13.5.1 RTI Persistence Service

Persistence Service is a *Connext DDS* application that is configured to persist topic data. For each one of the topics that must be persisted for a specific domain, the service will create a *DataWriter* (known as PRSTDataWriter) and a *DataReader* (known as PRSTDataReader). The samples received by the PRSTDataReaders will be published by the corresponding PRSTDataWriters to be available for late-joining *DataReaders*.

For more information on *Persistence Service*, please see:

- Introduction to RTI Persistence Service (Chapter 45 on page 1160)
- Configuring Persistence Service (Chapter 46 on page 1161)
- Running RTI Persistence Service (Chapter 47 on page 1186)

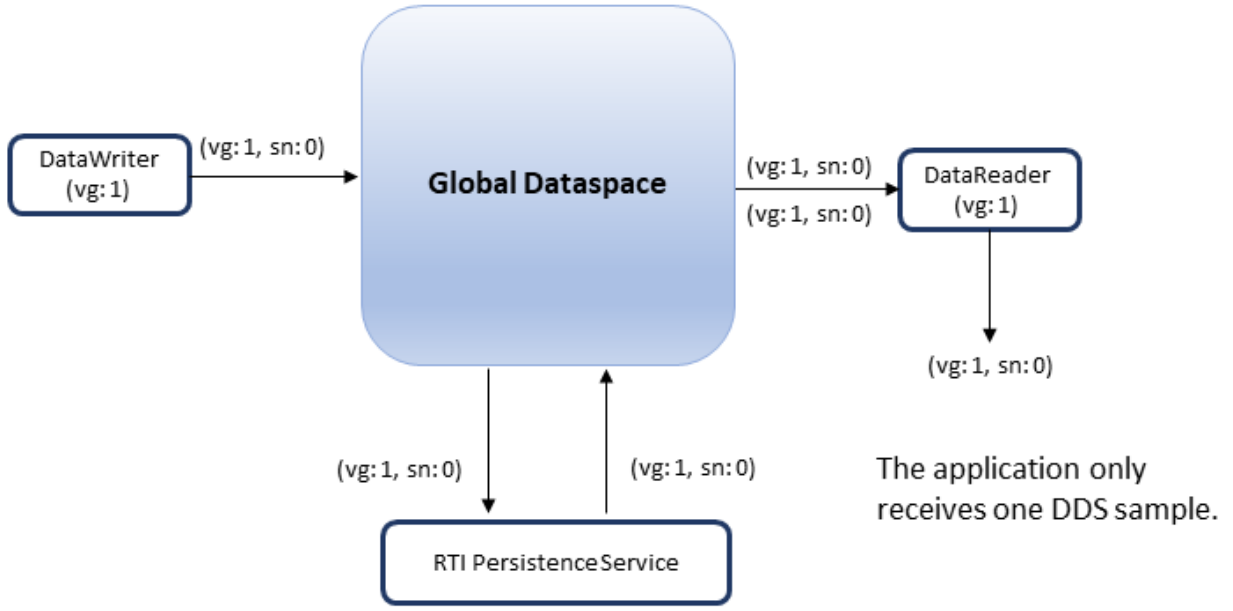
Persistence Service can be configured to operate in PERSISTENT or TRANSIENT mode:

- **TRANSIENT mode** The PRSTDataReaders and PRSTDataWriters will be created with TRANSIENT durability and *Persistence Service* will keep the received samples in memory. Samples published by a TRANSIENT *DataWriter* will survive the *DataWriter* lifecycle but will not survive the lifecycle of *Persistence Service* (unless you are running multiple copies).
- **PERSISTENT mode** The PRSTDataWriters and PRSTDataReaders will be created with PERSISTENT durability and *Persistence Service* will store the received samples in files or in an external relational database. Samples published by a PERSISTENT *DataWriter* will survive the *DataWriter* lifecycle as well as any restarts of *Persistence Service*.

Peer-to-Peer Communication:

By default, a PERSISTENT/TRANSIENT *DataReader* will receive samples directly from the original *DataWriter* if it is still alive. In this scenario, the *DataReader* may also receive the same samples from *Persistence Service*. Duplicates will be discarded at the middleware level. This Peer-To-Peer communication pattern is illustrated in Figure 13.6: Peer-to-Peer Communication on the next page. To use this peer-to-peer communication pattern, set the **direct_communication** field in the 7.5.9 DURABILITY QosPolicy on page 410 to TRUE. A PERSISTENT/TRANSIENT *DataReader* will receive information directly from PERSISTENT/TRANSIENT *DataWriters*.

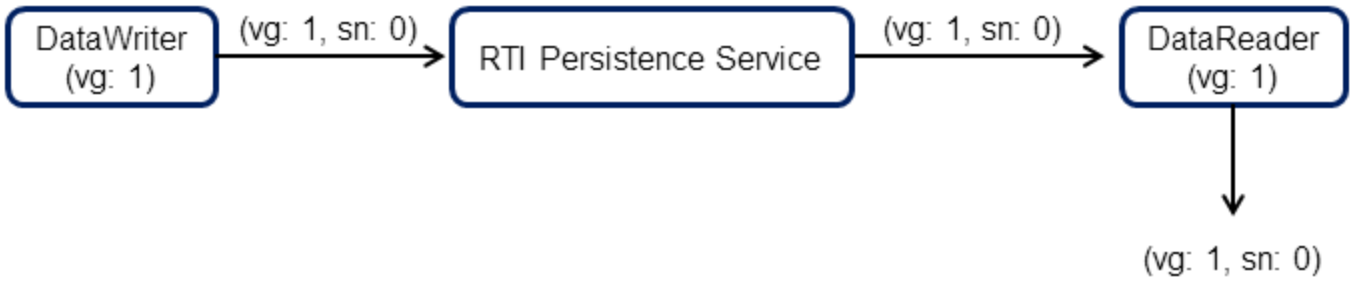
Figure 13.6: Peer-to-Peer Communication



Relay Communication

A PERSISTENT/TRANSIENT *DataReader* may also be configured to not receive samples from the original *DataWriter*. In this case the traffic is relayed by *Persistence Service*. This 'relay communication' pattern is illustrated in Figure 13.7: Relay Communication below. To use relay communication, set the **direct_communication** field in the 7.5.9 DURABILITY QosPolicy on page 410 to FALSE. A PERSISTENT/TRANSIENT *DataReader* will receive all the information from *Persistence Service*.

Figure 13.7: Relay Communication



Chapter 14 Guaranteed Delivery of Data

14.1 Introduction

Some application scenarios need to ensure that the information produced by certain producers is delivered to all the intended consumers. This chapter describes the mechanisms available in *Connext DDS* to guarantee the delivery of information from producers to consumers such that the delivery is robust to many kinds of failures in the infrastructure, deployment, and even the producing/consuming applications themselves.

Guaranteed information delivery is not the same as protocol-level reliability (described in Reliable Communications (Chapter 11 on page 682)) or information durability (described in Mechanisms for Achieving Information Durability and Persistence (Chapter 13 on page 726)). Guaranteed information delivery is an end-to-end application-level QoS, whereas the others are middleware-level QoS. There are significant differences between these two:

- With protocol-level reliability alone, the producing application knows that the information is received by the protocol layer on the consuming side. However the producing application cannot be certain that the consuming application read that information or was able to successfully understand and process it. The information could arrive in the consumer's protocol stack and be placed in the *DataReader* cache but the consuming application could either crash before it reads it from the cache, not read its cache, or read the cache using queries or conditions that prevent that particular DDS data sample from being accessed. Furthermore, the consuming application could access the DDS sample, but not be able to interpret its meaning or process it in the intended way.
- With information durability alone, there is no way to specify or characterize the intended consumers of the information. Therefore the infrastructure has no way to know when the information has been consumed by all the intended recipients. The information may be persisted such that it is not lost and is available to future applications, but the infrastructure and producing applications have no way to know that all the intended consumers have joined the system, received the information, and processed it successfully.

The guaranteed data-delivery mechanism provided in *Connext DDS* overcomes the limitations described above by providing the following features:

- **Required subscriptions**. This feature provides a way to configure, identify and detect the applications that are intended to consume the information. See 7.3.13 Required Subscriptions on page 322.
- **Application-level acknowledgments**. This feature provides the means ensure that the information was successfully processed by the application-layer in a consumer application. See 7.3.12 Application Acknowledgment on page 316.
- **Durable subscriptions**. This feature leverages the RTI Persistence Service to persist DDS DDS samples intended for the required subscriptions such that they are delivered even if the originating application is not available. See 46.9 Configuring Durable Subscriptions in Persistence Service on page 1180.

These features used in combination with the mechanisms provided for Information Durability and Persistence (see Mechanisms for Achieving Information Durability and Persistence (Chapter 13 on page 726)) enable the creation of applications where the information delivery is guaranteed despite application and infrastructure failures. 14.2 Scenarios on page 751 describes various guaranteed-delivery scenarios and how to configure the applications to achieve them.

When implementing an application that needs guaranteed data delivery, we have to consider three key aspects:

Key Aspects to Consider	Related Features and QoS
Identifying the required consumers of information	Required subscriptions Durable subscriptions EntityName QoS policy Availability QoS policy
Ensuring the intended consumer applications process the data successfully	Application-level acknowledgment Acknowledgment by a quorum of required and durable subscriptions Reliability QoS policy (acknowledgment mode) Availability QoS policy
Ensuring information is available to late joining applications	Persistence Service Durable Subscriptions Durability QoS Durable Writer History

14.1.1 Identifying the Required Consumers of Information

The first step towards ensuring that information is processed by the intended consumers is the ability to specify and recognize those intended consumers. This is done using the *required subscriptions* feature (7.3.13

Required Subscriptions on page 322) configured via the 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416 and 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369).

Connext DDS DataReader entities (as well as *DataWriter* and *DomainParticipant* entities) can have a *name* and a **role_name**. These names are configured using the 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416, which is propagated via DDS discovery and is available as part of the builtin-topic data for the Entity (see Built-In Topics (Chapter 18 on page 825)).

The DDS *DomainParticipant*, *DataReader* and *DataWriter* entities created by RTI-provided applications and services, specifically services such as *RTI Persistence Service*, automatically configure the ENTITY_NAME QoS policy according to their function. For example the *DataReaders* created by *RTI Persistence Service* have their **role_name** set to "PERSISTENCE_SERVICE".

Unless explicitly set by the user, the *DomainParticipant*, *DataReader* and *DataWriter* entities created by end-user applications have their **name** and **role_name** set to NULL. However applications may modify this using the 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416.

Connext DDS uses the **role_name** of *DataReaders* to identify the consumer's logical function. For this reason *Connext DDS's required subscriptions* feature relies on the **role_name** to identify intended consumers of information. The use of the *DataReader*'s **role_name** instead of the **name** is intentional. From the point of view of the information producer, the important thing is not the concrete *DataReader* (identified by its **name**, for example, "Logger123") but rather its logical function in the system (identified by its **role_name**, for example "LoggingService").

A *DataWriter* that needs to ensure its information is delivered to all the intended consumers uses the 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369 to configure the role names of the consumers that must receive the information.

The AVAILABILITY QoS Policy set on a *DataWriter* lets an application configure the required consumers of the data produced by the *DataWriter*. The required consumers are specified in the **required_matched_endpoint_groups** attribute within the AVAILABILITY QoS Policy. This attribute is a sequence of DDS *EndpointGroup* structures. Each *EndpointGroup* represents a required information consumer characterized by the consumer's **role_name** and **quorum_count**. The **role_name** identifies a logical consumer; the **quorum_count** specifies the minimum number of consumers with that **role_name** that must acknowledge the DDS sample before the *DataWriter* can consider it delivered to that required consumer.

For example, an application that wants to ensure data written by a *DataWriter* is delivered to at least two Logging Services and one Display Service would configure the *DataWriter*'s AVAILABILITY QoS Policy with a **required_matched_endpoint_groups** consisting of two elements. The first element would specify a required consumer with the **role_name** "LoggingService" and a **quorum_count** of 2. The second element would specify a required consumer with the **role_name** "DisplayService" and a **quorum_count** of 1. Furthermore, the application would set the logging service *DataReader* ENTITY_NAME policy to have a **role_name** of "LoggingService" and similarly the display service *DataReader* ENTITY_NAME policy to have the **role_name** of "DisplayService."

A *DataWriter* that has been configured with an AVAILABILITY QoS policy will not remove DDS samples from the *DataWriter* cache until they have been "delivered" to both the already-discovered *DataReaders* and the minimum number (**quorum_count**) of *DataReaders* specified for each role. In particular, DDS samples will be retained by the *DataWriter* if the **quorum_count** of matched *DataReaders* with a particular **role_name** have not been discovered yet.

We used the word "delivered" in quotes above because the level of assurance a *DataWriter* has that a particular DDS sample has been delivered depends on the setting of the 7.5.21 RELIABILITY QosPolicy on page 444. We discuss this next in 14.1.2 Ensuring Consumer Applications Process the Data Successfully below.

14.1.2 Ensuring Consumer Applications Process the Data Successfully

14.1.1 Identifying the Required Consumers of Information on page 747 described mechanisms by which an application could configure who the required consumers of information are. This section is about the criteria, mechanisms, and assurance provided by *Connext DDS* to ensure consumers have the information delivered to them and process it in a successful manner.

RTI provides four levels of information delivery guarantee. You can set your desired level using the 7.5.21 RELIABILITY QosPolicy on page 444. The levels are:

- **Best-effort, relying only on the underlying transport**The *DataWriter* considers the DDS sample delivered/acknowledged as soon as it is given to the transport to send to the *DataReader*'s destination. Therefore, the only guarantee is the one provided by the underlying transport itself. Note that even if the underlying transport is reliable (e.g., shared memory or TCP) the reliability is limited to the transport-level buffers. There is no guarantee that the DDS sample will arrive to the *DataReader* cache because after the transport delivers to the *DataReader*'s transport buffers, it is possible for the DDS sample to be dropped because it exceeds a resource limit, fails to deserialize properly, the receiving application crashes, etc.
- **Reliable with protocol acknowledgment**The DDS-RTPS reliability protocol used by *Connext DDS* provides acknowledgment at the RTPS protocol level: a *DataReader* will acknowledge it has deserialized the DDS sample correctly and stored it in the *DataReader*'s cache. However, there is no guarantee the application actually processed the DDS sample. The application might crash before processing the DDS sample, or it might simply fail to read it from the cache.
- **Reliable with Application Acknowledgment (Auto)**Application Acknowledgment in Auto mode causes *Connext DDS* to send an additional application-level acknowledgment (above and beyond the RTPS protocol level acknowledgment) after the consuming application has read the DDS sample from the *DataReader* cache and the application has subsequently called the *DataReader's* **return_loan()** operation (see 8.4.2 Loaning and Returning Data and SampleInfo Sequences on page 548) for that DDS sample. This mode guarantees that the application has fully read the DDS sample all the way until it indicates it is done with it. However it does not provide a guarantee that the application was able to successfully interpret or process the DDS sample. For example, the DDS

sample could be a command to execute a certain action and the application may read the DDS sample and not understand the command or may not be able to execute the action.

- **Reliable with Application Acknowledgment (Explicit)**Application Acknowledgment in Explicit mode causes *Connext DDS* to send an application-level acknowledgment only after the consuming application has read the DDS sample from the *DataReader* cache and subsequently called the *DataReader*'s **acknowledge_sample()** operation (see 8.4.4 Acknowledging DDS Samples on page 558) for that DDS sample. This mode guarantees that the application has fully read the DDS sample and completed operating on it as indicated by explicitly calling **acknowledge_sample()**. In contrast with the Auto mode described above, the application can delay the acknowledgment of the DDS sample beyond the time it holds onto the data buffers, allowing it to be process in a more flexible manner. Similar to the Auto mode, it does not provide a guarantee that the application was able to successfully interpret or process the DDS sample. For example, the DDS sample could be a command to execute a certain action and the application may read the DDS sample and not understand the command or may not be able to execute the action. Applications that need guarantees that the data was successfully processed and interpreted should use a request-reply interaction (see Part 4: Request-Reply and RPC Communication Patterns on page 983).

14.1.3 Ensuring Information is Available to Late-Joining Applications

The third aspect of guaranteed data delivery addresses situations where the application needs to ensure that the information produced by a particular *DataWriter* is available to *DataReaders* that join the system after the data was produced. The need for data delivery may even extend beyond the lifetime of the producing application; that is, it may be required that the information is delivered to applications that join the system after the producing application has left the system.

Connext DDS provides four mechanisms to handle these scenarios:

- **The DDS Durability QoS Policy**. The 7.5.9 DURABILITY QosPolicy on page 410 specifies whether DDS samples should be available to late joiners. The policy is set on the *DataWriter* and the *DataReader* and supports four kinds: VOLATILE, TRANSIENT_LOCAL, TRANSIENT, or PERSISTENT. If the *DataWriter's* Durability QoS policy is set to VOLATILE kind, the *DataWriter's* DDS samples will not be made available to any late joiners. If the *DataWriter's* policy kind is set to TRANSIENT_LOCAL, TRANSIENT, or PERSISTENT, the DDS samples will be made available for late-joining *DataReaders* who also set their DURABILITY QoS policy kind to something other than VOLATILE.
- **Durable Writer History**. A *DataWriter* configured with a DURABILITY QoS policy kind other than VOLATILE keeps its data in a local cache so that it is available when the late-joining application appears. The data is maintained in the *DataWriter's* cache until it is considered to be no longer needed. The precise criteria depends on the configuration of additional QoS policies such as 7.5.14 LIFESPAN QoS Policy on page 423, 7.5.12 HISTORY QosPolicy on page 418, 7.5.22 RESOURCE_LIMITS QosPolicy on page 449, etc. For the purposes of guaranteeing information delivery it is important to note that the *DataWriter's* cache can be configured to be a memory cache

or a durable (disk-based) cache. A memory cache will not survive an application restart. However, a durable (disk-based) cache can survive the restart of the producing application. The use a durable writer history, including the use of an external ODBC database as a cache is described in 13.3 Durable Writer History on page 733.

- **RTI Persistence Service**. This service allows the information produced by a *DataWriter* to survive beyond the lifetime of the producing application. *Persistence Service* is an stand-alone application that runs on many supported platforms. This service complies with the Persistent Profile of the OMG DDS specification. The service uses DDS to subscribe to the *DataWriters* that specify a 7.5.9 DURABILITY QosPolicy on page 410 kind of TRANSIENT or PERSISTENT. *Persistence Service* receives the data from those *DataWriters*, stores the data in its internal caches, and makes the data available via *DataWriters* (which are automatically created by *Persistence Service*) to late-joining *DataReaders* that specify a Durability kind of TRANSIENT or PERSISTENT. *Persistence Service* can operate as a relay for the information from the original writer, preserving the **source_timestamp** of the data, as well as the original DDS sample virtual writer GUID (see 13.5.1 RTI Persistence Service on page 743). In addition, you can configure *Persistence Service* itself to use a memory-based cache or a durable (disk-based or database-based) cache. See 46.6 Configuring Persistent Storage on page 1169. Configuration of redundant and load-balanced persistence services is also supported.
- **Durable Subscriptions**. This is a *Persistence Service* configuration setting that allows configuration of the required subscriptions (14.1.1 Identifying the Required Consumers of Information on page 747) for the data stored by *Persistence Service* (7.3.14 Managing Instances (Working with Keyed Data Types) on page 324). Configuring required subscriptions for *Persistence Service* ensures that the service will store the DDS samples until they have been delivered to the configured number (**quorum_count**) of *DataReaders* that have each of the specified roles.

14.2 Scenarios

In each of the scenarios below, we assume both the *DataWriter* and *DataReader* are configured for strict reliability (RELIABLE ReliabilityQosPolicyKind and KEEP_ALL HistoryQosPolicyKind, see 11.3.3 Controlling Queue Depth with the History QosPolicy on page 697). As a result, when the *DataWriter's* cache is full of unacknowledged DDS samples, the **write()** operation will block until DDS samples are acknowledged by all the intended consumers.

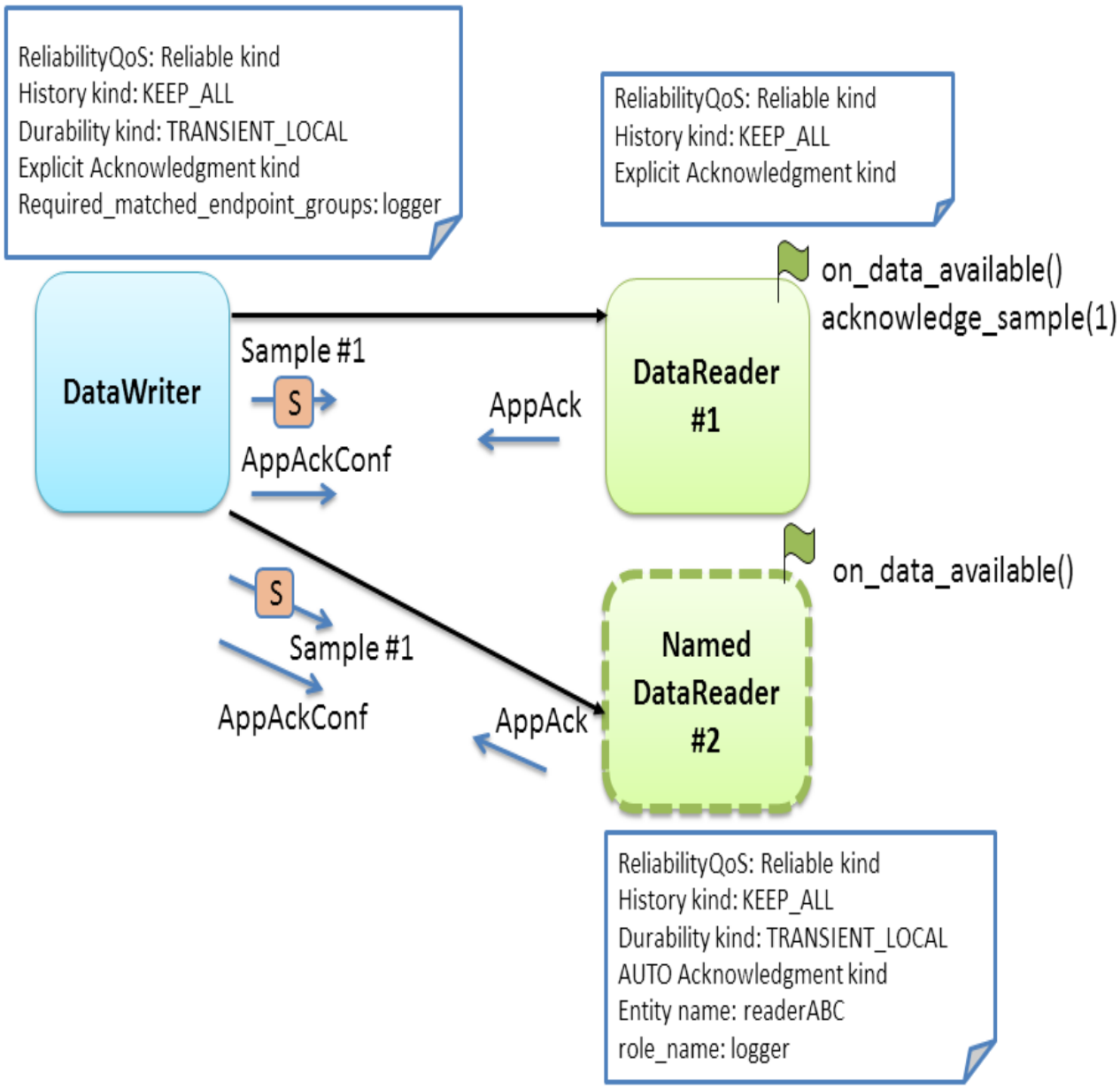
14.2.1 Scenario 1: Guaranteed Delivery to a-priori Known Subscribers

A common use case is to guarantee delivery to a set of known subscribers. These subscribers may be already running and have been discovered, they may be temporarily non-responsive, or it could be that some of those subscribers are still not present in the system. See Figure 14.1: Guaranteed Delivery Scenario 1 on the next page.

To guarantee delivery, the list of required subscribers should be configured using the 7.5.1 AVAILABILITY QosPolicy (DDS Extension) on page 369 on the *DataWriters* to specify the **role_name**

and **quorum_count** for each required subscription. Similarly the 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416 should be used on the *DataReaders* to specify their **role_name**. In addition we use 7.3.12 Application Acknowledgment on page 316 to guarantee the DDS sample was delivered and processed by the *DataReader*.

Figure 14.1: Guaranteed Delivery Scenario 1



The *DataWriter's* and *DataReader's* RELIABILITY QoS Policy can be configured for either AUTO or EXPLICIT application acknowledgment kind. As the *DataWriter* publishes the DDS sample, it will await

acknowledgment from the *DataReader* (through the protocol-level acknowledgment) and from the subscriber application (though the additional application-level acknowledgment). The *DataWriter* will only consider the DDS sample acknowledged when it has been acknowledged by all discovered active *DataReaders and* also by the **quorum_count** of each required subscription.

In this specific scenario, DataReader #1 is configured for EXPLICIT application acknowledgment. After reading and processing the DDS sample, the subscribing application calls **acknowledge_sample()** or **acknowledge_all()** (see 8.4.4 Acknowledging DDS Samples on page 558). As a result, *Connext DDS* will send an application-level acknowledgment to the *DataWriter*, which will in its turn confirm the acknowledgment.

If the DDS sample was lost in transit, the reliability protocol will repair the DDS sample. Since it has not been acknowledged, it remains available in the writer's queue to be automatically resent by *Connext DDS*. The DDS sample will remain available until acknowledged by the application. If the subscribing application crashes while processing the DDS sample and restarts, *Connext DDS* will repair the unacknowledged DDS sample. DDS samples which already been processed and acknowledged will not be resent.

In this scenario, DataReader #2 may be a late joiner. When it starts up, because it is configured with TRANSIENT_LOCAL Durability, the reliability protocol will re-send the DDS samples previously sent by the writer. These DDS samples were considered unacknowledged by the *DataWriter* because they had not been confirmed yet by the required subscription (identified by its **role_name**: 'logger').

DataReader #2 does not explicitly acknowledge the DDS samples it reads. It is configured to use AUTO application acknowledgment, which will automatically acknowledge DDS samples that have been read or taken after the application calls the *DataReader return_loan* operation.

This configuration works well for situations where the *DataReader* may not be immediately available or may restart. However, this configuration does not provide any guarantee if the *DataWriter* restarts. When the *DataWriter* restarts, DDS samples previously unacknowledged are lost and will no longer be available to any late joining DataReaders.

14.2.2 Scenario 2: Surviving a Writer Restart when Delivering DDS Samples to a priori Known Subscribers

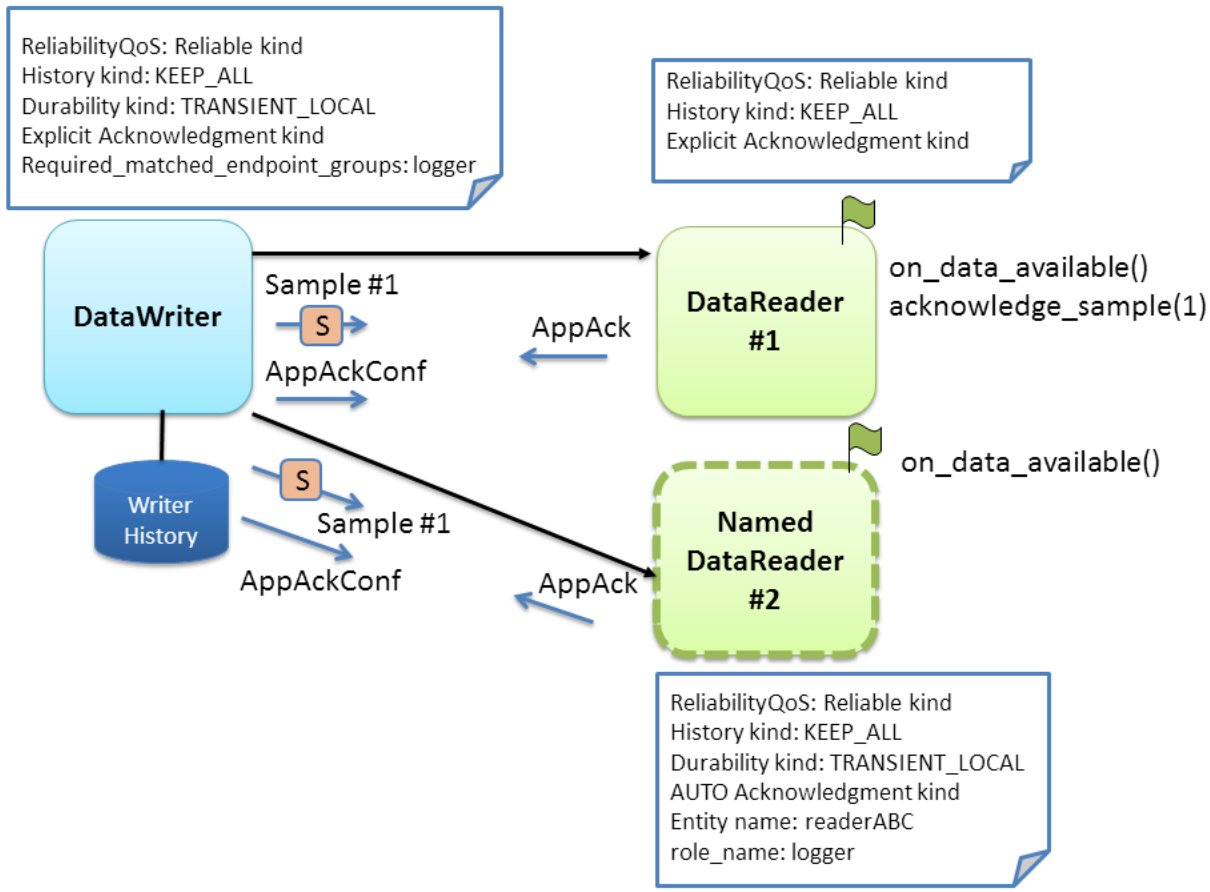
Scenario 1 describes a use case where DDS samples are delivered to a list of a priori known subscribers. In that scenario, *Connext DDS* will deliver DDS samples to the late-joining or restarting subscriber. However, if the producer is re-started the DDS samples it had written will no longer be available to future subscribers.

To handle a situation where the producing application is restarted, we will use the 13.3 Durable Writer History on page 733 feature. See Figure 14.2: Guaranteed Delivery Scenario 2 on the next page.

A *DataWriter* can be configured to maintain its data and state in durable storage. This configuration is done using the PROPERTY QoS policy as described in 13.3.2 How To Configure Durable Writer

History on page 735.. With this configuration the DDS data samples written by the *DataWriter* and any necessary internal state is persisted by the *DataWriter* into durable storage As a result, when the *DataWriter* restarts, DDS samples which had not been acknowledged by the set of required subscriptions will be resent and late-joining *DataReaders* specifying DURABILITY kind different from VOLATILE will receive the previously-written DDS samples.

Figure 14.2: Guaranteed Delivery Scenario 2



14.2.3 Scenario 3: Delivery Guaranteed by Persistence Service (Store and Forward) to a priori Known Subscribers

Previous scenarios illustrated that using the DURABILITY, RELIABILITY, and AVAILABILITY QoS policies we can ensure that as long as the *DataWriter* is present in the system, DDS samples written by a *DataWriter* will be delivered to the intended consumers. The use of the durable writer history in the previous scenario extended this guarantee even in the presence of a restart of the application writing the data.

This scenario addresses the situation where the originating application that produced the data is no longer available. For example, the network could have become partitioned, the application could have been terminated, it could have crashed and not have been restarted, etc.

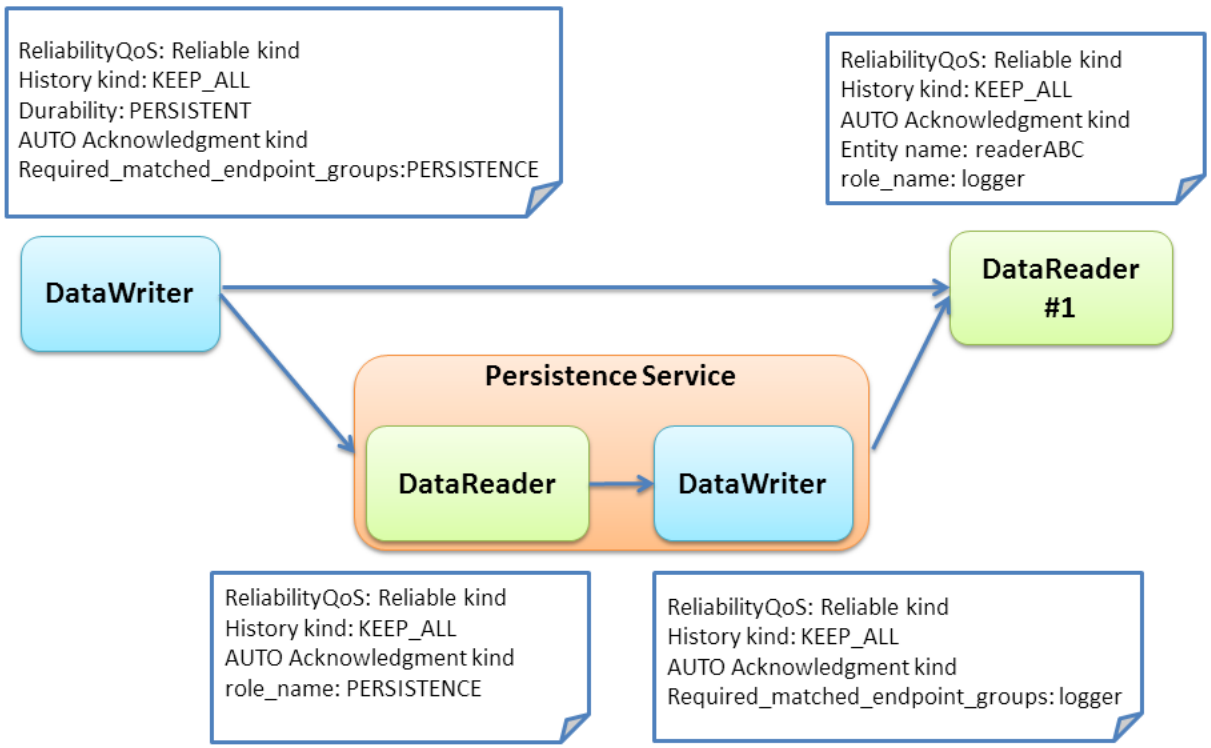
In order to deliver data to applications that appear after the producing application is no longer available on the network it is necessary to have another service that stores those DDS samples and delivers them. This is the purpose of the *RTI Persistence Service*.

Persistence Service can be configured to automatically discover *DataWriters* that specify a DURABILITY QoS with **kind** TRANSIENT or PERSISTENT and automatically create pairs (DataReader, DataWriter) that receive and store that information (see Introduction to RTI Persistence Service (Chapter 45 on page 1160)).

All *DataReaders* created by the *RTI Persistence Service* have the ENTITY_QOS policy set with the **role_name** of "PERSISTENCE_SERVICE". This allows an application to specify *Persistence Service* as one of the required subscriptions for its *DataWriters*.

In this third scenario, we take advantage of this capability to configure the *DataWriter* to have the RTI *Persistence Service* as a required subscription. See Figure 14.3: Guaranteed Delivery Scenario 3 below.

Figure 14.3: Guaranteed Delivery Scenario 3



The RTI *Persistence Service* can also have its *DataWriters* configured with required subscriptions. This feature is known as *Persistence Service* "durable subscriptions". DataReader #1 is pre configured in *Persistence Service* as a Durable Subscription. (Alternatively, DataReader #1 could have registered itself dynamically as Durable Subscription using the *DomainParticipant* **register_durable_subscription()** operation).

We also configure the RELIBILITY QoS policy setting of the AcknowledgmentKind to APPLICATION_AUTO_ACKNOWLEDGMENT_MODE in order to ensure DDS samples are stored in the *Persistence Service* and properly processed on the consuming application prior to them being removed from the DataWriter cache.

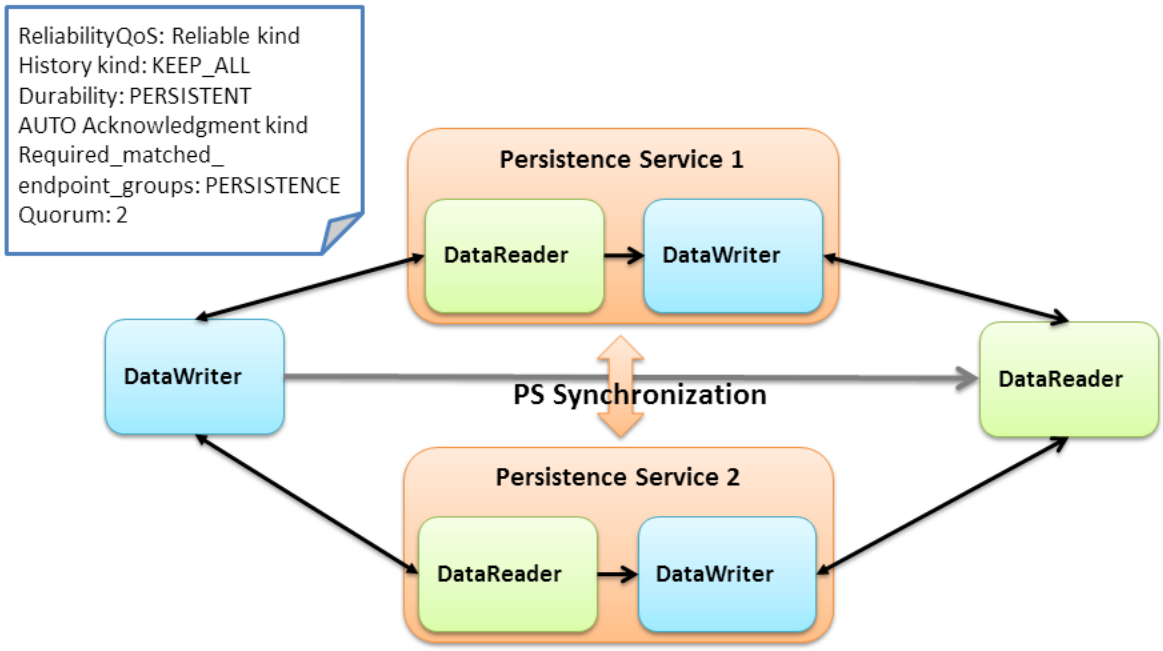
With this configuration in place the *DataWriter* will deliver DDS samples to the *DataReader* and to the *Persistence Service* reliably and wait for the Application Acknowledgment from both. Delivery of DDS samples to DataReader #1 and the *Persistence Service* occurs concurrently. The *Persistence Service* in turn takes responsibility to deliver the DDS samples to the configured "logger" durable subscription. If the original publisher is no longer available, DDS samples can still be delivered by the *Persistence Service*. to DataReader #1 and any other late-joining *DataReaders*.

When DataReader #1 acknowledges the DDS sample through an application-acknowledgment message, both the original *DataWriter* and *Persistence Service* will receive the application-acknowledgment. *Connext DDS* takes advantage of this to reduce or eliminate delivery if duplicate DDS samples, that is, the *Persistence Service* can notice that DataReader #1 has acknowledged a DDS sample and refrain from separately sending the same DDS sample to DataReader #1.

14.2.3.1 Variation: Using Redundant Persistence Services

Using a single Persistence Service to guarantee delivery can still raise concerns about having the Persistence Service as a single point of failure. To provide a level of added redundancy, the publisher may be configured to await acknowledgment from a quorum of multiple persistence services (**role_name** remains PERSISTENCE). Using this configuration we can achieve higher levels of redundancy

Figure 14.4: Guaranteed Delivery Scenario 3 with Redundant Persistence Service



The RTI *Persistence Services* will automatically share information to keep each other synchronized. This includes both the data and also the information on the durable subscriptions. That is, when a Persistence Service discovers a durable subscription, information about durable subscriptions is automatically replicated and synchronized among persistence services (CITE: New section to be written in Persistence Service Chapter).

14.2.3.2 Variation: Using Load-Balanced Persistent Services

The *Persistence Service* will store DDS samples on behalf of many DataWriters and, depending on the configuration, it might write those DDS samples to a database or to disk. For this reason the *Persistence Service* may become a bottleneck in systems with high durable DDS sample throughput.

It is possible to run multiple instances of the *Persistence Service* in a manner where each is only responsible for the guaranteed delivery of certain subset of the durable data being published. These *Persistence Service* can also be run different computers and in this manner achieve much higher throughput. For example, depending on the hardware, using typical hard-drives a single a *Persistence Service* may be able to store only 30000 DDS samples per second. By running 10 persistence services in 10 different computers we would be able to handle storing 10 times that system-wide, that is, 300000 DDS samples per second.

The data to be persisted can be partitioned among the persistence services by specifying different Topics to be persisted by each *Persistence Service.* If a single Topic has more data that can be handled y a single *Persistence Service* it is also possible to specify a content-filter so that only the data within that Topic that matches the filter will be stored by the *Persistence Service*. For example assume the Topic being persisted has an member named “x” of type float. It is possible to configure two *Persistence Services* one with the filter “x>10”, and the other “x <=10”, such that each only stores a subject of the data published on the Topic. See also: 46.9 Configuring Durable Subscriptions in Persistence Service on page 1180.

Chapter 15 Discovery

This section discusses how *Connext DDS* objects on different nodes find out about each other using the default Simple Discovery Protocol (SDP). It describes the sequence of messages that are passed between *Connext DDS* on the sending and receiving sides.

This section includes:

- 15.1 What is Discovery? on the next page
- 15.2 Configuring the Peers List Used in Discovery on page 761
- 15.3 Discovery Implementation on page 766
- 15.4 Debugging Discovery on page 782
- 15.5 Ports Used for Discovery on page 785

The discovery process occurs automatically, so you do not have to implement any special code. We recommend that all users read 15.1 What is Discovery? on the next page and 15.2 Configuring the Peers List Used in Discovery on page 761. The remaining sections contain advanced material for those who have a particular need to understand what is happening 'under the hood.' This information can help you debug a system in which objects are not communicating.

You may also be interested in reading Transport Plugins (Chapter 16 on page 790) , as well as learning about these QosPolicies:

- 7.5.27 TRANSPORT_SELECTION QosPolicy (DDS Extension) on page 456
- 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660
- 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458
- 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586

15.1 What is Discovery?

Discovery is the behind-the-scenes way in which *Connext DDS* objects (*DomainParticipants*, *DataWriters*, and *DataReaders*) on different nodes find out about each other. Each *DomainParticipant* maintains a database of information about all the active *DataReaders* and *DataWriters* that are in the same DDS domain. This database is what makes it possible for *DataWriters* and *DataReaders* to communicate. To create and refresh the database, each application follows a common discovery process.

This chapter describes the default discovery mechanism known as the Simple Discovery Protocol, which includes two phases: 15.1.1 Simple Participant Discovery below and 15.1.2 Simple Endpoint Discovery on the next page.

The goal of these two phases is to build, for each *DomainParticipant*, a complete picture of all the entities that belong to the remote participants that are in its peers list. The peers list is the list of nodes with which a participant may communicate. It starts out the same as the *initial_peers* list that you configure in the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635. If the accept_unknown_peers flag in that same QosPolicy is TRUE, then other nodes may also be added as they are discovered; if it is FALSE, then the peers list will match the initial_peers list, plus any peers added using the *DomainParticipant*'s **add_peer()** operation.

15.1.1 Simple Participant Discovery

This phase of the Simple Discovery Protocol is performed by the Simple Participant Discovery Protocol (SPDP).

During the Participant Discovery phase, *DomainParticipants* learn about each other. The *DomainParticipant*'s details are communicated to all other *DomainParticipants* in the same DDS domain by sending participant declaration messages, also known as *participant DATA* submessages or *participant announcements*. The details include the *DomainParticipant's* unique identifying key (GUID or Globally Unique ID described below), transport locators (addresses and port numbers), and QoS. These messages are sent on a periodic basis using best-effort communication.

Participant DATAs are sent periodically to maintain the liveliness of the *DomainParticipant*. They are also used to communicate changes in the *DomainParticipant's* QoS. Only changes to QosPolicies that are part of the *DomainParticipant's* built-in data (namely, the 7.5.30 USER_DATA QosPolicy on page 462) need to be propagated.

When receiving remote participant discovery information, *Connext DDS* determines if the local participant matches the remote one. A 'match' between the local and remote participant occurs only if the local and remote participant have the same Domain ID and Domain Tag (see 9.3.4 Choosing a Domain ID and Creating Multiple DDS Domains on page 613 and 9.3.5 Choosing a Domain Tag on page 614). This matching process occurs as soon as the local participant receives discovery information from the remote one. If there is no match, the discovery DATA is ignored, resulting in the remote participant (and all its associated entities) not being discovered.

When a *DomainParticipant* is deleted, a *participant DATA (delete)* submessage with the *DomainParticipant's* identifying GUID is sent.

The GUID is a unique reference to an entity. It is composed of a GUID prefix and an Entity ID. By default, the GUID prefix is calculated from the IP address and the process ID. (For more on how the GUID is calculated, see 9.5.9.3 Controlling How the GUID is Set (rtps_auto_id_kind) on page 667.) The IP address and process ID are stored in the *DomainParticipant's* 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664. The entityID is set by *Connext DDS* (you may be able to change it in a future version).

Once a pair of participants have discovered each other, they can move on to the Endpoint Discovery phase, which is how *DataWriters* and *DataReaders* find each other.

15.1.2 Simple Endpoint Discovery

This phase of the Simple Discovery Protocol is performed by the Simple Endpoint Discovery Protocol (SEDP).

During the Endpoint Discovery phase, *Connext DDS* matches *DataWriters* and *DataReaders*. Information (GUID, QoS, etc.) about your application's *DataReaders* and *DataWriters* is exchanged by sending publication/subscription declarations in DATA messages that we will refer to as *publication DATAs* and *subscription DATAs*. The Endpoint Discovery phase uses reliable communication.

As described in 15.3 Discovery Implementation on page 766, these declaration or *DATA* messages are exchanged until each *DomainParticipant* has a complete database of information about the participants in its peers list and their entities. Then the discovery process is complete and the system switches to a steady state. During steady state, *participant DATAs* are still sent periodically to maintain the liveliness status of participants. They may also be sent to communicate QoS changes or the deletion of a *DomainParticipant*.

When a remote *DataWriter*/*DataReader* is discovered, *Connext DDS* determines if the local application has a matching *DataReader*/*DataWriter*. A 'match' between the local and remote entities occurs only if the *DataReader* and *DataWriter* have the same *Topic*, same data type, and compatible QosPolicies (which includes having the same partition name string, see 7.4.5 PARTITION QosPolicy on page 355). Furthermore, if the *DomainParticipant* has been set up to ignore certain *DataWriters*/*DataReaders*, those entities will not be considered during the matching process. See 18.4.2 Ignoring Publications and Subscriptions on page 837 for more on ignoring specific publications and subscriptions.

This 'matching' process occurs as soon as a remote entity is discovered, even if the entire database is not yet complete: that is, the application may still be discovering other remote entities.

A *DataReader* and *DataWriter* can only communicate with each other if each one's application has hooked up its local entity with the matching remote entity. That is, both sides must agree to the connection.

15.3 Discovery Implementation on page 766 describes the details about the discovery process.

15.2 Configuring the Peers List Used in Discovery

As part of the participant phase of the discovery process, *Connext DDS* will announce itself within the DDS domain. *Connext DDS* will try to contact all possible participants in the 'initial peers list,' specified in the *DomainParticipant's* 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635. Note, however, it is not known if there are actually *Connext DDS* applications running on the hosts in the inital peers list. The initial peers list may include both unicast and multicast peer locators.

After startup, you can add to the 'peers list' with the **add_peer()** operation (see 9.5.2.3 Adding and Removing Peers List Entries on page 636). The 'peers list' may also grow as peers are automatically discovered (if accept_unknown_peers is TRUE, see 9.5.2.6 Controlling Acceptance of Unknown Peers on page 638).

When you call **get_default_participant_qos()** for a *DomainParticipantFactory*, the values used for the DiscoveryQosPolicy's **initial_peers** and **multicast_receive_addresses** may come from the following:

- A file named **NDDS_DISCOVERY_PEERS**, which is formatted as described in 15.2.3 NDDS_DISCOVERY_PEERS File Format on page 766. The file must be in your application's current working directory.
- An environment variable named NDDS_DISCOVERY_PEERS, defined as a comma-separated list of peer descriptors (see 15.2.2 NDDS_DISCOVERY_PEERS Environment Variable Format on page 765).
- The value specified in the default XML QoS profile (see 19.4 Tags for Configuring QoS with XML on page 868).

If **NDDS_DISCOVERY_PEERS** (file or environment variable) does *not* contain a multicast address, then **multicast_receive_addresses** is cleared and the RTI discovery process will not listen for discovery messages via multicast.

If **NDDS_DISCOVERY_PEERS** (file or environment variable) contains one or more multicast addresses, the addresses are stored in **multicast_receive_addresses**, starting at element 0. They will be stored in the order in which they appear in **NDDS_DISCOVERY_PEERS**.

Note: Setting **initial_peers** in the default XML QoS Profile does not modify the value of **multicast_receive_address**.

If both the file and environment variable are found, the file takes precedence and the environment variable will be ignored.[1] The settings in the default XML QoS Profile take precedence over the file and environment variable. In the absence of a file, environment variable, or default XML QoS profile values, *Connext DDS* will use a default value. See the API Reference HTML documentation for details (in the section on the DISCOVERY QosPolicy).

[1]This is true even if the file is empty.

If initial peers are specified in both the currently loaded QoS XML profile and in the NDDS_DISCOVERY_PEERS file, the values in the profile take precedence.

The file, environment variable, and default XML QoS Profile make it easy to reconfigure which nodes will take part in the discovery process—without recompiling your application.

The file, environment variable, and default XML QoS Profile are the possible sources for the *default* initial peers list. You can, of course, explicitly set the initial list by changing the values in the QoS provided to the DomainParticipantFactory's **create_participant()** operation, or by adding to the list after startup with the *DomainParticipant's* **add_peer()** operation (see 9.5.2.3 Adding and Removing Peers List Entries on page 636).

If you set NDDS_DISCOVERY_PEERS *and* You Want to Communicate over Shared Memory:

Suppose you want to communicate with other *Connext DDS* applications on the same host and you are explicitly setting **NDDS_DISCOVERY_PEERS** (generally in order to use unicast discovery with applications on other hosts).

If the local host platform does *not* support the shared memory transport, then you can include the name of the local host in the **NDDS_DISCOVERY_PEERS** list. (To check if your platform supports shared memory, see the RTI Connext DDS Core Libraries Platform Notes.)

If the local host platform supports the shared memory transport, then you must do one of the following:

- Include "**shmem://**" in the **NDDS_DISCOVERY_PEERS** list. This will cause shared memory to be used for discovery and data traffic for applications on the same host.

or:

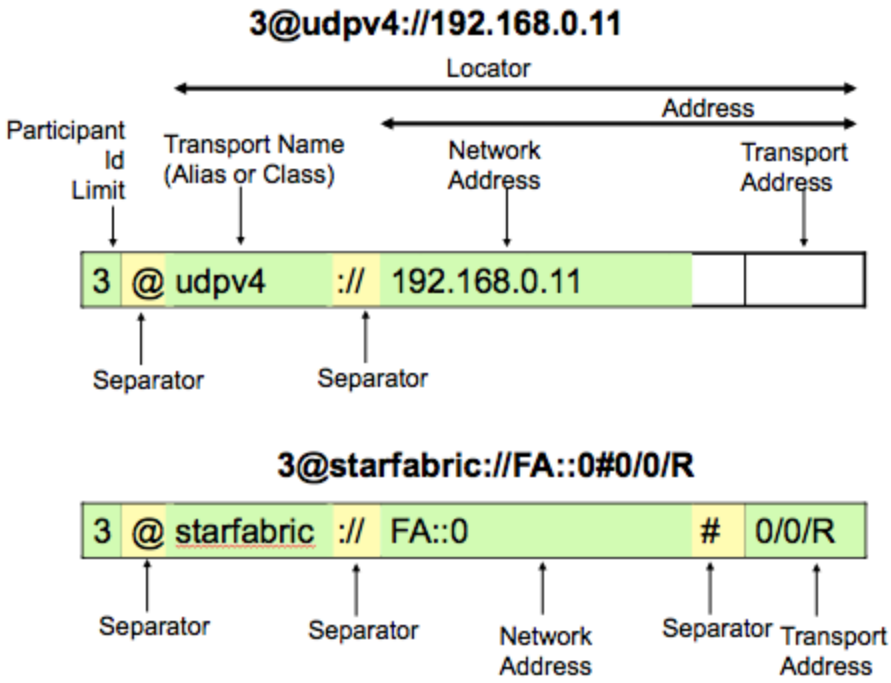
- Include the name of the local host in the **NDDS_DISCOVERY_PEERS** list, and disable the shared memory transport in the 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660 of the *DomainParticipant*. This will cause UDP loopback to be used for discovery and data traffic for applications on the same host.

15.2.1 Peer Descriptor Format

A peer descriptor string specifies a range of participants at a given locator. Peer descriptor strings are used in the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635 *initial_peers* field (see 9.5.2.2 Setting the 'Initial Peers' List on page 636) and the *DomainParticipant's* **add_peer()** and **remove_peer()** operations (see 9.5.2.3 Adding and Removing Peers List Entries on page 636).

The anatomy of a peer descriptor is illustrated in Figure 15.1: Example Peer Descriptor Address Strings on the next page using a special "StarFabric" transport example.

Figure 15.1: Example Peer Descriptor Address Strings



A peer descriptor consists of:

- *[optional]* A participant ID limit. If a simple integer is specified, it indicates the maximum participant ID to be contacted by the *Connext DDS* discovery mechanism at the given locator. If that integer is enclosed in square brackets (e.g., [2]), then *only* that Participant ID will be used. You can also specify a range in the form of **[a-b]**: in this case only the Participant IDs in that specific range are contacted. If omitted, a default value of 4 is implied and participant IDs 0, 1, 2, 3, and 4 will be contacted.
- A locator, as described in 15.2.1.1 Locator Format below.

These are separated by the '@' character. The separator may be omitted if a participant ID limit is not explicitly specified.

The "participant ID limit" only applies to unicast locators; it is ignored for multicast locators (and therefore should be omitted for multicast peer descriptors).

15.2.1.1 Locator Format

A locator string specifies a transport and an address in string format. Locators are used to form peer descriptors. A locator is equivalent to a peer descriptor with the default participant ID limit (4).

A locator consists of:

- *[optional]* Transport name (alias or class). This identifies the set of transport plug-ins (transport aliases) that may be used to parse the address portion of the locator. Note that a transport class name is an implicit alias used to refer to all the transport plug-in instances of that class.
- [optional] An address, as described in 15.2.1.2 Address Format below.

These are separated by the "://" string. The separator is specified if and only if a transport name is specified.

If a transport name is specified, the address may be omitted; in that case all the unicast addresses (across all transport plug-in instances) associated with the transport class are implied. Thus, a locator string may specify several addresses.

If an address is specified, the transport name and the separator string may be omitted; in that case all the available transport plug-ins for the *Entity* may be used to parse the address string.

The transport names for the built-in transport plug-ins are:

- shmem - Shared Memory Transport
- udpv4 - UDPv4 Transport
- udpv6 - UDPv6 Transport

15.2.1.2 Address Format

An address string specifies a transport-independent network address that qualifies a transport-dependent address string. Addresses are used to form locators. Addresses are also used in the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635 multicast_receive_addresses and the DDS_TransportMulticastSettings_t::receive_address fields. An address is equivalent to a locator in which the transport name and separator are omitted.

An address consists of:

- *[optional]* A network address in IPv4 or IPv6 string notation. If omitted, the network address of the transport is implied.
- *[optional]* A transport address, which is a string that is passed to the transport for processing. The transport maps this string into **NDDS_Transport_Property_t::address_bit_count** bits. If omitted, the network address is used as the fully qualified address. The transport plugin sets the value for **NDDS_Transport_Property_t::address_bit_count** bits.

The network and transport addressed are separated by the '#' character. If a separator is specified, it must be followed by a non-empty string that is passed to the transport plug-in. If the separator is omitted, it is treated as a transport address with an implicit network address (of the transport plugin). The implicit network address is the address used when registering the transport: e.g., the UDPv4 implicit network address is 0.0.0.0.0.0.0.0.0.0.0.0.

The bits resulting from the transport address string are prepended with the network address. The least significant **NDDS_Transport_Property_t::address_bit_count** bits of the network address are ignored.

15.2.2 NDDS_DISCOVERY_PEERS Environment Variable Format

You can set the default value for the initial peers list in an environment variable named NDDS_DISCOVERY_PEERS. Multiple peer descriptor entries must be separated by commas. Table 15.1 NDDS_DISCOVERY_PEERS Environment Variable Examples shows some examples. The examples use an implied maximum participant ID of 4 unless otherwise noted. (If you need instructions on how to set environment variables, see Set Up Environment Variables (rtisetenv), in "Hands-On 1" of *Introduction to Publish/Subscribe*, in the RTI Connext DDS Getting Started Guide.)

Table 15.1 NDDS_DISCOVERY_PEERS Environment Variable Examples

NDDS_DISCOVERY_PEERS	Description of Host(s)
239.255.0.1	multicast
localhost	localhost
192.168.1.1	10.10.30.232 (IPv4)
FAA0::1	FAA0::0 (IPv6)
himalaya,gangotri	himalaya and gangotri
1@himalaya,1@gangotri	himalaya and gangotri (with a maximum participant ID of 1 on each host)
FAA0::0#localhost	FAA0::0#localhost (could be a UDPv4 transport plug-in registered at network address of FAA0::0) (IPv6)
udpv4://himalaya	himalaya accessed using the "udpv4" transport plug-in (IPv4)
udpv4://FAA0::0#localhost	localhost using the "udpv4" transport plug-in registered at network address FAA0::0
0/0/R #0/0/R	0/0/R (StarFabric)
starfabric://0/0/R starfabric://#0/0/R	0/0/R (StarFabric) using the "starfabric" (StarFabric) transport plug-ins
starfabric://FBB0::0#0/0/R	0/0/R (StarFabric) using the "starfabric" (StarFabric) transport plug-ins registered at network address FAA0::0
starfabric://	all unicast addresses accessed via the "starfabric" (StarFabric) transport plug-ins
shmem://FCC0::0	all unicast addresses accessed via the "shmem" (shared memory) transport plug-ins registered at network address FCC0::0

15.2.3 NDDS_DISCOVERY_PEERS File Format

You can set the default value for the initial peers list in a file named NDDS_DISCOVERY_PEERS. The file must be in your application's current working directory.

The file is optional. If it is found, it supersedes the values in any environment variable of the same name.

Entries in the file must contain a sequence of peer descriptors separated by whitespace or the comma (',') character. The file may also contain comments starting with a semicolon (';') character until the end of the line.

Example file contents:

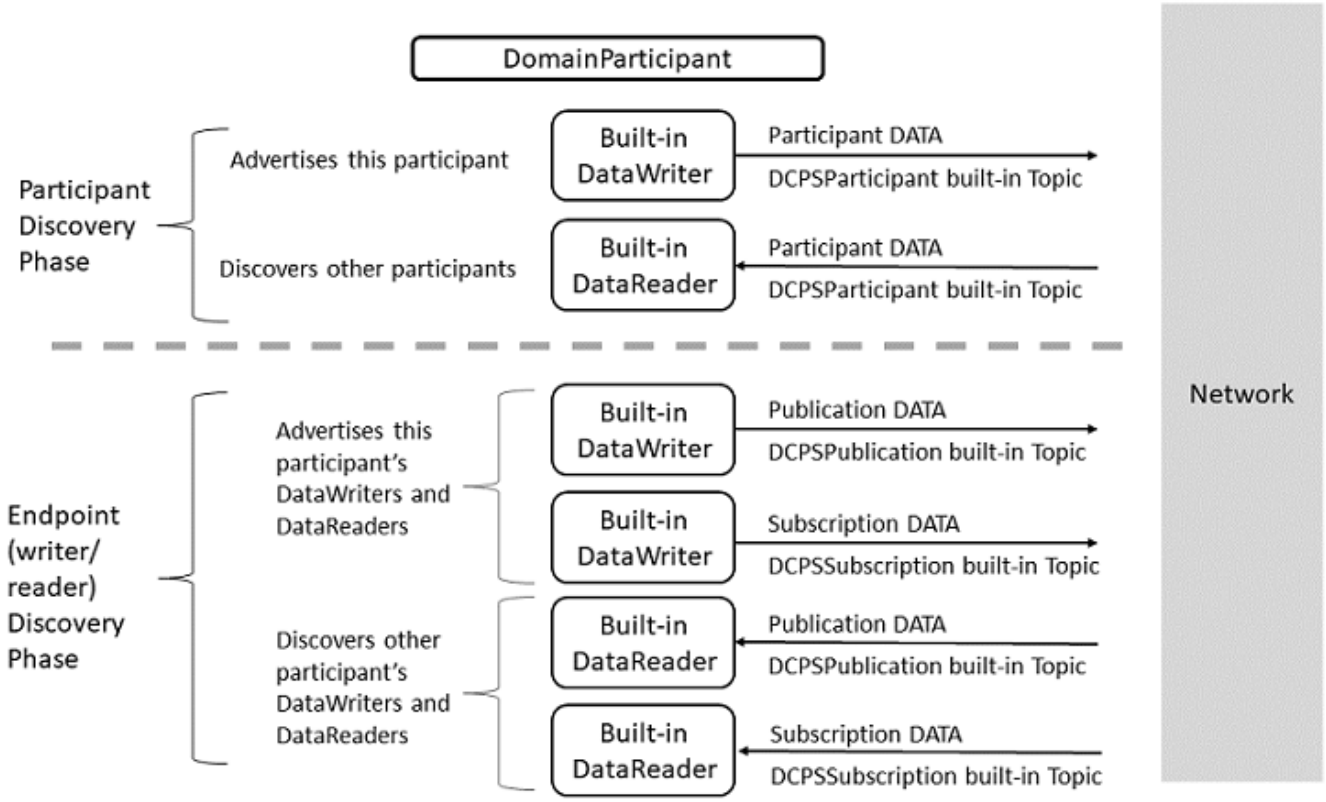
```
;; NDDS_DISCOVERY_PEERS - Discovery Configuration File
;; Multicast builtin.udpv4://239.255.0.1 ; default discovery multicast addr

;; Unicast
localhost,192.168.1.1          ; A comma can be used a separator
FAA0::1 FAA0::0#localhost      ; Whitespace can be used as a separator
1@himalaya                     ; Max participant ID of 1 on 'himalaya'
1@gangotri

;; UDPv4
udpv4://himalaya               ; 'himalaya' via 'udpv4' transport plugin(s)
udpv4://FAA0::0#localhost      ; 'localhost' via 'updv4' transport plugin
                               ; registered at network address FAA0::0
;; Shared Memory
shmem://                       ; All 'shmem' transport plugin(s)
builtin.shmem://               ; The builtin builtin 'shmem' transport plugin
shmem://FCC0::0                ; Shared memory transport plugin registered
                               ; at network address FCC0::0
;; StarFabric
0/0/R                          ; StarFabric node 0/0/R
starfabric://0/0/R             ; 0/0/R accessed via 'starfabric'
                               ; transport plugin(s)
starfabric://FBB0::0#0/0/R     ; StarFabric transport plugin registered
                               ; at network address FBB0::0
starfabric://                  ; All 'starfabric' transport plugin(s)
```

15.3 Discovery Implementation

Note: this section contains advanced material not required by most users.

Discovery is implemented using built-in *DataWriters* and *DataReaders*. These are the same class of entities your application uses to send/receive data. That is, they are also of type DDSDataWriter/DDSDataReader. For each *DomainParticipant*, three built-in *DataWriters* and three *built-in DataReaders* are automatically created for discovery purposes. Figure 15.2: Built-in Writers and Readers for Discovery on the next page shows how these objects are used. (For more on built-in *DataReaders* and *DataWriters*, see Built-In Topics (Chapter 18 on page 825)).

Figure 15.2: Built-in Writers and Readers for Discovery



For each DomainParticipant, there are six objects automatically created for discovery purposes. The top two objects are used to send/receive participant DATA messages, which are used in the Participant Discovery phase to find remote DomainParticipants. This phase uses best-effort communications. Once the participants are aware of each other, they move on to the Endpoint Discovery Phase to learn about each other's DataWriters and DataReaders. This phase uses reliable communications.

The implementation is split into two separate protocols:

Simple Participant Discovery Protocol (SPDP)
+ Simple Endpoint Discovery Protocol (SEDP)

= Simple Discovery Protocol (SDP)

15.3.1 Participant Discovery

When a *DomainParticipant* is created, a *DataWriter* and a *DataReader* are automatically created to exchange *participant DATA* messages in the network. These *DataWriters* and *DataReader*s are "special" because the *DataWriter* can send to a given list of destinations, regardless of whether there is a *Connext DDS* application at the destination, and the *DataReader* can receive data from any source, whether the source is previously known or not. In other words, these special readers and writers do not need to discover the remote entity and perform a match before they can communicate with each other.

When a *DomainParticipant* joins or leaves the network, it needs to notify its peer participants. The list of remote participants to use during discovery comes from the peer list described in the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635. The remote participants are notified via *participant DATA* messages. In addition, if a participant's QoS is modified in such a way that other participants need to know about the change (that is, changes to the 7.5.30 USER_DATA QosPolicy on page 462), a new *participant DATA* will be sent immediately.

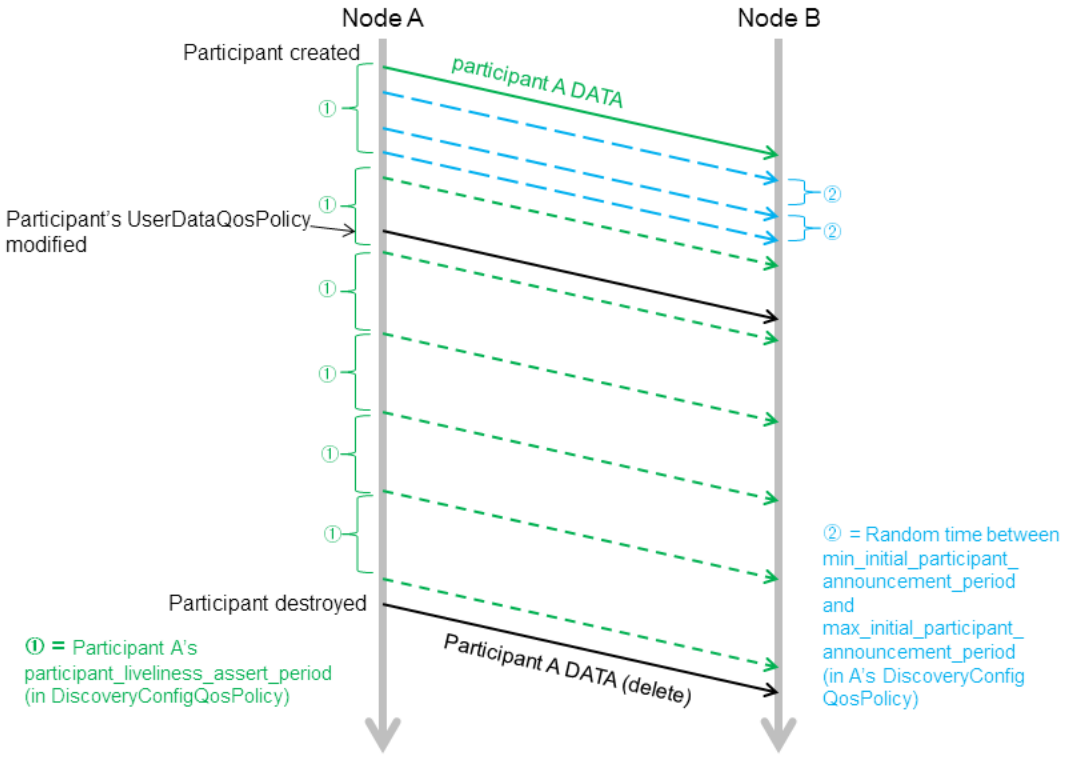
Participant DATAs are also used to maintain a participant's liveliness status. These are sent at the rate set in the **participant_liveliness_assert_period** in the 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639.

Let's examine what happens when a new remote participant is discovered. If the new remote participant is in the local participant's peer list, the local participant will add that remote participant into its database. If the new remote participant is not in the local application's peer list, it may still be added, if the **accept_unknown_peers** field in the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635 is set to TRUE.

Once a remote participant has been added to the *Connext DDS* database, *Connext DDS* keeps track of that remote participant's **participant_liveliness_lease_duration**. If a *participant DATA* for that participant (identified by the GUID) is not received at least once within the **participant_liveliness_lease_duratio**n, the remote participant is considered stale, and the remote participant, together with all its entities, will be removed from the database of the local participant.

To keep from being purged by other participants, each participant needs to periodically send a *participant DATA* to refresh its liveliness. The rate at which the *participant DATA* is sent is controlled by the **participant_liveliness_assert_perio**d in the participant's 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639. This exchange, which keeps Participant A from appearing 'stale,' is illustrated in Figure 15.3: Periodic 'participant DATAs' on the next page. Figure 15.4: Ungraceful Termination of a Participant on page 770 shows what happens when Participant A terminates ungracefully and therefore needs to be seen as 'stale.'

Figure 15.3: Periodic 'participant DATAs'

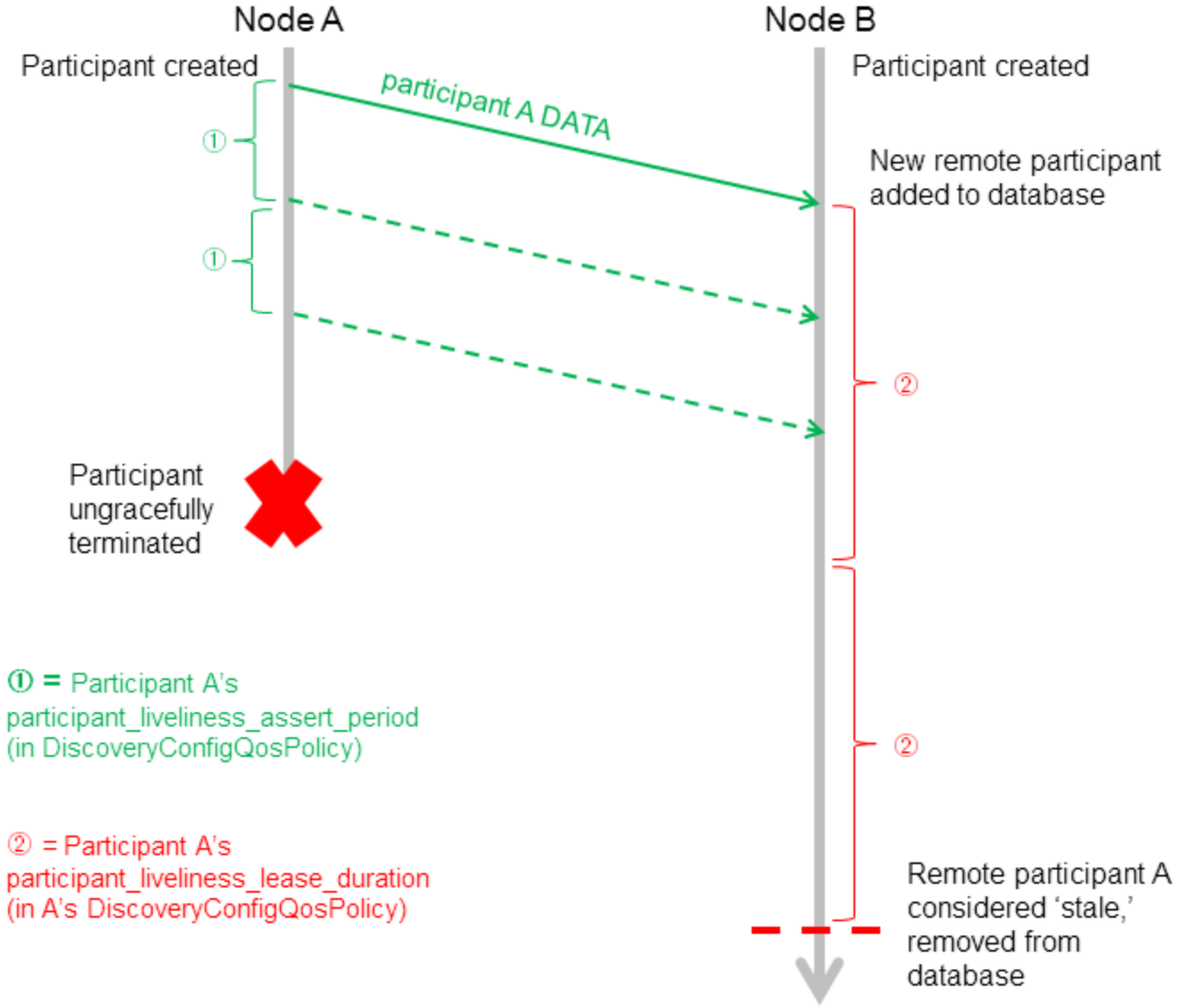


The DomainParticipant on Node A sends a 'participant DATA' to Node B, which is in Node A's peers list. This occurs regardless of whether or not there is a Connext DDS application on Node B.

① *The green short dashed lines are periodic participant DATAs. The time between these messages is controlled by* ***the participant_liveliness_assert_period*** *in the DiscoveryConfig QosPolicy.*

k *In addition to the periodic participant DATAs, 'initial repeat messages' (shown in blue, with longer dashes) are sent from A to B. These messages are sent at a random time between* ***min_initial_participant_announcement_period*** *and* ***max_initial_participant_announcement_period*** *(in A's DiscoveryConfig QosPolicy). The number of these initial repeat messages is set in initial_participant_announcements.*

Figure 15.4: Ungraceful Termination of a Participant



Participant A is removed from participant B's database if it is not refreshed within the liveliness lease duration. Dashed lines are periodic participant DATA messages.

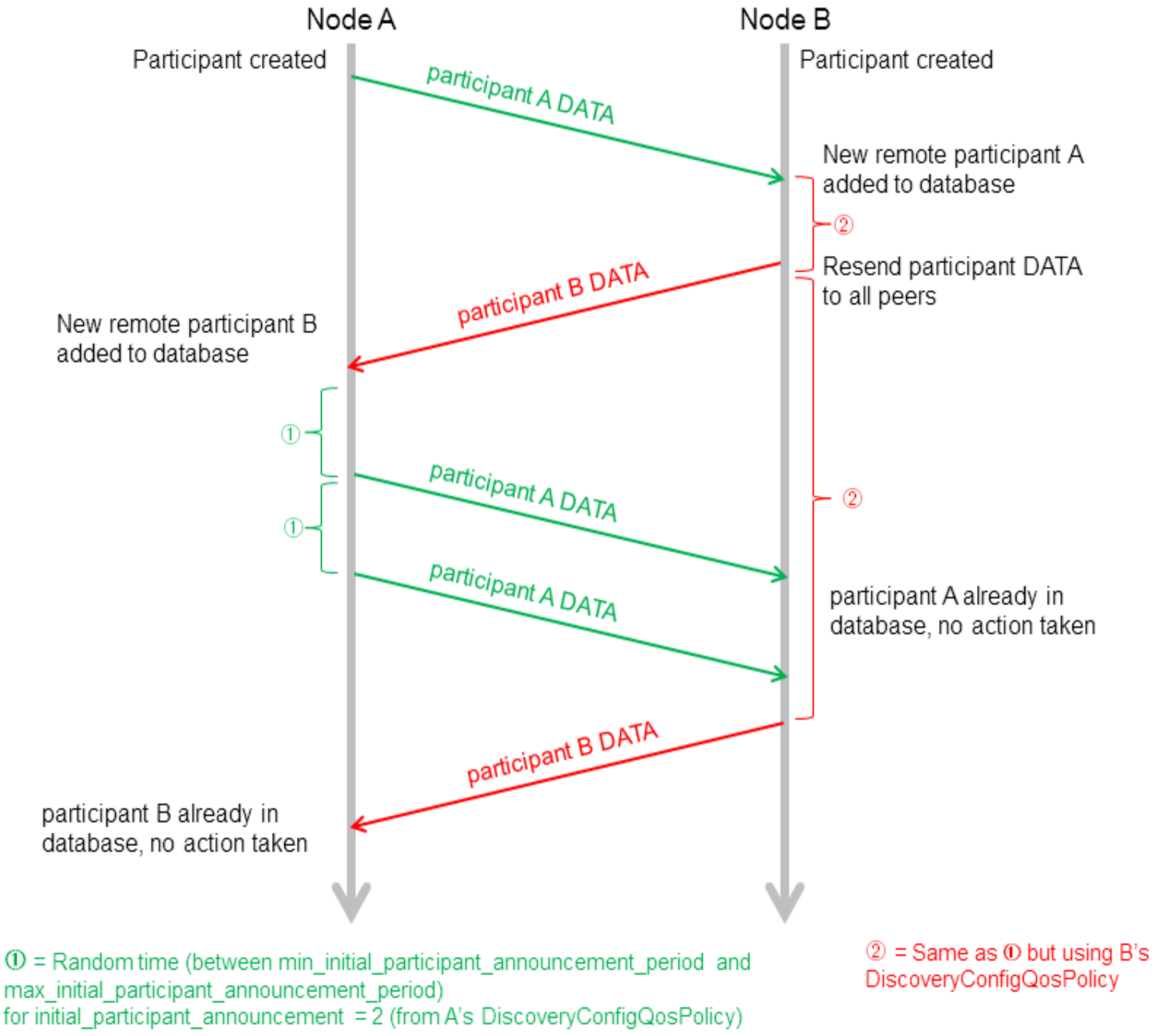
(Periodic resends of 'participant B DATA' from B to A are omitted from this diagram for simplicity. Initial repeat messages from A to B are also omitted from this diagram—these messages are sent at a random time between ***min_initial_participant_announcement_period*** *and* ***max_initial_participant_announcement_period****, see Figure 15.3: Periodic 'participant DATAs' on the previous page.)*

15.3.1.1 Refresh Mechanism

To ensure that a late-joining participant does not need to wait until the next refresh of the remote *participant DATA* to discover the remote participant, there is a resend mechanism. If the received *participant DATA* is from a never-before-seen remote participant, and it is in the local participant's peers list, the application will resend its own *participant DATA* to *all its peers*. This resend can potentially be done multiple times, with a random sleep time in between. Figure 15.5: Resending 'participant DATA' to a Late-Joiner on the next page illustrates this scenario.

The number of retries and the random amount of sleep between them are controlled by each participant's 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639 (see Figure 15.5: Resending 'participant DATA' to a Late-Joiner on the next page).

Figure 15.5: Resending 'participant DATA' to a Late-Joiner

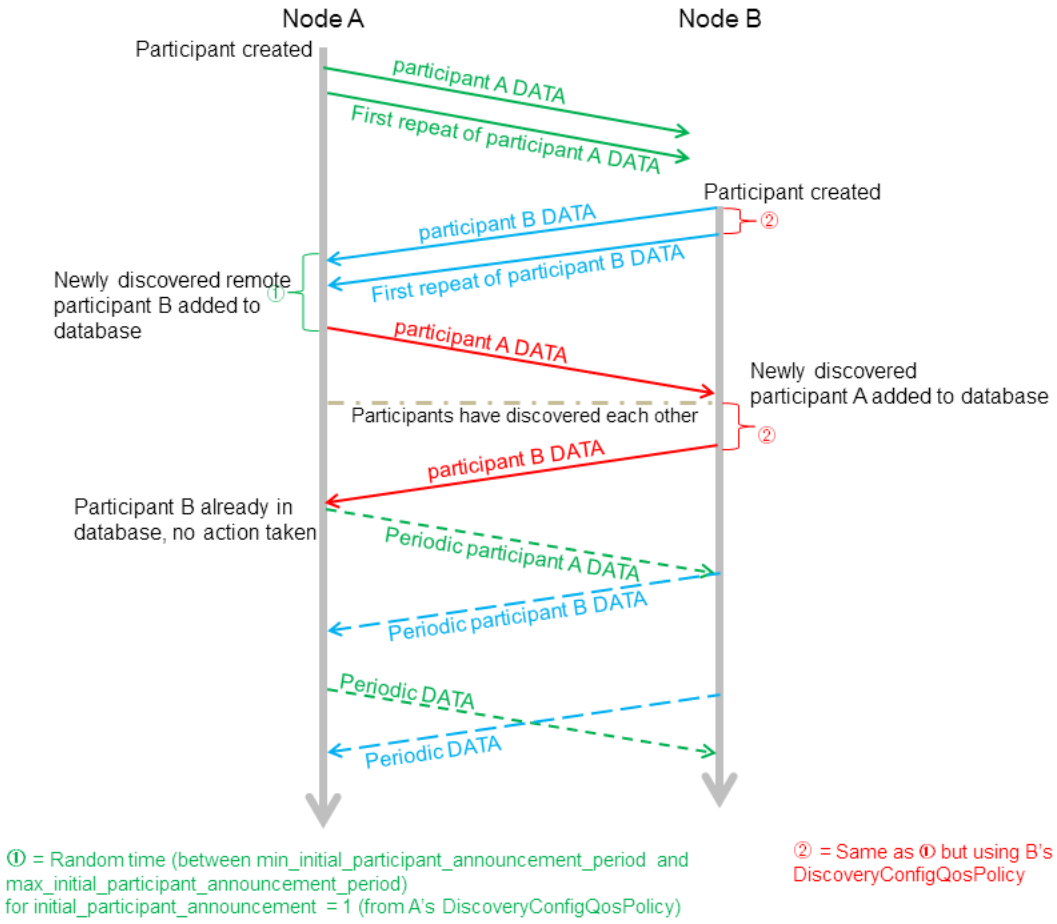


Participant A has Participant B in its peers list. Participant B does not have Participant A in its peers list, but [DiscoveryQosPolicy.accept_unknown_peers] is set to DDS_BOOLEAN_TRUE. Participant A joins the system after B has sent its initial announcement. After B discovers A, it waits for time Á, then resends its participant DATA.

(Initial repeat messages are omitted from this diagram for simplicity, see Figure 15.3: Periodic 'participant DATAs' on page 769.)

Figure 15.6: Participant Discovery Summary below provides a summary of the messages sent during the participant discovery phase.

Figure 15.6: Participant Discovery Summary



Participants A and B both have each other in their peers lists. Participant A is created first.

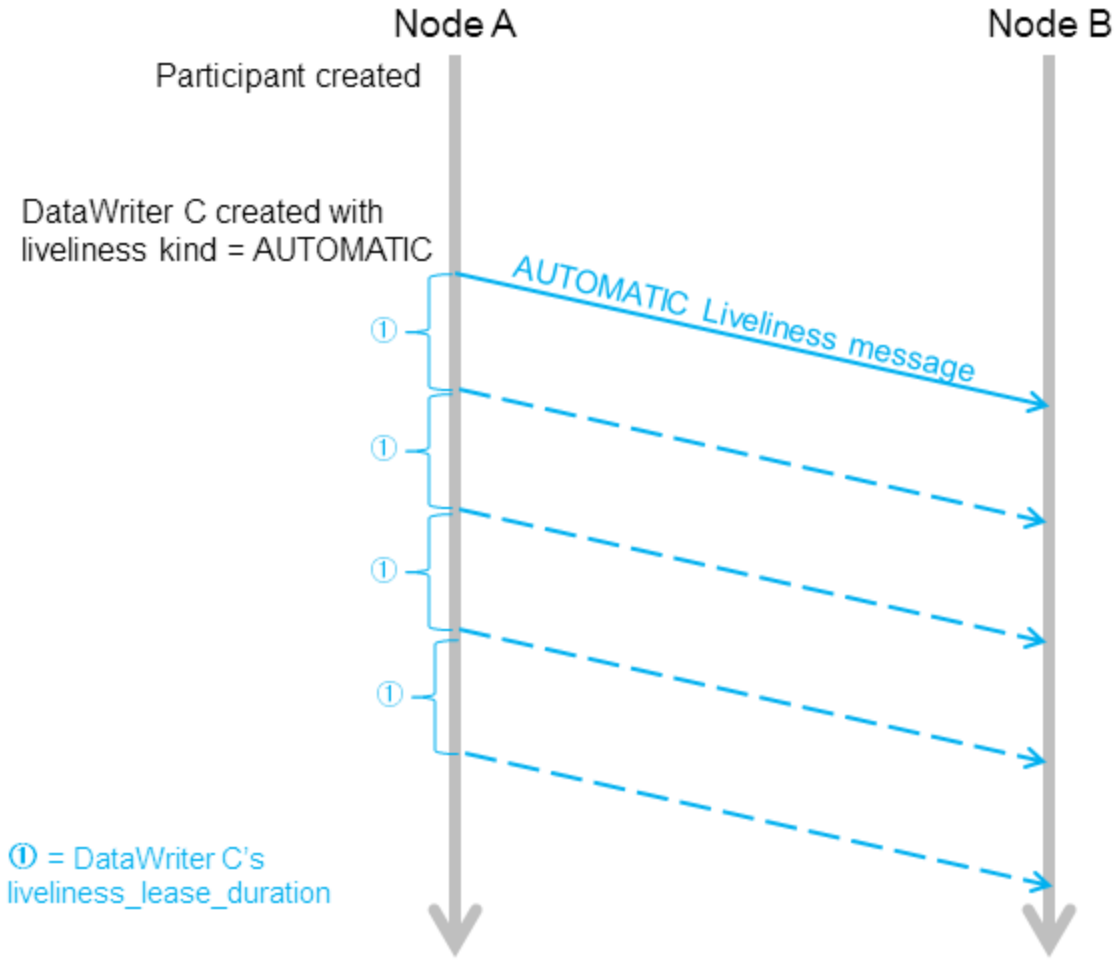
15.3.1.2 Maintaining DataWriter Liveliness for kinds AUTOMATIC and MANUAL_BY_PARTICIPANT

To maintain the liveliness of *DataWriters* that have a 7.5.15 LIVELINESS QosPolicy on page 425 **kind** field set to **AUTOMATIC** or **MANUAL_BY_PARTICIPANT**, *Connext DDS* uses a built-in *DataWriter* and *DataReader* pair, referred to as the *inter-participant reader* and *inter-participant writer*.

If the *DomainParticipant* has any *DataWriters* with Liveliness QosPolicy **kind** set to **AUTOMATIC**, the inter-participant writer will reliably broadcast an **AUTOMATIC** liveliness message at a period equal to the shortest **lease_duration** of these *DataWriters*. (The **lease_duration** is a field in the 7.5.15

LIVELINESS QosPolicy on page 425.) Figure 15.7: DataWriter with AUTOMATIC Liveliness below illustrates this scenario.

Figure 15.7: DataWriter with AUTOMATIC Liveliness

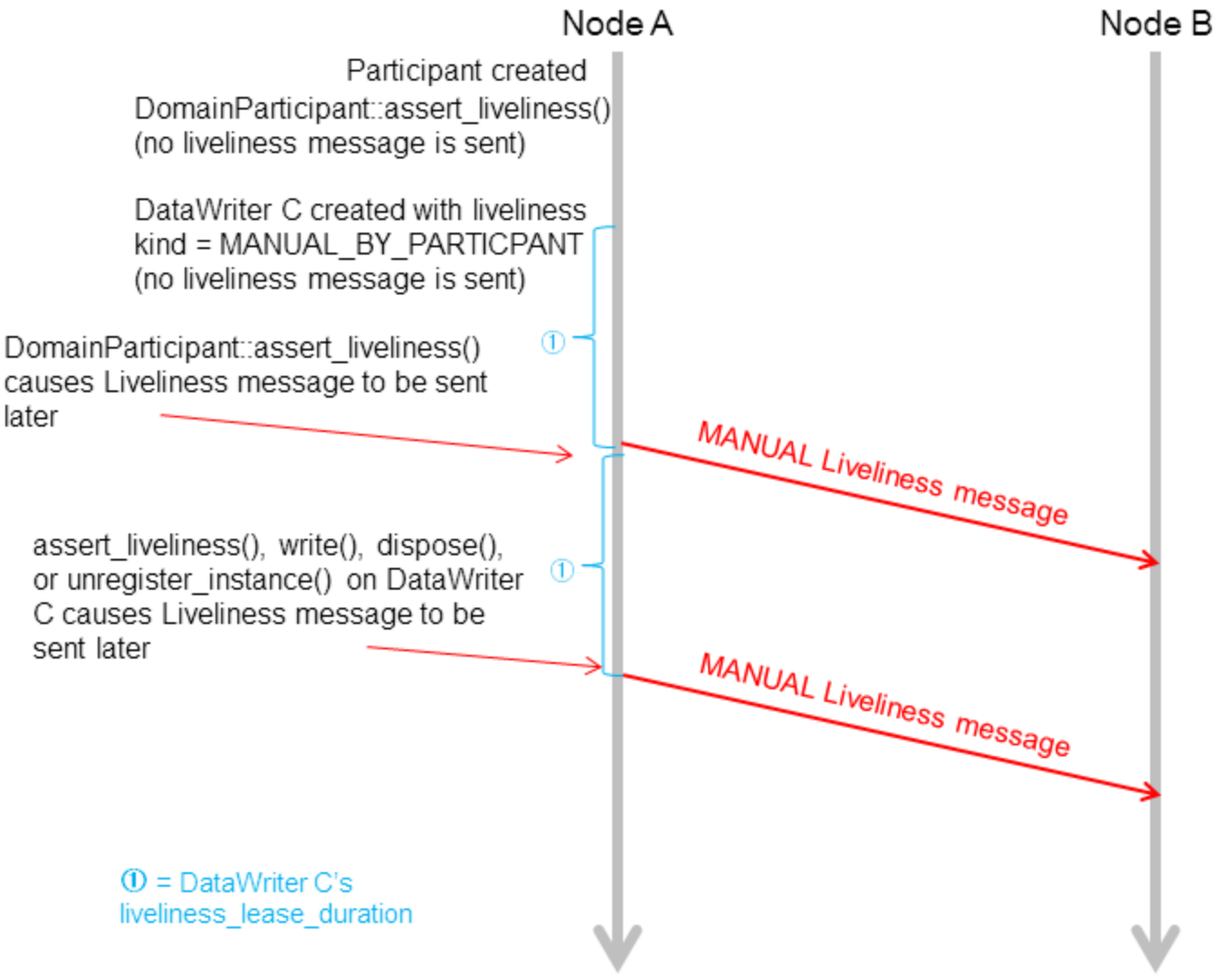


*A liveliness message is sent automatically when a DataWriter with AUTOMATIC Liveliness kind is created, and then periodically, every **DDS_DataWriterQos.liveliness.lease_duration**.*

If the *DomainParticipant* has any *DataWriters* with Liveliness QosPolicy **kind** set to **MANUAL_BY_PARTICIPANT**, *Connext DDS* will periodically check to see if any of them have called **write()**, **assert_liveliness()**, **dispose()** or **unregister()**. The rate of this check is every X seconds, where X is the smallest **lease_duration** among all the *DomainParticipant's* **MANUAL_BY_PARTICIPANT** *DataWriters*. (The **lease_duration** is a field in the 7.5.15 LIVELINESS QosPolicy on page 425.) If any of the **MANUAL_BY_PARTICIPANT** *DataWriters* have called any of those operations, the inter-participant writer will reliably broadcast a **MANUAL** liveliness message.

If a *DomainParticipant's* **assert_liveliness()** operation is called, and that *DomainParticipant* has any **MANUAL_BY_PARTICIPANT** *DataWriters*, the inter-participant writer will reliably broadcast a **MANUAL** liveliness message within the above-defined X time period. These **MANUAL** liveliness messages are used to update the liveliness of all the *DomainParticipant's* **MANUAL_BY_PARTICIPANT** *DataWriters*, as well as the liveliness of the *DomainParticipant* itself. Figure 15.8: DataWriter with MANUAL_BY_PARTICIPANT Liveliness below shows an example sequence.

Figure 15.8: DataWriter with MANUAL_BY_PARTICIPANT Liveliness



Once a MANUAL_BY_PARTICIPANT DataWriter is created, subsequent calls to assert_liveliness, write, dispose, or unregister_instance will trigger Liveliness messages, which update the liveliness status of all the participant's DataWriters, and the participant itself.

The inter-participant reader receives data from remote inter-participant writers and asserts the liveliness of remote *DomainParticipants* endpoints accordingly.

If the *DomainParticipant* has no *DataWriters* with 7.5.15 LIVELINESS QosPolicy on page 425 **kind** set to **AUTOMATIC** or **MANUAL_BY_PARTICIPANT**, then no liveliness messages are ever sent from the inter-participant writer.

15.3.2 Endpoint Discovery

As we saw in Figure 15.2: Built-in Writers and Readers for Discovery on page 767, reliable *DataReaders* and *Datawriters* are automatically created to exchange publication/subscription information for each *DomainParticipant*. We will refer to these as 'discovery endpoint readers and writers.' However, nothing is sent through the network using these entities until they have been 'matched' with their remote counterparts. This 'matching' is triggered by the Participant Discovery phase. The goal of the Endpoint Discovery phase is to add the remote endpoint to the local database, so that user-created endpoints (your application's *DataWriters*/*DataReaders*) can communicate with each other.

When a new remote *DomainParticipant* is discovered and added to a participant's database, *Connext DDS* assumes that the remote *DomainParticipant* is implemented in the same way and therefore is creating the appropriate counterpart entities. Therefore, *Connext DDS* will automatically add two remote discovery endpoint readers and two remote discovery endpoint writers for that remote *DomainParticipant* into the local database. Once that is done, there is now a match with the local discovery endpoint writers and readers, and *publication DATAs* and *subscription DATAs* can then be sent between the discovery endpoint readers/writers of the two *DomainParticipant*.

When you create a *DataWriter*/*DataReader* for your user data, a *publication/subscription DATA* describing the newly created object is sent from the local discovery endpoint writer to the remote discovery endpoint readers of the remote *DomainParticipant*s that are currently in the local database.

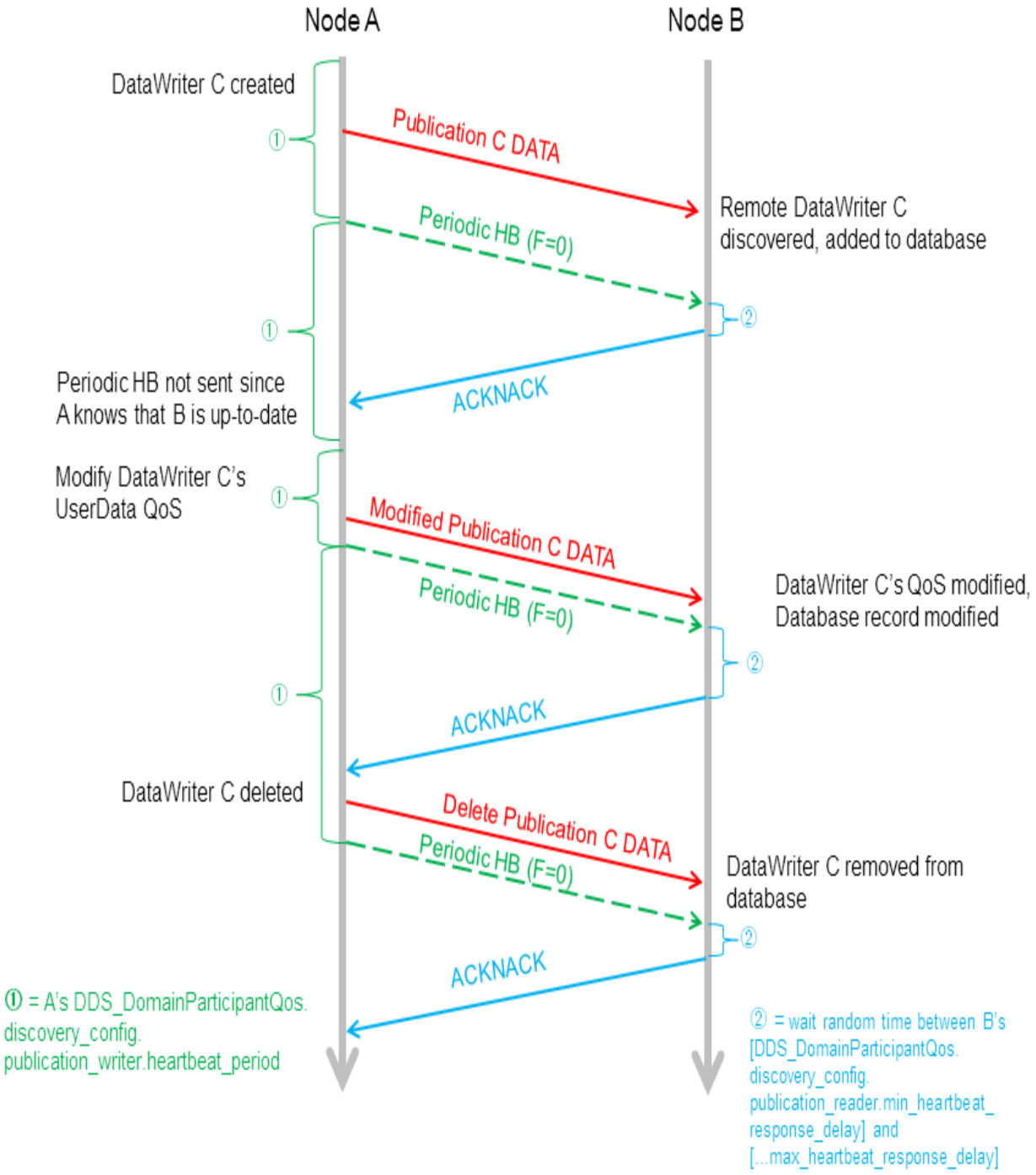
If your application changes any of the following QosPolicies for a local user-data *DataWriter/DataReader*, a modified *subscription/publication DATA* is sent to propagate the QoS change to other *DomainParticipant*s:

- 5.2.1 TOPIC_DATA QosPolicy on page 224
- 7.4.4 GROUP_DATA QosPolicy on page 352
- 7.5.30 USER_DATA QosPolicy on page 462
- 7.5.18 OWNERSHIP_STRENGTH QosPolicy on page 435
- 7.4.5 PARTITION QosPolicy on page 355
- 8.6.4 TIME_BASED_FILTER QosPolicy on page 583
- 7.5.14 LIFESPAN QoS Policy on page 423

What the above QosPolicies have in common is that they are all changeable and part of the built-in data (see Built-In Topics (Chapter 18 on page 825)).

Similarly, if the application deletes any user-data writers/readers, the discovery endpoint writer/readers send *delete publication/subscription DATAs*. In addition to sending *publication/subscription DATAs*, the discovery endpoint writer will check periodically to see if the remote discovery endpoint reader is up-to-date. (The rate for this check is the publication_writer.heartbeat_period or subscription_writer.heartbeat_period in the 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639. If the discovery endpoint writer has not been acknowledged by the remote discovery endpoint reader regarding receipt of the latest DATA, the discovery endpoint writer will send a special Heartbeat (HB) message with the Final bit set to 0 (F=0) to request acknowledgement from the remote discovery endpoint reader, as seen in Figure 15.9: Endpoint Discovery Summary on the next page.

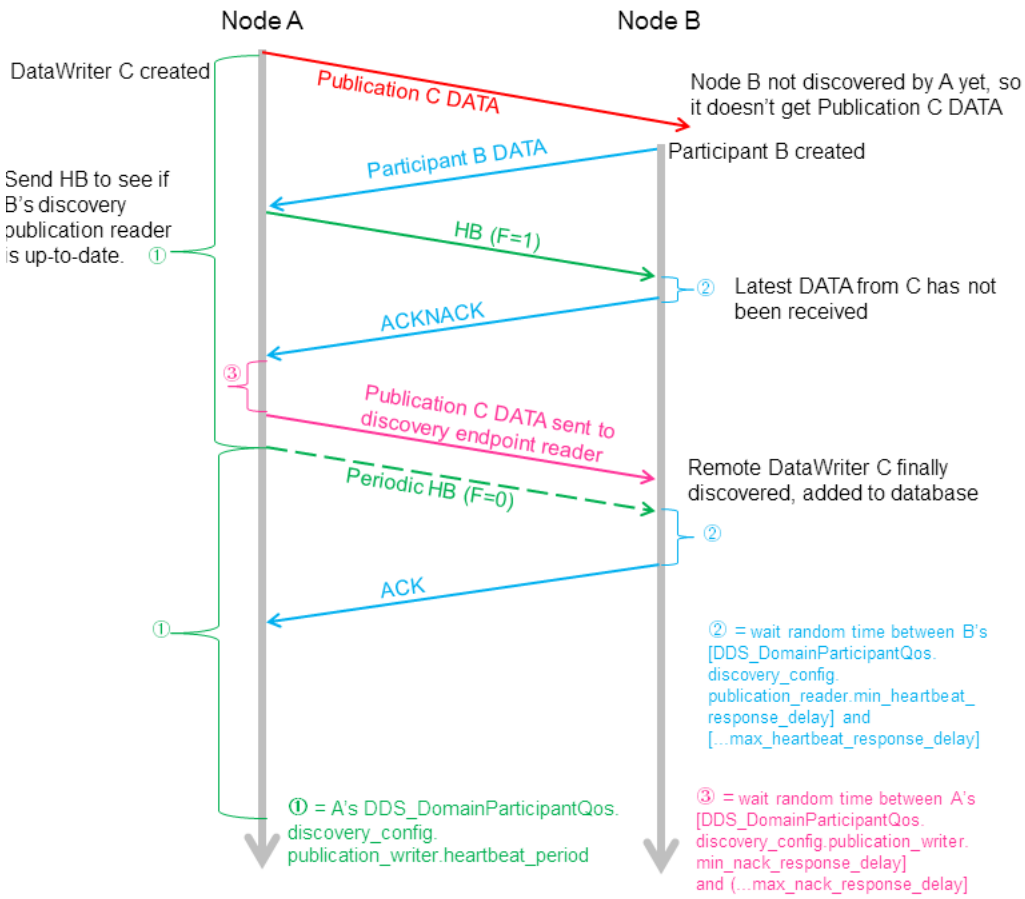
Figure 15.9: Endpoint Discovery Summary



Assume participants A and B have been discovered on both sides. A's DiscoveryConfigQosPolicy.publication_writer-.heartbeats_per_max_samples = 0, so no HB is piggybacked with the publication DATA. A HB with F=0 is a request for an ACK/NACK. The periodic and initial repeat participant DATAs are omitted from the diagram.

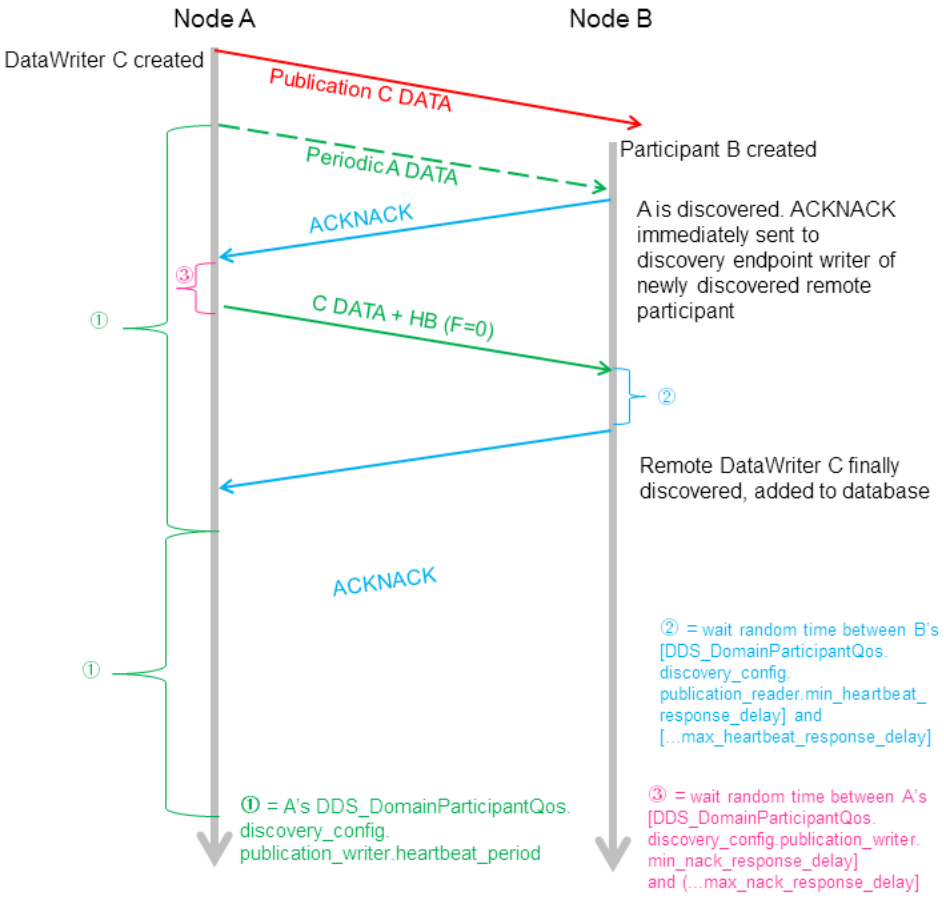
Discovery endpoint writers and readers have their 7.5.12 HISTORY QosPolicy on page 418 set to KEEP_LAST, and their 7.5.9 DURABILITY QosPolicy on page 410 set to TRANSIENT_LOCAL. Therefore, even if the remote *DomainParticipant* has not yet been discovered at the time the local user's *DataWriter/DataReader* is created, the remote *DomainParticipant* will still be informed about the previously created *DataWriter/DataReader*. This is achieved by the HB and ACK/NACK that are immediately sent by the built-in endpoint writer and built-in endpoint reader respectively when a new remote participant is discovered. Figure 15.10: DataWriter Discovered by Late-Joiner, Triggered by HB below and Figure 15.11: DataWriter Discovered by Late-Joiner, Triggered by ACKNACK on the next page illustrate this sequence for HB and ACK/NACK triggers, respectively.

Figure 15.10: DataWriter Discovered by Late-Joiner, Triggered by HB



Writer C is created on Participant A before Participant A discovers Participant B. Assuming DiscoveryConfigQosPolicy.publication_writer.heartbeats_per_max_samples = 0, no HB is piggybacked with the publication DATA. Participant B has A in its peer list, but not vice versa. Accept_unknown_locators is true. On A, in response to receiving the new participant B DATA message, a participant A DATA message is sent to B. The discovery endpoint reader on A will also send an ACK/NACK to the discovery endpoint writer on B. (Initial repeat participant messages and periodic participant messages are omitted from this diagram for simplicity, see Figure 15.3: Periodic 'participant DATAs' on page 769 in 15.3.1 Participant Discovery on page 767.)

Figure 15.11: DataWriter Discovered by Late-Joiner, Triggered by ACKNACK



Writer C is created on Participant A before Participant A discovers Participant B. Assuming DiscoveryConfigQosPolicy.publication_writer.heartbeats_per_max_samples = 0, no HB is piggybacked with the publication DATA message. Participant A has B in its peer list, but not vice versa. Accept_unknown_locators is true. In response to receiving the new Participant A DATA message on node B, a participant B DATA message will be sent to A. The discovery endpoint writer on Node B will also send a HB to the discovery endpoint reader on Node A. These are omitted in the diagram for simplicity. (Initial repeat participant messages and periodic participant messages are omitted from this diagram, see Figure 15.3: Periodic 'participant DATAs' on page 769 in 15.3.1 Participant Discovery on page 767.)

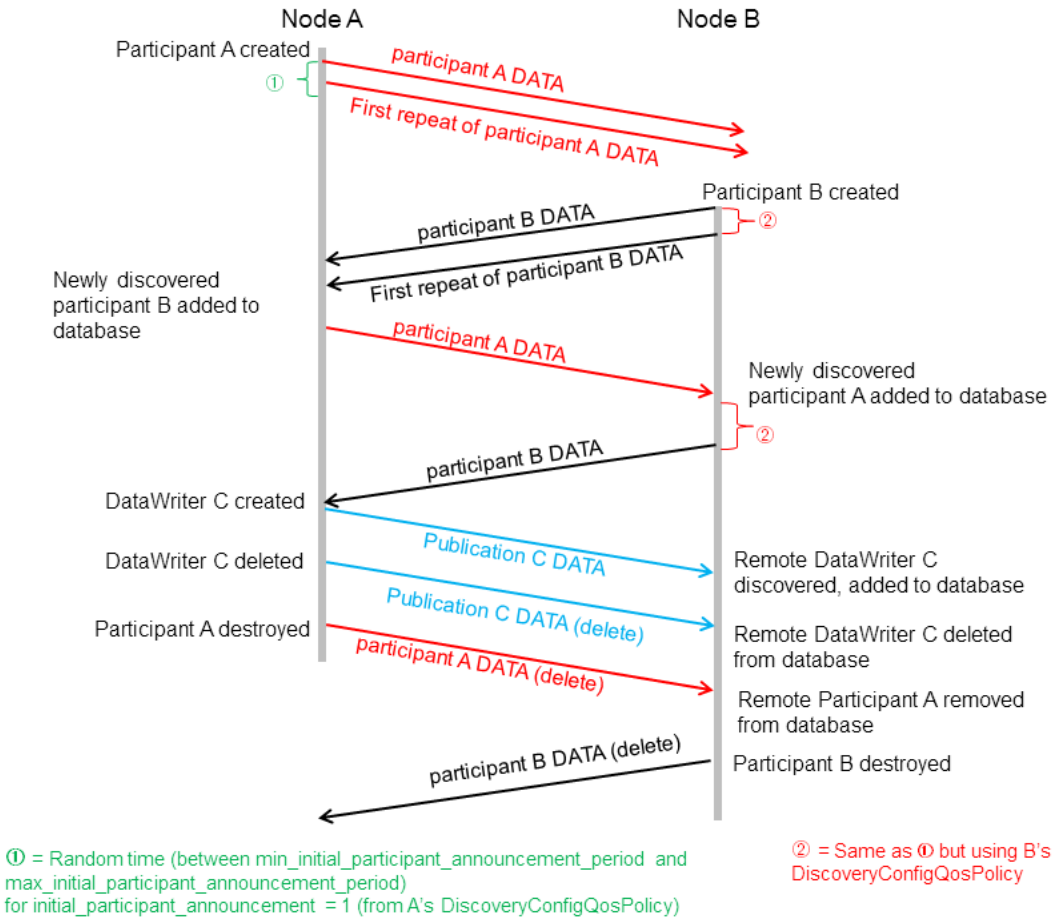
Endpoint discovery latency is determined by the following members of the *DomainParticipant's* 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639:

- **publication_writer**
- **subscription_writer**
- **publication_reader**
- **subscription_reader**

When a remote entity record is added, removed, or changed in the database, matching is performed with all the local entities. Only after there is a successful match on both ends can an application's user-created *DataReaders* and *DataWriters* communicate with each other.

For more information about reliable communication, see Reliable Communications (Chapter 11 on page 682).

15.3.3 Discovery Traffic Summary



This diagram shows both phases of the discovery process. Participant A is created first, followed by Participant B. Each has the other in its peers list. After they have discovered each other, a DataWriter is created on Participant A. Periodic participant DATAs, HBs and ACK/NACKs are omitted from this diagram.

15.3.4 Discovery-Related QoS

Each *DomainParticipant* needs to be uniquely identified in the DDS domain and specify which other *DomainParticipant*s it is interested in communicating with. The 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664 uniquely identifies a *DomainParticipant* in the DDS domain. The 9.5.2

DISCOVERY QosPolicy (DDS Extension) on page 635 specified the peer participants it is interested in communicating with.

There is a trade-off between the amount of traffic on the network for the purposes of discovery and the delay in reaching steady state when the *DomainParticipant* is first created.

For example, if the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635's participant_liveliness_assert_period and participant_liveliness_lease_duration fields are set to small values, the discovery of stale remote *DomainParticipant*s will occur faster, but more discovery traffic will be sent over the network. Setting the participant's **heartbeat_period**[1] to a small value can cause late-joining *DomainParticipant*s to discover remote user-data *DataWriters* and *DataReaders* at a faster rate, but *Connext DDS* might send HBs to other nodes more often. This timing can be controlled by the following *DomainParticipant* QosPolicies:

- 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635 — specifies how other *DomainParticipant*s in the network can communicate with this *DomainParticipant*, and which other *DomainParticipant*s in the network this *DomainParticipant* is interested in communicating with. See also: 15.5 Ports Used for Discovery on page 785.
- 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639 — specifies the QoS of the discovery readers and writers (parameters that control the HB and ACK rates of discovery endpoint readers/writers, and periodic refreshing of *participant DATA* from discovery participant readers/writers). It also allow you to configure asynchronous writers in order to send data with a larger size than the transport message size.
- 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649 — specifies the number of local and remote entities expected in the system.
- 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664 — specifies the rtps_app_id and rtps_host_id that uniquely identify the participant in the DDS domain.

The other important parameter is the domain ID: *DomainParticipant*s can only discover each other if they belong to the same DDS domain. The domain ID is a parameter passed to the **create_participant()** operation (see 9.3.1 Creating a DomainParticipant on page 610).

15.4 Debugging Discovery

To understand the flow of messages during discovery, you can increase the verbosity of the messages logged by *Connext DDS* so that you will see whenever a new entity is discovered, and whenever there is a match between a local entity and a remote entity.

This can be achieved with the logging API:

[1] **heartbeat_period** is part of the DDS_RtpsReliableWriterProtocol_t structure used in the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635's **publication_writer** and **subscription_writer** fields.

```
NDDSConfigLogger::get_instance()->set_verbosity_by_category (NDDS_CONFIG_LOG_CATEGORY_ENTITIES,
NDDS_CONFIG_LOG_VERBOSITY_STATUS_REMOTE);
```

Using the scenario in the summary diagram in 15.3.3 Discovery Traffic Summary on page 781, these are the messages as seen on DomainParticipant A:

```
[D0049|ENABLE]DISCPluginManager_onAfterLocalParticipantEnabled:announcing new local
participant: 0XA0A01A1,0X5522,0X1,0X1C1
[D0049|ENABLE]DISCPluginManager_onAfterLocalParticipantEnabled:at {46c614d9,0C43B2DC}
```

(The above messages mean: First participant A DATA sent out when participant A is enabled.)

```
DISCSimpleParticipantDiscoveryPluginReaderListener_onDataAvailable:discovered new participant:
host=0x0A0A01A1, app=0x0000552B, instance=0x00000001
DISCSimpleParticipantDiscoveryPluginReaderListener_onDataAvailable:at {46c614dd,8FA13C1F}
DISCParticipantDiscoveryPlugin_assertRemoteParticipant:plugin discovered/updated remote
participant: 0XA0A01A1,0X552B,0X1,0X1C1
DISCParticipantDiscoveryPlugin_assertRemoteParticipant:at {46c614dd,8FACE677}
DISCParticipantDiscoveryPlugin_assertRemoteParticipant:plugin accepted new remote participant:
0XA0A01A1,0X552B,0X1,0X1C1
DISCParticipantDiscoveryPlugin_assertRemoteParticipant:at {46c614dd,8FACE677}
```

(The above messages mean: Received participant B DATA.)

```
DISCSimpleParticipantDiscoveryPlugin_remoteParticipantDiscovered:re-announcing participant
self: 0XA0A01A1,0X5522,0X1,0X1C1
DISCSimpleParticipantDiscoveryPlugin_remoteParticipantDiscovered:at {46c614dd,8FC02AF7}
```

(The above messages mean: Resending participant A DATA to the newly discovered remote participant.)

```
PRESPsService_linkToLocalReader:assert remote 0XA0A01A1,0X552B,0X1,0X200C2, local 0x000200C7 in
reliable reader service
PRESPsService_linkToLocalWriter:assert remote 0XA0A01A1,0X552B,0X1,0X200C7, local 0x000200C2 in
reliable writer service
PRESPsService_linkToLocalWriter:assert remote 0XA0A01A1,0X552B,0X1,0X4C7, local 0x000004C2 in
reliable writer service
PRESPsService_linkToLocalWriter:assert remote 0XA0A01A1,0X552B,0X1,0X3C7, local 0x000003C2 in
reliable writer service
PRESPsService_linkToLocalReader:assert remote 0XA0A01A1,0X552B,0X1,0X4C2, local 0x000004C7 in
reliable reader service
PRESPsService_linkToLocalReader:assert remote 0XA0A01A1,0X552B,0X1,0X3C2, local 0x000003C7 in
reliable reader service
PRESPsService_linkToLocalReader:assert remote 0XA0A01A1,0X552B,0X1,0X100C2, local 0x000100C7 in
best effort reader service
```

(The above messages mean: Automatic matching of the discovery readers and writers. A built-in remote endpoint's object ID always ends with Cx.)

```
DISCSimpleParticipantDiscoveryPluginReaderListener_onDataAvailable:discovered modified
participant: host=0x0A0A01A1, app=0x0000552B, instance=0x00000001
DISCParticipantDiscoveryPlugin_assertRemoteParticipant:plugin discovered/updated remote
participant: 0XA0A01A1,0X552B,0X1,0X1C1
DISCParticipantDiscoveryPlugin_assertRemoteParticipant:at {46c614dd,904D876C}
```

(The above messages mean: Received participant B DATA.)

```
DISCPluginManager_onAfterLocalEndpointEnabled:announcing new local publication:
0XA0A01A1,0X5522,0X1,0X80000003
DISCPluginManager_onAfterLocalEndpointEnabled:at {46c614d9,1013B9F0}
DISCSimpleEndpointDiscoveryPluginPDFListener_onAfterLocalWriterEnabled:announcing new
publication: 0XA0A01A1,0X5522,0X1,0X80000003
DISCSimpleEndpointDiscoveryPluginPDFListener_onAfterLocalWriterEnabled:at {46c614d9,101615EB}
```

(The above messages mean: Publication C DATA has been sent.)

```
DISCSimpleEndpointDiscoveryPlugin_subscriptionReaderListenerOnDataAvailable:discovered
subscription: 0XA0A01A1,0X552B,0X1,0X80000004
DISCSimpleEndpointDiscoveryPlugin_subscriptionReaderListenerOnDataAvailable:at
{46c614dd,94FAEFEF}
DISCEndpointDiscoveryPlugin_assertRemoteEndpoint:plugin discovered/updated remote endpoint:
0XA0A01A1,0X552B,0X1,0X80000004
DISCEndpointDiscoveryPlugin_assertRemoteEndpoint:at {46c614dd,950203DF}
```

(The above messages mean: Receiving subscription D DATA from Node B.)

```
PRESPsService_linkToLocalWriter:assert remote 0XA0A01A1,0X552B,0X1,0X80000004, local 0x80000003
in best effort writer service
```

(The above message means: User-created DataWriter C and DataReader D are matched.)

```
[D0049|DELETE_CONTAINED]DISCPluginManager_onAfterLocalEndpointDeleted:announcing disposed local
publication: 0XA0A01A1,0X5522,0X1,0X80000003
[D0049|DELETE_CONTAINED]DISCPluginManager_onAfterLocalEndpointDeleted:at {46c61501,288051C8}
[D0049|DELETE_CONTAINED]DISCSimpleEndpointDiscoveryPluginPDFListener_
onAfterLocalWriterDeleted:announcing disposed publication: 0XA0A01A1,0X5522,0X1,0X80000003
[D0049|DELETE_CONTAINED]DISCSimpleEndpointDiscoveryPluginPDFListener_
onAfterLocalWriterDeleted:at {46c61501,28840E15}
```

(The above messages mean: Publication C DATA(delete) has been sent.)

```
DISCPluginManager_onBeforeLocalParticipantDeleted:announcing before disposed local participant:
0XA0A01A1,0X5522,0X1,0X1C1
DISCPluginManager_onBeforeLocalParticipantDeleted:at {46c61501,28A11663}
```

(The above messages mean: Participant A DATA(delete) has been sent.)

```
DISCParticipantDiscoveryPlugin_removeRemoteParticipantsByCookie:plugin removing 3 remote
entities by cookie
DISCParticipantDiscoveryPlugin_removeRemoteParticipantsByCookie:at {46c61501,28E38A7C}
DISCParticipantDiscoveryPlugin_removeRemoteParticipantI:plugin discovered disposed remote
participant: 0XA0A01A1,0X552B,0X1,0X1C1
DISCParticipantDiscoveryPlugin_removeRemoteParticipantI:at {46c61501,28E68E3D}
DISCParticipantDiscoveryPlugin_removeRemoteParticipantI:remote entity removed from database:
0XA0A01A1,0X552B,0X1,0X1C1
DISCParticipantDiscoveryPlugin_removeRemoteParticipantI:at {46c61501,28E68E3D}
```

(The above messages mean: Removing discovered entities from local database, before shutting down.)

As you can see, the messages are encoded, since they are primarily used by RTI support personnel.

For more information on the message logging API, see 25.2 Controlling Messages from Connext DDS on page 968.

If you notice that a remote entity is not being discovered, check the QoS related to discovery (see 15.3.4 Discovery-Related QoS on page 781).

If a remote entity is discovered, but does not match with a local entity as expected, check the QoS of both the remote and local entity.

15.5 Ports Used for Discovery

There are two kinds of traffic in a *Connext DDS* application: discovery (meta) traffic, and user traffic. Meta-traffic is for data (declarations) that is sent between the automatically-created discovery writers and readers; user traffic is for data that is sent between user-created *DataWriters* and *DataReaders*. To keep the two kinds of traffic separate, *Connext DDS* uses different ports, as described below.

Note: The ports described in this section are used for *incoming* data. *Connext DDS* uses ephemeral ports for outbound data.

Connext DDS uses the RTPS wire protocol. The discovery protocols defined by RTPS rely on well-known ports to initiate discovery. These well-known ports define the multicast and unicast ports on which a Participant will listen for meta-traffic from other Participants. The meta-traffic contains the information required by *Connext DDS* to establish the presence of remote *Entities* in the network.

The well-known incoming ports are defined by RTPS in terms of port mapping expressions with several tunable parameters. This allows you to customize what network ports are used for receiving data by *Connext DDS*. These parameters are shown in Table 15.2 WireProtocol QosPolicy's rtps_well_known_ports (DDS_RtpsWellKnownPorts_t). (For defaults and valid ranges, please see the API Reference HTML documentation.)

Table 15.2 WireProtocol QosPolicy's rtps_well_known_ports (DDS_RtpsWellKnownPorts_t)

Type	Field Name	Description
DDS_Long	port_base	The base port offset. All mapped well-known ports are offset by this value. Resulting ports must be within the range imposed by the underlying transport.
	domain_id_gain	Tunable gain parameters. See 15.5.4 Tuning domain_id_gain and participant_id_gain on page 787.
	participant_id_gain	
	builtin_multicast_port_offset	Additional offset for meta-traffic port. See 15.5.1 Inbound Ports for Meta-Traffic on the next page.
	builtin_unicast_port_offset	
	user_multicast_port_offset	Additional offset for user traffic port. See 15.5.2 Inbound Ports for User Traffic on page 787.
	user_unicast_port_offset	

In order for all Participants in a system to correctly discover each other, it is important that they all use the same port mapping expressions.

In addition to the parameters listed in Table 15.2 WireProtocol QosPolicy's rtps_well_known_ports (DDS_RtpsWellKnownPorts_t), the port formulas described below depend on:

- The domain ID specified when the *DomainParticipant* is created (see 9.3.1 Creating a DomainParticipant on page 610). The domain ID ensures no port conflicts exist between Participants belonging to different domains. This also means that discovery traffic in one DDS domain is not visible to *DomainParticipant*s in other DDS domains.
- The **participant_id** is a field in the 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664, see 9.5.9.1 Choosing Participant IDs on page 665. The **participant_id** ensures that unique unicast port numbers are assigned to *DomainParticipant*s belonging to the same DDS domain on a given host.

Backwards Compatibility: *Connext DDS* supports the standard DDS Interoperability Wire Protocol based on the Real-time Publish-Subscribe (RTPS) protocol. This protocol is not compatible with the one used by earlier releases (4.2c or lower). Therefore, applications built with 4.2d or higher will not interoperate with applications built with 4.2c or lower. The default port mapping from domainID and participant index has also been changed according to the new interoperability specification. The message types and formats used by RTPS have also changed.

Port Aliasing: When modifying the port mapping parameters, *avoid port aliasing*. This would result in undefined discovery behavior. The chosen parameter values will also determine the maximum possible number of DDS domains in the system and the maximum number of participants per DDS domain. Additionally, any resulting mapped port number must be within the range imposed by the underlying transport. For example, for UDPv4, this range typically equals [1024 - 65535].

15.5.1 Inbound Ports for Meta-Traffic

The Wire Protocol QosPolicy's **rtps_well_known_ports.metatraffic_unicast_port** determines the port used for receiving meta-traffic using unicast:

```
metatraffic_unicast_port = port_base +
                (domain_id_gain * Domain ID) +
                (participant_id_gain * participant_id) +
                builtin_unicast_port_offset
```

Similarly, **rtps_well_known_ports.metatraffic_multicast_port** determines the port used for receiving meta-traffic using multicast. The corresponding multicast group addresses are specified via **multicast_receive_addresses** (see 9.5.2.4 Configuring Multicast Receive Addresses on page 637).

```
metatraffic_multicast_port = port_base +
                (domain_id_gain * Domain ID) +
                builtin_multicast_port_offset
```

Note: Multicast is only used for meta-traffic if a multicast address is specified in the NDDS_DISCOVERY_PEERS environment variable or file or if the **multicast_receive_addresses** field of the 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639 is set.

15.5.2 Inbound Ports for User Traffic

RTPS also defines the default multicast and unicast ports on which *DataReaders* and *DataWriters* receive user traffic. These default ports can be overridden using the *DataReader's* 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586 and 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458, or the *DataWriter's* 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458.

The WireProtocol QosPolicy's **rtps_well_known_ports.usertraffic_unicast_port** determines the port used for receiving user data using unicast:

```
usertraffic_unicast_port =
        port_base +
       (domain_id_gain * Domain ID) +
       (participant_id_gain * participant_id)+
        user_unicast_port_offset
```

Similarly, **rtps_well_known_ports.usertraffic_multicast_port** determines the port used for receiving user data using multicast. The corresponding multicast group addresses can be configured using the 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458.

```
usertraffic_multicast_port =
        port_base +
       (domain_id_gain * Domain ID) +
        user_multicast_port_offset
```

15.5.3 Automatic Selection of participant_id and Port Reservation

The 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664**rtps_reserved_ports_mask** field determines what type of ports are reserved when the *DomainParticipant* is enabled. See 9.5.9.1 Choosing Participant IDs on page 665.

15.5.4 Tuning domain_id_gain and participant_id_gain

The **domain_id_gain** is used as a multiplier of the domain ID. Together with **participant_id_gain** (15.5.4 Tuning domain_id_gain and participant_id_gain above), these values determine the highest domain ID and **participant_id** allowed on this network.

In general, there are two ways to set up the **domain_id_gain** and **participant_id_gain** parameters.

- If **domain_id_gain** > **participant_id_gain**, it results in a port mapping layout where all *DomainParticipants* in a DDS domain occupy a consecutive range of **domain_id_gain** ports. Precisely, all ports occupied by the DDS domain fall within:

  ```
  (port_base + (domain_id_gain * Domain ID))
  ```

  and:

  ```
  (port_base + (domain_id_gain * (Domain ID + 1)) - 1)
  ```

  In this case, the highest domain ID is limited only by the underlying transport's maximum port. The highest **participant_id**, however, must satisfy:

  ```
  max_participant_id < (domain_id_gain / participant_id_gain)
  ```

- Or if **domain_id_gain** <= **participant_id_gain**, it results in a port mapping layout where a given DDS domain's *DomainParticipant* instances occupy ports spanned across the entire valid port range allowed by the underlying transport. For instance, it results in the following potential mapping:

<table>
<tr><th>Mapped Port</th><th>Domain ID</th><th>Participant ID</th></tr>
<tr><td rowspan="6">higher port number</td><td>1</td><td rowspan="2">2</td></tr>
<tr><td>0</td></tr>
<tr><td>1</td><td rowspan="2">1</td></tr>
<tr><td>0</td></tr>
<tr><td>1</td><td rowspan="2">0</td></tr>
<tr><td>lower port number</td><td>0</td></tr>
</table>

In this case, the highest **participant_id** is limited only by the underlying transport's maximum port. The highest **domain_id**, however, must satisfy:

```
max_domain_id < (participant_id_gain / domain_id_gain)
```

The **domain_id_gain** also determines the range of the port-specific offsets:

```
domain_id_gain >
abs(builtin_multicast_port_offset - user_multicast_port_offset)
```

and

```
domain_id_gain >
abs(builtin_unicast_port_offset - user_unicast_port_offset)
```

Violating this may result in port aliasing and undefined discovery behavior.

The **participant_id_gain** also determines the range of **builtin_unicast_port_offset** and **user_unicast_port_offset**.

```
participant_id_gain >
abs(builtin_unicast_port_offset - user_unicast_port_offset)
```

In all cases, the resulting ports must be within the range imposed by the underlying transport.

Chapter 16 Transport Plugins

Connext DDS has a pluggable-transports architecture. The core of *Connext DDS* is transport agnostic—it does not make any assumptions about the actual transports used to send and receive messages. Instead, *Connext DDS* uses an abstract "transport API" to interact with the transport plugins that implement that API. A transport plugin implements the abstract transport API, and performs the actual work of sending and receiving messages over a physical transport.

There are essentially three categories of transport plugins:

- **Builtin Transport Plugins** *Connext DDS* comes with a set of commonly used transport plugins. These 'builtin' plugins include UDPv4, UDPv6, and shared memory. So that *Connext DDS* applications can work out-of-the-box, some of these are enabled by default (see 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660).
- **Extension Transport Plugins** RTI offers extension transports, including *RTI Secure WAN Transport* (see Part 6: RTI Secure WAN Transport on page 1089 and *RTI TCP Transport* (see Part 7: RTI TCP Transport on page 1122).
- **Custom-developed Transport Plugins** RTI supports the use of custom transport plugins. This is a powerful capability that distinguishes *Connext DDS* from competing middleware approaches. If you are interested in developing a custom transport plugin for *Connext DDS*, please contact your local RTI representative or email **sales@rti.com**.

16.1 Builtin Transport Plugins

There are two ways in which the builtin transport plugins may be registered:

- **Default builtin Transport Instances**: Builtin transports that are turned "on" in the 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660 are implicitly registered when (a) the *DomainParticipant* is enabled, (b) the first *DataWriter/DataReader* is created, or (c) you look up a builtin *DataReader* (by calling **lookup_datareader()** on a Subscriber), whichever happens first. The builtin transport plugins have default properties. If

you want to change these properties, do so *before*[1] the transports are registered.

- **Other Transport Instances**: There are two ways to install non-default builtin transport instances:
  - Transport plugins may be explicitly registered by first creating an instance of the transport plugin (by calling **NDDS_Transport_UDPv4_new()**, **NDDS_Transport_UDPv6_new()** or **NDDS_Transport_Shmem_new()**, see 16.4 Explicitly Creating Builtin Transport Plugin Instances on the next page), then calling register_transport() (16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814). (For example, suppose you want an extra instance of a transport.) (Not available for the Java or .NET API.)
  - Additional builtin transport instances can also be installed through the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.

To configure the properties of the builtin transports:

- Set properties by calling **set_builtin_transport_property()** (see 16.5 Setting Builtin Transport Properties of Default Transport Instance—get/set_builtin_transport_properties() on page 793)

or

- Specify predefined property strings in the *DomainParticipant's* PropertyQosPolicy, as described in 16.6 Setting Builtin Transport Properties with the PropertyQosPolicy on page 795.

For other builtin transport instances:

- If the builtin transport plugin is created with **NDDS_Transport_UDPv4_new()**, **NDDS_Transport_UDPv6_new()** or **NDDS_Transport_Shmem_new()**, properties can be specified during creation time. See 16.4 Explicitly Creating Builtin Transport Plugin Instances on the next page.
- If the additional builtin transport instances are installed through the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436, the properties of the builtin transport plugins can also be specified through that same QosPolicy.

16.2 Extension Transport Plugins

If you want to change the properties for an extension transport plugin, do so *before* the plugin is registered. Any transport property changes made after the plugin is registered will have no effect.

There are two ways to install an extension transport plugin:

[1] Any transport property changes made after the plugin is registered will have no effect.

- **Implicit Registration:** Transports can be installed through the predefined strings in the *DomainParticipant's* PropertyQosPolicy. Once the transport's properties are specified in the PropertyQosPolicy, the transport will be implicitly registered when (a) the *DomainParticipant* is enabled, (b) the first *DataWriter/DataReader* is created, or (c) you look up a builtin *DataReader* (by calling **lookup_datareader()** on a Subscriber), whichever happens first.

  QosPolicies can also be configured from XML resources (files, strings)—with this approach, you can change the QoS without recompiling the application. The QoS settings are automatically loaded by the DomainParticipantFactory when the first *DomainParticipant* is created. For more information, see Configuring QoS with XML (Chapter 19 on page 842).

- **Explicit Registration:** Transports may be explicitly registered by first creating an instance of the transport plugin (see 16.4 Explicitly Creating Builtin Transport Plugin Instances below) and then calling **register_transport()** (see 16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814).

16.3 The NDDSTransportSupport Class

The **register_transport()** and **set_builtin_transport_property()** operations are part of the **NDDSTransportSupport** class, which includes the operations listed in Table 16.1 Transport Support Operations.

Table 16.1 Transport Support Operations

Operation	Description	Reference
get_transport_plugin	Retrieves a previously registered transport plugin.	16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814
register_transport	Registers a transport plugin for use with a *DomainParticipant*.	
get_builtin_transport_property	Gets the properties used to create a builtin transport plugin.	16.5 Setting Builtin Transport Properties of Default Transport Instance–get/set_builtin_transport_properties() on the next page
set_builtin_transport_property	Sets the properties used to create a builtin transport plugin.	
add_send_route	Adds a route for outgoing messages.	16.9.1 Adding a Send Route on page 818
add_receive_route	Adds a route for incoming messages.	16.9.2 Adding a Receive Route on page 819
lookup_transport	Looks up a transport plugin within a *DomainParticipant*.	16.9.3 Looking Up a Transport Plugin on page 819

16.4 Explicitly Creating Builtin Transport Plugin Instances

The builtin transports (UDPv4, UDPv6, and Shared Memory) are implicitly created by default (if they are enabled via the 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660). Therefore,

you only need to explicitly create a new instance if you want an extra instance (suppose you want two UDPv4 transports, one with special settings).

Transport plugins may be explicitly registered by first creating an instance of the transport plugin and then calling **register_transport()** (16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814). (For example, suppose you want an extra instance of a transport.) (Not available for the Java API.)

To create an instance of a builtin transport plugin, use one of the following functions:

```
NDDS_Transport_Plugin* NDDS_Transport_UDPv4_new (
        const struct NDDS_Transport_UDPv4_Property_t * property_in)
NDDS_Transport_Plugin* NDDS_Transport_UDPv4_new (
        const struct NDDS_Transport_UDPv4_Property_t * property_in)
NDDS_Transport_Plugin* NDDS_Transport_Shmem_new (
        const struct NDDS_Transport_Shmem_Property_t * property_in)
```

Where:

property_in Desired behavior of this transport. May be NULL for default properties.

For details on using these functions, please see the API Reference HTML documentation.

Your application may create and register multiple instances of these transport plugins with *Connext DDS*. This may be done to partition the network interfaces across multiple DDS domains. However, note that the underlying transport, the operating system's IP layer, is still a "singleton." For example, if a unicast transport has already bound to a port, and another unicast transport tries to bind to the same port, the second attempt will fail.

16.5 Setting Builtin Transport Properties of Default Transport Instance—get/set_builtin_transport_properties()

Perhaps you want to use one of the builtin transports, but need to modify the properties. (For default values, please see the API Reference HTML documentation.) Used together, the two operations below allow you to customize properties of the builtin transport when it is implicitly registered (see 16.1 Builtin Transport Plugins on page 790).

Note: Another way to change the properties is with the Property QosPolicy, see 16.6 Setting Builtin Transport Properties with the PropertyQosPolicy on page 795. Changing properties with the Property QosPolicy will overwrite the properties set by calling **set_builtin_transport_property()**.

```
DDS_ReturnCode_t
NDDSTransportSupport::get_builtin_transport_property(
       DDSDomainParticipant * participant_in,
       DDS_TransportBuiltinKind builtin_transport_kind_in,
       struct NDDS_Transport_Property_t
               &builtin_transport_property_inout)
DDS_ReturnCode_t
NDDSTransportSupport::set_builtin_transport_property(
```

```
       DDSDomainParticipant * participant_in,
        DDS_TransportBuiltinKind builtin_transport_kind_in,
        const struct NDDS_Transport_Property_t
               &builtin_transport_property_in)
```

Where:

participant_in	A valid non-NULL *DomainParticipant* that has not been enabled. If the *DomainParticipant* if already enabled when this operation is called, your transport property changes will not be reflected in the transport used by the *DomainParticipant's DataWriters* and *DataReaders*.
builtin_transport_kind_in	The builtin transport kind for which to specify the properties.
builtin_transport_property_inout	(Used by the "get" operation only.) The storage area where the retrieved property will be output. The specific type required by the **builtin_transport_kind_in** must be used.
builtin_transport_property_in	(Used by the "set" operation only.) The new transport property that will be used to the create the builtin transport plugin. The specific type required by the **builtin_transport_kind_in** must be used.

In this example, we want to use the builtin UDPv4 transport, but with modified properties.

```
/* Before this point, create a disabled DomainParticipant */
struct NDDS_Transport_UDPv4_Property_t property =
        NDDS_TRANSPORT_UDPV4_PROPERTY_DEFAULT;
if (NDDSTransportSupport::get_builtin_transport_property(
       participant, DDS_TRANSPORTBUILTIN_UDPv4,
        (struct NDDS_Transport_Property_t&)property) !=
        DDS_RETCODE_OK) {
       printf("**Error: get builtin transport property\n");
}
/* Make your desired changes here */
/* For example, to increase the UDPv4 max msg size to 64K: */
property.parent.message_size_max =  65535;
property.recv_socket_buffer_size =  65535;
property.send_socket_buffer_size =  65535;
if (NDDSTransportSupport::set_builtin_transport_property(
       participant, DDS_TRANSPORTBUILTIN_UDPv4,
       (struct NDDS_Transport_Property_t&)property)
       != DDS_RETCODE_OK) {
       printf("***Error: set builtin transport property\n");
}
/* Enable the participant to turn on communications with
   other participants in the DDS domain using the new
   properties for the automatically registered builtin
   transport plugins */
if (entity->enable()  != DDS_RETCODE_OK) {
        printf("***Error: failed to enable entity\n");
}
```

Note: Builtin transport property changes will have no effect after the builtin transport has been registered. The builtin transports are implicitly registered when (a) the *DomainParticipant* is enabled, (b) the first *DataWriter/DataReader* is created, or (c) you lookup a builtin *DataReader*, whichever happens first.

16.6 Setting Builtin Transport Properties with the PropertyQosPolicy

The 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 allows you to set name/value pairs of data and attach them to an entity, such as a *DomainParticipant*.

To assign properties, use the **add_property()** operation:

```
DDS_ReturnCode_t DDSPropertyQosPolicyHelper::add_property
                (DDS_PropertyQosPolicy policy,
                 const char * name,
                 const char * value,
                 DDS_Boolean  propagate)
```

For more information on **add_property()** and the other operations in the DDSPropertyQosPolicyHelper class, please see Table 7.64 PropertyQoSPolicyHelper Operations, as well as the API Reference HTML documentation.

The 'name' part of the name/value pairs is a predefined string. The property names for the builtin transports are described in these tables:

- Table 16.2 Properties for the Builtin UDPv4 Transport
- Table 16.3 Properties for Builtin UDPv6 Transport
- Table 16.4 Properties for Builtin Shared-Memory Transport

See also:

- 16.6.1 Setting the Maximum Gather-Send Buffer Count for UDP Transports on page 812
- 16.6.2 Formatting Rules for IPv6 'Allow' and 'Deny' Address Lists on page 813

Note:

Changing properties with the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 will overwrite any properties set by calling **set_builtin_transport_property()**.

Table 16.2 Properties for the Builtin UDPv4 Transport

Property Name (prefix with 'dds.transport.UDPv4.builtin.')	Property Value Description
parent.properties_bitmap	A bitmap that defines various properties of the transport to the *Connext DDS* core. Currently, the only property supported is whether or not the transport plugin will always loan a buffer when *Connext DDS* tries to receive a message using the plugin. This is in support of a zero-copy interface. Default: 0

Table 16.2 Properties for the Builtin UDPv4 Transport

Property Name (prefix with 'dds.transport.UDPv4.builtin.')	Property Value Description
parent. gather_send_buffer_count_max	Specifies the maximum number of buffers that *Connext DDS* can pass to the **send()** method of a transport plugin. The transport plugin **send()** API supports a gather-send concept, where the **send()** call can take several discontiguous buffers, assemble and send them in a single message. This enables *Connext DDS* to send a message from parts obtained from different sources without first having to copy the parts into a single contiguous buffer. However, most transports that support a gather-send concept have an upper limit on the number of buffers that can be gathered and sent. Setting this value will prevent *Connext DDS* from trying to gather too many buffers into a send call for the transport plugin. *Connext DDS* requires all transport-plugin implementations to support a gather-send of least a minimum number of buffers. This minimum number is NDDS_TRANSPORT_PROPERTY_GATHER_SEND_BUFFER_COUNT_MIN. See 16.6.1 Setting the Maximum Gather-Send Buffer Count for UDP Transports on page 812. Default: 16
parent.message_size_max	The maximum size of a message in bytes that can be sent or received by the transport plugin. This value must be set before the transport plugin is registered, so that *Connext DDS* can properly use the plugin. Default for Integrity platforms: 9216 Default for non-Integrity platforms: 65507
parent.allow_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. For example, the following are acceptable strings: 192.168.1.1 192.168.1.* 192.168.* 192.* ether0 If the list is non-empty, this "white" list is applied before the parent.deny_interfaces_list on the next page list. The *DomainParticipant* will use the resulting list of interfaces to inform its remote participant(s) about which unicast addresses may be used to contact the *DomainParticipant*. The resulting list restricts *reception* to a particular set of interfaces for unicast UDP. Multicast output will still be sent and may be received over the interfaces in the list (if multicast is supported on the platform). You must manage the memory of the list. The memory may be freed after the *DomainParticipant* is deleted. Default: empty list that represents all available interfaces

Table 16.2 Properties for the Builtin UDPv4 Transport

Property Name (prefix with 'dds.transport.UDPv4.builtin.')	Property Value Description
parent.deny_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name. If the list is non-empty, deny the use of these interfaces. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. For example, the following are acceptable strings: 192.168.1.1 192.168.1.* 192.168.* 192.* ether0 This "black" list is applied after the parent.allow_interfaces_list on the previous page list and filters out the interfaces that should *not* be used for receiving data. The resulting list restricts *reception* to a particular set of interfaces for unicast UDP. Multicast output will still be sent and may be received over the interfaces in the list (if multicast is supported on the platform). You must manage the memory of the list. The memory may be freed after the *DomainParticipant* is deleted. Default: empty list that represents no denied interfaces
parent. allow_multicast_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name. If the list is non-empty, allow the use of multicast only on these interfaces. If the list is empty, allow the use of all the allowed interfaces. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. This list sub-selects from the allowed interfaces that are obtained after applying the parent.allow_interfaces_list on the previous page "white" list *and* the parent.deny_interfaces_list above "black" list. From that resulting list, parent.deny_multicast_interfaces_list below is applied. Multicast output will be sent and may be received over the interfaces in the resulting list (if multicast is supported on the platform). If this list is empty, all the allowed interfaces may potentially be used for multicast. You must manage the memory of the list. The memory may be freed after the *DomainParticipant* is deleted. Default: empty list that represents all available interfaces
parent. deny_multicast_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name. If the list is non-empty, deny the use of those interfaces for multicast. Interfaces should be specified as comma-separated strings, with each comma delimiting an interface. This "black" list is applied after the parent.allow_multicast_interfaces_list above list and filters out the interfaces that should *not* be used for multicast. The final resulting list will be those interfaces that–if multicast is available–will be used for multicast sends. You must manage the memory of the list. The memory may be freed after the *DomainParticipant* is deleted. Default: empty list that represents no denied interfaces

Table 16.2 Properties for the Builtin UDPv4 Transport

Property Name (prefix with 'dds.transport.UDPv4.builtin.')	Property Value Description
send_socket_buffer_size	Size in bytes of the send buffer of a socket used for sending. On most operating systems, **setsockopt()** will be called to set the SENDBUF to the value of this parameter. This value must be greater than or equal to the property, parent.message_size_max on page 796. The maximum value is operating system-dependent. If -1, **setsockopt()** (or equivalent) will not be called to size the send buffer of the socket. The transport will use the OS default. Default: 131072
recv_socket_buffer_size	Size in bytes of the receive buffer of a socket used for receiving. On most operating systems, **setsockopt()** will be called to set the RECVBUF to the value of this parameter. This value must be greater than or equal to the property, parent.message_size_max on page 796. The maximum value is operating system-dependent. If -1, **setsockopt()** (or equivalent) will not be called to size the receive buffer of the socket. The transport will use the OS default. Default: 131072
unicast_enabled	Allows the transport plugin to use unicast UDP for sending and receiving. By default, it will be turned on. Also by default, it will use all the allowed network interfaces that it finds up and running when the plugin is instanced. Can be 1 (enabled) or 0 (disabled). Default: 1
multicast_enabled	Allows the transport plugin to use multicast for sending and receiving. You can turn multicast on or off for this plugin. The default is that multicast is on and the plugin will use the all network interfaces allowed for multicast that it finds up and running when the plugin is instanced. Can be 1 (enabled) or 0 (disabled). Default: 1
multicast_ttl	Value for the time-to-live parameter for all multicast sends using this plugin. This is used to set the TTL of multicast packets sent by this transport plugin. Default: 1
multicast_loopback_disabled	Prevents the transport plugin from putting multicast packets onto the loopback interface. If disabled, then when sending multicast packets, do not put a copy on the loopback interface. This will prevent other applications on the same node (including itself) from receiving those packets. **Note:** Windows CE does not support multicast loopback. This field is ignored for Windows CE targets. Default: 0, meaning multicast loopback is enabled. Turning off multicast loopback (setting to 1) may result in minor performance gains when using multicast.

Table 16.2 Properties for the Builtin UDPv4 Transport

Property Name (prefix with 'dds.transport.UDPv4.builtin.')	Property Value Description
ignore_loopback_interface	Prevents the transport plugin from using the IP loopback interface. Three values are allowed: • 0: Forces local traffic to be sent over loopback, even if a more efficient transport (such as shared memory) is installed (in which case traffic will be sent over both transports). • 1: Disables local traffic via this plugin. The IP loopback interface will not be used, even if no NICs are discovered. This is useful when you want applications running on the same node to use a more efficient transport (such as shared memory) instead of the IP loopback. • -1: Automatic. Enables local traffic via this plugin. To avoid redundant traffic, *Connext DDS* will selectively ignore the loopback destinations that are also reachable through shared memory. Default: -1

DEPRECATED
ignore_nonup_interfaces
	This property is only supported on Windows platforms with statically configured IP addresses.
	It allows/disallows the use of interfaces that are not reported as UP (by the operating system) in the UDPv4 transport. Two values are allowed:
	• 0: Allow interfaces that are reported as DOWN.
	  • Setting this value to 0 supports communication scenarios in which interfaces are enabled after the participant is created. Once the interfaces are enabled, discovery will not occur until the participant sends the next periodic announcement (controlled by the parameter **participant_qos.discovery_config.participant_liveliness_assert_period**).
	  • To reduce discovery time, you may want to decrease the value of **participant_liveliness_assert_period**. For the above scenario, there is one caveat: non-UP interfaces must have a static IP assigned.
	• 1: Do not allow interfaces that are reported as DOWN.
	
	Default: 1

ignore_nonrunning_interfaces	Prevents the transport plugin from using a network interface that is not reported as RUNNING by the operating system. The transport checks the flags reported by the operating system for each network interface upon initialization. An interface which is not reported as UP will not be used. This property allows the same check to be extended to the IFF_RUNNING flag implemented by some operating systems. The RUNNING flag is defined to mean that "all resources are allocated", and may be off if there is no link detected, e.g., the network cable is unplugged. Two values are allowed: • 0: Do not check the RUNNING flag when enumerating interfaces, just make sure the interface is UP. • 1: Check the flag when enumerating interfaces, and ignore those that are not reported as RUNNING. This can be used on some operating systems to cause the transport to ignore interfaces that are enabled but not connected to the network. By default this property is set to 1, so *Connext DDS* will ignore non-running interfaces.

Table 16.2 Properties for the Builtin UDPv4 Transport

Property Name (prefix with 'dds.transport.UDPv4.builtin.')	Property Value Description
DEPRECATED no_zero_copy	Prevents the transport plugin from doing a zero copy. By default, this plugin will use the zero copy on OSs that offer it. While this is good for performance, it may sometime tax the OS resources in a manner that cannot be overcome by the application. The best example is if the hardware/device driver lends the buffer to the application itself. If the application does not return the loaned buffers soon enough, the node may error or malfunction. In case you cannot reconfigure the hardware, device driver, or the OS to allow the zero-copy feature to work for your application, you may have no choice but to turn off zero-copy. By default this is set to 0, so *Connext DDS* will use the zero-copy API if offered by the OS.
send_blocking	Controls the blocking behavior of send sockets. **CHANGING THIS FROM THE DEFAULT CAN CAUSE SIGNIFICANT PERFORMANCE PROBLEMS**. Currently two values are defined: • 1 (NDDS_TRANSPORT_UDP_BLOCKING_ALWAYS): Sockets are blocking (default socket options for operating system). • 0 (NDDS_TRANSPORT_UDP_BLOCKING_NEVER): Sockets are modified to make them non-blocking. **This may cause significant performance problems.** Default: 1
transport_priority_mask	Mask for the transport priority field. This is used in conjunction with transport_priority_mapping_low below and transport_priority_mapping_high below to define the mapping from the 7.5.26 TRANSPORT_PRIORITY QosPolicy on page 455 to the IPv4 TOS field. Defines a contiguous region of bits in the 32-bit transport priority value that is used to generate values for the IPv4 TOS field on an outgoing socket. For example, the value 0x0000ff00 causes bits 9-16 (8 bits) to be used in the mapping. The value will be scaled from the mask range (0x0000 - 0xff00 in this case) to the range specified by low and high. If the mask is set to zero, then the transport will not set IPv4 TOS for send sockets. Default: 0
transport_priority_mapping_low	Sets the low and high values of the output range to IPv4 TOS. These values are used in conjunction with transport_priority_mask above to define the mapping from the 7.5.26 TRANSPORT_PRIORITY QosPolicy on page 455 to the IPv4 TOS field. Defines the low and high values of the output range for scaling. Note that IPv4 TOS is generally an 8-bit value. Default: 0 for **transport_priority_mapping_low** and 0xFF for **transport_priority_mapping_high**
transport_priority_mapping_high	
send_ping	This property specifies whether to send a PING message before commencing the discovery process. On certain operating systems or with certain switches the initial UDP packet, configuring the ARP table, was unfortunately dropped. To avoid dropping the initial RTPS discovery sample, a PING message is sent to preconfigure the ARP table in those environments. Default: 1

Table 16.2 Properties for the Builtin UDPv4 Transport

Property Name (prefix with 'dds.transport.UDPv4.builtin.')	Property Value Description
interface_poll_period	Specifies the period in milliseconds to query for changes in the state of all the interfaces. When possible, the detection of an IP address changes is done asynchronously using the APIs offered by the underlying OS. If there is no mechanism to do that, the detection will use a polling strategy where the polling period can be configured by setting this property. Default: 500
reuse_multicast_receive_resource	Controls whether or not to reuse receive resources. Setting this to 0 (FALSE) prevents multicast crosstalk by uniquely configuring a port and creating a receive thread for each multicast group address. Affects Linux systems only; ignored for non-Linux systems. Default: 1
protocol_overhead_max	Maximum size in bytes of protocol overhead, including headers. This value is the maximum size, in bytes, of protocol-related overhead. Normally, the overhead accounts for UDP and IP headers. The default value is set to accommodate the most common UDP/IP header size. Note that when parent.message_size_max on page 796 plus this overhead is larger than the UDPv4 maximum message size (65535 bytes), the middleware will automatically reduce the effective **message_size_max** to 65535 minus this overhead. Default: 28
disable_interface_tracking	Disables detection of network interface changes. By default, network interfaces changes are propagated in the form of locators to other applications. This is done to support IP mobility scenarios. For example, you could start a application with Wi-Fi and move to a wired connection. In order to continue communicating with other applications this interface change must be propagated. In 5.0 and earlier versions of the product, IP mobility scenarios were not supported. Applications using 5.2 will report errors if they detect locator changes in a *DataWriter* or *DataReader*. You can disable the notification and propagation of interface changes by setting this property to 1. This way, an interface change in a newer application will not trigger errors in an application running 5.2 GAR or earlier. Of course, this will prevent the new application from been able to detect network interface changes.

Table 16.2 Properties for the Builtin UDPv4 Transport

Property Name (prefix with 'dds.transport.UDPv4.builtin.')	Property Value Description
public_address	Public IP address associated with the transport instantiation. Setting the public IP address is only necessary to support communication over WAN that involves Network Address Translation (NAT). Typically, the address is the public address of the IP NAT router that provides access to the WAN. By default, the DomainParticipant creating the transport will announce the IP addresses obtained from the NICs to other DomainParticipants in the system. When this property is set, the DomainParticipant will announce the IP address corresponding to the property value instead of the LAN IP addresses associated with the NICs. Notes: Setting this property is necessary, but is not a sufficient condition for sending and receiving data over the WAN. You must also configure the IP NAT router to allow UDP traffic and to map the public IP address specified by this property to the *DomainParticipant's* private LAN IP address. This is typically done with one of these mechanisms: • Port Forwarding: You must map the private ports used to receive discovery and user data traffic to the corresponding public ports (see Table 9.21 DDS_RtpsWellKnownPorts_t). Public and private ports must be the same since the transport does not allow you to change the mapping. • 1:1 NAT:You must add a 1:1 NAT entry that maps the public IP address specified in this property to the private LAN IP address of the *DomainParticipant*. By setting this property, the *DomainParticipant* only announces its public IP address to other DomainParticipants. Therefore, communication with *DomainParticipants* within the LAN that are running on different nodes will not work unless the NAT router is configured to enable NAT reflection (hairpin NAT). There is another way to achieve simultaneous communication with *DomainParticipants* running in the LAN and WAN, that does not require hairpin NAT. This way uses a gateway application such as RTI Routing Service to provide access to the WAN. Default: NULL (the transport uses the IP addresses obtained from the NICs)
use_checksum	This property specifies whether the UDP checksum will be computed. On Windows and Linux systems, the UDP checksum will not be set when use_checksum is set to 0. This is useful when RTPS protocol statistics related to corrupted messages need to be collected through the operation **get_participant_protocol_status()** (see 9.3.14 Getting Participant Protocol Status on page 626). Default: 1
force_interface_ poll_detection	This property forces the interface tracker to use a polling method to detect changes to the network interfaces in IP mobility scenarios. It only applies to operating systems that support asynchronous notifications of interface changes. If set to TRUE, the interface tracker will use a polling method that queries the interfaces periodically to detect the changes. If set to FALSE, the interface tracker will use the operating system's default method. Basically, this property allows you–for an operating system that supports asynchronous notification–to use the polling method instead. Default: FALSE

Table 16.2 Properties for the Builtin UDPv4 Transport

Property Name (prefix with 'dds.transport.UDPv4.builtin.')	Property Value Description
join_multicast_group_timeout	Windows only. On Windows, a network interface may be detected before it is allowed to join a multicast group address. This property adjusts how much time (in milliseconds) to wait for the ADD_MEMBERSHIP multicast operation to succeed before withdrawing. Default: 5000
property_validation_action	By default, property names given in the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 are validated to avoid using incorrect or unknown names (for example, due to a typo). This property configures the validation of the property names associated with the transport: • VALIDATION_ACTION_EXCEPTION: validate the properties. Upon failure, log errors and fail. • VALIDATION_ACTION_SKIP: skip validation. • VALIDATION_ACTION_WARNING: validate the properties. Upon failure, log warnings and do not fail. If this property is not set, the property validation behavior will be the same as that of the *DomainParticipant*, which by default is VALIDATION_ACTION_EXCEPTION. See 7.5.19.1 Property Validation on page 439 for more information.
thread_name_prefix	You can set this field with your own value, to help you identify the transport thread in a way that's meaningful to you. Do not exceed 8 characters. If you do not set this field, *Connext DDS* creates the following prefix: 'r' + 'Tr' + participant identifier + '\0' Where 'r' indicates this is a thread from RTI, 'Tr' indicates the thread is related to a transport, and participant identifier contains 5 characters as follows: • If **participant_name** is set: The participant identifier will be the first 3 characters and the last 2 characters of the **participant_name**. • If **participant_name** is not set, then the identifier is computed as **domain_id** (3 characters) followed by **participant_id** (2 characters). • If **participant_name** is not set and the **participant_id** is set to -1 (default value), then the participant identifier is computed as the last 5 digits of the **rtps_instance_id** in the participant GUID. See 21.9 Identifying Threads Used by Connext DDS on page 908.

Table 16.3 Properties for Builtin UDPv6 Transport

Property Name (prefix with 'dds.transport.UDPv6.builtin.')	Description
parent.properties_bitmap	A bitmap that defines various properties of the transport to the *Connext DDS* core. Currently, the only property supported is whether or not the transport plugin will always loan a buffer when *Connext DDS* tries to receive a message using the plugin. This is in support of a zero-copy interface.
parent.gather_send_buffer_count_max	Specifies the maximum number of buffers that *Connext DDS* can pass to the send() method of a transport plugin. The transport plugin send() API supports a gather-send concept, where the send() call can take several discontiguous buffers, assemble and send them in a single message. This enables *Connext DDS* to send a message from parts obtained from different sources without first having to copy the parts into a single contiguous buffer. However, most transports that support a gather-send concept have an upper limit on the number of buffers that can be gathered and sent. Setting this value will prevent *Connext DDS* from trying to gather too many buffers into a send call for the transport plugin. *Connext DDS* requires all transport-plugin implementations to support a gather-send of least a minimum number of buffers. This minimum number is NDDS_TRANSPORT_PROPERTY_GATHER_SEND_BUFFER_COUNT_MIN.
parent.message_size_max	The maximum size of a message in bytes that can be sent or received by the transport plugin. This value must be set before the transport plugin is registered, so that *Connext DDS* can properly use the plugin.
parent.allow_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. See 16.6.2 Formatting Rules for IPv6 'Allow' and 'Deny' Address Lists on page 813. If the list is non-empty, this "white" list is applied before the parent.deny_interfaces_list below list. The *DomainParticipant* will use the resulting list of interfaces to inform its remote participant(s) about which unicast addresses may be used to contact the *DomainParticipant*. The resulting list restricts *reception* to a particular set of interfaces for unicast UDP. Multicast output will still be sent and may be received over the interfaces in the list (if multicast is supported on the platform). You must manage the memory of the list. The memory may be freed after the *DomainParticipant* is deleted.
parent.deny_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name. If the list is non-empty, deny the use of these interfaces. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. See 16.6.2 Formatting Rules for IPv6 'Allow' and 'Deny' Address Lists on page 813. This "black" list is applied after the parent.allow_interfaces_list above list and filters out the interfaces that should *not* be used. The resulting list restricts *reception* to a particular set of interfaces for unicast UDP. Multicast output will still be sent and may be received over the interfaces in the list (if multicast is supported on the platform). You must manage the memory of the list. The memory may be freed after the *DomainParticipant* is deleted.

Table 16.3 Properties for Builtin UDPv6 Transport

Property Name (prefix with 'dds.transport.UDPv6.builtin.')	Description
parent. allow_multicast_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name. If the list is non-empty, allow the use of multicast only these interfaces; otherwise allow the use of all the allowed interfaces. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. See 16.6.2 Formatting Rules for IPv6 'Allow' and 'Deny' Address Lists on page 813. This list sub-selects from the allowed interfaces that are obtained after applying the parent.allow_interfaces_list on the previous page "white" list *and* the parent.deny_interfaces_list on the previous page "black" list. Finally, the parent.deny_multicast_interfaces_list below is applied. Multicast output will be sent and may be received over the interfaces in the resulting list (if multicast is supported on the platform). If this list is empty, all the allowed interfaces may potentially be used for multicast. You must manage the memory of the list. The memory may be freed after the *DomainParticipant* is deleted.
parent. deny_multicast_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name. If the list is non-empty, deny the use of those interfaces for multicast. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. See 16.6.2 Formatting Rules for IPv6 'Allow' and 'Deny' Address Lists on page 813. This "black" list is applied after the parent.allow_multicast_interfaces_list above list and filters out the interfaces that should *not* be used for multicast. Multicast output will be sent and may be received over the interfaces in the resulting list (if multicast is supported on the platform). You must manage the memory of the list. The memory may be freed after the *DomainParticipant* is deleted.
send_socket_buffer_size	Size in bytes of the send buffer of a socket used for sending. On most operating systems, **setsockopt()** will be called to set the SENDBUF to the value of this parameter. This value must be greater than or equal to **parent.message_size_max**. The maximum value is operating system-dependent. If -1, **setsockopt()** (or equivalent) will not be called to size the send buffer of the socket. The transport will use the OS default. Default: 131072
recv_socket_buffer_size	Size in bytes of the receive buffer of a socket used for receiving. On most operating systems, **setsockopt()** will be called to set the RECVBUF to the value of this parameter. This value must be greater than or equal to **parent.message_size_max**. The maximum value is operating system-dependent. If -1, **setsockopt()** (or equivalent) will not be called to size the receive buffer of the socket. The transport will use the OS default. Default: 131072
unicast_enabled	Allows the transport plugin to use unicast UDP for sending and receiving. By default, it will be turned on (1). Also by default, it will use all the allowed network interfaces that it finds up and running when the plugin is instanced. Can be 1 (enabled) or 0 (disabled).

Table 16.3 Properties for Builtin UDPv6 Transport

Property Name (prefix with 'dds.transport.UDPv6.builtin.')	Description
multicast_enabled	Allows the transport plugin to use multicast for sending and receiving. You can turn multicast UDP on or off for this plugin. By default, it will be turned on (1). Also by default, it will use the all network interfaces allowed for multicast that it finds up and running when the plugin is instanced. Can be 1 (enabled) or 0 (disabled).
multicast_ttl	Value for the time-to-live parameter for all multicast sends using this plugin. This is used to set the TTL of multicast packets sent by this transport plugin
multicast_loopback_disabled	Prevents the transport plugin from putting multicast packets onto the loopback interface. If disabled, then when sending multicast packets, *Connext DDS* will not put a copy on the loopback interface. This will prevent applications on the same node (including itself) from receiving those packets. This is set to 0 by default, meaning multicast loopback is enabled. Disabling multicast loopback off (setting this value to 1) may result in minor performance gains when using multicast.
ignore_loopback_interface	Prevents the transport plugin from using the IP loopback interface. Three values are allowed: 0: Enable local traffic via this plugin. This plugin will only use and report the IP loopback interface if there are no other network interfaces (NICs) up on the system. 1: Disable local traffic via this plugin. Do not use the IP loopback interface even if no NICs are discovered. This is useful when you want applications running on the same node to use a more efficient plugin like Shared Memory instead of the IP loopback. -1: Automatic. Enables local traffic via this plugin. To avoid redundant traffic, *Connext DDS* will selectively ignore the loopback destinations that are also reachable through shared memory.
ignore_nonrunning_interfaces	Prevents the transport plugin from using a network interface that is not reported as RUNNING by the operating system. The transport checks the flags reported by the operating system for each network interface upon initialization. An interface which is not reported as UP will not be used. This property allows the same check to be extended to the IFF_RUNNING flag implemented by some operating systems. The RUNNING flag is defined to mean that "all resources are allocated", and may be off if there is no link detected, e.g., the network cable is unplugged. Two values are allowed: • 0: Do not check the RUNNING flag when enumerating interfaces, just make sure the interface is UP. • 1: Check the flag when enumerating interfaces, and ignore those that are not reported as RUNNING. This can be used on some operating systems to cause the transport to ignore interfaces that are enabled but not connected to the network. By default this property is set to 1, so *Connext DDS* will ignore non-running interfaces.
DEPRECATED no_zero_copy	Prevents the transport plugin from doing a zero copy. By default, this plugin will use the zero copy on OSs that offer it. While this is good for performance, it may sometime tax the OS resources in a manner that cannot be overcome by the application. The best example is if the hardware/device driver lends the buffer to the application itself. If the application does not return the loaned buffers soon enough, the node may error or malfunction. In case you cannot reconfigure the H/W, device driver, or the OS to allow the zero-copy feature to work for your application, you may have no choice but to turn off zero-copy. By default this is set to 0, so *Connext DDS* will use the zero-copy API if offered by the OS.

Table 16.3 Properties for Builtin UDPv6 Transport

Property Name (prefix with 'dds.transport.UDPv6.builtin.')	Description
send_blocking	Controls the blocking behavior of send sockets. **CHANGING THIS FROM THE DEFAULT CAN CAUSE SIGNIFICANT PERFORMANCE PROBLEMS.** Currently two values are defined: • 1 (NDDS_TRANSPORT_UDP_BLOCKING_ALWAYS): Sockets are blocking (default socket options for Operating System). • 0 (NDDS_TRANSPORT_UDP_BLOCKING_NEVER): Sockets are modified to make them non-blocking. **This may cause significant performance problems.** Default: 1
enable_v4mapped	Specifies whether the UDPv6 transport will process IPv4 addresses. Set this to 1 to turn on processing of IPv4 addresses. Note that this may make it incompatible with use of the UDPv4 transport within the same *DomainParticipant*.
transport_priority_mask	Sets a mask for use of transport priority field. If transport priority mapping is supported on the platform[1], this mask is used in conjunction with transport_priority_mapping_low below and transport_priority_mapping_high below to define the mapping from the DDS transport priority 7.5.26 TRANSPORT_PRIORITY QosPolicy on page 455 to the IPv6 TCLASS field. Defines a contiguous region of bits in the 32-bit transport priority value that is used to generate values for the IPv6 TCLASS field on an outgoing socket. For example, the value 0x0000ff00 causes bits 9-16 (8 bits) to be used in the mapping. The value will be scaled from the mask range (0x0000 - 0xff00 in this case) to the range specified by low and high. If the mask is set to zero, then the transport will not set IPv6 TCLASS for send sockets.
transport_priority_mapping_low	Sets the low and high values of the output range to IPv6 TCLASS. These values are used in conjunction with transport_priority_mask above to define the mapping from DDS transport priority to the IPv6 TCLASS field. Defines the low and high values of the output range for scaling. Note that IPv6 TCLASS is generally an 8-bit value.
transport_priority_mapping_high	
send_ping	This property specifies whether to send a PING message before commencing the discovery process. On certain operating systems or with certain switches the initial UDP packet, configuring the ARP table, was unfortunately dropped. To avoid dropping the initial RTPS discovery sample, a PING message is sent to preconfigure the ARP table in those environments.
interface_poll_period	See interface_poll_period on page 801 in Table 16.2 Properties for the Builtin UDPv4 Transport
reuse_multicast_receive_resource	This property controls whether or not to reuse multicast receive resources.

[1] See the *RTI Connext DDS Core Libraries Platform Notes* to find out if the transport priority is supported on a specific platform.

Table 16.3 Properties for Builtin UDPv6 Transport

Property Name (prefix with 'dds.transport.UDPv6.builtin.')	Description
protocol_overhead_max	This value is the maximum size, in bytes, of protocol-related overhead. Normally, the overhead accounts for UDP and IP headers. The default value is set to accommodate the most common UDP/IP header size. Note that when **NDDS_Transport_Property_t::message_size_max** plus this overhead is larger than the parent.message_size_max on page 804(65535 bytes), the middleware will automatically reduce the effective **message_size_max**, to 65535 minus this overhead.
disable_interface_tracking	Disables detection of network interface changes. See disable_interface_tracking in Table 16.2 Properties for the Builtin UDPv4 Transport.
public_address	See public_address in Table 16.2 Properties for the Builtin UDPv4 Transport.
force_interface_ poll_detection	This property forces the interface tracker to use a polling method to detect changes to the network interfaces in IP mobility scenarios. It only applies to operating systems that support asynchronous notifications of interface changes. If set to TRUE, the interface tracker will use a polling method that queries the interfaces periodically to detect the changes. If set to FALSE, the interface tracker will use the operating system's default method. Basically, this property allows you–for an operating system that supports asynchronous notification–to use the polling method instead. Default: FALSE
join_multicast_group_timeout	Windows only. On Windows, a network interface may be detected before it is allowed to join a multicast group address. This property adjusts how much time (in milliseconds) to wait for the ADD_MEMBERSHIP multicast operation to succeed before withdrawing. Default: 5000
property_validation_action	By default, property names given in the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 are validated to avoid using incorrect or unknown names (for example, due to a typo). This property configures the validation of the property names associated with the transport: • VALIDATION_ACTION_EXCEPTION: validate the properties. Upon failure, log errors and fail. • VALIDATION_ACTION_SKIP: skip validation. • VALIDATION_ACTION_WARNING: validate the properties. Upon failure, log warnings and do not fail. If this property is not set, the property validation behavior will be the same as that of the *DomainParticipant*, which by default is VALIDATION_ACTION_EXCEPTION. See 7.5.19.1 Property Validation on page 439 for more information.

Table 16.3 Properties for Builtin UDPv6 Transport

Property Name (prefix with 'dds.transport.UDPv6.builtin.')	Description
thread_name_prefix	You can set this field with your own value, to help you identify the transport thread in a way that's meaningful to you. Do not exceed 8 characters. If you do not set this field, *Connext DDS* creates the following prefix: 'r' + 'Tr' + participant identifier + '\0' Where 'r' indicates this is a thread from RTI, 'Tr' indicates the thread is related to a transport, and participant identifier contains 5 characters as follows: • If **participant_name** is set: The participant identifier will be the first 3 characters and the last 2 characters of the **participant_name**. • If **participant_name** is not set, then the identifier is computed as **domain_id** (3 characters) followed by **participant_id** (2 characters). • If **participant_name** is not set and the **participant_id** is set to -1 (default value), then the participant identifier is computed as the last 5 digits of the **rtps_instance_id** in the participant GUID. See 21.9 Identifying Threads Used by Connext DDS on page 908.

Table 16.4 Properties for Builtin Shared-Memory Transport

Property Name (prefix with 'dds.transport.shmem.builtin.')	Property Value Description
parent.properties_bitmap	A bitmap that defines various properties of the transport to the *Connext DDS* core. Currently, the only property supported is whether or not the transport plugin will always loan a buffer when *Connext DDS* tries to receive a message using the plugin. This is in support of a zero-copy interface.
parent.gather_send_buffer_count_max	Specifies the maximum number of buffers that *Connext DDS* can pass to the **send()** method of a transport plugin. The transport plugin **send()** API supports a gather-send concept, where the **send()** call can take several discontiguous buffers, assemble and send them in a single message. This enables *Connext DDS* to send a message from parts obtained from different sources without first having to copy the parts into a single contiguous buffer. However, most transports that support a gather-send concept have an upper limit on the number of buffers that can be gathered and sent. Setting this value will prevent *Connext DDS* from trying to gather too many buffers into a send call for the transport plugin. *Connext DDS* requires all transport-plugin implementations to support a gather-send of least a minimum number of buffers. This minimum is NDDS_TRANSPORT_PROPERTY_GATHER_SEND_BUFFER_COUNT_MIN.
parent.message_size_max	The maximum size of a message in bytes that can be sent or received by the transport plugin. This value must be set before the transport plugin is registered, so that *Connext DDS* can properly use the plugin.

Table 16.4 Properties for Builtin Shared-Memory Transport

Property Name (prefix with 'dds.transport.shmem.builtin.')	Property Value Description
parent.allow_interfaces_list	Not applicable to the Shared-Memory Transport
parent.deny_interfaces_list	
parent. allow_multicast_interfaces_list	
parent. deny_multicast_interfaces_list	
received_message_count_max	Number of messages that can be buffered in the receive queue. This is the maximum number of messages that can be buffered in a RecvResource of the Transport Plugin. This does not guarantee that the Transport-Plugin will actually be able to buffer **received_message_count_max** messages of the maximum size set in parent.message_size_max on the previous page. The total number of bytes that can be buffered for a RecvResource is actually controlled by receive_buffer_size below.
receive_buffer_size	The total number of bytes that can be buffered in the receive queue. This number controls how much memory is allocated by the plugin for the receive queue (on a per RecvResource basis). The actual number of bytes allocated is: size = **receive_buffer_size** + **message_size_max** + **received_message_count_max** * *fixedOverhead* where *fixedOverhead* is some small number of bytes used by the queue data structure. If **receive_buffer_size** < (**message_size_max** * **received_message_count_max**), the transport plugin will not be able to store **received_message_count_max** messages of size **message_size_max**. If **receive_buffer_size** > (**message_size_max** * **received_message_count_max**), then there will be memory allocated that cannot be used by the plugin and thus wasted. To optimize memory usage, specify a receive queue size less than that required to hold the maximum number of messages which are all of the maximum size. In most situations, the average message size may be far less than the maximum message size. So for example, if the maximum message size is 64K bytes, and you configure the plugin to buffer at least 10 messages, then 640K bytes of memory would be needed if all messages were 64K bytes. Should this be desired, then **receive_buffer_size** should be set to 640K bytes. However, if the average message size is only 10K bytes, then you could set the **receive_buffer_size** to 100K bytes. This allows you to optimize the memory usage of the plugin for the average case and yet allow the plugin to handle the extreme case. The queue will always be able to hold 1 message of **message_size_max** bytes, regardless of the value of **receive_buffer_size**.

Table 16.4 Properties for Builtin Shared-Memory Transport

Property Name (prefix with 'dds.transport.shmem.builtin.')	Property Value Description
host_id	Host ID used to generate the shared memory transport network address. Shared memory transport has an associated network address to communicate with other *DomainParticipants* within the same node. This network address is typically generated from the host ID, a unique host identifier. *Connext DDS* computes this host ID based on the hardware address, or media access control (MAC) address, of the first network interface found and the value of **rtps_auto_id_kind**. When set, this property forces the use of a specific host ID to generate the shared memory network address instead of computing it as described above. This property takes an unsigned integer value that is converted into the network address. This host ID should satisfy the following properties: • Should be unique across nodes. Otherwise, remote *DomainParticipants* may try to communicate using shared memory transport with *DomainParticipants* from a different node (which will not work). • Should be the same for all *DomainParticipants* within the same node that want to communicate using shared memory if **accept_unknown_peers** is set to FALSE or there are *DomainParticipants* in the system running a *Connext DDS* version previous to 6.0.0. **Note:** This property is needed in very few scenarios: for example, when two different *Connext DDS* applications in the same node have **rtps_auto_id_kind** set to DDS_RTPS_AUTO_ID_FROM_UUID, the first detected network interface is different for each application, and **accept_unknown_peers** is set to FALSE.
enable_udp_debugging	Enables UDP debugging when using shared memory. If set to '1', all shared memory traffic will be published to **udp_debugging_address::udp_debugging_port**, and the number of shared memory transport gather buffers will be the value of **parent.gather_send_buffer_count_max** or 16, whichever is smaller. Default: 0.
udp_debugging_address	IP address to which shared memory traffic will be published if **enable_udp_debugging** is set to '1'. Default: 239.255.1.2.
udp_debugging_port	Port to which shared memory traffic will be published if **enable_udp_debugging** is set to '1'. Default: 7399.
use_530_from_uuid_locator	This property only applies when the WireProtocol QoS policy (specifically **rtps_auto_id_kind**) is set to DDS_RTPS_AUTO_ID_FROM_UUID. If set to TRUE, the generated shared memory locator will be compatible with the locator created in version 5.3. If set to FALSE the generated shared memory locator will not be compatible, and communication will not occur. For more information, see the *Migration Guide* on the RTI Community Portal (https://community.rti.com/documentation). Default: FALSE

Table 16.4 Properties for Builtin Shared-Memory Transport

Property Name (prefix with 'dds.transport.shmem.builtin.')	Property Value Description
property_validation_action	By default, property names given in the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 are validated to avoid using incorrect or unknown names (for example, due to a typo). This property configures the validation of the property names associated with the transport: • VALIDATION_ACTION_EXCEPTION: validate the properties. Upon failure, log errors and fail. • VALIDATION_ACTION_SKIP: skip validation. • VALIDATION_ACTION_WARNING: validate the properties. Upon failure, log warnings and do not fail. If this property is not set, the property validation behavior will be the same as that of the *DomainParticipant*, which by default is VALIDATION_ACTION_EXCEPTION. See 7.5.19.1 Property Validation on page 439 for more information.
thread_name_prefix	You can set this field with your own value, to help you identify the transport thread in a way that's meaningful to you. Do not exceed 8 characters. If you do not set this field, *Connext DDS* creates the following prefix: 'r' + 'Tr' + participant identifier + '\0' Where 'r' indicates this is a thread from RTI, 'Tr' indicates the thread is related to a transport, and participant identifier contains 5 characters as follows: • If **participant_name** is set: The participant identifier will be the first 3 characters and the last 2 characters of the **participant_name**. • If **participant_name** is not set, then the identifier is computed as **domain_id** (3 characters) followed by **participant_id** (2 characters). • If **participant_name** is not set and the **participant_id** is set to -1 (default value), then the participant identifier is computed as the last 5 digits of the **rtps_instance_id** in the participant GUID. See 21.9 Identifying Threads Used by Connext DDS on page 908.

16.6.1 Setting the Maximum Gather-Send Buffer Count for UDP Transports

To minimize memory copies, *Connext DDS* uses the "gather send" API that may be available on the transport.

Some operating systems limit the number of gather buffers that can be given to the gather-send function. This limits *Connext DDS's* ability to concatenate multiple DDS samples into a single network message. An example is the UDP transport's **sendmsg()** call, which on some OSs (such as Solaris) can only take 16 gather buffers, limiting the number of DDS samples that can be concatenated to five or six.

To match this limitation, *Connext DDS* sets the UDP transport plug-ins' **gather_send_buffer_count_max** to 16 by default for all operating systems. This field is part of the **NDDS_Transport_Property_t** structure.

- On VxWorks 5.5 operating systems, **gather_send_buffer_count_max** can be set as high as 63.
- On Windows and INTEGRITY operating systems, **gather_send_buffer_count_max** can be set as high as 128.
- On most other operating systems, **gather_send_buffer_count_max** can be set as high as 16.

If you are using an OS that allows more than 16 gather buffers for a **sendmsg()** call, you may increase the UDP transport plug-in's **gather_send_buffer_count_max** from the default up to your OS's limit (but no higher than 128).

For example, if your OS imposes a limit of 64 gather buffers, you may increase the **gather_send_buffer_count_max** up to 64. However, if your OS's gather-buffer limit is 1024, you may only increase the **gather_send_buffer_count_max** up to 128.

By changing **gather_send_buffer_count_max**, you can increase performance in the following situations:

- When a *DataWriter* is sending multiple packets to a *DataReader* either because the *DataReader* is a late-joiner and needs to catch up, or because several packets were dropped by the network or rejected and need to be resent. Changing the setting will help when the *DataWriter* needs to send or resend more than five or six packets at a time.
- If your application has more than five or six *DataWriters* or *DataReaders* in a participant. (In this case, the change will make the discovery process more efficient.)
- When using an asynchronous *DataWriter*, DDS samples are sent asynchronously by a separate thread. DDS samples may not be sent immediately, but may be queued instead, depending on the settings of the associated FlowController. If multiple DDS samples in the queue must be sent to the same destination, they will be coalesced into as few network packets as possible. The number of DDS samples that can be put in a single message is directly proportional to **gather_send_buffer_count_max**. Therefore, by maximizing **gather_send_buffer_count_max**, you can minimize the number of packets on the wire.

16.6.2 Formatting Rules for IPv6 'Allow' and 'Deny' Address Lists

This section describes how to format the strings in the properties that create "allow" and "deny" lists:

- dds.transport.UDPv6.builtin. parent.allow_interfaces_list on page 796
- dds.transport.UDPv6.builtin. parent.deny_interfaces_list on page 797
- dds.transport.UDPv6.builtin. parent.allow_multicast_interfaces_list on page 797
- dds.transport.UDPv6.builtin. parent.deny_multicast_interfaces_list on page 797

These properties may contain a list of strings, each identifying a range of interface addresses or an interface name. Interfaces should be specified as comma-separated strings, with each comma delimiting an interface.

The strings can be addresses and patterns in IPv6 notation. They are case-insensitive.

They may contain a wildcard '*' and can expand up to 4 digits in a block. The wildcard must be either leading or trailing (cannot be in the middle of the string). Multiple wildcards can be specified in a single filter, but only one wildcard can be specified per block (between colons). Table 16.5 Examples of IPv6 Address Filters shows some examples.

Table 16.5 Examples of IPv6 Address Filters

Example Filter	Equivalent Filters	Matches
::*:*:*:*:*:*		
FE80::*:*	fe80::*:*,	
	Fe80:0:0::*:*	
	Fe80:0:0:0:0:0:*:*	FE80:0000:0000:0000:0000:0000:xxxx:xxxx
FE80:aBC::202:2*:*:*2		FE80:0ABC:0000:0000:0202:2xxx:xxxx:xxx2

16.7 Installing Additional Builtin Transport Plugins with register_transport()

After you create an instance of a transport plugin (see 16.4 Explicitly Creating Builtin Transport Plugin Instances on page 792) , you have to register it.

The builtin transports (UDPv4, UDPv6, and Shared Memory) are implicitly registered by default (if they are enabled via the 9.5.7 TRANSPORT_BUILTIN QosPolicy (DDS Extension) on page 660). Therefore, you only need to explicitly register a builtin transport if you want an extra instance of it (suppose you want two UDPv4 transports, one with special settings).

The **register_transport()** operation registers a transport plugin for use with a *DomainParticipant* and assigns it a network address. (Note: this operation is only available in the APIs other than Java or .NET. If you are using Java or .NET, use the Property QosPolicy to install additional transport plugins.)

```
NDDS_Transport_Handle_t NDDSTransportSupport::register_transport(
       DDSDomainParticipant * participant_in,
        NDDS_Transport_Plugin * transport_in,
        const DDS_StringSeq & aliases_in,
        const NDDS_Transport_Address_t & network_address_in)
```

Where:

participant_in A non-NULL, disabled DomainParticipant.

transport_in A non-NULL transport plugin that is currently not registered with another DomainParticipant.

aliases_in	A non-NULL sequence of strings used as aliases to refer to the transport plugin symbolically. The transport plugin will be "available for use" to an Entity contained in the DomainParticipant, if the transport alias list associated with the Entity contains one of these transport aliases. An empty alias list represents a WILDCARD and matches ALL aliases. See 16.7.2 Transport Aliases on the next page.
network_address_in	The network address at which to register this transport plugin. The least significant transport_in-.property.address_bit_count will be truncated. The remaining bits are the network address of the transport plugin. See 16.7.3 Transport Network Addresses on the next page.

Note: You must ensure that the transport plugin instance is only used by one *DomainParticipant* at a time. See 16.7.1 Transport Lifecycles below.

Upon success, a valid non-NIL transport handle is returned, representing the association between the *DomainParticipant* and the transport plugin. If the transport cannot be registered, NDDS_TRANSPORT_HANDLE_NIL is returned.

Note that a transport plugin's class name is automatically registered as an implicit alias for the plugin. Thus, a class name can be used to refer to all the transport plugin instances of that class.

The C and C++ APIs also have a operation to retrieve a registered transport plugin, **get_transport_plugin ()**.

```
NDDS_Transport_Plugin* get_transport_plugin(
        DDSDomainParticipant* participant_in,
       const char* alias_in);
```

16.7.1 Transport Lifecycles

If you create and register a transport plugin with a *DomainParticipant*, you are responsible for deleting it by calling its destructor. Builtin transport plugins are automatically managed by *Connext DDS* if they are implicitly registered through the TransportBuiltinQosPolicy.

User-created transport plugins must not be deleted while they are is still in use by a *DomainParticipant*. This generally means that a user-created transport plugin instance can only be deleted after the *DomainParticipant* with which it was registered is deleted. Note that a transport plugin cannot be "unregistered" from a *DomainParticipant*.

A transport plugin instance cannot be registered with more than one *DomainParticipant* at a time. This requirement is necessary to guarantee the multi-threaded safety of the transport API.

Thus, if the same physical transport resources are to be used with multiple *DomainParticipants* in the same address space, the transport plugin should be written in such a way so that it can be instantiated multiple times—once for each *DomainParticipant* in the address space. Note that it is always possible to write the transport plugin so that multiple transport plugin instances share the same underlying resources; however the burden (if any) of guaranteeing multi-threaded safety to access shared resource shifts to the transport plugin developer.

16.7.2 Transport Aliases

In order to use a transport plugin instance in a *Connext DDS* application, it must be registered with a *DomainParticipant* using the **register_transport()** operation (16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814). **register_transport()** takes a pointer to the transport plugin instance, and in addition allows you to specify a sequence of "alias" strings to symbolically refer to the transport plugin. The same alias strings can be used to register more than one transport plugin.

Multiple transport plugins can be registered with a *DomainParticipant*. An alias symbolically refers to one or more transport plugins registered with the *DomainParticipant*. Pre-configured builtin transport plugin instances can be referred to using preconfigured aliases.

A transport plugin's class name is automatically used as an implicit alias. It can be used to refer to all the transport plugin instance of that class.

You can use aliases to refer to transport plugins in order to specify:

- Transport plugins to use for discovery (see **enabled_transports** in 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635), and for *DataWriters* and *DataReaders* (see 7.5.27 TRANSPORT_SELECTION QosPolicy (DDS Extension) on page 456).
- Multicast addresses on which to receive discovery messages (see **multicast_receive_addresses** in 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635), and the multicast addresses and ports on which to receive user data (DDS_DataReaderQos::multicast).
- Unicast ports used for user data (see 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458) on both *DataWriters* and *DataReaders*.
- Transport plugins used to parse an address string in a locator.

A *DomainParticipant* (and its contained entities) will start using a transport plugin after the *DomainParticipant* is enabled (see 4.1.2 Enabling DDS Entities on page 168). An entity will use all the transport plugins that match the specified transport QoS policy. All transport plugins are treated uniformly, regardless of how they were created or registered; there is no notion of some transports being more "special" that others.

16.7.3 Transport Network Addresses

The address bits *not* used by the transport plugin for its internal addressing constitute its network address bits.

In order for *Connext DDS* to properly route the messages, each unicast interface in the DDS domain must have a unique address.

You specify the network address when installing a transport plugin via the **register_transport()** operation (16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814). Choose the

network address for a transport plugin so that the resulting fully qualified 128-bit address will be unique in the DDS domain.

If two instances of a transport plugin are registered with a *DomainParticipant*, they need different network addresses so that their unicast interfaces will have unique, fully qualified 128-bit addresses.

While it is possible to create multiple transports with the same network address (this can be useful for certain situations), this requires special entity configuration for most transports to avoid clashes in resource use (e.g., sockets for UDPv4 transport).

16.8 Installing Additional Builtin Transport Plugins with PropertyQosPolicy

Similar to default builtin transport instances, additional builtin transport instances can also be configured through 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.

To install additional instances of builtin transport, the Properties listed in Table 16.6 Properties for Dynamically Loading and Registering Additional Builtin Transport Plugins are required.

Table 16.6 Properties for Dynamically Loading and Registering Additional Builtin Transport Plugins

Property Name	Description
dds.transport.load_plugins	Comma-separated list of <TRANSPORT_PREFIX>. Up to 8 entries may be specified.
<TRANSPORT_PREFIX>	Indicates the additional builtin transport instances to be installed, and must be in one of the following form, where <STRING> can be any string other than "builtin": dds.transport.shmem.<STRING> dds.transport.UDPv4.<STRING> dds.transport.UDPv6.<STRING> In the following examples in this table, <TRANSPORT_PREFIX> is used to indicate one element of this string that is used as a prefix in the property names for all the settings that are related to the plugin.
<TRANSPORT_PREFIX>. aliases	Optional. Aliases used to register the transport to the *DomainParticipant*. Refer to the **aliases_in** parameter in **register_transport()** (see 16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814). Aliases should be specified as a comma separated string, with each comma delimiting an alias. If it is not specified, the prefix–without the leading **"dds.transport"**–is used as the default alias for the plugin. For example, if the <TRANSPORT_PREFIX> is **"dds.transport.mytransport"**, the default alias for the plugin is **"mytransport"**.
<TRANSPORT_PREFIX>. network_address	Optional. Network address used to register the transport to the *DomainParticipant*. Refer to **network_address_in** parameter in **register_transport()** (see 16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814). If it is not specified, the **network_address_out** output parameter from **NDDS_Transport_create_plugin** is used. The default value is a zeroed out network address.

Table 16.6 Properties for Dynamically Loading and Registering Additional Builtin Transport Plugins

Property Name	Description
<TRANSPORT_PREFIX>.<property_name>	Optional. Property for creating the transport plugin. More than one <TRANSPORT_PREFIX>.<property_name> can be specified. See Table 16.2 Properties for the Builtin UDPv4 Transport through Table 16.4 Properties for Builtin Shared-Memory Transport for the property names that can be used to configure the additional builtin transport instances. The only difference is that the property name will be prefixed by **dds.transport.<builitn_transport_name>.<instance_name>**, where **<instance_name>** is configured through the **dds.transport.load_plugins** property instead of **dds.transport.<builtin_transport_name>.builtin**.

16.9 Other Transport Support Operations

16.9.1 Adding a Send Route

By default, a transport plugin will send outgoing messages using the network address range at which the plugin was registered.

The **add_send_route()** operation allows you to control the routing of outgoing messages, so that a transport plugin will only send messages to certain ranges of destination addresses.

Before using this operation, the *DomainParticipant* to which the transport is registered must be disabled.

```
DDS_ReturnCode_t NDDSTransportSupport::add_send_route(
                const NDDS_Transport_Handle_t &  transport_handle_in,
                const NDDS_Transport_Address_t &  address_range_in,
                DDS_Long  address_range_bit_count_in)
```

Where:

transport_handle_in — A valid non-NIL transport handle as a result of a call to **register_transport()** (16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814).

address_range_in — The outgoing address range for which to use this transport plugin.

address_range_bit_count_in — The number of most significant bits used to specify the address range.

It returns one of the standard return codes or DDS_RETCODE_PRECONDITION_NOT_MET.

The method can be called multiple times for a transport plugin, with different address ranges. You can set up a routing table to restrict the use of a transport plugin to send messages to selected addresses ranges.

Outgoing Address Range 1	->	Transport Plugin
...	->	...
Outgoing Address Range K	->	Transport Plugin

16.9.2 Adding a Receive Route

By default, a transport plugin will receive incoming messages using the network address range at which the plugin was registered.

The **add_receive_route()** operation allows you to configure a transport plugin so that it will only receive messages on certain ranges of addresses.

Before using this operation, the *DomainParticipant* to which the transport is registered must be disabled.

```
DDS_ReturnCode_t NDDSTransportSupport::add_receive_route(
       const NDDS_Transport_Handle_t &  transport_handle_in,
       const NDDS_Transport_Address_t &  address_range_in,
       DDS_Long  address_range_bit_count_in)
```

Where:

transport_handle_in	A valid non-NIL transport handle as a result of a call to **register_transport()** (16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814).
address_range_in	The incoming address range for which to use this transport plugin.
address_range_bit_count_in	The number of most significant bits used to specify the address range.

It returns one of the standard return codes or DDS_RETCODE_PRECONDITION_NOT_MET.

The method can be called multiple times for a transport plugin, with different address ranges.

Transport Plugin	<-	Incoming Address Range 1
...	<-	...
Transport Plugin	<-	Incoming Address Range M

You can set up a routing table to restrict the use of a transport plugin to receive messages from selected ranges. For example, you may restrict a transport plugin to:

Receive messages from a certain multicast address range.

Receive messages only on certain unicast interfaces (when multiple unicast interfaces are available on the transport plugin).

16.9.3 Looking Up a Transport Plugin

If you need to get the handle associated with a transport plugin that is registered with a *DomainParticipant*, use the **lookup_transport()** operation.

```
NDDS_Transport_Handle_t NDDSTransportSupport::lookup_transport(
                        DDSDomainParticipant * participant_in,
                        DDS_StringSeq & aliases_out,
                        NDDS_Transport_Address_t & network_address_out,
                        NDDS_Transport_Plugin * transport_in )
```

Where:

participant_in	A non-NULL *DomainParticipant*.
aliases_out	A sequence of strings where the aliases used to refer to the transport plugin symbolically will be returned. NULL if not interested.
network_address_out	The network address at which to register the transport plugin will be returned here. NULL if not interested.
transport_in	A non-NULL transport plugin that is already registered with the *DomainParticipant*.

If successful, this operation returns a valid non-NIL transport handle, representing the association between the *DomainParticipant* and the transport plugin; otherwise it returns a NDDS_TRANSPORT_HANDLE_NIL upon failure.

Chapter 17 RTPS Locators and IP Mobility

DDS endpoints (*DataWriters* and *DataReaders*) can be reached at specific addresses called RTPS locators. An RTPS locator is an n-tuple (transport, address, port). For example (UDPv4, 192.168.1.1, 7400) is a locator for the UDPv4 transport. Locator information is sent as part of the Participant and Endpoint DATA messages (see Discovery (Chapter 15 on page 758)).

The initial set of locators that a *DomainParticipant* will use to communicate with other *DomainParticipants* is provided using a peer descriptor (see 15.2 Configuring the Peers List Used in Discovery on page 761).

17.1 Locator Changes at Run Time

In *Connext DDS* 5.2.3 and earlier, the set of locators associated with a DDS endpoint could not be changed after the *DomainParticipant* containing the endpoints was enabled. Therefore, *Connext DDS* was not prepared to deal with, for example, IP address changes in IP-based transports.

Starting with *Connext DDS* 5.3.0, locator changes are propagated as part of new Participant and Endpoint DATA messages.

17.1.1 Locator Changes in IP-Based Transports

For IP-based transports, including UDPv4 and UDPv6, the following IP mobility use cases (i.e., the need for IP-address changes at runtime) are supported in *Connext DDS* 5.3.0 and higher:

- Starting a *DomainParticipant* without network connectivity and connecting to the network at runtime.
- Switching network interfaces (for example, going from wired to Wi-Fi).
- Acquiring a new IP address after DHCP lease expiration.
- Having mobile devices roaming across network segments.

Connext DDS 5.3.0 introduced support for IP mobility for the following transports:

- UDPv4 and DTLSv4
- UDPv6
- TCPv4 and TLSv4
- LBRTPS
- ZRTPS

The functionality is enabled out-of-the-box.

When possible, the detection of IP address changes is done asynchronously using the APIs offered by the underlying OS. If there is no mechanism to do that, the detection will use a polling strategy.

The polling period can be configured using the following transport property in the *DomainParticipant's* PropertyQosPolicy: **<<transport prefix>>.interface_poll_period**. For example, for UDPv4 the property name is **dds.transport.UDPv4.builtin.interface_poll_period**.

17.1.1.1 Starting a DomainParticipant without Enabled Network Interfaces

For this use case, the GUID prefix generation algorithm must not be based on the IPv4/MAC address of the first enabled interface, but must use a UUID algorithm instead. This is necessary to avoid collisions on the GUID, which needs to be unique on the network.

In *Connext DDS* 5.3.x, to enable the use of a UUID algorithm to generate the GUID, you had to modify the **rtps_auto_id_kind** field in the *DomainParticipant's* 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664 to DDS_RTPS_AUTO_ID_FROM_UUID. Starting with *Connext DDS* 6.0.0, the default value of this field changed to DDS_RTPS_AUTO_ID_FROM_UUID, and you do not need to modify it.

17.1.1.2 Locator Changes in IP-Based Transports when NATs are Involved

Locator changes at run time are not supported for UDP communications in the presence of NATs because this functionality is currently not supported by the RTI Secure WAN Transport.

For TCP communication, locator changes are supported on the client side in the presence of NATs as long as the TCP transport is used in asymmetric mode.

17.1.1.3 Disabling IP Locator Change Propagation

Connext DDS 5.2.3 and earlier will report errors if it detects locator changes in a DDS endpoint. You can disable the notification and propagation of these changes for a *DomainParticipant*. This way, an interface change in a 5.3.0 or higher application will not trigger errors in an application running 5.2.3 or earlier. Setting this property to true will prevent a 5.3.0 application from being able to detect network interface changes.

To disable the notification of IP locator changes, set the following transport property in the *DomainParticipant's* PropertyQosPolicy: **<<transport prefix>>.disable_interface_tracking**. For example, for UDPv4 the property name is **dds.transport.UDPv4.builtin.disable_interface_tracking**.

17.2 Detection of Unreachable Locators

It is possible for a *DomainParticipant* to announce locators for endpoints that are temporarily or permanently unreachable from a different *DomainParticipant*.

For example, *DomainParticipant* 'A' may send to a different *DomainParticipant* 'B' one locator where the IP address corresponds to a subnet that is not reachable from *DomainParticipant* 'B'. In such case, the *DomainParticipant* 'B' running in a different subnet should not use this address to send information to the endpoints of *DomainParticipant* 'A'.

In *Connext DDS* 5.2.3 and earlier, the middleware did not have the ability to detect unreachable locators. This had two main consequences:

1. The middleware could waste CPU cycles and bandwidth sending messages to unreachable locators.
2. If the unreachable locator was a multicast locator, the destination endpoint would never receive live samples from the sender's endpoints. For best-effort communication, this would have resulted in never receiving samples. For reliable communication, this would have resulted in sending samples as repair traffic.

Connext DDS 5.3.0 introduces a new locator REACHABILITY PING mechanism, which the middleware can use to detect when an endpoint is not reachable at a locator; then it can stop using the locator to send data to the endpoint. For temporary disconnections, the middleware will be able to detect and use an endpoint's locator that becomes reachable again. While data is not being sent to an unreachable locator, the middleware still sends periodic REACHABILITY PING messages to see if it is still unreachable.

The configuration of the REACHABILITY mechanism is done using the following *DomainParticipant's* QosPolicy values:

- **participant_qos.discovery_config.locator_reachability_assert_period**
- **participant_qos.discovery_config.reachability_lease_duration**
- **participant_qos.discovery_config.locator_reachability_change_detection_period**

For more information on these QoS values, see Table 9.11 DDS_DiscoveryConfigQosPolicy.

17.3 Using DNS Tracker to Keep Peer List Updated

Connext DDS allows the use of hostnames instead of IP addresses when configuring peers for specific transports (e.g., UDPv4 and UDPv6). By default, *Connext DDS* resolves hostnames into IP addresses only when the *DomainParticipant* is created. But you can use the DNS tracker to keep the IP addresses of

these hostnames updated. The DNS tracker does this by creating a thread that regularly polls the DNS service. This thread detects changes in the IP address that a hostname is resolved to and updates the related peers accordingly.

Use the **dns_tracker_polling_period** field in the 9.5.3 DISCOVERY_CONFIG QosPolicy (DDS Extension) on page 639 to define how often the DNS tracker thread will query the DNS service for updates (e.g., every 30 seconds). When the period is set to DDS_DURATION_INFINITE (the default value), the tracker is disabled and changes in hostnames will not be tracked. You can also configure the polling period after the creation of the *DomainParticipant* using the *DomainParticipant's* **set_dns_tracker_polling_period()** operation. This operation can enable or disable the DNS tracker depending on the value of the **DDS_Duration_t** provided as parameter.

Connext DDS keeps information regarding the hostnames of peers, whether the hostnames are part of the **initial_peers** field in the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635 or the peers were added through the *DomainParticipant's* **add_peer()** API. When the DNS tracker is enabled, it builds the list of names to track from the *DomainParticipant's* current peers. Removing peers from the *DomainParticipant* (using the **remove_peer()** API) will also affect the DNS tracker. If all the peers with a specific name are removed, the DNS tracker will stop tracking that name.

Enabling the DNS tracker changes the behavior of the *DomainParticipant's* **add_peer()** API. If the DNS tracker has not been enabled, the API will fail to add a peer with a hostname that cannot be resolved into an IP address. If the DNS tracker has been enabled, the *DomainParticipant's* **add_peer()** API will successfully add a peer with a hostname that cannot be resolved into an IP address. Although the hostname or the DNS service may not be available when the **add_peer()** API is called, the enabled DNS tracker will be able to resolve the name and update the locator once the hostname can be resolved.

Once the DNS tracker has been enabled, the change in the behavior of the *DomainParticipant's* **add_peer()** API remains until the *DomainParticipant* is destroyed. Adding a peer with a hostname that cannot be resolved will not produce an error even if the DNS tracker is disabled. *Connext DDS* assumes that if the DNS tracker has been enabled once, all hostnames should be considered as valid peers independently of the status of the DNS tracker at the moment of adding the peer.

Chapter 18 Built-In Topics

This chapter discusses how to use Built-in Topics.

Connext DDS must discover and keep track of remote entities, such as new participants in the DDS domain. This information may also be important to the application itself, which may want to react to this discovery or access it on demand. To support these needs, *Connext DDS* provides *built-in Topic*s ("DCPSParticipant", "DCPSPublication", "DCPSSubscription" in Figure 15.2: Built-in Writers and Readers for Discovery on page 767) and the corresponding built-in *DataReader*s that you can use to access this discovery information.

The discovery information is accessed just as if it is normal application data. This allows the application to know (either via listeners or by polling) when there are any changes in those values. Note that only entities that belong to a *different DomainParticipant* are being discovered and can be accessed through the built-in readers. Entities that are created within the local *DomainParticipant* are not included as part of the data that can be accessed by the built-in readers.

Built-in topics contain information about the remote entities, including their QoS policies. These QoS policies appear as normal fields inside the topic's data, which can be read by means of the built-in Topic. Additional information is provided to identify the entity and facilitate the application logic.

18.1 Listeners for Built-in Entities

Built-in entities have default listener settings:

- The built-in *Subscriber* and its built-in topics have 'nil' listeners—all status bits are set in the listener masks, but the listener is NULL. This effectively creates a NO-OP listener that does not reset communication status.
- Built-in *DataReaders* have null listeners with no status bits set in their masks.

This approach prevents callbacks to the built-in *DataReader* listeners from invoking your *DomainParticipant's* listeners, and at the same time ensures that the status changed flag is not

reset. For more information, see Table 4.4 Effect of Different Combinations of Listeners and Status Bit Masks and 4.4.5 Hierarchical Processing of Listeners on page 194.

18.2 Built-in DataReaders

Built-in *DataReaders* belong to a built-in *Subscriber*, which can be retrieved by using the *DomainParticipant's* **get_builtin_subscriber()** operation. You can retrieve the built-in *DataReaders* by using the *Subscriber's* **lookup_datareader()** operation, which takes the Topic name as a parameter. The built-in *DataReader* is created when **lookup_datareader()** is called on a built-in topic for the first time.

To conserve memory, built-in *Subscribers* and *DataReader*s are created only if and when you look them up. Therefore, if you do not want to miss any built-in data, you should look up the built-in readers before the *DomainParticipant* is enabled.

The following tables describe the built-in topics and their data types. The 7.5.30 USER_DATA QosPolicy on page 462, 5.2.1 TOPIC_DATA QosPolicy on page 224 and 7.4.4 GROUP_DATA QosPolicy on page 352 are included as part of the built-in data type and are not used by *Connext DDS*. Therefore, you can use them to send application-specific information.

Built-in topics can be used in conjunction with the **ignore_*()** operations to ignore certain entities (see 18.4 Restricting Communication—Ignoring Entities on page 835).

Table 18.1 Participant Built-in Topic's Data Type (DDS_ParticipantBuiltinTopicData)

Type	Field	Description
DDS_BuiltinTopicKey	key	Key to distinguish the discovered *DomainParticipant*
DDS_User-DataQosPolicy	user_data	Data that can be set when the related *DomainParticipant* is created (via the 7.5.30 USER_DATA QosPolicy on page 462) and that the application may use as it wishes (e.g., to perform some security checking).
DDS_Prop-ertyQosPolicy	property	Pairs of names/values to be stored with the *DomainParticipant*. See 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436. The usage is strictly application-dependent.
DDS_Pro-tocolVersion_t	rtps_pro-tocol_ version	Version number of the RTPS wire protocol used.
DDS_VendorId_t	rtps_ vendor_id	ID of vendor implementing the RTPS wire protocol.
DDS_UnsignedLong	dds_ builtin_ endpoints	Bitmap set by the discovery plugins. Each bit in this field indicates a built-in endpoint present for discovery.
DDS_LocatorSeq	default_uni-cast_ locators	If the TransportUnicastQosPolicy is not specified when a *DataWriter/DataReader* is created, the unicast_locators in the corresponding Publication/Subscription built-in topic data will be empty. When the unicast_locators in the Publication/SubscriptionBuiltinTopicData is empty, the default_unicast_locators in the corresponding Participant Builtin Topic Data is assumed. If default_unicast_locators is empty, it defaults to DomainParticipantQos.default_unicast.

Table 18.1 Participant Built-in Topic's Data Type (DDS_ParticipantBuiltinTopicData)

Type	Field	Description
DDS_ProductVersion_t	product_version	Vendor-specific parameter. The current version of *Connext DDS*.
DDS_EntityNameQosPolicy	participant_name	Name and role_name assigned to the *DomainParticipant*. See 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416.
DDS_DomainId_t	domain_id	Domain ID associated with the discovered participant.
DDS_TransportInfoSeq	transport_info	A sequence of DDS_TransportInfo_t containing information about each of the installed transports of the discovered *DomainParticipant*. A DDS_TransportInfo_t structure contains the class_id and message_size_max for a single transport. The maximum length of this sequence is controlled by the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649 transport_info_list_max_length (see Table 9.13 DDS_DomainParticipantResourceLimitsQosPolicy). *Connext DDS* uses the transport information propagated via discovery to detect potential misconfigurations in a *Connext DDS* distributed system. If two *DomainParticipants* that discover each other have one common transport with different values for message_size_max, Connext DDS prints a warning message about that condition.
DDS_ServiceQosPolicy	service	Service associated with the discovered *DomainParticipant*.

Table 18.2 Publication Built-in Topic's Data Type (DDS_PublicationBuiltinTopicData)

Type	Field	Description
DDS_BuiltinTopicKey_t	key	Key to distinguish the discovered *DataWriter*
DDS_BuiltinTopicKey_t	participant_key	Key to distinguish the participant to which the discovered *DataWriter* belongs
DDS_String	topic_name	Topic name of the discovered *DataWriter*
DDS_String	type_name	Type name attached to the topic of the discovered *DataWriter*

Table 18.2 Publication Built-in Topic's Data Type (DDS_PublicationBuiltinTopicData)

Type	Field	Description
DDS_DurabilityQosPolicy	durability	QosPolicies of the discovered *DataWriter*
DDS_DurabilityService-QosPolicy	durability_service	
DDS_DeadlineQosPolicy	deadline	
DDS_DestinationOrder-QosPolicy	destination_order	
DDS_LatencyBudget-QosPolicy	latency_budget	
DDS_LivelinessQosPolicy	liveliness	
DDS_ReliabilityQosPolicy	reliability	
DDS_LifespanQosPolicy	lifespan	
DDS_UserDataQosPolicy	user_data	Data that can be set when the *DataWriter* is created (via the 7.5.30 USER_DATA QosPolicy on page 462) and that the application may use as it wishes.
DDS_OwnershipQosPolicy	ownership	QosPolicies of the discovered *DataWriter*
DDS_OwnershipStrength-QosPolicy	ownership_strength	
DDS_DestinationOrder-QosPolicy	destination_order	
DDS_PresentationQosPolicy	presentation	
DDS_PartitionQosPolicy	partition	Name of the partition, set in the 7.4.5 PARTITION QosPolicy on page 355 for the publisher to which the discovered *DataWriter* belongs
DDS_TopicDataQosPolicy	topic_data	Data that can be set when the *Topic* (with which the discovered *DataWriter* is associated) is created (via the 5.2.1 TOPIC_DATA QosPolicy on page 224) and that the application may use as it wishes.
DDS_GroupDataQosPolicy	group_data	Data that can be set when the *Publisher* to which the discovered *DataWriter* belongs is created (via the 7.4.4 GROUP_DATA QosPolicy on page 352) and that the application may use as it wishes.
DDS_TypeObject *	type	Describes the type of the remote *DataReader*. See the API Reference HTML documentation.
DDS_DataRepresentationQosPolicy	representation	Data representations that the *DataWriter* offers. See 7.5.3 DATA_REPRESENTATION QosPolicy on page 379.
DDS_DataTagQosPolicy	data_tags	Data tags (pairs of names/values) assigned to the corresponding *DataWriter*. Usage is strictly application-dependent. See 7.5.4 DATATAG QosPolicy on page 386.

Table 18.2 Publication Built-in Topic's Data Type (DDS_PublicationBuiltinTopicData)

Type	Field	Description
DDS_TypeCode *	type_code	Type code information about this *Topic*. See 3.7 Using Generated Types without Connext DDS (Standalone) on page 152.
DDS_BuiltinTopicKey_t	publisher_key	The key of the *Publisher* to which the *DataWriter* belongs.
DDS_PropertyQosPolicy	property	Properties (pairs of names/values) assigned to the corresponding *DataWriter*. Usage is strictly application-dependent. See 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.
DDS_LocatorSeq	unicast_ locators	If the TransportUnicastQosPolicy is not specified when a *DataWriter/DataReader* is created, the unicast_locators in the corresponding Publication/Subscription built-in topic data will be empty. When the unicast_locators in the Publication/SubscriptionBuiltinTopicData is empty, the default_ unicast_locators in the corresponding Participant Builtin Topic Data is assumed.
DDS_GUID_t	virtual_guid	Virtual GUID for the corresponding *DataWriter*. For more information, see 13.2 Durability and Persistence Based on Virtual GUIDs on page 731.
DDS_ServiceQosPolicy	service	Service associated with the discovered *DataWriter*.
DDS_ProtocolVersion_t	rtps_protocol_ version	Version number of the RTPS wire protocol in use.
DDS_VendorId_t	rtps_vendor_ id	ID of the vendor implementing the RTPS wire protocol.
DDS_Product_Version_t	product_ver- sion	Vendor-specific value. For RTI, this is the current version of *Connext DDS*.
DDS_LocatorFilterQosPolicy	locator_filter	When the 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429 is used on the discovered *DataWriter*, the locator_filter contains the sequence of LocatorFilters in that policy. There is one LocatorFilter per *DataWriter* channel. A channel is defined by a filter expression and a sequence of multicast locators. See 18.2.1 LOCATOR_FILTER QoS Policy (DDS Extension) on page 834.
DDS_Boolean	disable_pos- itive_ acks	Vendor specific parameter. Determines whether matching *DataReaders* send positive acknowledgements for reliability.
DDS_EntityNameQosPolicy	publication_ name	Name and role_name assigned to the *DataWriter*. See 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416.

Table 18.3 Subscription Built-in Topic's Data Type (DDS_SubscriptionBuiltinTopicData)

Type	Field	Description
DDS_BuiltinTopicKey_t	key	Key to distinguish the discovered *DataReader*.
DDS_BuiltinTopicKey_t	participant_ key	Key to distinguish the participant to which the discovered *DataReader* belongs.

Table 18.3 Subscription Built-in Topic's Data Type (DDS_SubscriptionBuiltinTopicData)

Type	Field	Description
char *	topic_name	Topic name of the discovered *DataReader*.
char *	type_name	Type name attached to the *Topic* of the discovered *DataReader*.
DDS_DurabilityQosPolicy	durability	QosPolicies of the discovered *DataReader*
DDS_DeadlineQosPolicy	deadline	
DDS_LatencyBudget-QosPolicy	latency_ budget	
DDS_LivelinessQosPolicy	liveliness	
DDS_ReliabilityQosPolicy	reliability	
DDS_OwnershipQosPolicy	ownership	
DDS_ DestinationOrderQosPolicy	destination_ order	
DDS_UserDataQosPolicy	user_data	Data that can be set when the *DataReader* is created (via the 7.5.30 USER_DATA QosPolicy on page 462) and that the application may use as it wishes.
DDS_ TimeBasedFilterQosPolicy	time_based_ filter	QosPolicies of the discovered *DataReader*
DDS_PresentationQosPolicy	presentation	
DDS_PartitionQosPolicy	partition	Name of the partition, set in the 7.4.5 PARTITION QosPolicy on page 355 for the *Subscriber* to which the discovered *DataReader* belongs.
DDS_TopicDataQosPolicy	topic_data	Data that can be set when the *Topic* to which the discovered *DataReader* belongs is created (via the 5.2.1 TOPIC_DATA QosPolicy on page 224) and that the application may use as it wishes.
DDS_GroupDataQosPolicy	group_data	Data that can be set when the *Publisher* to which the discovered *DataReader* belongs is created (via the 7.4.4 GROUP_DATA QosPolicy on page 352) and that the application may use as it wishes.
DDS_TypeObject *	type	Describes the type of the remote *DataReader*. See the API Reference HTML documentation.
DDS_TypeConsistencyEnforcementQosPolicy	type_ consistency	Indicates the type-consistency requirements of the remote *DataReader*. See 8.6.6 TYPE_CONSISTENCY_ENFORCEMENT QosPolicy on page 589 and the RTI Connext DDS Core Libraries Extensible Types Guide.
DDS_DataRepresentationQosPolicy	representation	Data representations that the *DataReader* requests. See 7.5.3 DATA_ REPRESENTATION QosPolicy on page 379.
DDS_DataTagQosPolicy	data_tags	Data tags (pairs of names/values) assigned to the corresponding *DataReader*. Usage is strictly application-dependent. See 7.5.4 DATATAG QosPolicy on page 386.

Table 18.3 Subscription Built-in Topic's Data Type (DDS_SubscriptionBuiltinTopicData)

Type	Field	Description
DDS_TypeCode *	type_code	Type code information about this *Topic*. See 3.7 Using Generated Types without Connext DDS (Standalone) on page 152.
DDS_BuiltinTopicKey_t	subscriber_key	Key of the *Subscriber* to which the *DataReader* belongs.
DDS_PropertyQosPolicy	property	Properties (pairs of names/values) assigned to the corresponding *DataReader*. Usage is strictly application-dependent. See 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.
DDS_LocatorSeq	unicast_locators	If the TransportUnicastQosPolicy is not specified when a *DataWriter/DataReader* is created, the unicast_locators in the corresponding Publication/Subscription builtin topic data will be empty. When the unicast_locators in the Publication/SubscriptionBuiltinTopicData is empty, the default_unicast_locators in the corresponding Participant Builtin Topic Data is assumed.
DDS_LocatorSeq	multicast_locators	Custom multicast locators that the endpoint can specify.
DDS_ContentFilter-Property_t	content_filter_property	Provides all the required information to enable content filtering on the writer side.
DDS_GUID_t	virtual_guid	Virtual GUID for the corresponding *DataReader*. For more information, see 13.2 Durability and Persistence Based on Virtual GUIDs on page 731.
DDS_ServiceQosPolicy	service	Service associated with the discovered *DataReader*.
DDS_ProtocolVersion_t	rtps_protocol_version	Version number of the RTPS wire protocol in use.
DDS_VendorId_t	rtps_vendor_id	ID of the vendor implementing the RTPS wire protocol.
DDS_Product_Version_t	product_version	Vendor-specific value. For RTI, this is the current version of *Connext DDS*.
DDS_Boolean	disable_positive_acks	Vendor specific parameter. Determines whether matching *DataReaders* send positive acknowledgements for reliability.
DDS_EntityNameQosPolicy	subscription_name	Name and role_name assigned to the *DataReader*. See 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416.

Table 18.4 Topic Built-in Topic's Data Type (DDS_TopicBuiltinTopicData)

Type	Field	Description
DDS_BuiltinTopicKey_t	key	Key to distinguish the discovered *Topic*

Table 18.4 Topic Built-in Topic's Data Type (DDS_TopicBuiltinTopicData)

Type	Field	Description
DDS_String	name	*Topic* name
DDS_String	type_name	type name attached to the *Topic*
DDS_DurabilityQosPolicy	durability	QosPolicy of the discovered *Topic*
DDS_Dur-abilityServiceQosPolicy	durability_ service	
DDS_DeadlineQosPolicy	deadline	
DDS_ LatencyBudgetQosPolicy	latency_ budget	
DDS_LivelinessQosPolicy	liveliness	
DDS_ReliabilityQosPolicy	reliability	
DDS_Trans-portPriorityQosPolicy	transport_ priority	
DDS_LifespanQosPolicy	lifespan	
DDS_Destin-ationOrderQosPolicy	destination_ order	
DDS_HistoryQosPolicy	history	
DDS_Re-sourceLimitsQosPolicy	resource_ limits	
DDS_OwnershipQosPolicy	ownership	
DDS_TopicDataQosPolicy	topic_data	Data that can be set when the *Topic* to which the discovered *DataReader* belongs is created (via the 5.2.1 TOPIC_DATA QosPolicy on page 224) and that the application may use as it wishes.

Table 18.5 QoS of Built-in Subscriber and DataReader lists the QoS of the built-in *Subscriber* and *DataReader* created for accessing discovery data. These are provided for your reference only; they cannot be changed.

Table 18.5 QoS of Built-in Subscriber and DataReader

QosPolicy	Value
Deadline	period = infinite
DestinationOrder	kind = BY_RECEPTION_TIMESTAMP_DESTINATIONORDER_QOS
Durability	kind = TRANSIENT_LOCAL_DURABILITY_QOS

Table 18.5 QoS of Built-in Subscriber and DataReader

QosPolicy	Value
EntityFactory	autoenable_created_entities = TRUE
GroupData	value = empty sequence
History	kind = KEEP_LAST_HISTORY_QOS depth = 1
LatencyBudget	duration = 0
Liveliness	kind = AUTOMATIC_LIVELINESS_QOS lease_duration = infinite
Ownership	kind = SHARED_OWNERSHIP_QOS
Ownership Strength	value = 0
Presentation	access_scope = TOPIC_PRESENTATION_QOS coherent_access = FALSE ordered_access = FALSE
Partition	name = empty sequence
ReaderDataLifecycle	autopurge_nowriter_samples_delay = infinite
Reliability	kind = RELIABLE_RELIABILITY_QOS max_blocking_time is irrelevant for the *DataReader*
ResourceLimits	Depends on setting of DomainParticipantResourceLimitsQosPolicy and DiscoveryConfigQosPolicy in DomainParticipantQos: max_samples = domainParticipantQos.discovery_config. [participant/publication/subscription]_reader_resource_limits.max_samples max_instances = domainParticipantQos.resource_limits. [remote_writer/reader/participant]_allocation.max_count max_samples_per_instance = 1
TimeBasedFilter	minimum_separation = 0
TopicData	value = empty sequence
UserData	value = empty sequence

Note:

The DDS_TopicBuiltinTopicData built-in topic (described in Table 18.4 Topic Built-in Topic's Data Type (DDS_TopicBuiltinTopicData)) is meant to convey information about discovered *Topics*. However, this topic's data is not sent separately and therefore a *DataReader* for DDS_TopicBuiltinTopicData will not receive any data. Instead, DDS_TopicBuiltinTopicData data is included in the information carried by the built-in topics for Publications and Subscriptions (DDS_PublicationBuiltinTopicData and DDS_SubscriptionBuiltinTopicData) and can be accessed with their built-in *DataReaders*.

18.2.1 LOCATOR_FILTER QoS Policy (DDS Extension)

The LocatorFilter QoS Policy is only applicable to the built-in topic for a Publication (see Table 18.2 Publication Built-in Topic's Data Type (DDS_PublicationBuiltinTopicData)).

Table 18.6 DDS_LocatorFilterQosPolicy

Type	Field Name	Description
DDS_ LocatorFilterSeq	locator_ filters	A sequence of locator filters, described in Table 18.7 DDS_LocatorFilter_t. There is one locator filter per *DataWriter* channel. If the length of the sequence is zero, the *DataWriter* is not using multi-channel.
char*	filter_ name	Name of the filter class used to describe the locator filter expressions. The following two values are supported: • DDS_SQLFILTER_NAME • DDS_STRINGMATCHFILTER_NAME

Table 18.7 DDS_LocatorFilter_t

Type	Field Name	Description
DDS_ LocatorSeq	locators	A sequence of multicast address locators for the locator filter. See Table 18.8 DDS_Locator_t.
char*	filter_ expression	A logical expression used to determine if the data will be published in the channel associated with this locator filter. See 5.4.6 SQL Filter Expression Notation on page 235 and 5.4.7 STRINGMATCH Filter Expression Notation on page 244 for information about the expression syntax.

Table 18.8 DDS_Locator_t

Type	Field Name	Description
DDS_Long	kind	If the locator kind is DDS_LOCATOR_KIND_UDPv4, the address contains an IPv4 address. The leading 12 octets of the address must be zero. The last 4 octets store the IPv4 address. If the locator kind is DDS_LOCATOR_KIND_UDPv6, the address contains an IPv6 address. IPv6 addresses typically use a shorthand hexadecimal notation that maps one-to-one to the 16 octets of the address. In C#, the locator kinds for UDPv4 and UDPv6 addresses are Locator_t.LOCATOR_KIND_UDPv4 and Locator_ t.LOCATOR_KIND_UDPv6.
DDS_Octet [16]	address	The locator address.
DDS_ UnsignedLong	port	The locator port number.

18.3 Accessing the Built-in Subscriber

Getting the built-in subscriber allows you to retrieve the built-in readers of the built-in topics through the *Subscriber's* **lookup_datareader()**operation. By accessing the built-in reader, you can access discovery information about remote entities.

```
// Lookup built-in reader
DDSDataReader *builtin_reader =
builtin_subscriber->lookup_datareader(DDS_PUBLICATION_TOPIC_NAME);

if (builtin_reader == NULL) {
    // ... error
}
// Register listener to built-in reader
MyPublicationBuiltinTopicDataListener builtin_reader_listener =
new MyPublicationBuiltinTopicDataListener();

if (builtin_reader->set_listener(builtin_reader_listener,
DDS_DATA_AVAILABLE_STATUS) != DDS_RETCODE_OK) {
    // ... error
}
// enable DomainParticipant
if (participant->enable() != DDS_RETCODE_OK) {
     // ... error
}
```

For example, you can call the *DomainParticipant*'s get_builtin_subscriber() operation, which will provide you with a built-in Subscriber. Then you can use that built-in Subscriber to call the *Subscriber*'s **lookup_datareader()** operation; this will retrieve the built-in reader. Another option is to register a *Listener* on the built-in subscriber instead, or poll for the status of the built-in subscriber to see if any of the built-in data readers have received data.

18.4 Restricting Communication–Ignoring Entities

The ignore_participant() operation allows an application to ignore all communication from a specific *DomainParticipant*. Or for even finer control you can use the ignore_publication(), ignore_subscription(), and ignore_topic() operations. These operations are described below.

```
DDS_ReturnCode_t  ignore_participant (const DDS_InstanceHandle_t &handle)
DDS_ReturnCode_t  ignore_publication (const DDS_InstanceHandle_t &handle)
DDS_ReturnCode_t  ignore_subscription (const DDS_InstanceHandle_t &handle)
DDS_ReturnCode_t  ignore_topic (const DDS_InstanceHandle_t &handle)
```

The entity to ignore is identified by the *handle* argument. It may be a local or remote entity. For **ignore_publication()**, the handle will be that of a local *DataWriter* or a discovered remote *DataWriter*. For **ignore_subscription()**, that handle will be that of a local *DataReader* or a discovered remote *DataReader*.

The safest approach for ignoring an entity is to call the ignore operation within the *Listener* callback of the built-in reader, or before any local entities are enabled. This will guarantee that the local entities (entities that are created by the local *DomainParticipant*) will never have a chance to establish communication with the remote entities (entities that are created by another *DomainParticipant*) that are going to be ignored.

If the above is not possible and a remote entity is to be ignored after the communication channel has been established, the remote entity will still be removed from the database of the local application as if it never existed. However, since the remote application is not aware that the entity is being ignored, it may potentially be expecting to receive messages or continuing to send messages. Depending on the QoS of the remote entity, this may affect the behavior of the remote application and may potentially stop the remote application from communicating with other entities.

You can use this operation in conjunction with the ParticipantBuiltinTopicData to implement access control. You can pass application data associated with a *DomainParticipant* in the 7.5.30 USER_DATA QosPolicy on page 462. This application data is propagated as a field in the built-in topic. Your application can use the data to implement an access control policy.

Ignore operations, in conjunction with the Built-in Topic Data, can be used to implement access control. You can pass data associated with an entity in the 7.5.30 USER_DATA QosPolicy on page 462, 7.4.4 GROUP_DATA QosPolicy on page 352 or 5.2.1 TOPIC_DATA QosPolicy on page 224. This data is propagated as a field in the built-in topic. When data for a built-in topic is received, the application can check the user_data, group_data or topic_data field of the remote entity, determine if it meets the security requirement, and ignore the remote entity if necessary.

See also: Discovery (Chapter 15 on page 758).

18.4.1 Ignoring Specific Remote DomainParticipants

The **ignore_participant()** operation is used to instruct *Connext DDS* to locally ignore a remote *DomainParticipant*. It causes *Connext DDS* to locally behave as if the remote *DomainParticipant* does not exist.

```
DDS_ReturnCode_t ignore_participant  (const DDS_InstanceHandle_t &  handle)
```

After invoking this operation, *Connext DDS* will locally ignore any *Topic*, *publication*, or *subscription* that originates on that *DomainParticipant*. (If you only want to ignore specific publications or subscriptions, see 18.4.2 Ignoring Publications and Subscriptions on the next page instead.) Figure 18.1: Ignoring Participants below provides an example.

By default, the maximum number of participants that can be ignored is limited by **ignored_entity_allocation.max_count** in the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649. However, that behavior can be changed by using **ignore_entity_replacement_kind** in the same QoS policy.

See also: 18.4.4 Resource Limits Considerations for Ignored Entities on page 839.

Caution: There is no way to reverse this operation. You can add to the peer list, however—see 9.5.2.3 Adding and Removing Peers List Entries on page 636.

Figure 18.1: Ignoring Participants

```
class MyParticipantBuiltinTopicDataListener :
public DDSDataReaderListener {
       public:
```

```
                virtual void on_data_available(DDSDataReader *reader);
                // ......
};
void MyParticipantBuiltinTopicdataListener::on_data_available(
       DDSDataReader *reader) {
       DDSParticipantBuiltinTopicDataDataReader
                *builtinTopicDataReader =
                DDSParticipantBuiltinTopicDataDataReader *) reader;
       DDS_ParticipantBuiltinTopicDataSeq data_seq;
       DDS_SampleInfoSeq info_seq;
       int = 0;
       if (builtinTopicDataReader->take(data_seq, info_seq,
                DDS_LENGTH_UNLIMITED, DDS_ANY_SAMPLE_STATE,
                DDS_ANY_VIEW_STATE, DDS_ANY_INSTANCE_STATE) !=
                DDS_RETCODE_OK){
                // ... error
       }
       for (i = 0; i < data_seq.length(); ++i) {
                if (info_seq[i].valid_data) {
                    // check user_data for access control
                    if (data_seq[i].user_data[0] != 0x9) {
                        if (builtinTopicDataReader->get_subscriber()
                                ->get_participant()
                                ->ignore_participant(
                                info_seq[i].instance_handle)
                                != DDS_RETCODE_OK) {
                                // ... error
                        }
                    }
                }
       }
       if (builtinTopicDataReader->return_loan(
                data_seq, info_seq) != DDS_RETCODE_OK) {
                // ... error
       }
}
```

18.4.2 Ignoring Publications and Subscriptions

You can instruct *Connext DDS* to locally ignore a publication or subscription. A publication/subscription is defined by the association of a *Topic* name, user data and partition set on the *Publisher/Subscriber*. After this call, any data written related to associated *DataWriter/DataReader* will be ignored.

The entity to ignore is identified by the **handle** argument. For **ignore_publication()**, the handle will be that of a *DataWriter*. For **ignore_subscription()**, that handle will be that of a *DataReader*.

This operation can be used to ignore local *and* remote entities:

- For local entities, you can obtain the handle argument by calling the **get_instance_handle()** operation for that particular entity.
- For remote entities, you can obtain the handle argument from the DDS_SampleInfo structure retrieved when reading DDS data samples available for the entity's built-in *DataReader*.

```
DDS_ReturnCode_t ignore_publication  (const DDS_InstanceHandle_t &  handle)
DDS_ReturnCode_t ignore_subscription (const DDS_InstanceHandle_t &  handle)
```

Caution: There is no way to reverse these operations.

Figure 18.2: Ignoring Publications below provides an example.

Figure 18.2: Ignoring Publications

```
class MyPublicationBuiltinTopicDataListener : public DDSDataReaderListener
{
       public:
       virtual void on_data_available(DDSDataReader *reader);
       // ......
};
void MyPublicationBuiltinTopicdataListener::on_data_available(
       DDSDataReader *reader) {
       DDSPublicationBuiltinTopicDataReader *builtinTopicDataReader =
               (DDS_PublicationBuiltinTopicDataReader *)reader;
       DDS_PublicationBuiltinTopicDataSeq data_seq;
       DDS_SampleInfoSeq info_seq;
       int = 0;
       if (builtinTopicDataReader->take(data_seq, info_seq,
               DDS_LENGTH_UNLIMITED, DDS_ANY_SAMPLE_STATE,
               DDS_ANY_VIEW_STATE, DDS_ANY_INSTANCE_STATE)
               != DDS_RETCODE_OK)
       {
       // ... error
       }
       for (i = 0; i < data_seq.length(); ++i) {
               if (info_seq[i].valid_data) {
                       // check user_data for access control
                       if (data_seq[i].user_data[0] != 0x9) {
                               if (builtinTopicDataReader->get_subscriber()
                               ->get_participant()
                               ->ignore_publication(
                               info_seq[i].instance_handle)
                                       != DDS_RETCODE_OK) {
                                       // ... error
                               }
                       }
               }
       }
if (builtinTopicDataReader->return_loan(data_seq, info_seq) !=
       DDS_RETCODE_OK) {
               ...
```

18.4.3 Ignoring Topics

The **ignore_topic()** operation instructs *Connext DDS* to locally ignore a *Topic*. This means it will locally ignore any publication or subscription to the *Topic*.

```
DDS_ReturnCode_t ignore_topic (const DDS_InstanceHandle_t & handle)
```

Caution: There is no way to reverse this operation.

If you know that your application will never publish or subscribe to data under certain topics, you can use this operation to save local resources.

The *Topic* to ignore is identified by the handle argument. This handle is the one that appears in the DDS_SampleInfo retrieved when reading the DDS data samples from the built-in DataReader to the *Topic*.

18.4.4 Resource Limits Considerations for Ignored Entities

When an entity is ignored, *Connext DDS* adds it to an internal 'ignore' table whose resource limits are configured using the **ignored_entity_allocation.max_count** in the 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649. The behavior of *Connext DDS* when this limit is exceeded can be modified by using the **ignored_entity_replacement_kind** in the same QoS policy.

The default value for **ignored_entity_replacement_kind** is **DDS_NO_REPLACEMENT_IGNORED_ENTITY_REPLACEMENT**, meaning that a call to the **DomainParticipant's ignore_participant()**, **ignore_publication()**, or **ignore_subscription()** will fail if the *DomainParticipant* has ignored more entities than the limit set in **ignored_entity_allocation.max_count entities**.

When **ignored_entity_replacement_kind** is set to **DDS_NOT_ALIVE_FIRST_IGNORED_ENTITY_REPLACEMENT**, a call to **ignore_participant()** will not fail when **ignored_entity_allocation.max_count** is exceeded, as long as there is one *DomainParticipant* already ignored. Instead, the call will replace one of the existing *DomainParticipants* in the internal table. The remote *DomainParticipant* that will be replaced is the one for which the local *DomainParticipant* had not received any message for the longest time.

When a remote *DomainParticipant* is replaced in the 'ignore' table, it becomes un-ignored. Thus, the local *DomainParticipant* would have to call **ignore_participant()** again to re-ignore the replaced entity.

Note: In this release, ignored publications and subscriptions are never replaced in the 'ignore' table. Since this table also contains the ignored *DomainParticipants*, a call to **ignore_participant()** will fail if **ignored_entity_allocation.max_count** is reached and none of the ignored entities is a DomainParticipant.

18.4.5 Supervising Endpoint Discovery

It is possible to control for which *DomainParticipants* endpoint discovery may occur. You can configure this behavior with the **enable_endpoint_discovery** field in the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635:

- When set to TRUE (the default value), endpoint discovery will automatically occur for every discovered *DomainParticipant*. This is the normal operation of the discovery process.

- When set to FALSE, endpoint discovery will be disabled for every discovered *DomainParticipant*. Then applications will have to manually enable endpoint discovery (described below) for the *DomainParticipants* they are interested in communicating with. By disabling endpoint discovery, the *DomainParticipant* will not store any state about remote endpoints and will not send local endpoint information to remote *DomainParticipants*.

When **enable_endpoint_discovery** is set to FALSE, you have two options after a remote *DomainParticipant* is discovered:

- Call the *DomainParticipant's* **resume_endpoint_discovery()** operation to enable endpoint discovery. After invoking this operation, the *DomainParticipant* will start to exchange endpoint information so that matching and communication can occur with the remote *DomainParticipant*.

```
DDS_ReturnCode_t resume_endpoint_discovery(
        const DDS_InstanceHandle_t & remote_participant_handle)
```

Or

- Call the *DomainParticipant's* **ignore_participant()** operation to permanently ignore endpoint discovery with the remote *DomainParticipant*.

Setting **enable_endpoint_discovery** to FALSE enables application-level authentication use cases, in which a *DomainParticipant* will resume endpoint discovery with a remote *DomainParticipant* after successful authentication at the application level. The following example shows how to provide access control using this feature:

```
class MyParticipantBuiltinTopicDataListener :
               public DDSDataReaderListener {
       public:
       virtual void on_data_available(DDSDataReader *reader);
       // ...
};
void MyParticipantBuiltinTopicdataListener::on_data_available(
        DDSDataReader *reader) {
DDSParticipantBuiltinTopicDataDataReader
*builtinTopicDataReader =
        DDSParticipantBuiltinTopicDataDataReader *) reader;
DDS_ParticipantBuiltinTopicDataSeq data_seq;
DDS_SampleInfoSeq info_seq;
int = 0;
if (builtinTopicDataReader->take(
       data_seq, info_seq,
        DDS_LENGTH_UNLIMITED,
        DDS_ANY_SAMPLE_STATE,
        DDS_ANY_VIEW_STATE,
        DDS_ANY_INSTANCE_STATE)!= DDS_RETCODE_OK){
       // ... error
}
for (i  = 0; i < data_seq.length(); ++i) {
    if (info_seq[i].valid_data) {
```

```
       DDSDomainParticipant * localParticipant =
          builtinTopicDataReader->
       get_subscriber()->get_participant();
       DDS_ReturnCode_t retCode;
       // check user_data for access control
       if (data_seq[i].user_data[0] != 0x9) {
               retCode = localParticipant->
                   ignore_participant(
                       info_seq[i].instance_handle);
       }else {
               retCode = localParticipant->
                   resume_endpoint_discovery(
                       info_seq[i].instance_handle)
       }
    }
}
if (builtinTopicDataReader->return_loan(
       data_seq, info_seq)
        != DDS_RETCODE_OK) {
       // ... error }
}
```

Chapter 19 Configuring QoS with XML

Connext DDS entities are configured by means of Quality of Service (QoS) policies, which may be set programmatically in one of the following ways:

- Directly when the entity is created as an additional argument to the **create_<entity>()** operation (or the Entity's constructor in the Modern C++ API).
- Directly via the **set_qos()** operation on the entity.
- Indirectly as a default QoS on the factory for the entity (**set_default_<entity>_qos()** operations on *Publisher, Subscriber, DomainParticipant*, DomainParticipantFactory)

Entities can also be configured from an XML file or XML string. With this feature, you can change QoS configurations simply by changing the XML file or string—you do not have to recompile the application. This chapter describes how to configure *Connext DDS* entities using XML.

19.1 Example XML File

The QoS configuration of a *Entity* can be loaded from an XML file or string.

The file contents must follow an important hierarchy: the file contains one or more libraries; each library contains one or more profiles; each profile contains QoS settings.

Let's look at a very basic configuration file, just to get an idea of its contents. You will learn the meaning of each line as you read the rest of this chapter:

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<!-- A XML configuration file -->
<dds version = 5.0.0>
  <qos_library name="RTILibrary">
      <!-- A QoS Profile is a set of related QoS -->
      <qos_profile name="StrictReliableCommunicationProfile">
          <datawriter_qos>
              <history>
                  <kind>KEEP_ALL_HISTORY_QOS</kind>
              </history>
```

```
            <reliability>
                <kind>RELIABLE_RELIABILITY_QOS</kind>
             </reliability>
        </datawriter_qos>
        <datareader_qos>
            <history>
                <kind>KEEP_ALL_HISTORY_QOS</kind>
            </history>
            <reliability>
                <kind>RELIABLE_RELIABILITY_QOS</kind>
            </reliability>
        </datareader_qos>
    </qos_profile>
    <!--Individual QoS are shortcuts for QoS Profiles with 1 QoS->
    <datawriter_qos name="KeepAllWriter">
        <history>
            <kind>KEEP_ALL_HISTORY_QOS</kind>
        </history>
    </datawriter_qos>
  </qos_library>
</dds>
```

See **<NDDSHOME>/resource/xml/NDDS_QOS_PROFILES.example.xml** for another example; this file contains the default QoS values for all entity kinds.

19.2 QoS Libraries

A QoS Library is a named set of QoS profiles.

One configuration file may have several QoS libraries, each one defining its own QoS profiles.

All QoS libraries must be declared within **<dds>** and **</dds>** tags. For example:

```
<dds>
    <qos_library name="RTILibrary">
        <!-- Individual QoSs are shortcuts
             for QoS Profiles with 1 QoS -->
      <datawriter_qos name="KeepAllWriter">
              <history>
                      <kind>KEEP_ALL_HISTORY_QOS</kind>
              </history>
      </datawriter_qos>
      <!-- Qos Profile -->
               <qos_profile name=
                  "StrictReliableCommunicationProfile">
              <datawriter_qos>
                      <history>
                          <kind>KEEP_ALL_HISTORY_QOS</kind>
                      </history>
                      <reliability>
                          <kind>RELIABLE_RELIABILITY_QOS</kind>
                      </reliability>
              </datawriter_qos>
              <datareader_qos>
                      <history>
```

```
                        <kind>KEEP_ALL_HISTORY_QOS</kind>
                    </history>
                    <reliability>
                        <kind>RELIABLE_RELIABILITY_QOS</kind>
                    </reliability>
                </datareader_qos>
        </qos_profile>
    </qos_library>
</dds>
```

A QoS library can be reopened within the same configuration file or across different configuration files. For example:

```
<dds>
        <qos_library name="RTILibrary">
        ...
    </qos_library>
    ...
        <qos_library name="RTILibrary">
        ...
    </qos_library>
</dds>
```

19.3 QoS Profiles

A QoS *Profile* groups a set of related QoS policies, by entity (e.g., <datawriter_qos>), identified by a name. For example:

```
<qos_profile name="StrictReliableCommunicationProfile">
        <datawriter_qos>
                <history>
                        <kind>KEEP_ALL_HISTORY_QOS</kind>
                </history>
                <reliability>
                        <kind>RELIABLE_RELIABILITY_QOS</kind>
                </reliability>
        </datawriter_qos>
        <datareader_qos>
                <history>
                        <kind>KEEP_ALL_HISTORY_QOS</kind>
                </history>
                <reliability>
                        <kind>RELIABLE_RELIABILITY_QOS</kind>
                </reliability>
        </datareader_qos>
</qos_profile>
```

Duplicate QoS profiles are not allowed. To overwrite a QoS profile, use 19.3.3 QoS Profile Inheritance and Composition on page 848.

There are functions that allow you to create *Entities* using profiles, such as **create_participant_with_profile()** (9.3.1 Creating a DomainParticipant on page 610), **create_topic_with_profile()** (5.1.1 Creating Topics on page 217), etc.

If you create an entity using a profile without a QoS definition or an inherited QoS definition (see 19.3.3 QoS Profile Inheritance and Composition on page 848) for that class of entity, *Connext DDS* uses the default QoS.

Example 1:

```
<qos_profile name=
"BatchStrictReliableCommunicationProfile"
base_name="StrictReliableCommunicationProfile">
    <datawriter_qos>
        <batch>
           <enable>true</enable>
        </batch>
   </datawriter_qos>
</qos_profile>
```

The *DataReader* QoS value in the profile **BatchStrictReliableCommunicationProfile** is inherited from the profile **StrictReliableCommunicationProfile**.

Example 2:

```
<qos_profile name="BatchProfile">
    <datawriter_qos>
        <batch>
           <enable>true</enable>
        </batch>
   </datawriter_qos>
</qos_profile>
```

The *DataReader* QoS value in the profile **BatchProfile** is the default *Connext DDS* QoS.

19.3.1 Built-in QoS Profiles

Several QoS Profiles are built into the *Connext DDS* core libraries and can be used as starting points when configuring QoS for your *Connext DDS* applications. There are two provided libraries, **BuiltinQosLib** and **BuiltinQosLibExp**, which contain different profiles. You can use any of these profiles as base profiles when creating your own XML configurations or simply use these profiles directly in the **DDS_*_create_*_with_profile()** APIs. There is also a **BuiltinQosSnippetLib** library, which contains profile "snippets" that can be overlaid upon the profiles to provide additional modifications to your QoS. See 19.3.3.2 QoS Profile Composition on page 852 for more information.

There are three types of built-in profiles:

- **Baseline.X.X.X** profiles represent the QoS defaults for *Connext DDS* version X.X.X. The defaults for the latest *Connext DDS* version can be accessed using the **BuiltinQosLib::Baseline** profile.
- **Generic.X** profiles allow you to easily configure different features and communication use-cases with *Connext DDS*. For example, there is a **Generic.StrictReliable** profile for use when your application has a requirement for no data loss, regardless of the application domain.

- **Pattern.X** profiles inherit from **Generic.X** profiles and allow you to configure various domain-specific communication use cases. For example, there is a **Pattern.Alarm** profile that can be used to manage the generation and consumption of alarm events.

The **USER_QOS_PROFILES.xml** file generated by *RTI Code Generator* contains a profile that inherits from the **BuiltinQosLibExp::Generic.StrictReliable** profile as an example of how to use these profiles in your own application.

Example use-cases for these profiles:

- To quickly enable *RTI Monitoring Library* by inheriting from the **BuiltinQosLib::Generic.Monitoring.Common** profile. (See note below.)
- To easily revert to the default QoS values from a previous *Connext DDS* version by inheriting from the correct **BuiltinQosLib::Baseline.X.X.X profile.**
- To set up common use-case configurations and patterns such as strict reliability or large data communication by inheriting from one of the **BuiltinQosLibExp::Generic.X** or **Pattern.X** profiles.

To see the contents of the built-in QoS profiles:

In **<NDDSHOME>/resource/xml**, you will find:

- **BaselineRoot.documentationONLY.xml**—This file contains the root baseline QoS profile corresponding to the default values of *Connext DDS* 5.0.0.
- **BuiltinProfiles.documentationONLY.xml**—This file contains the rest of the built-in QoS profiles.

Notes:

- The built-in QoS profiles that enable *RTI Monitoring Library* set the property **rti.monitor.create_function**. Consequently, they only work in *Connext DDS* applications in which the monitoring library can be loaded dynamically. Specifically, the built-in monitoring profiles will not work in these situations:
  - When the *Connext DDS* application links the monitoring libraries statically
  - When using a VxWorks platform with Java[1]

  For more information, see Part 9: RTI Monitoring Library on page 1203.

[1] VxWorks Java platforms require custom supported libraries. To see whether a VxWorks platform with Java is supported, consult the RTI Connext DDS Core Libraries Platform Notes.

- Some of the built-in profiles are experimental. All the experimental profiles are contained within the library **BuiltinQosLibExp**.

19.3.2 Overwriting Default QoS Values

There are two ways to overwrite the default QoS used for new entities with values from a profile: programmatically and with an XML attribute.

- You can overwrite the default QoS programmatically with **set_default_<*entity*>_qos_with_profile ()** (where <*entity*> is participant, topic, publisher, subscriber, datawriter, or datareader)
- You can overwrite the default QoS using the XML attribute **is_default_qos** with the **<qos_profile>** tag
- Only for the DomainParticipantFactory: You can overwrite the default QoS using the XML attribute **is_default_participant_factory_profile**. This attribute has precedence over **is_default_qos** if both are set.

In the following example, the *DataWriter* and *DataReader* default QoS will be overwritten with the values specified in a profile named '**StrictReliableCommunicationProfile**':

```
<qos_profile name="StrictReliableCommunicationProfile"
    is_default_qos="true">
    <datawriter_qos>
        <history>
            <kind>KEEP_ALL_HISTORY_QOS</kind>
        </history>
        <reliability>
            <kind>RELIABLE_RELIABILITY_QOS</kind>
        </reliability>
    </datawriter_qos>
    <datareader_qos>
        <history>
            <kind>KEEP_ALL_HISTORY_QOS</kind>
        </history>
        <reliability>
            <kind>RELIABLE_RELIABILITY_QOS</kind>
        </reliability>
    </datareader_qos>
</qos_profile>
```

If multiple profiles are configured to overwrite the default QoS, only the last one parsed applies.

Example:

In this example, the profile used to configure the default QoSs will be **StrictReliableCommunicationProfile**.

```
<qos_profile name="BestEffortCommunicationProfile"
       is_default_qos="true">
   ...
</qos_profile>
```

```
<qos_profile name="StrictReliableCommunicationProfile"
       is_default_qos="true">
   ...
</qos_profile>
```

19.3.3 QoS Profile Inheritance and Composition

An individual QoS Profile or Entity QoS (e.g., <datawriter_qos>) can *inherit* values from other QoS Profiles, and/or be *composed* out of QoS Snippets. In inheritance, a **base_name** attribute is used to inherit from a single, previously loaded QoS Profile. With composition, a **<base_name>** tag is used to specify a list of one or more QoS Snippets to overlay upon the base profile, creating a new composed profile. The following sections describe how these methods can be used, including best practices. See also 19.6 XML File Syntax on page 878.

19.3.3.1 QoS Profile Inheritance

An individual QoS Profile can inherit values from other QoS Profiles described in the XML file by using the attribute **base_name**.

A QoS Profile may also inherit values from other QoS Profiles described in *different* XML files. A QoS Profile can only inherit from other QoS Profiles that have already been loaded. The order in which XML resources are loaded is described in 19.5 How to Load XML-Specified QoS Settings on page 875.

The following examples show how to inherit from other profiles:

Inheritance Example 1:

```
<qos_library name="Library">
    <qos_profile name="BaseProfile">
        <datawriter_qos>
           ...
        </datawriter_qos>
        <datareader_qos>
           ...
        </datareader_qos>
    </qos_profile>

<!-- use the base_name attribute to inherit from another profile -->
    <qos_profile name="DerivedProfile" base_name="BaseProfile">
        <datawriter_qos>
           <batch>
               <enable>true</enable>
               <max_samples>100</max_samples>
               <max_data_bytes>LENGTH_UNLIMITED</max_data_bytes>
           </batch>
        </datawriter_qos>
        <datareader_qos>
           ...
        </datareader_qos>
    </qos_profile>
</qos_library>
```

In this example, the QoS Profile called DerivedProfile is constructed via inheritance from the QoS Profile BaseProfile. The profile DerivedProfile inherits BaseProfile by referencing the base profile in the qos_profile attribute base_name="BaseProfile". This means that the datawriter_qos and datareader_qos in DerivedProfile inherit their values from the corresponding datawriter_qos and datareader_qos in BaseProfile. The QoS Profile DerivedProfile first initializes all its QoS policies with the values obtained from BaseProfile. Then it applies any QoS policies explicitly listed in its own definition to override the initialized values. In this example, MyDerivedProfile only modifies the BatchQos policy on the DataWriter QoS.

If a QoS Profile definition does not specify the base_name attribute, then it is initialized from the builtin defaults provided by *Connext DDS*. See 19.3.1 Built-in QoS Profiles on page 845.

Inheritance Example 2:

```
<qos_library name="Library">
    <datareader_qos name="BaseProfile">
        ...
    </datareader_qos>
    <datareader_qos name="DerivedProfile" base_name="BaseProfile"
        ...
    </datareader_qos>
</qos_library>
```

The datareader_qos in DerivedProfile inherits its values from the datareader_qos of BaseProfile. In this example, the datareader_qos definition is a shortcut for a QoS Profile definition with a single QoS.

Inheritance Example 3:

```
<qos_library name="Library">
    <qos_profile name="Profile1">
        <datawriter_qos name="BaseWriterQoS">
            ...
        </datawriter_qos>
        <datareader_qos>
            ...
        </datareader_qos>
    </qos_profile>
    <qos_profile name="Profile2">
        <datawriter_qos name="DerivedWriterQos" base_name="Profile1::BaseWriterQos">
            ...
        </datawriter_qos>
        <datareader_qos>
            ...
        </datareader_qos>
    </qos_profile>
</qos_library>
```

The datawriter_qos in Profile2 inherits its values from the datawriter_qos in Profile1. The datareader_qos in Profile2 will not inherit the values from the corresponding QoS in Profile1. Since Profile2 doesn't inherit from any other QoS Profile, the datareader_qos values will be taken from the builtin defaults. See 19.3.1 Built-in QoS Profiles on page 845.

Inheritance Example 4:

```
<qos_library name=”Library”>
    <qos_profile name="Profile1">
        <datawriter_qos>
            ...
        </datawriter_qos>
        <datareader_qos>
            ...
        </datareader_qos>
    </qos_profile>
    <qos_profile name="Profile2">
        <datawriter_qos name="BaseWriterQoS">
            ...
        </datawriter_qos>
        <datareader_qos>
            ...
        </datareader_qos>
    </qos_profile>
    <qos_profile name="Profile3" base_name="Profile1">
        <datawriter_qos name="DerivedWriterQos" base_name="Profile2::BaseWriterQos">
            ...
        </datawriter_qos>
        <datareader_qos>
            ...
        </datareader_qos>
    </qos_profile>
</qos_library>
```

The datawriter_qos in Profile3 inherits its values from the datawriter_qos in Profile2. The datareader_qos in Profile3 inherits its values from the datareader_qos in Profile1.

Inheritance Example 5:

```
<qos_library name=”Library”>
    <datareader_qos name="BaseProfile">
       ...
    </datareader_qos>
    <profile name="DerivedProfile" base_name="BaseProfile">
        <datareader_qos>
            ...
        </datareader_qos>
    </profile>
</qos_library>
```

The datareader_qos in DerivedProfile inherits its values from the datareader_qos in BaseProfile.

Inheritance Example 6:

Global_QoS.xml

```
<qos_library name="GlobalLibrary">
    <qos_profile name="GlobalProfileA">
    </qos_profile
</qos_library>
```

Component_QoS.xml

```
<qos_library name="ComponentLibrary">
    <qos_profile name="ComponentProfileA" basename="GlobalLibrary::GlobalProfileA">
    </qos_profile
</qos_library>
```

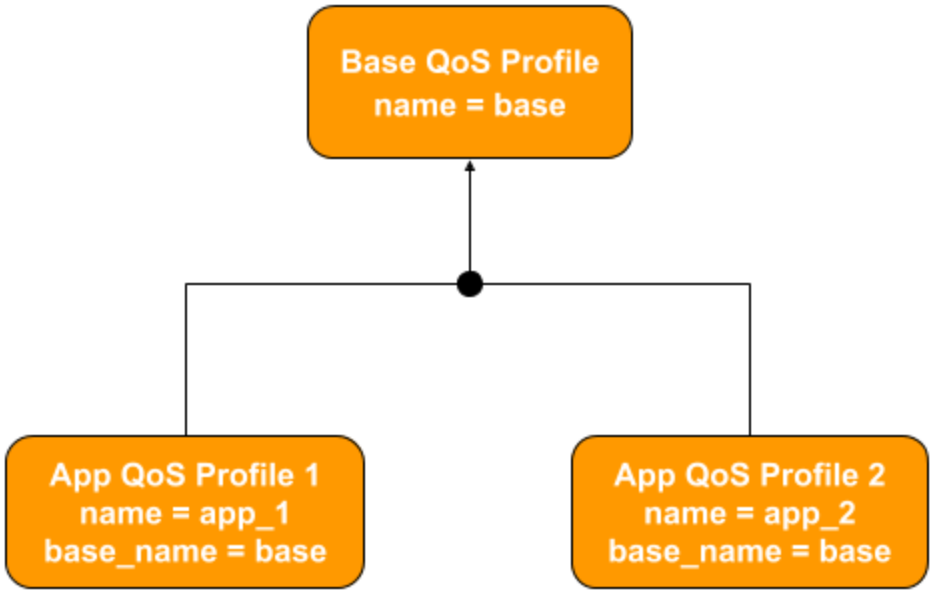
Previous examples show that a QoS Profile or QoS can inherit values from other QoS Profiles or QoSes, which should already be loaded. In this example, a QoS Profile inherits values from another QoS Profile defined in a separate QoS Library, in another file. This is a typical use case where QoSes are constructed by separating them into multiple files. In this example, Global_QoS.xml has to be loaded before Component_QoS.xml.

To learn more about how to load multiple files in your application, see 19.5 How to Load XML-Specified QoS Settings on page 875.

19.3.3.1.1 Limitations of QoS Profile Inheritance

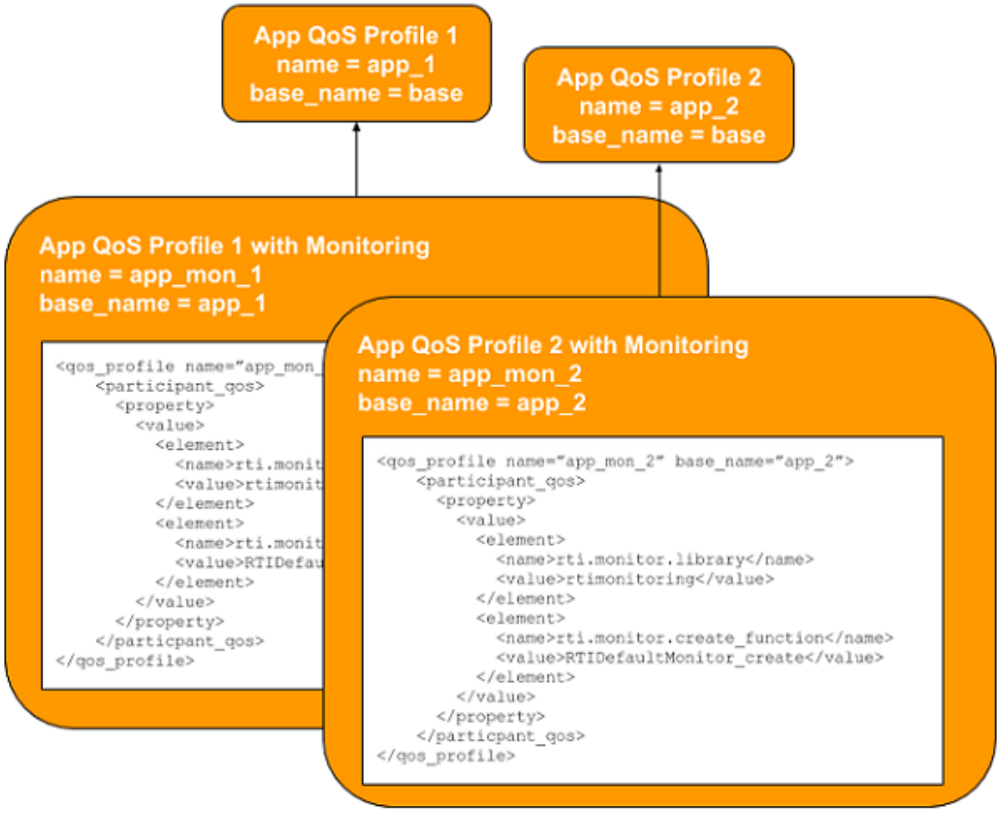
While useful, initializing a QoS Profile from a single base QoS Profile can also be limiting. For example, assume you have the configuration shown in Figure 19.1: Single Inheritance Example below

Figure 19.1: Single Inheritance Example



If you wanted to incorporate monitoring into the QoS Profiles app_1 and app_2, the only option with inheritance would be to create two new QoS Profiles, each inheriting from app_1 and app_2 respectively, and to copy the monitoring XML configuration into each of the two new QoS Profiles as shown in Figure 19.2: Duplication of Configuration in Inheritance on the next page. This results in significant XML code duplication and leads to maintainability issues.

Figure 19.2: Duplication of Configuration in Inheritance



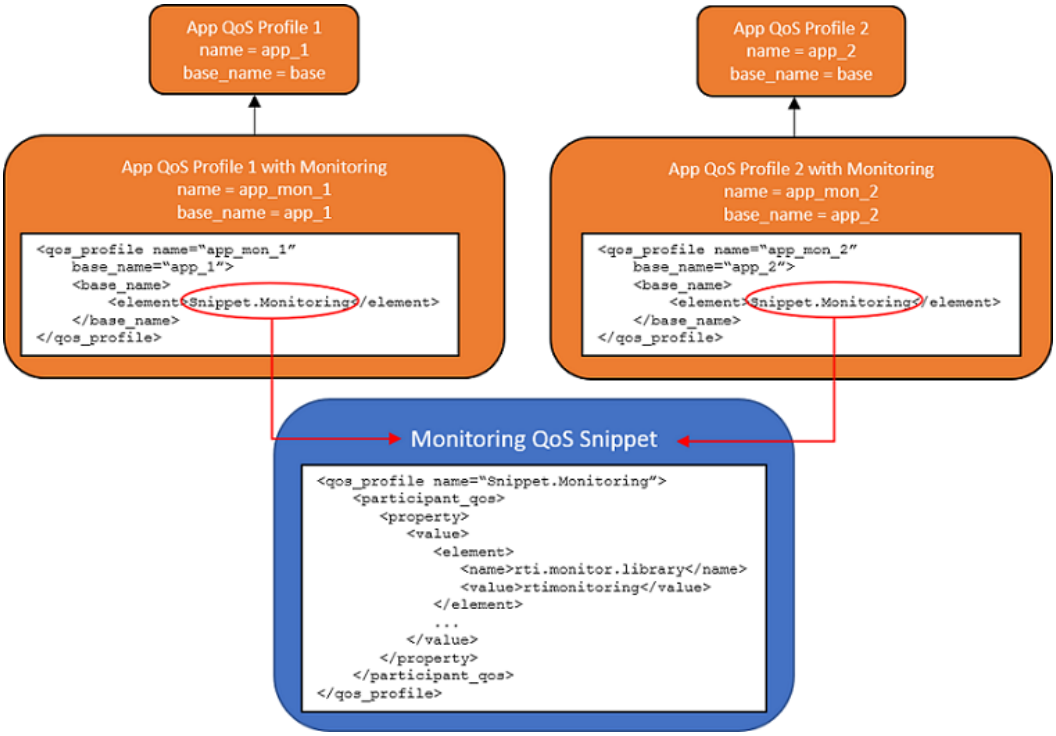
The following section describes how to handle the above scenario using QoS Profile *composition*.

19.3.3.2 QoS Profile Composition

QoS Profile composition uses QoS *Snippets* to more easily update profiles that you use or inherit. QoS Snippets are small pieces of well-formed, reusable XML QoS that configure a single aspect of QoS, such as enabling monitoring or security.

In the previous example, you could add the monitoring configuration to the new QoS Profiles app_mon_1 and app_mon_2 by referring to a QoS Snippet that configures monitoring.

Figure 19.3: One Reusable Configuration Snippet



QoS Snippets are intended to be composed into other QoS Snippets and QoS Profiles. As shown in the example below, the syntax used to define a QoS Snippet is the same as that of a QoS Profile, *but the intent and usage are different.*

The following is an example of the syntax used to define and use QoS Snippets.

Composition Example 1:

```
<!-- This is a QoS Snippet -->
    <qos_profile name="Snippet1">
        <datareader_qos>
            <reliability>
                <kind>RELIABLE_RELIABILITY</kind>
            </reliability>
        </datareader_qos>
    </qos_profile>

<!-- This is a QoS Snippet -->
    <qos_profile name="Snippet2">
        <datareader_qos>
            <durability>
                <kind>TRANSIENT_LOCAL_DURABILITY</kind>
            </durability>
        </datareader_qos>
    </qos_profile>

    <qos_profile name="Profile1">
```

```
        <datawriter_qos>
            <publication_name>
                <name>SampleDataWriter_A</name>
            </publication_name>
        </datawriter_qos>
    </qos_profile>

<!-- This QoS Profile definition uses the Snippets -->
    <qos_profile name="MyDerivedAndComposedProfile" base_name="Profile1">
        <base_name>
            <element>Snippet1</element>
            <element>Snippet2</element>
        </base_name>
        <datareader_qos>
            <history>
                <kind>KEEP_LAST_HISTORY_QOS</kind>
                <depth>6</depth>
            </history>
        </datareader_qos>
    </qos_profile>
```

In this example, a QoS Profile inherits from another QoS Profile and uses composition to weave in policies from two QoS Snippets. Specifically, MyDerivedAndComposedProfile is constructed by inheriting from Profile1, then by overlaying Snippet1 and Snippet2. Finally, MyDerivedAndComposedProfile applies its own QoS policies, which overwrite any others. See also 19.3.3.2.2 Order and Precedence of Inheritance on the next page.

It is recommended to use fully qualified names in the element tag if there is ambiguity in the QoS Profile or QoS Snippet names you have loaded in your application.

19.3.3.2.1 How Inheritance and Composition Work Together

The process of inheriting QoS Profiles and composing from QoS Snippets works as follows:

1. The QoS policies are initialized from those in the base profile, using the **base_name** attribute of the **<qos_profile>** tag. If the **base_name** attribute is not present, then the policies are initialized from the builtin defaults defined by *Connext DDS*.
2. The policies are overridden with those defined in the QoS Snippets listed inside the **<base_name>** XML tag. The QoS Snippets are applied in the order in which they appear. So the first QoS Snippet (Snippet1 in the example above) overrides the policies that were set from the inherited base QoS Profile (Profile1 in the example), the second QoS Snippet (Snippet2 in the example) overrides whatever was the result of applying Snippet1, and so on.
3. The policies that appear explicitly as elements in the QoS Profile are applied. These override the policies set by the base QoS Profile and the QoS Snippets. In this example, a KEEP_LAST_HISTORY_DEPTH of 6 overrides whatever was set by the base QoS Profile and the QoS Snippets.

You *inherit* a QoS Profile, but *overlay* one or more Qos Snippets. *Inherit* a QoS Profile because you want to subsume the complete definition of the QoS policies for a particular use case. *Overlay* QoS Snippets onto a QoS Profile so that you override only a single aspect of QoS: for instance, only what is logically associated with monitoring.

19.3.3.2.2 Order and Precedence of Inheritance

Values are inherited from the specified elements in the **<base_name>** tag, in order from top to bottom. Values inherited from elements lower in the order (Snippet2 in the examples) will overwrite the same values (if present) from elements higher up (Snippet1 in the examples). Remember that the QoS, QoS Profile, or QoS Snippet should already be loaded as a part of your XML file. (See 19.5 How to Load XML-Specified QoS Settings on page 875.)

In the following example, MyDerivedAndComposedProfile inherits from Profile1, keeping Profile1's SampleDataWriter_A but getting <durability> and <reliability> from the Snippets rather than from Profile1. Finally, MyDerivedAndComposedProfile applies its own local <history> policies.

Composition Example 2:

```
<!-- This is a QoS Snippet -->
    <qos_profile name="Snippet1">
        <datareader_qos>
            <reliability>
                <kind>RELIABLE_RELIABILITY_QOS</kind>
            </reliability>
        </datareader_qos>
    </qos_profile>

<!-- This is a QoS Snippet -->
    <qos_profile name="Snippet2">
        <datareader_qos>
            <durability>
                <kind>TRANSIENT_LOCAL_DURABILITY_QOS</kind>
            </durability>
        </datareader_qos>
    </qos_profile>

    <qos_profile name="Profile1">
        <datawriter_qos>
            <publication_name>
                <name>SampleDataWriter_A</name>
            </publication_name>
        </datawriter_qos>
        <datareader_qos>
            <durability>
                <kind>VOLATILE_DURABILITY_QOS</kind>
            </durability>
            <reliability>
                <kind>BEST_EFFORT_RELIABILITY_QOS</kind>
            </reliability>
        </datareader_qos>
```

```
    </qos_profile>

<!-- This QoS Profile definition uses the Snippets -->
    <qos_profile name="MyDerivedAndComposedProfile" base_name="Profile1">
        <base_name>
            <element>Snippet1</element>
            <element>Snippet2</element>
        </base_name>
        <datareader_qos>
            <history>
                <kind>KEEP_LAST_HISTORY_QOS</kind>
                <depth>6</depth>
            </history>
        </datareader_qos>
    </qos_profile>
```

The final values in MyDerivedAndComposedProfile will be as follows (map the colors in the example to what actually gets used), as shown here:

```
    <qos_profile name="MyDerivedAndComposedProfile">
        <datareader_qos>
            <reliability>
                <kind>RELIABLE_RELIABILITY</kind>
            </reliability>
            <history>
                <kind>KEEP_LAST_HISTORY_QOS</kind>
                <depth>6</depth>
            </history>
            <durability>
                <kind>TRANSIENT_LOCAL_DURABILITY</kind>
            </durability>
        </datareader_qos>
        <datawriter_qos>
            <publication_name>
                <name>SampleDataWriter_A</name>
            </publication_name>
        </datawriter_qos>
    </qos_profile>
```

Composition Example 3

Imagine that Example 2 had the following Snippets instead:

```
<!-- This is a QoS Snippet -->
    <qos_profile name="Snippet1">
        <datawriter_qos>
            <reliability>
                <kind>RELIABLE_RELIABILITY_QOS</kind>
                <max_blocking_time>
                    <sec>5</sec>
                    <nanosec>0</nanosec>
                </max_blocking_time>
            </reliability>
        </datawriter_qos>
```

```
    </qos_profile>

<!-- This is a QoS Snippet -->
    <qos_profile name="Snippet2">
        <datawriter_qos>
            <reliability>
                <kind>RELIABLE_RELIABILITY_QOS</kind>
                <max_blocking_time>
                    <nanosec>1000000</nanosec>
                </max_blocking_time>
            </reliability>
        </datawriter_qos>
    </qos_profile>

<!-- This QoS Profile definition uses the Snippets -->
    <qos_profile name="MyDerivedAndComposedProfile" base_name="Profile1">
        <base_name>
            <element>Snippet1</element>
            <element>Snippet2</element>
        </base_name>
    </qos_profile>
```

In this example, Snippet2's **nanosec** overwrites Snippet1's. But since Snippet2 does not specify a **sec**, Snippet1's **sec** is used. The resultant QoS is a combination of the two **reliability** policies:

```
<!-- The above example combines the reliability settings because one QoS Snippet is overlaid on
the other -->
            <reliability>
                <kind>RELIABLE_RELIABILITY_QOS</kind>
                <max_blocking_time>
                    <sec>5</sec>
                    <nanosec>1000000</nanosec>
                </max_blocking_time>
            </reliability>
```

Imagine now that the QoS Snippets in the above example were reversed, and Snippet2 was listed first in the file. Snippet2 would apply a **nanosec** of 1000000; then Snippet1 would overwrite that with 0 and apply its **sec** of 5. The result would be a **max_blocking_time** of 5 seconds and 0 nanoseconds.

You can use the **rtixmloutpututility** utility to see what the final QoS values will be in your system when composition and inheritance complete their derivations. See 19.3.3.5 Viewing Resolved QoS Values on page 863.

Composition Example 4:

If you specify **<base_name>** for a QoS Profile and also specify **<base_name>** for a QoS within it, the **<base_name>** tag or attribute in the QoS will take precedence. That is, **<base_name>** from the QoS Profile will be ignored for the QoS specifying its own **<base_name>**.

The following example illustrates this concept:

```
<dds>
    <qos_library>
```

```
        <qos_profile name="ParentProfile">
            <base_name>
                <element>A</element>
                <element>B</element>
            </base_name>
            ...
            <datawriter_qos name="DW_QoS">
                <base_name>
                    <element>C</element>
                    <element>D</element>
                </base_name>
            </datawriter_qos>
        </qos_profile>
    </qos_library>
</dds>
```

In this example, since DW_QoS has its own list for the **<base_name>** tag, DW_QoS will only inherit values from C and D. It will NOT inherit anything from A and B specified as a part of ParentProfile, since its own **<base_name>** tag overrides it.

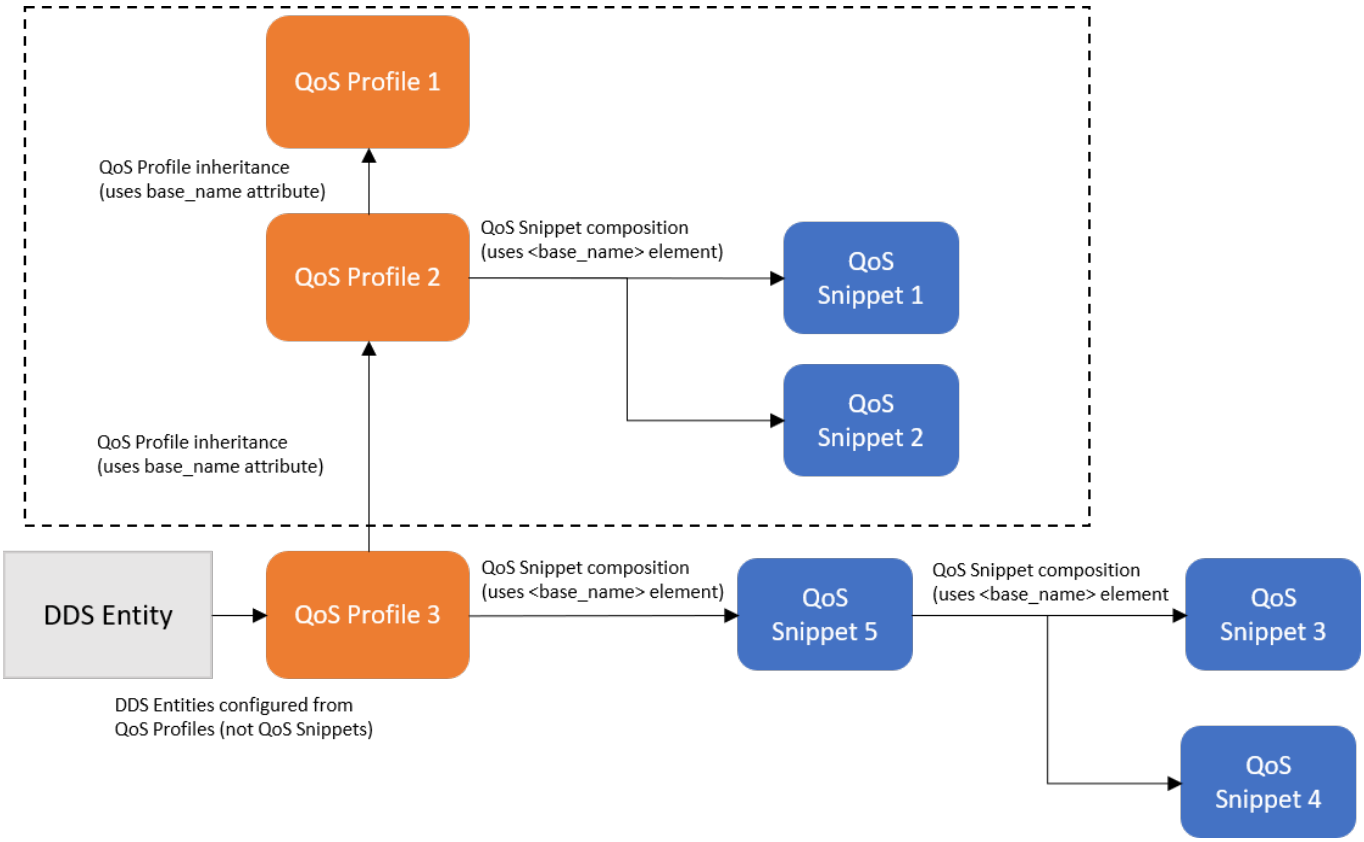
19.3.3.3 Best Practices for Inheritance and Composition

XML QoS Profile inheritance and composition provide a powerful way to define configurations, allowing flexibility and reusability. It is important to understand the underlying mechanics and follow the best practices described below to maximize usability and avoid unexpected results.

- *Differentiate between QoS Profiles and QoS Snippets.*
  - Think of QoS Profiles as complete definitions of all QoS policies for a particular use case. Construct QoS Profiles so that all aspects of the use case are covered.
  - Think of QoS Snippets as small, generic, orthogonal chunks of QoS policies. Construct QoS Snippets to configure a single aspect of a configuration, such as monitoring or security.
- *Use QoS Profiles for inheritance only, never composition.* Use a QoS Profile in a **base_name** attribute, never inside a **<base_name>** element.
- *Use QoS Snippets for composition, never inheritance.* Use a QoS Snippet inside a **<base_name>** element, never in a **base_name** attribute.
- *Use QoS Profiles, not QoS Snippets, to create DDS Entities.* Do not pass a QoS Snippet name to the DDS operations **create_<entity>_with_profile()**, **get_<entity>_qos_from_profile()**, **set_qos_with_profile()**, or **set_default_profile()**.
- *Keep QoS Snippets generic and reusable.* Never use the **<topic_filter>** element in a QoS Snippet.

These best practices are illustrated in the following figure and further described in the sections that follow.

Figure 19.4: Best Practices for Inheritance and Composition



In Figure 19.4: Best Practices for Inheritance and Composition above, imagine the results produced by the dotted box, as already illustrated in the previous examples. These results are inherited by QoS Profile 3. QoS Profile 3's snippets are then applied. (QoS Snippet 5 inherits from two other snippets first.) Finally, any policies in QoS Profile 3 that differ from the results produced by the inheritance from profiles 1 and 2 are applied.

Another way to look at Figure 19.4: Best Practices for Inheritance and Composition above is as a tree whose nodes are applied in this order, where "QP" refers to the QoS Profiles in the figure and "QS" refers to the QoS Snippets in the figure:

1. QP1 (because inheritance says we start all the way back at the first inherited profile)
2. QS1, then QS2 (because snippets are overlaid next)
3. QP2 (because it may have deltas that overwrite what has been composed so far)
4. QS3, then QS4 (because QS5 inherits from QS3 and QS4 first)
5. QS5 (because it may have deltas that overwrite QS3 and QS4)
6. QP3 (because it may have deltas that overwrite everything composed so far)

19.3.3.3.1 Differentiate between QoS Profiles and QoS Snippets

When defining a QoS Profile, decide whether you are:

- Creating a QoS Profile intended to create DDS *Entities* and/or fully define their QoS.
- Creating a QoS Snippet intended as a reusable block to be composed in the definition of QoS Profiles and other QoS Snippets.

These two options are fundamentally different.

A QoS Profile is intended to define the QoS policies used to create a DDS *Entity*. Therefore, it should match a specific application use case (e.g., sending alarms or streaming periodic data). Moreover, because the QoS Profile will be used to create a DDS *Entity*, it implicitly defines values for all the QoS Policies that apply to the entity.

When defining a QoS Profile, choose the builtin QoS Profile that most closely matches your use case. Use that builtin QoS Profile as a base profile. For example:

```
<qos_profile name="MyProfile" base_name="BuiltinQosLibExp::Pattern.AlarmEvent">
   <!-- modify the profile by composing with QoS Snippets -->
   <!-- modify the profile by overriding the QoS policies explicitly -->
   </qos_profile>
```

Give the QoS Profile a name that makes clear its intended use, as well as the fact that it is a QoS Profile (instead of a QoS Snippet). For example, use “Profile” as a suffix in the name of the QoS Profile or some other consistent naming convention.

A QoS Snippet is intended as a generic block of QoS policies for composition into QoS Profiles and other QoS Snippets. For example, configuring monitoring, configuring Security, and configuring a FlowController are good uses for QoS Snippets.

QoS Snippets should focus on a single aspect of QoS policy and try not to set unrelated policies. This maximizes composability, avoiding interfering with policies set by other QoS Snippets.

QoS Snippets should be generic and reusable across systems and deployments. Therefore, it does not make sense to constrain their applicability using the **<topic_filter>** element within their definition. Doing so may also result in conflict with topic filters set on QoS Profiles that use those QoS Snippets.

Give the QoS Snippet a name that makes clear its intended use, as well as the fact that it is a QoS Snippet (not a regular QoS Profile). For example, use “Snippet” as a suffix in the name of the QoS Snippet or some other consistent naming convention.

19.3.3.3.2 Use QoS Profiles for inheritance only, never composition

Aside from its use for creating DDS *Entities*, a QoS Profile may be used as the base definition of another QoS Profile. For example:

```
<qos_profile name="MyDerivedProfile" base_name="MyBaseProfile">
    ...
```

```
    </qos_profile>
```

When used for inheritance, the derived profile is initialized with the policies of the base profile.

A profile should never be used for composition. That is, it should not be referenced within the **<base_name>** element:

```
<qos_profile name="MyDerivedProfile">
    <base_name>
        <element>MyBaseProfile</element> <!-- never do this -->
    </base_name>
    </qos_profile>
```

Because a QoS Profile implicitly defines all the QoS policies, using it for composition would have the unintended effect of potentially overriding all the policies.

19.3.3.3.3 Use QoS Snippets for composition, never inheritance

QoS Snippets are small pieces of well-formed XML QoS intended to configure a single aspect of a QoS. The proper way to use them is for the composition of other QoS Profiles and QoS Snippets. Therefore, they must only appear within the **<base_name>** tag "element." For example:

```
<qos_profile name="MyComposedProfile" base_name="MyBaseProfile">
    <base_name>
        <element>Snippet1</element>
        <element>Snippet2</element>
        <element>Snippet3</element>
    </base_name>
     ...
    </qos_profile>

    <qos_profile name="MyComposedSnippet">
        <base_name>
            <element>Snippet1</element>
            <element>Snippet2</element>
            <element>Snippet3</element>
        </base_name>
        ...
    </qos_profile>
```

Do not use a QoS Snippet for inheritance. For example

```
<!-- do not do this -->
    <qos_profile name="MyComposedProfile" base_name="Snippet1">
        <base_name>
            <element>Snippet2</element>
            <element>Snippet3</element>
        </base_name>
        ...
    </qos_profile>
```

If you use a QoS Snippet for inheritance (i.e., for initializing another Qos Profile), you are using something that was not intended to be a full definition; thus, it may overlook the proper configuration of certain policies for your system.

19.3.3.3.4 Use QoS Profiles, not QoS Snippets, to create DDS Entities

The QoS configuration of DDS *Entities* can be specified using QoS Profiles. This is a convenient mechanism that allows separation of configuration from the functional logic of your application.

The *Connext DDS* API contains several operations that reference QoS Profiles by name, such as **create_participant_with_profile()** and **create_topic_with_profile()**. These operations are used to either create DDS *Entities* with the QoS policies referenced by the profile name, or to initialize the *Entity* QoS structure with the QoS policies referenced by the profile. Either way, these operations **should not be called using a QoS Snippet name** as the reference.

19.3.3.3.5 Keep QoS Snippets generic and reusable

QoS Snippets should be developed with reuse in mind and should not use the **<topic_filter>** element within the definition of the QoS Snippet.

```
<!-- do not do this -->
    <qos_profile name="MySnippet">
        <datawriter_qos topic_filter="Alarm">
            <reliability>
                <kind>RELIABLE_RELIABILITY</kind>
            </reliability>
        </datawriter_qos>
        <datawriter_qos topic_filter="SensorUpdate">
            <reliability>
                <kind>BEST_EFFORTS_RELIABILITY</kind>
            </reliability>
        </datawriter_qos>
         ...
    </qos_profile>
```

The **<topic_filter>** element conditionally defines the QoS Profile depending on the *Topic* name associated with the *Entity* being created or configured. Since the QoS Snippet is not intended to create or configure DDS *Entities* directly, it does not make sense to use the **<topic_filter>** element in its definition.

19.3.3.4 Enforcement of QoS Profile and QoS Snippet Conventions

Connext DDS uses the same syntax for the creation of QoS Profiles and QoS Snippets. Therefore, it does not enforce the conventions described here. Although *Connext DDS* will not detect or prevent violation of these conventions (e.g., if you use a QoS Profile for composition), following these conventions is strongly encouraged to avoid unexpected results. Furthermore, future versions of *Connext DDS* may introduce different syntax that allows differentiating QoS Profiles from QoS Snippets and enforces the conventions. If you follow these conventions now, you can continue using them without violating future syntax.

19.3.3.5 Viewing Resolved QoS Values

The final value for a QoS configuration, especially when using inheritance and QoS Snippet composition, can be visualized at runtime in a variety of ways:

- Locally in your application, the QoS **to_string** functions allow *Entity* QoS objects to be converted into strings and printed, so that you can see the current QoS being used. *Entity* QoS types are DataReaderQos, DataWriterQos, PublisherQos, SubscriberQos, TopicQos, DomainParticipantQos and DomainParticipantFactoryQos.
- Additionally, when an entity is created, or when the **set_qos** operation is called on an entity, the QoS settings it is using are output to the log, if logging is configured with a verbosity of NDDS_CONFIG_LOG_VERBOSITY_STATUS_LOCAL and category of NDDS_CONFIG_LOG_CATEGORY_API. (See 25.2 Controlling Messages from Connext DDS on page 968.) If the **DDS_EntityNameQosPolicy** is set, the names will be printed as part of a header to help associate logged QoS settings with the appropriate entities. *Connext DDS* automatically prints the QoSes of these entities to the log in XML format. Note it is not required that your QoS was configured in XML, it will always be logged in XML format to the log.

  The logged QoS when using logging, or the **to_string** functions, will show only the QoS settings that are different from the documented default (several **to_string** overloads can override this behavior). The documented default refers to the default value of a policy as specified by the API reference HTML documentation.

- Remotely, using *RTI Monitor*.
- Remotely, using *RTI Admin Console*. Note that when visualizing the QoS using *Admin Console*, only a subset of the QoS are shown. Only QoS policies that are required for matching are propagated to *Admin Console*.

Here is an example of a **to_string** function in the Modern C++ API:

```
using namespace rti::all;

DataWriterQos the_qos = writer.qos();

// Obtain a string representation of the DataWriterQos object
// Only differences with respect to the documented default will be included
std::string the_string = to_string(the_qos);

// Create another DataWriterQos object and change some policies
DataWriterQos other_qos;
other_qos << Reliability::BestEffort();
// The differences with respect to the other_qos object will now be stored to the string
the_string = to_string(the_qos, other_qos);

// Finally, we can print the entire QoS object (not just differences)
the_string = to_string(the_qos, rti::core::qos_print_all);
```

For older releases, or where code change/recompilation isn't possible, you can use **rtixmloutpututility** to visualize the end result of your QoS settings at entity creation time.

rtixmloutpututility allows you to see the final QoS values your entities will receive after inheritance and composition are resolved. Here is an example usage of this utility:

```
$ ./rtixmloutpututility
         -qosFile '/home/xxx/Documents/Tests/CORE-9446/USER_QOS_
PROFILES.xml;/home/xxx/Documents/Tests/CORE-1375/USER_QOS_PROFILES.xml'
         -profilePath Data_Library::Data_Profile
         -outputFile Dummy.txt
         -qosTag domain_participant_qos/property
```

To get this utility, including more information about its options and usage, please see: https://-github.com/rticommunity/rticonnextdds-xml-output-utility.

19.3.4 Topic Filters

A QoS profile may contain several writer, reader and topic QoSs. *Connext DDS* will select a QoS based on the evaluation of a filter expression on the topic name. The filter expression is specified as an attribute in the XML QoS definition. For example:

```
<qos_profile name="StrictReliableCommunicationProfile">
<datawriter_qos topic_filter="A*">
               <history>
                       <kind>KEEP_ALL_HISTORY_QOS</kind>
               </history>
               <reliability>
                       <kind>RELIABLE_RELIABILITY_QOS</kind>
               </reliability>
       </datawriter_qos>
<datawriter_qos topic_filter="B*">
               <history>
                       <kind>KEEP_ALL_HISTORY_QOS</kind>
               </history>
               <reliability>
                       <kind>RELIABLE_RELIABILITY_QOS</kind>
               </reliability>
               <resource_limits>
                       <max_samples>128</max_samples>
                       <max_samples_per_instance>128
                       </max_samples_per_instance>
                       <initial_samples>128</initial_samples>
                       <max_instances>1</max_instances>
                       <initial_instances>1</initial_instances>
               </resource_limits>
       </datawriter_qos>
       ...
</qos_profile>
```

If **topic_filter** is not specified in a QoS, *Connext DDS* will assume the filter **'*'**. The QoSs with an explicit **topic_filter** attribute definition will be evaluated in order; they have precedence over a QoS without a **topic_filter** expression.

The **topic_filter** attribute is only used with the following APIs:

DomainParticipantFactory:

- **get_<*entity*>_qos_from_profile_w_topic_name()** (where <*entity*> may be topic, datareader, or datareader; see 9.2.5 Getting QoS Values from a QoS Profile on page 603)

DomainParticipant:

- **create_datawriter_with_profile()** (see 7.3.1 Creating DataWriters on page 291)
- **create_datareader_with_profile()** (see 8.3.1 Creating DataReaders on page 507
- **create_topic_with_profile()** (see 5.1.1 Creating Topics on page 217)

Publisher:

- **create_datawriter_with_profile()** (see 7.3.1 Creating DataWriters on page 291)

Subscriber:

- **create_datareader_with_profile()** (see 8.3.1 Creating DataReaders on page 507)

Topic:

- **set_qos_with_profile()** (see 5.1.3 Setting Topic QosPolicies on page 219)

DataWriter:

- **set_qos_with_profile()** (see 7.2.4.3 Changing QoS Settings After the Publisher Has Been Created on page 280)

DataReader:

- **set_qos_with_profile()** (see 8.3.9 Setting DataReader QosPolicies on page 538)

Note: in the Modern C++ API, use **dds::core::QosProvider::<entity>_qos_w_topic_name()** to obtain the Qos associated with a topic. For example:

```
auto reader_qos = qos_provider.extensions().datareader_qos_w_topic_name("Example Topic");
dds::sub::DataReader<Foo> reader(subscriber, topic, reader_qos);
```

Other APIs will ignore QoSs with a **topic_filter** value different than "*". A QoS Profile with QoSs using **topic_filter** can also inherit from other QoS Profiles. In this case, inheritance will consider the value of the **topic_filter** expression.

Example 1:

```
<qos_library name=”Library”>
    <qos_profile name="BaseProfile">
        <datawriter_qos>
            ...
        </datawriter_qos>
        <datawriter_qos topic_filter="T1*">
            ...
        </datawriter_qos>
        <datawriter_qos topic_filter="T2*">
            ...
        </datawriter_qos>
    </qos_profile>
    <qos_profile name="DerivedProfile" base_name="BaseProfile">
        <datawriter_qos topic_filter="T11">
            ...
        </datawriter_qos>
        <datawriter_qos topic_filter="T21">
            ...
        </datawriter_qos>
        <datawriter_qos topic_filter="T31">
            ...
        </datawriter_qos>
    </qos_profile>
</qos_library>
```

The **datawriter_qos** with **topic_filter** T11 in DerivedProfile will inherit its values from the **datawriter_qos** with **topic_filter** T1* in BaseProfile. The **datawriter_qos** with **topic_filter** T21 in DerivedProfile will inherit its values from the **datawriter_qos** with **topic_filter** T2* in BaseProfile. The **datawriter_qos** with **topic_filter** T31 in DerivedProfile will inherit its values from the **datawriter_qos** without **topic_filter** in BaseProfile.

Example 2:

```
<qos_library name="Library">
    <qos_profile name="BaseProfile">
        <datawriter_qos topic_filter="T1*">
            ...
        </datawriter_qos>
        <datawriter_qos name="T2DataWriterQoS" topic_filter="T2*">
            ...
        </datawriter_qos>
    </qos_profile>
    <qos_profile name="DerivedProfile" base_name="BaseProfile">
        <datawriter_qos topic_filter="T11"
           base_name="BaseProfile::T2DataWriterQoS">
           ...
        </datawriter_qos>
        <datawriter_qos topic_filter="T21">
            ...
        </datawriter_qos>
    </qos_profile>
</qos_library>
```

Although the **topic_filter** expressions do not match, the **datawriter_qos** with **topic_filter** T11 in DerivedProfile will inherit its values from the **datawriter_qos** with **topic_filter** T2* in BaseProfile. **topic_filter** is not used with inheritance from QoS to QoS. The **datawriter_qos** with **topic_filter** T21 in DerivedProfile will inherit its values from the **datawriter_qos** with **topic_filter** T2* in BaseProfile.

Example 3:

```
<qos_library name="Library">
   <datawriter_qos name="BaseQos" topic_filter="T1">
       ...
   </datawriter_qos>
   <datawriter_qos name="DerivedQos" base_name="BaseQos" topic_filter="T2">
       ...
   </datawriter_qos>
</qos_library>
```

In the case of a single QoS profile, although the **topic_filter** expressions do not match, the datawriter_qos named DerivedQos with **topic_filter** T2 will inherit its values from the datawriter_qos named BaseQos with **topic_filter** T1.

Important Note About Topic Filters

Use the **topic_filter** attribute with caution. In most cases, governance of QoS is improved by using discrete, named QoS profiles with no more than one of each kind of entity QoS section (datareader_qos, datawriter_qos, etc.) in each profile. If the **topic_filter** attribute contains a typographical error or omission, it is possible for a topic not to match the intended filter expression. This can result in, for example, the entity being silently assigned the default QoS. The **topic_filter** attribute may be preferred in cases where wildcards are used extensively to reduce duplication in the XML. In these cases, the resulting QoS of each entity should be independently and empirically confirmed. Tools that can help confirm an entity's QoS are

RTI Monitor and (as described in 19.3.3.5 Viewing Resolved QoS Values on page 863) the **rtixmloutpututility**.

19.3.5 QoS Profiles with a Single QoS

The definition of an individual QoS outside a profile is a shortcut for defining a QoS profile with a single QoS. For example:

```
<datawriter_qos name="KeepAllWriter">
       <history>
              <kind>KEEP_ALL_HISTORY_QOS</kind>
       </history>
</datawriter_qos>
```

is equivalent to:

```
<qos_profile name="KeepAllWriter">
       <datawriter_qos>
              <history>
                     <kind>KEEP_ALL_HISTORY_QOS</kind>
              </history>
       </datawriter_qos>
</qos_profile>
```

19.4 Tags for Configuring QoS with XML

To configure the QoS for an *Entity* using XML, use the following tags:

- **<participant_factory_qos>**

  Note: The only QoS policies that can be configured for the DomainParticipantFactory are **<entity_factory>** and **<logging>**.

- **<domain_participant_qos>**
- **<publisher_qos>**
- **<subscriber_qos>**
- **<topic_qos>**
- **<datawriter_qos>** or **<writer_qos>** (writer_qos is valid only with DTD validation)
- **<datareader_qos>** or **<reader_qos>** (reader_qos is valid only with DTD validation)

Each QoS can be identified by a name. The QoS can inherit its values from other QoSs described in the XML file. For example:

```
<datawriter_qos name="DerivedWriterQos" base_name="Lib::BaseWriterQos">
    <history>
        <kind>KEEP_ALL_HISTORY_QOS</kind>
```

```
    </history>
</datawriter_qos>
```

In the above example, the datawriter_qos named 'DerivedWriterQos' inherits the values from 'BaseWriterQos' in the library 'Lib'. The HistoryQosPolicy **kind** is set to KEEP_ALL_HISTORY_QOS.

Each XML tag with an associated name can be uniquely identified by its fully qualified name in C++ style.

The writer, reader and topic QoSs can also contain an attribute called **topic_filter** that will be used to associate a set of topics to a specific QoS when that QoS is part of a QoS profile. See 19.3.4 Topic Filters on page 864 and 19.3 QoS Profiles on page 844.

19.4.1 QosPolicies

The fields in a QosPolicy are described in XML using a 1-to-1 mapping with the equivalent C representation. For example, the Reliability QosPolicy is represented with the following C structures:

```
struct DDS_Duration_t {
    DDS_Long sec;
    DDS_UnsignedLong nanosec;
}
struct DDS_ReliabilityQosPolicy {
    DDS_ReliabilityQosPolicyKind kind;
    DDS_Duration_t max_blocking_time;
}
```

The equivalent representation in XML is as follows:

```
<reliability>
    <kind></kind>
    <max_blocking_time>
        <sec></sec>
        <nanosec></nanosec>
    </max_blocking_time>
</reliability>
```

19.4.2 Sequences

In general, sequences in QosPolicies are described with the following XML format:

```
<a_sequence_member_name>
    <element>...</element>
    <element>...</element>
    ...
</a_sequence_member_name>
```

Each element of the sequence is enclosed in an <element> tag. For example:

```
<property>
    <value>
        <element>
            <name>my name</name>
            <value>my value</value>
```

```
        </element>
        <element>
            <name>my name2</name>
            <value>my value2</value>
        </element>
    </value>
</property>
```

A sequence without elements represents a sequence of length 0. For example:

```
<discovery>
    <!-- initial_peers sequence contains zero elements -->
    <initial_peers/>
</discovery>
```

For sequences that may have a default initialization that is *not empty* (such as the **initial_peers** field in the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635), using the above construct would result in an empty list and not the default value. So to simply show a sequence for the sake of completeness, but not change its default value, comment it out, as follows:

```
<discovery>
    <!-- initial_peers sequence contains the default value -->
    <!-- <initial_peers/> -->
</discovery>
```

As a general rule, sequences defined in a derived QoS will replace the corresponding sequences in the base QoS. (The concepts of *derived* and *base* QoS are described in 19.3.3 QoS Profile Inheritance and Composition on page 848.) For example, consider the following:

```
<qos_profile name="MyBaseProfile">
  <domain_participant_qos>
    <discovery>
       <initial_peers>
           <element>192.168.1.1</element>
           <element>192.168.1.2</element>
       </initial_peers>
    </discovery>
  </domain_participant_qos>
</qos_profile>
<qos_profile name="MyDerivedProfile" base_name="MyBaseProfile">
  <domain_participant_qos>
    <discovery>
       <initial_peers>
           <element>192.168.1.3</element>
       </initial_peers>
    </discovery>
  </domain_participant_qos>
</qos_profile>
```

The initial peers sequence defined above in the participant QoS of MyDerivedProfile will contain a single element with a value 192.168.1.3. The elements 192.168.1.1 and 192.168.1.2 will not be inherited. However, there is one exception to this behavior.

The <property> and <data_tags> tags provide an attribute called **inherit** that allows you to choose the inheritance behavior for the sequence defined within the tag.

By default, the value of the attribute **inherit** is true. Therefore, the <property> tag defined within a derived QoS profile will inherit its elements from the <property> tag defined within a base QoS profile.

In the following example, the property sequence defined in the participant QoS of MyDerivedProfile will contain two properties:

- **dds.transport.UDPv4.builtin.send_socket_buffer_size** will be inherited from the base profile and have the value 524288.
- **dds.transport.UDPv4.builtin.recv_socket_buffer_size** will overwrite the value defined in the base QoS profile with 1048576.

```
<qos_profile name="MyBaseProfile">
  <domain_participant_qos>
    <property>
      <value>
        <element>
            <name>
                dds.transport.UDPv4.builtin.send_socket_buffer_size
            </name>
            <value>524288</value>
        </element>
        <element>
           <name>
               dds.transport.UDPv4.builtin.recv_socket_buffer_size
           </name>
           <value>2097152</value>
        </element>
      </value>
    </property>
  </domain_participant_qos>
</qos_profile>
<qos_profile name="MyDerivedProfile" base_name="MyBaseProfile">
  <domain_participant_qos>
    <property>
      <value>
        <element>
            <name>
                dds.transport.UDPv4.builtin.recv_socket_buffer_size
            </name>
            <value>1048576</value>
        </element>
      </value>
    </property>
  </domain_participant_qos>
</qos_profile>
```

To discard all the properties defined in the base QoS profile, set **inherit** to false.

In the following example, the property sequence defined in the participant QoS of MyDerivedProfile will contain a single property named **dds.transport.UDPv4.builtin.recv_socket_buffer_size**, with a value of 1048576. The property **dds.transport.UDPv4.builtin.send_socket_buffer_size** will not be inherited.

```
<qos_profile name="MyBaseProfile">
  <participant_qos>
    <property>
      <value>
        <element>
            <name>
                dds.transport.UDPv4.builtin.send_socket_buffer_size
            </name>
            <value>524288</value>
        </element>
        <element>
            <name>
                dds.transport.UDPv4.builtin.recv_socket_buffer_size
            </name>
            <value>2097152</value>
        </element>
      </value>
    </property>
  </domain_participant_qos>
</qos_profile>
<qos_profile name="MyDerivedProfile" base_name="MyBaseProfile"
    <participant_qos>
        <property inherit="false">
            <value>
                <element>
                    <name>
                      dds.transport.UDPv4.builtin.recv_socket_buffer_size
                    </name>
                    <value>1048576</value>
                </element>
           </value>
       </property>
    </domain_participant_qos>
</qos_profile>
```

19.4.3 Arrays

In general, the arrays contained in the QosPolicies are described with the following XML format:

```
<an_array_member_name>
    <element>...</element>
    <element>...</element>
    ...
</an_array_member_name>
```

Each element of the array is enclosed in an <element> tag.

As a special case, arrays of octets are represented with a single XML tag enclosing an array of decimal/hexadecimal values between 0..255 separated with commas.

For example:

```
<reader_qos>
    ...
    <protocol>
        <virtual_guid>
```

```
            <value>
                1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
            </value>
        </virtual_guid>
    </protocol>
</reader_qos>
```

19.4.4 Enumeration Values

Enumeration values are represented using their C or Java string representation. For example:

```
<history>
    <kind>DDS_KEEP_ALL_HISTORY_QOS</kind>
</history>
```

or

```
<history>
    <kind>KEEP_ALL_HISTORY_QOS</kind>
</history>
```

When the XSD document is used for validation during editing (see 19.9.2 XML File Validation During Editing on page 883), only the Java representation is valid.

19.4.5 Time Values (Durations)

You can use the following special values for fields that require seconds or nanoseconds:

- DURATION_INFINITE_SEC or DDS_DURATION_INFINITE_SEC,
- DURATION_ZERO_SEC or DDS_DURATION_ZERO_SEC,
- DURATION_INFINITE_NSEC or DDS_DURATION_INFINITE_NSEC
- DURATION_ZERO_NSEC or DDS_DURATION_ZERO_NSEC

For example:

```
<deadline>
    <period>
           <sec>DURATION_INFINITE_SEC</sec>
        <nanosec>DURATION_INFINITE_NSEC</nanosec>
    </period>
</deadline>
```

When the XSD document is used for validation during editing (see 19.9.2 XML File Validation During Editing on page 883), only the values without the DDS prefix are considered valid.

19.4.6 Transport Properties

You can configure transport plugins using the *DomainParticipant's* 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.

- Properties for the builtin transports are described in 16.6 Setting Builtin Transport Properties with the PropertyQosPolicy on page 795. You can also set these properties in XML using the <transport_builtin> tag.
- Properties for other transport plugins such as *RTI TCP Transport*[1] are described in their respective chapters in this manual.

This example configures the builtin UDPv4 transport using the <transport_builtin> tags:

```
<domain_participant_qos>
    <transport_builtin>
        <udpv4>
            <message_size_max>1024</message_size_max>
        </udpv4>
    </transport_builtin>
</domain_participant_qos>
```

This example configures the builtin UDPv4 transport using the regular XML tags:

```
<domain_participant_qos>
    <property>
       <value>
           <element>
               <name>
                  dds.transport.UDPv4.builtin.parent.message_size_max
               </name>
               <value>65507</value>
           </element>
           <element>
               <name>
                  dds.transport.UDPv4.builtin.send_socket_buffer_size
               </name>
               <value>131072</value>
           </element>
           <element>
               <name>
                  dds.transport.UDPv4.builtin.recv_socket_buffer_size
               </name>
               <value>131072</value>
           </element>
       </value>
    </property>
</domain_participant_qos>
```

19.4.7 Thread Settings

See Table 21.1 XML Tags for ThreadSettings_t.

[1] *RTI TCP Transport* is included with *Connext DDS*, but is not enabled by default.

19.4.8 Entity Names

The **name** and **role_name** fields in the 7.5.11 ENTITY_NAME QosPolicy (DDS Extension) on page 416 have three distinct possible values: NULL, an empty string, and a non-empty string. Each of these three states are specified in XML in a different way.

To specify that the **name** or **role_name** of an entity is NULL, use the **xsi:nil** attribute. The **xsi:nil** attribute can be set to either "true" or "false". For example, to set the participant name to NULL:

```
<participant_name>
    <name xsi:nil="true">
</participant_name>
```

To specify the empty string, leave the XML element empty:

```
<participant_name>
    <name/>
</participant_name>
```

To specify a non-empty string:

```
<participant_name>
    <name>"My Participant's Name"</name>
</participant_name>
```

19.5 How to Load XML-Specified QoS Settings

There are several ways to load XML QoS profiles into your application. In C, Traditional C++, Java and .NET, it's the singleton DomainParticipantFactory that loads these profiles. Applications using the Modern C++ API can create any number of instances of **dds::core::QosProvider** with different parameters to load different QoS profiles or, they can use the singleton **QosProvider::Default()**. The profiles configured in the default QosProvider are used when creating an Entity without an explicit QoS parameter.

Here are the various approaches, listed in load order:

- **$NDDSHOME/resource/xml/NDDS_QOS_PROFILES.xml**
  This file is loaded automatically *if it exists* (not the default) *and* **ignore_resource_profile** in the 9.4.2 PROFILE QosPolicy (DDS Extension) on page 628 is FALSE (the default). **NDDS_QOS_PROFILES.xml** does not exist by default. However, **NDDS_QOS_PROFILES.example.xml** is shipped with the host bundle of the product; you can copy it to **NDDS_QOS_PROFILES.xml** and modify it for your own use. The file contains the default QoS values that will be used for all entity kinds. (*First to be loaded*)
- **XML files in NDDS_QOS_PROFILES**
  One or more XML files separated by semicolons referenced by the environment variable **NDDS_QOS_PROFILES** are loaded automatically if they exist *and* **ignore_environment_profile** in 9.4.2 PROFILE QosPolicy (DDS Extension) on page 628 is FALSE (the default).

Semicolons indicate to *Connext DDS* to load multiple files or strings all at once. For example:

On Linux and macOS systems, with bash:

```
export NDDS_QOS_PROFILES='file:///usr/local/default_dds_1.xml; file:///usr/local/default_dds_2.xml'
```

From a Windows command prompt:

```
set NDDS_QOS_PROFILES=file://D:/Data/ConnextDDSExample/default_dds_1.xml;
file://D:/Data/ConnextDDSExample/default_dds_2.xml
```

- **<working directory>/USER_QOS_PROFILES.xml**
  This file is loaded automatically if it exists *and* **ignore_user_profile** in 9.4.2 PROFILE QosPolicy (DDS Extension) on page 628 is FALSE (the default).
- **XML files in url_profile**
  One or more XML files referenced by **url_profile** (in 9.4.2 PROFILE QosPolicy (DDS Extension) on page 628) will be loaded automatically if specified.
- **XML strings in string_profile**
  The sequence of XML strings referenced by **string_profile** (in 9.4.2 PROFILE QosPolicy (DDS Extension) on page 628) will be loaded automatically if specified. See 19.7 XML String Syntax on page 881. (*Last to be loaded*)

  Note: The **url_profile** and **string_profile** fields are useful for adding profiles programmatically, when you do not want to use an environment variable.

You may use a combination of the above approaches.

The location of the XML documents (only files and strings are supported) is specified using URL (Uniform Resource Locator) format. For example:

- File Specification: **file:///usr/local/default_dds.xml**
- String Specification: **str://"<dds><qos_library>…</qos_library></dds>"**

If you omit the URL schema name, *Connext DDS* will assume a file name. For example:

- File Specification: **/usr/local/default_dds.xml**

Note: The path you specify can be absolute or relative. If you specify a relative path, it should be a path to a file that is lower down in the file hierarchy, not higher up.

Duplicate QoS profiles are not allowed. *Connext DDS* will report an error message in these scenarios. To overwrite a QoS profile, use 19.3.3 QoS Profile Inheritance and Composition on page 848.

Several QoS profiles are built into the *Connext DDS* core libraries and can be used as starting points when configuring QoS for your *Connext DDS* applications. For details, see 19.4 Tags for Configuring QoS with XML on page 868.

To load redundant locations for a single XML file, see 19.8 URL Groups (Loading Redundant Locations) on page 881.

19.5.1 Loading, Reloading and Unloading Profiles

You do not have to explicitly call **load_profiles()**. QoS profiles are loaded when any of these DomainParticipantFactory operations are called:

- **create_participant()** (see 9.3.1 Creating a DomainParticipant on page 610)
- **create_participant_with_profile()** (see 9.3.1 Creating a DomainParticipant on page 610)
- **get_<*entity*>_qos_from_profile()** (where <*entity*> is **participant**, **topic**, **publisher**, **subscriber**, **datawriter**, or **datareader**) (see 9.2.5 Getting QoS Values from a QoS Profile on page 603)
- **get_<*entity*>_qos_from_profile_w_topic_name()** (where <*entity*> is **topic**, **datawriter**, or **datareader**) (see 9.2.5 Getting QoS Values from a QoS Profile on page 603)
- **get_default_participant_qos()** (see 9.2.2 Getting and Setting Default QoS for DomainParticipants on page 602)
- **get_qos_profile_libraries()** (See 19.10.1 Retrieving a List of Available Libraries on page 886)
- **get_qos_profiles()** (See 19.4 Tags for Configuring QoS with XML on page 868)
- **load_profiles()**
- **set_default_participant_qos_with_profile()** (see 9.2.2 Getting and Setting Default QoS for DomainParticipants on page 602)
- **set_default_library()** (see 7.2.4.4 Getting and Setting the Publisher's Default QoS Profile and Library on page 281)
- **set_default_profile()** (see 7.2.4.4 Getting and Setting the Publisher's Default QoS Profile and Library on page 281)

In the Modern C++ API, the previous operations cause the default QosProvider (QosProvider::Default()) to load the QoS profiles. Any other QosProvider that an application instantiates will load the QoS Profiles it is configured to load in its constructor.

QoS profiles are reloaded when either of these DomainParticipantFactory operations are called:

- **reload_profiles()**
- **set_qos()** (see 4.1.7 Getting, Setting, and Comparing QosPolicies on page 172)

It is important to distinguish between loading and reloading:

- *Loading* only happens when there are no previously loaded profiles. This could be when the profiles are loaded the first time or after a call to **unload_profiles()**.
- *Reloading* replaces all previously loaded profiles. Reloading a profile does not change the QoS of entities that have already been created with previously loaded profiles.

The DomainParticipantFactory also has an **unload_profiles()** operation that frees the resources associated with the XML QoS profiles.

```
DDS_ReturnCode_t unload_profiles()
```

19.6 XML File Syntax

The contents of the XML configuration file must follow an important hierarchy: the file contains one or more libraries; each library contains one or more profiles; each profile contains QoS settings.

In addition, the file must follow these syntax rules:

- The syntax is XML and the character encoding is UTF-8.
- Opening tags are enclosed in <>; closing tags are enclosed in </>.
- A tag value is a UTF-8 encoded string. Legal values are alphanumeric characters. The middleware's parser will remove all leading and trailing spaces[a] from the string before it is processed.
- For example, **<tag> value </tag>** is the same as **<tag>value</tag>**.
- All values are case-sensitive unless otherwise stated.
- Comments are enclosed as follows: **<!-- comment -->**.
- The root tag of the configuration file must be **<dds>** and end with **</dds>**.
- The primitive types for tag values are specified in Table 19.1 Supported Tag Values.

Table 19.1 Supported Tag Values

Type	Format	Notes
DDS_Boolean	true, false	Not case-sensitive
DDS_Enum	A string. Legal values are those listed in the API Reference HTML documentation for the C or Java API.	Must be specified as a string. (Do not use numeric values.)

[a]Leading and trailing spaces in enumeration fields will not be considered valid if you use the distributed XSD document to do validation at run-time with a code editor.

Table 19.1 Supported Tag Values

Type	Format	Notes
DDS_Long	-2147483648 to 2147483647 or 0x80000000 to 0x7fffffff or LENGTH_UNLIMITED or DDS_LENGTH_UNLIMITED	A 32-bit signed integer
DDS_ UnsignedLong	0 to 4294967296 or 0 to 0xffffffff	A 32-bit unsigned integer
String	UTF-8 character string	All leading and trailing spaces are ignored between two tags

See also:

- 19.6.1 Using Environment Variables in XML below
- 19.6.2 Using Special Characters in XML below
- 19.6.3 Specifying Fully Qualified Names in XML on the next page

19.6.1 Using Environment Variables in XML

The text within an XML tag and attribute can refer to environment variable. To do so, use the following notation:

```
$(MY_VARIABLE)
```

For example:

```
<element attr="The attribute is $(MY_ATTRIBUTE)">
    <name>The name is $(MY_NAME)</name>
    <value>The value is $(MY_VALUE)</value>
</element>
```

When the *Connext DDS* XML parser parses the above tags, it will replace the references to environment variables with their actual values.

19.6.2 Using Special Characters in XML

In the XML QoS configuration file, you may sometimes want to use special characters for the name of an element. If so, escape them by surrounding the attribute value with **"** symbols in XML. The **"** symbol is a special escape character within the XML standard that represents double quotes (").

For example:

```
<qos_profile name="&quot;&lt;MySpecial::NameProfile&gt;&quot;">
</qos_profile>
```

The name of this profile is **<MySpecial::NameProfile>**. It contains special characters like **<**, **>** and **:** within its name. When not escaped, "::" is often used as a name separator when referring to an element in the XML hierarchy. (See 19.6.3 Specifying Fully Qualified Names in XML below.)

You can use the same scheme when inheriting from the QoS profile in the **base_name** attribute or the <base_name> tag.

For example:

```
<qos_profile name="SpecialNameDerived"
        is_default_qos="true">
    <base_name>
        <element>Data_Library::&quot;&lt;MySpecial::NameProfile&gt;&quot;</element>
    </base_name>
</qos_profile>

<qos_profile name="SpecialNameDerived"
        base_name="Data_Library::&quot;&lt;MySpecial::NameProfile&gt;&quot;"
        is_default_qos="true">
</qos_profile>
```

In this example, the profile is contained within the **Data_Library** QoS Library.

This idea is applicable to all tags that can perform inheritance (any tag that has a **base_name** attribute or can contain the <base_name> tag).

19.6.3 Specifying Fully Qualified Names in XML

When specifying a parent to inherit from in the **base_name** attribute or the <base_name> tag of a QoS policy in an XML file, you can refer to elements using a fully qualified naming scheme. This causes the search to begin from the root of the XML Document Object Model (DOM) tree parsed by the XML parser.

For that you need to follow this scheme:

```
<parent_tag_name>::<child_tag_name>::<grandchild_tag_name> . . .
```

The resulting name should match the declaration hierarchy. The declaration hierarchy represents the ordering of the tags as described in the XML schema. For QoS configuration, the hierarchy is as follows:

```
<qos_library_name>::<qos_profile_name>
```

Here "::" is the path separator in the XML DOM tree. Specifying a fully qualified name is useful when you want to refer to elements within another <qos_library> tag.

For example:

```
<qos_library name="Data_Library">
    <qos_profile name="Data_Profile" base_name="BuiltinQosLib::Generic.StrictReliable">
        . . .
```

```
    </qos_profile>
</qos_library>
```

19.7 XML String Syntax

XML profiles can be described using strings. This configuration is useful for architectures without a file system.

There are two different ways to configure *Entities* via XML strings:

- String URLs are prefixed by the URI schema **str://** and enclosed in double quotes. For example:

  ```
  str://"<dds><qos_library>...</qos_library></dds>"
  ```

  The string URLs can be specified in the environment variable **NDDS_QOS_PROFILES** as well as in the field **url_profile** in 9.4.2 PROFILE QosPolicy (DDS Extension) on page 628. Each string URL must contain a whole XML document.
- The **string_profile** field in the 9.4.2 PROFILE QosPolicy (DDS Extension) on page 628 allows you to split an XML document into multiple strings. For example:

  ```
  const char * MyXML[4] =
  {
      "<dds>",
         "<qos_library name=\"MyLibrary\">",
         "</qos_library>",
      "</dds>"
  };
  factoryQos.profile.string_profile.from_array(MyXML,4);
  ```

Only one XML document can be specified with the **string_profile** field.

19.8 URL Groups (Loading Redundant Locations)

Use URL groups to specify multiple locations for a single XML file, to provide redundancy and fault tolerance. Specify the locations by enclosing them in square brackets. The syntax of a URL group is:

```
[URL1 | URL2 | URL2 | ... | URLn]
```

You can specify either an XML file or an XML string. For example:

```
[file:///usr/local/default_dds.xml | file:///usr/local/alternative_default_dds.xml |
str://"<dds><qos_library name="Data_Library"><qos_profile  name="Data_Profile" base_
name="BuiltinQosLibExp::Generic.StrictReliable" is_default_qos="true" /></qos_library></dds>"]
```

The OR operand (|) tells *Connext DDS* to load one file/string at a time, starting from the left. If the first file/string is not available, *Connext DDS* tries loading the next one, and so on. For example, if the first location loaded successfully, *Connext DDS* does not load the subsequent locations. Brackets are not required for URL groups with a single file/string. In fact, single XML files separated by semicolons are URL groups without brackets.

Here's an example (on a Linux system with bash) that loads multiple files, including one bracketed URL group with redundant file locations:

```
export NDDS_QOS_PROFILES='[file:///usr/local/default_dds.xml | file:///usr/local/alternative_
default_dds.xml]; file:///usr/local/default_dds_2.xml'
```

See also 19.5 How to Load XML-Specified QoS Settings on page 875 for information on loading multiple XML files.

19.9 How the XML is Validated

19.9.1 Validation at Run-Time

Connext DDS validates the input XML files using a builtin Document Type Definition (DTD).

You can find a copy of the builtin DTD in **<NDDSHOME>/resource/schema/rti_dds_qos_profiles.dtd**. (This is only a *copy* of what the *Connext DDS* core uses. Changing this file has no effect unless you specify its path with the <!DOCTYPE> tag, described below.)

You can overwrite the builtin DTD by using the XML tag, <!DOCTYPE>. For example, the following indicates that *Connext DDS* must use a DTD file from a user's directory to perform validation:

```
<!DOCTYPE dds SYSTEM "/local/joe/rti/dds/mydds.dtd">
```

- The DTD path can be absolute, or relative to the application's current working directory.
- If the specified file does not exist, you will see the following error:

  ```
  RTIXMLDtdParser_parse:!open DTD file
  ```

- If you do not specify the DOCTYPE tag in the XML file, the builtin DTD is used.
- The XML files used by *Connext DDS* can be versioned using the attribute version in the <dds> tag. For example:

  ```
  <dds version="6.1.0">
     ...
  </dds>
  ```

  Although the attribute version is not required during the validation process, it helps to detect DTD incompatibility scenarios by providing better error messages.

  For example, if an application using *Connext DDS* 6.1.0 tries to load an XML file from *Connext DDS* 4.5z and there is some incompatibility in the XML content, the following parsing error will be printed:

  ```
  ATTENTION: The version declared in this file (4.5z) is different from the version of
  Connext DDS (6.1.0).
  If these versions are not compatible, that incompatibility could be the cause of this
  error.
  ```

19.9.2 XML File Validation During Editing

Connext DDS provides DTD and XSD files that describe the format of the XML content. We recommend including a reference to one of these documents in the XML file that contains the QoS profiles—this provides helpful features in code editors such as Visual Studio and Eclipse, including validation and auto-completion while you are editing the XML file.

The DTD and XSD definitions of the XML elements are in **<NDDSHOME>/resource/schema/rti_dds_qos_profiles.dtd** and **<NDDSHOME>/resource/schema/rti_dds_qos_profiles.xsd**, respectively. (**<NDDSHOME>** is described in Paths Mentioned in Documentation on page 1.)

To include a reference to the XSD document in your XML file, use the attribute **xsi:noNamespaceSchemaLocation** in the <dds> tag. For example:

```
<?xml version="1.0" encoding="UTF-8"?>
<dds xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:noNamespaceSchemaLocation=
"<NDDSHOME>/resource/schema/rti_dds_qos_profiles.xsd">
    ...
</dds>
```

To include a reference to the DTD document in your XML file use the <!DOCTYPE> tag. For example:

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE dds SYSTEM
"<NDDSHOME>/resource/schema/rti_dds_qos_profiles.dtd">
<dds>
    ...
</dds>
```

We recommend including a reference to the XSD file in the XML documents because it provides stricter validation and better auto-completion than the corresponding DTD file.

19.10 Using QoS Profiles in Your *Connext DDS* Application

You can use the operations listed in Table 19.2 Operations for Working with QoS Profiles to refer to and use QoS profiles (see 19.3 QoS Profiles on page 844) described in XML files and XML strings.

Table 19.2 Operations for Working with QoS Profiles

Working With ...	Profile-Related Operations	Reference
DataReaders	set_qos_with_profile	8.3.9.3 Changing QoS Settings After the DataReader has been Created on page 543
DataWriters	set_qos_with_profile	7.3.15.3 Changing QoS Settings After the DataWriter Has Been Created on page 337

Table 19.2 Operations for Working with QoS Profiles

Working With ...	Profile-Related Operations	Reference
DomainParticipants	create_datareader_with_profile	8.3.1 Creating DataReaders on page 507
	create_datawriter_with_profile	7.3.1 Creating DataWriters on page 291
	create_publisher_with_profile	7.2.2 Creating Publishers on page 275
	create_subscriber_with_profile	8.2.2 Creating Subscribers on page 488
	create_topic_with_profile	5.1.1 Creating Topics on page 217
	get_default_library	9.3.7.4 Getting and Setting DomainParticipant's Default QoS Profile and Library on page 621
	get_default_profile	
	get_default_profile_library	
	set_default_datareader_qos_with_profile	9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622
	set_default_datawriter_qos_with_profile	
	set_default_library	9.3.7.4 Getting and Setting DomainParticipant's Default QoS Profile and Library on page 621
	set_default_profile	
	set_default_publisher_qos_with_profile	9.3.7.5 Getting and Setting Default QoS for Child Entities on page 622
	set_default_subscriber_qos_with_profile	
	set_default_topic_qos_with_profile	
	set_qos_with_profile	9.3.7.3 Changing QoS Settings After DomainParticipant Has Been Created on page 620

Table 19.2 Operations for Working with QoS Profiles

Working With ...	Profile-Related Operations	Reference
DomainParticipantFactory	create_participant_with_profile	9.3.1 Creating a DomainParticipant on page 610
	get_datareader_qos_from_profile	9.2.5 Getting QoS Values from a QoS Profile on page 603
	get_datawriter_qos_from_profile	
	get_datawriter_qos_from_profile_w_topic_name	
	get_datareader_qos_from_profile_w_topic_name	
	get_default_library	9.2.1.1 Getting and Setting the DomainParticipantFactory's Default QoS Profile and Library on page 601
	get_default_profile	
	get_default_profile_library	
	get_participant_qos_from_profile	9.2.5 Getting QoS Values from a QoS Profile on page 603
	get_publisher_qos_from_profile	
	get_subscriber_qos_from_profile	
	get_topic_qos_from_profile	
	get_topic_qos_from_profile_w_topic_name	
	get_qos_profiles	19.10.2 Retrieving a List of Available QoS Profiles on page 887
	get_qos_profile_libraries	19.10.1 Retrieving a List of Available Libraries on the next page
	load_profiles	19.5.1 Loading, Reloading and Unloading Profiles on page 877
	reload_profiles	
	set_default_participant_qos_with_profile	9.2.2 Getting and Setting Default QoS for DomainParticipants on page 602
	set_default_library	9.2.1.1 Getting and Setting the DomainParticipantFactory's Default QoS Profile and Library on page 601
	set_default_profile	
	unload_profiles	19.5.1 Loading, Reloading and Unloading Profiles on page 877

Table 19.2 Operations for Working with QoS Profiles

Working With ...	Profile-Related Operations	Reference
Publishers	create_datawriter_with_profile	7.2.2 Creating Publishers on page 275
	get_default_library	7.2.4.4 Getting and Setting the Publisher's Default QoS Profile and Library on page 281
	get_default_profile	
	get_default_profile_library	
	set_default_datawriter_qos_with_profile	7.2.4.5 Getting and Setting Default QoS for DataWriters on page 281
	set_default_library	7.2.4.4 Getting and Setting the Publisher's Default QoS Profile and Library on page 281
	set_default_profile	
	set_qos_with_profile	7.2.4.3 Changing QoS Settings After the Publisher Has Been Created on page 280
Subscribers	create_datareader_with_profile	8.3.1 Creating DataReaders on page 507
	get_default_library	8.2.4.4 Getting and Settings Subscriber's Default QoS Profile and Library on page 494
	get_default_profile	
	get_default_profile_library	
	set_default_datareader_qos_with_profile	8.2.4.5 Getting and Setting Default QoS for DataReaders on page 495
	set_default_library	8.2.4.4 Getting and Settings Subscriber's Default QoS Profile and Library on page 494
	set_default_profile	
	set_qos_with_profile	8.2.4.3 Changing QoS Settings After Subscriber Has Been Created on page 493
Topics	set_qos_with_profile	5.1.3 Setting Topic QosPolicies on page 219

Note: For the Modern C++ API, please refer to the RTI Connext DDS API Reference HTML documentation, Configuring QoS Profiles with XML.

19.10.1 Retrieving a List of Available Libraries

To get a list of available QoS libraries, call the DomainParticipantFactory's **get_qos_profile_libraries()** operation, which returns the names of all QoS libraries that have been loaded by *Connext DDS*.

```
DDS_ReturnCode_t get_qos_profile_libraries (struct DDS_StringSeq *profile_names)
```

19.10.2 Retrieving a List of Available QoS Profiles

To get a list of available QoS profiles, call the DomainParticipantFactory's **get_qos_profiles()** operation, which returns the names of all profiles within a specified QoS library. Either the input QoS library name must be specified or the default profile library must have been set prior to calling this function.

```
DDS_ReturnCode_t get_qos_profiles (struct DDS_StringSeq *profile_names,
                                   const char *library_name)
```

19.11 Configuring Logging Via XML

Logging can be configured via XML using the DomainParticipantFactory's LoggingQosPolicy. See 25.2.2 Configuring Logging via XML on page 976 for additional details.

Chapter 20 Multi-channel DataWriters

In *Connext DDS*, producers publish data to a *Topic,* identified by a topic name; consumers subscribe to a *Topic* and optionally to specific content by means of a content-filter expression.

A Market Data Example:

A producer can publish data on the Topic "MarketData" which can be defined as a structured record containing fields that identify the exchange (e.g., "NYSE" or "NASDAQ"), the stock symbol (e.g., "APPL" or "JPM"), volume, bid and ask prices, etc.

Similarly, a consumer may want to subscribe to data on the "MarketData" Topic, but only if the exchange is "NYSE" or the symbol starts with the letter "M." Or the consumer may want all the data from the "NYSE" whose volume exceeds a certain threshold, or may want MarketData for a specific stock symbol, regardless of the exchange, and so on.

The middleware's efficient implementation of content-filtering is critical for scenarios such as the above "Market Data" example, where there are large numbers of consumers, large volumes of data, or Topics that transmit information about many data-objects or subjects (e.g., individual stocks).

Traditionally, middleware products use four approaches to implement content filtering: Producer-based, Consumer-based, Server-based, and Network Switch-based.

- **Producer-based approaches** push the burden of filtering to the producer side. The producer knows what each consumer wants and delivers to the consumer only the data that matches the consumer's filter. This approach is suitable when using point-to-point protocols such as TCP—it saves bandwidth and lowers the load on the consumer—but it does not work if data is distributed via multicast. Also, this approach does not scale to large numbers of consumers, because the producer would be overburdened by the need to filter for each individual consumer.

- **Consumer-based approaches** push the burden of filtering to the consumer side. The producer sends all the data to every consumer and the middleware on the consumer side decides whether the application wants it or not, automatically filtering the unwanted data. This approach is simple and fits well in systems that use multicast protocols as a transport. But the approach is not efficient for consumers that want small subsets of the data, since the consumers have to spend a lot of time filtering unwanted data. This approach is also unsuitable for systems with large volumes of data, such as the above Market Data system.
- **Server-based approaches** push the burden of filtering to a third component: a server or broker. This approach has some scalability advantages—the server can be run on a more powerful computer and can be federated to handle a large number of consumers. Some providers also provide hardware-assisted filtering in the server. However, the server-based approach significantly increases latency and jitter. It is also far more expensive to deploy and manage.
- **Network Switch-based approaches** leverage the network hardware, specifically advanced (IGMP snooping) network switches, to offload most of the burden of filtering from the producers and consumers without introducing additional hardware, servers or proxies. This approach preserves the low latency and ease of deployment of the brokerless approaches while still providing most of the offloading and scalability benefits of the broker.

RTI supports the producer-based, consumer-based and network-switch approaches to content filtering:

- RTI automatically uses the producer-based and consumer-based approaches as soon as it detects a consumer that specifies a content filter. The producer-based approach is used if the consumer is receiving data over a point-to-point protocol (i.e., not multicast) and the number of consumers that specify filters is reasonably low (below 32). Otherwise, RTI uses a subscriber-based approach.
- To use the more scalable network-switched based approach, an application must configure the *DataWriter* as a *Multi-channel DataWriter*. This concept is described in the following section.

20.1 What is a Multi-channel DataWriter?

A *Multi-channel DataWriter* is a *DataWriter* that is configured to send data over multiple multicast addresses, according to some filtering criteria applied to the data.

To determine which multicast addresses will be used to send the data, the middleware evaluates a set of filters that are configured for the *DataWriter*. Each filter "guards" a *channel*—a set of multicast addresses. Each time a multi-channel *DataWriter* writes data, the filters are applied. If a filter evaluates to true, the data is sent over that filter's associated channel (set of multicast addresses). We refer to this type of filter as a *Channel Guard filter*.

Figure 20.1: Multi-channel Data Flow

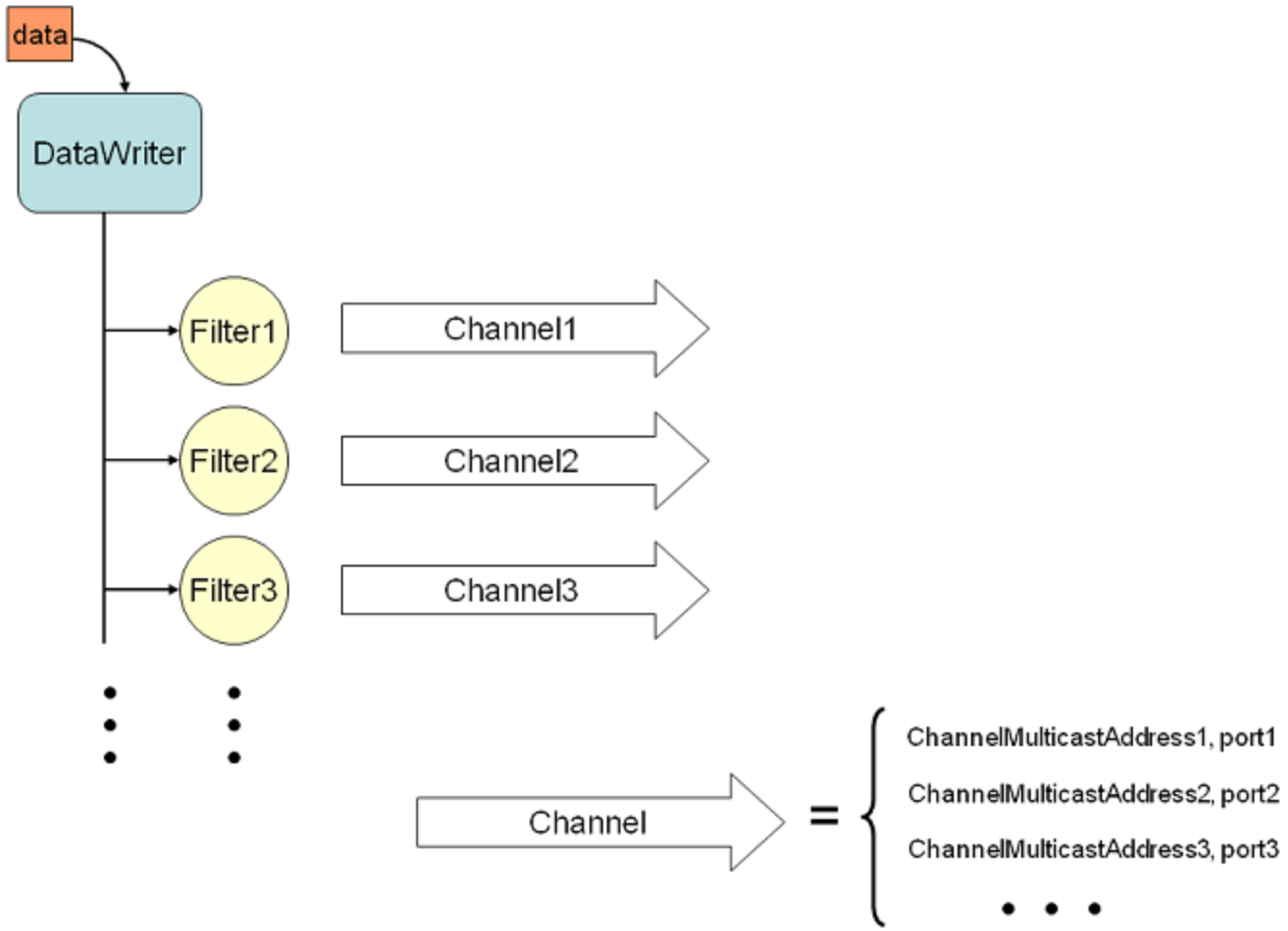
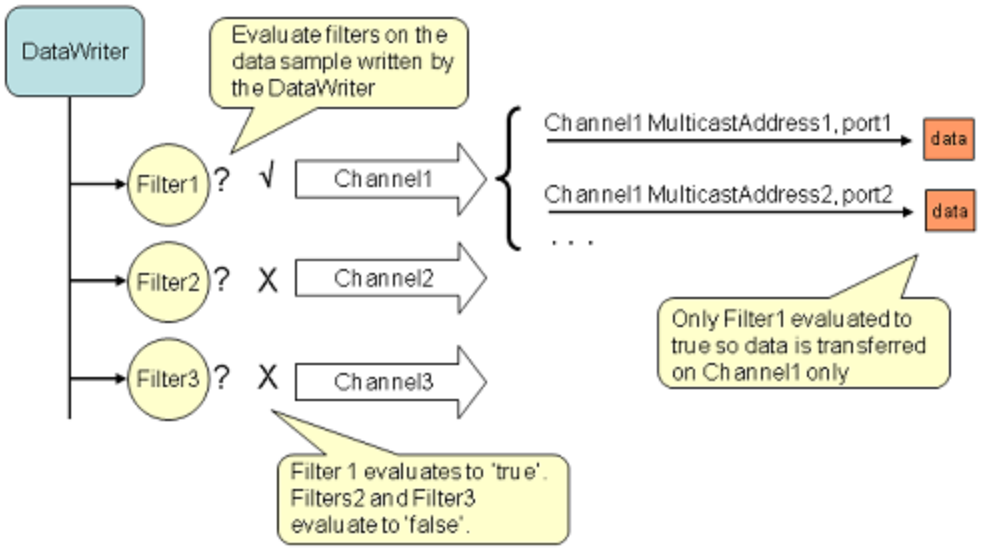


Figure 20.2: Multi-Channel Evaluation



Multi-channel *DataWriters* can be used to trade off network bandwidth with the unnecessary processing of unwanted data for situations where there are multiple *DataReaders* who are interested in different subsets of data that come from the same data stream (Topic). For example, in Financial applications, the data stream may be quotes for different stocks at an exchange. Applications usually only want to receive data (quotes) for only a subset of the stocks being traded. In tracking applications, a data stream may carry information on hundreds or thousands of objects being tracked, but again, applications may only be interested in a subset.

The problem is that the most efficient way to deliver data to multiple applications is to use multicast so that a data value is only sent once on the network for any number of subscribers to the data. However, using multicast, an application will receive all of the data sent and not just the data in which it is interested, thus extra CPU time is wasted to throw away unwanted data. With this QoS, you can analyze the data-usage patterns of your applications and optimize network vs. CPU usage by partitioning the data into multiple multicast streams. While network bandwidth is still being conserved by sending data only once using multicast, most applications will only need to listen to a subset of the multicast addresses and receive a reduced amount of unwanted data.

Note: Your system can gain more of the benefits of using multiple multicast groups if your network uses Layer 2 Ethernet switches. Layer 2 switches can be configured to only route multicast packets to those ports that have added membership to specific multicast groups. Using those switches will ensure that only the multicast packets used by applications on a node are routed to the node; all others are filtered-out by the switch.

20.2 How to Configure a Multi-channel DataWriter

To configure a multi-channel *DataWriter,* simply define a list of all its *channels* in the *DataWriter's* 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429.

Each *channel* consists of filter criterion to apply to the data and a set of multicast destinations (transport, address, port) that will be used for sending data that matches the filter. You can think of this sequence of channels as a table like the one shown below:

If the Data Matches this Filter...	Send the Data to these Multicast Destinations
Symbol MATCH '[A-K]*	UDPv4:225.0.0.1:9000
Symbol MATCH '[L-Q]*	UDPv4:225.0.0.2:9001
Symbol MATCH '[P-Z]*	UDPv4:225.0.0.3:9002; 225.0.0.4:9003;

The example C++ code in Figure 20.3: Using the MULTI_CHANNEL QosPolicy below shows how to configure the channels.

Figure 20.3: Using the MULTI_CHANNEL QosPolicy

```
// initialize writer_qos with default values
publisher->get_default_datawriter_qos(writer_qos);
// Initialize MULTI_CHANNEL Qos Policy
// Assign the filter name
// Possible options: DDS_STRINGMATCHFILTER_NAME, DDS_SQLFILTER_NAME
writer_qos.multi_channel.filter_name =
       (char*) DDS_STRINGMATCHFILTER_NAME;
// Create two channels
writer_qos.multi_channel.channels.ensure_length(2,2);
// First channel
writer_qos.multi_channel.channels[0].filter_expression =
       DDS_String_dup("Symbol MATCH '[A-M]*'");
writer_qos.multi_channel.channels[0].
       multicast_settings.ensure_length(1,1);
writer_qos.multi_channel.channels[0].
       multicast_settings[0].receive_port = 8700;
writer_qos.multi_channel.channels[0].
       multicast_settings[0].receive_address =
       DDS_String_dup("239.255.1.1");
// Second channel
writer_qos.multi_channel.channels[1].
       multicast_settings.ensure_length(1,1);
writer_qos.multi_channel.channels[1].
       multicast_settings[0].receive_port = 8800;
writer_qos.multi_channel.channels[1].
       multicast_settings[0].receive_address =
       DDS_String_dup("239.255.1.2");
writer_qos.multi_channel.channels[1].filter_expression =
       DDS_String_dup("Symbol MATCH '[N-Z]*'");
// Create writer
```

```
writer = publisher->create_datawriter(
       topic, writer_qos, NULL, DDS_STATUS_MASK_NONE);
```

The MULTI_CHANNEL QosPolicy is propagated along with discovery traffic. The value of this policy is available in the builtin topic for the publication (see the **locator_filter** field in Table 18.2 Publication Built-in Topic's Data Type (DDS_PublicationBuiltinTopicData)).

20.2.1 Limitations

When considering use of a multi-channel DataWriter, please be aware of the following limitations:

- A *DataWriter* that uses the MULTI_CHANNEL QosPolicy will ignore multicast and unicast addresses specified on the reader side through the 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586 and 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458. The *DataWriter* will not publish DDS samples on these locators.
- Multi-channel *DataWriters* cannot be configured to use the Durable Writer History feature (described in 13.3 Durable Writer History on page 733).
- Multi-channel *DataWriters* rely on the **rtps_object_id** in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388 to be DDS_RTPS_AUTO_ID (which causes automatic assignment of object IDs to channels).
- To guarantee reliable delivery, a *DataReader's* 7.4.6 PRESENTATION QosPolicy on page 361 must be set to per-instance ordering (DDS_INSTANCE_PRESENTATION_QOS, the default value), instead of per-topic ordering (DDS_TOPIC_PRESENTATION_QOS), and the matching *DataWriter's* 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429 must use expressions that only refer to key fields.

20.3 Multi-Channel Configuration on the Reader Side

No special changes are required in a subscribing application to get data from a multi-channel DataWriter.

If you want the *DataReader* to subscribe to only a subset of the channels, use a ContentFilteredTopic, as described in 5.4 ContentFilteredTopics on page 227. For example:

```
// Create a content filtered topic
contentFilter =
       participant->create_contentfilteredtopic_with_filter(
       "FilteredTopic",
       topic,
       "symbol MATCH 'NYE/BAC,NASDAQ/MSFT,NASDAQ/GOOG",
       parameters,
       DDS_STRINGMATCHFILTER_NAME);
// Create a DataReader that uses the content filtered topic
reader = subscriber->create_datareader(contentFilter,
                DDS_DATAREADER_QOS_DEFAULT,
               NULL,0);
```

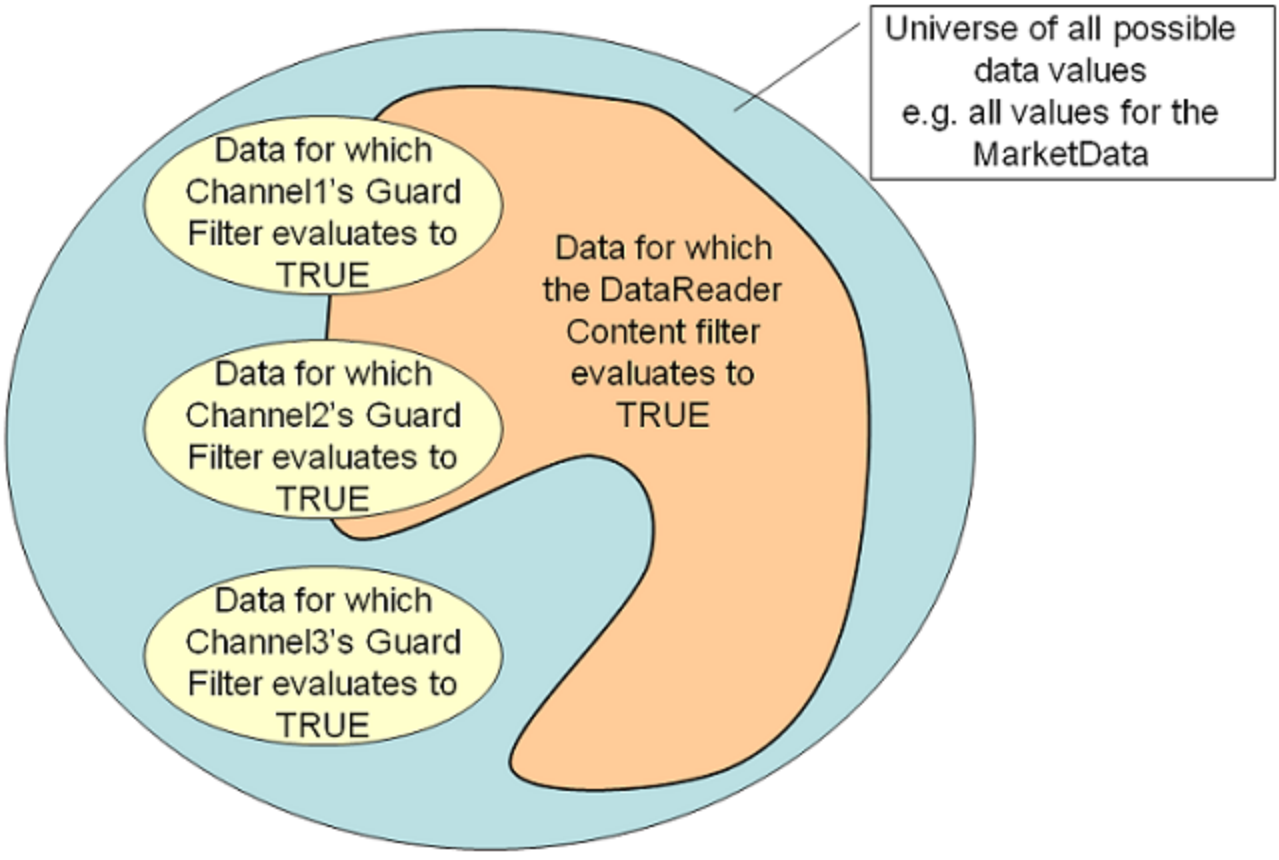
From there, *Connext DDS* takes care of all the necessary steps:

- The *DataReader* automatically discovers all the *DataWriters*—including multi-channel *DataWriters*—for the Topic it subscribes to.
- When the *DataReader* discovers a multi-channel *DataWriter*, it also discovers the list of channels used by that *DataWriter*.
- When the multi-channel *DataWriter* discovers a *DataReader*, it also discovers the content filters specified by that *DataReader*, if any.

With all this information, *Connext DDS* automatically determines which channels are of "interest" to the *DataReader*.

A *DataReader* is interested in a channel if and only if the set of data values for which the channel guard filter evaluates to TRUE intersects the set of data values for which the *DataReader's* content filter evaluates to TRUE. If a *DataReader* does not use a content filter, then it is interested in all the channels.

Figure 20.4: Filter Intersection



In this scenario, the DataReader is interested in Channel1 and Channel2, but not Channel3.

Market Data Example, continued:

If the channel guard filter for Channel 1 is 'Symbol MATCH '[A-K]*' then the channel will only transfer data for stocks whose symbol starts with a letter in the A to K range.

That is, it will transfer data on 'APPL', "GOOG', and 'IBM', but not on 'MSFT', 'ORCL', or 'YHOO'. Channel 1 will be of interest to *DataReaders* whose content filter includes at least one stock whose symbol starts with a letter in the A to K range.

A *DataReader* that specifies a content filter such as "Symbol MATCH 'IBM, YHOO' " will be interested in Channel1.

A *DataReader* that specifies a content filter such as "Symbol MATCH '[G-M]*'" will also be interested in Channel1.

A *DataReader* that specifies a content filter such as "Symbol MATCH '[M-T]*' " will not be interested in Channel1.

20.4 Where Does the Filtering Occur?

If multi-channel *DataWriters* are used, the filtering can occur in three places:

- 20.4.1 Filtering at the DataWriter below
- 20.4.2 Filtering at the DataReader below
- 20.4.3 Filtering on the Network Hardware on the next page

20.4.1 Filtering at the DataWriter

Each time data is written, the *DataWriter* evaluates each of the channel guard filters to determine which channels will transmit the data. This filtering occurs on the *DataWriter*.

Filtering on the *DataWriter* side is scalable because the number of filter evaluations depends only on the number of channels, not on the number of *DataReaders*. Usually, the number of channels is smaller than the number of possible *DataReaders*.

As explained in 20.7 Performance Considerations on page 898, if the channel guard filters are configured to only look at the "key" fields in the data, the channel filtering becomes a very efficient lookup operation.

20.4.2 Filtering at the DataReader

The *DataReader* will listen on the multicast addresses that correspond to the channels of interest (see Figure 20.3: Using the MULTI_CHANNEL QosPolicy on page 892). When a channel is 'of interest', it means that it is possible for the channel to transmit data that meets the content filter of the *DataReader*, however the channel may also transmit data that does not pass the *DataReader's* content filter. Therefore, the *DataReader* has to filter all incoming data on that channel to determine if it passes its content filter.

Market Data Example, continued:

Channel 1, identified by guard filter "Symbol MATCH '[A-M]*'", will be of interest to *DataReaders* whose content filter includes at least one stock whose symbol starts with a letter in the A to K range.

A *DataReader* with content filter "Symbol MATCH 'GOOG'" will listen on Channel1.

In addition to 'GOOG', the *DataReader* will also receive DDS samples corresponding to stock symbols such as 'MSFT' and 'APPL'. The *DataReader* must filter these DDS samples out.

As explained in 20.7 Performance Considerations on page 898, if the *DataReader's* content filters are configured to only look at the "key" fields in the data, the *DataReader* filtering becomes a very efficient lookup operation.

20.4.3 Filtering on the Network Hardware

DataReaders will only listen to multicast addresses that correspond to the channels of interest. The multicast traffic generated in other channels will be filtered out by the network hardware (routers, switches).

Layer 3 routers will only forward multicast traffic to the actual destination ports. However, by default, layer 2 switches treat multicast traffic as broadcast traffic. To take advantage of network filtering with layer 2 devices, they must be configured with IGMP snooping enabled (see 20.7.1 Network-Switch Filtering on page 898).

20.5 Fault Tolerance and Redundancy

To achieve fault tolerance and redundancy, configure the *DataWriter's* 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429 to publish a DDS sample over multiple channels or over different multicast addresses within a single channel. Figure 20.5: Using the MULTI_CHANNEL QosPolicy with Overlapping Channels below shows how to use overlapping channels.

If a DDS sample is published to multiple multicast addresses, a *DataReader* may receive multiple copies of the DDS sample. By default, duplicates are discarded by the *DataReader* and not provided to the application. To change this default behavior, use the Durable Reader State property, **dds.data_reader.state.filter_redundant_samples** (see 13.4.4 How To Configure a DataReader for Durable Reader State on page 741).

Figure 20.5: Using the MULTI_CHANNEL QosPolicy with Overlapping Channels

```
// initialize writer_qos with default values
publisher->get_default_datawriter_qos(writer_qos);
// Initialize MULTI_CHANNEL Qos Policy
// Assign the filter name
// Possible options: DDS_STRINGMATCHFILTER_NAME and DDS_SQLFILTER_NAME
writer_qos.multi_channel.filter_name = (char*) DDS_STRINGMATCHFILTER_NAME;
// Create two channels
writer_qos.multi_channel.channels.ensure_length(2,2);
// First channel
```

```
writer_qos.multi_channel.channels[0].filter_expression =
       DDS_String_dup("Symbol MATCH '[A-M]*'");
writer_qos.multi_channel.channels[0].multicast_settings.ensure_length(2,2);
writer_qos.multi_channel.channels[0].multicast_settings[0].receive_port = 8700;
writer_qos.multi_channel.channels[0].multicast_settings[0].receive_address =
       DDS_String_dup("239.255.1.1");
// Second channel
writer_qos.multi_channel.channels[1].multicast_settings.ensure_length(1,1);
writer_qos.multi_channel.channels[1].multicast_settings[0].receive_port = 8800;
writer_qos.multi_channel.channels[1].multicast_settings[0].receive_address =
       DDS_String_dup("239.255.1.2");
writer_qos.multi_channel.channels[1].filter_expression =
       DDS_String_dup("Symbol MATCH '[C-Z]*'");
// Symbols starting with [C-M] will be published in two different channels
// Create writer
writer = publisher->create_datawriter(
       topic, writer_qos, NULL, DDS_STATUS_MASK_NONE);
```

20.6 Reliability with Multi-Channel DataWriters

20.6.1 Reliable Delivery

Reliable delivery is only guaranteed when the **access_scope** in the *Subscriber's* 7.4.6 PRESENTATION QosPolicy on page 361 is set to DDS_INSTANCE_PRESENTATION_QOS (default value) and the filters in the *DataWriter's* 7.5.16 MULTI_CHANNEL QosPolicy (DDS Extension) on page 429) are keyed-only based.

Market Data Example, continued:

Given the following IDL description for our MarketData topic type:

```
Struct MarketData {
    @key string<255> Symbol;
    double Price;
}
```

A guard filter "Symbol MATCH 'APPL'" is keyed-only based.

A guard filter "Symbol MATCH 'APPL' and Price < 100" is not keyed-only based.

If any of the guard filters are based on non-key fields, *Connext DDS* only guarantees reception of the most recent data from the multi-channel *DataWriter*.

20.6.2 Reliable Protocol Considerations

Reliability is maintained on a per-channel basis. Each channel has its own reliability channel send window:

- **low_watermark** and **high_watermark**: The low and high watermarks control the send-window levels (when not using batching, this is a number of DDS samples; when using batching, this is a

number of batches) that determine when to switch between regular and fast heartbeat rates (see 7.5.5.1 High and Low Watermarks on page 393). With multi-channel *DataWriters*, **high_watermark** and **low_watermark** are computed from the channel with the smaller send-window size and they apply to all the channels. Therefore, because the watermark is determined by the channel with the smallest send-window, periodic heartbeating cannot be controlled on a per-channel basis.

- **heartbeats_per_max_samples**: This field defines the number of piggyback heartbeats per current send-window. For multi-channel *DataWriters*, piggyback heartbeats are sent per channel. The send-window size that is used to calculate the piggyback heartbeat rate is the smallest across all channels..

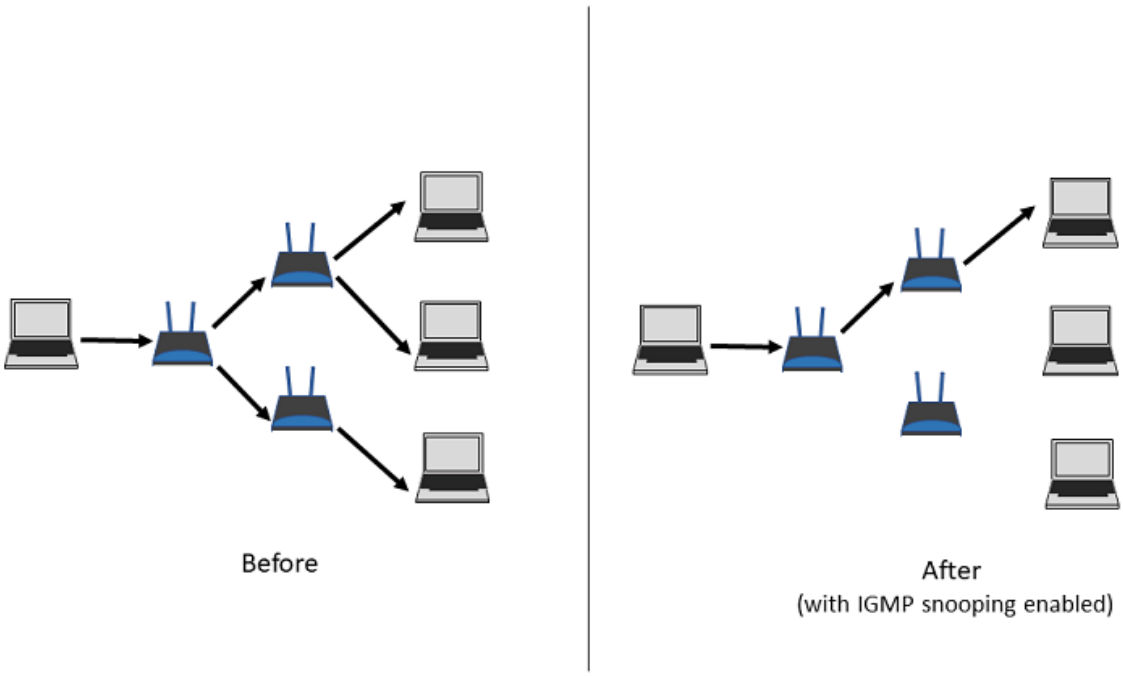
20.7 Performance Considerations

20.7.1 Network-Switch Filtering

By default, multicast traffic is treated as broadcast traffic by layer 2 switches. To avoid flooding the network with broadcast traffic and take full advantage of network filtering, the layer 2 switches should be configured to use IGMP snooping. Refer to your switch's manual for specific instructions.

When IGMP snooping is enabled, a switch can route a multicast packet to just those ports that subscribe to it, as seen in Figure 20.6: IGMP Snooping below.

Figure 20.6: IGMP Snooping



20.7.2 DataWriter and DataReader Filtering

20.4 Where Does the Filtering Occur? on page 895 describes the three places where filtering can occur with Multi-channel *DataWriters*. To improve performance when filtering occurs on the reader and/or

writer sides, use filter expressions that are only based on keys (see 2.4 DDS Samples, Instances, and Keys on page 18). Then the results of the filter are cached in a hash table on a per-key basis.

Market Data Example, continued:

The filter expressions in the Market Data example are based on the value of the field, **Symbol**. To make filter operations on this field more efficient, declare **Symbol** as a key. For example:

```
struct {
    @key string<MAX_SYMBOL_SIZE> Symbol;
}
```

You can also improve performance by increasing the number of buckets associated with the hash table. To do so, use the **instance_hash_buckets** field in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449 on both the writer and reader sides. A higher number of buckets will provide better performance, but requires more resources.

Chapter 21 Connext DDS Threading Model

This chapter describes the internal threads that *Connext DDS* uses for sending and receiving data, maintaining internal state, and calling user code when events occur such as the arrival of new DDS data samples. It may be important for you to understand how these threads may interact with your application.

A *DomainParticipant* uses three main types of threads:

- **Database Thread** maintains the database of DDS *Entities* stored in the *DomainParticipant*. It is responsible for purging the objects marked for deletion when they are no longer needed. See 21.1 Database Thread on the next page.
- **Event Thread** detects triggered events and acts accordingly, invoking user functions when needed (e.g., when a callback was specified for that specific event). See 21.2 Event Thread on page 902.
- **Receive Threads** get bytes from transport plugins, then deserialize and store the (meta)data in the receive queue of a *DataReader* and invoke the **on_data_available()** callback. Receive threads are also responsible for processing metadata (e.g., discovery traffic, ACKs, NACKs). See 21.3 Receive Threads on page 903.

The actual number of threads depends on the configuration of various QoS policies as well as the implementation of the transports used by the *DomainParticipant* to send and receive data. In addition, other threads might be created for specific purposes:

- **Interface Tracking Thread** checks if there is new interface data. It notifies the user-/application and updates the interface data. Note: this thread is created in support of the IP Mobility feature.
- **Transport-Specific Threads** handle the tasks that are specific to a transport (e.g., the TCP Transport plugin creates two threads, one for control and one for events).

- **Asynchronous Publishing Threads** handle the data transmission for Asynchronous Publishers (see 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344).
- **Asynchronous Batch Flushing Threads** handle batches of data samples, flushing them when needed. These threads are only created when batching is enabled (see 7.5.2 BATCH QosPolicy (DDS Extension) on page 373) and **max_flush_delay** is not DURATION_INFINITE.
- **Topic Query Publication Threads** publish historical samples in response to a TopicQuery. These threads are only created when topic query dispatch is enabled (see 7.5.24 TOPIC_QUERY_DISPATCH_QosPolicy (DDS Extension) on page 453).
- **User Threads:** in addition, your application may present threads that are not part of *Connext DDS*. If those threads call a DDS API, *Connext DDS* will automatically register them (i.e., allocate some resources to keep statistics and to handle concurrent access to DDS *Entities*). To free up all the allocated resources, you may need to unregister these threads, as explained in 21.8 Unregistering Threads on page 908.

Through various QosPolicies, the user application can configure the priorities and other properties of the threads created by *Connext DDS*. In real-time systems, the user often needs to set the priorities of all threads in an application relative to each other for the proper operation of the system.

For information on checking thread names, see 21.9 Identifying Threads Used by Connext DDS on page 908.

21.1 Database Thread

Connext DDS uses internal data structures to store information about locally-created and remotely-discovered *Entities*. In addition, it will store various objects and data used by *Connext DDS* for maintaining proper communications between applications. This “database” is created for each *DomainParticipant*.

As *Entities* and objects are created and deleted during the normal operation of the user application, different entries in the database may be created and deleted as well. Because multiple threads may access objects stored in the database simultaneously, the deletion and removal of an object from the database happens in two phases to support thread safety.

When an entry/object in the database is deleted either through the actions of user code or as a result of a change in system state, it is only marked for deletion. It cannot be actually deleted and removed from the database until *Connext DDS* can be sure that no threads are still accessing the object. Instead, the actual removal of the object is delegated to an internal thread that *Connext DDS* spawns to periodically wake up and purge the database of deleted objects.

This thread is known as the Database thread (also referred to as the database cleanup thread).

- Only one Database thread is created for each *DomainParticipant*.

The 9.5.1 DATABASE QosPolicy (DDS Extension) on page 632 of the *DomainParticipant* configures both the resources used by the database as well as the properties of the cleanup thread. Specifically, the user may want to use this QosPolicy to set the priority, stack size and thread options of the cleanup thread. You must set these options before the *DomainParticipant* is created, because once the cleanup thread is started as a part of participant creation, these properties cannot be changed.

The period at which the database-cleanup thread wakes up to purge deleted objects is also set in the DATABASE QosPolicy. Typically, this period is set to a long time (on the order of a minute) since there is no need to waste CPU cycles to wake up a thread only to find nothing to do.

However, when a *DomainParticipant* is destroyed, all of the objects created by the *DomainParticipant* will be destroyed as well. Many of these objects are stored in the database, and thus must be destroyed by the cleanup thread. The *DomainParticipant* cannot be destroyed until the database is empty and is destroyed itself. Thus, there is a different parameter in the DATABASE QosPolicy, shutdown_cleanup_period, that is used by the database cleanup thread when the *DomainParticipant* is being destroyed. Typically set to be on the order of a second, this parameter reduces the additional time needed to destroy a *DomainParticipant* simply due to waiting for the cleanup thread to wake up and purge the database.

21.2 Event Thread

During operation, *Connext DDS* must wake up at different intervals to check the condition of many different time-triggered or periodic events. These events are usually to determine if something happened or did not happen within a specified time. Often the condition must be checked periodically as long as the *Entity* for which the condition applies still exists. Also, the *DomainParticipant* may need to do something periodically to maintain connections with remote *Entities*.

For example, the 7.5.7 DEADLINE QosPolicy on page 404 is used to ensure that *DataWriters* have published data or *DataReaders* have received data within a specified time period. Similarly, the 7.5.15 LIVELINESS QosPolicy on page 425 configures *Connext DDS* both to check periodically to see if a *DataWriter* has sent a liveliness message and to send liveliness messages periodically on the behalf of a *DataWriter*. As a last example, for reliable connections, heartbeats must be sent periodically from the *DataWriter* to the *DataReader* so that the *DataReader* can acknowledge the data that it has received, see Reliable Communications (Chapter 11 on page 682).

Connext DDS uses an internal thread, known as the Event thread, to do the following:

- Check whether or not deadlines have been missed
- Invoke user-installed *Listener* callbacks to notify the application of missed deadlines
- Send heartbeats to maintain reliable connections

Note: Only one Event thread is created per *DomainParticipant*.

The 9.5.5 EVENT QosPolicy (DDS Extension) on page 656 of the *DomainParticipant* configures both the properties and resources of the Event thread. Specifically, the user may want to use this QosPolicy to

set the priority, stack size and thread options of the Event thread. You must set these options before the *DomainParticipant* is created, because once the Event thread is started as a part of participant creation, these properties cannot be changed.

The EVENT QosPolicy also configures the maximum number of events that can be handled by the Event thread. While the Event thread can only service a single event at a time, it must maintain a queue to hold events that are pending. The **initial_count** and **max_count** parameters of the QosPolicy set the initial and maximum size of the queue.

The priority of the Event thread should be carefully set with respect to the priorities of the other threads in a system. While many events can tolerate some amount of latency between the time that the event expires and the time that the Event thread services the event, there may be application-specific events that must be handled as soon as possible.

For example, if an application uses the liveliness of a remote *DataWriter* to infer the correct operation of a remote application, it may be critical for the user code in the *DataReader Listener* callback, **on_liveliness_changed()**, to be called by the Event thread as soon as it can be determined that the remote application has died. The operating system uses the priority of the Event thread to schedule this action.

21.3 Receive Threads

Connext DDS uses internal threads, known as Receive threads, to process the data packets received via underlying network transports. These data packets may contain meta-traffic exchanged by *DomainParticipants* for discovery, or user data (and meta-data to support reliable connections) destined for local *DataReaders*.

As a result of processing packets received by a transport, a Receive thread may respond by sending packets on the network. Discovery packets may be sent to other *DomainParticipants* in response to ones received. ACK/NACK packets are sent in response to heartbeats to support a reliable connection.

When a DDS sample arrives, the Receive thread is responsible for deserializing and storing the data in the receive queue of a *DataReader* as well as invoking the **on_data_available()** *DataReaderListener* callback (see 8.3.4 Setting Up DataReaderListeners on page 509).

The number of Receive threads that *Connext DDS* will create for a *DomainParticipant* depends on how you have configured the QosPolicies of *DomainParticipants*, *DataWriters* and *DataReaders* as well as on the implementation of a particular transport. The behavior of the builtin transports is well specified. However, if a custom transport is installed for a *DomainParticipant*, you will have to understand how the custom transport works to predict how many Receive threads will be created.

The following discussion applies on a per-transport basis. A single Receive thread will only service a single transport.

Connext DDS will try to create receive resources[1] for every port of every transport on which it is configured to receive messages. The 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458 for *DomainParticipant*, *DataWriters*, and *DataReaders*, the 8.6.5 TRANSPORT_MULTICAST QosPolicy (DDS Extension) on page 586 for *DataReaders* and the 9.5.2 DISCOVERY QosPolicy (DDS Extension) on page 635 for *DomainParticipants* all configure the number of ports and the number of transports that *Connext DDS* will try to use for receiving messages.

Generally, transports will require *Connext DDS* to create a new receive resource for every unique port number. However, this is both dependent on how the underlying physical transport works and the implementation of the transport plug-in used by *Connext DDS*. Sometimes *Connext DDS* only needs to create a single receive resource for any number of ports.

When *Connext DDS* finds that it is configured to receive data on a port for a transport for which it has not already created a receive resource, it will ask the transport if any of the existing receive resources created for the transport can be shared. If so, then *Connext DDS* will not have to create a new receive resource. If not, then *Connext DDS* will.

The TRANSPORT_UNICAST, TRANSPORT_MULTICAST, and DISCOVERY QosPolicies allow you customize ports for receiving user data (on a per-*DataReader* basis) and meta-traffic (*DataWriters* and *DomainParticipants*); ports can be also set differently for unicast and multicast.

How do receive resources relate to Receive threads? *Connext DDS* will create a Receive thread to service every receive resource that is created. If you use a socket analogy, then for every socket created, *Connext DDS* will use a separate thread to process the data received on that socket.

So how many threads will *Connext DDS* create by default–using only the builtin UDPv4 and shared memory transports and without modifying any QosPolicies?

Three Receive threads are created for meta-traffic[2]:

- 2 for unicast (one for UDPv4, one for shared memory)
- 1 for multicast (for UDPv4)[3]

Two Receive threads created for user data:

- 2 for unicast (UDPv4, shared memory)
- 0 for multicast (because user data is not sent via multicast by default)

[1] If UDPv4 was the only transport that *Connext DDS* supports, we would call these receive resources 'sockets.'

[2] Meta-traffic refers to traffic internal to *Connext DDS* related to dynamic discovery (see Discovery (Chapter 15 on page 758).

[3] Multicast is not supported by shared memory transports.

Therefore, by default, you will have a total of five Receive threads per *DomainParticipant*. By using only a single transport and disabling multicast, a *DomainParticipant* can have as few as 2 Receive threads.

Similar to the Database and Event threads, a Receive thread is configured by the 9.5.6 RECEIVER_POOL QosPolicy (DDS Extension) on page 658. However, note that the thread properties in the RECEIVER_POOL QosPolicy apply to all Receive threads created for the *DomainParticipant*.

21.4 Exclusive Areas, RTI Connext DDS Threads, and User Listeners

Connext DDS Event and Receive threads may invoke user code through the *Listener* callbacks installed on different *Entities* while executing internal *Connext DDS* code. In turn, user code inside the callbacks may invoke *Connext DDS* APIs that reenter the internal code space of *Connext DDS*. For thread safety, *Connext DDS* allocates and uses mutual exclusion semaphores (mutexes).

As discussed in 4.5 Exclusive Areas (EAs) on page 197, when multiple threads and multiple mutexes are mixed together, deadlock may result. To prevent deadlock from occurring, *Connext DDS* is designed using careful analysis and following rules that force mutexes to be taken in a certain order when a thread must take multiple mutexes simultaneously.

However, because the Event and Receive threads already hold mutexes when invoking user callbacks, and because the *Connext DDS* APIs that the user code can invoke may try to take other mutexes, deadlock may still result. Thus, to prevent user code to cause internal *Connext DDS* threads to deadlock, we have created a concept called Exclusive Areas (EA) that follow rules that prevent deadlock. The more EAs that exist in a system, the more concurrency is allowed through *Connext DDS* code. However, the more EAs that exist, the more restrictions on the *Connext DDS* APIs that are allowed to be invoked in *Entity Listener* callbacks.

The 7.4.3 EXCLUSIVE_AREA QosPolicy (DDS Extension) on page 350 control how many EAs will be created by *Connext DDS*. For a more detailed discussion on EAs and the restrictions on the use of *Connext DDS* APIs within *Entity Listener* methods, please see 4.5 Exclusive Areas (EAs) on page 197.

21.5 Controlling CPU Core Affinity for RTI Threads

Two fields in the DDS_ThreadSettings_t structure (see 19.4.7 Thread Settings on page 874) are related to CPU core affinity: **cpu_list** and **cpu_rotation**.

Note: Although DDS_ThreadSettings_t is used in the Event, Database, ReceiverPool, and AsynchronousPublisher QoS policies, **cpu_list** and **cpu_rotation** are only relevant in the 9.5.6 RECEIVER_POOL QosPolicy (DDS Extension) on page 658.

While most thread-related QoS settings apply to a single thread, the ReceiverPool QoS policy's thread-settings control *every* receive thread created. In this case, there are several schemes to map *M* threads to *N* processors; **cpu_rotation** controls which scheme is used.

The **cpu_rotation** determines how **cpu_list** affects processor affinity for thread-related QoS policies that apply to multiple threads. If **cpu_list** is empty, **cpu_rotation** is irrelevant since no affinity adjustment will

occur. Suppose instead that **cpu_list** ={0,1} and that the middleware creates three receive threads: {A, B, C}. If **cpu_rotation** is set to CPU_NO_ROTATION, threads A, B and C will have the same processor affinities (0-1), and the OS will control thread scheduling within this bound.

CPU affinities are commonly denoted with a bitmask, where set bits represent allowed processors to run on. This mask is printed in hex, so a CPU affinity of 0-1 can be represented by the mask 0x3.

If **cpu_rotation** is CPU_RR_ROTATION, each thread will be assigned in round-robin fashion to one of the processors in **cpu_list**; perhaps thread A to 0, B to 1, and C to 0. Note that the order in which internal middleware threads spawn is unspecified.

The RTI Connext DDS Core Libraries Platform Notes describe which architectures support this feature.

21.6 Configuring Thread Settings with XML

Table 21.1 XML Tags for ThreadSettings_t describes the XML tags that you can use to configure thread settings. For more information on thread settings, see:

- 19.4.7 Thread Settings on page 874
- The RTI Connext DDS Core Libraries Platform Notes
- The API Reference HTML documentation (select **Modules**, **RTI Connext DDS API Reference**,**Infrastructure Module**, **QoS Policies**, **Extended QoS Support**, **Thread Settings**)

Table 21.1 XML Tags for ThreadSettings_t

Tags within <thread>	Description	Number of Tags Allowed

<cpu_list>	Each <element> specifies a processor on which the thread may run.
	`<cpu_list>`
	`  <element>value</element>`
	`</cpu_list>`
	Only applies to platforms that support controlling CPU core affinity (see 21.5 Controlling CPU Core Affinity for RTI Threads on the previous page and the RTI Connext DDS Core Libraries Platform Notes).
		0 or 1

<cpu_ rotation>	Determines how the CPUs in <cpu_list> will be used by the thread. The value can be either: • THREAD_SETTINGS_CPU_NO_ROTATION The thread can run on any listed processor, as determined by OS scheduling. • THREAD_SETTINGS_CPU_RR_ROTATION The thread will be assigned a CPU from the list in round-robin order. Only applies to platforms that support controlling CPU core affinity (see the RTI Connext DDS Core Libraries Platform Notes).	0 or 1

Table 21.1 XML Tags for ThreadSettings_t

Tags within <thread>	Description	Number of Tags Allowed
<mask>	A collection of flags used to configure threads of execution. Not all of these options may be relevant for all operating systems. May include these bits: • STDIO • FLOATING_POINT • REALTIME_PRIORITY • PRIORITY_ENFORCE It can also be set to a combination of the above bits by using the "or" symbol (|), such as STDIO|FLOATING_POINT. Default: MASK_DEFAULT	0 or 1

<priority>	Thread priority. The value can be specified as an unsigned integer or one of the following strings.
	• THREAD_PRIORITY_DEFAULT
	• THREAD_PRIORITY_HIGH
	• THREAD_PRIORITY_ABOVE_NORMAL
	• THREAD_PRIORITY_NORMAL
	• THREAD_PRIORITY_BELOW_NORMAL
	• THREAD_PRIORITY_LOW
	When using an unsigned integer, the allowed range is platform-dependent.
	When thread priorities are configured using XML, the values are considered native priorities.
	Example:
	`<thread>`
	`<mask>STDIO|FLOATING_POINT</mask>`
	`<priority>10</priority>`
	`<stack_size>THREAD_STACK_SIZE_DEFAULT</stack_size>`
	`</thread>`
	When the XML file is loaded using the Java API, the priority is a native priority, not a Java thread priority.
		0 or 1

<stack_size>	Thread stack size, specified as an unsigned integer or set to the string THREAD_STACK_SIZE_DEFAULT. The allowed range is platform-dependent.	0 or 1

21.7 User-Managed Threads

In certain scenarios, you may want full control over the internal threads created by your *Connext DDS* applications. For instance, in memory-constrained systems, applications may want to manage the resources required by internal *Connext DDS* threads. Also, you may want to use a different thread technology than the one *Connext DDS* incorporates by default (i.e., pthread on POSIX platforms).

Connext DDS can create the internal threads from the application layer via the abstract factory pattern. You can provide a *Connext DDS* application with a **ThreadFactory** implementation that *DomainParticipants* will use to create and delete all the threads.

The **ThreadFactory** interface exposes operations for creating and deleting threads. These operations are called on demand as *DomainParticipants* require new threads or need to delete existing ones.

The same **ThreadFactory** instance can be used by multiple *DomainParticipants*. To select which ThreadFactory to use, use the **set_thread_factory()** operation in the *DomainParticipantFactory*:

```
MyThreadFactory myThreadFactory; // Implements DDSThreadFactory
retcode = DDSTheParticipantFactory->set_thread_factory(&myThreadFactory);
```

Then you can create *DomainParticipants* using any of the available APIs (i.e. **create_participant()**, **create_participant_from_config()**, etc). A *DomainParticipant* will use the **ThreadFactory** object that is set in the DomainParticipantFactory at the time it is created and throughout its entire lifecycle. If a new ThreadFactory is set, existing *DomainParticipants* will not be affected; they will still use the same ThreadFactory with which they were created.

This feature is only available for the C/C++ APIs. For further information, please see the API Reference HTML documentation.

21.8 Unregistering Threads

If the logic of your application requires spawning new threads, and in those threads you are calling a *Connext DDS* API such as **write()**, you may notice a memory growth.

To ensure that all the resources allocated in that thread are correctly released, remember to call **unregister_thread()** right before exiting the thread.

Here is what the full API looks like:

```
DDS_ReturnCode_t DDS_DomainParticipantFactory_unregister_thread(DDS_DomainParticipantFactory *
self);
```

For more information, search for **DDS_DomainParticipantFactory_unregister_thread** in the API Reference HTML documentation.

21.9 Identifying Threads Used by Connext DDS

Connext DDS uses multiple internal threads for sending and receiving data, maintaining internal state, and calling user code when events occur. Further details regarding *Connext DDS*'s threading model can be found in Chapter 21 Connext DDS Threading Model on page 900. This section explains how these threads can be identified in your system.

21.9.1 Checking Thread Names at the OS Level

On some systems, it is possible to check the internal name of RTI threads directly at the operating system level. Threads created by *Connext DDS* will have RTI-specific thread names, unless otherwise stated in the RTI Connext DDS Core Libraries Platform Notes, which lists architectures that do not support setting thread names.

In general, thread names follow this pattern:

```
r<Module>[<Participant identifier>][<Thread index>][Transport name>]<Task type>
```

Where:

- The maximum length for a thread name is 16, including the '\0'.
- **r** indicates this is a thread from RTI.
- The second and third characters identify the **<Module>**:

Table 21.2 Module in the Thread Representation

Module	Thread Representation
Core	Co
Transport	Tr
Security	Se
Distributed Logger	Dl
Persistence Service	Ps
Database Integration Service	Ds
Web Integration Service	Ws
Monitor	Mo
Recording Service	Re
Routing Service	Rs

- **<Participant identifier>** is represented with five characters, as follows:
  - If **participant_name** is set: the participant identifier will be the first three characters and the last two characters of the **participant_name**.
  - If **participant_name** is not set: the identifier is computed as **domain_id** (three characters), **participant_id** (two characters).

  - If **participant_name** is not set and the **participant_id** is set to -1 (default value): the participant identifier is computed as the last five digits of the **rtps_instance_id** in the participant GUID.

- **<Thread index>** - index used to distinguish among threads with the same name.

  For example, there are several instantiations of the receive thread; the thread index is used to differentiate them:

```
rCo32265##00Rcv
rCo32265##01Rcv
rCo32265##02Rcv
rCo32265##03Rcv
rCo32265##04Rcv
```

- **<Transport name>** is represented with four characters:

Table 21.3 Transport Name in the Thread Representation

Transport Name	Thread Representation
Transmission Control Protocol version 4 (TCPv4)	TCP4
Datagram Transport Layer Security (DTLS)	DTLS
Transport Layer Security (TLS)	TLS
Wide Area Network (WAN)	WAN
User Datagram Protocol version 4 (UDPv4)	UDP4
User Datagram Protocol version 6 (UDPv6)	UDP6

- **<taskType>** - the type of thread is represented with three characters:

Table 21.4 Task Type in the Thread Representation

Transport Name	Thread Representation
Event	Evt
Receive	Rcv
Database	Dtb
Asynchronous waitSet	AWs
Dispatcher	Dsp

Transport Name	Thread Representation
Asynchronous batch flushing	ABF
Topic query publication	TQP
DNS tracker	DNS
Writer	Wri
Logger	Log
Control	Ctr
Server	Svr
Interface tracker	Itr
Discovery	Dis
Publication	Pub
Timer	Tim
Connection	Con

The details on checking the thread names depend on the operating system. The following is an example output from a publisher application running on VxWorks 6.9.4:

```
-> taskSpawn "test", 255, <floating_point_option>, 150000, publisher_main, 1, 100
value = 83748528 = 0x4fde6b0
-> i
NAME          ENTRY        TID    PRI   STATUS      PC        SP     ERRNO  CPU #
----------  ------------ -------- --- ---------- -------- -------- ------- -----
[...]
rCoHelnt##> RTIOsapiThr>  444a010  71 PEND         37b218  53f7c00       0     -
rCoHelnt##> RTIOsapiThr>  540b2b0  71 PEND         37b218  542ac00       0     -
rCoHelnt##> RTIOsapiThr>  543e080  71 PEND         37b218  545dc90       0     -
rCoHelnt##> RTIOsapiThr>  543ea78  71 PEND         37b218  5490c00       0     -
rCoHelnt##> RTIOsapiThr>  5471860  71 PEND         37b218  54c5c90       0     -
Test        REDATester_>  456c010 100 STOP         2cf594  501cc94       0     -
rCoHelnt##> RTIOsapiThr>  44d4358 110 PEND+T       37b218  735fda0  3d0010     -
rCoHelnt##> RTIOsapiThr>  44dea68 120 PEND+T       37b218  730fe04       0     -
rTrHelntUD> RTIOsapiThr>  53bbcb0 120 PEND+T       37b218  53c4e2c       0     -
tZynq7Task  2c8e9c        43f0228 240 DELAY        384288  4df5fa4       0     -
miiBusMoni> 2c9974        464bb60 252 DELAY        384288  4654fb8       0     -
test        publisher_m>  4fde6b0 255 DELAY        384288  7231ee8  3d0010     -
tIdleTask0  idleTaskEnt>  43d5418 287 READY        37a918  43d53ec       0     -
tIdleTask1  idleTaskEnt>  43d9670 287 READY        37a918  43d9644       0     -
value = 0 = 0x0
-> ti 0x444a010
NAME            ENTRY           TID     PRI   STATUS    PC      SP      ERRNO  DELAY
----------  ------------ -------- --- ---------- -------- -------- ------- -----
rCoHelnt##> RTIOsapiThr>  444a010  71 PEND      37b218  53f7c00         0       0
full task name : rCoHelnt##00Rcv
```

```
task entry     : RTIOsapiThreadChild_onSpawned
task affinity  : 0x00000000
[...]
```

Where <floating_point_option> is a numeric value that varies depending on the hardware. See Enabling Floating Point Coprocessor in Kernel Tasks, in the RTI Connext DDS Core Libraries Platform Notes.

In this example, the `i` command in VxWorks retrieves information about the running threads. The `>` at the end of the name (**rCoHelnt##>**) indicates that the full thread name could not be displayed, because it exceeds 10 characters. You can use the `ti` command in VxWorks (shown above), followed by the thread ID (TID), to retrieve information about a specific thread, including its full name (in this case, **rCoHelnt##00Rcv**).

The following is an example from running a subscriber on a Linux machine:

```
$ ./objs/x64Linux3gcc5.4.0/HelloWorld_subscriber
HelloWorld subscriber sleeping for 4 sec...
HelloWorld subscriber sleeping for 4 sec...
HelloWorld subscriber sleeping for 4 sec...
[...]
$ ps -eT | grep rC
22966 22967 pts/19   00:00:00 rCo32265####Dtb
22966 22968 pts/19   00:00:00 rCo32265####Evt
22966 22970 pts/19   00:00:00 rCo32265##00Rcv
22966 22971 pts/19   00:00:00 rCo32265##01Rcv
22966 22972 pts/19   00:00:00 rCo32265##02Rcv
22966 22973 pts/19   00:00:00 rCo32265##03Rcv
22966 22974 pts/19   00:00:00 rCo32265##04Rcv
```

> **Note:** For transport threads, you have the option of setting your own thread name prefix, which substitutes the first three components (**r<Module>[<Participant identifier>]**) of the thread name with your own prefix. Setting your own thread name prefix allows you to add extra information to the transport thread, such as your own identifier for the threads or the *Topic* used. You can optionally set this prefix using the **thread_name_prefix** field in the transport (for example, in the 44.7 TCP/TLS Transport Properties on page 1138).

Table 21.5 Example Thread Names shows names for the majority of threads created by *Connext DDS*:

Table 21.5 Example Thread Names

Thread Information	Name	Fields	Example: Domain: 111 Participant Id : 22 ThreadIndex: 33 Topic: HelloWorld DataBase: Test Application Name: TestPersistence
Receive thread	rCo%5s##%02dRcv	Participant identifier, thread index	rCo11122##33Rcv
Asynchronous waitset thread	rCo%5s##%02dAWs	Participant identifier, thread index	rCo11122##33AWs
Database thread	rCo%5s####Dtb	Participant identifier	rCo11122####Dtb
Dispatcher (i.e., asynchronous publishing) thread	rCo%5s##%02dDsp	Participant identifier, thread index	rCo11122##33Dsp
Asynchronous batch flushing thread	rCo%5s####ABF	Participant identifier	rCo11122####ABF
Topic query publication thread	rCo%5s####TQP	Participant identifier	rCo11122####TQP
Event thread	rCo%5s####Evt	Participant identifier	rCo11122####Evt
DNS tracker thread	rCo%5s####DNS	Participant identifier	rCo11122####DNS
Distributed logger writer thread	rDl#########Wri		rDl#########Wri
Secure distributed logger thread	rSe%5s####Log	Participant identifier	rSe11122####Log
TCP control thread	rTr%5s%04sCtr	Participant identification, transportName (TCP4)	rTr11122TCP4Ctr
TCP event thread	rTr%5s%04sEvt	Participant identification, transportName (TCP4)	rTr11122TCP4Evt
DTLS event thread	rTr%5s%04sEvt	Participant identification, transportName (DTLS)	rTr11122DTLSEvt
TLS receive thread	rTr%5s%04sRcv	Participant identification, transportName (TLS)	rTr11122#TLSRcv
WAN receive thread	rTr%5s%04sRcv	Participant identification, transportName (WAN)	rTr11122#WANRcv
WAN server thread	rTr%5s%04sSvr	Participant identification, transportName (WAN)	rTr11122#WANCtr
Interface tracking thread	rTr%5s%04sITr	Participant identification, transportName (UDP4, UDP6, TCP4)	rTr11122UDP4ITr
Persistence Service receive administration command request thread	rPs%03d######RAC	domainId	rPs111######RAC

Thread Information	Name	Fields	Example: Domain: 111 Participant Id : 22 ThreadIndex: 33 Topic: HelloWorld DataBase: Test Application Name: TestPersistence
Persistence Service discovery thread	rPs%09sDis	Application name	rPsTestPersiDis
Persistence Service reception thread (topic)	rPs%07s%02dRcv	topic name, thread index	rPsHello##33Rea
Persistence Service publication thread	rPs%07s%02dPub	topic name, thread index	rPsHello##33Pub
Persistence Service reception thread (TopicSet)	rPsTopic##%02dRcv	thread index	rPsHello##33Rea
Persistence Service event thread	rPs#########Evt		rPsHello##33Rea
Recording Service timer thread	rRe#########Tim		rRe#########Tim
Monitor event thread	rMo%5s####Evt	Participant identifier	rREHelloWorlPub
Routing Service polling timer thread	rRs#########Tim		rRs#########Tim
Routing Service filter tracker event thread	rRsFilterTr#Evt		rRsFilterTr#Evt
Routing Service monitor statistics event thread	rRsMoSta####Evt		rRsMoSta####Evt
Routing Service monitor publication event thread	rRsMoPub####Evt		rRsMoPub####Evt
Routing Service discovery event thread	rRsDisc#####Evt		rRsDisc#####Evt
Routing Service aysnchronous admin thread	rRsAdmin##%02dAWs	thread index	rRsAdmin##33AWs
Routing Service aysnchronous discovery thread	rRsDisc###%02dAWs	thread index	rRsDisc###33dAWs
Database Integrated Service discovery thread	rDs#########Dis		rDs#########Dis
Database Integrated Service connection thread	rDs%.9sCon	Database name	rDsTestsCon
Database Integrated Service refresh thread	rDs%.9sRef	Database name	rDsTestsRef
Database Integrated Service finalization Library thread	rDsFinalizeLib#		rDsFinalizeLib#
Database Integrated Service event manager thread	rDsManager##Evt		rDsManager##Evt
Web Integrated Service access control list dataBase thread	rWsACL######Dtb		rWsACL######Dtb

21.9.2 Checking Thread Names from the Call Stack

Thread names are only available in a subset of architectures. See the RTI Connext DDS Core Libraries Platform Notes for which architectures support checking thread names at the OS level. This section lists the correspondence between *Connext DDS* threads and the functions they run. You can use this information to identify *Connext DDS* threads from the call stack, independently of your architecture. If you are using VxWorks or Integrity, see 21.9.1 Checking Thread Names at the OS Level on page 909.

This is the correspondence between threads and the functions they run:

- **Database Thread:** RTIEventActiveDatabaseThread_loop()
- **(Main) Event Thread:** RTIEventActiveGeneratorThread_loop(). Note that this function is generic to all the event threads. That is, all of the event threads run RTIEventActiveGeneratorThread_loop(), which detects and handles events. For this reason, it can be difficult to distinguish the Main Event Thread from other event threads (such as the Topic Query Publication Event Thread); however, to better make this distinction, you can check whether some (sub)functions are called (for example, the subfunctions related to the Asynchronous Batch Flushing Event Thread and Topic Query Publication Event Thread below).
- **Receive Thread:** COMMENDActiveFacadeReceiver_loop(), which calls to a different function depending on what transport is being used to get the (meta)data:
  - **Shared Memory:** NDDS_Transport_Shmem_receive_rEA()
  - **UDP:** NDDS_Transport_UDP_receive_rEA()
  - **TCP:** NDDS_Transport_TCP_receive_rEA()
- **Interface Tracking Thread:** RTIOsapiInterfaceTracker_()
- **Transport-Specific Threads:**
  - **TCP Control Thread:** NDDS_Transport_TCPv4_Plugin_threadLoop()
  - **TCP Event Thread:** RTIEventActiveGeneratorThread_loop() and NDDS_Transport_TCPv4_Plugin_clientOn<event_name>()
- **Asynchronous Publishing Thread:** RTIEventJobDispatcherThread_spawnedFnc()
- **Asynchronous Batch Flushing Event Thread:** RTIEventActiveGeneratorThread_loop() and PRESPsWriter_onFlushBatch()
- **Topic Query Publication Event Thread:** RTIEventActiveGeneratorThread_loop() and PRESPsService_onWriterServiceDispatchActiveTopicQueriesEvent()

For example, if you are on GNU/Linux, you can run the following command on gdb to get the call stack:

```
(gdb) thread apply all backtrace
```

The same information can be seen with Visual Studio. To see this information in Visual Studio, select Debug > Windows > Threads, then do Ctrl+D, T. You will need to add a breakpoint and start the application in debug mode.

21.9.3 Checking Thread Names Using the Worker's Name

Connext DDS uses the concept of a *worker* as an abstraction for threads. Workers are RTI-specific entities used internally to manage critical sections and to provide access to thread-specific storage. Most of the threads created by *Connext DDS* have an associated worker. In addition, user threads calling certain APIs from *Connext DDS* will have a worker associated with them. Workers are given a name when they are created. If you have the proper debug symbols, you can use the worker's name to identify the thread (on a debugger, for instance).

To check the workers' names, first locate these workers in the threads. You can do that by selecting a thread and printing its full backtrace. Another option is moving up and down through the frames on the thread's stack. The worker will be either a local variable or the last argument to one of the RTI functions. Here is an example using gdb on GNU/Linux to identify a thread with the method just described:

```
(gdb) info thread
  Id   Target Id         Frame
* 1    Thread 0x7ffff7fce700 (LWP 6801) "HelloWorld_publ" __clock_nanosleep (clock_
id=<optimized out>, flags=0, req=0x7fffffffcb20, rem=0x7fffffffcb30) at
../sysdeps/unix/sysv/linux/clock_nanosleep.c:48
  2    Thread 0x7ffff6ec1700 (LWP 6805) "HelloWorld_publ" pthread_cond_timedwait@@GLIBC_2.3.2
() at ../sysdeps/unix/sysv/linux/x86_64/pthread_cond_timedwait.S:225
  3    Thread 0x7ffff66c0700 (LWP 6806) "HelloWorld_publ" pthread_cond_timedwait@@GLIBC_2.3.2
() at ../sysdeps/unix/sysv/linux/x86_64/pthread_cond_timedwait.S:225
[...]

(gdb) thread 2
[Switching to thread 2 (Thread 0x7ffff6ec1700 (LWP 6805))]

(gdb) backtrace full
[...]
#3  0x0000000000c6095b in RTIEventActiveDatabaseThread_loop (param=0x13fc8c0) at
ActiveDatabase.c:156
        timeStr = 0x7ffff6ec0dc0 "{0000003d,00000000}"
        t = 0x13fc8c0
        canBeDeleted = 0
        timeBuf = "{0000003d,00000000}"
        workerName = 0x1351cb0 "rDtb2081a9101"
        METHOD_NAME = 0x100a0d0 "RTIEventActiveDatabaseThread_loop"
[...]
```

As you can see in the example, workers follow the same naming convention as threads (in some cases, a shortened version of it). Workers associated with user threads use the following convention: **U<threadId>**, where:

- **U** - indicator that this is a User Thread
- **<threadId>** - ID given to the thread by the OS

Chapter 22 DDS Sample and Instance Memory Management

This chapter describes how *Connext DDS* manages the memory for the DDS data samples that are sent by *DataWriters* and received by *DataReaders*.

22.1 DDS Sample Memory Management for DataWriters

To configure DDS sample memory management on the writer side, use the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436. Table 22.1 DDS Sample Memory Management Properties for DataWriters lists the supported memory-management properties for *DataWriters*. This section applies to *DataWriters* that use IDL-generated type-plugins as well as DynamicDataWriters.

Table 22.1 DDS Sample Memory Management Properties for DataWriters

Property	Description
dds.data_writer.history.memory_manager.fast_pool.pool_buffer_max_size	If the serialized size of the DDS sample is <= **pool_buffer_max_size**: The buffer is obtained from a pre-allocated pool and released when the *DataWriter* is deleted. If the serialized size of the DDS sample is > **pool_buffer_max_size**: The buffer is dynamically allocated from the heap and returned to the heap when the DDS sample is removed from the *DataWriter's* queue. The size of the buffer allocated from the heap is the sample serialized size. Default: -1 (UNLIMITED). All DDS sample buffers are obtained from the pre-allocated pool; the buffer size is the maximum serialized size of the DDS samples, as returned by the type plugin **get_serialized_sample_max_size()** operation. See 22.1.1 Memory Management without Batching on the next page. Note: This property also controls the memory allocation for the serialized key buffer that is stored with every instance. See 22.3 Instance Memory Management for DataWriters on page 932.

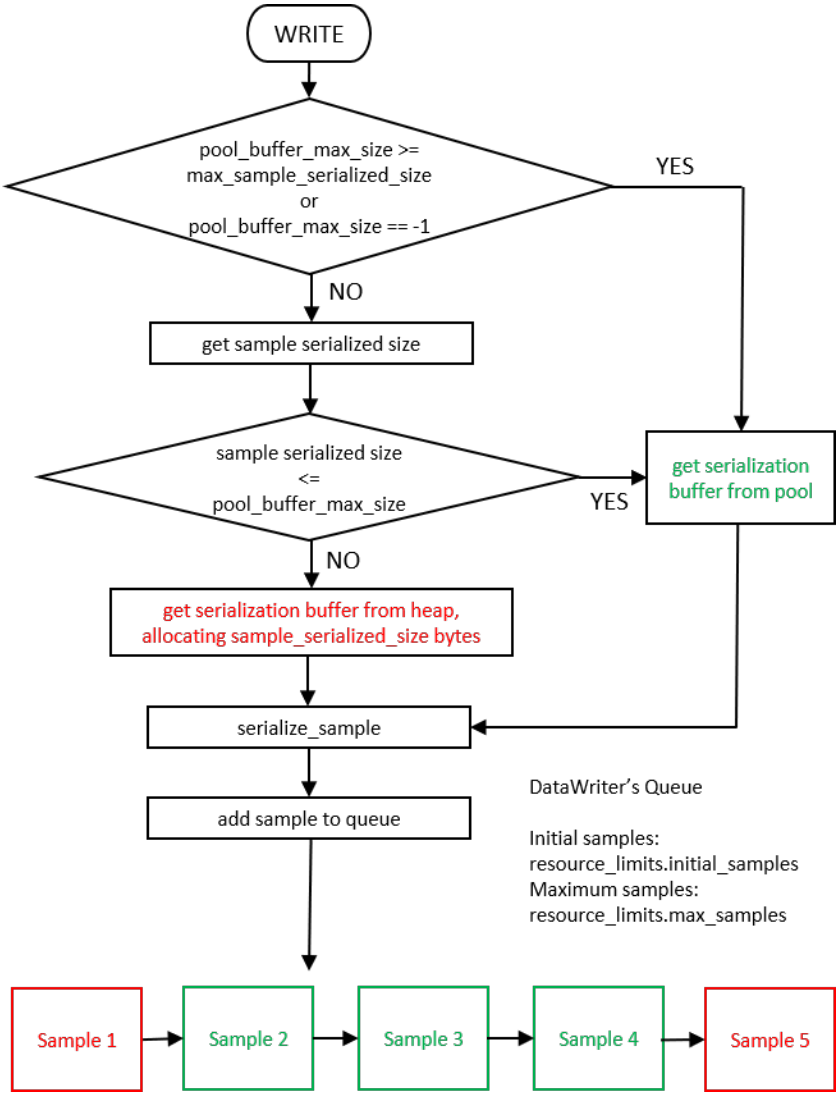
Table 22.1 DDS Sample Memory Management Properties for DataWriters

Property	Description
dds.data_writer.history.memory_manager.java_stream.min_size	Only supported when using the Java API. Defines the minimum size of the buffer that will be used to serialize DDS samples. When a *DataWriter* is created, the Java layer will allocate a buffer of this size and associate it with the *DataWriter*. Default: -1 (UNLIMITED). This is a sentinel that refers to the maximum serialized size of a DDS sample, as returned by the type plugin **get_serialized_sample_max_size()** operation See 22.1.3 Writer-Side Memory Management when Using Java on page 923.
dds.data_writer.history.memory_manager.java_stream.trim_to_size	Only supported when using the Java API. A boolean value that controls the growth of the serialization buffer. If set to 0 (default): The buffer will not be reallocated unless the serialized size of a new DDS sample is greater than the current buffer size. If set to 1: The buffer will be reallocated with each new DDS sample to a smaller size in order to just fit the DDS sample serialized size. The new size cannot be smaller than **min_size**. See 22.1.3 Writer-Side Memory Management when Using Java on page 923.

22.1.1 Memory Management without Batching

When the **write()** operation is called on a *DataWriter* that does not have batching enabled, the *DataWriter* serializes (marshals) the input DDS sample and stores it in the *DataWriter's* queue (see Figure 22.1: DataWriter Actions when Batching is Disabled on the next page). The size of this queue is limited by **initial_samples/max_samples** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.

Figure 22.1: DataWriter Actions when Batching is Disabled



Each DDS sample in the queue has an associated serialization buffer in which the *DataWriter* will serialize the DDS sample. This buffer is either obtained from a pre-allocated pool (if the serialized size of the DDS sample is <= **dds.data_writer.history.memory_manager.fast_pool.pool_buffer_max_size**) or the buffer is dynamically allocated from the heap (if the serialized size of the DDS sample is > **dds.data_writer.history.memory_manager.fast_pool.pool_buffer_max_size).** The size of the buffer allocated on the heap is the sample serialized size. See Table 22.1 DDS Sample Memory Management Properties for DataWriters.

The default value of **pool_buffer_max_size** is -1 (UNLIMITED). In this case, all the DDS samples come from the pre-allocated pool and the size of the buffers is the maximum serialized size of the DDS samples as returned by the type plugin **get_serialized_sample_max_size()** operation. The default value is optimum for real-time applications where determinism and predictability is a must. The trade-off is higher memory usage, especially in cases where the maximum serialized size of a DDS sample is large.

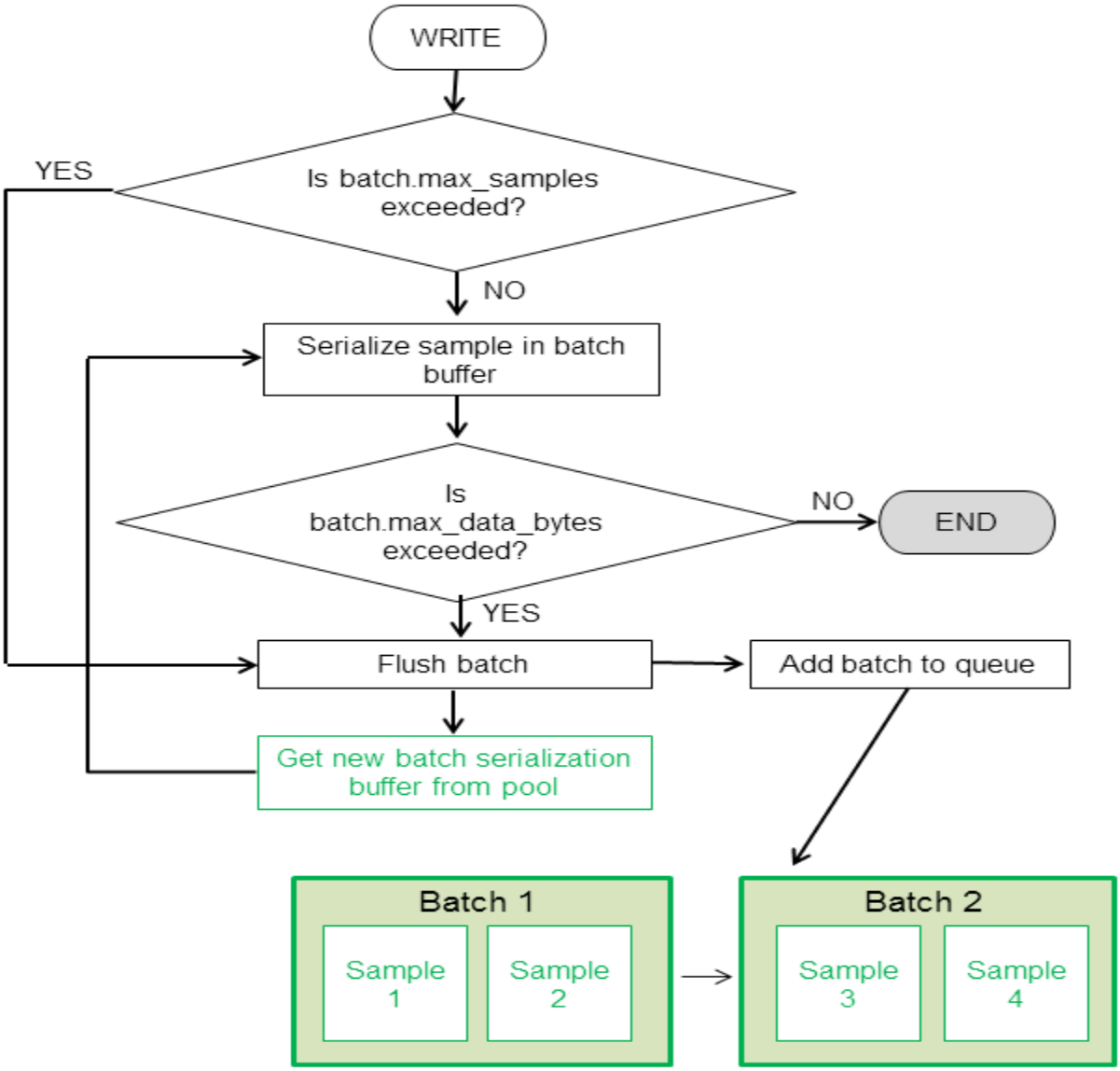
Connext DDS cannot send arbitrarily large samples. For details on serialization limits see 3.10 Data Sample Serialization Limits on page 164.

22.1.2 Memory Management with Batching

When the **write()** operation is called on a *DataWriter* for which batching is enabled (see 7.5.2 BATCH QosPolicy (DDS Extension) on page 373), the *DataWriter* serializes (marshals) the input DDS sample into the current batch buffer (see Figure 22.2: DataWriter Actions when Batching is Enabled on the next page). When the batch is flushed, it is stored in the *DataWriter's* queue along with its DDS samples. The *DataWriter* queue can be sized based on:

- The number of DDS samples, using **initial_samples/max_samples** (both set in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449)
- The number of batches, using **initial_batches/max_batches** (both set in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400)
- Or a combination of **max_samples** and **max_batches**

Figure 22.2: DataWriter Actions when Batching is Enabled



When batching is enabled, the memory associated with the batch buffers always comes from a pre-allocated pool. The size of the buffers is determined by the QoS values **max_samples** and **max_data_bytes** (both set in the 7.5.2 BATCH QosPolicy (DDS Extension) on page 373) as follows:

- If **max_data_bytes** is a finite value, the size of the buffer is the maximum of this value and the maximum serialized size of a DDS sample (**max_sample_serialized_size**) as returned by the type-plugin **get_serialized_sample_max_size()**, since that batch must contain at least one DDS sample.
- Otherwise, the size of the buffer is calculated by (**batch.max_samples** * **max_sample_serialized_size**).

Notice that for variable-size DDS samples (for example, DDS samples containing sequences) it is good practice to size the buffer based on **max_data_bytes**, since this leads to more efficient memory usage.

Note: The value of the property **dds.data_writer.history.memory_manager.fast_pool.pool_buffer_max_size** is ignored by *DataWriters* with batching enabled.

22.1.3 Writer-Side Memory Management when Using Java

When the Java API is used, *Connext DDS* allocates a Java buffer per *DataWriter*; this buffer is used to serialize the Java DDS samples published by the *DataWriters*. After a DDS sample is serialized into a Java buffer, the result is copied into the underlying native buffer described in 22.1.1 Memory Management without Batching on page 919 and 22.1.2 Memory Management with Batching on page 921.

You can use the following two *DataWriter* properties to control memory allocation for the Java buffers that are used for serialization (see Table 22.1 DDS Sample Memory Management Properties for DataWriters):

- **dds.data_writer.history.memory_manager.java_stream.min_size**
- **dds.data_writer.history.memory_manager.java_stream.trim_to_size**

22.1.4 Writer-Side Memory Management when Working with Large Data

Large DDS samples are DDS samples with a large *maximum* size relative to the memory available to the application. Notice the use of the word *maximum*, as opposed to *actual* size.

As described in 22.1.1 Memory Management without Batching on page 919, by default, the middleware preallocates the DDS samples in the *DataWriter* queue to their maximum serialized size. This may lead to high memory-usage in *DataWriters* where the maximum serialized size of a DDS sample is large.

For example, let's consider a video conferencing application:

```
struct VideoFrame {
       boolean keyFrame;
       sequence<octet,1024000> data;
};
```

The above IDL definition can be used to work with video streams.

Each frame is transmitted as a sequence of octets with a maximum size of 1 MB. In this example, the video stream has two types of frames: I-Frames (also called key frames) and P-Frames (also called delta frames). I-Frames represent full images and do not require information about the preceding frames in order to be decoded. P-frames require information about the preceding frames in order to be decoded.

A video stream consists of a sequence of frames in which I-Frames are followed by multiple P-frames. The number of P-frames between I-Frames affects the video quality since, in a non-reliable configuration, losing a P-frame will degrade the image quality until the next I-frame is received.

For our use case, let's assume that I-frames may require 1 MB, while P-Frames require less than 32 KB. Also, there are 20 times more P-Frames than I-Frames.

Although the actual size of the frames sent by the *Connext DDS* application is usually significantly smaller than 1 MB since they are P-Frames, the default memory management will use 1 MB per frame in the *DataWriter* queue. If **resource_limits.max_samples** is 256, the *DataWriter* may end up allocating 256 MB.

Using some domain-specific knowledge, such as the fact that most of the P-Frames have a size smaller than 32 KB, we can optimize memory usage in the *DataWriter's* queue while still maintaining determinism and predictability for the majority of the frames sent on the wire.

The following XML file shows how to optimize the memory usage for the previous example (rather than focusing on efficient usage of the available network bandwidth).

```
<?xml version="1.0"?>
<!-- XML QoS Profile for large data -->
<dds xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
    <!-- QoS Library containing the QoS profile used for large data -->
    <qos_library name="ReliableLargeDataLibrary">
        <!-- QoS profile to optimize memory usage in DataWriters sending
             large images
         -->
        <qos_profile name="ReliableLargeDataProfile"
                     is_default_qos="true">
            <!-- QoS used to configure the DataWriter -->
            <datawriter_qos>
                <resource_limits>
                    <max_samples>32</max_samples>
                    <!— No need to pre-allocate 32 images unless needed -->
                    <initial_samples>1</initial_samples>
                </resource_limits>


                <property>
                    <value>
                    <!-- For frames with size smaller or
```

```
                        equal to 33 KB the serialization
                        buffer is obtained from a
                        pre-allocated pool. For sizes
                        greater than 33 KB, the DataWriter
                        will use dynamic memory allocation.
                    -->
                        <element>
                            <name>
        dds.data_writer.history.memory_manager.fast_pool.pool_buffer_max_size
                            </name>
                            <value>33792</value>
                        </element>
                        <!-- Java will use a 33 KB buffer to
                             serialize all frames with a size
                             smaller than or equal to 33 KB.
                             When an I-frame is published,
                             Java will reallocate the
                             serialization buffer to match
                             the serialized size of the new frame.
                         -->
                        <element>
                            <name>
        dds.data_writer.history.memory_manager.java_stream.min_size
                            </name>
                            <value>33792</value>
                        </element>
                        <element>
                            <name>
        dds.data_writer.history.memory_manager.java_stream.trim_to_size
                            </name>
                            <value>1</value>
                        </element>
                    </value>
                </property>
            </datawriter_qos>
        </qos_profile>
    </qos_library>
</dds>
```

Working with large data DDS samples will likely require throttling the network traffic generated by single DDS samples. For additional information on shaping network traffic, see 7.6 FlowControllers (DDS Extension) on page 467.

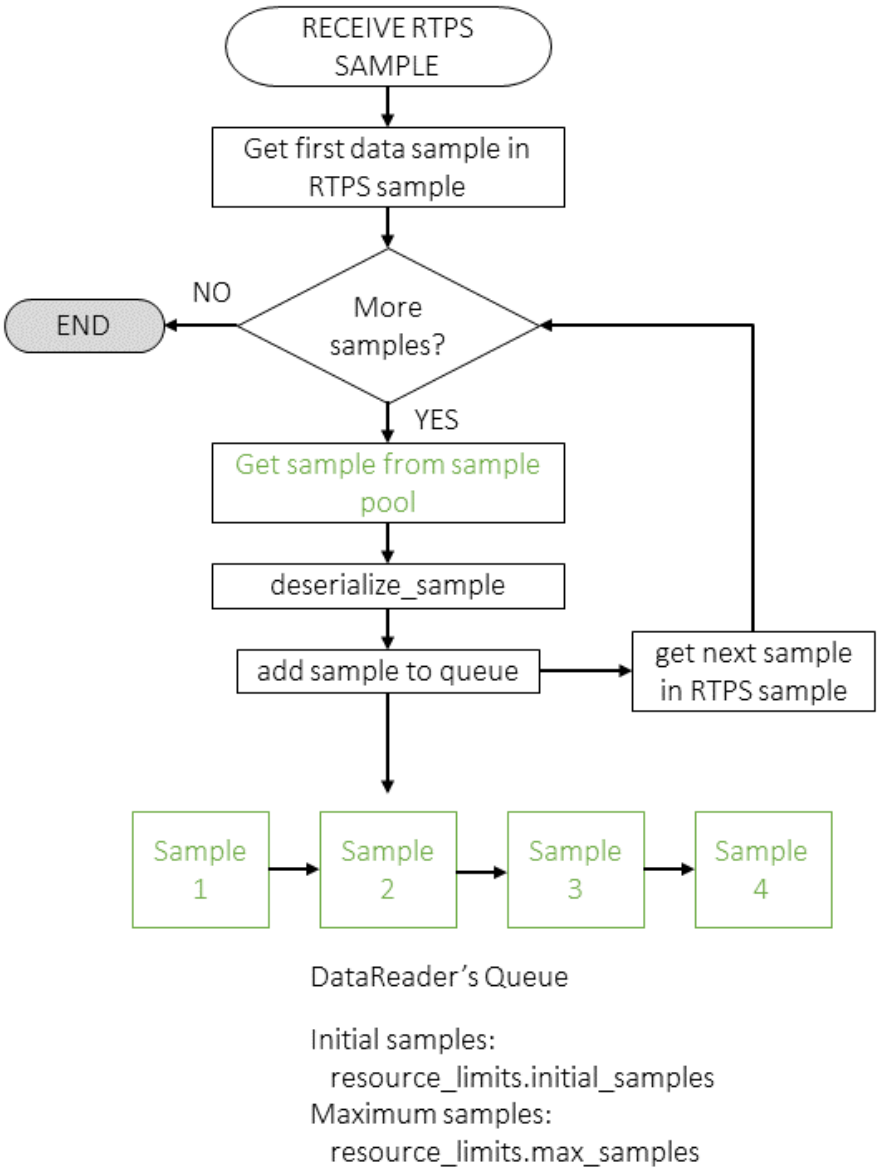
22.2 DDS Sample Memory Management for DataReaders

The DDS data samples received by a *DataReader* are deserialized (demarshaled) and stored in the *DataReader's* queue (see Figure 22.3: Adding DDS Samples to DataReader's Queue on the next page). The size of this queue is limited by **initial_samples/max_samples** in the 7.5.22 RESOURCE_LIMITS QosPolicy on page 449.

22.2.1 Memory Management for DataReaders Using Generated Type-Plugins

Figure 22.3: Adding DDS Samples to DataReader's Queue below shows how DDS samples are processed and added to the *DataReader's* queue.

Figure 22.3: Adding DDS Samples to DataReader's Queue



The RTPS DATA DDS samples received by a *DataReader* can be either batch DDS samples or individual DDS samples. The *DataReader* queue does not store batches. Therefore, each one of the DDS samples within a batch will be deserialized and processed individually.

When the *DataReader* processes a new sample, it will deserialize it into a sample obtained from a pre-allocated pool. By default, to provide predictability and determinism, the sample obtained from the pool is allocated to its maximum size. For example, with the following IDL type, each sample in the *DataReader* queue will consume 1 MB, even if the actual size is smaller.

```
struct VideoFrame {
       boolean keyFrame;
       sequence<octet,1024000> data;
};
```

In the above example, it is possible to reduce the memory consumption by declaring the data sequence as unbounded and by generating code for the type with the command-line option **-unboundedSupport**. In this case, the middleware will not preallocate 1 MB for the data member. Instead, the generated code will deserialize incoming samples by dynamically allocating and deallocating memory to accommodate the actual size of the data sequence.

22.2.2 Reader-Side Memory Management when Using Java

When the Java API is used with *DataReaders* using generated type-plugins, *Connext DDS* allocates a Java buffer per *DataReader;* this buffer is used to copy the native serialized data, so that the received DDS samples can be deserialized into the Java objects obtained from the DDS sample pool in Figure 22.3: Adding DDS Samples to DataReader's Queue on the previous page.

You can use the *DataReader* properties in Table 22.2 DDS Sample Memory Management Properties for DataReaders when Using Java API to control memory allocation for the Java buffer used for deserialization:

Table 22.2 DDS Sample Memory Management Properties for DataReaders when Using Java API

Property	Description
dds.data_reader.history.memory_manager.java_stream.min_size	Only supported when using the Java API. Defines the minimum size of the buffer used for the serialized data. When a *DataReader* is created, the Java layer will allocate a buffer of this size and associate it with the *DataReader*. Default: -1 (UNLIMITED) This is a sentinel to refer to the maximum serialized size of a DDS sample, as returned by the type plugin method **get_serialized_sample_max_size()**.
dds.data_reader.history.memory_manager.java_stream.trim_to_size	Only supported when using the Java API. A Boolean value that controls the growth of the deserialization buffer. If set to 0 (the default), the buffer will not be re-allocated unless the serialized size of a new DDS sample is greater than the current buffer size. If set to 1, the buffer will be re-allocated with each new DDS sample in order to just fit the DDS sample serialized size. The new size cannot be smaller than **min_size**.

22.2.3 Memory Management for DynamicData DataReaders

Unlike *DataReaders* that use generated type-plugin code, DynamicData *DataReaders* provide configuration mechanisms to control the memory usage for use cases involving large data DDS samples. It is not required to set any of the following properties in order to support unbounded types in your application. The default behavior for a DynamicData *DataReader* is that samples are allocated to the minimum deserialized size and can grow to any size required to store incoming samples.

A DDS DynamicData sample stored in the *DataReader's* queue has an associated underlying buffer that contains the DynamicData-specific representation of the DDS sample. The buffer is allocated according to the configuration provided in the **data** and **serialization** members of the **DynamicDataTypeProperty_t** used to create the **DynamicDataTypeSupport** (see 3.8 Interacting Dynamically with User Data Types on page 154).

```
struct DDS_DynamicDataTypeProperty_t {
    DDS_DynamicDataProperty_t data;
    DDS_DynamicDataTypeSerializationProperty_t serialization;
};

struct DDS_DynamicDataTypeSerializationProperty_t {
    DDS_Boolean trim_to_size;
}

struct DDS_DynamicDataProperty_t {
    DDS_Long buffer_initial_size;
    DDS_Long buffer_max_size;
};
```

Table 22.3 struct DDS_DynamicDataTypeSerializationProperty_t below describes the member of DDS_DynamicDataTypeSerializationProperty_t.

Table 22.3 struct DDS_DynamicDataTypeSerializationProperty_t

Name	Description
trim_to_size	Controls the growth of the serialization buffer in a DynamicData object. This property only applies to DynamicData samples that are obtained from the sample pool that is created by each DynamicData *DataReader*. If set to 0 (default): The buffer will not be reallocated unless the deserialized size of the incoming DDS sample is greater than the current buffer size. If set to 1: The buffer of a DynamicData object obtained from the DDS sample pool will be re-allocated for each sample to just fit the size of the deserialized data of the incoming sample. The newly allocated size will not be smaller than **max**(**min_deserialized_size**, **buffer_initial_size**).

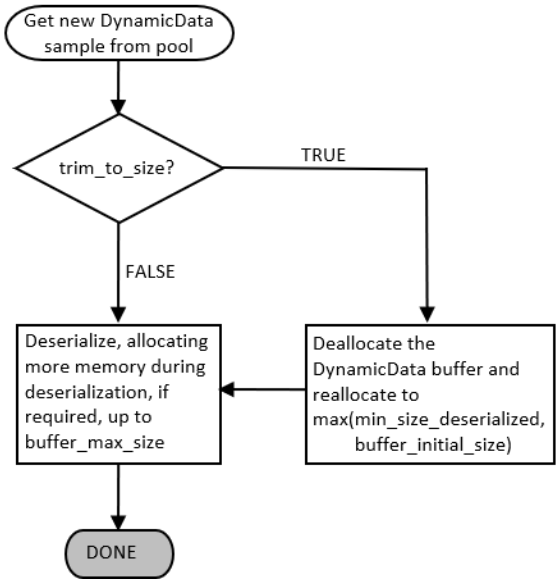
The following table describes the members of DDS_DynamicDataProperty_t.

Table 22.4 struct DDS_DynamicDataProperty_t

Name	Description
buffer_initial_size	The initial amount of memory used by the underlying DynamicData buffer, in bytes. This property is used to configure the DynamicData objects that are created stand-alone as well as the DynamicData samples that are obtained from the sample pool that is created by each DynamicData *DataReader*. If set to 0 (default): The initial buffer size will be set to the minimum amount of space required to hold the overhead required by the DynamicData internal representation (about 100 bytes) in addition to the minimum deserialized size of a sample. The minimum deserialized size of a sample assumes that all strings are allocated to their default values, sequences are left to length 0, and all optional members are unset. If set to any value other than 0: The underlying buffer will be allocated to the provided size plus the overhead required by the DynamicData internal representation (about 100 bytes). If the provided size plus the overhead is less than the size used when **buffer_initial_size** is left to 0, then the default value is used.
buffer_max_size	The maximum amount of memory that the underlying DynamicData buffer may use, in bytes. This property is used to configure the DynamicData objects that are created stand-alone as well as the DynamicData samples that are obtained from the sample pool that is created by each DynamicData *DataReader*. A DynamicData object will grow to this size from the initial size as needed. The **buffer_max_size** includes all overhead that is required for the internal DynamicData representation and therefore represents a hard upper limit on the size of the underlying DynamicData buffer. If set to -1 (default): The buffer will grow unbounded to the size required to fit all members. If set to any value other than -1: The buffer will not grow beyond this size. If setting a member's values requires the buffer to grow beyond the maximum, the member will fail to be set. If the buffer is required to grow beyond this maximum during deserialization, the sample will fail to be deserialized. The **buffer_max_size** cannot be smaller than the **buffer_initial_size**.

Figure 22.4: Allocation of DDS Samples in DataReader Queue for DynamicData DataReaders below shows how DDS samples are allocated in the *DataReader* queue for DynamicData *DataReaders*.

Figure 22.4: Allocation of DDS Samples in DataReader Queue for DynamicData DataReaders



22.2.4 Memory Management for Fragmented DDS Samples

When a *DataWriter* writes DDS samples with a serialized size greater than the minimum of the largest transport message sizes across all transports installed with the *DataWriter*, the DDS samples are fragmented into multiple RTPS fragment messages.

The different fragments associated with a DDS sample are assembled in the *DataReader* side into a single buffer that will contain the DDS sample serialized data after the last fragment is received.

By default, the *DataReader* keeps a pool of pre-allocated serialization buffers that will be used to reconstruct the serialized data of a DDS sample from the different fragments. Each buffer hold one individual DDS sample and it has a size equal to the maximum serialized size of a DDS sample. The pool size can be configured using the QoS values **initial_fragmented_samples** and **max_fragmented_samples** in 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571.

The main disadvantage in pre-allocating the serialization buffers is an increase in memory usage, especially when the maximum serialized of a DDS sample is quite large. *Connext DDS* offers a setting that allows memory for a DDS sample to be allocated from the heap the first time a fragment is received. The amount of memory allocated equals the amount of memory needed to store all fragments in the DDS sample.

22.2.5 Reader-Side Memory Management when Working with Large Data

This section describes how to configure the *DataReader* side of the videoconferencing application introduced in 22.1.4 Writer-Side Memory Management when Working with Large Data on page 923 to optimize memory usage.

The following XML file can be used to optimize the memory usage in the previous example:

```
<?xml version="1.0"?>
<!-- XML QoS Profile for large data -->
<dds xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
       <!-- QoS Library containing the QoS profile used for large data -->
       <qos_library name="ReliableLargeDataLibrary">
               <!-- QoS profile used to optimize the memory usage in a
                    DataWriter sending large data images
               -->
               <qos_profile name="ReliableLargeDataProfile"
                is_default_qos="true">
                  <!-- QoS used to configure the DataWriter -->
                  <datareader_qos>
                      <history>
                          <kind>KEEP_ALL_HISTORY_QOS</kind>
                      </history>
                      <resource_limits>
                          <max_samples>32</max_samples>
                          <!– No need to pre-allocate 32 frames unless
                              needed -->
                          <initial_samples>1</initial_samples>
                      </resource_limits>
                      <reader_resource_limits>
                      <!-- Since the video frame samples have a
```

```
                            large maximum serialized size we can configure
                            the fragmented samples pool to use dynamic
                            memory allocation. As an alternative,
                            reduce max_fragmented_samples. However, that
                            may cause fragment retransmission.
                        -->
                        <dynamically_allocate_fragmented_samples>
                            1
                        </dynamically_allocate_fragmented_samples>
                    </reader_resource_limits>
                    <property>
                        <value>
                                <!-- Java will use a buffer of 33KB to
                                     deserialize all frames with a
                                     serialized size smaller or equal than
                                     33KB. When an I-frame is received,
                                     Java will re-allocate the
                                     deserialization buffer to match the
                                     serialized size of the new frame.
                                -->
                                <element>
                                    <name>
        dds.data_reader.history.memory_manager.java_stream.min_size
                                    </name>
                                    <value>33792</value>
                                </element>
                                <element>
                                    <name>
        dds.data_reader.history.memory_manager.java_stream.trim_to_size
                                    </name>
                                    <value>1</value>
                                </element>
                        </value>
                    </property>
                </qos_profile>
        </qos_library>
</dds>
```

To avoid preallocation of the samples in the *DataReader's* queue to their maximum size for Type-Plugin generated code in C, C++, Java, and .NET, replace the bounded sequence in VideoFrame with an unbounded sequence and generate code using the **-unboundedSupport** command-line option:

```
struct VideoFrame {
        boolean keyFrame;
        sequence<octet> data;
};
```

See 22.2.1 Memory Management for DataReaders Using Generated Type-Plugins on page 926 for more details.

To avoid preallocation of the samples in the *DataReader's* queue to their maximum size for DynamicData, set the **min_size_serialized** property to avoid the allocation of 1MB buffers for the *DataReader* queue samples (See 22.2.3 Memory Management for DynamicData DataReaders on page 928.

22.3 Instance Memory Management for DataWriters

When an instance is registered with a *DataWriter*, the *DataWriter* serializes the key value and stores it with the instance.

Each instance maintained by the *DataWriter* has an associated buffer in which the *DataWriter* serializes the key. This buffer is either:

- Obtained from a pre-allocated pool (if the key's serialized size is <= **dds.data_writer-.history.memory_manager.fast_pool.pool_buffer_max_size**).
- Dynamically allocated from the heap (if the key's serialized size is > **dds.data_writer-.history.memory_manager.fast_pool.pool_buffer_max_size**).

See Table 22.5 Instance Memory Management Properties for DataWriters.

Table 22.5 Instance Memory Management Properties for DataWriters

Property	Description
dds.data_writer.history.memory_manager.fast_pool.pool_buffer_max_size	Controls the memory allocation for the serialized key buffer that is stored with every instance. Default: -1 (UNLIMITED). All DDS sample buffers are obtained from the pre-allocated pool. The buffer size is the maximum serialized size of the DDS samples, as returned by the type plugin **get_serialized_sample_max_size()** operation. Note: This property also controls DDS sample memory management. See 22.1 DDS Sample Memory Management for DataWriters on page 918.

22.4 Instance Memory Management for DataReaders

There are a number of features that require *DataReaders* to allocate a buffer to store an intermediate, serialized representation of a sample. The size of these buffers is controlled with the property **dds.data_reader.history.memory_ manager.fast_pool.pool_buffer_max_size**.

When a buffer is needed:

- If the required size is <= **dds.data_reader.history.memory_ manager.fast_pool.pool_buffer_ max_size**, a preallocated buffer will be used. This buffer will not be freed until the *DataReader* is deleted and is therefore reused whenever a buffer is needed for a sample that matches this condition.
- If the required size is > **dds.data_reader.history.memory_manager.fast_pool.pool_buffer_max_ size**, the buffer will be dynamically allocated from the heap and then freed once it is no longer needed.

This property must be set if you are using any of the following features:

- Keyed data types
- Query conditions (only required if also using DynamicData, or the Java, .NET, or Modern C++ language APIs)
- Data encryption using *RTI Security Plugins*
- User-data payload compression (see 7.5.3.2 Data Compression on page 382)

In the case of keyed data types, a buffer is used per-instance to store the serialized representation of the key value for that instance.

In the case of query conditions, when a query condition is created, all samples that are in the *DataReader's* queue need to be temporarily re-serialized in order to be evaluated against the query condition. A buffer that is allocated based on the value of this property is used for that serialization.

In the case of data encryption and compression, a buffer is needed when a sample is first received in order to decode or uncompress the sample into. If data encryption and compression are both being used, then two buffers will be allocated (because the sample must first be decoded into one buffer and then uncompressed into another buffer).

Setting this property to a finite value

The key buffers, used to store the serialized key per-instance, come from a pre-allocated pool with **ResourceLimits::initial_instances** initial buffers. Setting this property to a finite value will cause the buffers in the key buffer pool to be allocated to that size. If a larger buffer is needed when a new instance is received by the *DataReader*, a buffer of the correct size will be allocated at that time.

The buffers that are needed for samples are shared and are allocated once they are needed for the first time. When a buffer is needed, the required size will be checked against the value of this property. If the required size is less than or equal to this property's value and a buffer has not been allocated before, a buffer will be allocated with the property's size. This buffer will not be deallocated until the *DataReader* is deleted and will be reused every time a buffer with this size or smaller is needed. If a buffer is needed that is larger than the value configured by this property, it will be dynamically allocated to the correct size and then freed as soon as it is not needed anymore (once the sample has been deserialized). There will be at most two buffers allocated to the configured size. This will only happen if both data encryption and user-data payload compression are being used at the same time.

Setting this property to unlimited (DEFAULT)

If this property is set to -1 (UNLIMITED), the size of the key buffers is the maximum serialized size of the key as returned by the type plugin **get_serialized_key_max_size()** operation. These buffers still come from a pre-allocated pool. The size of the buffers used for samples will be allocated, when needed, to the maximum serialized size of a sample as returned by the type plugin **get_serialized_sample_max_size()** operation. They are not deallocated until the *DataReader* is deleted so that they can be reused whenever needed.

Chapter 23 Sending Large Data

This section describes the capabilities offered by *Connext DDS* to allow sending and receiving large data samples. In this section, "large data" refers to samples with a large serialized size, usually on the order of MBs, such as video frame samples.

The definition of "large data" in this chapter contrasts with other definitions of large data in this manual:

- In 7.4.1 ASYNCHRONOUS_PUBLISHER QosPolicy (DDS Extension) on page 344, "large data" is defined as data that cannot be sent as a single packet by a transport. The concept of large data in this section is decoupled from the maximum message size of the underlying transport, although these two things are related: samples with a size in the order of MBs will usually be greater than the underlying transport's maximum message size.
- In Chapter 22 DDS Sample and Instance Memory Management on page 918, "large data" refers to types whose samples have a large maximum serialized size independently of the actual serialized size of the samples sent on the wire. This contrasts with the definition of "large data" in this section, which refers to samples with a large serialized size.

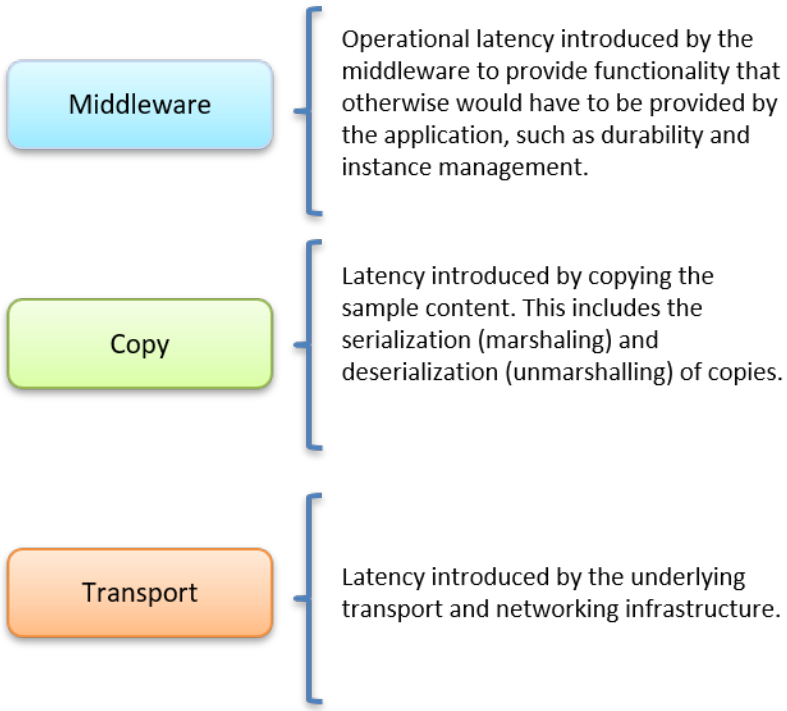
Connext DDS offers the following solutions to optimize the sending and receiving of large data:

- Reducing latency using either or both of the following to reduce the number of copies produced by the middleware; see 23.1 Reducing Latency on the next page:
  - *RTI FlatData™ language binding*; see 23.5 FlatData Language Binding on page 940
  - Zero Copy transfer over shared memory; see 23.6 Zero Copy Transfer Over Shared Memory on page 953
- Reducing bandwidth usage by compressing samples with a set of standard compression algorithms; see 7.5.3 DATA_REPRESENTATION QosPolicy on page 379

23.1 Reducing Latency

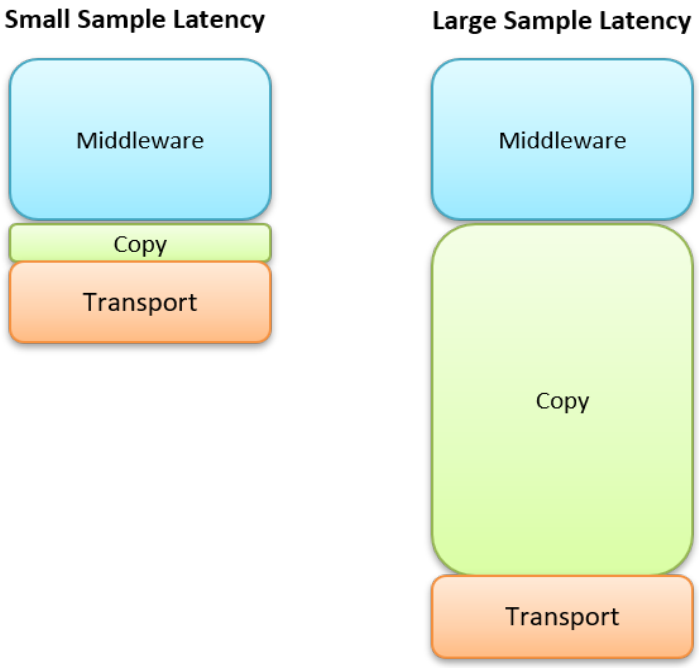
One of the main considerations when sending large samples is latency. When using *Connext DDS*, and in general any connectivity framework, sample latency has three components: middleware, copy, and transport (see Figure 23.1: Basic Components of Latency below).

Figure 23.1: Basic Components of Latency



When *Connext DDS* is used to send small data samples, such as temperature readings, the weight of the copy component in the total sample latency is small. But when samples are large, the weight of the copy component becomes considerable. (See Figure 23.2: Copy Components Compared on the next page.)

Figure 23.2: Copy Components Compared



Therefore, reducing the number of copies made by the middleware or network infrastructure when publishing and receiving large samples becomes critical. Two features allow reducing the number of sample copies and consequently the transmission latency: *Zero Copy transfer over shared memory* and *FlatData language binding*. These two features can be used individually or in combination.

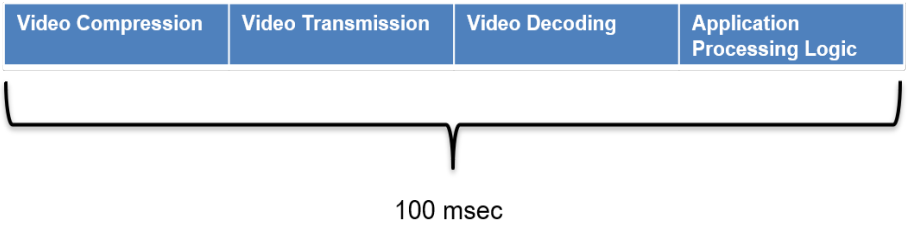
> **Important:** "Large samples" in this context refers to samples with a large serialized size, usually on the order of MBs, such as video frame samples. If you implement FlatData language binding or Zero Copy transfer over shared memory with data smaller than this, you may not see significant difference in latency or even pay a penalty in latency.

23.2 Use Cases

Zero Copy transfer over shared memory and FlatData language binding are recommended when your strict latency requirements cannot be met by regular C/C++ language binding (which defines the in-memory representation of a type), and the UDP and shared memory transports. For example, video applications such as video conferencing, video surveillance, or computer vision usually have strict latency requirements, especially if the video signal is used to do control. Consider, for instance, a latency requirement of less than 100 milliseconds. This latency must account for different components such as:

- Video compression
- Video decoding
- Transmission

- Image scaling
- Application processing logic

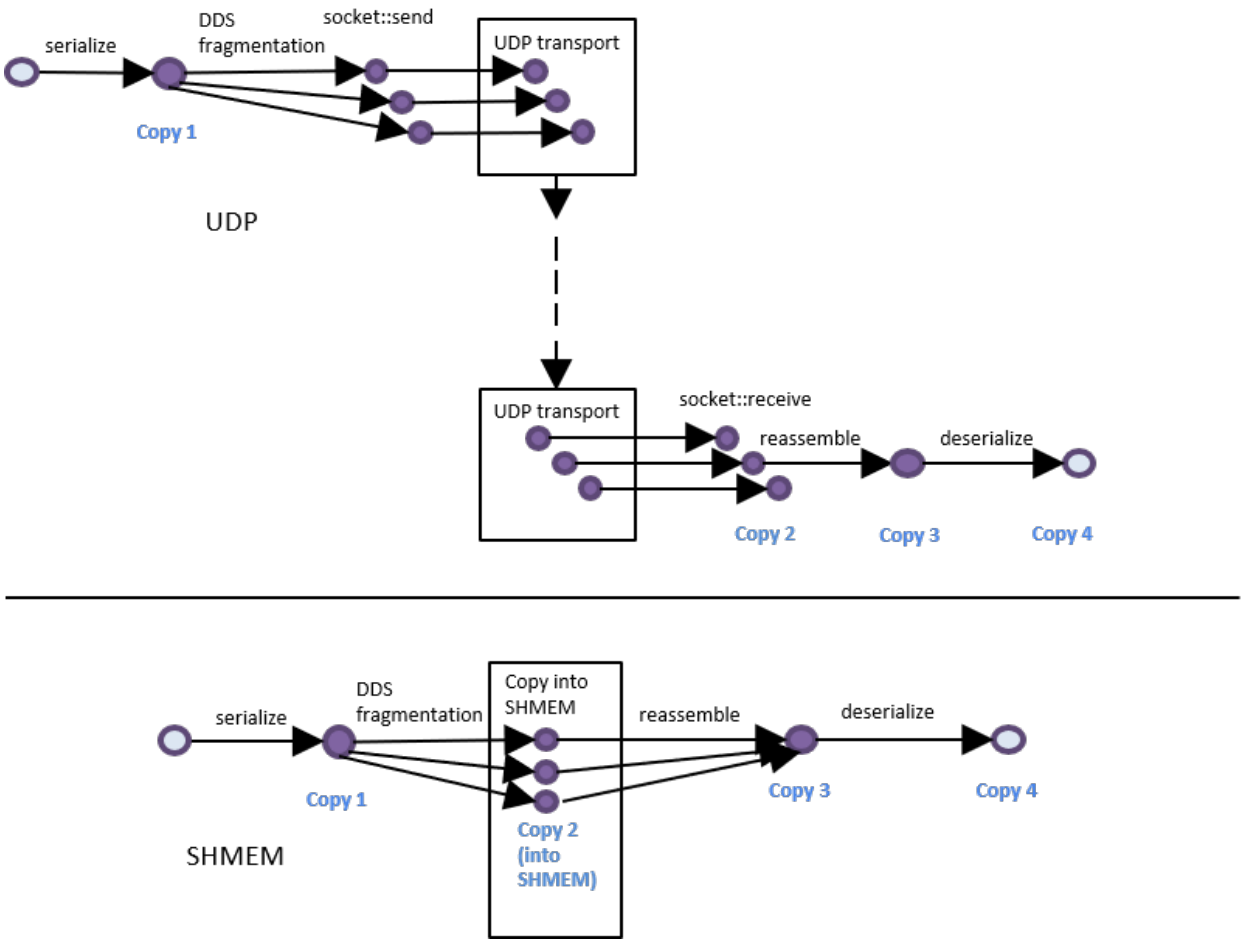


To keep latency to a minimum for large data samples, reduce the number of copies made by the middleware or network infrastructure by using FlatData language binding, Zero Copy transfer over shared memory, or both.

23.3 Copies in the Middleware Memory Space

Figure 23.3: Number of Copies Out-of-the-Box on the next page shows how many times *Connext DDS* may copy a large sample sent over UDP or shared memory. The diagram assumes that the samples have to be fragmented by the middleware (via DDS fragmentation) because their serialized size is greater than the underlying transport MTU (maximum transmission unit), which can be configured by setting **message_size_max** in the transport properties (see Chapter 16 Transport Plugins on page 790). Note that these are copies in the middleware memory space—the operating system network stack may make additional copies.

Figure 23.3: Number of Copies Out-of-the-Box



For both UDP and shared memory (SHMEM), the copies are as follows, out of the box:

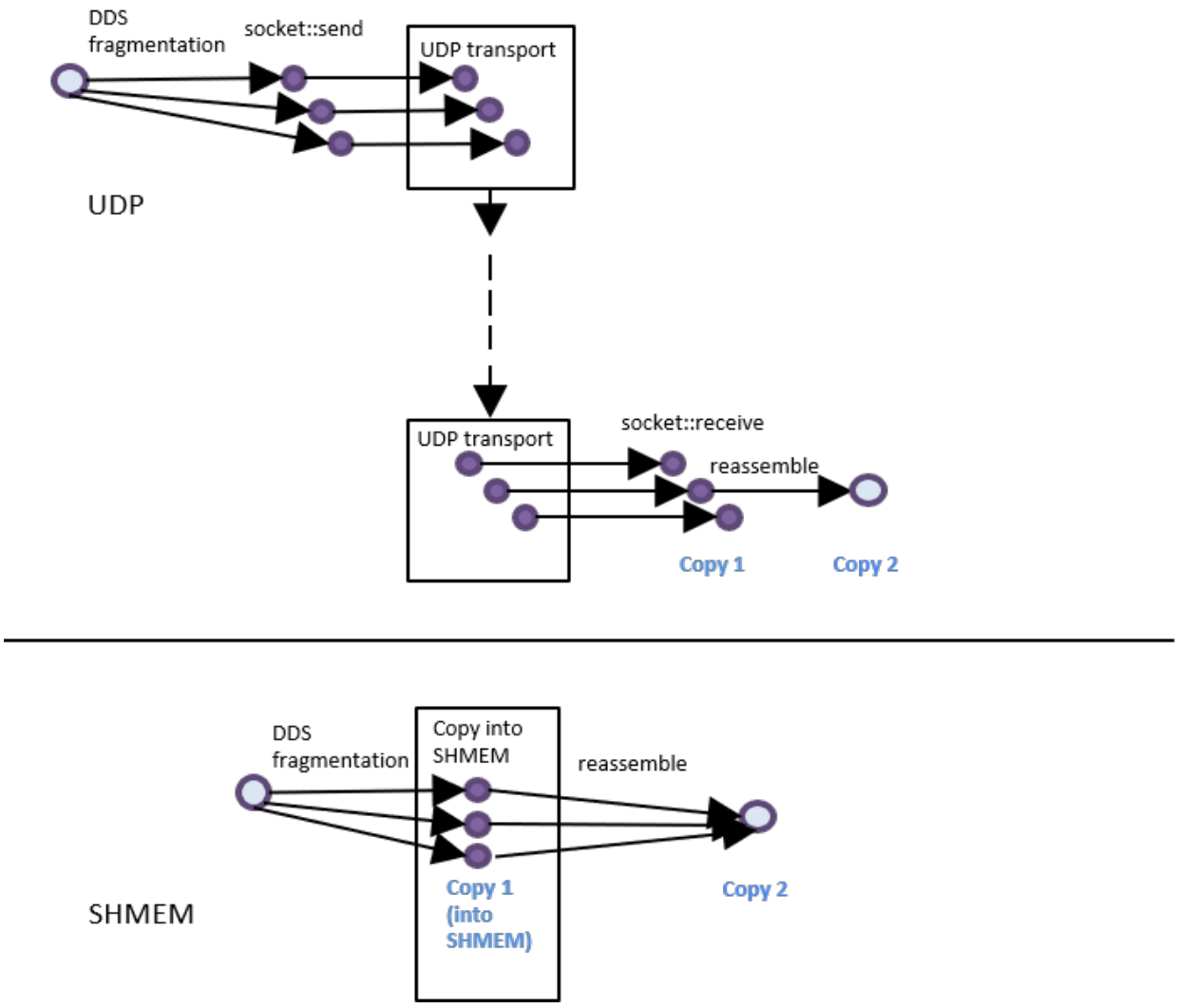
1. Copy 1 is the serialization copy. *Connext DDS* calls **TypePlugin::serialize** to convert the in-memory representation of a sample, such as a C++ object, into a data representation, called a wire representation, with a format suitable for storage or transmission.

   After a sample is serialized, it is sent to the subscribing application using one or more of the available transports. When the underlying transport maximum message size is smaller than the serialized size of the sample, the sample must be fragmented. The fragmentation process does not require any extra copy. Fragments refer directly to offsets in the serialization buffer.

   Note: The transport maximum message size can be configured using the property **dds.transport.UDPv4.builtin.parent.message_size_max** for UDPv4 and **dds.transport.shmem.builtin.parent.message_size_max** for SHMEM. There are equivalent properties for other transports, such as TCPv4 and UDPv6.

2. Copy 2: For SHMEM, the sample fragments that live in the local memory space of the publishing process have to be copied into the shared memory segment from which the subscribing application will read them. For UDP, the call to the socket receive operation copies the fragments.
3. Copy 3: After they are received, the sample fragments are reassembled into a single buffer.
4. Copy 4 is the deserialization copy. Connext DDS calls **TypePlugin::deserialize** to convert the wire memory representation of a sample into its in-memory representation, such as a C++ object.

Figure 23.4: Number of Copies Using FlatData Language Binding



FlatData is a language binding in which the in-memory representation of a sample matches the wire representation. Therefore, the cost of serialization/deserialization is zero. You can directly access the serialized data without deserializing it first. When using FlatData language binding, Copy 1 and Copy 4 in Figure 23.3: Number of Copies Out-of-the-Box on the previous page are removed for both UDP and SHMEM communications. See Figure 23.4: Number of Copies Using FlatData Language Binding above.

23.4 Choosing between FlatData Language Binding and Zero Copy Transfer over Shared Memory

Whether to use Zero Copy transfer over shared memory or FlatData language binding, or both, depends on whether the *DataReaders* run on the same host as the *DataWriters*, on different hosts, or a combination of both. It also depends on the definition of the type. Zero Copy transfer over shared memory requires the FlatData language binding when the type is variable-size. The following table summarizes how to choose between these features:

Table 23.1 Zero Copy Transfer Over Shared Memory vs. FlatData Language Binding

	Readers and writers run on same host	Readers and writers run on different hosts	Some readers/writers run on same host, some on different hosts
Fixed-size types	Use Zero Copy	Use FlatData	Use both Zero Copy and FlatData
Variable-size types	Use both Zero Copy and FlatData	Use FlatData	Use both Zero Copy and FlatData

In summary, for *DataReaders* running on the same host as the *DataWriter*, the *DataWriter* can take advantage of Zero Copy transfer over shared memory. For *DataReaders* running on a different host, the *DataWriter* won't use Zero Copy transfer over shared memory, but can benefit from FlatData language binding. Therefore, when you have writers and readers running on the same and different hosts, it is recommended to use both Zero Copy transfer over shared memory and FlatData language binding, and let the *DataWriter* use the correct option for each *DataReader*.

For more information, see 23.5 FlatData Language Binding below and 23.6 Zero Copy Transfer Over Shared Memory on page 953.

23.5 FlatData Language Binding

FlatData language binding offers the following benefits:

- Reduced number of copies: from four to two for both SHMEM and UDP transports (see Figure 23.4: Number of Copies Using FlatData Language Binding on the previous page), because there is no need to serialize and deserialize a sample.
- Reduced memory consumption and CPU load, due to reduced data copying.
- Improved latency for large data samples.

23.5.1 FlatData Representation

When you create a FlatData sample (see 23.5.2.2 Programming with FlatData Language Binding on page 943), the in-memory representation for the sample buffer is XCDR encoding version 2 (XCDR2), using the endianness of the host where the sample is created to populate the buffer. The use of the host

platform endianness allows fast access to the sample content, because the setters and getters do not have to change the endianness.

If you use a *DataReader* to read a FlatData sample that was received from a *DataWriter* running on a platform with a different endianness, however, direct access to the sample content is not possible, making the subscribing application less performant.

Note: Because the in-memory representation of a FlatData sample is XCDR2 and older versions of *Connext DDS* use encoding version 1 (XCDR), applications using the FlatData language binding will not communicate with older versions of *Connext DDS*. See *Choosing the Right Data Representation*, in the *Data Representation* chapter of the RTI Connext DDS Core Libraries Extensible Types Guide.

23.5.2 Using FlatData Language Binding

The following sections contain more information about using FlatData language binding:

- 23.5.2.1 Selecting FlatData Language Binding below
- 23.5.2.2 Programming with FlatData Language Binding on page 943
- 23.5.2.3 Languages Supported by FlatData Language Binding on page 951
- 23.5.2.4 Interactions with RTI Security Plugins and Compression on page 952
- 23.5.2.5 Notes on Batching on page 952

For examples of FlatData language binding and Zero Copy transfer over shared memory, including example code, see https://community.rti.com/kb/flatdata-and-zerocopy-examples.

23.5.2.1 Selecting FlatData Language Binding

To select FlatData as the language binding of a type, annotate it with @language_binding(FLAT_DATA). (See 3.3.9.9 The @language_binding Annotation on page 120.)

For example, consider a surveillance application in which high-definition (HD) video signal is published and subscribed to. The application publishes a *Topic* of the type **CameraImage**. This is the IDL:

```
enum Format {
   RGB,
   HSV,
   YUV
};

@final
@language_binding(FLAT_DATA)
struct Resolution {
 long height;
 long width;
};
```

```
@final
@language_binding(FLAT_DATA)
struct Pixel {
   octet red;
   octet green;
   octet blue;
};

const long MAX_IMAGE_SIZE = 8294400;

@mutable
@language_binding(FLAT_DATA)
struct CameraImage {
 string<128> source;
 Format format;
 Resolution resolution;
 sequence<Pixel, MAX_IMAGE_SIZE> pixels;
};
```

The language binding annotation supports two values: FLAT_DATA and PLAIN (default). PLAIN refers to the regular in-memory representation, where an IDL struct maps to a C++ class or C struct.

There are some restrictions regarding the kinds of structures, value types, and unions to which the FlatData language binding can be applied.

For final types, the FlatData language binding can be applied only to fixed-size types. A fixed-size type is a type whose wire representation always has the same size. This includes primitive types, arrays of fixed-size types, and structs containing only members of fix-size types. Unions are not fixed-size types.[1]

The FlatData language binding can be applied to any mutable type. This enables support for variable-size types containing bounded sequences, bounded strings, or optional members (unbounded sequences or strings are not supported with FlatData). It also allows using unions.

FlatData cannot be applied to extensible types.

Final types provide the best performance, while mutable types are the most flexible. Typically, the best compromise between flexibility and performance comes from a mutable type whose largest member is either a final type or a sequence of final elements. In the **CameraImage** example, the top-level type is mutable, which allows for type evolution, optional members, and variable-size members (such as the source string member). On the other hand, its member **pixels**, which contains the bulk of the data, is defined as a sequence of the final type **Pixel**, which allows for an efficient manipulation.

[1] These restrictions on final types only apply to the FlatData language binding. Final types with the plain language binding can be variable-size.

23.5.2.2 Programming with FlatData Language Binding

When a type is marked with the FlatData language binding, the in-memory representation for samples of this type is equal to the wire representation (according to XCDR version 2[1]). That is, the data sample is in its serialized format at all times. To facilitate accessing and setting the sample content, *RTI Code Generator* generates helper types that provide the operations to create and access these data samples. These helper types are Samples, Offsets, and Builders.

A FlatData **Sample** is a buffer holding the wire representation of the data. In the code generated for the previous IDL, a sample of the type **CameraImage** contains this buffer. This is the top-level object that can be written or read:

```
typedef rti::flat::Sample<CameraImageOffset> CameraImage;
```

(**Note:** These examples show code for the Modern C++ API. See 23.5.2.3 Languages Supported by FlatData Language Binding on page 951.)

To access this sample, applications use **Offset** types. An Offset represents the type of a member and its location in the buffer. An Offset can be described as an "iterator," a light-weight object that points to the data, but doesn't own it. Copying an Offset copies the "iterator," not the data it points to.

```
class NDDSUSERDllExport CameraImageConstOffset : public rti::flat::MutableOffset {
 public:
   const rti::flat::StringOffset source() const;
   Format format() const;
   Resolution::ConstOffset resolution() const;
   rti::flat::SequenceOffset<Pixel::ConstOffset> pixels() const;
};

class NDDSUSERDllExport CameraImageOffset : public rti::flat::MutableOffset {
 public:
   typedef CameraImageConstOffset ConstOffset;

   // Const accessors
   const rti::flat::StringOffset source() const;
   Format format() const;
   Resolution::ConstOffset resolution() const;
   rti::flat::SequenceOffset<Pixel::ConstOffset> pixels() const;

   // Modifiers
   rti::flat::StringOffset source();
   bool format(Format value);
   Resolution::Offset resolution();
   rti::flat::SequenceOffset<Pixel::Offset> pixels();
};
```

There are two kinds of Offset types:

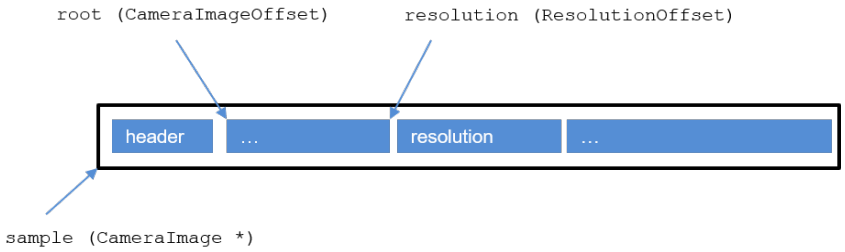
[1] See *Data Representation*, in the RTI Connext DDS Core Libraries Extensible Types Guide for more information on XCDR2.

- Generated, named Offsets, to access a user-defined struct or union type (**CameraImageOffset**, **PixelOffset**). They provide accessors to directly get or set primitive members, and one getter for each non-primitive member to retrieve its corresponding Offset.

  Each named offset has a corresponding read-only version (**CameraImageConstOffset**). This is analogous to a read-only iterator (e.g., **std::vector<T>::const_iterator** and **std::vector<T>::iterator**).
- Offsets to arrays, sequences, strings, and other IDL types. They provide access to their elements. Primitive elements can be accessed directly; non-primitive elements are accessed through Offsets for their types.

For details on all the Offset types and their interface, see the API Reference HTML documentation, under RTI Connext DDS API Reference > Topic Module > FlatData Topic-Types.

The **function CameraImage::root()** provides the Offset to the top-level type (**CameraImageOffset**). If the sample is **const** (for example, in a **LoanedSamples** container), **root()** returns a read-only offset (**CameraImageConstOffset**).



To create variable-size (mutable) data-samples, applications use **Builders**. A Builder type provides the interface to create a mutable sample member by member. Once all the desired members for a sample have been added, the Builder is "finished," returning the built sample, which can be published.

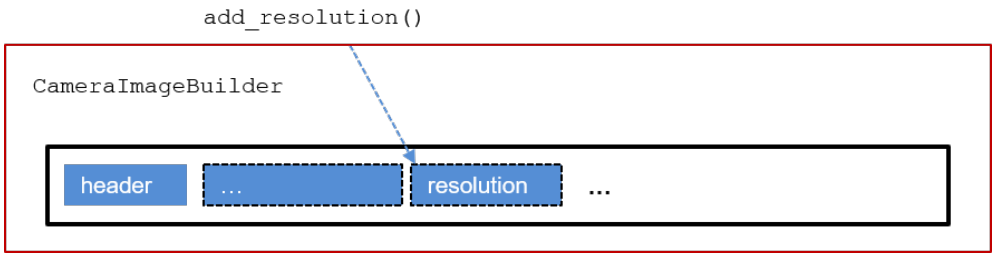
```
class NDDSUSERDllExport CameraImageBuilder : public rti::flat::AggregationBuilder {
 public:
   typedef CameraImageOffset Offset;

   Offset finish();
   CameraImage * finish_sample();

   rti::flat::StringBuilder build_source();
   bool add_format(Format value);
   Resolution::Offset add_resolution();
   rti::flat::FinalSequenceBuilder<Pixel::Offset> build_pixels();
};
```

Builders provide three kinds of functions:

- **add_<member>** functions insert a member of a final type, returning an Offset to it.
- **build_<member>** functions provide another Builder to create a member of a mutable type.

- **finish** and **finish_sample** end the construction of a member or a sample, respectively.

Similarly to Offsets, Builders can correspond to user-defined struct and union types, or other IDL types such as sequences, arrays, and strings. For details on all the Builder types see the API Reference HTML documentation.



The following sections summarize how to use FlatData language binding:

- Creating a FlatData sample below
- Writing a FlatData sample on page 948
- Reading a FlatData sample on page 948
- Working with unmanaged FlatData samples on page 949
- Multi-threading notes on page 950
- Notes on Extensible Types on page 951

Creating a FlatData sample

The following sections assume you have created a *DataWriter* for the type **Pixel** or **CameraImage**, following the usual process.

To write FlatData, first create a FlatData sample. The way to create a sample varies depending on whether the type is final or mutable. In both cases, this section shows how to create *DataWriter*-managed samples. See also Working with unmanaged FlatData samples on page 949.

Creating a FlatData sample for a final type

In this section we will create a sample for the final type **Pixel**. To create a sample for the mutable type **CameraImage**, see *Creating a FlatData sample for a mutable type* after this.

Samples for final FlatData types are created directly with a single call to the *DataWriter* function **get_loan**. The *DataWriter* manages this sample and will return it to a pool at some point after the sample is written.

```
Pixel *pixel_sample = writer.extensions().get_loan();
```

pixel_sample contains the buffer that can be written. To set its values, first locate the position of the top-level type:

```
PixelOffset pixel = pixel_sample->root();
```

The **root()** function returns **PixelOffset**, which points to the position where the data begins. To set the values, use the following setters:

```
pixel.red(10);
pixel.green(20);
pixel.blue(30);
```

Creating a FlatData sample for a mutable type

Samples for mutable types are created using Builders. To obtain a **CameraImageBuilder** to build a **CameraImage** sample, use the function **build_data**:

```
CameraImageBuilder image_builder = rti::flat::build_data(writer);
```

This function loans the memory necessary to create a **CameraImage** sample from the *DataWriter* and provides a **CameraImageBuilder** to populate it. Use the Builder functions to set the sample's members (in any order). Non-key members can be omitted, even when they are not optional.[1] These Builder functions work on a pre-allocated buffer; they do not allocate any additional memory.

First, we add the member **format**. As a primitive member, the function **add_format** directly adds the member and sets its value:

```
image_builder.add_format(Format::RGB);
```

Next, we add the member **resolution**. Its type being final, the function **add_resolution** adds the member and provides the Offset that allows setting its values:

```
ResolutionOffset resolution = image_builder.add_resolution();
resolution.height(100);
resolution.width(200);
```

To build the string member **source**, the function **build_source** returns a **StringBuilder**. We use this builder (in this case it's as simple as calling **set_string**), and then call **finish**. The function **finish** (not to be confused with **finish_sample**) completes the construction of the member and renders **source_builder** invalid.

```
auto source_builder = image_builder.build_source();
source_builder.set_string("CAM-1");
source_builder.finish();
```

Since this builder is so simple, it is possible to simplify the above code:

```
image_builder.build_source().set_string("CAM-1");
```

(The Builder destructor takes care of calling **finish**.)

To create the **pixels** member, we build a sequence of Pixels:

---

[1] See *Optional Members, in the Type System Enhancement* chapter of the RTI Connext DDS Core Libraries Extensible Types Guide.

```
auto pixels_builder = image_builder.build_pixels();
```

There are two ways to populate this member.

Method 1: add and initialize each element:

```
for (int i = 0; i < 20000; i++) {
   PixelOffset pixel = pixels_builder.add_next();
   pixel.red(i % 256);
   pixel.green((i + 1) % 256);
   pixel.blue((i + 2) % 256);
}
pixels_builder.finish();
```

Builders for sequences with elements of a final type provide the function **add_next** to add the elements. When the element type is mutable, the sequence (and array) Builder provides the function **build_next**, which provides a Builder for each element. See more details in the API Reference HTML documentation.

Method 2: cast the elements in the sequence to the equivalent C++ plain type. This method only works for types that meet the conditions required by **rti::flat::plain_cast**, as described in the API Reference HTML documentation. Basically, the in-memory representation must match the XCDR2 serialized representation. **Pixel** meets these conditions.

Method 2 is more efficient. First, we use the Builder function **add_n** to add 20000 elements at once, leaving them uninitialized. Then, after finishing the Builder, we obtain the Offset to the member, cast it, and manipulate the data as a plain C++ type:

```
pixels_builder.add_n(20000);
auto pixels_offset = pixels_builder.finish();

auto plain_pixels = rti::flat::plain_cast(pixels_offset);
for (int i = 0; i < 20000; i++) {
   plain_pixels[i].red(i % 256);
   plain_pixels[i].green((i + 1) % 256);
   plain_pixels[i].blue((i + 2) % 256);
}
```

The function **rti::flat::plain_cast** casts the position in memory that **pixels_offset** points to into a C-style array of **PixelPlainHelper**, a type with the same IDL definition as **Pixel**, but with **@language_binding (PLAIN)**. **plain_cast** can receive an offset to a final struct, or an offset to an array or sequence of final structs or primitive types. See the API Reference HTML documentation for more information.

Finally, call **finish_sample** to obtain the complete sample. After this, the Builder instance is invalid and cannot be further used.

```
CameraImage *image_sample = image_builder.finish_sample();
```

Once the sample has been created, it is still possible to modify its values, as long as these modifications don’t change the size. For example, it is possible to change the value of an existing pixel, but it’s not possible to add a new one:

```
auto pixels_offset = image_sample->root().pixels();
pixels_offset.get_element(100).blue(0);
```

The next section shows how to write the sample.

Writing a FlatData sample

When you write a sample using a regular *DataWriter* (for a type with a plain language binding), the *DataWriter* copies the sample in its internal queue, so when **write()** ends, the application still owns the sample. A *DataWriter* for a FlatData type, however, doesn't copy the sample; it keeps a reference. You yield ownership of the data sample from the moment you call **write()**.

```
writer.write(*image_sample);
```

The *DataWriter* will decide when to return samples created with **get_loan** or **build_data** to a pool, where the sample will be reused.

To write a new sample, don't use **image_sample** again, but obtain a new one with **get_loan** or build a new one with **build_data**.

If the sample cannot be written, to return it to the *DataWriter* pool call:

```
writer.extensions().discard_loan(*image_sample);
```

Or, if the sample has not been completely built yet, discard the Builder:

```
rti::flat::discard_builder(writer, image_builder);
```

Reading a FlatData sample

The method for reading data for a FlatData type is the same regardless of whether the type is final or mutable.

Create a *DataReader* as you normally would; see 8.3.1 Creating DataReaders on page 507.

Read the data samples:

```
dds::sub::LoanedSamples<CameraImage> samples = camera_reader.take();
```

Let's work with the first sample (assuming **samples.length() > 0** and **samples[0].info().valid()**):

```
const CameraImage& image_sample = samples[0].data();
```

Using the **root** Offset and the Offset to the members, the following code prints the sample values. Note that in this example, **image_sample** is **const**, so **camera_image** is a **CameraImageConstOffset**, which only allows reading the buffer, not modifying it.

```
auto camera_image = image_sample->root();

std::cout << "Source: " << camera_image.source().get_string() << std::endl;
std::cout << "Timestamp: " << camera_image.timestamp() << std::endl;
std::cout << "Format: " << camera_image.format() << std::endl;

auto resolution = camera_image.resolution();
```

```
std::cout << "Resolution (height: " << resolution.height()
          << ", width: " << resolution.width() << ")\n";
```

To access the sequence of pixels, the same two methods that allowed building it (element by element or plain cast) are available:

Method 1 (access each element offset):

```
for (auto pixel : camera_image.pixels()) {
   std::cout << "Pixel (" << pixel.red() << ", " << pixel.green()
             << ", " << pixel.blue() << ")\n";
}
```

Method 2 (**plain_cast**):

```
auto pixel_count = camera_image.pixels().element_count();
auto plain_pixels = rti::flat::plain_cast(camera_image.pixels());
for (int i = 0; i < pixel_count; i++) {
    const auto& pixel = plain_pixels[i];
    std::cout << "Pixel (" << pixel.red() << ", " << pixel.green()
              << ", " << pixel.blue() << ")\n";
}
```

Method 2 is more efficient, provided that the type meets the requirements of **plain_cast**. Also, the endianness of the publishing application must be the same as the local endianness.

Note that you can directly print the sample:

```
std::cout << *image_sample << std::endl;
```

Working with unmanaged FlatData samples

The previous sections describe how to create and write *DataWriter*-managed samples (via **get_loan** or **build_data**). While this is the recommended and easiest way, sometimes applications may need to use unmanaged samples. For example, they may need to reuse the same sample after it is written or to obtain the memory from some other source.

Note that a given *DataWriter* cannot write both unmanaged and managed samples. The functions **get_loan** or **build_data** will fail if an unmanaged sample has been written. Conversely, the *DataWriter* will fail to write an unmanaged sample if **get_loan** or **build_data** have been called.

To create a **CameraImage** using memory from an arbitrary buffer, **my_buffer**, with a capacity of **my_buffer_size** bytes, use the following constructor:

```
unsigned char *my_buffer = ...;
unsigned int my_buffer_size = ...;
CameraImageBuilder image_builder(my_buffer, my_buffer_size);
// use image_builder...
CameraImage *image_sample = image_builder.finish_sample();
```

image_builder will fail if it runs out of space. The maximum size of a **CameraImage** can be obtained from its dynamic type:

```
unsigned int max_size =
rti::topic::dynamic_type<CameraImage>::get().cdr_serialized_sample_max_size();
```

After writing **image_sample**, the *DataWriter* takes ownership of it. In order to reuse the sample, the application needs to monitor the **on_sample_removed** callback in the *DataWriter* listener, and correlate the cookie it receives with the sample. The following is a simple *DataWriterListener* implementation that does that:

```
class FlatDataWriterListener
   : public dds::pub::NoOpDataWriterListener<CameraImage> {
public:
   void on_sample_removed(
           dds::pub::DataWriter<CameraImage>& writer,
           const rti::core::Cookie& cookie) override
   {
        // The cookie identifies the sample being removed
        last_removed_sample = cookie.to_pointer<CameraImage>();
}

CameraImage *last_removed_sample = NULL;
};
```

The application will need to wait until **last_removed_sample** is equal to **image_sample**. This indicates that the *DataWriter* no longer needs to hold ownership of **image_sample**.

Another way to create an unmanaged sample is **CameraImage::create_data()** or **Pixel::create_data()** (the result of **CameraImage::create_data()** must be passed to the **CameraImageBuilder** constructor mentioned before). Samples can be copied with the **clone()** function. These samples need to be released with the respective **delete_data()** functions. See the API Reference HTML documentation for more information.

Multi-threading notes

- It's not safe to use the same Offset object in parallel, even for reading. For efficiency, each offset object contains an internal state that may change when accessing a member.

```
void my_thread1(CameraImageOffset& camera_image)
{
    auto format = camera_image.format();
}

void my_thread2(CameraImageOffset& camera_image)
{
    auto resolution = camera_image.resolution();
}

// Unsafe:
auto camera_image = camera_image_sample.root();
std::async(my_thread1, camera_image);
std::async(my_thread2, camera_image);
```

- It is safe to use different Offset objects to read the same member in a sample.

```
// Safe
auto camera_image1 = camera_image_sample.root();
auto camera_image2 = camera_image_sample.root();
std::async(my_thread1, camera_image1);
std::async(my_thread2, camera_image2);
```

- It is not safe to build a sample using a Builder in parallel.

Notes on Extensible Types

There are a few differences in how a plain and a FlatData *DataReader* behave when they receive samples of types that are different but compatible.

Before a *DataReader* and *DataWriter* can communicate, their types are inspected to determine if they are compatible. The same is true when using FlatData; however, even after two types have been deemed compatible, there may be specific data samples that are not.

DataReaders for plain types verify sample compatibility during data deserialization, but *DataReaders* for FlatData types don't deserialize the data, passing FlatData samples directly to the application. For that reason, there may be situations where a plain *DataReader* would lose or reject a data-sample, while a *DataReader* for a FlatData type with the same definition will pass the same sample to the application. Therefore, if you are using FlatData you may need to explicitly check if all the received samples are consistent with your application logic. For more information on the rules that determine the assignability of a sample, see the RTI Connext DDS Core Libraries Extensible Types Guide (see the section "Verifying Sample Consistency: Sample Assignability") or the OMG 'Extensible and Dynamic Topic Types for DDS' specification, version 1.3.

For example, a FlatData *DataReader* won't drop a sample when a sequence (or a string) member exceeds the bounds in the reader's type definition, and the application will be able to read this sequence (or string). This can only happen if **ignore_sequence_bounds** (or **ignore_string_bounds**) in TypeConsistencyEnforcement is set to true; otherwise the *DataWriter*'s type won't match the *DataReader*'s. The **@min** and **@max** annotations are another example. FlatData *DataReaders* will not enforce the **@min**/**@max** range set for a member, and applications will be able to access such samples.

Another difference in behavior involves the reception of samples that don't include some data members. When a regular *DataReader* for a mutable (plain) type receives a data sample that doesn't include one of its non-optional members, it automatically assigns a default value during the data deserialization. A FlatData *DataReader* for a mutable (FlatData) type will not do that. Instead, if the application tries to access that member, the corresponding member getter will return a null Offset. Only if the member is primitive will it return a default value. This means that, for a FlatData *DataReader* in this case, all non-primitive members will be treated as if they were optional.

23.5.2.3 Languages Supported by FlatData Language Binding

The FlatData language binding is supported in the Modern and Traditional C++ APIs:

- **rtiddsgen -language C++11** generates code for the Modern C++ API.
- **rtiddsgen -language C++** generates code for the Traditional C++ API.

The FlatData language binding is basically the same in both APIs, as described in the previous sections, with a few differences:

- Modern C++ may throw exceptions in Sample, Offset, and Builder operations, such as **dds::core::PreconditionNotMetError**; Traditional C++ doesn't throw exceptions and in these cases it would return invalid objects. See the API Reference HTML documentation for each language for details.
- Modern C++ maps integer types to int32_t, uint16_t, etc; Traditional C++ uses DDS_Long, DDS_UnsignedShort, etc. This is consistent with these languages' respective plain language bindings.
- Modern C++ provides an overloaded **operator<<** to print a sample; Traditional C++ uses **FooTypeSupport::print_data**. Both provide a function to transform to a string with format options. This behavior is also consistent with the plain binding.

23.5.2.4 Interactions with *RTI Security Plugins* and Compression

When the FlatData language binding is used in combination with either payload encryption or compression (see 7.5.3 DATA_REPRESENTATION QosPolicy on page 379), there is no reduction in the number of copies used to send or receive the samples. There are unavoidable copies that must be made during the encryption/decryption and/or compression/decompression processes, resulting in the same number of copies that would be made if you were using regular data in combination with these features. This is a known issue that will be addressed in future releases (see "Known Issues" in the RTI Connext DDS Core Libraries Release Notes).

Therefore, using the FlatData language binding in combination with payload encryption and/or compression is not generally useful. However, when using Zero Copy transfer over shared memory, you will also need to use FlatData for variable-sized data types. (See 23.4 Choosing between FlatData Language Binding and Zero Copy Transfer over Shared Memory on page 940.) In this case, you may want to configure the *DataWriter* to use encryption/compression when sending to *DataReaders* running on different hosts, even though you are not saving copies. This configuration allows using Zero Copy for *DataReaders* running on the same host as the *DataWriter*, while encrypting/compressing data that is sent to *DataReaders* on different hosts.

23.5.2.5 Notes on Batching

A FlatData *DataWriter* (a *DataWriter* that sends FlatData samples) cannot batch samples. That is, *Connext DDS* will not let you set up a FlatData *DataWriter* to use batching. Both FlatData and regular *DataReaders*, however, can receive batched samples from a regular *DataWriter* as well as all samples from a FlatData *DataWriter*.

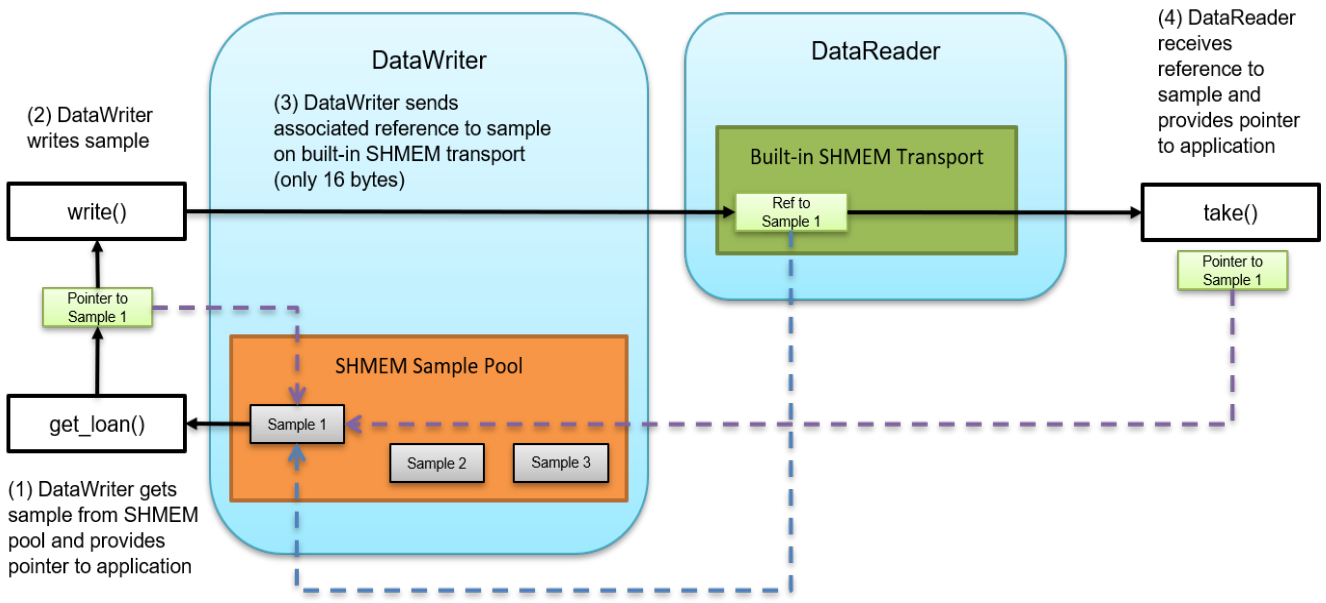
23.6 Zero Copy Transfer Over Shared Memory

For communication within the same node using the built-in shared memory transport, by default *Connext DDS* copies a sample four times (see Figure 23.3: Number of Copies Out-of-the-Box on page 938). FlatData language binding reduces the number of copies to two (see Figure 23.4: Number of Copies Using FlatData Language Binding on page 939): the copy of the sample into the shared memory segment in the publishing application and the copy to reassemble the sample in the subscribing application. Two copies, however, may still be too many depending on the sample size and system requirements.

Zero Copy transfer over shared memory, provided as a separate library called *nddsmetp*, allows reducing the number of copies to zero for communications within the same host. The *nddsmetp* library can be linked with *Connext DDS* C or C++ libraries. This feature accomplishes zero copies by using the shared memory (SHMEM) built-in transport to send 16-byte references to samples within a SHMEM segment owned by the *DataWriter*, instead of using the SHMEM built-in transport to send the serialized sample content by making a copy. See Figure 23.5: Zero Copy Transfer Over Shared Memory below.

With Zero Copy transfer over shared memory, there is no need for the *DataWriter* to serialize a sample, and there is no need for the *DataReader* to deserialize an incoming sample since the sample is accessed directly on the SHMEM segment created by the *DataWriter*.

Figure 23.5: Zero Copy Transfer Over Shared Memory



This feature offers the following benefits:

- Number of copies is reduced from four to zero (see SHMEM in Figure 23.3: Number of Copies Out-of-the-Box on page 938). Instead of transferring the entire sample by making multiple copies, only the location in shared memory is distributed to *DataReaders* (see Figure 23.5: Zero Copy Transfer Over Shared Memory above).

- Because of this reduced data copying, memory consumption and CPU load are also reduced.
- Latency is independent of the size of the sample.
- Fragmentation is not required when using Zero Copy transfer over shared memory because the *DataWriter* exchanges SHMEM references (only 16-bytes) with *DataReaders* and not the full sample.
- Data can still be sent off-board, simplifying application deployment and configuration. When the data is sent off-board, the middleware is still making the same copies described in Figure 23.3: Number of Copies Out-of-the-Box on page 938. To reduce the number of copies for sending off-board, use FlatData language binding in conjunction with Zero Copy transfer over shared memory.

Note: A Zero Copy *DataWriter* is defined as any *DataWriter* with the ability to send a sample reference. You can have a *DataWriter* that does both: sends sample references to Zero Copy *DataReaders*, and sends serialized samples to non-Zero Copy *DataReaders*. In this case, the *DataWriter* is still considered a Zero Copy *DataWriter* in this documentation.

23.6.1 Using Zero Copy Transfer Over Shared Memory

To use Zero Copy transfer over shared memory, perform the following basic steps:

- Identify types that require Zero Copy transfer over shared memory and annotate them with **@transfer_mode(SHMEM_REF)** in the IDL files. (See: 3.3.9.8 The @transfer_mode annotation on page 119.)

  Note: Zero Copy transfer over shared memory requires the FlatData language binding when the type is variable-size.

- Use the *DataWriter*'s **get_loan()** API to get a loaned sample for writing with Zero Copy. (You would use this API to create the sample rather than creating the sample using the TypeSupport. See the example in the following sections and the API Reference HTML documentation for more information on **get_loan()**.)
- Link the publisher and subscriber application with the additional Zero Copy library, *nddsmetp*. (*RTI Code Generator* (*rtiddsgen*) generates examples that link *nddsmetp* for you automatically. If you are using a custom build system, make sure you link with *nddsmetp*.)

RTI Code Generator generates additional TypePlugin code when a type is annotated with **@transfer_mode(SHMEM_REF)** in the IDL files. This code allows a *DataWriter* and a *DataReader* to communicate using a reference to the sample in shared memory (see Figure 23.5: Zero Copy Transfer Over Shared Memory on the previous page). In addition to sending a sample reference, the *DataWriter* can also send the serialized sample to a *DataReader* that doesn't support Zero Copy transfer over shared memory.

The following sections contain more information about using Zero Copy transfer over shared memory:

- 23.6.1.1 Sending data with Zero Copy transfer over shared memory below
- 23.6.1.2 Receiving data with Zero Copy transfer over shared memory on page 957
- 23.6.1.3 Checking data consistency with Zero Copy transfer over shared memory on page 957
- 23.6.1.4 Languages Supported by Zero Copy Transfer Over Shared Memory on page 958
- 23.6.1.5 Interactions with RTI Security Plugins and Compression on page 958
- 23.6.1.6 Notes on Batching on page 959

For examples of FlatData language binding and Zero Copy transfer over shared memory, including example code, see https://community.rti.com/kb/flatdata-and-zerocopy-examples.

23.6.1.1 Sending data with Zero Copy transfer over shared memory

The following example shows how to use Zero Copy transfer mode for a surveillance application in which high-definition (HD) video signal is published and subscribed to. The application publishes a *Topic* of the type **CameraImage**. This is the IDL:

```
enum Format {
    RGB,
    HSV,
    YUV
};

struct Resolution {
  long height;
  long width;
};

const long IMAGE_SIZE = 8294400 * 3;

@transfer_mode(SHMEM_REF)
struct CameraImage {
  long long timestamp;
  Format format;
  Resolution resolution;
  octet data[IMAGE_SIZE];
};
```

The **CameraImage** type is annotated with @transfer_mode(SHMEM_REF) to allow Zero Copy communication. Note that it is sufficient to annotate only top-level types with this annotation.

Any final or appendable type annotated with @transfer_mode(SHMEM_REF) should be a fixed-size type. This means the type can include primitive members, arrays of fixed-size types, and structs containing only members of fixed-size types. To use a variable-sized type, the type should be annotated with @language_binding(FLAT_DATA) and @mutable in combination with @transfer_mode(SHMEM_REF).

With Zero Copy transfer mode, an application writes samples coming from a shared memory sample pool created by a Zero Copy *DataWriter*. Therefore, create a *DataWriter* before creating a sample. The steps for creating a Zero Copy *DataWriter* are the same as for a regular *DataWriter*.

```
const int MY_DOMAIN_ID = 0;
dds::domain::DomainParticipant participant(MY_DOMAIN_ID);
dds::topic::Topic<CameraImage> camera_topic(participant, "Camera");
dds::pub::DataWriter<CameraImage> camera_writer(
       rti::pub::implicit_publisher(participant),
       camera_topic);
```

To get a sample from shared memory, use the *DataWriter*'s **get_loan()** API:

```
CameraImage *camera_image = camera_writer->get_loan();
```

The sample returned by **get_loan()** is uninitialized by default (the members are not set to default values). If you would like to allow the *DataWriter* to return an initialized sample from **get_loan()**, set **initialize_writer_loaned_sample** to true in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400.

Populate the fields of the sample as you would a regular sample:

```
camera_image->timestamp(12345678);
camera_image->format(Format::HSV);
camera_image->resolution().height(1024);
camera_image->resolution().width(2048);
// populate the image data
```

The example above, showing the population of the fields, assumes regular PLAIN language binding. Zero Copy transfer over shared memory also works with types using FLAT_DATA language binding. In this case, you must use the FlatData API described in 23.5 FlatData Language Binding on page 940 to populate the sample.

The number of samples in the shared memory sample pool created by the *DataWriter* can be configured using the **writer_loaned_sample_allocation** settings in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400.

Initially all the samples are in a free state. When you call the *DataWriter*'s **get_loan()**, the *DataWriter* provides a sample from this pool, and its state changes to allocated. The samples are provided using an LRU (Least Recently Used) policy.

Write the sample with the regular write operation:

```
camera_writer.write(*camera_image);
```

When a sample is written, its state transitions from allocated to enqueued, and the *DataWriter* takes responsibility for returning the sample back to the shared memory pool. The sample remains in the enqueued state until it is removed from the *DataWriter* queue. When this happens, the sample is put back into the shared memory sample pool, and its state transitions from enqueued to removed. At this time, a new call to the *DataWriter*'s **get_loan()** may return the same sample.

You should not try to reuse a sample that has been written with a *DataWriter* to publish a new value. Instead, get a new sample using the *DataWriter*'s **get_loan()** and populate its content with the new value.

A sample that has not been written can be returned to the shared memory pool by using the *DataWriter*'s **discard_loan()**:

```
camera_writer->discard_loan(camera_image)
```

The shared memory sample pool is destroyed when the *DataWriter* is deleted.

See the API Reference HTML documentation for more information on **get_loan()**.

23.6.1.2 Receiving data with Zero Copy transfer over shared memory

Create a *DataReader* as you normally would; see 8.3.1 Creating DataReaders on page 507.

Read the data samples:

```
dds::sub::LoanedSamples<CameraImage> samples = camera_reader.take();
```

Let's work with the first sample (assuming **samples.length() > 0** and **samples[0].info().valid()**):

```
const CameraImage& camera_image_sample = samples[0].data();
// Process the sample
process_data(camera_image_sample);
if (!camera_reader->is_data_consistent(camera_image_sample)) {
       // Sample was overwritten, ignore this sample
       rollback(camera_image_sample);
}
```

For more information on the *DataReader*'s **is_data_consistent()** API, see 23.6.1.3 Checking data consistency with Zero Copy transfer over shared memory below.

23.6.1.3 Checking data consistency with Zero Copy transfer over shared memory

Zero Copy transfer over shared memory makes no copies. This means the sample being processed in the subscribing application actually resides in the *DataWriter's* send queue. The *DataWriter* in the publishing application can decide to reuse this memory to send a different sample before or while the original sample is being processed by a *DataReader*, which can lead to data consistency problems. There are several ways to prevent and detect these inconsistencies.

A reliable *DataWriter* will not attempt to reuse sample memory if the sample has not been acknowledged. With reliable communication and application-level acknowledgments (see 7.3.12 Application Acknowledgment on page 316), the subscribing application can prevent the writer from reusing the sample by delaying the acknowledgment until after the sample has been processed.

Note: Application Acknowledgment is not currently available with *RTI Connext DDS Micro*.

Applications can also use other, custom, application-level mechanisms to guarantee data consistency between the publisher and the subscriber.

Without an application-level synchronization mechansim, when the application's *DataWriter* and *DataReader* are not synchronized, the subscribing application can use the *DataReader's* **is_data_consistent()** API to detect data inconsistencies, as long as the type is not annotated with @language_binding (FLAT_DATA). If the type is FlatData, reading a data sample while the *DataWriter* is reusing it is undefined behavior.

If the type is not FlatData, for **is_data_consistent()** to work, configure the *DataWriter's* 7.5.25 TRANSFER_MODE QosPolicy on page 454 setting **writer_qos.transfer_mode.shmem_ref_settings.enable_data_consistency_check** to true (the default). A *DataWriter* with this setting sends a special sequence number associated with each sample as an inline QoS (metadata), which can be used to check the sample's validity at the *DataReader* with the *DataReader's* **is_data_consistent()** API. Simply, the API checks if the shared memory space has been reused for that sample. If it has, the data is inconsistent.

If data consistency checks are disabled, **is_data_consistent()** will return a PRECONDITION_NOT_MET error.

The **is_data_consistent()** API helps detect a data inconsistency, not prevent it. Therefore, the recommended way of using the API is to follow this general scheme:

```
process(data);
if (! reader->is_data_consistent(data, sample_info))
    discard(processed_data);
```

When **is_data_consistent()** returns true *after* the sample has been processed, subscribers can be sure processed data was not inconsistent and can be trusted (e.g., by committing it to a database). When **is_data_consistent()** returns false, processed data should be discarded. If **is_data_consistent()** is only called *before* processing data, it could return true at that point but the sample could be modified while being processed, leading to a race condition. Therefore, if you want to call **is_data_consistent()** *before* processing the data (for instance, because the processing is expensive), that is fine, but be sure to also call it *after* processing the data.

If the publisher sends data in best-effort mode and the expected send frequency is known in advance, the *DataWriter's* resource limits can be configured with an appropriate **writer_loaned_sample_allocation** max count (see the API Reference HTML documentation) to minimize the chances of sample reuse and of **is_data_consistent()** returning false.

23.6.1.4 Languages Supported by Zero Copy Transfer Over Shared Memory

Zero Copy transfer over shared memory is supported in the C, Modern C++, and Traditional C++ APIs.

23.6.1.5 Interactions with *RTI Security Plugins* and Compression

When you use security in combination with Zero Copy transfer over shared memory, the samples in the shared memory segment are not serialized and are therefore not protected, regardless of the selected protection kind. With Zero Copy, *Security Plugins* only protects the 16-byte references sent to *DataReaders*.

You can use any protection kind to protect the reference (see "Securing DDS Messages on the Wire" and "Understanding ProtectionKinds" in the *RTI Security Plugins User's Manual*).

If a *DataWriter* is using Zero Copy transfer over shared memory, the samples sent to *DataReaders* over non-shared memory transports will be serialized and protected according to the configured protection kinds (see "Related Governance Rules" in the *RTI Security Plugins User's Manual*).

Likewise, with compression (see 7.5.3 DATA_REPRESENTATION QosPolicy on page 379), the samples in the shared memory segment are not serialized and are therefore not compressed, regardless of the compression setting. However, the shared memory reference (see 23.6 Zero Copy Transfer Over Shared Memory on page 953) will be compressed if the **writer_compression_threshold** is set to a value less than or equal to 16 bytes. To avoid this compression when using Zero Copy, it is recommended to set the **writer_compression_threshold** to a value greater than 16.

If a *DataWriter* is using Zero Copy transfer over shared memory, the samples sent to *DataReaders* over non-shared memory transports will be serialized and compressed according to the compression settings.

23.6.1.6 Notes on Batching

A Zero Copy *DataWriter* (a DataWriter that sends sample references) cannot batch samples. That is, *Connext DDS* will not let you set up a Zero Copy *DataWriter* to use batching. A Zero Copy *DataReader*, however, can receive batched samples from a regular *DataWriter* as well as all samples from a Zero Copy *DataWriter*.

23.6.2 Other Considerations

23.6.2.1 Type Matching for Zero Copy Transfer Over Shared Memory

The default value for TypeConsistencyEnforcementQosPolicy **kind** is AUTO_TYPE_COERCION.

For a regular *DataReader*, AUTO_TYPE_COERCION is translated to ALLOW_TYPE_COERCION. A Zero Copy *DataReader*, however, should use a topic type that is identical to its matched Zero Copy *DataWriter*'s topic type, because it accesses the sample directly in the *DataWriter* queue. Therefore, AUTO_TYPE_COERCION for a Zero Copy *DataReader* is translated to DISALLOW_TYPE_COERCION. The creation of a Zero Copy *DataReader* with ALLOW_TYPE_COERCION will return an error.

See 8.6.6 TYPE_CONSISTENCY_ENFORCEMENT QosPolicy on page 589.

23.6.2.2 Resource Limits Related to Zero Copy Transfer Over Shared Memory

There are resource limits on the *DataWriter*, *DataReader*, and *DomainParticipant* that configure different aspects of Zero Copy transfer over shared memory.

DataWriter Resource Limits

The **writer_loaned_sample_allocation** setting configures the initial and maximum number of loaned samples managed by the *DataWriter*. It also configures the growth policy.

By default this setting is derived from the DDS_ResourceLimitsQosPolicy: the initial and maximum counts are equal to **initial_samples** + 1 and **max_samples** + 1. The incremental_count defaults to initial_count if the initial_count is not the same as max_count. If these are the same, then **incremental_count** defaults to 0.

If you want to extend the time to reuse a sample, use a large sample pool by increasing the initial_count of the **writer_loaned_sample_allocation**.

See 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400.

DataReader Resource Limits

The **shmem_ref_transfer_mode_attached_segment_allocation** setting configures the initial and maximum shared memory segments to which a *DataReader* can attach.

By default this setting is derived from other fields in the DDS_DataReaderResourceLimitsQosPolicy: the initial and maximum counts of shared memory segments are equal to **initial_remote_writers** and **max_remote_writers**. The incremental_count defaults to -1 (doubling of resources) if the initial_count is not the same as max_count. If these are the same, then incremental_count defaults to 0.

The **max_count** controls the maximum number of shared memory segments that a *DataReader* can attach at a time. Once this limit is hit, if there is a need to attach to a new segment, the *DataReader* will try to detach from a segment that doesn't contain any loaned samples and attach to the new segment.

If there are samples loaned in all the attached segments, then the new segment will not be attached and this will result in losing the sample.

See 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571.

DomainParticipant Resource Limits

The **shmem_ref_transfer_mode_max_segments** setting sets the maximum number of shared memory segments that can be created by all *DataWriters* belonging to the participant. The default value of this setting is 500. The maximum value of this setting will be limited by the operating system setting that controls the system wide maximum number of shared memory segments.

See 9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649.

23.7 Reducing Bandwidth Usage

Another important consideration when sending large samples (besides 23.1 Reducing Latency on page 935) is bandwidth usage. *Connext DDS* allows you to compress samples using different builtin

algorithms described in 7.5.3 DATA_REPRESENTATION QosPolicy on page 379.

Chapter 24 Topic Queries

TopicQueries allow a *DataReader* to query the sample cache of its matching *DataWriters*. You can create a TopicQuery with the *DataReader's* **create_topic_query()** API. When a *DataReader* creates a TopicQuery, DDS will propagate TopicQueries to other *DomainParticipants* and their *DataWriters*. When a *DataWriter* matching with the *DataReader* that created the TopicQuery receives it, it will send the cached samples that pass the TopicQuery's filter.

To configure how to dispatch a TopicQuery, use the *DataWriter's* 7.5.24 TOPIC_QUERY_DISPATCH_QosPolicy (DDS Extension) on page 453. By default, a *DataWriter* ignores TopicQueries unless they are explicitly enabled using this policy.

The delivery of TopicQuery samples occurs in a separate RTPS channel. This allows *DataReaders* to receive TopicQuery samples and live samples in parallel. This is a key difference with respect to the 7.5.9 DURABILITY QosPolicy on page 410.

Late-joining *DataWriters* will also discover existing TopicQueries. To delete a TopicQuery you must use the *DataReader's* **delete_topic_query()**.

After deleting a TopicQuery, new *DataWriters* will not discover it and existing *DataWriters* currently publishing cached samples may stop before delivering all of them.

By default, a TopicQuery queries the samples that were in the *DataWriter's* queue at the time the *DataWriter* received the TopicQuery. However, a TopicQuery can be created in "continuous" mode; in this case, a *DataWriter* will continue delivering samples that pass a continuous TopicQuery filter until the *DataReader* application explicitly deletes it.

The samples received in response to a TopicQuery are stored in the associated *DataReader's* cache. Any of the read/take operations can retrieve TopicQuery samples. The field **DDS_SampleInfo::topic_query_guid** associates each sample with its TopicQuery. If the read sample is not in response to a TopicQuery, this field will be DDS_GUID_UNKNOWN.

You can choose to read or take only TopicQuery samples, only live samples, or both. To support this, ReadConditions and QueryConditions provide the *DataReader's* **create_querycondition_w_params()** and **create_readcondition_w_params()** APIs.

Each TopicQuery is identified by a GUID that can be accessed using the TopicQuery's **get_guid()** method.

24.1 Reading TopicQuery Samples

Data samples that are received by a *DataReader* in response to a TopicQuery can be identified with two pieces of information from the corresponding DDS_SampleInfo to the sample. First, if the **DDS_SampleInfo::topic_query_guid** is not equal to DDS_GUID_UNKNOWN, then the sample is in response to the TopicQuery with that GUID. Second, if the sample is in response to a TopicQuery and the DDS_SampleInfo::flag DDS_INTERMEDIATE_TOPIC_QUERY_SAMPLE flag is set, then this is not the last sample in response to the TopicQuery for a *DataWriter* identified by **DDS_SampleInfo::original_publication_virtual_guid**. If that flag is not set, then there will be no more samples corresponding to that TopicQuery coming from the *DataWriter*.

24.2 Debugging Topic Queries

There are a number of ways in which to gain more insight into what is happening in an application that is creating Topic Queries.

24.2.1 The Built-in ServiceRequest DataReader

TopicQueries are communicated to publishing applications through a built-in ServiceRequest channel. The ServiceRequest channel is designed to be generic so that it can be used for many different purposes, one of which is TopicQueries.

When a *DataReader* creates a TopicQuery, a ServiceRequest message is sent containing the TopicQuery information. Just as there are built-in *DataReaders* for ParticipantBuiltinTopicData, SubscriptionBuiltinTopicData, and PublicationBuiltinTopicData, there is a fourth built-in *DataReader* for ServiceRequests. This built-in DataReader can be retrieved using the built-in Subscriber and its **lookup_datareader()**. The topic name is DDS_SERVICE_REQUEST_TOPIC_NAME. Installing a listener with the DataReaderListener's **on_data_available callback()** implemented will allow a publishing application to be notified whenever a TopicQuery has been received from a subscribing application.

The **service_id** of a ServiceRequest corresponding to a TopicQuery will be DDS_TOPIC_QUERY_SERVICE_REQUEST_ID and the **instance_id** will be equal to the GUID of the TopicQuery.

The **request_body** is a sequence of bytes containing more information about the TopicQuery. This information can be retrieved using the **DDS_TopicQueryHelper_topic_query_data_from_service_request()** function. The resulting TopicQueryData contains the TopicQuerySelection that the TopicQuery was created with, the GUID of the original *DataReader* that created the TopicQuery, and the topic name of that *DataReader*.

Note: When TopicQueries are propagated through one or more instances of *Routing Service*, the last *DataReader* that issued the TopicQuery will be a Routing Service DataReader. The **DDS_Top-**

icQueryData::original_related_reader_guid, however, will be that of the first *DataReader* to have created the TopicQuery.

24.2.2 The on_service_request_accepted() DataWriter Listener Callback

It is possible that a ServiceRequest for a TopicQuery is received but is not immediately dispatched to a *DataWriter*. This can happen, for example, if a *DataWriter* was not matching with a *DataReader* at the time that the TopicQuery was received by the publishing application. The DDS_DataWriterListener's **on_service_request_accepted()** callback notifies a *DataWriter* when a ServiceRequest has been dispatched to that *DataWriter*. The DDS_ServiceRequestAcceptedStatus provides information about how many ServiceRequests have been accepted by the *DataWriter* since the last time that the status was read. The status also includes the **DDS_ServiceRequestAcceptedStatus::last_request_handle**, which is the InstanceHandle of the last ServiceRequest that was accepted. This instance handle can be used to read samples per instance from the built-in ServiceRequest *DataReader* and correlate which ServiceRequests have been dispatched to which *DataWriters*.

24.3 System Resource Considerations

24.3.1 Publishing Application

On the publishing side, the resource allocation associated with TopicQueries can be controlled using **remote_topic_query_allocation** (in the9.5.4 DOMAIN_PARTICIPANT_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 649 at the *DomainParticipant* level.

At the *DataWriter* level, you can control how many TopicQueries can be served in parallel by the *DataWriter* by setting the resource limit **max_active_topic_queries** in the 7.5.6 DATA_WRITER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 400).

24.3.2 Subscribing Application

On the *DataReader* side, each TopicQuery will get its own resources. These resources will not interfere with the resource limits associated with live data samples or other TopicQueries. For example, if **max_samples** (see 7.5.22 RESOURCE_LIMITS QosPolicy on page 449) is set to 10 and the *DataReader* creates one TopicQuery, then the *DataReader* will be able to store 10 samples for that TopicQuery and 10 samples for live data.

The maximum number of active TopicQueries that can be associated with a *DataReader* is configured using the resource limit **max_topic_queries** (see 8.6.2 DATA_READER_RESOURCE_LIMITS QosPolicy (DDS Extension) on page 571).

Chapter 25 Troubleshooting

This chapter contains tips on troubleshooting *Connext DDS* applications. For an up-to-date list of frequently asked questions, see the Knowledge Base on the RTI Community Portal: https://-community.rti.com/kb. There you can find example code, general information on *Connext DDS*, performance information, troubleshooting tips, and technical details.

25.1 What Version am I Running?

There are three ways to obtain version information:

- By looking at the revision files, as described in 25.1.1 Finding Version Information in Revision Files below.
- By using Visual Studio or the command line, as described in 25.1.2 Finding Version Information on Windows or Linux Systems on the next page.
- Programmatically at run time, as described in 25.1.3 Finding Version Information Programmatically on the next page.

25.1.1 Finding Version Information in Revision Files

In the top-level directory of your *Connext DDS* installation (**${NDDSHOME}**), you will find text files that include revision information. The files are named **rev_<*product*>_rtidds.<*version*>**. For example, you might see files called **rev_host_rtidds.6.x.y** and **rev_persistence_rtidds.6.x.y** (where **x** and **y** stand for the version numbers of the current release). Each file contains more details, such as a patch level and if the product is license managed.

For example:

```
Host Build 6.x.y rev 04 (0x04050200)
```

The revision files for *Connext DDS* target libraries are in the same directory as the libraries (**${NDDSHOME}/lib/<*architecture*>**).

25.1.2 Finding Version Information on Windows or Linux Systems

Another way to find the version is with these commands:

- On Windows platforms, run the DUMPBIN utility that comes with Visual Studio®. (You could also use any other COFF dumper application.) For example:

  ```
  DUMPBIN/HEADERS nddscore.dll
  ```

  You will find the version number encoded in the 'image version' line in the ' OPTIONAL HEADER VALUES ' section:

  ```
  OPTIONAL HEADER VALUES
  <snip>
  50200.00 image version
  <snip>
  ```

  The format is <major_version><minor_version><terciary_version>.<patch_version>. For example, version 5.2.6.3 would appear as image version 50206.03.
- On Linux platforms, run the command **strings** on the library in question and filter for 'BUILD'. For example:

  ```
  strings libnddsc.so | grep BUILD
  ```

  You will see a string similar to

  ```
  NDDSCORE_VERSION_5.2.6.0_BUILD_2017-01-27T15:43:23-08:00_RTI_RELEASE
  ```

25.1.3 Finding Version Information Programmatically

The methods in the NDDSConfigVersion class can be used to retrieve version information for the *Connext DDS* product, the core library, and the C, C++ or Java libraries.

The version information includes four fields:

- A major version number
- A minor version number
- A release number
- A build number

Table 25.1 NDDSConfigVersion Operations lists the available operations (they will vary somewhat depending on the programming language you are using; consult the API Reference HTML documentation for more information).

Table 25.1 NDDSConfigVersion Operations

Purpose	Operation	Description
To retrieve version information in a structured format	get_product_version	Gets version information for the *Connext DDS* product.
	get_core_version	Gets version information for the *Connext DDS* core library.
	get_c_api_version	Gets version information for the *Connext DDS* C library.
	get_cpp_api_version	Gets version information for the *Connext DDS* C++ library.
To retrieve version information in string format	to_string	Converts the version information for each library into a string. The strings for each library are put in a single hyphen-delimited list.

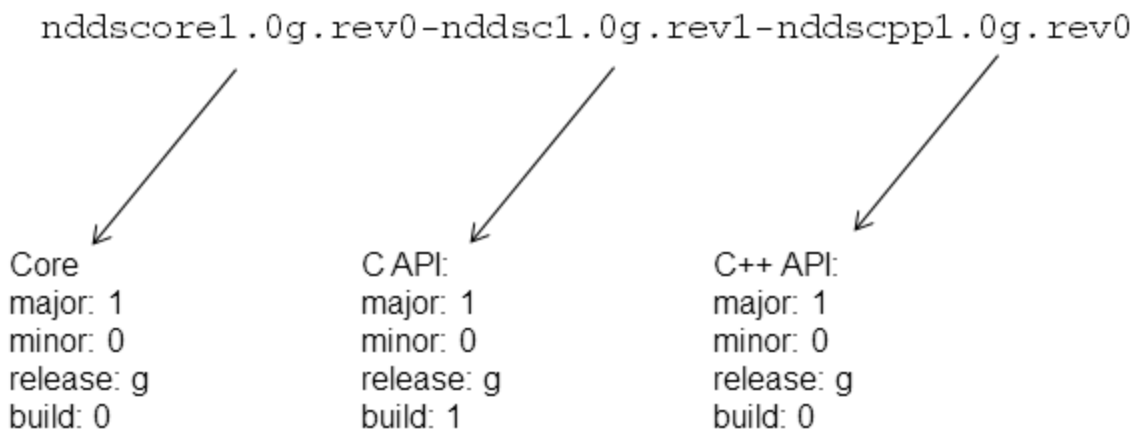
The **get_product_version()** operation returns a reference to a structure of type DDS_ProductVersion_t:

```
struct NDDS_Config_ProductVersion_t {
       DDS_Char  major;
       DDS_Char  minor;
       DDS_Char  release;
       DDS_Char  revision;
};
```

The other **get_*_version()** operations return a reference to a structure of type NDDS_Config_LibraryVersion_t:

```
struct NDDS_Config_LibraryVersion_t {
       DDS_Long  major;
       DDS_Long  minor;
       char release;
       DDS_Long  build;
};
```

The **to_string()** operation returns version information for the *Connext DDS* core, followed by the C and C++ API libraries, separated by hyphens. For example:



25.2 Controlling Messages from Connext DDS

Connext DDS's builtin logging system provides several types of messages to help you debug your system and alert you to errors during run time. You can control how much information is reported and where it is logged. By default, the builtin logging system writes to the standard output, but you can configure it to use a logging file or an output device such as a custom logging device or the Distributed Logger. (See Part 10: RTI Distributed Logger on page 1219.) See also Table 25.4 NDDSConfigLogger Operations and 25.2.2 Configuring Logging via XML on page 976 for information on configuring the builtin logging system.

How much information is logged is known as the *verbosity* setting. Table 25.2 Message Logging Verbosity Levels describes the increasing verbosity levels. Note that the verbosities are cumulative: logging at a high verbosity means also logging all lower verbosity messages. If you change nothing, the default verbosity will be set to NDDS_CONFIG_LOG_VERBOSITY_ERROR.

> Logging at high verbosities can be detrimental to your application's performance. You should generally not set the verbosity above NDDS_CONFIG_LOG_VERBOSITY_WARNING, unless you are debugging a specific problem.

Table 25.2 Message Logging Verbosity Levels

Verbosity (NDDS_CONFIG_LOG_VERBOSITY_*)	Description	Log level values corresponding to this verbosity (NDDS_CONFIG_LOG_LEVEL_*)
SILENT	No messages will be logged. (lowest verbosity)	-

Table 25.2 Message Logging Verbosity Levels

Verbosity (NDDS_CONFIG_LOG_VERBOSITY_*)	Description	Log level values corresponding to this verbosity (NDDS_CONFIG_LOG_LEVEL_*)
ERROR (default level for all categories)	Log only high-priority error messages. An error indicates something is wrong with how *Connext DDS* is functioning. The most common cause of this type of error is an incorrect configuration.	ERROR, FATAL_ERROR
WARNING	Additionally log warning messages. A warning indicates that *Connext DDS* is taking an action that may or may not be what you intended. Some configuration information is also logged at this verbosity to aid in debugging.	WARNING, ERROR, FATAL_ERROR
STATUS_LOCAL	Additionally log verbose information about the lifecycles of local *Connext DDS* objects.	STATUS_LOCAL, WARNING, ERROR, FATAL_ERROR
STATUS_REMOTE	Additionally log verbose information about the lifecycles of remote *Connext DDS* objects.	STATUS_REMOTE, STATUS_LOCAL, WARNING, ERROR, FATAL_ERROR
STATUS_ALL	Additionally log verbose information about periodic activities and *Connext DDS* threads. (highest verbosity)	DEBUG, STATUS_REMOTE, STATUS_LOCAL, WARNING, ERROR, FATAL_ERROR

You will typically change the verbosity of all of *Connext DDS* at once. However, in the event that such a strategy produces too much output, you can further discriminate among the messages you would like to see. The types of messages logged by *Connext DDS* fall into the categories listed in Table 25.3 Message Logging Categories; each category can be set to a different verbosity level.

Table 25.3 Message Logging Categories

Category (NDDS_CONFIG_LOG_CATEGORY_*)	Description
PLATFORM	Messages about the underlying platform (hardware and OS).
COMMUNICATION	Messages about data serialization and deserialization and network traffic.
DATABASE	Messages about the internal database of *Connext DDS* objects.
ENTITIES	Messages about local and remote entities and the discovery process.
API	Messages about *Connext DDS*'s API layer, such as method argument validation and what QoS is being used (for details on QoS information, see 19.3.3.5 Viewing Resolved QoS Values on page 863).
ALL	Messages about all of the categories (default value)

The methods in the **NDDSConfigLogger** class can be used to change verbosity settings, as well as the destination and format of the logged messages. Table 25.4 NDDSConfigLogger Operations lists the available operations; consult the API Reference HTML documentation for more information.

Table 25.4 NDDSConfigLogger Operations

Purpose	Operation	Description
Change Verbosity for all Categories	get_verbosity	Gets the current verbosity. If per-category verbosities are used, returns the highest verbosity of any category.
	set_verbosity	Sets the verbosity of all categories.
Change Verbosity for a Specific Category	get_verbosity_by_category	Gets/Sets the verbosity for a specific category.
	set_verbosity_by_category	
Change Destination of Logged Messages	get_output_file	Returns the file to which messages are being logged, or NULL for the default destination (standard output on most platforms).
	set_output_file	Redirects future logged messages to a set of files. For better performance when log messages are generated frequently, the log messages are not flushed into a file immediately after they are generated. In other words, while writing a log message, *Connext DDS* only calls the function fwrite(); it does not call the function fflush(). If your application requires a different flushing behavior, you may configure a custom logging device (see 25.2.3 Customizing the Handling of Generated Log Messages on page 977).
	get_output_device	Returns the logging device installed with the logger.
	set_output_device	Registers a specified logging device with the logger. See 25.2.3 Customizing the Handling of Generated Log Messages on page 977
Change Message Format	get_print_format	Gets/Sets the current message format for the log level NDDS_CONFIG_LOG_LEVEL_ERROR. See 25.2.1 Format of Logged Messages on the next page. Use **get_print_format_by_log_level** and **set_print_format_by_log_level** to retrieve/set the format for other log levels.
	set_print_format	
	get_print_format_by_log_level	Gets/Sets the current message format, by log level, that *Connext DDS* is using to log diagnostic information.
	set_print_format_by_log_level	

25.2.1 Format of Logged Messages

You can control the amount of information in each message with the **set_print_format()** or **set_print_format_by_log_level()** operation (see Table 25.4 NDDSConfigLogger Operations). The format options are listed in Table 25.5 Message Formats.

Table 25.5 Message Formats

Message Format (NDDS_CONFIG_LOG_PRINT_FORMAT_*)	Description
DEFAULT	(default) Message, method name, and activity context (what was happening when the event occurred).
TIMESTAMPED	Message, method name, activity context, and timestamp.
VERBOSE	Message with all available context information (includes thread identifier, activity context).
VERBOSE_TIMESTAMPED	Message with all available context information and timestamp.
DEBUG	Information (including activity context and backtrace information) for internal debugging by RTI personnel.
MINIMAL	Message number, method name.
MAXIMAL	All available fields (including backtrace information).

See also 25.2.1.3 Activity Context on the next page and 25.5 Logging a Backtrace for Failures on page 980.

By default, NDDS_CONFIG_LOG_PRINT_FORMAT_DEFAULT is assigned to all log levels except FATAL_ERROR. By default, FATAL_ERROR is assigned to NDDS_CONFIG_LOG_PRINT_FORMAT_DEBUG, which prints the backtrace information. See Table 25.2 Message Logging Verbosity Levels.

You could use a less verbose **print_format**, such as NDDS_CONFIG_LOG_PRINT_FORMAT_MINIMAL, for warnings, as follows:

```
NDDS_Config_Logger *logger = NDDS_Config_Logger_get_instance();
NDDS_Config_Logger_set_print_format_by_log_level(
    logger,
    NDDS_CONFIG_LOG_PRINT_FORMAT_MINIMAL,
    NDDS_CONFIG_LOG_LEVEL_WARNING));
```

You could use a more verbose **print_format**, such as NDDS_CONFIG_LOG_PRINT_FORMAT_DEBUG (which contains the backtrace) when you are troubleshooting errors, as follows:

```
NDDS_Config_Logger *logger = NDDS_Config_Logger_get_instance();
NDDS_Config_Logger_set_print_format_by_log_level(
    logger,
    NDDS_CONFIG_LOG_PRINT_FORMAT_DEBUG,
    NDDS_CONFIG_LOG_LEVEL_ERROR));
```

This way, you will reduce the amount of logging on warnings, and errors will contain more information. This configuration is key to understanding and solving issues when needed.

Of course, you are not likely to recognize all of the method names; many of the operations that perform logging are deep within the implementation of *Connext DDS*. However, in case of errors, logging will typically take place at several points within the call stack; the output thus implies the stack trace at the time the error occurred. You may only recognize the name of the operation that was the last to log its message (i.e., the function that called all the others); however, the entire stack trace is extremely useful to RTI support personnel in the event that you require assistance.

You may notice that many of the logged messages begin with an exclamation point character. This convention indicates an error and is intended to be reminiscent of the negation operator in many programming languages. For example, the message "!create socket" means "cannot create socket."

25.2.1.1 Timestamps

Reported times are in seconds from a system-dependent starting time; these are equivalent to the output format from *Connext DDS*. The timestamp is in the form YYYY-MM-DD HH:MM::SS.<microseconds>, where SS is the number of seconds and <microseconds> is a fraction of that second expressed in microseconds. Enabling timestamps will result in some additional overhead for clock access for every message that is logged.

Logging of timestamps is not enabled by default. To enable it, use NDDS_Config_Logger method **set_print_format()**.

25.2.1.2 Thread identification

Thread identification strings uniquely identify active threads when a message is output to the console. A thread may be a user (application) thread or one of several types of internal threads. See Chapter 21 Connext DDS Threading Model on page 900.

Logging of thread IDs is not enabled by default. To enable it, use NDDS_Config_Logger method **set_print_format()**. It adds the thread name to the log message, so you know which thread is responsible for the message. See 21.9 Identifying Threads Used by Connext DDS on page 908.

25.2.1.3 Activity Context

Many middleware APIs now store information in thread-specific storage about the activity context operation.

Activity Context provides more context about a logging message. It is a group of *resources* and *activities* associated with an action, such as the creation of an entity:

- A *resource* is an abstraction of an entity. It can contain attributes such as *Topic* or Domain ID.
- An *activity* is a general task that a resource is doing, such as "Getting QoS."

The activity context is one of the **NDDS_Config_LogPrintFormat** DDS logging infrastructure formats. If a format that prints activity context is selected (see Table 25.5 Message Formats), then every time *Connext DDS* logs a message, it will contain the contextual information.

For example, in the creation of a *DataWriter*, the activity context will provide information about:

- Resource: the *Publisher* creating the *DataWriter*. The attributes of the publisher will be GUID, *Entity* kind, name, and Domain ID.
- Activity: entity creation. It will have two parameters, the *Entity* kind and the *Topic*—in the example below, "Writer" and "TestTopic."

The string representation of the above activity context would be:

```
[0X101A76B,0X79E5D71,0X50EE914:0X80000088{E=Pu,N=TestPublisher,D=1}|CREATE Writer WITH TOPIC
TestTopic]
```

In this example, the activity context fields are as follows:

- GUID is **0X101A76B,0X79E5D71,0X50EE914:0X80000003**

  ```
  [0X101A76B,0X79E5D71,0X50EE914:0X80000003{E=Pu,N=TestPublisher,D=1}|CREATE Writer WITH
  TOPIC TestTopic]
  ```

- *Entity* name is **N=TestPublisher**

  ```
  [0X101A76B,0X79E5D71,0X50EE914:0X80000003 {E=Pu,N=TestPublisher,D=1}|CREATE Writer WITH
  TOPIC TestTopic]
  ```

- *Entity* kind is **E=Pu** (for Publisher)

  ```
  [0X101A76B,0X79E5D71,0X50EE914:0X80000003 {E=Pu,N=TestPublisher,D=1}|CREATE Writer WITH
  TOPIC TestTopic]
  ```

- Domain ID is **D=1**

  ```
  [0X101A76B,0X79E5D71,0X50EE914:0X80000003 {E=Pu,N=TestPublisher,D=1}|CREATE Writer WITH
  TOPIC TestTopic]
  ```

- Activity is **CREATE Writer WITH TOPIC TestTopic**

  ```
  [0X101A76B,0X79E5D71,0X50EE914:0X80000003 {E=Pu,N=TestPublisher,D=1}|CREATE Writer WITH
  TOPIC TestTopic]
  ```

When a *DataWriter* writes a sample, the activity context will provide information about:

- Resource: the *DataWriter* writing the sample. The attributes of the *DataWriter* will be GUID, name, *Entity* kind, *Topic*, data type, and Domain ID.
- Activity: the writing of a sample.

The string representation of this activity context would be:

```
[0X101A76B,0X79E5D71,0X50EE914:0X1C1:0X80000003{N=TestDataWriter,E=DW,T=test,C=Foo,D=1}|Write]
```

In this example, the additional activity context fields are as follows:

- Topic is **T=test**

```
[0X101A76B,0X79E5D71,0X50EE914:0X80000003
{N=testDataWriterName,E=DW,T=test,Y=Foo,D=1}|Write]
```

- Data type is **C=Foo**

```
[0X101A76B,0X79E5D71,0X50EE914:0X80000003
{N=testDataWriterName,E=DW,T=test,C=Foo,D=1}|Write]
```

25.2.1.4 Activity Context Strings and Attributes

The resources of the activity context can have multiple associated attributes. Those attributes provide extra information about the entity such as GUID prefix, *Topic*, data type (class), *Entity* kind, *Entity* name, and Domain ID. The following tables describe how those attributes are represented.

Table 25.6 Activity Context Attributes

Attribute	Description
GUID	(given at the beginning of the context, such as: **0X101A76B,0X79E5D71,0X50EE914:0X1C1:0X80000003**)
N	Name of the entity, such as **TestPublisher**
E	Entity kind, such as **Pu** for **Publisher**
D	Domain ID
T	*Topic* name
C	Data type

Table 25.7 Activity Context Resources and Entities

Entity Kind	Entity Type
DP	DDS_DomainParticipant
Pu	DDS_Publisher
Su	DDS_Subscriber
To	DDS_Topic
DW	DDS_<*>DataWriter
DR	DDS_<*>DataReader

Table 25.8 Activity Context Activities

String	Operation
Entity operations:	
ENABLE	Entity::enable
GET_QOS	Entity::get_qos
SET_QOS	Entity::set_qos
GET_LISTENER	Entity::get_listener
SET_LISTENER	Entity::set_listener
Factory operations (DomainParticipantFactory, DomainParticipant, Publish/Subscribe):	
CREATE <Entity>	Factory::create_<entity>
DELETE <Entity>	Factory::delete_<entity>
GET_DEFAULT_QOS <Entity>	Factory::get_default_<entity>_qos
SET_DEFAULT_QOS <Entity>	Factory::set_default_<entity>_qos
Participant-specific operations:	
GET_PUBS	Participant::get_publishers
GET_SUBS	Participant::get_subscribers
LOOKUP Topic(<name>)	Participant::lookup_topicdescription
LOOKUP FlowController(<name>)	Participant::lookup_flowcontroller
IGNORE <Entity>(<host ID>)	Participant::ignore_<entity>

25.2.1.5 Configuring Activity Context Attributes

The attributes that **NDDS_Config_ActivityContextAttribute** uses in the string representation of the activity context can be configured through a mask. This mask indicates what resource attributes are used when *Connext DDS* logs a message or when the Heap Monitoring utility saves statistics for a memory allocation.

```
void NDDS_Config_ActivityContext_set_attribute_mask(
        NDDS_Config_ActivityContextAttributeKindMask attribute_mask);

enum NDDS_Config_ActivityContextAttributeKind {
  NDDS_CONFIG_ACTIVITY_CONTEXT_ATTRIBUTE_GUID_PREFIX,
  NDDS_CONFIG_ACTIVITY_CONTEXT_ATTRIBUTE_TOPIC,
  NDDS_CONFIG_ACTIVITY_CONTEXT_ATTRIBUTE_TYPE,
  NDDS_CONFIG_ACTIVITY_CONTEXT_ATTRIBUTE_ENTITY_KIND,
  NDDS_CONFIG_ACTIVITY_CONTEXT_ATTRIBUTE_DOMAIN_ID,
  NDDS_CONFIG_ACTIVITY_CONTEXT_ATTRIBUTE_ENTITY_NAME
```

```
}
#define NDDS_CONFIG_ACTIVITY_CONTEXT_ATTRIBUTE_MASK_DEFAULT
#define NDDS_CONFIG_ACTIVITY_CONTEXT_ATTRIBUTE_MASK_NONE
```

25.2.2 Configuring Logging via XML

Logging can also be configured using the DomainParticipantFactory's 9.4.1 LOGGING QosPolicy (DDS Extension) on page 627 with the tags, <participant_factory_qos><logging>. The fields in the LoggingQosPolicy are described in XML using a 1-to-1 mapping with the equivalent C representation shown below:

```
struct DDS_LoggingQosPolicy {
       NDDS_Config_LogVerbosity verbosity;
       NDDS_Config_LogCategory category;
       NDDS_Config_LogPrintFormat print_format;
       char * output_file;
};
```

The equivalent representation in XML:

```
<participant_factory_qos>
    <logging>
        <verbosity></verbosity>
        <category></category>
        <print_format></print_format>
        <output_file></output_file>
    </logging>
</participant_factory_qos>
```

The attribute **<is_default_participant_factory_profile>** can be set to true for the **<qos_profile>** tag to indicate from which profile to use **<participant_factory_qos>**. If multiple QoS profiles have **<is_default_participant_factory_profile>** set to true, the last profile with **<is_default_participant_factory_profile>** set to true will be used.

If none of the profiles have set **<is_default_participant_factory_profile>** to true, the profile with **<is_default_qos>** set to true will be used.

In the following example, DefaultProfile2 will be used:

```
<dds xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xsi:noNamespaceSchemaLocation="../xsd/rti_dds_qos_profiles.xsd">
    <!-- Qos Library -->
    <qos_library name="DefaultLibrary">
        <qos_profile name="DefaultProfile1"
         is_default_participant_factory_profile ="true">
            <participant_factory_qos>
                <logging>
                    <verbosity>ALL</verbosity>
                    <category>ENTITIES</category>
                    <print_format>MAXIMAL</print_format>
                    <output_file>LoggerOutput1.txt</output_file>
                </logging>
            </participant_factory_qos>
```

```
        </qos_profile>
        <qos_profile name=
         "DefaultProfile2"
         is_default_participant_factory_profile ="true">
            <participant_factory_qos>
                <logging>
                    <verbosity>WARNING</verbosity>
                    <category>API</category>
                    <print_format>VERBOSE_TIMESTAMPED</print_format>
                    <output_file>LoggerOutput2.txt</output_file>
                </logging>
            </participant_factory_qos>
        </qos_profile>
        <qos_profile name="DefaultProfile3" is_default_qos="true">
            <participant_factory_qos>
                <logging>
                    <verbosity>ERROR</verbosity>
                    <category>DATABASE</category>
                    <print_format>VERBOSE</print_format>
                    <output_file>LoggerOutput3.txt</output_file>
                </logging>
            </participant_factory_qos>
        </qos_profile>
    </qos_library>
</dds>
```

Note: The LoggingQosPolicy is currently the only QoS policy that can be configured using the **<participant_factory_qos>** tag.

25.2.3 Customizing the Handling of Generated Log Messages

By default, the log messages generated by *Connext DDS* are sent to the standard output. You can redirect the log messages to a file by using the **set_output_file()** operation,

To further customize the management of the generated log messages, you can use the Logger's **set_output_device()** operation to install a user-defined logging device. The logging device must implement an interface with two operations: **write()** and **close()**.

Connext DDS will call the **write()** operation to write a new log message to the input device. The log message provides the text and the verbosity corresponding to the message.

Connext DDS will call the **close()** operation when the logging device is uninstalled.

Note: It is not safe to make any calls to the *Connext DDS* core library including calls to **DDS_DomainParticipant_get_current_time()** from any of the logging device operations.

For additional details on user-defined logging devices, see the API Reference HTML documentation (under **Modules, RTI Connext DDS API Reference**, **Configuration Utilities**).

25.3 Monitoring Native Heap Memory Usage

Connext DDS allows you to monitor the memory allocations done by the middleware on the native heap. This feature can be used to analyze and debug unexpected memory growth.

This feature includes the following APIs (available in all languages):

- **NDDSUtilityHeapMonitoring::enable**
- **NDDSUtilityHeapMonitoring::disable**
- **NDDSUtilityHeapMonitoring::pause**
- **NDDSUtilityHeapMonitoring::resume**
- **NDDSUtilityHeapMonitoring::take_heap_snapshot**

After **NDDSUtilityHeapMonitoring::enable** is called, you may invoke **NDDSUtilityHeapMonitoring::take_heap_snapshot** to save the current heap memory usage to a file. By comparing two snapshots, you can tell if new memory has been allocated and, in many cases, where.

For more information, see the API Reference HTML documentation.

25.4 Network Capture

Connext DDS allows you to capture network traffic that one or more *DomainParticipants* send or receive. This feature can be used to analyze and debug communication problems between your DDS applications. When network capture is enabled, each *DomainParticipant* will generate a pcap-based file that can then be opened by a packet analyzer like Wireshark, provided the right dissectors are installed.

To some extent, network capture can be used as an alternative to existing pcap-based network capture software (such as Wireshark). This will be the case when you are only interested in analyzing the traffic a *DomainParticipant* sends/receives. In this scenario, network capture will actually have some advantages over more general pcap-based network capture applications: RTI's network capture includes additional information, such as security-related data; it also removes information that is not needed, such as user data, when you want to reduce the capture size. That said, RTI's network capture is not a replacement for other pcap-based network capture applications: it only captures the traffic exchanged by the *DomainParticipants*, but it does not capture any other traffic exchanged through the system network interfaces.

To capture network traffic, **NDDSUtilityNetworkCapture::enable** must be invoked before creating any *DomainParticipant*. Similarly, **NDDSUtilityNetworkCapture::disable** must be called after deleting all participants. In between these calls, you may start, stop, pause, or resume capturing traffic for one or all *DomainParticipants*.

This feature includes the following APIs (available in all languages):

- **NDDSUtilityNetworkCapture::enable**
- **NDDSUtilityNetworkCapture::disable**
- **NDDSUtilityNetworkCapture::start**
- **NDDSUtilityNetworkCapture::stop**
- **NDDSUtilityNetworkCapture::pause**
- **NDDSUtilityNetworkCapture::resume**

For more information, see the API Reference HTML documentation.

25.4.1 Capturing Shared Memory Traffic

Every RTPS frame in network capture has a source and a destination associated with it. In the case of shared memory traffic, a process identifier and a port determine the source and destination endpoints.

Access to the process identifier (PID) of the source for inbound traffic requires changes in the shared memory segments. These changes would break shared memory compatibility with versions of *Connext DDS* earlier than 6.1.0. For this reason, by default, network capture will not populate the value of the source PID for inbound shared memory traffic.

If interoperability with pre-6.1.0 versions of *Connext DDS* is not necessary, you can generate capture files containing the source PID for inbound traffic. To do so, configure the value of the **dds.transport.minimum_compatibility_version** property to 6.1.0. (See 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.)

```
<domain_participant_qos>
    <property>
        <value>
            <element>
                <name>dds.transport.minimum_compatibility_version</name>
                <value>6.1.0</value>
                <propagate>false</propagate>
            </element>
        </value>
    </property>
</domain_participant_qos>
```

This property is never propagated, so it must be consistently configured throughout the whole system.

> **Note:** Changing the value of this property affects the type of shared memory segments that *Connext DDS* uses. For that reason, you may see the following warning, resulting from leftover shared memory segments:
>
> ```
> [0xC733A001,0xB248F671,0xAEC4A0C1:0x000001C1{D=200}|CREATE DP|ENABLE] NDDS_Transport_Shmem_
> is_segment_compatible:incompatible shared memory protocol detected.
> Current version 4.0 not compatible with 2.0.
> ```

The leftover shared memory segments can be removed using the **ipcrm** command. See https://-community.rti.com/kb/what-are-possible-solutions-common-shared-memory-issues for more information.

25.5 Logging a Backtrace for Failures

In some scenarios, it might be desirable to log the backtrace from the code. A backtrace is a list of the function calls that are currently active in a thread. You can usually inspect a backtrace by using debugging utilities like **gdb**, but sometimes these are not available.

Now, *Connext DDS* logs the backtrace when a precondition fails in debug mode and when a segmentation fault occurs, for macOS, Windows, and Linux systems. The backtrace feature is automatically enabled upon creation of the first *DomainParticipant*. (That is, you will not see the backtrace log in a failure until the first *DomainParticipant* is created.)

- Normally when a precondition fails, the execution continues and there is no information about the problem, but *Connext DDS* provides a backtrace with context about where the issue was.
- When a segmentation fault occurs, the processor or operating system does not always provide a core dump, but *Connext DDS* provides a backtrace with context about where the issue was.

For Linux systems, the output of the backtrace will look like this:

```
#1 RTIOsapiProcessTester_testPrintBacktrace
/connextdds/osapi.1.0/srcC/process/test/processTester.c:638 [0x417371]
#2 RTITestSetting_runTestsExt /connextdds/test.1.0/srcC/setting/Setting.c:719 [0x4623B8]
#3 RTITestSetting_runTests /connextdds/test.1.0/srcC/setting/Setting.c:905 [0x462B85]
#4 RTIOsapiProcessTester_run /connextdds/osapi.1.0/srcC/process/test/processTester.c:683
[0x41750C]
#5 RTITestSetting_runTestsExt /connextdds/test.1.0/srcC/setting/Setting.c:719 [0x4623B8]
#6 RTITestSetting_runTests /connextdds/test.1.0/srcC/setting/Setting.c:905 [0x462B85]
#7 RTIOsapiTester_run /connextdds/osapi.1.0/srcC/test/Tester.c:128 [0x4039CB]
#8 main /connextdds/osapi.1.0/srcC/test/Tester.c:213 [0x403A65] #9 ?? ??:0 [0xE8434830] #10 _
start ??:? [0x403759]
```

See the RTI Connext DDS Core Libraries Platform Notes for further details on enabling this feature on macOS, Windows, and Linux systems.

The backtrace feature is smart enough to log the backtrace only once for a given error and not for the following errors in the same code path of the caller's functions. For example, in the failure of the creation of the DDSDomainParticipant, *Connext DDS* logs the backtrace for just one error instead of logging it for all of the error messages in the same code path:

```
U00007f86a87df700 Mx08:Udpv4SocketFactory.c:685:RTI0x2080010:invalid port 5562900
Backtrace:
#3 NDDS_Transport_UDPv4_Socket_bind_with_ip ??:? [0xCB235C]
#4 NDDS_Transport_UDPv4_SocketFactory_create_receive_socket ??:? [0xCB2619]
#5 NDDS_Transport_UDP_create_recvresource_rrEA Udp.c:? [0xCAB170]
#6 RTINetioReceiver_addEntryport ??:? [0xCA33F3]
#7 COMMENDActiveFacade_addEntryport ActiveFacade.c:? [0xC12B56]
```

```
#8 DDS_DomainParticipantPresentation_reserve_entryportI DomainParticipantPresentation.c:?
[0x7E4F11]
#9 DDS_DomainParticipantPresentation_reserve_participant_index_entryports ??:? [0x7E8015]
#10 DDS_DomainParticipant_reserve_participant_index_entryports DomainParticipant.c:? [0x7B0B7E]
#11 DDS_DomainParticipant_enableI DomainParticipant.c:? [0x7CC15E]
#12 DDS_Entity_enable ??:? [0x72EC92]
#13 DDS_DomainParticipantFactory_create_participant ??:? [0x7DACF1]
#14 main ??:? [0x40675F]
#15 ?? ??:0 [0xA76F4830]
#16 _start ??:? [0x405EC9]
U00007f86a87df700 Mx0F:DomainParticipant.c:13313:RTI0x20f0c02:Automatic participant index
failed to initialize. PLEASE VERIFY CONSISTENT TRANSPORT / DISCOVERY CONFIGURATION.
U00007f86a87df700 Mx0F:DomainParticipantFactory.c:1314:RTI0x20f000e:ERROR: Failed to auto-
enable entity
U00007f86a87df700 Mx01:DomainParticipantTester.c:9325:RTI0x2000007:!
[DomainParticipantTester.c:9325] pointer is null: participant
```

By default, the **print_format** NDDS_CONFIG_LOG_PRINT_FORMAT_DEBUG is set for the log level NDDS_CONFIG_LOG_LEVEL_FATAL_ERROR. This means that by default the backtrace is logged for precondition and segmentation faults; however, you can disable the backtrace for NDDS_CONFIG_LOG_LEVEL_FATAL_ERROR. In the following code, the log level NDDS_CONFIG_LOG_LEVEL_FATAL_ERROR uses the print_format NDDS_CONFIG_LOG_PRINT_FORMAT_DEFAULT, which does not contain the backtrace information:

```
NDDS_Config_Logger *logger = NDDS_Config_Logger_get_instance();
NDDS_Config_Logger_set_print_format_by_log_level(
           logger,
           NDDS_CONFIG_LOG_PRINT_FORMAT_DEFAULT,
           NDDS_CONFIG_LOG_LEVEL_FATAL_ERROR));
```

See 25.2.1 Format of Logged Messages on page 971 and 25.2 Controlling Messages from Connext DDS on page 968.

25.6 Setting Warnings for Operation Delays

You can configure logging a warning when a specific operation takes more time than expected. This capability is useful for discovering problems related to contentions, delays, and blocks. By default, these warnings are not logged. You have to explicitly enter a timeout period for the desired warning to see it. You can set these timeouts via properties in the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436.

The operations for which you can set timeouts are:

- Send operation: Print a warning message when the send operation time exceeds the time threshold configured by the property **dds.participant.logging.time_based_logging.send.timeout**. The output message will look like this:

```
It took '0.359548' seconds to send '96' bytes to
'shmem://903A:C1C4:91F3:A80F:CA5B:3B82:0000:0000:7661', which exceeds the time threshold
configured in 'dds.participant.logging.time_based_logging.send.timeout'."
```

- Event operations: Print a warning message when the event start or execution time exceeds the time threshold configured by the property **dds.participant.logging.time_based_logging.event.timeout**. The output message will look like this:

```
The event thread took '2.502871' seconds waiting to trigger the event, which exceeds the
time threshold configured in 'dds.participant.logging.time_based_logging.event.timeout'.
```

```
The event thread took '1.436886' seconds executing the event, which exceeds the time
threshold configured in 'dds.participant.logging.time_based_logging.event.timeout'.
```

- Process received data operation: Print a warning message when the processing of a received message on a specific port exceeds a time threshold set in **dds.participant.logging.time_based_logging.process_received_message.timeout**.

  The tracking ports can be configured using the property **dds.participant.logging.time_based_logging.process_received_message.tracked_ports**. The ports will be separated by a comma ','. They can be described using a regular expression, such as, "76*,1234". If ports are not specified, all of the ports will be tracked.

  The output message will look like this:

```
It took '0.003795' seconds to process the received message of '496' bytes by the port
'7662', which exceeds the threshold configured in 'dds.participant.logging.time_based_
logging.process_received_message.timeout'."
```

- Authentication process (if using *RTI Security Plugins*): Print a warning message when the authentication operation time exceeds the time threshold configured by the property **dds.participant.logging.time_based_logging.authentication.timeout**. The output message will look like this:

```
[0xC0A87A01,0x00007BFC,0x00000001:0x000201C4{E=DR,I=21}|RECEIVE FROM
0xC0A87A01,0x00007BFC,0x00000002:0x000201C3]PRESParticipant_processHandshake:It took
'1.096696' seconds to authenticate the remote participant
[0xC0A87A01,0x00007BFC,0x00000002], which exceeds the threshold configured in
'dds.participant.logging.time_based_logging.authentication.timeout'.
```

These and other properties are documented in the Property Reference Guide.

Part 4: Request-Reply and RPC Communication Patterns

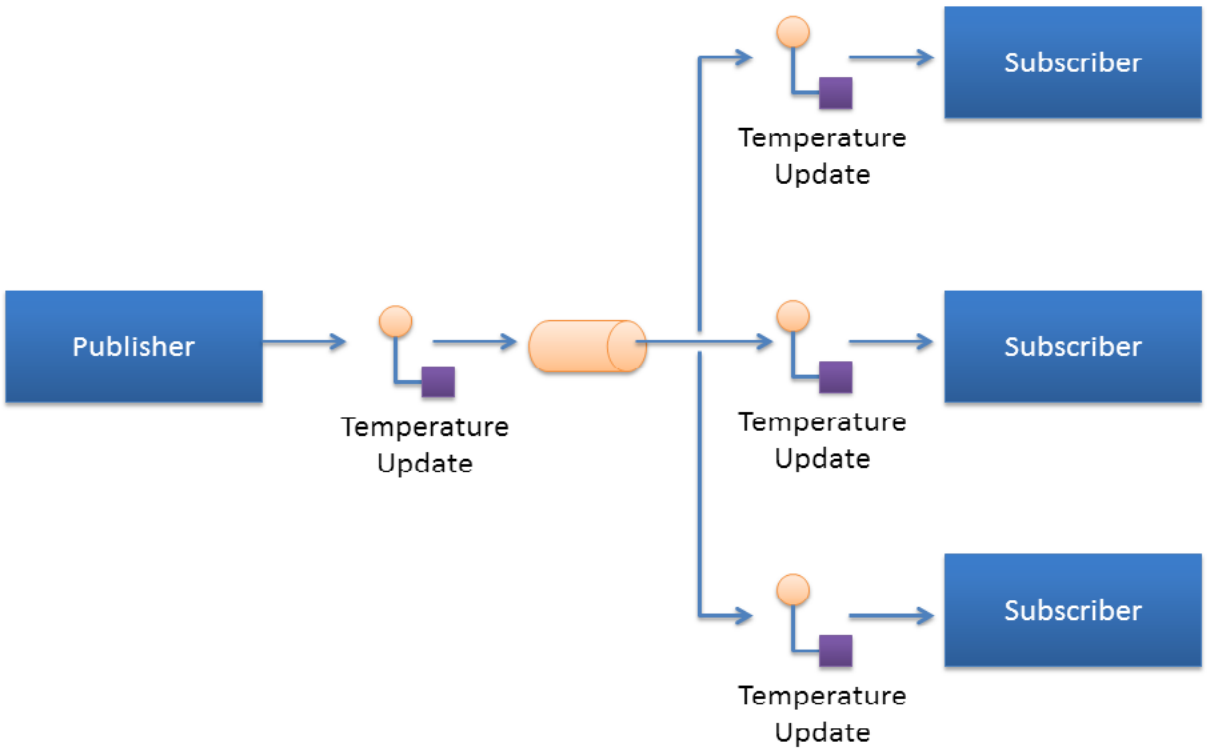
As real-time and embedded applications become more complex, and require integration with enterprise applications, you may need additional communication patterns besides publish-subscribe. Perhaps your application needs certain information only occasionally—such as changes in temperature over the past hour, or even just once, such as application configuration data that is required only at startup. To get information only when needed, *Connext DDS* supports a *request-reply* communication pattern, which is described in the following sections:

- Introduction to the Request-Reply Communication Pattern (Chapter 26 on page 984)
- Using the Request-Reply Communication Pattern (Chapter 27 on page 990)
- Remote Procedure Calls (RPC)—Experimental Feature (Chapter 28 on page 1008)

Chapter 26 Introduction to the Request-Reply Communication Pattern

The fundamental communication pattern provided by *Connext DDS* is known as DDS data-centric *publish-subscribe*. The data-centric publish-subscribe pattern is particularly well-suited in situations where the same data must flow from one producer to many consumers, or when data is streaming continuously from producers to consumers. For example, the values produced by a temperature sensor may be observed by multiple applications, such as control applications, UI applications, supervisory applications, historians, etc.

Figure 26.1: Publish-Subscribe Overview



Sending temperature updates using the publish-subscribe pattern

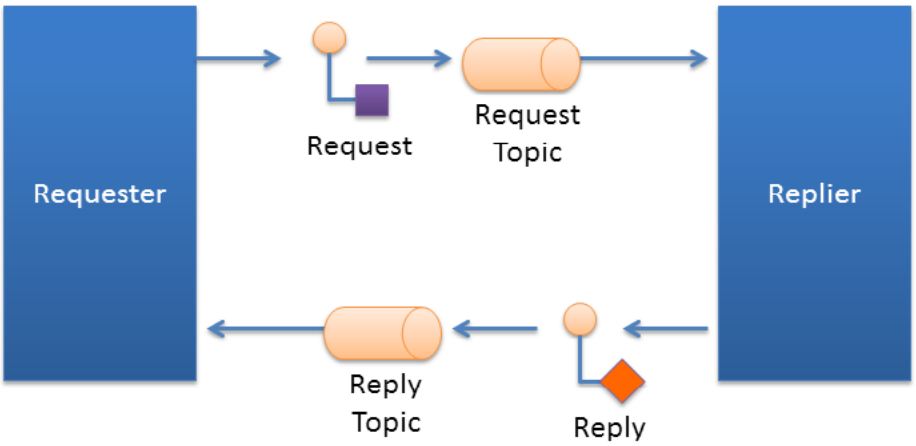
The publish-subscribe pattern supports multicast, which allows efficient distribution from a single source to multiple applications, devices, or subscribers simultaneously. But even with a single subscriber, the publish-subscribe pattern is still advantageous, because the publisher can push new updates to a subscriber as soon as they happen. That way the subscriber always has access to the latest data, with minimum delays, and without incurring the overhead of periodically polling what may be stale data. This efficient, low-latency access to the most current information is important for real-time applications.

26.1 The Request-Reply Pattern

As applications become more complex, it often becomes necessary to use other communication patterns in addition to publish-subscribe. Sometimes an application needs to get a one-time snapshot of information; for example, to make a query into a database or retrieve configuration parameters that never change. Other times an application needs to ask a remote application to perform an action on its behalf; for example, to invoke a remote procedure call or a service.

To support these scenarios, *Connext DDS* includes support for the request-reply communication pattern.

Figure 26.2: Request-Reply Overview



Request-Reply communication pattern using a Requester and a Replier

The request-reply pattern has two roles: The requester (service consumer or client) sends a request message and waits for a reply message. The replier (service provider) receives the request message and responds with a reply message.

Using the request-reply pattern with a *Replier* is straightforward. *Connext DDS* provides two Entities: the *Requester* and the *Replier* manage all the interactions on behalf of the application. The *Requester* and *Replier* automatically discover each other based on an application-specified *service name*. When the application invokes a request, the *Requester* sends a message (on an automatically-created request *Topic*) to the *Replier,* which notifies the receiving application. The application, in turn, uses the *Replier* to receive the

request and send the reply message. The reply message is sent by *Connext DDS* back to the original *Requester* (using a different automatically created reply *Topic*).

Connext DDS supports both blocking and non-blocking request-reply interactions:

- In a blocking (a.k.a. synchronous) interaction, the requesting application blocks while waiting for the reply. This is typical of applications desiring remote-procedure-call or remote-method-invocation interactions.
- In a non-blocking (a.k.a. asynchronous) interaction, the requesting application can proceed with other work and gets notified when a reply is available.

27.2 Repliers on page 999 explains how an application can use the methods provided by the *Requester* and the *Replier* to perform both blocking and non-blocking request-reply interactions.

The implementation of request-reply in *Connext DDS* is highly scalable. A *Replier* can receive requests from thousands of *Requesters* at the same time. *Connext DDS* will efficiently deliver each reply only to the original *Requester*, allowing the number of *Requesters* to grow without significantly impacting each other.

26.1.1 Request-Reply Correlation

An application might have multiple outstanding requests, all originating from the same *Requester.* This can be as a result of using a non-blocking request-reply interaction, or as a result of having multiple application threads using the same *Requester.* Because of this, *Connext DDS* provides a way for the application to correlate a reply with the request it is associated with. This meta-data is provided as part of a *SampleInfo* structure that accompanies the reply.

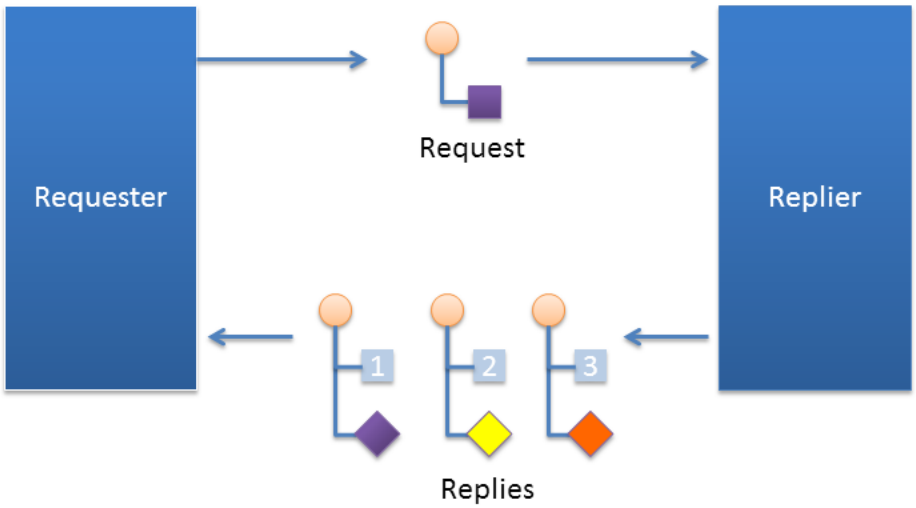
When using a blocking request operation, *Connext DDS* provides an easy-to-use API that automatically does the correlation for you.

26.2 Single-Request, Multiple-Replies

Connext DDS also supports the single-request multiple-reply pattern. This pattern is an extension of the basic request-reply pattern in which multiple reply messages can flow back as a result of a single request.

The single-request multiple-reply pattern is very useful when getting large amounts of data as a reply, such as when querying a system for all data that matches a certain criteria. Another common use-case is invoking a service that goes through multiple stages and provides updates on each: service commencement, progress reports, and final completion.

Figure 26.3: Single Request, Multiple Replies



Request/Reply communication pattern with multiple replies resulting from a single request

For example, a mobile asset management system may need to locate a particular asset (truck, locomotive, etc.). The system sends out the request. The first reply that comes back will read "locating." The service has not yet determined the position, but it notifies the requester that the search operation has started. The second reply might provide a status update on the search, perhaps including a rough area of location. The third and final reply will have the exact location of the asset.

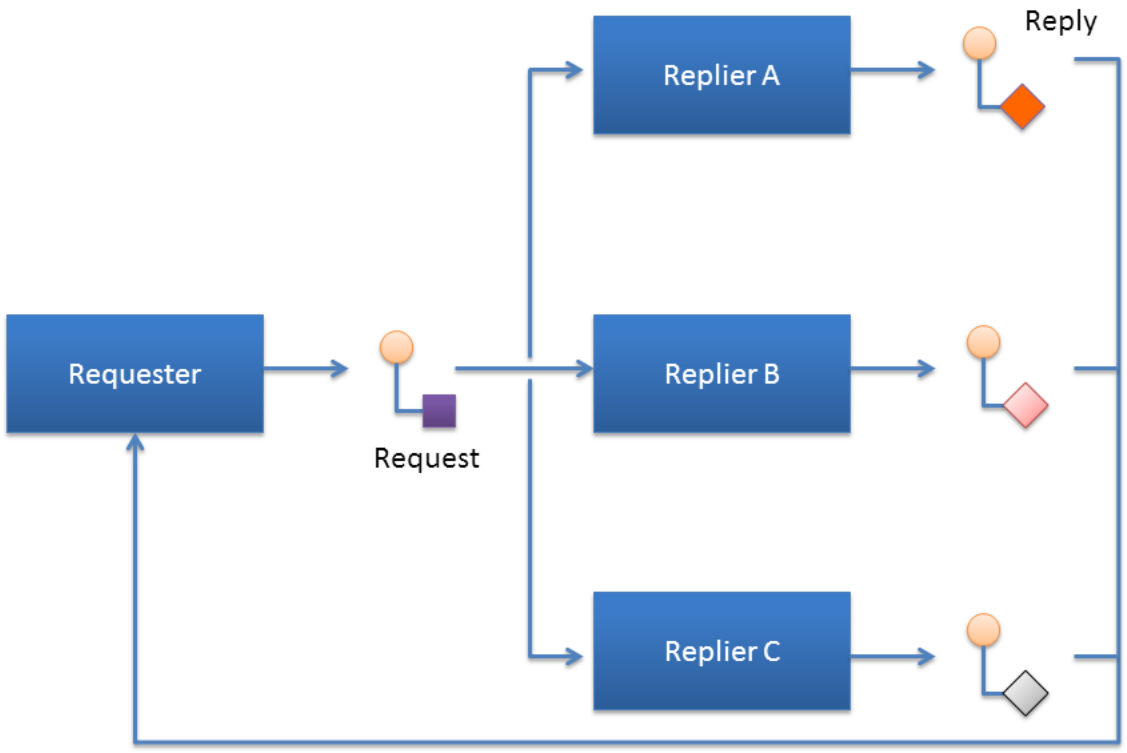
26.3 Multiple Repliers

Connext DDS directly supports applications that obtain results from multiple providers in parallel instead of in sequence, basically implementing functional parallelism.

To illustrate, consider a system managing a fleet of drones, like unmanned aerial vehicles (UAVs). Using the single request-multiple reply pattern, the application can use a *Requester* to send a single 'DroneInfo' request to all the drones to query for their current mission and status. Each drone replies with the information on its own status and the *Requester* aggregates all the responses for the application.

As another example, consider a system that would like to locate the best printer to perform a particular job. The application can use a *Requester* to query all the printers that are on-line for their characteristics and load. The *Requester* receives the replies and accumulates them until an application-specified number of replies is received (or a timeout elapses). The application can then use the *Requester* to access all the replies, examine their contents, and select the best printer for the job.

Figure 26.4: Multiple Repliers

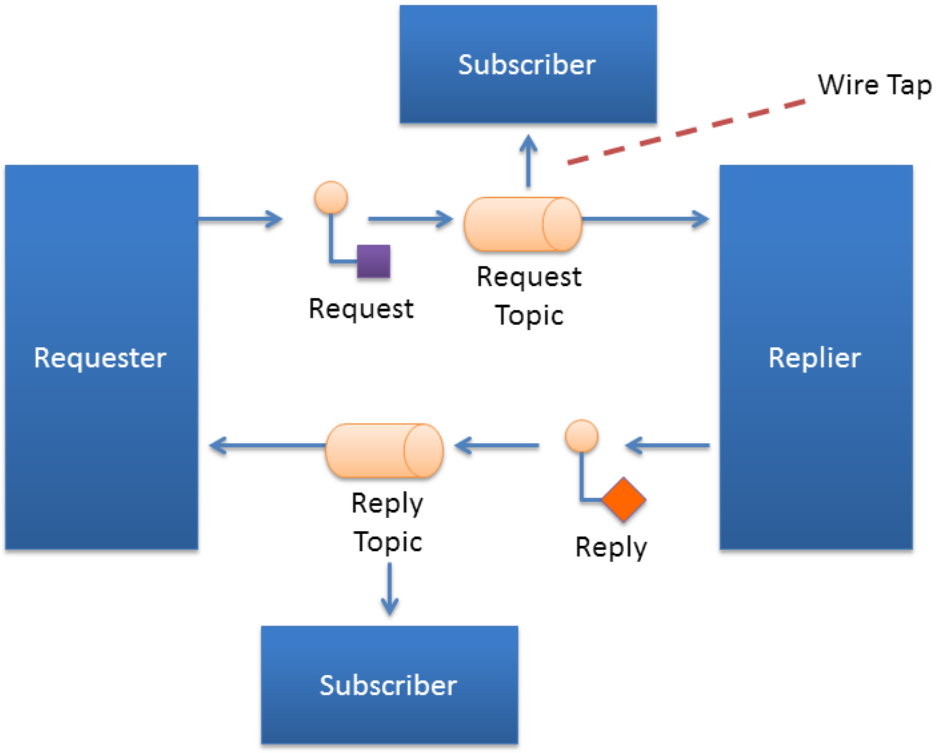


Request/Reply communication pattern with a single Requester and multiple Repliers

26.4 Combining Request-Reply and Publish-Subscribe

Under the hood, *Connext DDS* implements request-reply using the DDS data-centric publish-subscribe pattern. This has a key benefit in that the two patterns can be combined, and mapped without interference.

Figure 26.5: Combining Patterns



Combining Request-Reply and Publish-Subscribe patterns

For example, a pair of applications may be involved in a two-way conversation using request-reply. For debugging purposes or regulatory compliance, you want to inspect those request-reply messages, but without disrupting the conversation.

Since *Connext DDS* implements requests and replies using DDS data-centric publish subscribe, others can simply subscribe to the request and reply messages. You can introduce a subscriber to the reply *Topic*, without interfering with the two-way conversation between the *Requester* and the *Replier*. This pattern is also known as a Wire Tap. For example, you can use *RTI Recording Service* to non-intrusively capture request-reply traffic.

Chapter 27 Using the Request-Reply Communication Pattern

There are two basic *Connext DDS* entities used by the Request-Reply communication pattern: *Requester* and *Replier*.

- A *Requester* publishes a request *Topic* and subscribes to a reply *Topic*. See 27.1 Requesters on the next page.
- A *Replier* subscribes to the request *Topic* and publishes the reply *Topic*. See 27.2 Repliers on page 999.

  There is an alternate type of replier known as a *SimpleReplier*:
  - A *SimpleReplier* is useful for cases where there is a single reply to each request and the reply can be generated quickly, such as looking up some data from memory.
  - A *SimpleReplier* is used in combination with a user-provided *SimpleReplierListener*. Requests are passed to a callback in the *SimpleReplierListener*, which returns the reply.
  - The *SimpleReplier* is not suitable if the replier needs to generate more than one reply for a single request or if generating the reply can take significant time or needs to occur asynchronously. For more information, see 27.3 SimpleRepliers on page 1005.

Additional resources. In addition to the information in this section, you can find more information and example code here:

- The *Connext DDS* API Reference HTML documentation[1] contains example code that will show you how to use the API: From the **Modules** tab, navigate to **Programming How-**

[1] The API Reference HTML documentation is available for all supported programming languages. Open <NDDSHOME>/README.html.

To's, Request-Reply Examples.

- The *Connext DDS* API Reference HTML documentation also contains the full API documentation for the *Requester*, *Replier,* and *SimpleReplier*. Under the **Modules** tab, navigate to **RTI Connext DDS API Reference**, **RTI Connext Messaging API Reference, Request-Reply Pattern**.

27.1 Requesters

A *Requester* is an entity with two associated DDS *Entities*: a DDS *DataWriter* bound to a request *Topic* and a DDS *DataReader* bound to a reply *Topic*. A *Requester* sends requests by publishing samples of the request *Topic*, and receives replies for those requests by subscribing to the reply *Topic*.

Valid types for request and reply *Topics* can be:

- For the C API:
  - DDS types generated by RTI Code Generator
- For all other APIs:
  - DDS types generated by RTI Code Generator
  - Built-in DDS types, such as, *String*, *KeyedString*, *Octets*, and *KeyedOctets*
  - DDS *DynamicData* Types

To communicate, a *Requester* and *Replier* must use the same request *Topic* name, the same reply *Topic* name, and be associated with the same DDS **domain_id.**

A Requester has an associated *DomainParticipant*, which can be shared with other requesters or *Connext DDS* entities. All the other entities required for request-reply interaction, including the request and reply *Topics*, the *DataWriter* for writing requests, and a *DataReader* for reading replies, are automatically created when the *Requester* is constructed.

Connext DDS guarantees that a *Requester* will only receive replies associated with the requests it sends.

The *Requester* uses the underlying *DataReader* not only to receive the replies, but also as a cache that can hold replies to multiple outstanding requests or even multiple replies to a single request. Depending on the HistoryQoSPolicy configuration of the *DataReader,* the *Requester* may allow replies to replace previous replies based on the reply data having the same value for the Key fields (see 2.4 DDS Samples, Instances, and Keys on page 18). The default configuration of the *Requester* does not allow replacing.

You can configure the QoS for the underlying *DataWriter* and *DataReader* in a QoS profile. By default, the *DataWriter* and *DataReader* are created with default values (DDS_DATAWRITER_QOS_DEFAULT and DDS_DATAREADER_QOS_DEFAULT, respectively) except for the following:

- 7.5.21 RELIABILITY QosPolicy on page 444: **kind** is set to RELIABLE.
- 7.5.12 HISTORY QosPolicy on page 418: **kind** is set to KEEP_ALL.
- Several other protocol-related settings for *Requesters* (see the API Reference HTML documentation: select **Modules, Programming How-To's, Request-Reply Examples**; then scroll down to the section on **Configuring Request-Reply QoS profiles**).

27.1.1 Creating a Requester

Before you can create a *Requester*, you need a *DomainParticipant* and a service name.

Note: The example code snippets in this section use the C++ API. You can find more complete examples in all the supported programming languages (C, C++, Java, C#) in the *Connext DDS* API Reference HTML documentation and in the "example" directory found in your *Connext DDS* installation.

To create a Requester with the minimum set of parameters, you can use the basic constructor that receives only an existing DDS *DomainParticipant* and the name of the service:

```
Requester <MyRequestType, MyReplyType> *requester =
       new Requester <MyRequestType,MyReplyType> (
       participant, "ServiceName");
```

To create a Requester with specific parameters, you may use a different constructor that receives a *RequesterParams* structure (described in 27.1.3 Setting Requester Parameters on the next page):

```
Requester (const RequesterParams &params)
```

The **ServiceName** parameter is used to generate the names of the request and reply *Topics* that the *Requester* and *Replier* will use to communicate. For example, if the service name is "MyService", the topic names for the *Requester* and *Replier* will be "MyServiceRequest" and "MyServiceReply", respectively. Therefore, for communication to occur, you must use the same service name when creating the *Requester* and the *Replier* entities.

If you want to use topic names different from the ones that would be derived from the ServiceName, you can override the default names by setting the actual request and reply *Topic* names using the **request_topic_name()** and **reply_topic_name()** accessors to the *RequesterParams* structure prior to creating the *Requester*.

Example: To create a *Requester* with default QoS and topic names derived from the service name, you may use the following code:

```
Requester<Foo, Bar> * requester =
       new Requester<Foo, Bar>(
       participant,"MyService");
```

Example: To create a *Requester* with a specific QoS profile with library name "MyLibrary" and profile "MyProfile" defined inside **USER_QOS_PROFILES.xml** in the current working directory, you may use the following code:

```
Requester<Foo, Bar> * requester = new Requester<Foo, Bar>(
       RequesterParams(participant).
       service_name("MyService").qos_profile(
       "MyLibrary", "MyProfile"));
```

Once you have created a *Requester*, you can use it to perform the operations in Table 27.2 Requester Operations.

27.1.2 Destroying a Requester

To destroy a Requester and free its underlying entities you may use the destructor:

```
virtual ~Requester ()
```

27.1.3 Setting Requester Parameters

To change the RequesterParams that can be used when creating a Requester, you can use the operations listed in Table 27.1 Operations to Set Requester Parameters.

Table 27.1 Operations to Set Requester Parameters

Operation	Description
datareader_qos	Sets the QoS of the reply DataReader.
datawriter_qos	Sets the QoS of the request DataWriter.
publisher	Sets a specific Publisher.
qos_profile	Sets a QoS profile for the DDS entities in this requester.
request_topic_name	Sets the name of the Topic used for the request. If this parameter is set, then you must also set the reply_topic_name parameter and you should not set the service_name parameter.
reply_topic_name	Sets the name of the Topic used for the reply. If this parameter is set, then you must also set the request_topic_name parameter and you should not set the service_name parameter.
reply_type_support	Sets the type support for the reply type.
request_type_support	Sets the type support for the request type.
service_name	Sets the service name. This will automatically set the name of the request Topic and the reply Topic. If this parameter is set you should not set the request_topic_name or the reply_topic_name.
subscriber	Sets a specific Subscriber.

27.1.4 Summary of Requester Operations

There are several kinds of operations an application can perform using the *Requester*:

- Sending requests (i.e., publishing request samples on the request *Topic*)
- Waiting for replies to be received.
- Taking the reply data. This gets the reply data from the *Requester* and removes from the *Requester* cache.
- Reading the reply data. This gets the reply data from the *Requester* but leaves it in the *Requester* cache so it remain accessible to future operations on the *Requester*.
- Receiving replies (a convenience operation that is a combination of 'waiting' and 'taking' the data in a single operation)

These operations are summarized in Table 27.2 Requester Operations

Table 27.2 Requester Operations

Operation		Description	Reference
Sending Requests	send_ request	Sends a request.	27.1.5 Sending Requests on the next page
Waiting for Replies	wait_for_ replies	Waits for replies to any request or to a specific request.	27.1.6.1 Waiting for Replies on page 996
Taking Reply Data	take_reply	Copies a single reply into a Sample container. There are variants that allow getting the next reply available or the next reply to a specific request. This operation removes the reply from the Requester cache. So subsequent calls to take or read replies will not get the same reply again.	27.2 Repliers on page 999
	take_ replies	Returns a LoanedSamples container with the collection of replies received by the Requester. There are variants that allow accessing all the replies available or only the replies to a specific request. This operation removes the returned replies from the Requester cache. So subsequent calls to take or read replies will not get the same replies again.	
Reading Reply Data	read_reply	Copies a single reply into a Sample container. There are variants that allow getting the next reply available or the next reply to a specific request. This operation leaves the reply on the Requester cache. So subsequent calls to take or read replies can get the same reply again.	27.2 Repliers on page 999
	read_ replies	Returns a LoanedSamples container with the collection of replies received by the Requester. There are variants that allow accessing all the replies available or only the replies to a specific request. This operation leaves the returned replies in the Requester cache. So subsequent calls to take or read replies can get the same replies again.	
Receiving Replies	receive_ reply	Convenience function that combines a call to wait_for_replies with a call to take_reply.	27.1.6.3 Receiving Replies on page 998
	receive_ replies	Convenience function that combines a call to wait_for_replies with a call to take_ replies.	

Table 27.2 Requester Operations

Operation		Description	Reference
Getting Underlying Entities	get_request_datawriter	Retrieves the underlying DataWriter that writes requests.	27.4 Accessing Underlying DataWriters and DataReaders on page 1007
	get_reply_datareader	Retrieves the underlying DataReader that reads replies.	

27.1.5 Sending Requests

To send a request, use the **send_request()** operation on the *Requester*. There are three variants of this operation, depending on the parameters that are passed in:

1. **send_request (const TRequest &request)**
2. **send_request (WriteSample<TRequest> &request)**
3. **send_request (WriteSampleRef<TRequest> &request)**

The first variant simply sends a request.

The second variant sends a request and gets back information about the request in a *WriteSample* container. This information can be used to correlate the request with future replies.

The third variant is just like the second, but puts the information in a *WriteSampleRef,* which holds references to the data and parameters. Both *WriteSample* and *WriteSampleRef* provide information about the request that can be used to correlate the request with future replies.

27.1.6 Processing Incoming Replies with a Requester

The *Requester* provides several operations that can be used to wait for and access replies:

- **wait_for_replies()**, see 27.1.6.1 Waiting for Replies on the next page
- **take_reply()**, **take_replies()**, **read_reply()** and **read_replies()**, see 27.1.6.2 Getting Replies on the next page
- **receive_reply()** and **receive_replies()**, see 27.1.6.3 Receiving Replies on page 998

The **wait_for_replies** operations are used to wait until the replies arrive.

The **take_reply, take_replies**, **read_reply**, and **read_replies()** operations access the replies once they have arrived.

The **receive_reply** and **receive_replies** are convenience functions that combine waiting and accessing the replies and are equivalent to calling the 'wait' operation followed by the corresponding **take_reply** or **take_replies** operations.

Each of these operations has several variants, depending on the parameters that are passed in.

27.1.6.1 Waiting for Replies

Use the **wait_for_replies()** operation on the *Requester* to wait for the replies to previously sent requests. There are three variants of this operation, depending on the parameters that are passed in. All these variants block the calling thread until either there are replies or a timeout occurs.

```
1. wait_for_replies (const DDS_Duration_t &max_wait)
2. wait_for_replies (int min_count,
          const DDS_Duration_t &max_wait)
3. wait_for_replies (int min_count,
           const DDS_Duration_t &max_wait,
           const SampleIdentity_t &related_request_id)
```

The first variant (only passing in **max_wait**) blocks until a reply is available or until **max_wait** time has elapsed, whichever comes first. The reply can be to any of the requests made by the *Requester*.

The second variant (passing in **min_count** and **max_wait**) blocks until at least **min_count** replies are available or until **max_wait** time has elapsed, whichever comes first. These replies may all be to the same request or to different requests made by the *Requester*.

The third variant (passing in **min_count**, **max_wait**, and **related_request_id**) blocks until at least **min_count** replies to the request identified by the **related_request_id** are available, or until **max_wait** time has passed, whichever comes first. Note that unlike the previous variants, the replies must all be to the same single request (identified by the **related_request_id**) made by the *Requester*.

Typically after waiting for replies, you will call **take_reply, take_replies**, **read_reply,** or **read_replies()**, see 27.2 Repliers on page 999.

If you call **wait_for_replies()** several times without 'taking' the replies (using the **take_reply** or **take_replies** operation), future calls to **wait_for_replies()** will return immediately and will not wait for new replies.

27.1.6.2 Getting Replies

You can use the following operations to access replies: **take_reply, take_replies**, **read_reply,** and **read_replies().**

As mentioned in 27.1.4 Summary of Requester Operations on page 993, the difference between the 'take' operations (**take_reply**, **take_replies**) and the 'read' operations (**read_reply**, **read_replies)** is that 'take' operations remove the replies from the *Requester* cache. This means that future calls to **take_reply**, **read_reply**, **read_reply**, and **read_reply** will not get the same reply again.

The **take_reply** and **read_reply** operations access a *single* reply, whereas the **take_replies** and **read_replies** can access a *collection* of replies.

There are four variants of the **take_reply** and **read_reply** operations, depending on the parameters that are passed in:

```
1. take_reply (Sample<TReply> &reply)
   read_reply (Sample<TReply> &reply)

2. take_reply (SampleRef<TReply> reply)
   read_reply (SampleRef<TReply> reply)

3. take_reply (Sample<TReply> &reply,
               const SampleIdentity_t &related_request_id)
   read_reply (Sample<TReply> &reply,
               const SampleIdentity_t &related_request_id)

4. take_reply (SampleRef<TReply> reply,
               const SampleIdentity_t &related_request_id)
   read_reply (SampleRef<TReply> reply,
               const SampleIdentity_t &related_request_id)
```

The first two variants provide access to the next reply in the *Requester* cache. This is the earliest reply to any previous requests sent by the *Requester* that has not been 'taken' from the *Requester* cache. The remaining two variants provide access to the earliest non-previously 'taken' reply to the request specified by the **related_request_id**.

Notice that some of these variants use a *Sample*, while other use a *SampleRef*. A *SampleRef* can be used much like a *Sample*, but it holds *references* to the reply data and *DDS SampleInfo*, so there is no additional copy. In contrast using the *Sample* obtains a copy of both the data and *DDS SampleInfo*.

The **take_replies** and **read_replies** operations access a collection of (one or more) replies to previously sent requests. These operations are convenient when you expect multiple replies to a single request, or when issuing multiple requests concurrently without waiting for intervening replies.

The **take_replies** and **read_replies** operations return a *LoanedSamples* container that holds the replies. To increase performance, the *LoanedSamples* does not copy the reply data. Instead it 'loans' the necessary resources from the *Requester.* The resources loaned by the *LoanedSamples* container must be eventually returned, either explicitly calling the **return_loan()** operation on the *LoanedSamples* or through the destructor of the *LoanedSamples*.

There are three variants of the **take_replies** and **read_replies** operations, depending on the parameters that are passed in:

```
1. take_replies (int max_count=DDS_LENGTH_UNLIMITED)
   read_replies (int max_count=DDS_LENGTH_UNLIMITED)

2. take_replies (int max_count,
                 const SampleIdentity_t &related_request_id)
   read_replies (int max_count,
                 const SampleIdentity_t &related_request_id)
```

```
3. take_replies (const SampleIdentity_t &related_request_id)
   read_replies (const SampleIdentity_t &related_request_id)
```

The first variant (only passing in **max_count**) returns a container holding up to **max_count** replies.

The second variant (passing in **max_count** and **related_request_id**) returns a *LoanedSamples* container holding up to **max_count** replies that correspond to the request identified by the **related_request_id**.

The third variant (only passing in **related_request_id**) returns a *LoanedSamples* container holding an unbounded number of replies that correspond to the request identified by the **related_request_id**. This is equivalent to the second variant with **max_count** = DDS_LENGTH_UNLIMITED.

The resources for the *LoanedSamples* container must be eventually be returned, either by calling the **return_loan()** operation on the *LoanedSamples* or through the *LoanedSamples* destructor.

For multi-reply scenarios, in which a *Requester* receives multiple replies from a *Replier* for a given request, the *Requester* can check if a reply is the last reply in a sequence of replies. To do so, see if the bit INTERMEDIATE_REPLY_SEQUENCE_SAMPLE is set in DDS_SampleInfo's flag field (see Table 8.17 DDS_SampleInfo Structure) after receiving each reply. This bit indicates it is NOT the last reply.

27.1.6.3 Receiving Replies

The **receive_reply()** operation is a shortcut that combines calls to **wait_for_replies()** and to **take_reply().** Similarly the **receive_replies()** operation combines **wait_for_replies()** and **take_replies().**

There is only one variant of the **receive_reply()** operation:

```
1. receive_reply (Sample<TReply> &reply, const DDS_Duration_t &timeout)
```

This operation blocks until either a reply is received or a timeout occurs. The contents of the reply are copied into the provided sample (**reply**).

There are two variants of the **receive_replies()** operation, depending on the parameters that are passed in:

```
1. receive_replies (const DDS_Duration_t &max_wait)

2. receive_replies (int min_count, int max_count,
                    const DDS_Duration_t &max_wait)
```

These two variants block until *multiple* replies are available or a timeout occurs.

The first variant (only passing in **max_wait**) blocks until at least one reply is available or until **max_wait** time has passed, whichever comes first. The operation returns a *LoanedSamples* container holding the replies. Note that there could be more than one reply. This can occur if, for example, there were already replies available in the *Requester* from previous requests that were not processed. This operation does not limit the number of replies that can be returned on the *LoanedSamples* container.

The second variant (passing in **min_count**, **max_count**, and **max_wait**) will block until **min_count** replies are available or until **max_wait** time has passed, whichever comes first. Up to **max_count** replies will be stored into the *LoanedSamples* container which is returned to the caller.

The resources held in the *LoanedSamples* container must eventually be returned, either with an explicit call to **return_loan()** on the *LoanedSamples* or through the *LoanedSamples* destructor.

27.2 Repliers

A *Replier* is an entity with two associated DDS *Entities*: a DDS *DataReader* bound to a request *Topic* and a DDS *DataWriter* bound to a reply *Topic*. The *Replier* receives requests by subscribing to the request *Topic* and sends replies to those requests by publishing on the reply *Topic*.

Valid data types for these topics are the same as specified for the *Requester*, see 27.1 Requesters on page 991.

For multi-reply scenarios in which a *Replier* generates more than one reply for a request, the *Replier* should mark all intermediate replies (all but the last reply) with the INTERMEDIATE_REPLY_SEQUENCE_SAMPLE bit-flag in the WriteParams_t flag field (see Table 7.17 DDS_WriteParams_t).

Much like a *Requester*, a *Replier* has an associated DDS *DomainParticipant* which can be shared with other *Connext DDS* entities. All the other entities required for the request-reply interaction, including a *DataWriter* for writing replies and a *DataReader* for reading requests, are automatically created when the *Replier* is constructed.

You can configure the QoS for the underlying *DataWriter* and *DataReader* in a QoS profile. By default, the *DataWriter* and *DataReader* are created with default QoS values (using DDS_DATAWRITER_QOS_DEFAULT and DDS_DATAREADER_QOS_DEFAULT, respectively) except for the following:

- 7.5.21 RELIABILITY QosPolicy on page 444: **kind** is set to RELIABLE
- 7.5.12 HISTORY QosPolicy on page 418: **kind** is set to KEEP_ALL

The *Replier* API supports several ways in which the application can be notified of, and process, requests:

- **Blocking**: The application thread blocks waiting for requests, processes them, and dispatches the reply. In this situation, if the computation necessary to process the request and produce the reply is small, you may consider using the *SimpleReplier,* which offers a simplified API.
- **Polling**: The application thread checks (polls) for requests periodically but does not block to wait for them. To check for data without blocking, call **take_requests()** or **read_requests()**.
- **Asynchronous notification**: The application installs a *ReplierListener* to receive notifications whenever a request is received.

27.2.1 Creating a Replier

To create a *Replier* with the minimum set of parameters you can use the basic constructor that receives only an existing DDS *DomainParticipant* and the name of the service:

```
Replier (DDSDomainParticipant * participant,
                const std::string & service_name)
```

Example:

```
Replier<Foo, Bar> * replier =
                new Replier<Foo, Bar>(participant, "MyService");
```

To create a *Replier* with specific parameters you may use a different constructor that receives a *ReplierParams* structure:

```
Replier (const ReplierParams<TRequest, TReply> &params)
```

Example:

```
Replier<Foo, Bar> * replier = new Replier<Foo, Bar>(
               ReplierParams(participant).service_name("MyService")
               .qos_profile("MyLibrary", "MyProfile"));
```

The **service_name** is used to generate the names of the request and reply *Topics* that the *Requester* and *Replier* will use to communicate. For example, if the service name is "MyService", the topic names for the *Requester* and *Replier* will be "MyServiceRequest" and "MyServiceReply", respectively. Therefore it is important to use the same **service_name** when creating the *Requester* and the *Replier*.

If you need to specify different *Topic* names, you can override the default names by setting the actual request and reply *Topic* names using **request_topic_name()** and **reply_topic_name()** accessors to the *ReplierParams* structure prior to creating the *Replier*.

27.2.2 Destroying a Replier

To destroy a Replier and free its underlying entities:

```
virtual ~Replier ()
```

27.2.3 Setting Replier Parameters

To change the *ReplierParams* that are used to create a *Replier*, use the operations listed in Table 27.3 Operations to Set Replier Parameters.

Table 27.3 Operations to Set Replier Parameters

Operation	Description
datareader_qos	Sets the quality of service of the request *DataReader*.
datawriter_qos	Sets the quality of service of the reply *DataWriter*.
publisher	Sets a specific Publisher.
qos_profile	Sets a QoS profile for the entities in this replier.
replier_listener	Sets a listener that is called when requests are available.

Table 27.3 Operations to Set Replier Parameters

Operation	Description
reply_topic_name	Sets a specific reply topic name.
reply_type_support	Sets the type support for the reply type.
request_topic_name	Sets a specific request topic name.
request_type_support	Sets the type support for the request type.
service_name	Sets the service name the Replier offers and Requesters use to match.
subscriber	Sets a specific Subscriber.

27.2.4 Summary of Replier Operations

There are four kinds of operations an application can perform using the *Replier*:

- Waiting for requests to be received
- Reading/taking the request data and associated information
- Receiving requests (a convenience operation that combines waiting and getting the data into a single operation)
- Sending a reply for received request (i.e., publishing a reply sample on the reply *Topic* with special meta-data so that the original *Requester* can identify it).

The *Replier* operations are summarized in Table 27.4 Replier Operations.

Table 27.4 Replier Operations

Operation		Description	Reference
Waiting for Requests	wait_for_requests	Waits for requests.	27.2.5.1 Waiting for Requests on the next page
Taking Requests	take_request	Copies the contents of a single request into a *Sample* and removes it from the *Replier* cache.	27.2.5.2 Reading and Taking Requests on page 1003
	take_requests	Returns a *LoanedSamples* to access multiple requests and removes the requests from the *Replier* cache.	
Reading Requests	read_request	Copies the contents of a single request into a *Sample*, leaving it in the *Replier* cache	
	read_requests	Returns a *LoanedSamples* to access multiple requests, leaving them in the *Replier* cache.	

Table 27.4 Replier Operations

Operation		Description	Reference
Receiving Requests	receive_request	Waits for a single request and copies its contents into a *Sample* container.	27.2.5.3 Receiving Requests on page 1004
	receive_requests	Waits for multiple requests and provides a *LoanedSamples* container to access them.	
Sending Replies	send_reply	Sends a reply for a previous request.	27.2.6 Sending Replies on page 1004
Getting Underlying Entities	get_request_datareader	Retrieves the underlying *DataReader*.	27.4 Accessing Underlying DataWriters and DataReaders on page 1007
	get_reply_datawriter	Retrieves the underlying *DataWriter*.	

27.2.5 Processing Incoming Requests with a Replier

The *Replier* provides several operations that can be used to wait for and access the requests:

- **wait_for_requests()**, see 27.2.5.1 Waiting for Requests below
- **take_request()**, **take_requests()**, **read_request()**, and **read_requests()**, see 27.2.5.2 Reading and Taking Requests on the next page
- **receive_request()** and **receive_requests()**, see 27.2.5.3 Receiving Requests on page 1004

The **wait_for_requests()** operations are used to wait until requests arrive.

The **take_request(), take_requests()**, **read_request(),** and **read_requests()** operations access the requests, once they have arrived.

The **receive_request()** and **receive_requests()** operations are convenience functions that combine waiting for and accessing requests and are equivalent to calling the 'wait' operation followed by the corresponding **take_request()** or **take_requests()** operations.

Each of these operations has several variants, depending on the parameters that are passed in.

27.2.5.1 Waiting for Requests

Use the **wait_for_requests()** operation on the *Replier* to wait for requests. There are two variants of this operation, depending on the parameters that are passed in. All these variants block the calling thread until either there are replies or a timeout occurs.:

```
1. wait_for_requests (const DDS_Duration_t &max_wait)

2. wait_for_requests (int min_count, const DDS_Duration_t &max_wait)
```

The first variant (only passing in **max_wait**) blocks until one request is available or until **max_wait** time has passed, whichever comes first.

The second variant blocks until **min_count** number of requests are available or until **max_wait** time has passed.

Typically after waiting for requests, you will call **take_request, take_requests**, **read_request,** or **read_requests**, see 27.2.6 Sending Replies on the next page.

27.2.5.2 Reading and Taking Requests

You can use the following four operations to access requests: **take_request**, **take_requests**, **read_request**, or **read_requests.**

As mentioned in 27.2.4 Summary of Replier Operations on page 1001, the difference between the 'take' operations (**take_request**, **take_requests**) and the 'read' operations (**read_request**, **read_requests)** is that 'take' operations remove the requests from the *Replier* cache. This means that future calls to **take_request**, **take_requests**, **read_request**, or **read_requests** will not get the same request again.

The **take_request** and **read_request** operations access a *single* reply, whereas the **take_requests** and **read_requests** can access a *collection* of replies.

There are two variants of the **take_request** and **read_request** operations, depending on the parameters that are passed in:

```
1. take_request (connext::Sample<TRequest> & request)
   read_request (connext::Sample<TRequest> & request)

2. take_request (connext::SampleRef<TRequest  request)
   read_request (connext::SampleRef<TRequest  request)
```

The first variant returns the request using a *Sample* container. The second variant uses a *SampleRef* container instead. A *SampleRef* can be used much like a *Sample*, but it holds *references* to the request data and *DDS SampleInfo*, so there is no additional copy. In contrast, using the *Sample* makes a copy of both the data and *DDS SampleInfo*.

The **take_requests** and **read_requests** operations access a collection of (one or more) requests in the *Replier* cache. These operations are convenient when you want to batch-process a set of requests.

The **take_requests** and **read_requests** operations return a *LoanedSamples* container that holds the requests. To increase performance, the *LoanedSamples* does not copy the request data. Instead it 'loans' the necessary resources from the *Replier.* The resources loaned by the *LoanedSamples* container must be eventually returned, either explicitly by calling the **return_loan()** operation on the *LoanedSamples* or through the destructor of the *LoanedSamples*.

There is only one variant of these operations:

```
1. take_requests (int max_samples = DDS_LENGTH_UNLIMITED)
   read_requests (int max_samples = DDS_LENGTH_UNLIMITED)
```

The returned container may contain up to **max_samples** number of requests.

27.2.5.3 Receiving Requests

The **receive_request()** operation is a shortcut that combines calls to **wait_for_requests()** and **take_request().** Similarly, the **receive_requests()** operation combines **wait_for_requests()** and **take_requests().**

There are two variants of the **receive_request()** operation:

```
1. receive_request (connext::Sample<TRequest> & request,
                    const DDS_Duration_t & max_wait)
2. receive_request (connext::SampleRef<TRequest> request,
                    const DDS_Duration_t & max_wait)
```

The **receive_request** operation blocks until either a request is received or a timeout occurs. The contents of the request are copied into the provided container (**request**). The first variant uses a *Sample* container, whereas the second variant uses a *SamepleRef* container. A *SampleRef* can be used much like a *Sample*, but it holds *references* to the request data and *DDS SampleInfo*, so there is no additional copy. In contrast, using the *Sample* obtains a copy of both the data and the *DDS SampleInfo*.

There are two variants of the **receive_requests()** operation, depending on the parameters that are passed in:

```
1. receive_requests (const DDS_Duration_t & max_wait)

2. receive_requests (int min_request_count,
                           int max_request_count,
                           const DDS_Duration_t & max_wait)
```

The **receive_requests** operation blocks until one or more requests are available, or a timeout occurs.

The first variant (only passing in **max_wait**) blocks until one request is available or until **max_wait** time has passed, whichever comes first. The contents of the request are copied into a *LoanedSamples* container which is returned to the caller. An unlimited number of replies can be copied into the container.

The second variant blocks until **min_request_count** number of requests are available or until **max_wait** time has passed, whichever comes first. Up to **max_request_count** number of requests will be copied into a *LoanedSamples* container which is returned to the caller.

The resources for the *LoanedSamples* container must eventually be returned, either with **return_loan()** or through the *LoanedSamples* destructor.

27.2.6 Sending Replies

There are three variants for **send_reply()**, depending on the parameters that are passed in:

```
1. send_reply (const TReply & reply,
               const SampleIdentity_t & related_request_id)
2. send_reply (WriteSample<TReply> & reply,
               const SampleIdentity_t & related_request_id)
3. send_reply (WriteSampleRef<TReply> & reply,
               const SampleIdentity_t & related_request_id)
```

This operation sends a reply for a previous request. The related request ID can be retrieved from an existing request Sample.

The first variant is recommended if you do not need to change any of the default write parameters.

The other two variants allow you to set custom parameters for writing a reply. Unlike the *Requester*, where retrieving the sample ID for correlation is common, on the *Replier* side using a WriteSample or WriteSampleRef is only necessary when you need to overwrite the default write parameters. If that's not the case, use the first variant.

One reason to override the default write parameters is a multi-reply scenario in which a *Replier* generates more than one reply for a request. In this case, all the intermediate replies (all but the last reply) should be marked with the INTERMEDIATE_REPLY_SEQUENCE_SAMPLE bit-flag in the **flag** field within **WriteSample::info** or **WriteSampleRef::info**.

A *Requester* can detect if a reply is the last reply in a sequence of replies by seeing if INTERMEDIATE_REPLY_SEQUENCE_SAMPLE is NOT set in the **flag** field of **Sample::info** after receiving each reply.

27.3 SimpleRepliers

The *SimpleReplier* offers a simplified API to receive and process requests. The API is based on a user-provided object that implements the *SimpleReplierListener* interface. Requests are passed to the listener operation implemented by the user-provided object, which processes the request and returns a reply.

The *SimpleReplier* is recommended if each request generates a single reply and computing the reply can be done quickly with very little CPU resources and without calling any operations that may block the processing thread. For example, looking something up in an internal memory-based data structure would be a good use case for using a *SimpleReplier*.

27.3.1 Creating a SimpleReplier

To create a *SimpleReplier* with the minimum set of parameters, you can use the basic constructor:

```
SimpleReplier (DDSDomainParticipant *participant,
               const std::string &service_name,
               SimpleReplierListener<TRequest, TReply> &listener)
```

To create a *SimpleReplier* with specific parameters, you may use a different constructor that receives a *SimpleReplierParams* structure:

```
SimpleReplier (const SimpleReplierParams<TRequest, TReply> &params)
```

27.3.2 Destroying a SimpleReplier

To destroy a *SimpleReplier* and free its resources use the destructor:

```
virtual ~SimpleReplier ()
```

27.3.3 Setting SimpleReplier Parameters

To change the *SimpleReplierParams* used to create a *SimpleReplier*, use the operations in Table 27.5 Operations to Set SimpleReplier Parameters.

Table 27.5 Operations to Set SimpleReplier Parameters

Operation	Description
datareader_qos	Sets the quality of service of the reply DataReader.
datawriter_qos	Sets the quality of service of the reply DataWriter.
publisher	Sets a specific Publisher.
qos_profile	Sets a QoS profile for the entities in this replier.
reply_topic_name	Sets a specific reply topic name.
reply_type_support	Sets the type support for the reply type.
request_topic_name	Sets a specific request topic name.
request_type_support	Sets the type support for the request type.
service_name	Sets the service name the Replier offers and Requesters use to match.
subscriber	Sets a specific Subscriber.

27.3.4 Getting Requests and Sending Replies with a SimpleReplierListener

The **on_request_available()** operation on the *SimpleReplierListener* receives a request and returns a reply.

```
on_request_available(TRequest &request)
```

This operation gets called when a request is available. It should immediately return a reply. After calling **on_request_available()**, *Connext DDS* will call the operation **return_loan()** on the *SimpleReplierListener;* this gives the application-defined listener an opportunity to release any resources related to computing the previous reply.

```
retun_loan(TReply &reply)
```

27.4 Accessing Underlying DataWriters and DataReaders

Both *Requester* and *Replier* entities have underlying DDS *DataWriter* and *DataReader* entities. These are created automatically when the *Requester* and *Replier* are constructed.

Accessing the *DataWriter* used by a *Requester* may be useful for a number of advanced use cases, such as:

- Finding matching subscriptions (e.g., *Replier* entities), see 7.3.16.1 Finding Matching Subscriptions on page 341
- Setting a *DataWriterListener*, see 7.3.4 Setting Up DataWriterListeners on page 293
- Getting *DataWriter* protocol or cache statuses, see 7.3.6 Statuses for DataWriters on page 295
- Flushing a data batch after sending a number of request samples, see 7.3.9 Flushing Batches of DDS Data Samples on page 314
- Modifying the QoS

Accessing the reply *DataReader* may be useful for a number of advanced use cases, such as:

- Finding matching publications (e.g., *Requester* entities), see 8.3.10 Navigating Relationships Among Entities on page 546
- Getting *DataReader* protocol or cache statuses, see 8.3.5 Checking DataReader Status and StatusConditions on page 511 and 8.3.7 Statuses for DataReaders on page 513.
- Modifying the QoS

To access these underlying objects:

- **RequestDataWriter * get_request_datawriter()**
- **RequestDataReader * get_request_datareader()**
- **ReplyDataWriter * get_reply_datawriter()**
- **ReplyDataReader * get_reply_datareader()**

Chapter 28 Remote Procedure Calls (RPC)—Experimental Feature

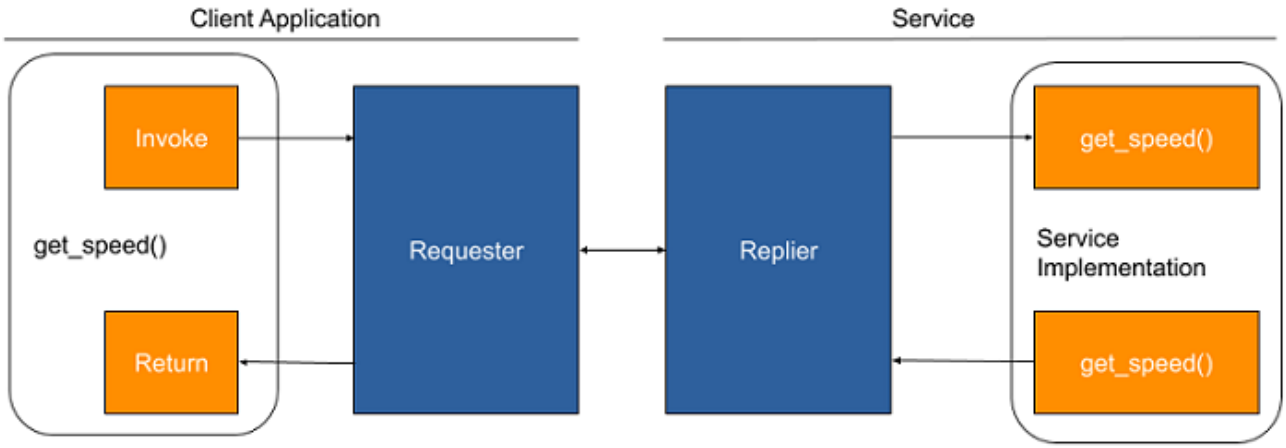
Remote Procedure Calls, or RPC, is an inter-process communication that allows a computer program to cause a subroutine or procedure to execute in another address space.

> **Note:** RPC is an experimental feature available only on C++11, for certain platforms. See the RTI Connext DDS Core Libraries Platform Notes for the supported architectures. See also *Experimental Features* in the RTI Connext DDS Core Libraries Release Notes.

RPC has two participants: a *client* and a *service*. Under the hood, the *client* uses a Requester to send requests and receive replies; the *service* uses a Replier to receive the requests and send the replies.

RPC over DDS uses a function-call style where the *client/Requester* directly calls the *service/Replier* by calling the service's functions, abstracting sending the request and receiving the corresponding reply on the client side.

Figure 28.1: RPC Overview



Connext DDS supports both blocking and non-blocking interactions:

- In a blocking (or synchronous) interaction, the client application blocks while waiting for the service's answer.
- In a non-blocking (or asynchronous) interaction, the client application can proceed with other work, ask if the service's answer is already available, or wait for the service's answer.

It is possible for a client to call more than one function at a time, particularly when asynchronous invocations are used.

28.2 RPC Client on page 1013 explains how a client application can use the method provided by the interface to perform both blocking and non-blocking interactions with the service.

Additional resources. In addition to the information in this section, you can find more information and example code here:

- The *Connext DDS* API Reference HTML documentation contains example code that will show you how to use the API: From the **Modules** tab, navigate to **Programming How-To's, RPC Tutorial**.
- The *Connext DDS* API Reference HTML documentation also contains the full API documentation for the client-side and server-side APIs. Under the **Modules** tab, navigate to **RTI Connext DDS API Reference**, **RTI Connext Messaging API Reference**, **Remote Procedure Call**.

28.1 RPC Service

A *service/Replier* receives requests from those *clients/Requesters* that are subscribed to it, and sends replies to those clients. To communicate, a *service* and a *client* must use the same service name, and be associated with the same DDS **domain_id**.

A *service* has an associated *Replier*. All the entities required by the *Replier*—including the *DomainParticipant*, the request and reply *Topics*, the *DataWriter* for writing replies, and a *DataReader* for reading the requests—are automatically created when the service is created.

You can configure the QoS policies for the underlying *DataWriter* and *DataReader* by setting them either in the *DomainParticipant* that the service is using or in a QoS Profile.

A *service* definition in IDL is represented as an *interface* with the annotation @DDSService or @service[1]. An interface may define as many operations and attributes as you like. Exceptions are also supported by an interface and can be thrown by operations and attributes.

[1]The @service annotation receives the type of service as an argument. *Connext DDS* accepts only "DDS" or "*". If no parameter is passed to the annotation, "*" is assumed.

Attributes are defined by using 'attribute' before the type of the attribute. For example: **attribute *float* speed**. Other elements inside an interface are considered operations. See 28.2.3 Summary of Client Operations on page 1014.

```
module robot {
    exception TooFast {};
    enum Command { START_COMMAND, STOP_COMMAND };
    struct Status {
        string msg;
    };

    @DDSService
    interface RobotControl {
        void command(Command com);
        float setSpeed(float speed) raises (TooFast);
        float getSpeed();
        void getStatus(out Status status);
    };
}; //module robot
```

28.1.1 Creating a Service

Before you can create a *service/Replier*, you need a *DomainParticipant*, a Server, a ServiceParams, and an instance of the *service interface*.

A Server defines the execution context for one or more *services*. A Server is created with ServerParams, which allow configuring a thread pool that executes the *services*.

```
dds::rpc::ServerParams server_params;
server_params.extensions().thread_pool_size(4);
dds::rpc::Server server(server_params);
```

A *service* requires a *DomainParticipant* and an identifier, which are specified (among other optional configuration parameters) using ServiceParams:

```
dds::domain::DomainParticipant client_participant(domain_id);
dds::rpc::ServiceParams params(participant);
params.service_name("Example RobotControl Service");
```

The **service_name** function is used to generate the names of the request and reply *Topics* that the internal *Requester (client)* and *Replier (service)* will use to communicate. For example, if the *service* name is “MyService”, the *Topic* names for the *Requester* and *Replier* will be “MyServiceRequest” and “MyServiceReply”, respectively. Therefore, for communication to occur, you must use the same *service* name when creating the *Requester* and the *Replier* entities. If you want to use *Topic* names different from the ones that would be derived from the ServiceName, you can override the default names by setting the actual request and reply *Topic* names using the **request_topic_name()** and **reply_topic_name()** accessors to the RequesterParams structure before creating the *Requester*.

Next, create an instance of the interface implementation:

```
auto service_impl = std::make_shared<RobotControlExample>();
```

The *service* implementation contains the definition of each operation defined inside the interface in IDL. The *service/Replier* will call these methods upon receiving the request from the *client/Requester*.

Finally, create a *service* for the interface implementation, attached to the server and using the parameters specified before:

```
RobotControlService service(service_impl, server, params);
```

The *service* is ready to receive function calls as soon as it is created.

You can create additional *services* and attach them to the same Server.

Note that just like *DomainParticipant*, 'RobotControlService' and 'server' are reference types and behave like shared pointers. You need to keep one or more references to them to avoid their destruction. You can also use the **run()** operation on the Server to block the current thread, and explicitly call **close()** to unblock it and destroy the Server (see Table 28.2 Server Operations).

28.1.2 Setting the Server Parameters

To change the ServerParameters that can be used when creating a Server (for the *service/Replier*), you can use the operations listed in Table 28.1 Operations to Set Server Parameters.

Table 28.1 Operations to Set Server Parameters

Operation	Description
thread_pool_size	Configures the number of threads of a Server thread pool.
async_waitset_property	Allows fine-tuning the internal AsyncWaitSet used to process function calls.

Note: These operations are extensions, they must be called via **this->extensions()**.

28.1.3 Summary of Server Operations

There are two kinds of operations an application can perform using the Server:

- Running the service
- Closing the service

The Server operations are summarized in Table 28.2 Server Operations.

Table 28.2 Server Operations

Operation		Description	Reference
Run the Server	run	Holds the execution of the current thread.	28.1.4 Run the Server below
Close the Server	close	Unblocks **run()** and forces the destruction of this entity. Note that calling **close()** is not necessary since Server is a reference type and is destroyed automatically when no longer referenced.	

28.1.4 Run the Server

The Server is ready to run as soon as it is created and one or more *services/Repliers* are attached to it. It doesn't require any specific call to start running. However, *Connext DDS* provides two optional **run()** operations that simply hold the execution of the current thread:

- **run (const dds::core::Duration &maxWait)**
- **run ()**

The first operation holds the execution of the current thread for the specified amount of time. The second operation holds the execution of the current thread for an unlimited period of time.

To close the Server, the Server provides a **close()** operation, which unblocks **run()** and then releases all resources.

28.1.5 Setting the Service Parameters

To change the ServiceParams that can be used when creating a *service/Replier*, you can use the operations listed in Table 28.3 Operations to Set Service Parameters.

Table 28.3 Operations to Set Service Parameters

Operation	Description
service_name	The service name the *Replier* offers and *Requesters* use to match.
request_topic_name	Sets a specific request *Topic* name.
reply_topic_name	Sets a specific reply *Topic* name.
datawriter_qos	Sets the Quality of Service of the reply *DataWriter*.
datareader_qos	Sets the Quality of Service of the reply *DataReader*.
publisher	Sets a specific *Publisher*.
subscriber	Sets a specific *Subscriber*.

Operation	Description
request_type	The request type, when DynamicData is used.
reply_type	The reply type, when DynamicData is used.

28.2 RPC Client

A *client* allows making remote function calls to the *services* that it is subscribed to, and receives the results to those calls from those *services*. To communicate, a *client* and a *service* must use the same *service* name, and be associated with the same DDS **domain_id**.

A *client* has an associated *Requester*. All the entities required by the *Requester*—including the *DomainParticipant*, the request and reply *Topics*, the *DataWriter* for writing the requests, and a *DataReader* for reading replies—are automatically created when the *client* is created.

You can configure the QoS for the underlying *DataWriter* and *DataReader* by setting them either in the *DomainParticipant* that the client is using or in a QoS Profile.

A client is also defined as an interface in IDL with the annotation @DDSService or @service.

28.2.1 Creating a Client

To create a *client/Requester*, you need a ClientParams, a *DomainParticipant*, and a *service* name:

```
dds::domain::DomainParticipant client_participant(domain_id);
dds::rpc::ClientParams client_params(client_participant);
client_params.service_name("Example RobotControl Service");
```

The **service_name** function is used to generate the names of the request and reply *Topics* that the internal *Requester* and *Replier* will use to communicate. For example, if the service name is "MyService", the *Topic* names for the *Requester* and *Replier* will be "MyServiceRequest" and "MyServiceReply", respectively. Therefore, for communication to occur, you must use the same service name when creating the *Requester* and the *Replier* entities. If you want to use *Topic* names different from the ones that would be derived from the ServiceName, you can override the default names by setting the actual request and reply *Topic* names using the **request_topic_name()** and **reply_topic_name()** accessors to the RequesterParams structure prior to creating the *Requester*.

To create a client, use the constructor that receives the ClientParams:

```
RobotControlClient client(client_params);
```

Once you have created a client, you can use it to perform the operations in Table 28.5 Client Operations.

28.2.2 Setting the Client Parameters

To change the ClientParams that can be used when creating a *client/Requester*, you can use the operations listed in Table 28.4 Operations to Set Client Parameters.

Table 28.4 Operations to Set Client Parameters

Operation	Description
function_call_max_wait	Specifies the maximum wait time for all the remote calls.
service_name	The service name that *Replier* and *Requesters* use to match and communicate.
request_topic_name	Sets a specific request *Topic* name.
reply_topic_name	Sets a specific reply *Topic* name.
datawriter_qos	Sets the Quality of Service of the request *DataWriter*.
datareader_qos	Sets the Quality of Service of the request *DataReader*.
publisher	Sets a specific *Publisher*.
subscriber	Sets a specific *Subscriber*.
request_type	The request type, when DynamicData is used.
reply_type	The reply type, when DynamicData is used.

28.2.3 Summary of Client Operations

There are several kinds of operations an application can perform using the *client/Requester*:

- Waiting for service to be discovered
- Making remote function calls (synchronous or asynchronous)

The Client operations are summarized in Table 28.5 Client Operations.

The <operation_name> comes from the IDL file. In the example IDL file in 28.1 RPC Service on page 1009, the client will have an operation with the same name as **void command(Command com)**. In the case of an attribute, such as **attribute long test**, the client in C++ will have two operations, named **long get_operation_test();** and **void set_operation_test(long test);**. The <attribute_name> is defined by adding 'attribute' before its type: **attribute <type> <name>**, such as **attribute long test**.

Table 28.5 Client Operations

Operation		Description	Reference
Waiting for Service	wait_for_service	Waits for services.	28.2.3.1 Waiting for Services on the next page

Operation		Description	Reference
Sending Request	<operation_name>	Makes a synchronous remote function call.	28.2.3.2 Making Remote Function Calls below
	<get/set>_attribute_<attribute_name>		
	<operation_name>_async	Makes an asynchronous remote function call.	
	<get/set>_attribute_<attribute_name>_async		
Getting Underlying Entities	request_datawriter	Retrieves the underlying *DataWriter* that sends the request.	28.3 Accessing Underlying DataWriters and DataReaders on the next page
	reply_datareader	Retrieves the underlying *DataReader* that receives the replies.	

28.2.3.1 Waiting for Services

The *client/Requester* provides two operations that can be used to wait for services:

- **wait_for_service (const dds::core::Duration &maxWait)**
- **wait_for_service ()**

The first operation blocks until one service is available or until **maxWait** time has passed, whichever comes first. The second operation blocks until one service is available for an unlimited period of time.

28.2.3.2 Making Remote Function Calls

To send a request, use the operations and attributes defined in the interface:

- **<operation_name>(<args>)**
- **get_attribute_<attribute_name>(<args>)**
- **set_attribute_<attribute_name>(<args>)**

These functions block the *client* until the *service* sends a reply.

The client also provides asynchronous functions that don't block the client:

- **<operation_name>_async(<args>)**
- **get_attribute_<attribute_name>_async(<args>)**
- **set_attribute_<attribute_name>_async(<args>)**

Asynchronous functions return a **std::future** that will contain the result when it's received:

```
std::future<float> future_speed = client.getSpeed_async();
...
std::cout << "Current speed is " << future_speed.get() << std::endl;
```

The call to **std::future::get()** provides the result if it's already available or blocks until it is.

28.3 Accessing Underlying DataWriters and DataReaders

Both *client* and *service* entities have underlying DDS *DataWriter* and *DataReader* entities. These are created automatically when the *client* and *service* are constructed.

Accessing the *DataWriter* used by a *client* may be useful for a number of advanced use cases, such as:

- Finding matching subscriptions (i.e., *service* entities), see 7.3.16.1 Finding Matching Subscriptions on page 341.
- Setting a *DataWriterListener*, see 7.3.4 Setting Up DataWriterListeners on page 293.
- Getting *DataWriter* protocol or cache statuses, see 7.3.6 Statuses for DataWriters on page 295.
- Flushing a data batch after sending a number of request samples, see 7.3.9 Flushing Batches of DDS Data Samples on page 314.
- Modifying the QoS.

Accessing the service *DataReader* may be useful for a number of advanced use cases, such as:

- Finding matching publications (i.e., *client* entities), see 8.3.10.1 Finding Matching Publications on page 546.
- Getting *DataReader* protocol or cache statuses, see 8.3.5 Checking DataReader Status and StatusConditions on page 511 and 8.3.7 Statuses for DataReaders on page 513.
- Modifying the QoS.

To access these underlying objects:

- **dds::pub::DataWriter<RequestType> request_datawriter()**
- **dds::sub::DataReader<ReplyType> reply_datareader()**
- **dds::pub::DataWriter<ReplyType> reply_datawriter()**
- **dds::sub::DataReader<RequestType> request_datareader()**

28.4 Generating RPC Code from IDL using RTI Code Generator

To use RPC, add the @DDSService or @service annotation to an interface in an IDL file. For example:

```
module robot {
    exception TooFast {};
```

```
    enum Command { START_COMMAND, STOP_COMMAND };
    struct Status {
        string msg;
    };

    @DDSService
    interface RobotControl {
        void command(Command com);
        float setSpeed(float speed) raises (TooFast);
        float getSpeed();
        void getStatus(out Status status);
    };
}; //module robot
```

This IDL file defines an interface with four methods:

- *command* receives one argument and returns nothing.
- *setSpeed* receives one argument, returns a *float*, and can throw a *TooFast* exception.
- *getSpeed* receives no argument and returns a *float*.
- *getStatus* receives one output argument and returns nothing.

To generate the supporting code and example *client* and *service* applications, run *RTI Code Generator* as follows:

```
rtiddsgen -language C++11 -example <architecture> <IDL file name>.idl
```

This will generate:

- **<IDL file name>.hpp**, **<IDL file name>.cxx**, **<IDL file name>Plugin.hpp**, **<IDL file name>Plugin.cxx**. These files contain the support code for the type defined in the IDL.
- **<IDL file name>_service.cxx** contains the example service application, and the service implementation.
- **<IDL file name>_client.cxx** contains the example client application.

For more information and an example, see the RPC Tutorial in the RTI Connext Modern C++ API Reference HTML documentation.

Part 5: RTI Real-Time WAN Transport

Real-Time WAN Transport is a *Connext DDS* transport plugin that enables communication over wide area networks (WANs) using UDP as the underlying IP transport-layer protocol.

> The material in this part of the manual is only relevant if you have installed *Real-Time WAN Transport*. This feature is not installed as part of a *Connext DDS* package; it must be downloaded and installed separately. See the RTI Real-Time WAN Transport Installation Guide for details.

> All new applications that communicate over wide area networks using UDP should use *Real-Time WAN Transport*. This release includes *RTI Secure WAN Transport* (described in Part 6: RTI Secure WAN Transport on page 1089) only for compatibility with existing applications, which should upgrade to *Real-Time WAN Transport*. RTI may not support *Secure WAN Transport* in future versions of *Connext DDS* and no longer provides it to new customers.

This section includes:

- Introduction to Real-Time WAN Transport (Chapter 29 on page 1019)
- Transport Capabilities (Chapter 30 on page 1022)
- Communication Scenarios (Chapter 31 on page 1029)
- Deployment Scenarios (Chapter 32 on page 1035)
- Enabling Real-Time WAN Transport (Chapter 33 on page 1047)
- Transport Initial Peers (Chapter 34 on page 1049)
- Transport Configuration (Chapter 35 on page 1051)
- Security (Chapter 36 on page 1067)
- Advanced Concepts (Chapter 37 on page 1068)
- Transport Debugging (Chapter 38 on page 1076)
- Troubleshooting (Chapter 40 on page 1085)

Chapter 29 Introduction to Real-Time WAN Transport

Real-Time WAN Transport is a smart transport that enables secure, scalable, and high-performance communication over wide area networks (WANs), including public networks. It extends *Connext DDS* capabilities to WAN environments. *Real-Time WAN Transport* uses UDP as the underlying IP transport-layer protocol to better anticipate and adapt to the challenges of diverse network conditions, device mobility, and the dynamic nature of WAN system architectures.

Real-Time WAN Transport, in combination with *RTI Cloud Discovery Service*, provides a complete, seamless solution out of the box for WAN connectivity. This WAN connectivity solution, including *Real-Time WAN Transport* and *Cloud Discovery Service*, is available as an optional add-on.

Real-Time WAN Transport replaces the transport capabilities of the *Secure WAN Transport* optionally available with previous *Connext DDS* releases, and provides the following capabilities:

- **NAT (Network Address Translator) traversal:** Ability to communicate between *DomainParticipants* running in a Local Area Network (LAN) that is behind a NAT-enabled router, and *DomainParticipants* on the outside of the NAT across a WAN. This functionality is provided in combination with *Cloud Discovery Service* (see 30.1 NAT Traversal on page 1022).
- **IP mobility:** Support for network transitions and changes in IP addresses in any of the *DomainParticipants* participating in the communication (see 30.2 IP Mobility on page 1027).
- **Security:** Secure communications between *DomainParticipants* using *Security Plugins* (see Chapter 36 Security on page 1067).

Real-Time WAN Transport does not require third-party components, such as STUN servers, or protocols like SIP to handle session establishment. Using a single API and security model, you can leverage the extensive capabilities of the *Connext DDS* framework and ecosystem, including tools

and infrastructure services, even for real-time connectivity from edge to cloud and back in highly distributed systems that communicate across wide area networks.

For *Real-Time WAN Transport* example code, see https://github.com/rticommunity/rticonnextdds-examples/tree/develop/examples/connext_dds/real_time_wan_transport.

29.1 Key Terms

29.1.1 Basic Terms

Wide Area Network (WAN): A wide area network (WAN) is a collection of local area networks (LANs) or other networks that communicate with one another. A WAN is essentially a network of networks, with the Internet being the world's largest WAN.

Cellular Network (or Cellular WAN): A cellular network is a wide area network for voice and data that is typically provided by the cellular carriers to transmit a wireless signal over a range of several miles to a mobile device.

External DomainParticipant: A *DomainParticipant* using a *Real-Time WAN Transport* that is publicly reachable at a public address. Being reachable at a public IP address does not mean that the *DomainParticipant* is not behind a NAT-enabled router. It is possible that an external *DomainParticipant* is behind a NAT-enabled router if the network administrator configures a static NAT mapping between the *DomainParticipant* private address and a public address.

29.1.2 IP Address Types

IP Transport Address (or Address): The combination of the IPv4 address and the UDP Port where an application accepts incoming traffic. Sometimes you will also see the term "address" being used to refer to an IP transport address when the context is clear.

External IP Transport Address (or External Address or Public Address): An IP transport address that is routable on a WAN. When the WAN is the Internet, the term "Internet-routable address" can be used instead.

Private IP Transport Address (or Private Address or Internal Address): The IP transport address of an application that sits behind a NAT. This address is not reachable from external applications running outside the NAT.

Service Reflexive Address: The public IP transport address that *Cloud Discovery Service* obtains for a UUID locator contained in the participant announcement sent by a *DomainParticipant*.

29.1.3 Locators

RTPS Locator (or Locator): A *Connext DDS* endpoint (*DataWriter* or *DataReader*) address unit that consists of a transport class, RTPS port, and locator transport address (128-bit).

Reachable Locator: Locator associated with a DDS endpoint (*DataWriter* or *DataReader*) to which another DDS endpoint can send data.

RTPS UUID WAN Locator (or UUID Locator): A WAN locator for a *Real-Time WAN Transport* that is not reachable. UUID locators are transformed into UUID+PUBLIC locators by associating a public IP transport address to the UUID.

RTPS UUID+PUBLIC WAN Locator (or UUID+PUBLIC Locator): A WAN locator for a *Real-Time WAN Transport* that is reachable. The locator encapsulates a public IP transport address as part of the locator address.

29.1.4 WAN Ecosystem

Session Traversal Utilities for NAT (STUN): Standardized set of methods, including a network protocol, for traversal of network address translator gateways in applications of real-time voice, video, messaging, and other interactive communications.

STUN Server: A STUN server enables clients to find out their public IP transport address and NAT type.

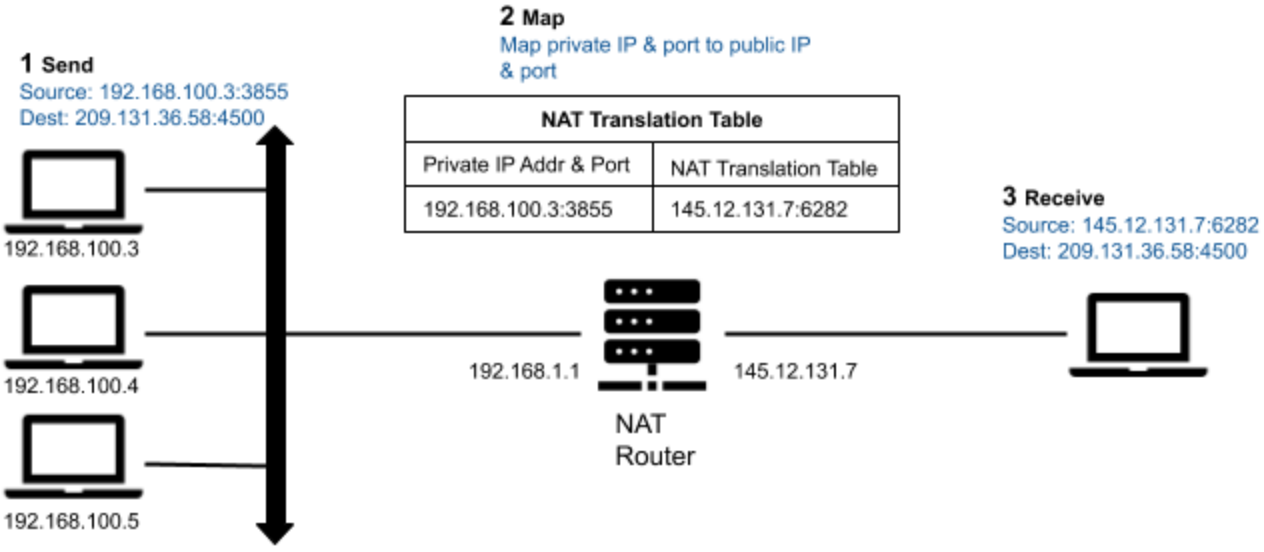
Interactive Connectivity Establishment (ICE): ICE is a protocol used for NAT traversal. ICE uses a combination of methods including STUN and Traversal Using Relay NAT (TURN) to traverse NATs.

Chapter 30 Transport Capabilities

30.1 NAT Traversal

In WAN environments, applications running behind a NAT-enabled router typically need to communicate with applications running behind a different NAT-enabled router. NAT (Network Address Translation) is a method of remapping one private IP address and port into a public IP address and port by modifying the IP address and port information in the IP header of the packets while they are in transit across a NAT-enabled router. The technique has become a popular and essential tool in conserving the IPv4 global address space in the face of IPv4 address exhaustion. Many applications with individual private IP addresses can utilize a NAT-enabled router to communicate with external applications using a single public IP address.

Figure 30.1: NAT Traversal



Real-Time WAN Transport in combination with *Cloud Discovery Service* will enable communications between *Connext DDS* applications running between different kinds of NATs. For information on the various NAT kinds, please see the following sections.

30.1.1 NAT Kinds

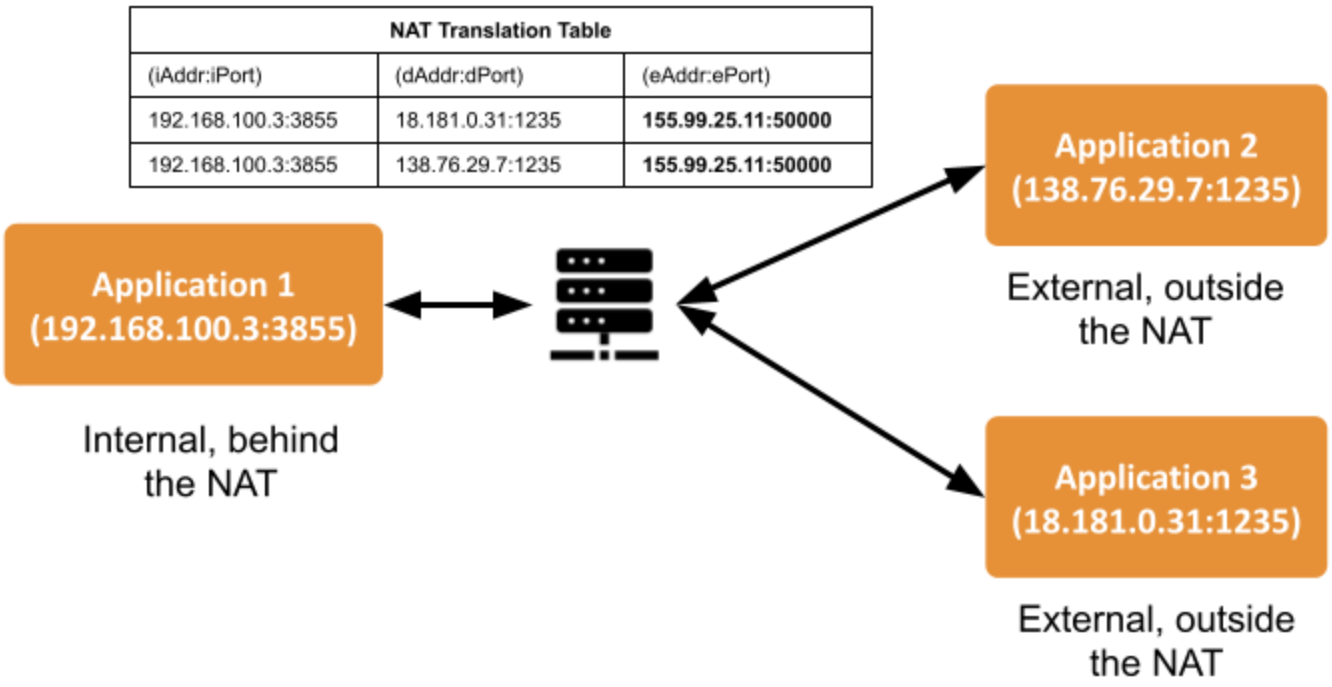
There are four kinds of NATs:

30.1.1.1 Full-Cone NAT (or One-to-One NAT)

A full-cone NAT, also known as a one-to-one NAT, has the following characteristics:

- Once an internal address (iAddr:iPort) is mapped to an external address (eAddr:ePort) by the NAT router, any packets from (iAddr:iPort) are sent through (eAddr:ePort).
- Any external host can send packets to (iAddr:iPort) by sending packets to (eAddr:ePort), regardless of the external host address/port (dAddr:dPort) used to send the packets.

Figure 30.2: Full-Cone NAT



30.1.1.2 Address-Restricted-Cone NAT

- Once an internal address (iAddr:iPort) is mapped to an external address (eAddr:ePort) by the NAT router, any packets from (iAddr:iPort) are sent through eAddr:ePort.
- An external host (dAddr:any) can send packets to (iAddr:iPort) by sending packets to (eAddr:ePort) only if (iAddr:iPort) has previously sent a packet to (dAddr:any). "Any" means the port number doesn't matter.

30.1.1.3 Port-Restricted Cone NAT

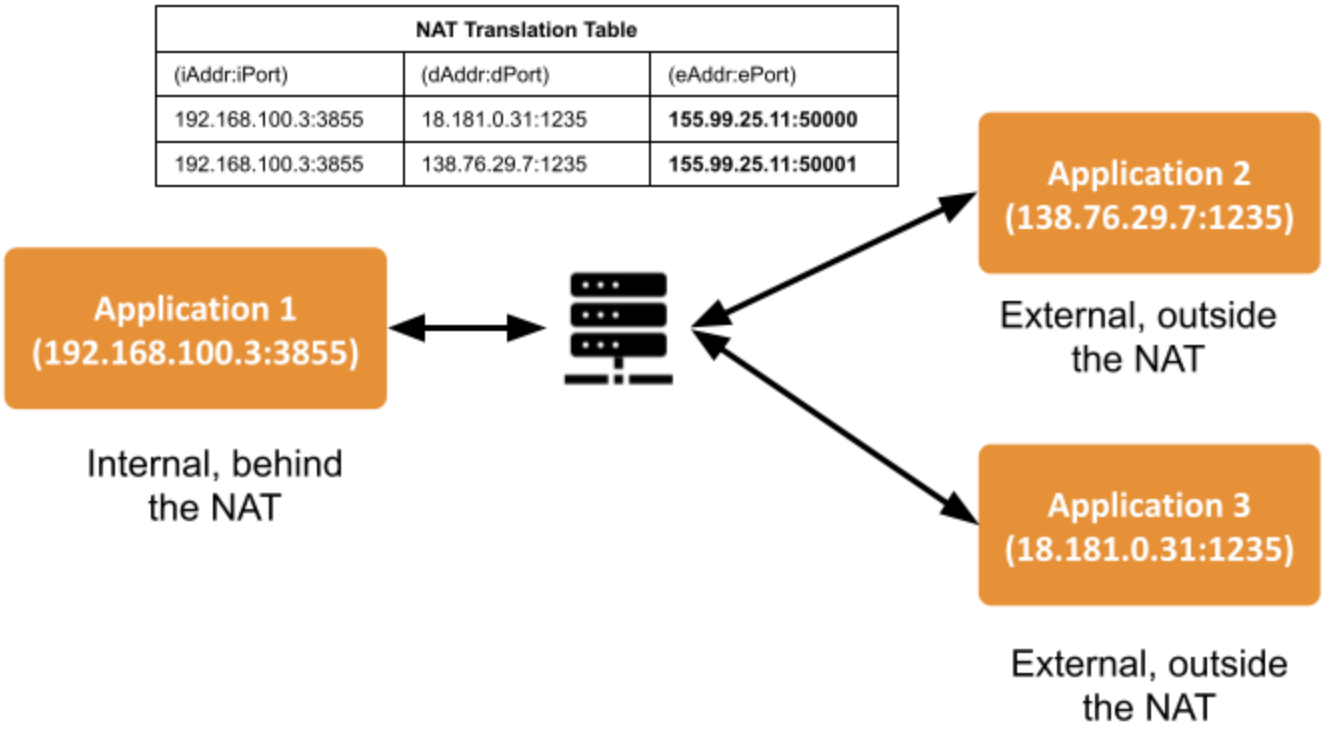
This NAT is similar to an address-restricted cone NAT, but the restriction also includes port numbers.

- Once an internal address (iAddr:iPort) is mapped to an external address (eAddr:ePort) by the NAT router, any packets from (iAddr:iPort) are sent through (eAddr:ePort).
- An external host (dAddr:dPort) can send packets to (iAddr:iPort) by sending packets to (eAddr:ePort) only if (iAddr:iPort) has previously sent a packet to (dAddr:dPort).

30.1.1.4 Symmetric NAT

- Each request from the same internal IP address and port (iAddr:iPort) to a specific destination IP address and port (dAddr:dPort) is mapped by the NAT router to a unique external source IP address and port (eAddr:ePort). If the same internal host sends a packet even with the same source address and port but to a different destination, a different mapping is used.
- Only an external host that receives a packet from an internal host can send a packet back.

Figure 30.3: Symmetric NAT



30.1.2 Identifying the NAT Type

There are multiple third-party utilities that you can download to find out the NAT type. One example is *natat* (https://github.com/songjiayang/natat).

```
> ./natat
2020/11/21 11:10:52 start stun server ping...
2020/11/21 11:10:53 stun.l.google.com:19302 mapped: 0.0.0.0:3489 -> 99.35.17.233:3489
2020/11/21 11:10:53 stun1.l.google.com:19302 mapped: 0.0.0.0:3489 -> 99.35.17.233:3489
2020/11/21 11:10:53 start NAT type assert...
2020/11/21 11:10:53 It's Cone NAT
```

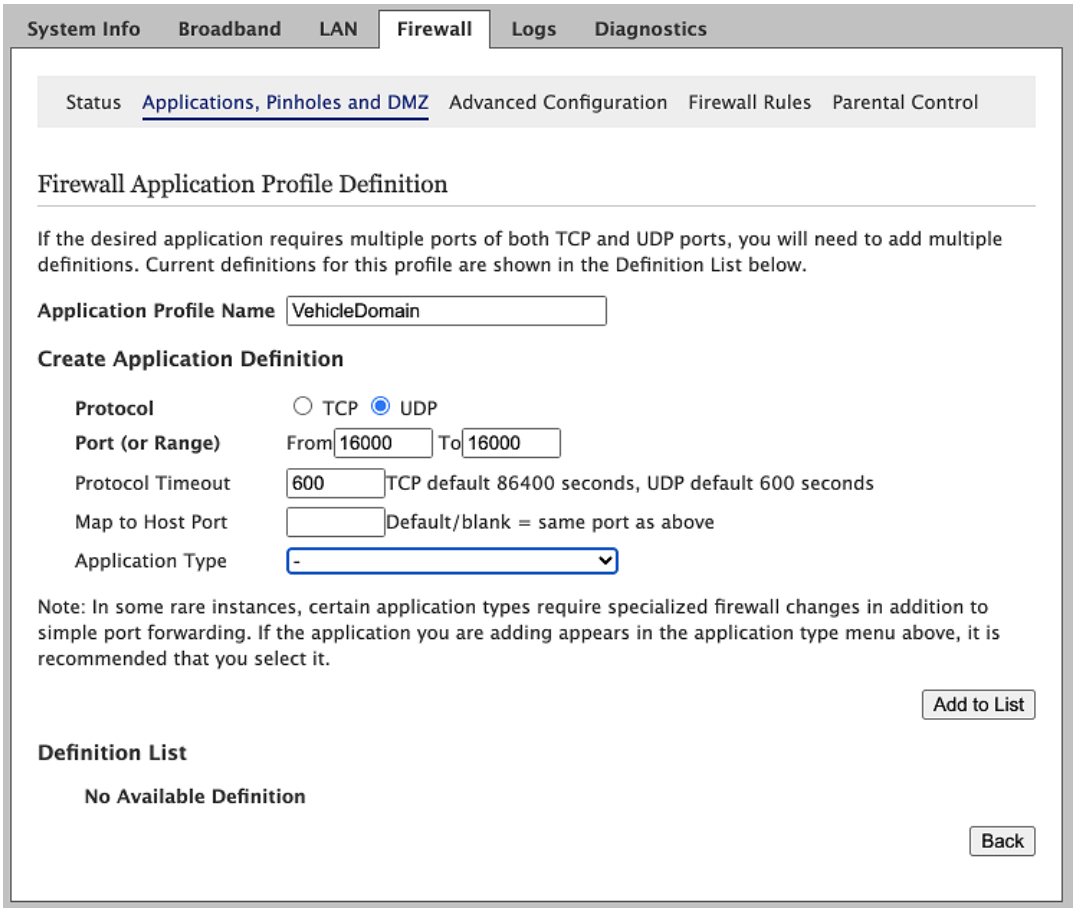
30.1.3 NAT Bindings

Applications behind a NAT cannot receive data from applications outside the NAT unless they open a UDP NAT binding (or UDP hole) with each one of the public IP transport addresses associated with the applications running outside the NAT.

A NAT binding creates a mapping between a private IP transport address (iAddr:iPort) and a public IP transport address (eAddr:ePort) for a given set of destination IP transport addresses. There are two kinds of bindings:

- **Static bindings (also known as port forwarding):** You can set the configuration of a NAT-enabled router to map (iAddr:iPort) to (eAddr:ePort) (see Figure 30.4: Open a Static Binding in a NAT-Enabled Router below) for all destination addresses. These bindings allow incoming traffic from any external IP transport address.
- **Dynamic bindings:** The bindings are opened dynamically when the application running inside the NAT sends a message to a destination IP transport address outside the NAT. The behavior of the dynamic bindings depends on the type of NAT (see 30.1.1 NAT Kinds on page 1023). Unlike static bindings, dynamic bindings can expire if there is no outgoing traffic (see 30.1.4 NAT Bindings Expiration below).

Figure 30.4: Open a Static Binding in a NAT-Enabled Router



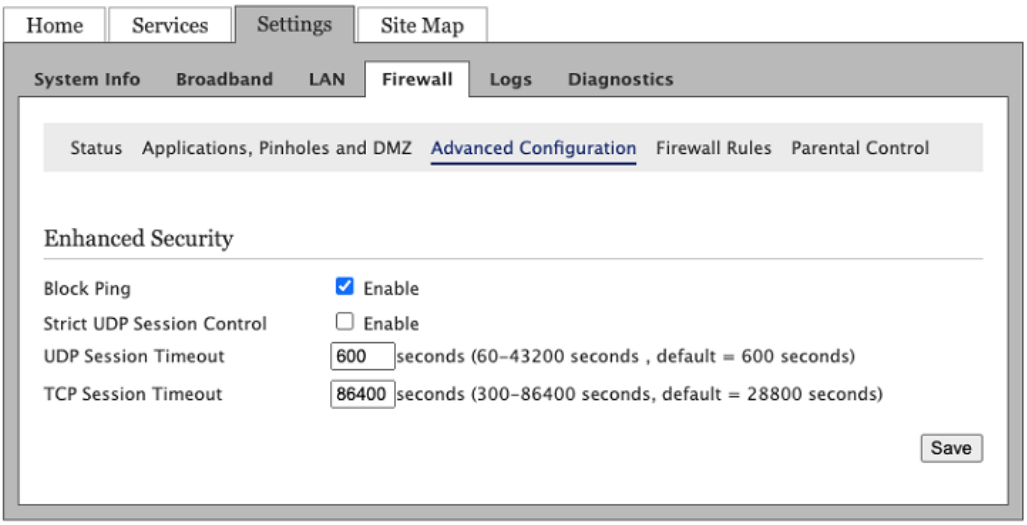
30.1.4 NAT Bindings Expiration

Real-Time WAN Transport will be able to establish new NAT bindings if the old bindings are closed by the NAT-enabled router without any user intervention. In addition, *Real-Time WAN Transport* provides a builtin **Ping** mechanism to keep the NAT bindings open at all times. This

capability eliminates the latency penalty that is introduced during the process of establishing a new NAT binding.

For security purposes, in the absence of outbound traffic, the NAT binding from an internal address (iAddr:iPort) to an external address (eAddr:ePort) usually expires after periods of time in the range of tens of seconds to a few minutes. When it expires, the NAT binding is removed and it closes. The expiration time can usually be configured (see Figure 30.5: Session Timeout below).

Figure 30.5: Session Timeout



30.1.5 NAT Hairpinning

Real-Time WAN Transport does not require support for NAT hairpinning and can be used in combination with the builtin UDPv4 transport in a *DomainParticipant* to support both communication with *DomainParticipants* within the same LAN and communication with *DomainParticipants* in a WAN simultaneously.

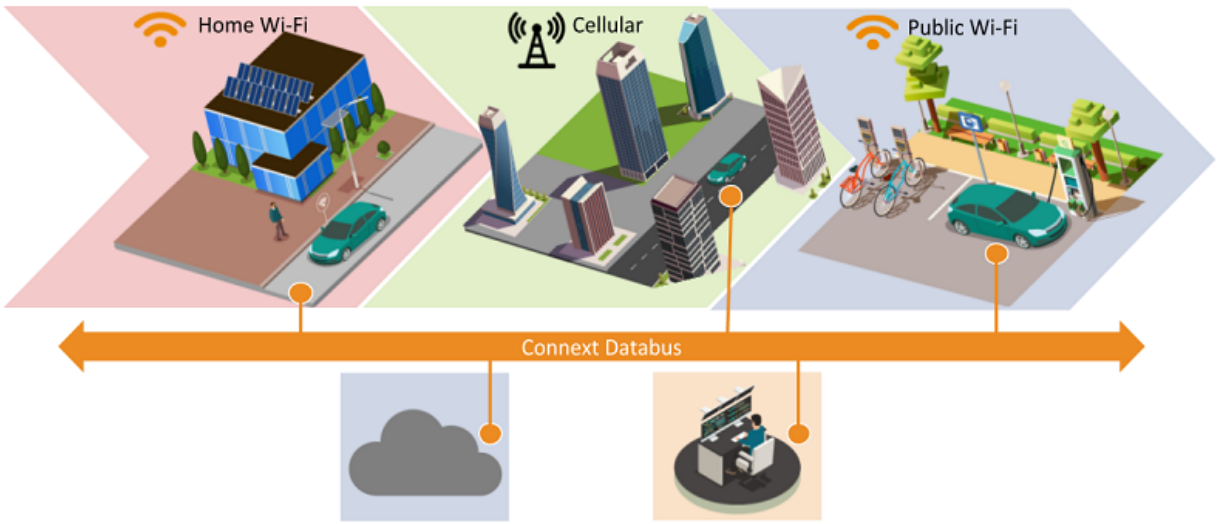
In network computing, hairpinning (or NAT loopback) refers to communication between two hosts behind the same NAT router using their mapped external address (eAddr:ePort). Because not all NAT routers support this communication configuration, usually applications must be designed to be aware of it.

30.2 IP Mobility

Real-Time WAN Transport automatically and transparently handles the IP address changes in the applications communicating over the WAN, without any application intervention.

In WAN communication scenarios, it is common for applications to roam among different networks, changing their IP addresses. For example, assume the following scenario:

Figure 30.6: Network Transition



Connectivity continues with the vehicle while it transitions between different networks as it drives from one point to another in the city

Chapter 31 Communication Scenarios

Real-Time WAN Transport can be used to address two basic communication scenarios between *Connext DDS DomainParticipants*.

31.1 Peer-to-Peer Communication with a Participant that has a Public Address

In this scenario, one or more *DomainParticipants* behind any kind of NAT (including symmetric NATs) communicate with a *DomainParticipant* with a well-known public IP transport address (see Figure 31.1: Peer-to-Peer between a Participant behind Any Kind of NAT and an External Participant below).

Figure 31.1: Peer-to-Peer between a Participant behind Any Kind of NAT and an External Participant

Note that *Cloud Discovery Service* (CDS) is not needed to facilitate NAT traversal in this scenario because the external *DomainParticipant* can figure out the public IP transport addresses at which the Internal Participant is reachable by looking at the UDP packets coming from the Internal Participant.

The external *DomainParticipant* must be reachable at a well-known public address (50.10.23.45:2345 in this example). What this means is that the address must be routable on the WAN.

There are two configurations that allow the association of External Participant with a well-known public address:

- **Sub-Scenario 1:** The *DomainParticipant* is associated directly with the public address 50.10.23.45:2345, or

- **Sub-Scenario 2:** The *DomainParticipant* is behind a NAT-enabled router in which you have created a static NAT mapping from the *DomainParticipant* private IP transport address 192.168.1.1:1234 to the public IP transport address 50.10.23.45:2345.

For a detailed description of how the communication establishment protocol works in this scenario, see 37.4 Communication Establishment Protocol for Peer-to-Peer Communication with a Participant that has a Public Address on page 1073.

The following section provides an example configuration for the scenario described in Figure 31.1: Peer-to-Peer between a Participant behind Any Kind of NAT and an External Participant on the previous page.

31.1.1 External Participant Configuration: Sub-Scenario 1

```
<dds>
    <qos_profile name="ExternalParticipant">
        <domain_participant_qos>
            <transport_builtin>
                <mask>UDPv4_WAN</mask>
                <udpv4_wan>
                    <public_address>50.10.23.45</public_address>
                    <comm_ports>
                        <default>
                            <host>2345</host>
                        </default>
                    </comm_ports>
                </udpv4_wan>
            </transport_builtin>
        </domain_participant_qos>
    </qos_profile>
</dds>
```

- To enable *Real-Time WAN Transport*, <mask> within <transport_builtin> must contain UDPv4_WAN.
- <public_address> contains the IP address of the host where the external *DomainParticipant* is running.
- <comm_ports> defines the port (<host>) in which the external *DomainParticipant* receives/sends data.

31.1.2 External Participant Configuration: Sub-Scenario 2

```
<dds>
    <qos_profile name="ExternalParticipant">
        <domain_participant_qos>
            <transport_builtin>
                <mask>UDPv4_WAN</mask>
                <udpv4_wan>
                    <public_address>50.10.23.45</public_address>
                    <comm_ports>
                        <default>
```

```
                            <host>1234</host>
                            <public>2345</public>
                        </default>
                    </comm_ports>
                </udpv4_wan>
            </transport_builtin>
        </domain_participant_qos>
    </qos_profile>
</dds>
```

- To enable *Real-Time WAN Transport*, <mask> within <transport_builtin> must contain UDPv4_WAN.
- <public_address> contains the public IP address in the NAT-enabled router to which the private IP address is mapped.
- <comm_ports> defines the mapping between the following ports:
  - <host>: local UDP port in which the external *DomainParticipant* receives/sends data in the machine where it is running.
  - <public>: public port to which the local UDP port is mapped in the NAT-enabled router.

31.1.3 Internal Participants Configuration

```
<dds>
    <qos_profile name="InternalParticipant">
        <domain_participant_qos>
            <transport_builtin>
                <mask>UDPv4_WAN</mask>
            </transport_builtin>
            <discovery>
                <initial_peers>
                    <element>0@udpv4_wan://50.10.23.45:2345</element>
                </initial_peers>
            </discovery>
        </domain_participant_qos>
    </qos_profile>
</dds>
```

- To enable *Real-Time WAN Transport*, <mask> within <transport_builtin> must contain UDPv4_WAN.
- In addition, the InternalParticipant must set its initial peers to point to the external *DomainParticipant* public address.

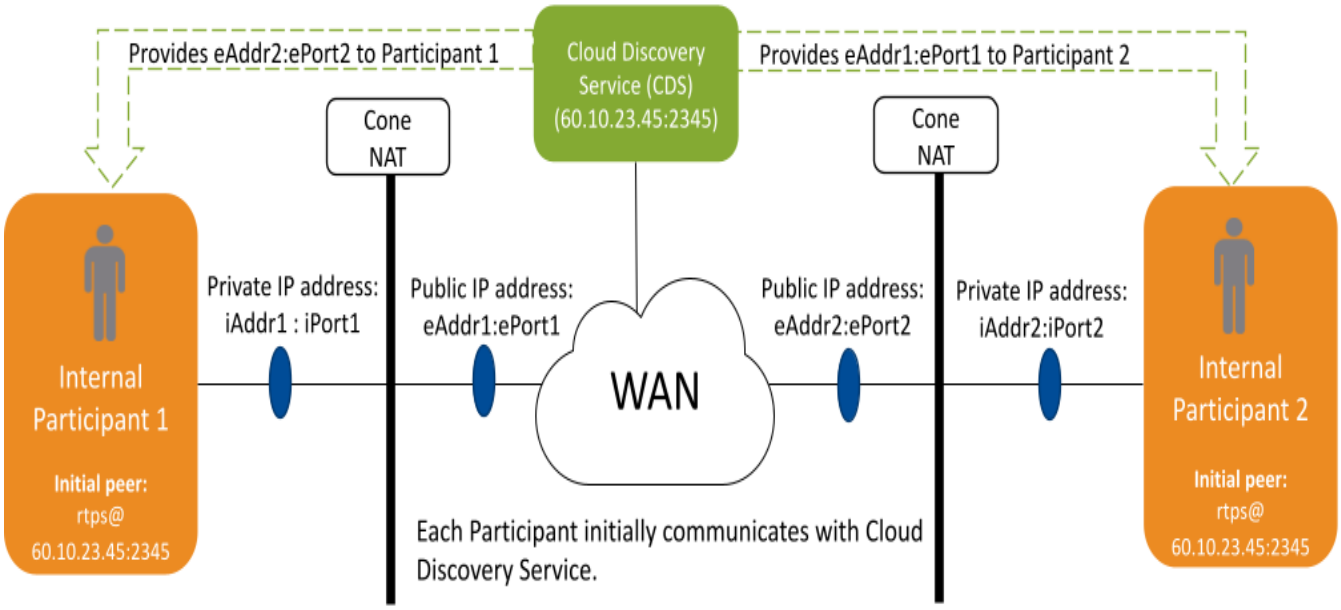
31.2 Peer-to-Peer Communication with Participants behind Cone NATs Using Cloud Discovery Service

In this communication scenario, all the *DomainParticipants* communicating over a WAN are behind cone NATs (see Figure 31.2: Peer-to-Peer between Participants behind Cone NATs on the next page).

This scenario requires *Cloud Discovery Service* (CDS) to map the private addresses of a *DomainParticipant* into public addresses (called service reflexive addresses) and to provide these public addresses to other *DomainParticipants* so that they can start communicating with the *DomainParticipant* peer-to-peer.

In this scenario, CDS must be reachable at a well-known public address, and the *DomainParticipants* participating in the communication must include the CDS address in their initial peers.

Figure 31.2: Peer-to-Peer between Participants behind Cone NATs



Cloud Discovery Service also serves as a directory, so that a participant only needs to know about the CDS public address to connect to multiple peers automatically.

The service reflexive addresses obtained by CDS are provided as part of the WAN locators contained in the participant announcement sent from CDS to the application *DomainParticipants*.

In Figure 31.2: Peer-to-Peer between Participants behind Cone NATs above, eAddr2:ePort2 is the service reflexive address that CDS obtains for Internal Participant 2, and eAddr1:ePort1 is the service reflexive address that CDS obtains for Internal Participant 1. CDS provides eAddr2:ePort2 to the Internal Participant 1 so that it can reach the Internal Participant 2; it provides eAddr1:ePort1 to the Internal Participant 2 so that it can reach the Internal Participant 1.

For a detailed description of how the communication establishment protocol works in this scenario, see 37.3 Communication Establishment Protocol for Peer-to-Peer Communication with Participants behind Cone NATs on page 1070.

The following section provides an example configuration for the scenario described in Figure 31.2: Peer-to-Peer between Participants behind Cone NATs on the previous page.

31.2.1 Internal Participants Configuration

```
<dds>
    <qos_profile name="InternalParticipant">
        <domain_participant_qos>
            <transport_builtin>
                <mask>UDPv4_WAN</mask>
            </transport_builtin>
            <discovery>
                <initial_peers>
                    <element>rtps@udpv4_wan://60.10.23.45:2345</element>
                </initial_peers>
            </discovery>
        </domain_participant_qos>
    </qos_profile>
</dds>
```

- To enable the *Real-Time WAN Transport*, specify the transport in <transport_builtin>/<mask> as UDPv4_WAN.
- When you specify the initial peers of the InternalParticipant in <initial peers>/<element>, use the public address of the *Cloud Discovery Service*.

31.2.2 Cloud Discovery Service Configuration

```
<dds>
    <cloud_discovery_service name="CDS">
        <transport>
            <element>
                <alias>builtin.udpv4_wan</alias>
                <receive_port>2345</receive_port>
                <property>
                    <element>
                        <name>dds.transport.UDPv4_WAN.builtin.public_address</name>
                        <value>60.10.23.45</value>
                    </element>
                </property>
            </element>
        </transport>
    </cloud_discovery_service>
</dds>
```

- To enable *Real-Time WAN Transport* in CDS, set <alias> to builtin.udpv4_wan.
- <receive_port> contains the public UDP port in which CDS is reachable by the *DomainParticipants*.

- dds.transport.UDPv4.builtin.public_address contains the public IP address in which CDS is reachable by the *DomainParticipants*.

For additional details on each one of the parameters of the CDS instance configuration, see the *RTI Cloud Discovery Service* documentation.

As described above, CDS must be reachable in a well-known public address, in this example 60.10.23.45:2345. A "well-known" public address is an address that is routable on the WAN.

There are two configurations that allow the association of CDS with a well-known public address:

1. The CDS network interface card (NIC) is associated directly with the public address.
2. CDS is behind a NAT-enabled router, and you have created a static NAT mapping from the CDS private address iAddr:iPort to the public address 60.10.23.45:2345.

If CDS is behind a NAT-enabled router, the host port (iPort) must be the same as the <receive_port> (2345). If you want to use a different host port, it will be necessary to configure the property **dds.transport.UDPv4_WAN.builtin.comm_ports** (35.2.1.1 Changing the UDP Port Mapping on page 1062).

As described above, this communication scenario requires that all the *DomainParticipants* participating in the communication are behind cone NATs. Communication is not possible if any of them is behind a symmetric NAT. Therefore, it is mandatory that you verify the type of NAT in which the applications run. See 30.1.2 Identifying the NAT Type on page 1025.

Chapter 32 Deployment Scenarios

The communication scenarios described in Chapter 31 Communication Scenarios on page 1029 provide the building blocks for WAN communication using *Real-Time WAN Transport*. However, they do not take into consideration important communication aspects such as scalability.

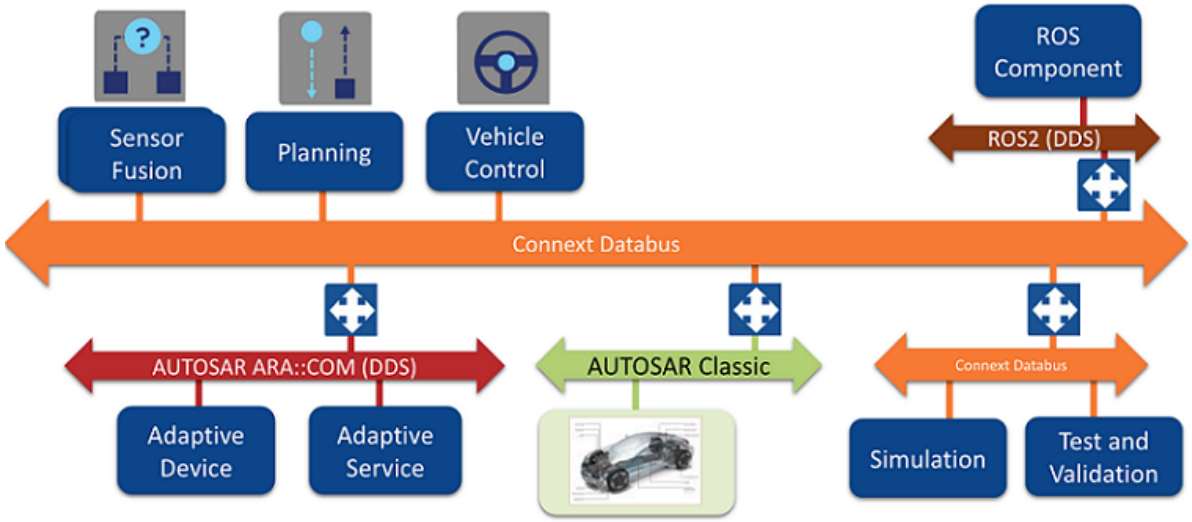
The intent of this section is to describe some of the most common deployment scenarios for *Real-Time WAN Transport*.

32.1 Edge-to-Data Center Deployment Scenario

In traditional *Connext DDS* applications, most of the data processing is done on the edge devices. However, as these applications are distributed across the WAN, it becomes necessary to move some computation and storage to data centers or clouds.

Consider the use case of autonomous driving technology. In this scenario, each vehicle has one or more internal Connext databuses in which different applications run to provide capabilities such as sensor fusion, path planning, vehicle control, and so on.

Figure 32.1: In-Vehicle Edge Connext Databus



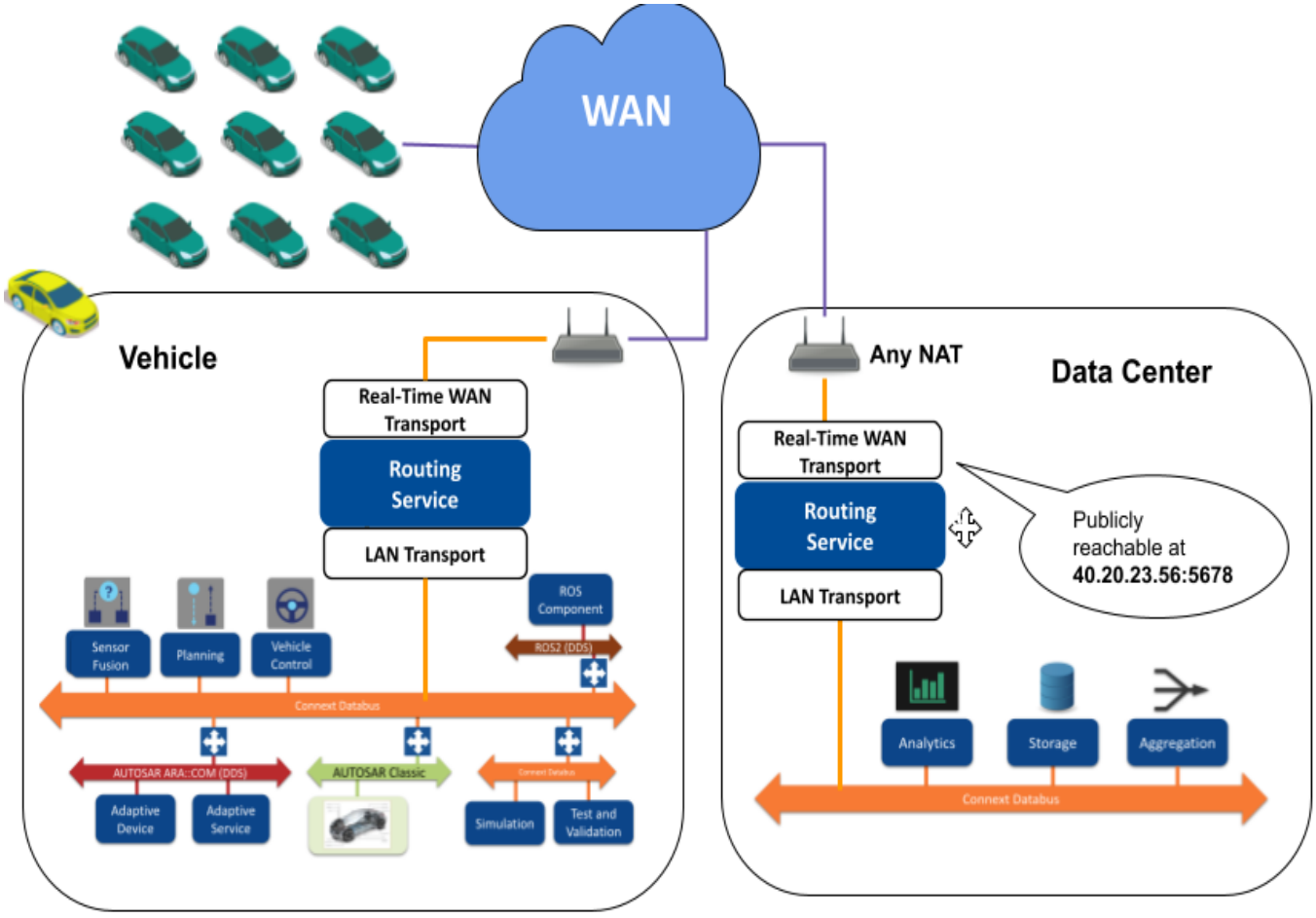
Some of the information generated in the Edge Connext Databus may have to be sent outside the vehicle to different data centers and/or clouds to support use cases such as data storage, data analytics, and others. Likewise, the vehicle may have to receive information from the data centers and/or cloud such as over-the-air (OTA) updates.

Instead of configuring a large number of *DomainParticipants* running inside the vehicle to use *Real-Time WAN Transport*, it is more scalable and secure to provide a gateway component within the vehicle whose main purpose is to send and receive the necessary information from the data centers. This gateway component is provided by *RTI Routing Service*.

There is also a gateway *Routing Service* instance running in the data center in order to send and receive information from the vehicles. That way it is not necessary to configure every *DomainParticipant* running in the data center to use *Real-Time WAN Transport*.

Figure 32.2: Edge-to-Data Center Communication on the next page shows the deployment scenario for a fleet of vehicles using a *Routing Service* in the vehicles and in the data center.

Figure 32.2: Edge-to-Data Center Communication



The following sections provide an example configuration for the scenario described in Figure 32.2: Edge-to-Data Center Communication above. The *Routing Service* instances are configured to propagate every *Topic*. However, in a real scenario only a subset of the *Topics* would be propagated.

32.1.1 Data Center Routing Service Configuration

```
<dds>
   <routing_service name="RS">
       <domain_route name="TwoWayDomainRoute">
           <participant name="0">
                <participant_qos>
                    <transport_builtin>
                        <mask>UDPv4</mask>
                    </transport_builtin>
                </participant_qos>
           </participant>

           <participant name="1">
               <participant_qos>
```

```
                    <transport_builtin>
                        <mask>UDPv4_WAN</mask>
                        <udpv4_wan>
                            <public_address>40.20.23.56</public_address>
                                <comm_ports>
                                    <default>
                                        <host>4500</host>
                                        <public>5678</public>
                                    </default>
                                </comm_ports>
                        </udpv4_wan>
                    </transport_builtin>
                </participant_qos>
            </participant>

            <session name="Session1">
                    <auto_topic_route name="AllForward">
                        <input participant="0">
                            <allow_topic_name_filter>*</allow_topic_name_filter>
                            <allow_registered_type_name_filter>*
                            </allow_registered_type_name_filter>
                        </input>
                        <output participant="1">
                            <allow_topic_name_filter>*</allow_topic_name_filter>
                            <allow_registered_type_name_filter>*
                            </allow_registered_type_name_filter>
                        </output>
                    </auto_topic_route>
            </session>

            <session name="Session2">
                    <auto_topic_route name="AllBackward">
                        <input participant="1">
                            <allow_topic_name_filter>*</allow_topic_name_filter>
                            <allow_registered_type_name_filter>*
                            </allow_registered_type_name_filter>
                        </input>
                        <output participant="0">
                            <allow_topic_name_filter>*</allow_topic_name_filter>
                            <allow_registered_type_name_filter>*
                            </allow_registered_type_name_filter>
                       </output>
                    </auto_topic_route>
            </session>

        </domain_route>
    </routing_service>
</dds>
```

Participant 0 in the domain route is the *DomainParticipant* that will be used to send/receive data from the internal *Connext* databus running in the data center network. The *DomainParticipant* is configured to use the builtin UDPv4 transport.

Participant 1 is used to send/receive data to/from the WAN, and it has the role of the External Participant described in Sub-scenario 2 in 31.1 Peer-to-Peer Communication with a Participant that has a Public Address on page 1029.

> **Note:** By making Participant 1 reachable at a well-known public address 40.20.23.56:5678 (by configuring the data center's NAT router to do port forwarding), the system doesn't depend on the kinds of NATs in the vehicles and the rest of the components in the system. Communication is always allowed.

32.1.2 In-Vehicle Routing Service Configuration

```
<dds>
    <routing_service name="RS">
        <domain_route name="TwoWayDomainRoute">
            <participant name="0">
                <participant_qos>
                    <transport_builtin>
                        <mask>UDPv4</mask>
                    </transport_builtin>
                </participant_qos>
            </participant>

            <participant name="1">
                <participant_qos>
                    <transport_builtin>
                        <mask>UDPv4_WAN</mask>
                    </transport_builtin>
                    <discovery>
                        <initial_peers>
                            <element>0@udpv4_wan://40.20.23.56:5678</element>
                        </initial_peers>
                    </discovery>
                </participant_qos>
            </participant>

            <session name="Session1">
                <auto_topic_route name="AllForward">
                    <input participant="0">
                        <allow_topic_name_filter>*</allow_topic_name_filter>
                        <allow_registered_type_name_filter>*
                        </allow_registered_type_name_filter>
                    </input>
                    <output participant="1">
                        <allow_topic_name_filter>*</allow_topic_name_filter>
                        <allow_registered_type_name_filter>*
                        </allow_registered_type_name_filter>
                    </output>
                </auto_topic_route>
            </session>

            <session name="Session2">
```

```
                <auto_topic_route name="AllBackward">
                    <input participant="1">
                        <allow_topic_name_filter>*</allow_topic_name_filter>
                        <allow_registered_type_name_filter>*
                        </allow_registered_type_name_filter>
                    </input>
                    <output participant="0">
                        <allow_topic_name_filter>*</allow_topic_name_filter>
                        <allow_registered_type_name_filter>*
                        </allow_registered_type_name_filter>
                    </output>
                </auto_topic_route>
            </session>

        </domain_route>
    </routing_service>
</dds>
```

Participant 0 in the domain route is the *DomainParticipant* that will be used to send/receive data from the internal *Connext* databus running in the in-vehicle network. The *DomainParticipant* is configured to use the builtin UDPv4 transport.

Participant 1 is used to send/receive data to/from the WAN and it has the role of the Internal Participant described in Sub-scenario 2 in 31.1 Peer-to-Peer Communication with a Participant that has a Public Address on page 1029.

Notice the use of the '0@' as the participant ID limit in the <initial_peers> for Participant 1. This is done to minimize the amount of discovery traffic sent to the *Routing Service* running in the data center. There is no need to use a number different than 0 when using *Real-Time WAN Transport*. (You can, but there will be more traffic.) See 15.2.1 Peer Descriptor Format on page 762 for additional information on the participant ID limit.

32.2 Relayed Edge-to-Edge Deployment Scenario

For this deployment scenario, consider a webinar platform built using *Connext DDS*. In this use case, the platform provider does not have any control over the attendees or the presenter network environment, including the NAT configuration. Communication cannot be peer-to-peer for two main reasons:

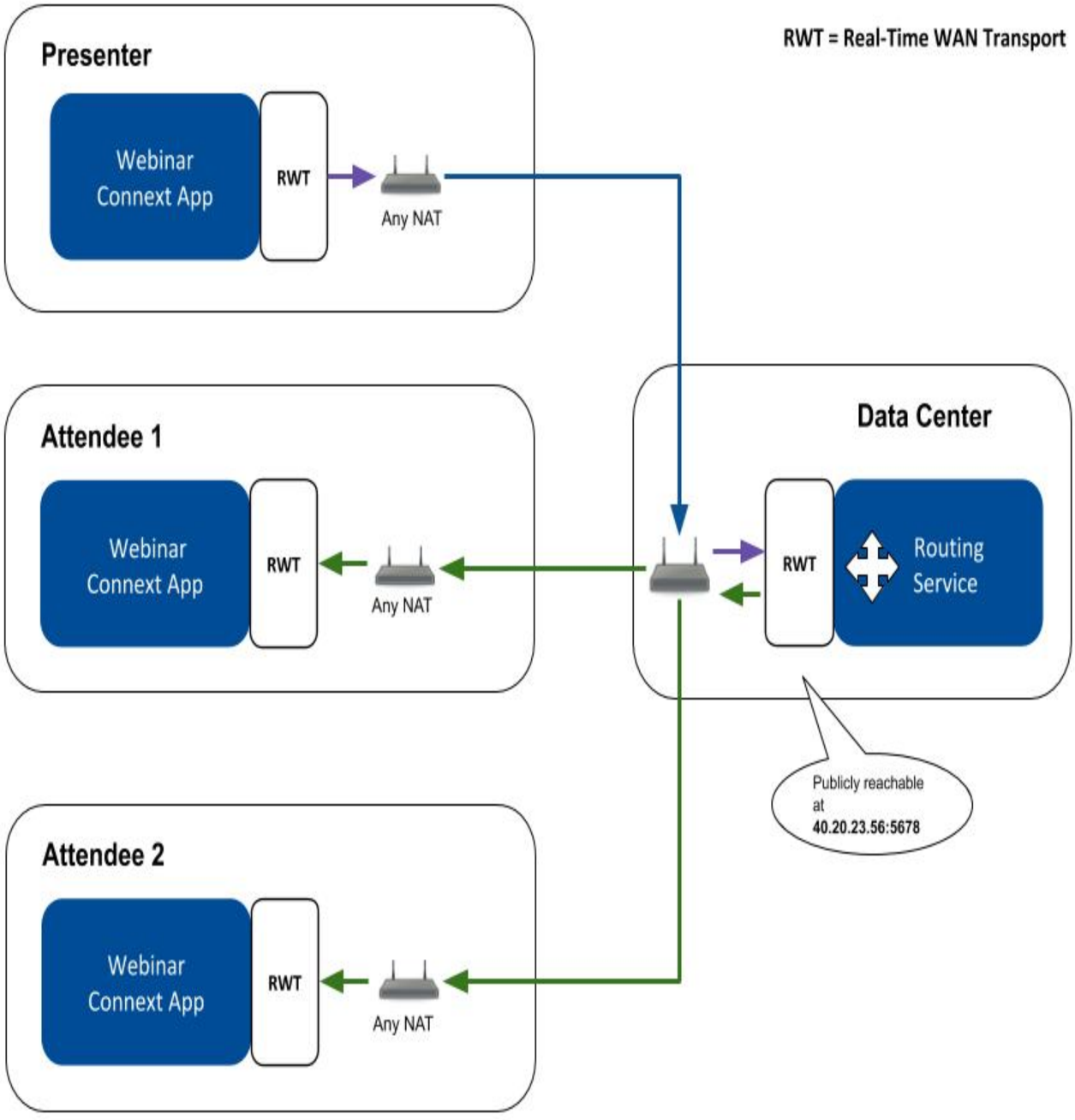
- The NATs environment is not known in advance.
- Communication is one-to-many. The presenter computer may not have enough resources (CPU and bandwidth) to broadcast the webinar content to all attendees.

To implement this use case, the *Connext DDS* application running in the presenter's computer will distribute the webinar content to a *Routing Service* instance running in a data center or the cloud. Unlike in the edge-to-data center scenario, where *Routing Service* is used as a gateway distributing information to components that are running inside the cloud, in this scenario *Routing Service* is used as a relay service.

The edge applications cannot communicate with each other directly, so in order to exchange messages, an application sends the message to *Routing Service*, which relays this message to the other applications.

In this case, the *Routing Service* instance will be in charge of relaying the content to the different attendees. Note that, for the sake of simplicity, we only have one *Routing Service* in this example. In a real use case, there may be multiple *Routing Services* organized in a hierarchical manner relaying the signal to different sets of attendees.

Figure 32.3: Relayed Edge-to-Edge Communication



The following sections provide an example configuration for the scenario described in Figure 32.3: Relayed Edge-to-Edge Communication on the previous page. The *Routing Service* instance is configured to propagate every *Topic* using an *AutoTopicRoute*.

32.2.1 Data Center Routing Service Configuration

```
<dds>
    <routing_service name="RS">
        <domain_route name="TwoWayDomainRoute">
            <participant name="1">
                <participant_qos>
                    <transport_builtin>
                        <mask>UDPv4_WAN</mask>
                        <udpv4_wan>
                            <public_address>40.20.23.56</public_address>
                            <comm_ports>
                                <default>
                                    <host>4500</host>
                                    <public>5678</public>
                                </default>
                            </comm_ports>
                        </udpv4_wan>
                    </transport_builtin>
                </participant_qos>
            </participant>

            <session name="Session1">
                <auto_topic_route name="AllForward">
                    <input participant="1">
                        <allow_topic_name_filter>*</allow_topic_name_filter>
                        <allow_registered_type_name_filter>*
                        </allow_registered_type_name_filter>
                    </input>
                    <output participant="1">
                        <allow_topic_name_filter>*</allow_topic_name_filter>
                        <allow_registered_type_name_filter>*
                        </allow_registered_type_name_filter>
                    </output>
                </auto_topic_route>
            </session>

            <session name="Session2">
                <auto_topic_route name="AllBackward">
                    <input participant="1">
                        <allow_topic_name_filter>*</allow_topic_name_filter>
                        <allow_registered_type_name_filter>*
                        </allow_registered_type_name_filter>
                    </input>
                    <output participant="1">
                        <allow_topic_name_filter>*</allow_topic_name_filter>
                        <allow_registered_type_name_filter>*
                        </allow_registered_type_name_filter>
```

```
                    </output>
                </auto_topic_route>
            </session>

        </domain_route>
    </routing_service>
</dds>
```

The domain route in *Routing Service* only creates one Participant that is used to relay the webinar content and that has the role of the External Participant described in Sub-Scenario 2 in 31.1 Peer-to-Peer Communication with a Participant that has a Public Address on page 1029. The *Routing Service* Participant is reachable at a well-known public IP transport address, 40.20.23.56:5678.

32.2.2 Webinar Application Configuration

```
<dds>
    <qos_profile name="WebinarParticipant">
        <domain_participant_qos>
            <transport_builtin>
                <mask>UDPv4_WAN</mask>
           </transport_builtin>
           <discovery>
               <initial_peers>
                   <element>0@udpv4_wan://40.20.23.56:5678</element>
               </initial_peers>
           </discovery>
        </domain_participant_qos>
    </qos_profile>
</dds>
```

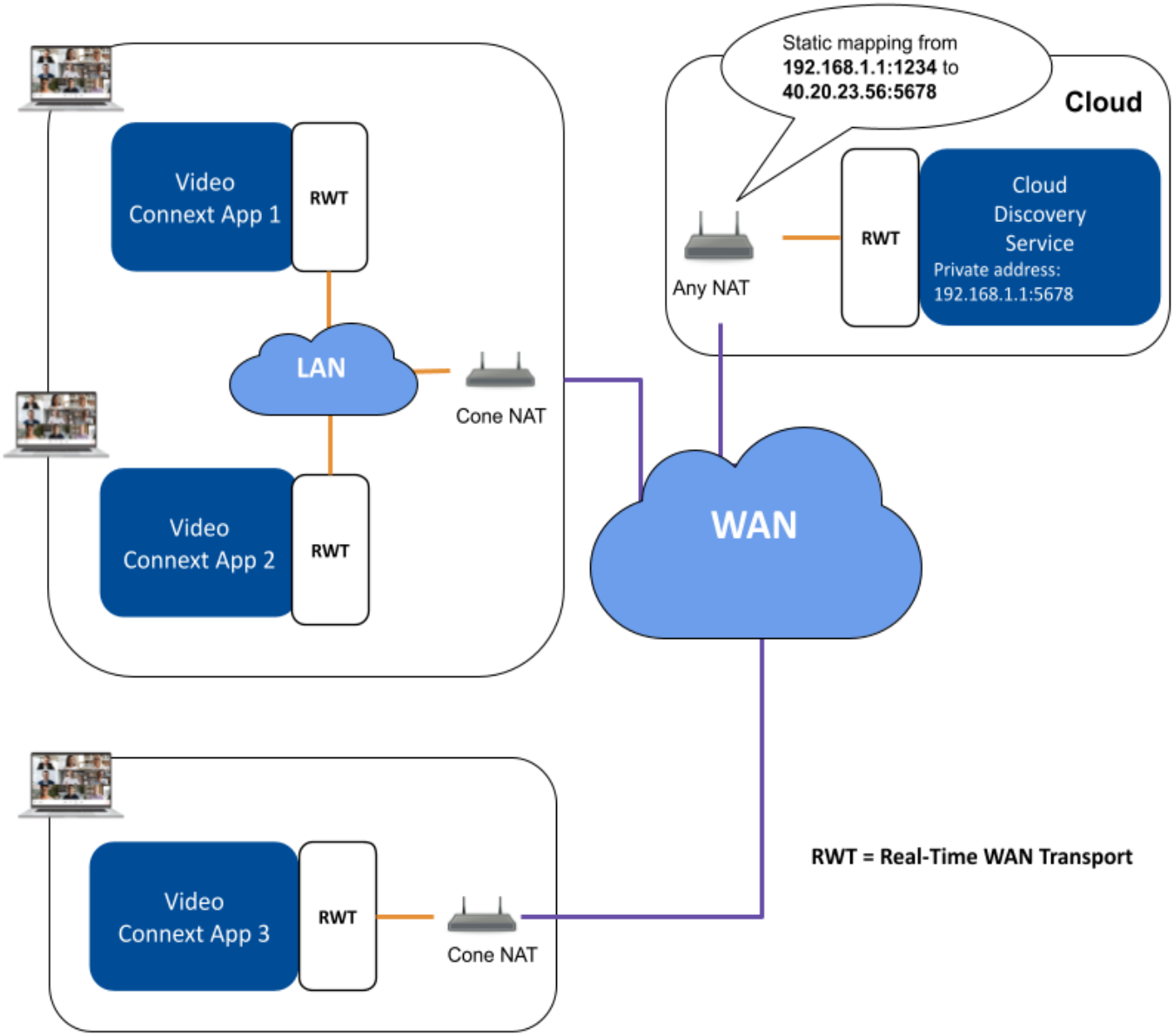
The Participant in the webinar application is used to send/receive webinar data to/from the WAN. This WebinarParticipant has the role of the Internal Participant described in Sub-scenario 2 in 31.1 Peer-to-Peer Communication with a Participant that has a Public Address on page 1029.

Notice the use of the '0@' participant index in the <initial_peers>. This is done to minimize the amount of discovery traffic sent to the *Routing Service* running in the data center. There is no need to use a number different than 0 when using *Real-Time WAN Transport*. (You can, but there will be more traffic.) See 15.2.1 Peer Descriptor Format on page 762 for additional information on the participant ID limit.

32.3 Peer-to-Peer, Edge-to-Edge Deployment Scenario

Currently, this scenario is only supported in environments in which the NATs involved in the communication are cone NATs. Consider a videoconferencing system in which users establish 1-1 calls with each other. Users communicate with other users within their own LAN and in different LANs across a WAN.

Figure 32.4: Peer-to-Peer and Edge-to-Edge Communication



Because each user is behind a cone NAT, the users can communicate peer-to-peer with other users across the WAN with the help of *Cloud Discovery Service* to facilitate both the NAT traversal process and the discovery of *DomainParticipants* as described in 31.2 Peer-to-Peer Communication with Participants behind Cone NATs Using Cloud Discovery Service on page 1031.

In addition, some users will be running in the same LAN. Because NAT loopback (see 30.1.5 NAT Hairpinning on page 1027) is not allowed by NAT routers in most cases, it is necessary to use the builtin UDPv4 transport in combination with the *Real-Time WAN Transport* to enable communications within the LAN.

The following sections provide an example configuration for the scenario described in Figure 32.4: Peer-to-Peer and Edge-to-Edge Communication on the previous page.

32.3.1 Video Connext Application Configuration

```
<dds>
    <qos_profile name="VideoAppParticipant">
        <domain_participant_qos>
            <transport_builtin>
               <mask>UDPv4|UDPv4_WAN</mask>
            </transport_builtin>
            <discovery>
                <initial_peers>
                    <element>udpv4://239.255.0.1</element>
                    <element>rtps@udpv4_wan://40.20.23.56:5678</element>
                </initial_peers>
            </discovery>
            <discovery_config>
                <locator_reachability_assert_period>
                    <sec>15</sec>
                    <nanosec>0</nanosec>
                </locator_reachability_assert_period>
                <locator_reachability_lease_duration>
                    <sec>60</sec>
                    <nanosec>0</nanosec>
                </locator_reachability_lease_duration>
            </discovery_config>
        </domain_participant_qos>
    </qos_profile>
</dds>
```

Within the LAN, discovery is configured to be done over multicast by setting <initial_peers> to udpv4://239.255.0.1. Over the WAN, discovery will occur using *Cloud Discovery Service*.

32.3.2 Cloud Discovery Service Configuration

```
<dds>
    <cloud_discovery_service name="CDS">
        <transport>
            <element>
                <alias>builtin.udpv4_wan</alias>
                <receive_port>5678</receive_port>
                <property>
                    <element>
                        <name>dds.transport.UDPv4.builtin.public_address</name>
                        <value>50.10.23.45</value>
                    </element>
                </property>
            </element>
        </transport>
    </cloud_discovery_service>
</dds>
```

Chapter 33 Enabling Real-Time WAN Transport

To use *Real-Time WAN Transport*, you have two options:

- **(Recommended for all platforms that support dynamic library loading)** Automatic dynamic load of the transport library. This approach only requires you to make sure the *Real-Time WAN Transport* dynamic Release or Debug library is available in your library path. See the RTI Connext DDS Core Libraries Platform Notes for the platforms that support dynamic *Real-Time WAN Transport* libraries. See 33.1 Dynamically Loading the Real-Time WAN Transport below.
- Manual link against the applicable transport library. See the RTI Connext DDS Core Libraries Platform Notes for a list of the *Real-Time WAN Transport* libraries available for your platform. See 33.2 Linking the Real-Time WAN Transport against your Application on the next page for details.

Note: Normally, you cannot mix static and dynamic libraries. (See 10.3.2 Mixing Static and Dynamic Libraries not Supported on page 676.) For *Real-Time WAN Transport*, however, it is recommended that you load the library dynamically, regardless of how you load your core libraries. There is one exception: if your platform does not support dynamic loading, follow the instructions in 33.2 Linking the Real-Time WAN Transport against your Application on the next page for more information on how to link your application against the corresponding *Real-Time WAN Transport* library.

33.1 Dynamically Loading the Real-Time WAN Transport

The recommended way to use the transport is to let *Connext DDS* automatically load the *Real-Time WAN Transport* dynamic library. (Not all platforms support dynamic loading. See the RTI Connext DDS Core Libraries Platform Notes for details.)

To allow *Connext DDS* to load the *Real-Time WAN Transport* dynamic library, simply make sure that the applicable *Real-Time WAN Transport* dynamic Release or Debug library is available in your system library search path (e.g., LD_LIBRARY_PATH in Linux systems, PATH on Windows systems, DYLD_LIBRARY_PATH on macOS systems).

33.2 Linking the Real-Time WAN Transport against your Application

If the method described in 33.1 Dynamically Loading the Real-Time WAN Transport on the previous page is not available in your system (because your architecture does not support dynamic library loading), you can still use the *Real-Time WAN Transport* by linking your application against the transport library.

Compared with dynamic loading, you need to pay attention to two things.

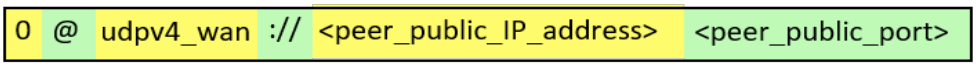
First, include the *Real-Time WAN Transport* library in the list of libraries used during your application linking. See the RTI Connext DDS Core Libraries Platform Notes for the specific library to link for your target platform.

Second, manually tell *Connext DDS* the pointer to the function of the entry point of the *Real-Time WAN Transport* library before you create the *DomainParticipant*. Setting this pointer requires setting the **dds.transport.UDPv4_WAN.builtin.plugin_enabled_function_ptr** property. (See 35.1 Setting Real-Time WAN Transport Properties on page 1051.) Here is an example of how to set this pointer in code:

```
/* Include the symbol for NDDS_Transport_UDP_WAN_Library_is_plugin_enabled */
#include "transport/transport_udp_wan_library.h"

  /* The property name "dds.transport.UDPv4_WAN.builtin.plugin_enabled_function_ptr"
   * indicates the entry point for the Real-Time WAN Transport library.
   * The value MUST be the stringified value of the function pointer of
   * NDDS_Transport_UDP_WAN_Library_is_plugin_enabled. Note that
   * add_pointer_property() API will automatically convert the
   * function pointer to a string.
   */
if (DDS_PropertyQosPolicyHelper_add_pointer_property(
      &participantQos.property,
      "dds.transport.UDPv4_WAN.builtin.plugin_enabled_function_ptr",
      (void *) NDDS_Transport_UDP_WAN_Library_is_plugin_enabled)
    != DDS_RETCODE_OK) {
  /* error */
}
```

Chapter 34 Transport Initial Peers

The initial peers (see 9.5.2.2 Setting the 'Initial Peers' List on page 636) for *Real-Time WAN Transport* have the following form:

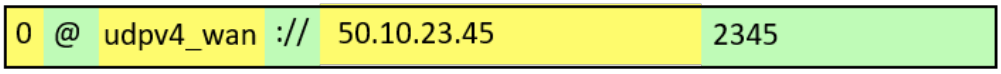


Notice that the participant ID limit should always be '0@', since there can be only one *DomainParticipant* associated with the public IP transport address <peer_public_IP_address>:<peer_public_port>. Note that a participant ID limit different than 0 will be accepted, but it will generate more discovery traffic than necessary.

<peer_public_IP_address>:<peer_public_port> defines the public IP transport address at which the remote *DomainParticipant* is reachable. For example, assume the following configuration for a remote *DomainParticipant*:

```
<dds>
    <qos_profile name="ExternalParticipant">
        <domain_participant_qos>
            <transport_builtin>
                <mask>UDPv4_WAN</mask>
                <udpv4_wan>
                    <public_address>50.10.23.45</public_address>
                        <comm_ports>
                            <default>
                                <host>1234</host>
                                <public>2345</public>
                            </default>
                        </comm_ports>
                </udpv4_wan>
            </transport_builtin>
        </domain_participant_qos>
    </qos_profile>
</dds>
```

The initial peer that can be used to establish communication with the remote *DomainParticipant* is:

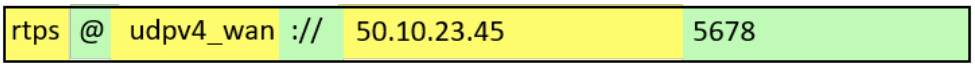


For scenarios in which *Cloud Discovery Service* (CDS) is involved, the initial peers have the following form:

<CDS_public_IP_address>:<CDS_public_port> defines the public IP transport address at which CDS is reachable. For example, assume the following CDS configuration:

```
<dds>
    <cloud_discovery_service name="CDS">
        <transport>
            <element>
                <alias>builtin.udpv4_wan</alias>
                <receive_port>5678</receive_port>
                <property>
                    <element>
                        <name>dds.transport.UDPv4.builtin.public_address</name>
                        <value>50.10.23.45</value>
                    </element>
                </property>
            </element>
        </transport>
    </cloud_discovery_service>
</dds>
```

The initial peer that can be used to establish communication with CDS is:



Chapter 35 Transport Configuration

Real-Time WAN Transport is a transport plugin that can be configured in three different ways:

- Programmatically by calling **set_builtin_transport_property()** (see 16.5 Setting Builtin Transport Properties of Default Transport Instance—get/set_builtin_transport_properties() on page 793).
- By specifying predefined property strings in the *DomainParticipant's* PropertyQosPolicy (see 16.6 Setting Builtin Transport Properties with the PropertyQosPolicy on page 795).
- By using the tag <domain_participant_qos>/<transport_builtin>/<udpv4_wan> in the XML configuration.

35.1 Setting Real-Time WAN Transport Properties

Table 35.1 Properties for Real-Time WAN Transport describes the configuration parameters for *Real-Time WAN Transport*:

Table 35.1 Properties for *Real-Time WAN Transport*

XML tag (under <udpv4_wan>)	Property Name (prefix with 'dds.transport.UDPv4_WAN.builtin.')	Property Value Description
General Transport Properties		
<gather_send_buffer_count_max>	parent.gather_send_buffer_count_max	Specifies the maximum number of buffers that *Connext DDS* can pass to the **send()** method of a transport plugin. The transport plugin **send()** API supports a gather-send concept, where the **send()** call can take several discontiguous buffers, assemble and send them in a single message. This enables *Connext DDS* to send a message from parts obtained from different sources without first having to copy the parts into a single contiguous buffer. However, most transports that support a gather-send concept have an upper limit on the number of buffers that can be gathered and sent. Setting this value will prevent *Connext DDS* from trying to gather too many buffers into a send call for the transport plugin. *Connext DDS* requires all transport-plugin implementations to support a gather-send of least a minimum number of buffers. This minimum number is NDDS_TRANSPORT_PROPERTY_GATHER_SEND_BUFFER_COUNT_MIN. See 16.6.1 Setting the Maximum Gather-Send Buffer Count for UDP Transports on page 812. Default: 16
<message_size_max>	parent.message_size_max	The maximum size of a message in bytes that can be sent or received by the transport plugin. This value must be set before the transport plugin is registered, so that *Connext DDS* can properly use the plugin. Default for Integrity platforms: 9216 Default for non-Integrity platforms: 65507

XML tag (under <udpv4_wan>)	Property Name (prefix with 'dds.transport.UDPv4_WAN.builtin.')	Property Value Description
<allow_interfaces_list>	parent.allow_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name. As a property value, interfaces must be specified as comma-separated strings, with each comma delimiting an interface. In XML, they are provided as a set of elements (<element>) under <allow_interfaces_list>. For example, the following are acceptable strings: 192.168.1.1 192.168.1.* 192.168.* 192.* ether0 If the list is non-empty, this "white" list is applied before the **parent.deny_interfaces_list** list. The *DomainParticipant* will use the resulting list of interfaces to inform its remote participant(s) about which unicast addresses may be used to contact the *DomainParticipant*. The resulting list restricts reception to a particular set of interfaces for unicast UDP. You must manage the memory of the list. The memory may be freed after the *DomainParticipant* is deleted. Default: empty list that represents all available interfaces
<deny_interfaces_list>	parent.deny_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name. If the list is non-empty, deny the use of these interfaces. As a property value, interfaces must be specified as comma-separated strings, with each comma delimiting an interface. In XML, they are provided as a set of elements (<element>) under <deny_interfaces_list>. For example, the following are acceptable strings: 192.168.1.1 192.168.1.* 192.168.* 192.* ether0 This "black" list is applied after the **parent.allow_interfaces_list** and filters out the interfaces that should not be used for receiving data. The resulting list restricts reception to a particular set of interfaces for unicast UDP. You must manage the memory of the list. The memory may be freed after the *DomainParticipant* is deleted. Default: empty list that represents no deny interfaces

XML tag (under <udpv4_wan>)	Property Name (prefix with 'dds.transport.UDPv4_WAN.builtin.')	Property Value Description
`<properties_bitmap>`	parent.properties_bitmap	A bitmap that defines various properties of the transport to the *Connext DDS* core. Currently, the only property supported is whether or not the transport plugin will always loan a buffer when *Connext DDS* tries to receive a message using the plugin. This is in support of a zero-copy interface. Default: 0
N/A	property_validation_action	By default, property names given in the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 are validated to avoid using incorrect or unknown names (for example, due to a typo). This property configures the validation of the property names associated with the transport: • VALIDATION_ACTION_EXCEPTION: validate the properties. Upon failure, log errors and fail. • VALIDATION_ACTION_SKIP: skip validation. • VALIDATION_ACTION_WARNING: validate the properties. Upon failure, log warnings and do not fail. If this property is not set, the property validation behavior will be the same as that of the *DomainParticipant*, which by default is VALIDATION_ACTION_EXCEPTION. See 7.5.19.1 Property Validation on page 439 for more information.
`<thread_name_prefix>`	thread_name_prefix	If you do not set this field, *Connext DDS* creates the following prefix: 'r' + 'Tr' + participant identifier + '\0' Where 'r' indicates this is a thread from RTI, 'Tr' indicates the thread is related to a transport, and participant identifier contains 5 characters as follows: • If **participant_name** is set: The participant identifier will be the first 3 characters and the last 2 characters of the **participant_name**. • If **participant_name** is not set, then the identifier is computed as **domain_id** (3 characters) followed by **participant_id** (2 characters). • If **participant_name** is not set and the **participant_id** is set to -1 (default value), then the participant identifier is computed as the last 5 digits of the **rtps_instance_id** in the participant GUID. See 21.9 Identifying Threads Used by Connext DDS on page 908.

XML tag (under <udpv4_wan>)	Property Name (prefix with 'dds.transport.UDPv4_WAN.builtin.')	Property Value Description
General UDP Properties		
<protocol_overhead_max>	protocol_overhead_max	Maximum size in bytes of protocol overhead, including headers. This value is the maximum size, in bytes, of protocol-related overhead. Normally, the overhead accounts for UDP and IP headers. The default value is set to accommodate the most common UDP/IP header size. Note that when **parent.message_size_max** plus this overhead is larger than the UDPv4 maximum message size (65535 bytes), the middleware will automatically reduce the effective **message_size_max** to 65535 minus this overhead. Default: 28
<send_socket_buffer_size>	send_socket_buffer_size	Size in bytes of the send buffer of a socket used for sending. On most operating systems, **setsockopt()** will be called to set the SENDBUF to the value of this parameter. This value must be greater than or equal to **parent.message_size_max**. The maximum value is operating system-dependent. If -1, **setsockopt()** (or equivalent) will not be called to size the send buffer of the socket. The transport will use the OS default. Default: 131072
<recv_socket_buffer_size>	recv_socket_buffer_size	Size in bytes of the receive buffer of a socket used for receiving. On most operating systems, **setsockopt()** will be called to set the RECVBUF to the value of this parameter. This value must be greater than or equal to **parent.message_size_max**. The maximum value is operating system-dependent. If -1, **setsockopt()** (or equivalent) will not be called to size the receive buffer of the socket. The transport will use the OS default. Default: 131072

XML tag (under <udpv4_wan>)	Property Name (prefix with 'dds.transport.UDPv4_WAN.builtin.')	Property Value Description
<ignore_loopback_interface>	ignore_loopback_interface	Prevents the transport plugin from using the IP loopback interface. Three values are allowed: • 0: Forces local traffic to be sent over loopback, even if a more efficient transport (such as shared memory) is installed (in which case traffic will be sent over both transports). • 1: Disables local traffic via this plugin. The IP loopback interface will not be used, even if no NICs are discovered. This is useful when you want applications running on the same node to use a more efficient transport (such as shared memory) instead of the IP loopback. • -1: Automatic. Enables local traffic via this plugin. To avoid redundant traffic, *Connext DDS* will selectively ignore the loopback destinations that are also reachable through shared memory. Default: -1

DEPRECATED
N/A
	DEPRECATED
	ignore_nonup_interfaces
		This property is only supported on Windows platforms with statically configured IP addresses.
		It allows/disallows the use of interfaces that are not reported as UP (by the operating system) in the UDPv4_WAN transport. Two values are allowed:
		• 0: Allow interfaces that are reported as DOWN.
		  • Setting this value to 0 supports communication scenarios in which interfaces are enabled after the participant is created. Once the interfaces are enabled, discovery will not occur until the participant sends the next periodic announcement (controlled by the parameter **participant_qos.discovery_config.participant_liveliness_assert_period**).
		  • To reduce discovery time, you may want to decrease the value of **participant_liveliness_assert_period**. For the above scenario, there is one caveat: non-UP interfaces must have a static IP assigned.
		• 1: Do not allow interfaces that are reported as DOWN.
		Default:1

XML tag (under <udpv4_wan>)	Property Name (prefix with 'dds.transport.UDPv4_WAN.builtin.')	Property Value Description
<ignore_nonrunning_interfaces>	ignore_nonrunning_interfaces	Prevents the transport plugin from using a network interface that is not reported as RUNNING by the operating system. The transport checks the flags reported by the operating system for each network interface upon initialization. An interface which is not reported as UP will not be used. This property allows the same check to be extended to the IFF_RUNNING flag implemented by some operating systems. The RUNNING flag is defined to mean that "all resources are allocated", and may be off if there is no link detected, e.g., the network cable is unplugged. Two values are allowed: • 0: Do not check the RUNNING flag when enumerating interfaces, just make sure the interface is UP. • 1: Check the flag when enumerating interfaces, and ignore those that are not reported as RUNNING. This can be used on some operating systems to cause the transport to ignore interfaces that are enabled but not connected to the network. By default this property is set to 1, so *Connext DDS* will ignore non-running interfaces.
DEPRECATED N/A	DEPRECATED no_zero_copy	Prevents the transport plugin from doing a zero copy. By default, this plugin will use the zero copy on OSs that offer it. While this is good for performance, it may sometimes tax the OS resources in a manner that cannot be overcome by the application. The best example is if the hardware/device driver lends the buffer to the application itself. If the application does not return the loaned buffers soon enough, the node may error or malfunction. In case you cannot reconfigure the hardware, device driver, or the OS to allow the zero-copy feature to work for your application, you may have no choice but to turn off zero-copy. By default this is set to 0, so *Connext DDS* will use the zero-copy API if offered by the OS.
<send_blocking>	send_blocking	Controls the blocking behavior of send sockets. **CHANGING THIS FROM THE DEFAULT CAN CAUSE SIGNIFICANT PERFORMANCE PROBLEMS**. Currently two values are defined: • 1 (NDDS_TRANSPORT_UDP_BLOCKING_ALWAYS): Sockets are blocking (default socket options for operating system). • 0 (NDDS_TRANSPORT_UDP_BLOCKING_NEVER): Sockets are modified to make them non-blocking. **This may cause significant performance problems.** Default: 1

XML tag (under <udpv4_wan>)	Property Name (prefix with 'dds.transport.UDPv4_WAN.builtin.')	Property Value Description
`<transport_priority_mask>`	transport_priority_mask	Sets the mask for the transport priority field. This is used in conjunction with **transport_priority_mapping_low** and **transport_priority_mapping_high** to define the mapping from the 7.5.26 TRANSPORT_PRIORITY QosPolicy on page 455 to the IPv4 TOS field. Defines a contiguous region of bits in the 32-bit transport priority value that is used to generate values for the IPv4 TOS field on an outgoing socket. For example, the value 0x0000ff00 causes bits 9-16 (8 bits) to be used in the mapping. The value will be scaled from the mask range (0x0000 - 0xff00 in this case) to the range specified by low and high. If the mask is set to zero, then the transport will not set IPv4 TOS for send sockets. Default: 0
`<transport_priority_mapping_low>`	transport_priority_mapping_low	Sets the low and high values of the output range to IPv4 TOS. These values are used in conjunction with **transport_priority_mask** to define the mapping from the 7.5.26 TRANSPORT_PRIORITY QosPolicy on page 455 to the IPv4 TOS field. Defines the low and high values of the output range for scaling. Note that IPv4 TOS is generally an 8-bit value. Default: 0 for **transport_priority_mapping_low** and 0xFF for **transport_priority_mapping_high**
`<transport_priority_mapping_high>`	transport_priority_mapping_high	
`<send_ping>`	send_ping	This property specifies whether to send a PING message before commencing the discovery process. On certain operating systems or with certain switches the initial UDP packet, configuring the ARP table, was unfortunately dropped. To avoid dropping the initial RTPS discovery sample, a PING message is sent to preconfigure the ARP table in those environments. Default: 1
`<use_checksum>`	use_checksum	This property specifies whether the UDP checksum will be computed. On Windows and Linux systems, the UDP checksum will not be set when **use_checksum** is set to 0. This is useful when RTPS protocol statistics related to corrupted messages need to be collected through the operation **get_participant_protocol_status()** (see 9.3.14 Getting Participant Protocol Status on page 626). Default: 1

XML tag (under <udpv4_wan>)	Property Name (prefix with 'dds.transport.UDPv4_WAN.builtin.')	Property Value Description
IP Mobility Properties		
<interface_poll_period>	interface_poll_period	Specifies the period in milliseconds to query for changes in the state of all the interfaces. When possible, the detection of an IP address changes is done asynchronously using the APIs offered by the underlying OS. If there is no mechanism to do that, the detection will use a polling strategy where the polling period can be configured by setting this property. Default: 500
<force_interface_poll_detection>	force_interface_poll_detection	This property forces the interface tracker to use a polling method to detect changes to the network interfaces in IP mobility scenarios. It only applies to operating systems that support asynchronous notifications of interface changes. If set to TRUE, the interface tracker will use a polling method that queries the interfaces periodically to detect the changes. If set to FALSE, the interface tracker will use the operating system's default method. Basically, this property allows you—for an operating system that supports asynchronous notification—to use the polling method instead. Default: FALSE
<disable_interface_tracking>	disable_interface_tracking	Disables detection of network interface changes. By default, network interfaces changes are propagated in the form of locators to other applications. This is done to support IP mobility scenarios. For example, you could start an application with Wi-Fi and move to a wired connection. In order to continue communicating with other applications, this interface change must be propagated. You can disable the notification and propagation of interface changes by setting this property to 1.
WAN Properties		
<public_address>	public_address	Public IP address associated with the transport instantiation. The address is the public IP address of the NAT-enabled router that provides access to the WAN. Setting the public IP address is only necessary for the *Real-Time WAN Transport* associated with an external *DomainParticipant* in order to support the communication scenario described in 31.1 Peer-to-Peer Communication with a Participant that has a Public Address on page 1029. When this property is set, the *DomainParticipant* will announce PUBLIC+UUID locators to other *DomainParticipants*. These locators are reachable locators because they contain a public IP transport address for the *DomainParticipant*. For additional information on *Real-Time WAN Transport* locators, see 37.1 Transport Locators on page 1068. By default, the public address is not set.

XML tag (under <udpv4_wan>)	Property Name (prefix with 'dds.transport.UDPv4_WAN.builtin.')	Property Value Description
`<binding_ping_period>`	binding_ping_period	Configures the period in milliseconds at which BINDING_PING messages are sent by a local transport instance to a remote transport instance. For example, 1000 means to send BINDING_PING messages every second. BINDING_PING messages are used on the sending side to open NAT bindings from a local transport instance to a remote transport instance and they are sent periodically to keep the bindings open. For additional information on the role of BINDING_PING messages opening NAT bindings, see 37.3 Communication Establishment Protocol for Peer-to-Peer Communication with Participants behind Cone NATs on page 1070. On the receiving side, BINDING_PINGS are used to calculate the public IP transport address of a UUID locator. This address will be used to send data to the locator. For additional information on the role of BINDING_PING to associate UUID locators to public IP transport addresses, see 37.4 Communication Establishment Protocol for Peer-to-Peer Communication with a Participant that has a Public Address on page 1073. From a configuration point of view, and to avoid communication disruptions, the period at which a transport instance sends BINDING_PING messages should be smaller than the NAT binding session timeout. This timeout depends on the NAT router configuration. Default: 1000 (1 sec)

`<port_offset>`	port_offset	This property allows using the builtin UDPv4 transport and the *Real-Time WAN Transport* at the same time.
		`<transport_builtin>`
		`  <mask>UDPv4_WAN|UDPv4</mask>`
		`</transport_builtin>`
		When the UDP ports used by *Real-Time WAN Transport* are not explicitly set, they are calculated as follows: RTPS port + port_offset. See 35.2 Managing UDP Ports Used for Communication on the next page for additional details.
		Default: 125

`<comm_ports>`	comm_ports	Configures the public and private UDP ports that a transport instance uses to receive/send RTPS data. See 35.2 Managing UDP Ports Used for Communication on the next page for additional details. If this property is not set (default), the UDP ports used for communications will be derived from the RTPS ports associated with the locators for the *DomainParticipant* and its endpoints (*DataWriters* and *DataReaders*).

XML tag (under <udpv4_wan>)	Property Name (prefix with 'dds.transport.UDPv4_WAN.builtin.')	Property Value Description
<plugin_enabled_function_ptr>	plugin_enabled_function_ptr	Only required if your platform does not support dynamic loading of libraries (independently of how the application was linked). A string that must be set programmatically to the stringified pointer value of the *Real-Time WAN Transport* library's **NDDS_Transport_UDP_WAN_Library_is_plugin_enabled** function. See Chapter 33 Enabling Real-Time WAN Transport on page 1047 for details. Default: NULL

35.2 Managing UDP Ports Used for Communication

35.2.1 Receiving Data

By default, *Real-Time WAN Transport* uses one UDP port per RTPS port to receive data. The UDP port number is calculated as RTPS port + port_offset.

A *DomainParticipant* uses two RTPS ports, one for discovery and one for user data. Therefore, *Real-Time WAN Transport* uses two UDP ports out-of-the-box. For information on how the RTPS ports are obtained, see 9.5.9.2 Ports Used for Discovery on page 666.

You can also configure a specific *DataWriter* and *DataReader* to receive unicast data in a different RTPS port by configuring the 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458). This will also lead to the usage of a different UDP port by *Real-Time WAN Transport*.

There are two main use cases in which the default mapping from RTPS ports to UDP ports is not suitable:

- The first use case involves the configuration of the External Participant described in 31.1 Peer-to-Peer Communication with a Participant that has a Public Address on page 1029. In this use case, you must be able to select the private and public UDP ports used for communication because you have to create a static NAT binding on the router for the External Participant.
- The second use case involves the use of UDP load balancers. With UDP load balancers, you must be able to configure a single UDP port to handle all data reception because the load balancer would not know how to map different ports to the same *DomainParticipant*.

For these use cases, *Real-Time WAN Transport* provides a way to specify the private and public UDP ports that will be used to serve specific RTPS ports.

35.2.1.1 Changing the UDP Port Mapping

The <comm_ports> XML tag or the property **dds.transport.UDPv4_WAN.builtin.comm_ports** can be used to change the mapping of UDP ports to RTPS ports.

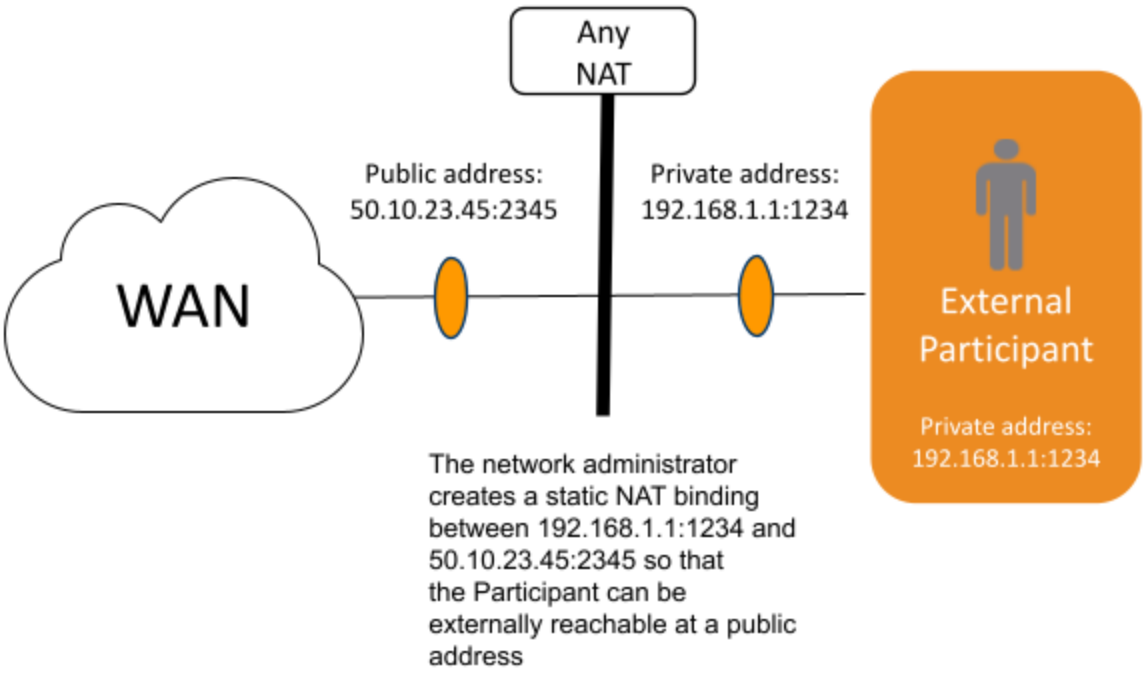
You can specify a list of mappings from an RTPS port to a host, and (optionally) a public UDP port. For RTPS ports that are not part of the list, you can provide a default mapping.

When the property **dds.transport.UDPv4_WAN.builtin.comm_ports** is used instead of XML, the list is a JSON string.

35.2.1.2 Configuring the Transport to Use a Single Port for an External Participant behind a NAT

This configuration will be needed for the External Participant behind a NAT in the scenario described in 31.2 Peer-to-Peer Communication with Participants behind Cone NATs Using Cloud Discovery Service on page 1031.

Figure 35.1: Single Port External Participant



XML:

```
<udpv4_wan>
    <comm_ports>
        <default>
            <host>1234</host>
            <public>2345</public>
        </default>
    </comm_ports>
</udpv4_wan>
```

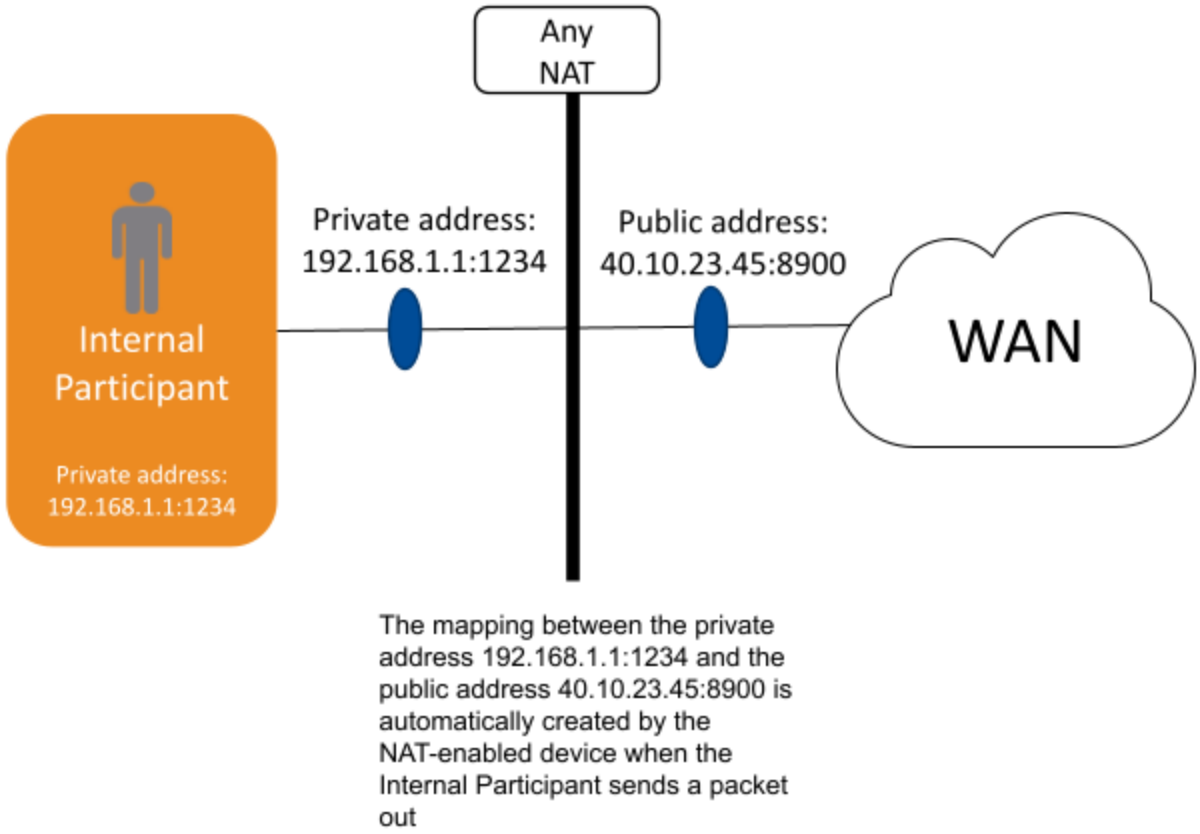
Property **dds.transport.UDPv4_WAN.builtin.comm_ports**:

```
{
    "default": {
        "host": 1234,
        "public": 2345
    }
}
```

35.2.2 Configuring the Transport to Use a Single Port for an Internal Participant behind a NAT

For the Internal Participants behind NATs used in the scenarios described in Chapter 31 Communication Scenarios on page 1029, it is not necessary to configure the public port. The public port will be automatically assigned by the NAT once packages are sent from the private address.

Figure 35.2: Single Port Internal Participant



XML:

```
<udpv4_wan>
    <comm_ports>
        <default>
            <host>1234</host>
        </default>
    </comm_ports>
</udpv4_wan>
```

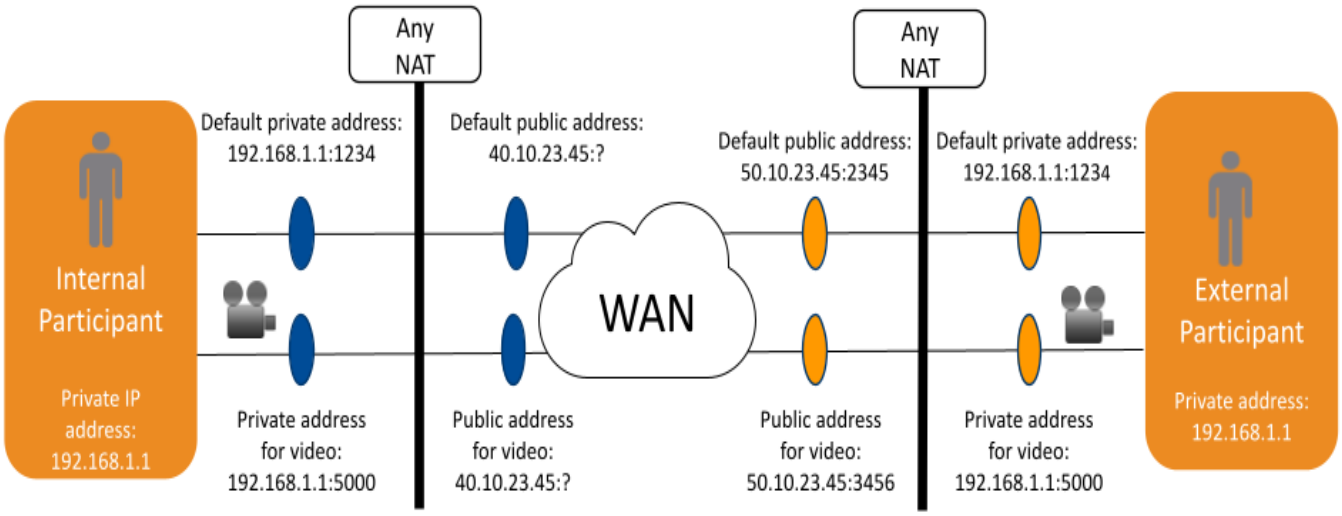
Property **dds.transport.UDPv4_WAN.builtin.comm_ports**:

```
{
    "default": {
        "host": 1234,
    }
}
```

35.2.3 Configuring the Transport to Segregate Traffic for a Topic in its own Port

In some cases, you may want to segregate the RTPS traffic for a *Topic*, such as a Video *Topic*, in its own port. This *Topic* will get its own socket and receive a socket buffer. It will also get its own receive thread, which will make data reception on the *Topic* completely concurrent. For details on the middleware threads, see Chapter 21 Connext DDS Threading Model on page 900.

Figure 35.3: Traffic Segregation in Different Port



35.2.3.1 External Participant Configuration

```
<dds>
    <qos_profile name="ExternalParticipant">
        <domain_participant_qos>
            <transport_builtin>
                <mask>UDPv4_WAN</mask>
                <udpv4_wan>
                    <public_address>50.10.23.45</public_address>
                    <comm_ports>
                        <default>
                            <host>1234</host>
                            <public>2345</public>
                        </default>
                        <mappings>
                            <element>
                                <rtps>5001</rtps>
                                <host>5000</host>
                                <public>3456</public>
                            </element>
                        </mappings>
                    </comm_ports>
                </udpv4_wan>
            </transport_builtin>
```

```
        </domain_participant_qos>
    </qos_profile>

    <qos_profile name="VideoTopic" base_name="ExternalParticipant">
        <datareader_qos>
            <unicast>
                <value>
                    <element>
                        <receive_port>5001</receive_port>
                        <transports>
                            <element>udpv4_wan</element>
                        </transports>
                    </element>
                </value>
            </unicast>
        </datareader_qos>
    </qos_profile>
</dds>
```

To use a different port for the Video *Topic*, you will have to first change the 7.5.28 TRANSPORT_UNICAST QosPolicy (DDS Extension) on page 458 to specify an RTPS port (<unicast>/<receiver_port>) for video data reception. Then, you will have to configure the mapping to UDP ports by updating the **comm_ports** configuration.

If you choose to configure the comm_ports using the property **dds.transport.UDPv4_WAN.built-in.comm_ports**, the following example will be the JSON string for the scenario described in Figure 35.3: Traffic Segregation in Different Port on the previous page

```
{
    "default": {
        "host": 1234,
        "Public": 2345
    }
    "mappings":
    [
    {
            "rtps": 5001,
            "Host": 5000,
            "Public": 3456
    }
]
}
```

35.2.4 Sending Data

Data is always sent from a single UDP port. There is no way to send data using different UDP ports for different *Topics*.

The UDP port used for sending data corresponds to the port associated with the discovery RTPS port according to the rules described in 35.2.1 Receiving Data on page 1061. When the <comms_port>/<default> is defined, the port used for sending data is the one provided in <comms_port>/<default>.

Chapter 36 Security

Fine-grained security and access control at the *Topic* level is provided through the use of *RTI Security Plugins*, which are the *Connext DDS* implementation of the OMG 'DDS Security' specification, version 1.1, builtin plugins. For detailed information on how to secure your *Connext DDS* system, see the *RTI Security Plugins User's Manual*.

In addition, you can use symmetric cryptography using pre-shared keys to protect the integrity of the Binding Ping messages (see 37.2 Binding Ping Messages on page 1069) and the communication with *Cloud Discovery Service*. For further details, see the "Support for RTI Real-Time WAN Transport" chapter in the *RTI Security Plugins User's Manual*.

Chapter 37 Advanced Concepts

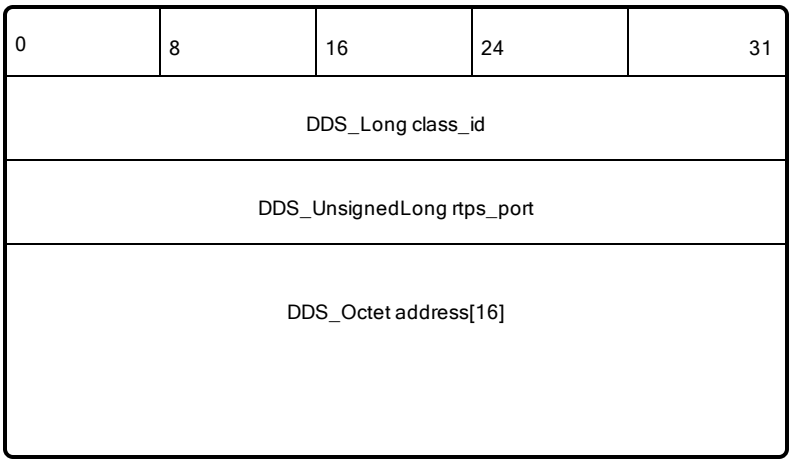
37.1 Transport Locators

This section provides information about the format of the locators associated with the *Real-Time WAN Transport*. For general information about RTPS locators, see Chapter 17 RTPS Locators and IP Mobility on page 821.

An RTPS locator is an address at which a DDS endpoint (*DataWriter* or *DataReader*) can be reached. Default locators for discovery endpoints and user data endpoints are exchanged with the Participant Announcement (PA).

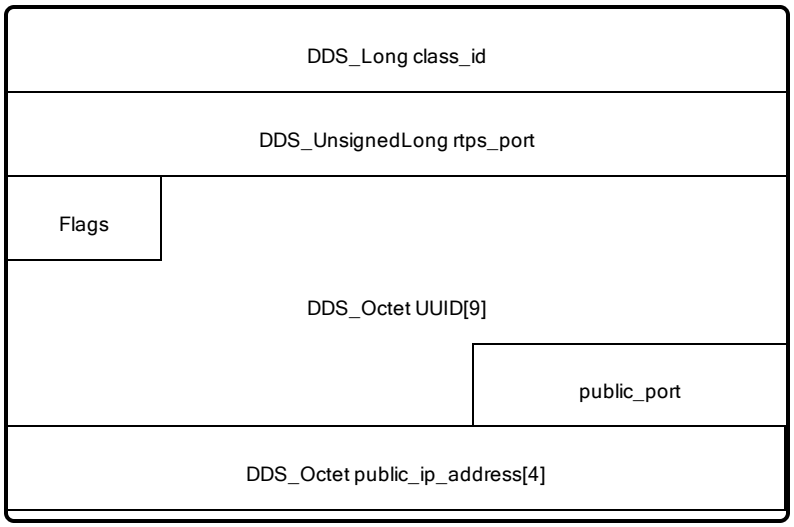
An RTPS locator consists of a transport Class ID, an address of 128 bits, and a logical port called the RTPS port, as shown in Figure 37.1: RTPS Locator below.

Figure 37.1: RTPS Locator



The locators for *Real-Time WAN Transport* use the following mapping:

Figure 37.2: RTPS WAN Locator



Flags has the following format: x|x|x|x|x|B|P|U

The B flag indicates whether the locator is unidirectional or bidirectional. Bidirectional locators can send/receive RTPS traffic. Unidirectional locators can only receive RTPS traffic. If the B flag is set, the P flag must be set, too. Locators with the B flag set are called BIDIRECTIONAL locators.

The P flag indicates that the locator contains a public IP address and public port where a DDS endpoint can be reached. **public_ip_address** contains the public IP address, and **public_port** contains the public UDP port. The public UDP port is always used to receive data, and, if the B flag is set, it is also used to send data. Locators with the P flag set are called **PUBLIC locators**.

The U flag indicates whether the locator contains a UUID. While this identifier by itself cannot be directly used to reach a DDS endpoint in a *DomainParticipant* DP1, the UUID can be mapped to a public address by *Cloud Discovery Service* and other *DomainParticipants*. Also, a locator can have both the U flag and the P flag, enabled simultaneously. Locators with the U flag set are called **UUID locators**.

A **PUBLIC+UUID locator** is a locator in which both the U flag and P flag are set.

Initial peers locators will have the B and P flags set and the U flag unset.

The U flag will be set for locators generated automatically by a *DomainParticipant*.

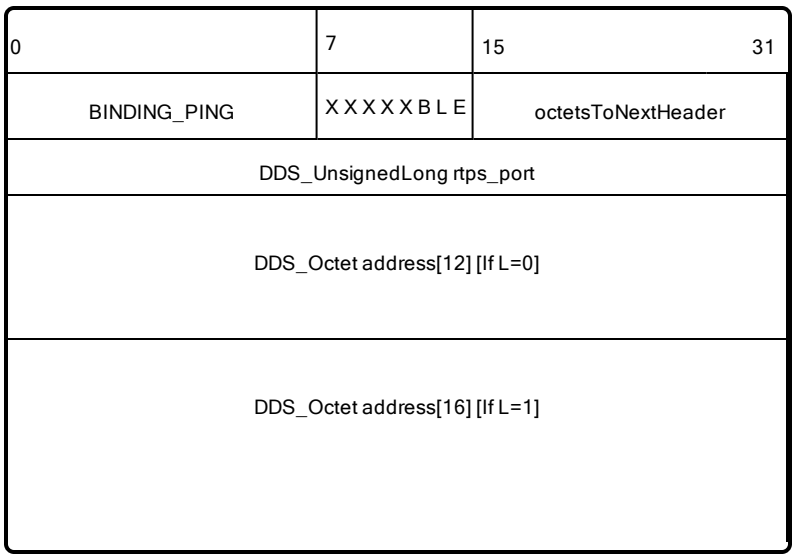
The P flag will be automatically set for locators generated for a transport that is configured using the property **dds.transport.UDPv4_WAN.builtin.public_address**. The flag will be also be set by *Cloud Discovery Service* when generating locators that contain the service reflexive address for a UUID locator.

37.2 Binding Ping Messages

As described in 35.1 Setting Real-Time WAN Transport Properties on page 1051, *Real-Time WAN Transport* uses special RTPS messages called Binding Ping messages to open NAT bindings and to resolve UUID locators into public IP transport addresses.

Binding Ping messages contain the UUID and the RTPS port of the locator with which they are associated. This information allows the receiving *Real-Time WAN Transport* to create and update the mapping between a (UUID, RTPS port) pair and its corresponding public address. Figure 37.3: BINDING_PING messages below depicts the structure of a Binding Ping message.

Figure 37.3: BINDING_PING messages



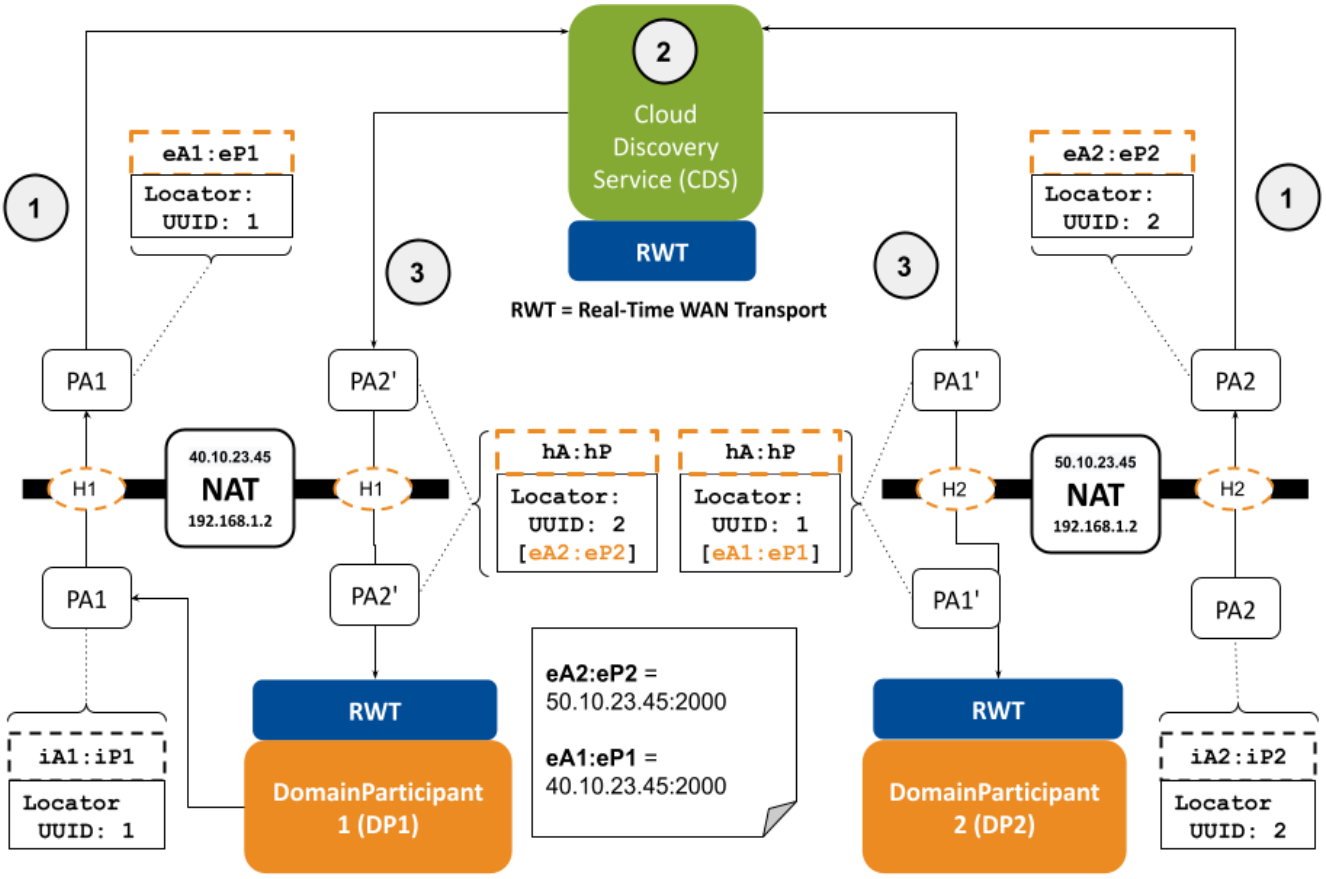
The security of the Binding Pings can be configured using the **com.rti.serv.secure.cryptography.rtps_protection_key** property. For further details, see the "Support for RTI Real-Time WAN Transport" chapter in the *RTI Security Plugins User's Manual*.

37.3 Communication Establishment Protocol for Peer-to-Peer Communication with Participants behind Cone NATs

This section describes the communication establishment protocol for the scenario described in 31.2 Peer-to-Peer Communication with Participants behind Cone NATs Using Cloud Discovery Service on page 1031.

Communication is established as indicated in Figure 37.4: Public Address Resolution Phase Using Cloud Discovery Service (CDS) on the next page and Figure 37.5: UDP Hole Punching Phase on page 1072.

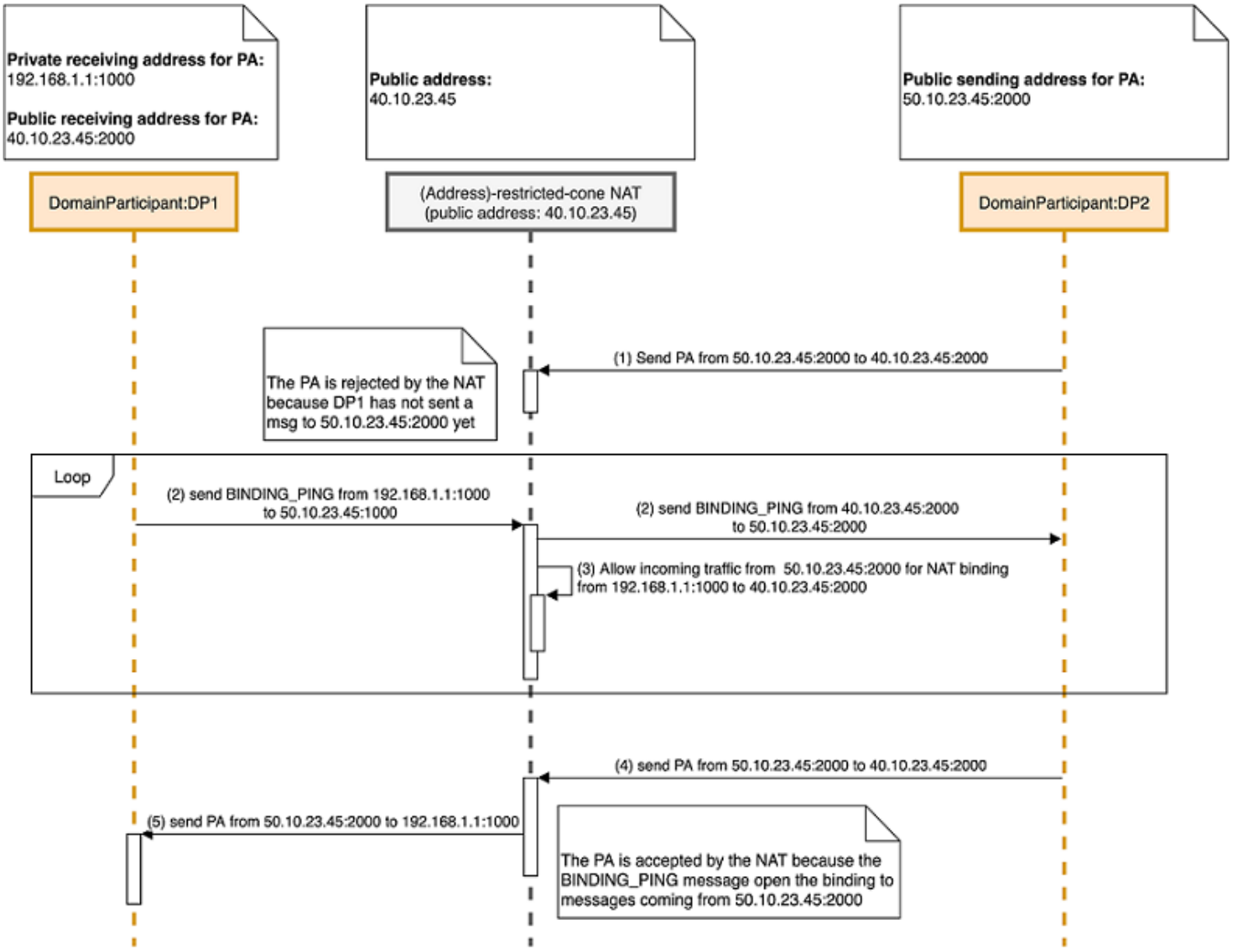
Figure 37.4: Public Address Resolution Phase Using Cloud Discovery Service (CDS)



1. *DomainParticipants* DP1 and DP2 register with CDS by sending DDS Participant Announcements PA1 and PA2. Each PA contains two (one for discovery and one for user data) or more UUID locators. These UUID locators are not directly reachable. For the sake of simplicity, Figure 37.4: Public Address Resolution Phase Using Cloud Discovery Service (CDS) above only shows the discovery UUID locator being exchanged.
2. When CDS gets the PAs, it obtains the service reflexive address for each one of the UUID locators and updates the PAs, replacing the UUID locators with UUID+PUBLIC locators that contain the service reflexive addresses. UUID+PUBLIC locators are reachable locators.
3. CDS sends PA1', which contains the UUID+PUBLIC locators for DP1, to DP2. It sends PA2', which contains the UUID+PUBLIC locators for DP2, to DP1.
4. After DP1 and DP2 receive each other's UUID+PUBLIC locators from CDS, they start communicating peer-to-peer using these locators by applying a technique called UDP hole punching.

Figure 37.5: UDP Hole Punching Phase on the next page illustrates how UDP hole punching works to allow sending PAs (PA1 and PA2) from DP2 data to DP1. For simplicity, the restricted-cone NAT for DP2 has been removed from the sequence diagram.

Figure 37.5: UDP Hole Punching Phase



In the initial state, DP2 has received a PUBLIC+UUID locator from *Cloud Discovery Service* indicating that DP1 can be reached at the address 40.10.23.45:2000. The PUBLIC+UUID locator was part of PA1' in Figure 37.4: Public Address Resolution Phase Using Cloud Discovery Service (CDS) on the previous page.

1. When DP2 tries to send a PA to DP1, the NAT router for DP1 will drop the message because the NAT binding from 192.168.1.1:100 to 40.10.23.45:2000 does not allow incoming traffic from 50.10.23.445:2000 (see 30.1.1 NAT Kinds on page 1023 for additional details).
2. To allow incoming traffic from DP2, DP1 sends an RTPS BINDING_PING message to DP2 public address 50.10.23.445:2000.
3. After the BINDING_PING is sent, the NAT router for DP1 will allow PA traffic from DP2 through the NAT binding from 192.168.1.1:100 to 40.10.23.45:2000. For additional details on the BINDING_PING message see 37.2 Binding Ping Messages on page 1069.

4. and 5) The next PA announcement coming from DP2 to DP1 will make it through the NAT router for DP1.

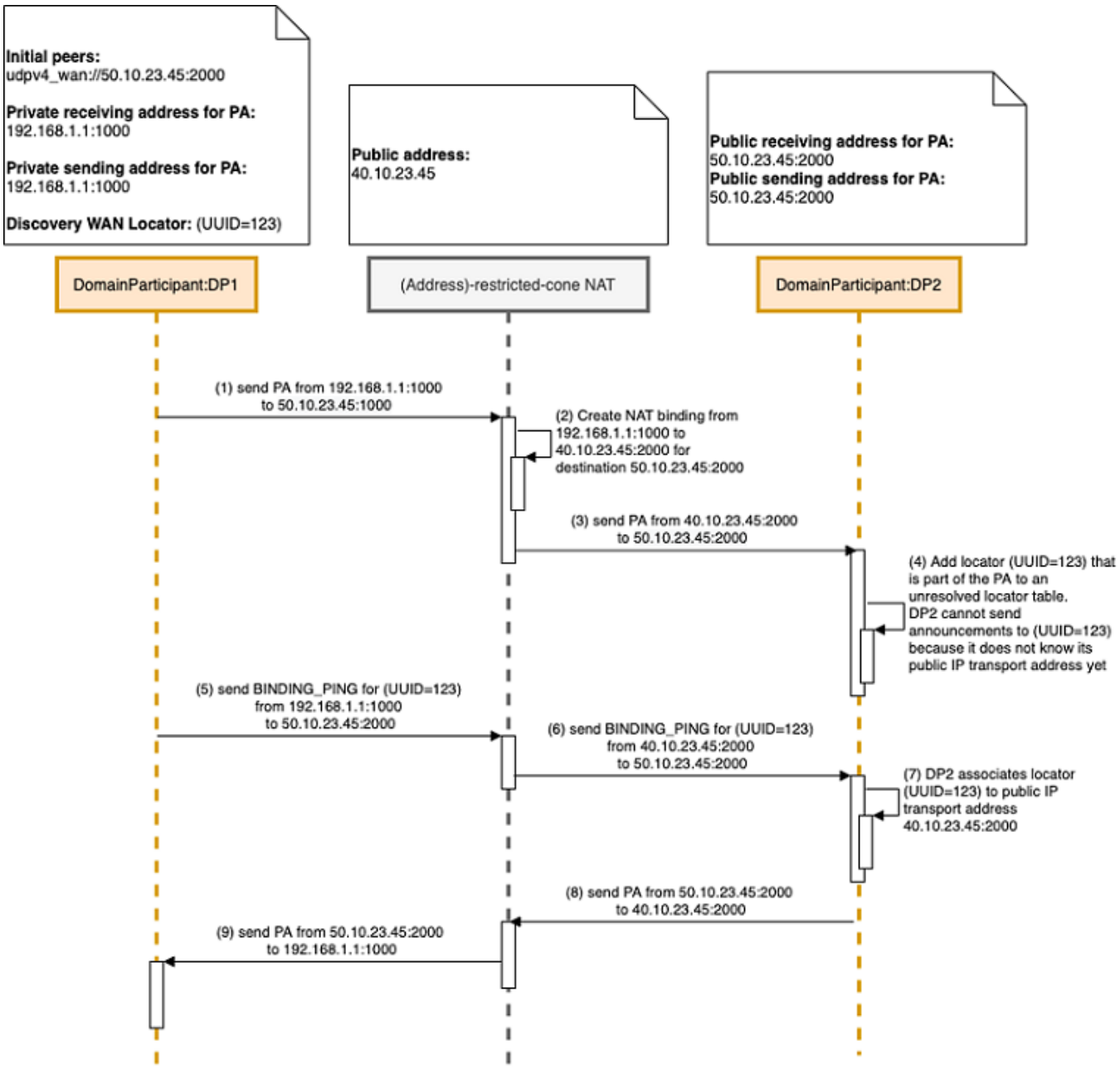
The same UDP hole punching mechanism is also used in the opposite direction so that DP1 can send PAs to DP2.

37.4 Communication Establishment Protocol for Peer-to-Peer Communication with a Participant that has a Public Address

This section describes the communication establishment protocol for the scenario described in 31.1 Peer-to-Peer Communication with a Participant that has a Public Address on page 1029.

Communication is established using a technique called “Connection Reversal” as described in Figure 37.6: Connection Reversal Protocol on the next page.

Figure 37.6: Connection Reversal Protocol



1. DP1 sends a PA to DP2 by using the public IP transport address contained in DP1's initial peers (50.10.23.45:2000).
2. The PA creates a NAT binding in the DP1 NAT router from 192.168.1.1:100 to 40.10.23.45:2000 for the destination address 50.10.23.45:2000.
3. The NAT router sends the PA from DP1 to DP2 by replacing the source IP transport address with 40.10.23.45:2000.

4. When DP2 receives the PA from DP1, it will add the discovery UUID locator for DP1 contained in the PA to an unresolved locator table. DP1 cannot send PAs to DP2 yet because it does not know the public IP transport address corresponding to the discovery UUID locator for DP1.
5. DP1 sends a BINDING_PING message from the address associated with the discovery UUID locator to the initial peer for DP2. The initial peer contains the address from which DP2 will send PAs.
6. Explained in 5).
7. When DP2 receives the BINDING_PING from DP1, it extracts the source IP transport address (40.10.23.45:2000) from the UDP packet containing the BINDING_PING and associates this address to the unresolved discovery UUID locator from DP1.
8. and 9) At this point, DP2 can send a PA to DP1.

Chapter 38 Transport Debugging

It is recommended that you read Chapter 37 Advanced Concepts on page 1068 before proceeding with this section.

The *Real-Time WAN Transport* operation can be debugged by setting the *Connext DDS* verbosity to LOCAL for the COMMUNICATION category:

```
<participant_factory_qos>
    <logging>
        <category>COMMUNICATION</category>
        <verbosity>LOCAL</verbosity>
    </logging>
</participant_factory_qos>
```

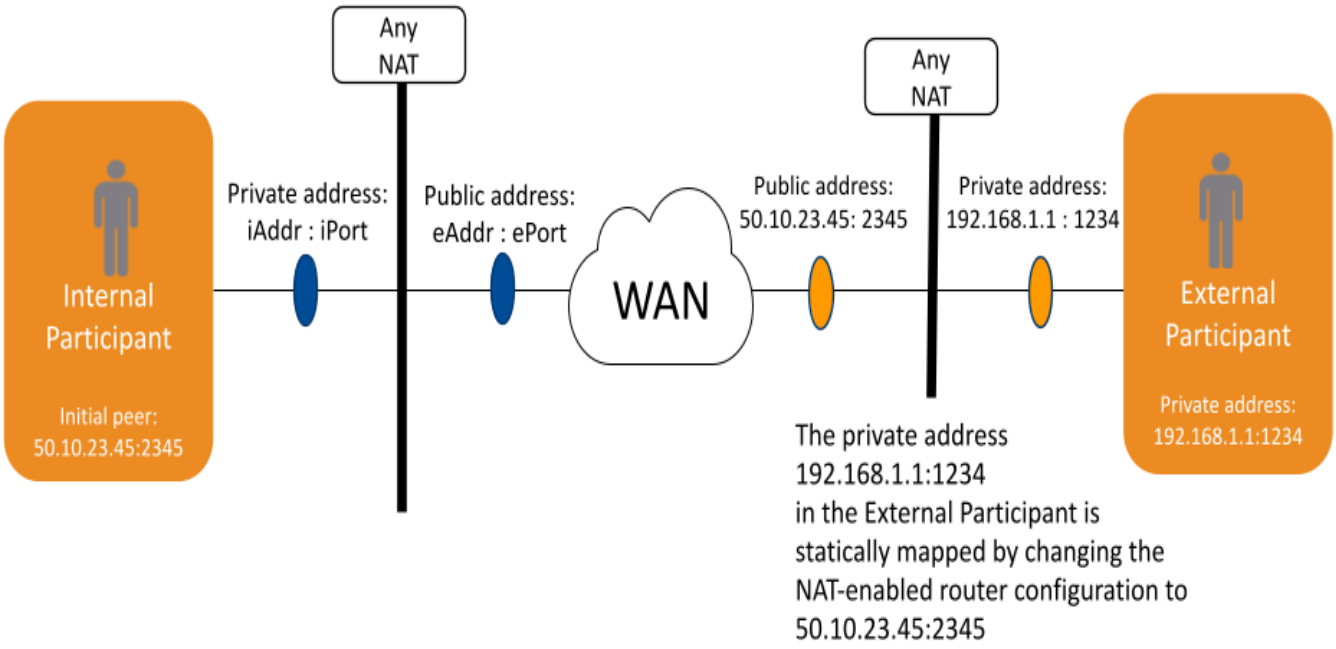
Or programmatically, shown here in modern C++ (other languages are similar):

```
Logger::instance().verbosity_by_category(LogCategory::COMMUNICATION, Verbosity::STATUS_
LOCAL);
```

38.1 Debugging Peer-to-Peer Communication with a Participant that has a Public Address

Consider the communication scenario described in 31.1 Peer-to-Peer Communication with a Participant that has a Public Address on page 1029. Let's assume the External Participant creates a *DataReader* on a *Topic* 'T' and the Internal Participant a *DataWriter* on the same *Topic* 'T'.

Figure 38.1: Peer-to-Peer with Any-NAT with a Public Participant



After enabling logging verbosity as indicated above, we can follow the *Real-Time WAN Transport* life-cycle by looking at the logging output:

1. When the Internal Participant is started, it creates a send resource for the locator provided in the initial peers 50.10.23.45:2345:

   ```
   [0x01015FAF,0xBA456FDC,0x040952B8:0x000001C1{D=0}|CREATE DP|ENABLE]
   NDDS_Transport_UDP_create_sendresource_srEA:Created send resource for
   f=BP,u={00,00,00,00,00,00,00,00,00,00},p=50.10.23.45:2345:7410
   ```

   A send resource is a transport object that can be used to send data to a locator.

   We know this is the initial peer locator because:

   - The locator UUID is all zeros: u={00,00,00,00,00,00,00,00,00,00}.
   - The public address is the one provided in the initial peers: 50.10.23.45:2345.

   7410 is the RTPS port for discovery data on domain 0. To see how RTPS ports are calculated, see 9.5.9.2 Ports Used for Discovery on page 666.

   At this point, the Internal Participant starts sending PAs to the External Participant.
2. When the External Participant receives the PA from the Internal Participant, it creates a send resource for the discovery UUID locator contained in the PA.

```
[0x01017AA5,0x4B4691C4,0x600386AD:0x000100C7{E=DR,I=21}|RECEIVE FROM
0x00000000,0x00000000,0x00000000:0x000100C2]
NDDS_Transport_UDP_create_sendresource_srEA:Created send resource for
f=U,u={47,82,BA,ED,A3,27,6F,A8,42},p=172.31.11.80:0:7410
```

The UUID locator is a non-reachable locator.

- f=U indicates that this is a non-reachable UUID locator.
- u={47,82,BA,ED,A3,27,6F,A8,42} is the UUID of the discovery locator coming from the Internal Participant.
- Even though the public address field has the value (p=172.31.11.80:0:7410), the IP address in the log message is not reachable and it corresponds to the private IP address of the Internal Participant.

The External Participant also creates a send resource for the user data UUID locator contained in the PA once it discovers the *DataWriter* created by the Internal Participant. The user data locator will be used to send RTPS traffic for *Topic* 'T'.

```
[0x01017AA5,0x4B4691C4,0x600386AD:0x80000004{E=DR,T=Example Quote,C=Quote,D=0}|LINK
0x01010402,0x1CA21E93,0xB02F44C3:0x80000003{C=Quote}]
NDDS_Transport_UDP_create_sendresource_srEA:Created send resource for
f=U,u={47,82,BA,ED,A3,27,6F,A8,42},p=172.31.11.80:0:7411
```

The distinction between discovery and user data locators is based on the RTPS port. 7410 is discovery and 7411 is user data.

3. The External Participant cannot send a PA to the Internal Participant until it resolves the public address for the locator with UUID {47,82,BA,ED,A3,27,6F,A8,42} and the RTPS port 7410 associated with the discovery send resource created in step 2.

   The public address resolution is done when a BINDING_PING is received from the Internal Participant.

```
[0x01017AA5,0x4B4691C4,0x600386AD:0x000001C1|PROCESS BINDING PING]
NDDS_Transport_UDPv4_WAN_PublicAddressMappingInfo_log:added
P=7410,u={47,82,BA,ED,A3,27,6F,A8,42},k=3,p=54.151.6.102:7535,f=BPU,r=0
```

   - P=7410 is the RTPS port.
   - u={47,82,BA,ED,A3,27,6F,A8,42} is the UUID of the locator coming from the Internal Participant.
   - f=BPU indicates that the resolved locator is a PUBLIC+UUID locator that can be used for bidirectional communication. This means that the Internal Participant will be sending RTPS messages using the address 54.151.6.102:7535.
   - k=3 and r=0 are internal fields not relevant for this discussion.

The External Participant also will not be able to send RTPS data for *Topic* 'T' until it resolves the public address for the locator identified by the UUID {47,82,BA,ED,A3,27,6F,A8,42} and the RTPS port 7411. This resolution is also done by the reception of a BINDING_PING:

```
[0x01017AA5,0x4B4691C4,0x600386AD:0x000001C1|PROCESS BINDING PING]
NDDS_Transport_UDPv4_WAN_PublicAddressMappingInfo_log:added
P=7411,u={47,82,BA,ED,A3,27,6F,A8,42},k=3,p=54.151.6.102:7536,f=PU,r=0
```

4. The Internal Participant receives a PA from the External Participant, and it creates two transport send resources: one for sending discovery data and one for sending user data:

   Discovery data:

   ```
   [0x01010402,0x1CA21E93,0xB02F44C3:0x000100C7{E=DR,I=21}|RECEIVE FROM
   0x00000000,0x00000000,0x00000000:0x000100C2]
   NDDS_Transport_UDP_create_sendresource_srEA:Created send resource for
   f=BPU,u={F2,7D,8B,5D,90,AF,93,DD,90},p=50.10.23.45:2345:7410
   ```

   User data:

   ```
   [0x01010402,0x1CA21E93,0xB02F44C3:0x80000003{E=DW,T=Example Quote,C=Quote,D=0}|LINK
   0x01017AA5,0x4B4691C4,0x600386AD:0x80000004{C=Quote}]
   NDDS_Transport_UDP_create_sendresource_srEA:Created send resource for
   f=BPU,u={F2,7D,8B,5D,90,AF,93,DD,90},p=50.10.23.45:2345:7411
   ```

   The user data locator will be used to send RTPS traffic for *Topic* 'T'.

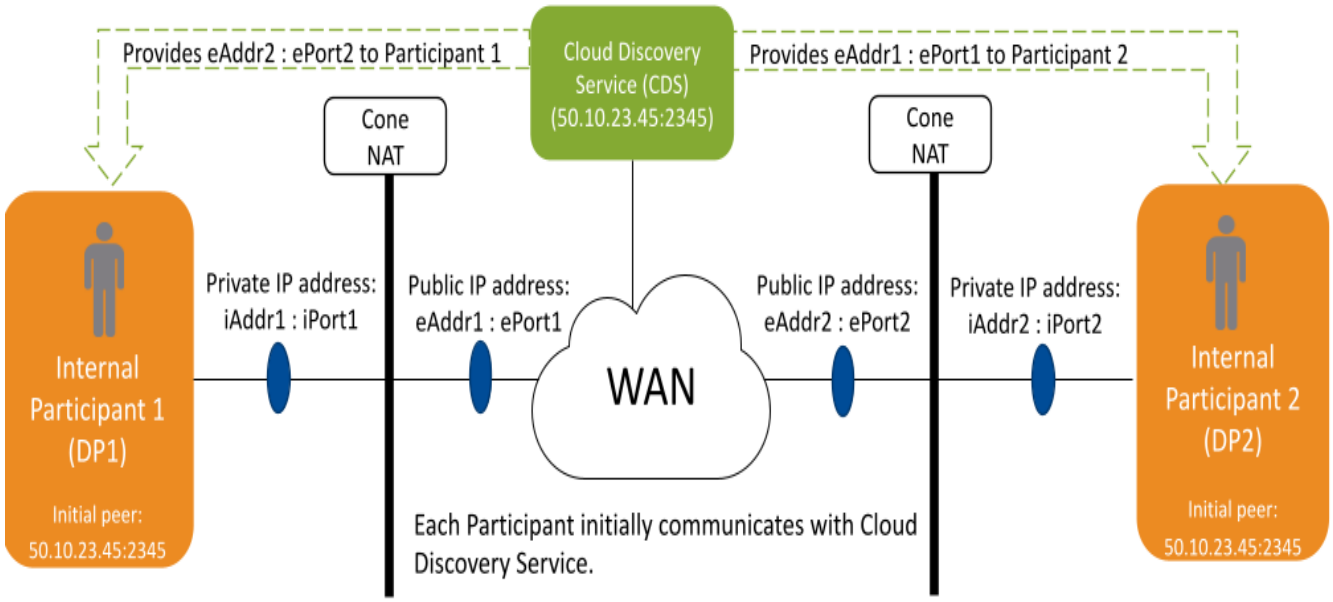
   Note that the public address 50.10.23.45:2345 is the same for both send resources because we are configuring the External Participant to use a single UDP port for communications. The distinction between user data and discovery data is done by looking at the RTPS port. 7410 is the port for discovery and 7411 is the port for user data.

5. At this point, both Participants can communicate with each other. The External Participant will start receiving samples for *Topic* 'T' from the Internal Participant.

38.2 Peer-to-Peer Communication with Participants behind Cone NATs

This section covers the scenario described in 31.2 Peer-to-Peer Communication with Participants behind Cone NATs Using Cloud Discovery Service on page 1031. It is recommended that you read that section to interpret some of the log messages.

Figure 38.2: Peer-to-Peer with Cone NATs



Cloud Discovery Service also serves as a directory, so that a participant only needs to know about the CDS to connect to multiple peers automatically.

The Internal Participant 1 (DP1) will create a *DataWriter* publishing data on a *Topic* 'T', and the Internal Participant 2 (DP2) will create a *DataReader* subscribing to *Topic* 'T'.

This section will focus on debugging the *Real-Time WAN Transport* lifecycle for DP1 and DP2. For details on how to debug *Cloud Discovery Service* (CDS), see "Debugging Cloud Discovery Service with the UDP WAN Transport," in the *NAT Traversal* section of the *RTI Cloud Discovery Service* documentation .

1. When DP1 is started, it creates a send resource for the locator provided as the initial peer 50.10.23.45:2345. This locator corresponds to the CDS locator.

   ```
   [0x01016F1B,0x2294D448,0x8060E06B:0x000001C1{D=0}|CREATE DP|ENABLE]
   NDDS_Transport_UDP_create_sendresource_srEA:Created send resource for
   f=BP,u={00,00,00,00,00,00,00,00,00,00},p=50.10.23.45:2345:2345
   ```

   We know this is the initial peer locator because:

   - The locator UUID is all zeros: u={00,00,00,00,00,00,00,00,00,00}.
   - The public address is the one provided in the initial peers: 50.10.23.45:2345.

   At this point the DP1 starts sending PAs to CDS.

2. Likewise, when DP2 is started, it creates a send resource for the CDS locator provided as the initial peer 50.10.23.45:2345.

```
[0x01017116,0xF14A169C,0xE7799A94:0x000001C1{D=0}|CREATE DP|ENABLE]
NDDS_Transport_UDP_create_sendresource_srEA:Created send resource for
f=BP,u={00,00,00,00,00,00,00,00,00,00},p=50.10.23.45:2345:2345
```

   At this point, DP2 starts sending PAs to CDS.
3. To start sending PAs to DP2, DP1 must receive a PA from CDS on behalf of DP2 containing the discovery UUID+PUBLIC locator at which DP2 can be reached.
4. Once DP1 receives the PA from CDS, it creates a send resource for the discovery UUID+PUBLIC locator used for discovery and starts sending PAs to DP2.

```
[0x01016F1B,0x2294D448,0x8060E06B:0x000100C7{E=DR,I=21}|RECEIVE FROM
0x00000000,0x00000000,0x00000000:0x000100C2]
NDDS_Transport_UDP_create_sendresource_srEA:Created send resource for
f=BPU,u={50,26,6D,EA,B7,11,AC,B9,5F},p=99.35.17.233:7535:7410
```

   99.35.17.233:7535 is the public address at which DP2 will receive RTPS discovery traffic.
5. To start sending PAs to DP1, DP2 must receive a PA from CDS on behalf of DP1 containing the discovery UUID+PUBLIC locator at which DP1 can be reached.
6. Once DP2 receives the PA from CDS, it creates a send resource for the UUID+PUBLIC locator used for discovery and starts sending PAs to DP1.

```
[0x01017116,0xF14A169C,0xE7799A94:0x000100C7{E=DR,I=21}|RECEIVE FROM
0x00000000,0x00000000,0x00000000:0x000100C2]
NDDS_Transport_UDP_create_sendresource_srEA:Created send resource for
f=BPU,u={B1,1D,4B,B5,A1,58,5E,E1,58},p=54.151.6.102:7535:7410
```

   54.151.6.102:7535 is the public address at which DP 1 will receive RTPS discovery traffic.
7. After DP1 discovers DP2's *DataReader* for *Topic* 'T', DP1 will create a send resource to send RTPS data for *Topic* 'T' (samples, GAPs, and HBs) to the *DataReader* in DP2.

```
[0x01016F1B,0x2294D448,0x8060E06B:0x80000003{E=DW,T=Example Quote,C=Quote,D=0}|LINK
0x01017116,0xF14A169C,0xE7799A94:0x80000004{C=Quote}]
NDDS_Transport_UDP_create_sendresource_srEA:Created send resource for
f=PU,u={50,26,6D,EA,B7,11,AC,B9,5F},p=99.35.17.233:7536:7411
```

   99.35.17.233:7536 is the public address at which DP1 will receive RTPS user data traffic for *Topic* 'T'.
8. After DP2 discovers DP1's *DataWriter* for *Topic* 'T', DP2 will create a send resource to send RTPS data for *Topic* 'T' (NACKs) to the *DataWriter* in DP1.

```
[0x01017116,0xF14A169C,0xE7799A94:0x80000004{E=DR,T=Example Quote,C=Quote,D=0}|LINK
0x01016F1B,0x2294D448,0x8060E06B:0x80000003{C=Quote}]
NDDS_Transport_UDP_create_sendresource_srEA:Created send resource for
```

```
f=U,u={B1,1D,4B,B5,A1,58,5E,E1,58},p=172.31.11.80:0:7411
```

Note that in this case, the send resource has been created with a UUID locator that is not reachable. When this occurs, the public IP transport address for the UUID locator will be resolved by receiving a BINDING_PING from DP1.

```
[0x01017116,0xF14A169C,0xE7799A94:0x80000004{E=DR,T=Example Quote,C=Quote,D=0}|MODIFY
LINK 0x01016F1B,0x2294D448,0x8060E06B:0x80000003{C=Quote}]
NDDS_Transport_UDPv4_WAN_PublicAddressMappingInfo_log:updated
P=7411,u={B1,1D,4B,B5,A1,58,5E,E1,58},k=1,p=54.151.6.102:7536,f=PU,r=1
```

9. At this point, both Participants can communicate with each other. DP2's *DataReader* will start receiving samples for *Topic* ‘T’ from DP1's *DataWriter*.

Chapter 39 Tools Integration

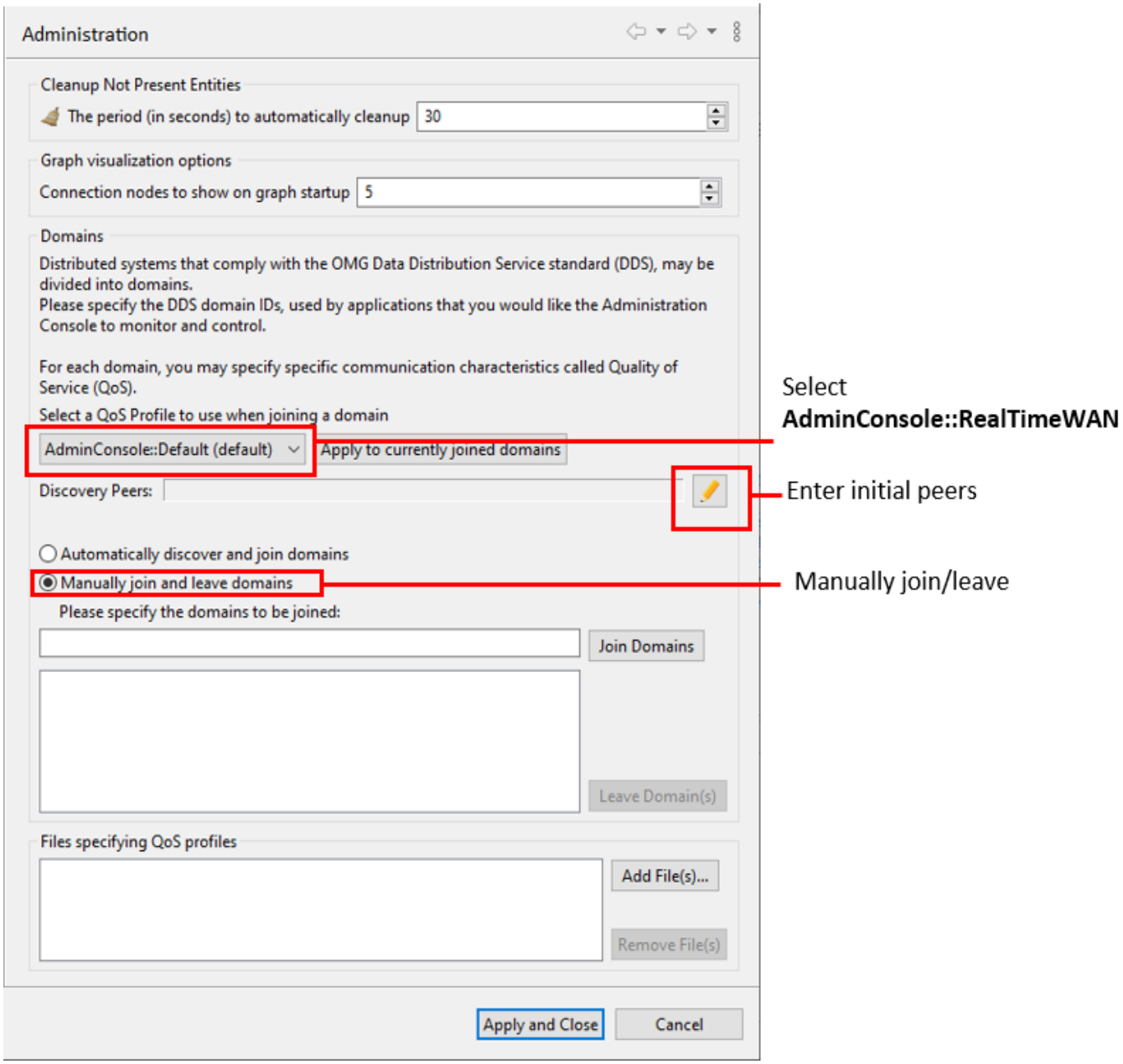
RTI Tools such as *RTI Admin Console* can use *Real-Time WAN Transport* if they are configured appropriately.

Admin Console ships with a builtin profile that enables use of the *Real-Time WAN Transport*: **AdminConsole::RealTimeWAN**. Make sure you select that profile in the *Admin Console* Preferences and provide the right initial peers (see Chapter 34 Transport Initial Peers on page 1049) to *Admin Console* to inspect *Connext DDS* applications running across the WAN. See Figure 39.1: Real-Time WAN Transport and Admin Console on the next page.

```
<qos_library name="AdminConsole">
    <qos_profile name="RealTimeWAN" base_name="AdminConsole::Default">
        <participant_qos>
            <transport_builtin>
                <mask>MASK_DEFAULT|UDPv4_WAN</mask>
            </transport_builtin>
        </participant_qos>
    </qos_profile>
</qos_library>
```

Important: The auto-join feature will not work when using *Real-Time WAN Transport* because multicast is not available in WAN environments. You will have to join the WAN domain(s) explicitly.

Figure 39.1: *Real-Time WAN Transport* and *Admin Console*



Chapter 40 Troubleshooting

40.1 Communication Stops Working after Application Transitions to Different Network

Possible Root Cause:

If you are using *Cloud Discovery Service*, it is possible that before the network transition, all the applications were behind cone NATs. When the transition occurs, the application that is changing to a new network connects to a symmetric NAT.

This configuration is not currently supported. Symmetric NATs are only supported in scenarios like the one described in Figure 31.1: Peer-to-Peer between a Participant behind Any Kind of NAT and an External Participant on page 1029.

To validate if you are behind a symmetric NAT in the new network, you can run the application *natat* as described in 30.1.2 Identifying the NAT Type on page 1025.

Solution:

When you do not know in advance whether the networks in which applications run are behind cone NATs or symmetric NATs, you may want to do a relay deployment as indicated in 32.2 Relayed Edge-to-Edge Deployment Scenario on page 1040.

40.2 Communication not Established after Changing Cloud Discovery Service <receiver_port>

For example, when changing the *Cloud Discovery Service* configuration from:

```
<dds>
    <cloud_discovery_service name="CDS">
        <transport>
            <element>
                <alias>builtin.udpv4_wan</alias>
                <receive_port>2345</receive_port>
                <property>
```

```
                    <element>
                        <name>dds.transport.UDPv4_WAN.builtin.public_address</name>
                        <value>50.10.23.45</value>
                    </element>
                </property>
            </element>
        </transport>
    </cloud_discovery_service>
</dds>
```

To:

```
<dds>
    <cloud_discovery_service name="CDS">
        <transport>
            <element>
                <alias>builtin.udpv4_wan</alias>
                <receive_port>6001</receive_port>
                <property>
                    <element>
                        <name>dds.transport.UDPv4_WAN.builtin.public_address</name>
                        <value>50.10.23.45</value>
                    </element>
                </property>
            </element>
        </transport>
    </cloud_discovery_service>
</dds>
```

Possible Root Cause:

If *Cloud Discovery Service* (CDS) is running behind a NAT-enabled router, it is possible that you have not created a static NAT binding in the router for the new public address: 50.10.23.45:6001.

Solution:

Create a new static NAT binding to support the port change. The NAT binding must create this mapping:

<CDS private address X>:<port number Y> → <new public address Z>:<port number Y>

<CDS private address>:6001 → 50.10.23.45:6001

Note that the private host CDS port and public port must be the same (6001 is the port number for both in the example above). To make them different, use the transport property **dds.transport.UDPv4_WAN.builtin.comm_ports**. See 35.1 Setting Real-Time WAN Transport Properties on page 1051.

40.3 Communication not Established even though Transport Settings are Set Correctly

Possible Root Cause:

There may be an IP fragmentation problem. For WAN communications, it is not a good idea to rely on IP fragmentation. IP fragmentation causes significant issues in UDP, where there is no support for an MTU (maximum transmission unit) discovery protocol as there is in TCP. These are some of the problems associated with IP fragmentation:

- To successfully reassemble a packet, all fragments must be delivered. No fragment can become corrupt or get lost in-flight. If a fragment is lost, the whole packet will be lost.
- Before reassembly, a host must hold partial, fragment datagrams in memory. This opens an opportunity for memory exhaustion attacks.
- Subsequent fragments lack the higher-layer header. The TCP or UDP header is only present in the first fragment, making it impossible for firewalls to filter fragment datagrams based on criteria like source or destination ports.

When testing over some cellular networks, in some cases you may not be able to send samples larger than the IP MTU, such as images, without losing a large percentage of the frames.

Solution:

Because of these problems with IP fragmentation, the *Real-Time WAN Transport* configuration should set its MTU (**<message_size_max>**) to be smaller than the typical IP MTU of around 1500 bytes. The recommendation is to be even more conservative and set the transport MTU to 1400 bytes.

This MTU configuration also requires the use of asynchronous publication for reliable *Topics* (user and builtin *Topics*) in the application. For example:

```
<qos_profile name="Transport.UDP.WAN">
    <participant_qos>
        <discovery_config>
            <publication_writer_publish_mode>
                <kind>ASYNCHRONOUS_PUBLISH_MODE_QOS</kind>
            </publication_writer_publish_mode>
            <subscription_writer_publish_mode>
                <kind>ASYNCHRONOUS_PUBLISH_MODE_QOS</kind>
            </subscription_writer_publish_mode>
            <secure_volatile_writer_publish_mode>
                <kind>ASYNCHRONOUS_PUBLISH_MODE_QOS</kind>
            </secure_volatile_writer_publish_mode>
            <service_request_writer_publish_mode>
                <kind>ASYNCHRONOUS_PUBLISH_MODE_QOS</kind>
            </service_request_writer_publish_mode>
        </discovery_config>
        <transport_builtin>
            <mask>UDPv4_WAN</mask>
            <udpv4_wan>
                <message_size_max>1400</message_size_max>
            </udpv4_wan>
        </transport_builtin>
        <property>
```

```
            <value>
                <element>
                    <name>dds.participant.protocol.rtps_overhead</name>
                    <value>128</value>
                </element>
            </value>
        </property>
    </participant_qos>

    <datawriter_qos>
        <publish_mode>
            <kind>ASYNCHRONOUS_PUBLISH_MODE_QOS</kind>
        </publish_mode>
    </datawriter_qos>
</qos_profile>
```

Part 6: RTI Secure WAN Transport

Secure WAN Transport is an optional package that enables participant discovery and data exchange in a secure manner over the public WAN. *Secure WAN Transport* enables *Connext DDS* to address the challenges in NAT traversal and authentication of all participants. By implementing UDP hole punching using the STUN protocol and providing security to channels by leveraging DTLS (Datagram TLS), you can securely exchange information between different sites separated by firewalls.

> The material in this part of the manual is only relevant if you have installed *Secure WAN Transport*. This feature is not installed as part of a *Connext DDS* package; it must be downloaded and installed separately. It is only available on specific architectures. See the RTI Secure WAN Transport Release Notes and RTI Secure WAN Transport Installation Guide for details.

> RTI may not support *Secure WAN Transport* in future versions of *Connext DDS*. Existing applications that use it should be updated to take advantage of *Real-Time WAN Transport* as soon as feasible. All new applications should use *Real-Time WAN Transport*. See Part 5: RTI Real-Time WAN Transport on page 1018.

This section includes:

- Introduction to Secure WAN Transport (Chapter 41 on page 1090)
- Configuring RTI Secure WAN Transport (Chapter 42 on page 1102)

Chapter 41 Introduction to Secure WAN Transport

Secure WAN Transport provides transport plugins that can be used by developers of *Connext DDS* applications. These transport plugins allow *Connext DDS* applications running on private networks to communicate securely over a Wide-Area Network (WAN), such the internet. There are two primary components in the package which may be used independently or together: communication over Wide-Area Networks that involve Network Address Translators (NATs), and secure communication with support for peer authentication and encrypted data transport.

The *Connext DDS* core is transport-agnostic. *Connext DDS* offers three built-in transports: UDP/IPv4, UDP/IPv6, and inter-process shared memory. The implementation of NAT traversal and secure communication is done at the transport level so that the *Connext DDS* core is not affected and does not need to be changed, although there is additional on-the-wire traffic.

The basic problem to overcome in a WAN environment is that messages sent from an application on a private local-area network (LAN) appear to come from the LAN's router address, not from the internal IP address of the host running the application. This is due to the existence of a Network Address Translator (NAT) at the gateway. This does not cause problems for client/server systems because only the server needs to be globally addressable; it is only a problem for systems with peer-to-peer communication models, such as *Connext DDS*.*Secure WAN Transport* solves this problem, allowing communication between peers that are in separate LAN networks, using a UDP hole-punching mechanism based on the STUN protocol (IETF RFC 3489bis) for NAT traversal. This requires the use of an additional rendezvous server application, the RTI WAN Server.

Once the transport has enabled traffic to cross the NAT gateway to the WAN, it is flowing on network hardware that is shared (in some cases, over the public internet). In this context, it is important to consider the security of data transmission. There are three primary issues involved:

- Authenticating the communication peer (source or destination) as a trusted partner;
- Encrypting the data to hide it from other parties that may have access to the network;

- Validating the received data to ensure that it was not modified in transmission.

Secure WAN Transport addresses these problems by wrapping all RTPS-encoded data using the DTLS protocol (IETF RFC 4347), which is a variant of SSL/TLS that can be used over a datagram network-layer transport such as UDP. The security features of the WAN Transport may also be used on an untrusted local-area network with the Secure Transport.

In summary, the package includes two transports:

- The WAN Transport is for use on a WAN and includes security. It must be used with the WAN Server, a rendezvous server that provides the ability to discover public addresses and to register and look up peer addresses based on a unique WAN ID. The WAN Server is based on the STUN (Session Traversal Utilities for NAT) protocol (https://tools.ietf.org/html/rfc5389), with some extensions. Once information about public addresses for the application and its peers has been obtained and connections have been initiated, the server is no longer required to maintain communication with a peer. (Note: security is disabled by default.)
- The Secure Transport is an alternate transport that provides security on an untrusted LAN. Use of the RTI WAN Server is not required.

Multicast communication is not supported by either of these transports.

This chapter provides a technical overview of:

- 41.1 WAN Traversal via UDP Hole-Punching below
- 41.2 WAN Locators on page 1095
- 41.3 Datagram Transport-Layer Security (DTLS) on page 1096
- 41.4 Certificate Support on page 1098

For information on how to use *Secure WAN Transport* with your *Connext DDS* application, see Configuring RTI Secure WAN Transport (Chapter 42 on page 1102).

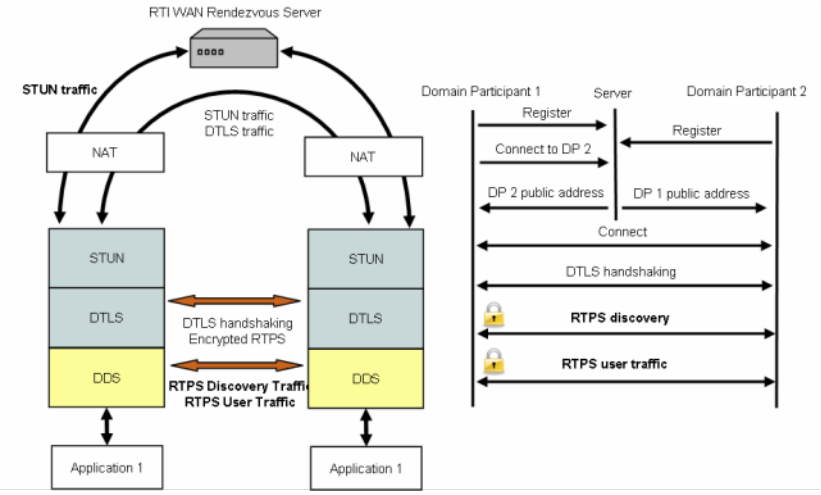
41.1 WAN Traversal via UDP Hole-Punching

In order to resolve the problem of communication across NAT boundaries, the WAN Transport implements a UDP hole-punching solution for NAT traversal [draft-ietf-behave-p2p-state]. This solution uses a rendezvous server, which provides the ability to discover public addresses, and to register and lookup peer addresses based on a unique WAN ID. This server is based on the STUN (Session Traversal Utilities for NAT) protocol [draft-ietf-behave-rfc3489bis], with some extensions. This protocol is a part of the solution used for standards-based voice over IP applications; similar technology has be used by systems such as Skype and has proven to be highly reliable. A key advantage of STUN is that it is based on UDP and therefore is able to preserve the real-time characteristics of the DDS Interoperability Wire Protocol.

Once information about public addresses for the application and its peers has been obtained, and connections have been initiated, the server is no longer required to maintain communication with a peer. However, if communication fails, possibly due to changes in dynamically-allocated addresses, the server will be needed to reopen new public channels.

Figure 41.1: RTI WAN Transport Architecture below shows the RTI WAN transport architecture.

Figure 41.1: RTI WAN Transport Architecture



41.1.1 Protocol Details

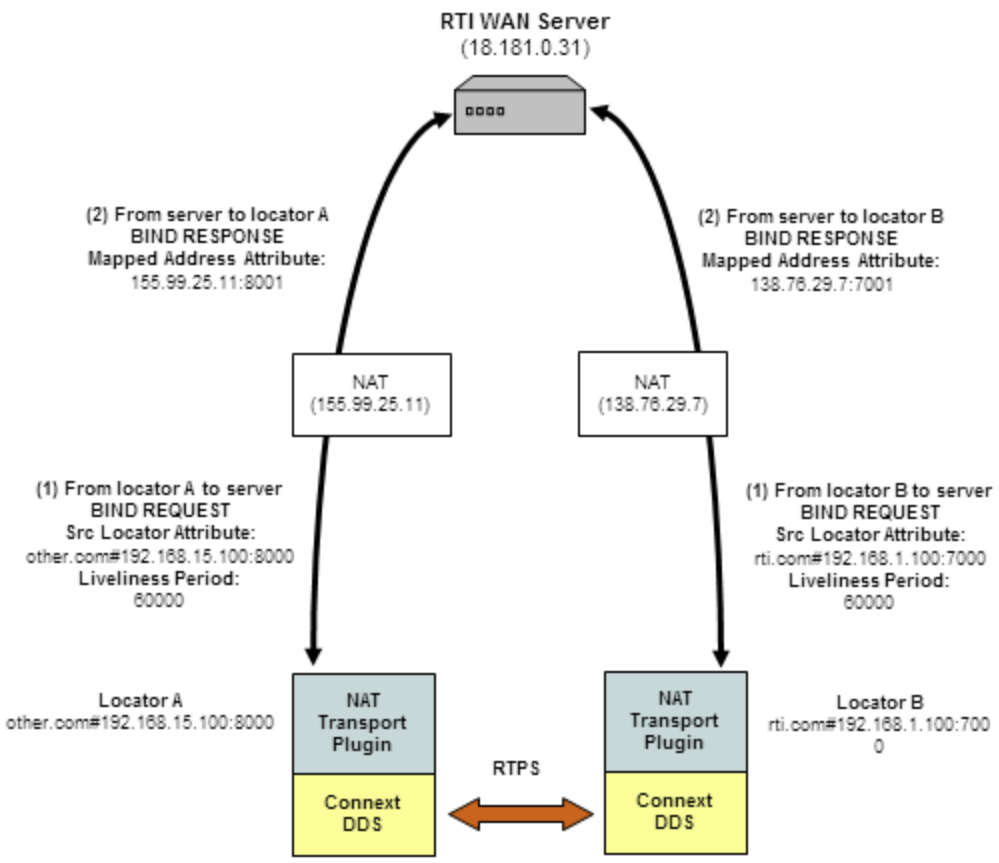
The UDP hole-punching algorithm implemented by the WAN transport has two different phases: registration and connection. This algorithm only works with cone or asymmetric NATs where the same public address/port is assigned to all the sessions with the same private address/port address.

- Registration Phase

  The RTI WAN Server application runs on a machine that resides on the WAN network (i.e., not in a private LAN). It has to be globally accessible to LAN applications. It is started by a script and acts as a rendezvous point for LAN applications. During the registration phase, each transport locator is registered with the RTI WAN Server using a STUN binding request message.

  The RTI WAN Server associates RTPS locators with their corresponding public IPv4 transport addresses (a combination of IP address and port) and stores that information in an internal table. Figure 41.2: Registration Phase on the next page illustrates the registration phase.

Figure 41.2: Registration Phase



- Connection Phase

  The connection phase starts when locator A wants to establish a connection with locator B. Locator A obtains information about locator B via Connext DDS discovery traffic or the initial NDDS_DISCOVERY_PEERS list. To establish a connection with locator B, locator A sends a STUN connect request to the RTI WAN server. The server sends a STUN connect response to locator A, including information about the public IP transport address (IP address and port) of locator B. In parallel, the RTI WAN server contacts locator B using another STUN connect request to let it know that locator A wants to establish a connection with it.

  When locator A receives the public IP address of locator B, it will try to contact B using two STUN binding request messages. The first message is sent to the public address of B and the second message is sent to the private address of B. The private address was obtained using the last 32 bits of the locator address of B. The STUN binding request message directed to the public transport address of B sent by locator A will open a hole in A's NAT to receive messages from B.

When locator B receives the public address of locator A, it will try to contact A sending a STUN binding request message to that public address. This message will open a hole in B's NAT to receive messages from A. When locator A receives the first STUN binding response from locator B, it starts sending RTPS traffic.

The connection phase includes two processes: the connect process (Figure 41.3: Connect Process below) and the NAT hole punching process (Figure 41.4: NAT Hole Punching Process on the next page).

Figure 41.3: Connect Process

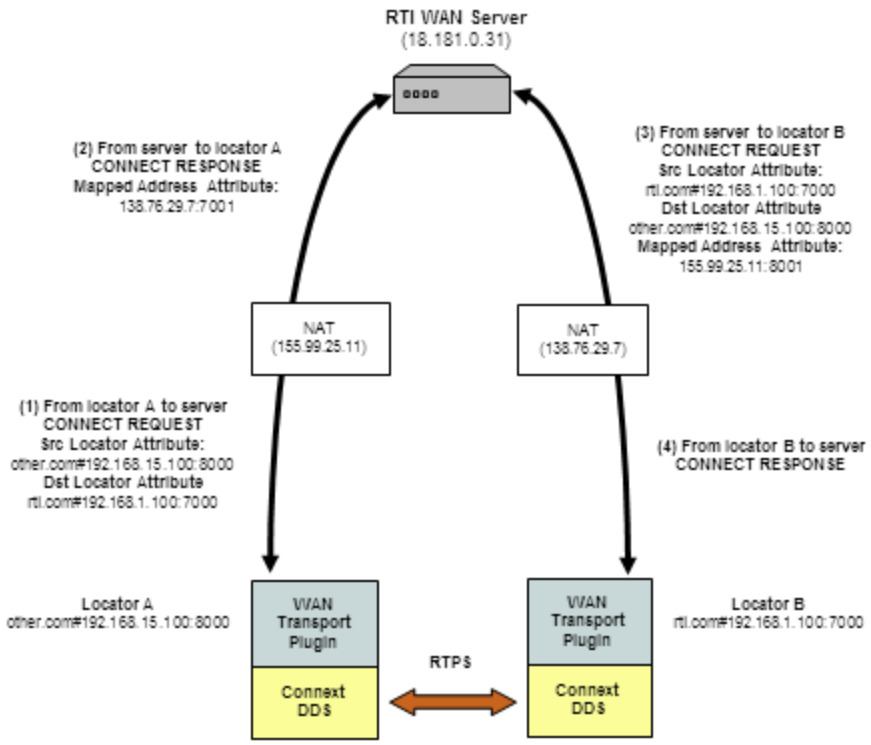
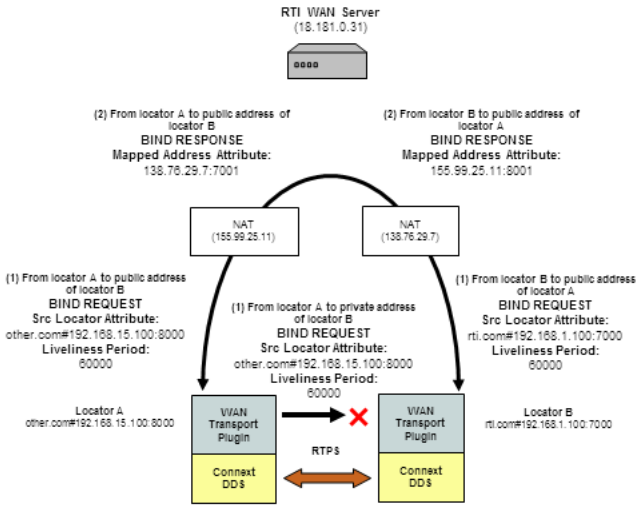


Figure 41.4: NAT Hole Punching Process

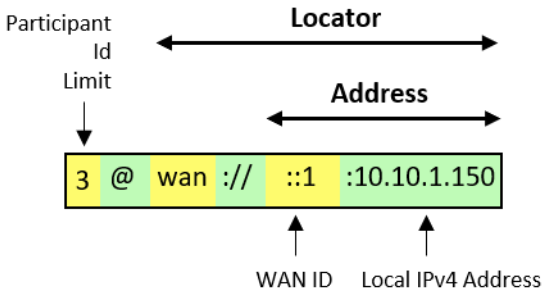


- STUN Liveliness

  Finally, since bindings allocated by NAT expire unless refreshed, the clients (locators) must generate binding request messages for the server and other clients to refresh the bindings. The RTI STUN protocol implementation uses the attribute LIVELINESS-PERIOD in the STUN binding request to indicate the period in milliseconds at which a client will assert its liveliness. The WAN Server will remove a locator from its mapping table when the liveliness contract is not met. Likewise, a transport instance will remove a STUN connection with a locator when this locator does not assert its liveliness as indicated in the last binding request.

41.2 WAN Locators

The WAN transport does not use simple IP addresses to locate peers. A WAN transport locator consists of a WAN ID, which is an arbitrary 12-byte value, and a bottom 4-byte value that specifies a fallback local IPv4 address. Your peers list (NDDS_DISCOVERY_PEERS) must be configured to look for peers with locators of the form:



- The address is a 128-bit address in IPv6 notation.
- The first part, "3@", specifies the maximum participant ID to be contacted at the given locator. See 15.2.1 Peer Descriptor Format on page 762.
- The "wan://" part specifies that the address is for the WAN transport.
- The next part, "::1", specifies the top 12 bytes of the address to be 11 zero bytes, followed by a byte with value 1 (this corresponds to the peer's WAN ID). The WAN ID must be in hexadecimal format. For example, if the WAN ID was decimal 23, the locator would be: 3@wan://::17:10.10.1.150 (not 3@wan://::23:10.10.1.150).
- The last part, "10.10.1.150" refers to the peers local IPv4 address, which will be used if the peers are on the same local network.

A *DomainParticipant* using the WAN transport will have to initialize the DDS_DiscoveryQosPolicy's **initial_peers** field with the WAN locator addresses corresponding to the peers to which it wants to connect to. The value of **initial_peers** can be set using the environment variable NDDS_DISCOVERY_PEERS or the NDDS_DISCOVERY_PEERS configuration file. (See 15.2 Configuring the Peers List Used in Discovery on page 761.)

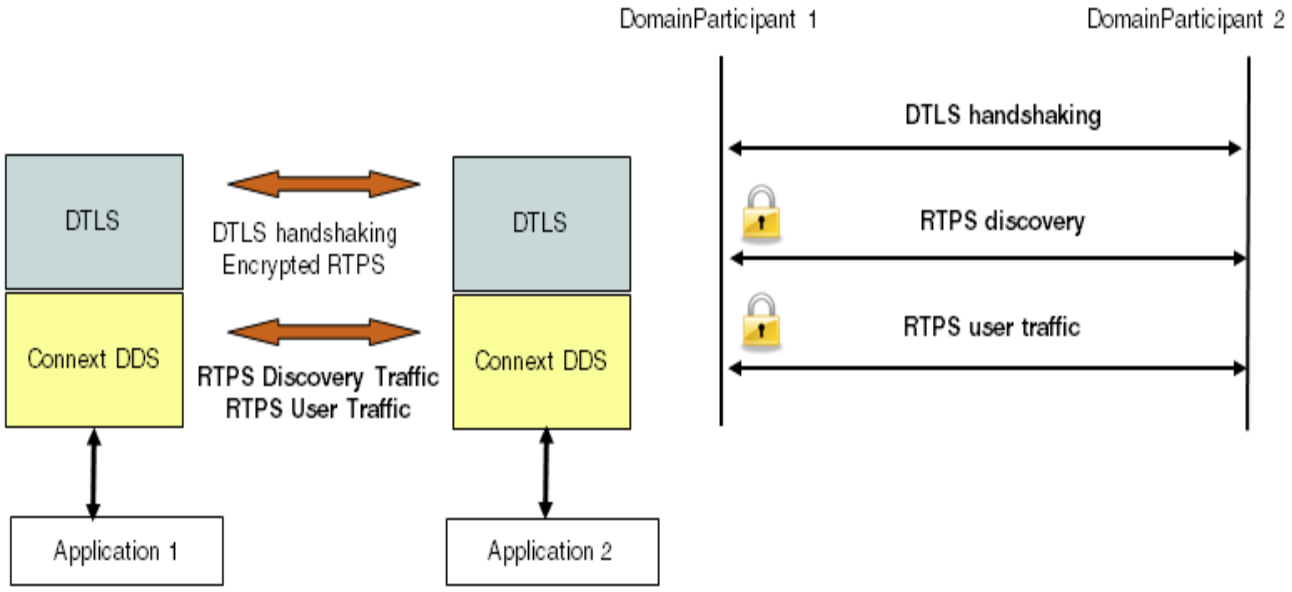
41.3 Datagram Transport-Layer Security (DTLS)

Data security is provided by wrapping all *Connext DDS* network traffic with the Datagram Transport Layer Security (DTLS) protocol (IETF RFC 4347). DTLS is a relatively recent variant of the mature SSL/TLS family of protocols which adds the capability to secure communication over a connectionless network-layer transport such as UDP. UDP is the preferred network layer transport for the DDS wire protocol RTPS, as well as for NAT traversal. Like SSL/TLS, the DTLS protocol provides capabilities for certificate-based authentication, data encryption, and message integrity. The protocol specifies a number of standard cryptographic algorithms that must be available; the base set is listed in the TLS 1.1 specification (IETF RFC 4346).

Secure protocol support is provided by the open source OpenSSL library, which has supported the DTLS protocol since the release of OpenSSL 0.9.8. Note however that many critical issues in DTLS were resolved by the OpenSSL 0.9.8f release. For more detailed information about available ciphers, certificate support, etc. please refer to the OpenSSL documentation. The DTLS protocol securely authenticates with each individual peer; as such, multicast communication is not supported by the Secure Transport. There is also a FIPS security-certified version of OpenSSL (OpenSSL-FIPS 1.1.1), but this does not yet support DTLS.

The Secure Transport protocol stack is similar to the Secure WAN transport stack, but without the STUN layer and server. See Figure 41.5: DTLS Architecture on the next page.

Figure 41.5: DTLS Architecture



41.3.1 Security Model

In order to communicate securely, an instance of the secure plugin requires: 1) a certificate authority (shared with all peers), 2) an identifying certificate which has been signed by the authority, 3) the private key associated with the public key contained in the certificate.

The Certificate Authority (CA) is specified by using a PEM format file containing its public key or by using a directory of PEM files following standard OpenSSL naming conventions. If a single CA file is used, it may contain multiple CA keys. In order to successfully communicate with a peer, the CA keys that are supplied must include the CA that has signed that peer's identifying certificate.

The identifying certificate is specified by using a PEM format file containing the chain of CAs used to authenticate the certificate. The identifying certificate must be signed by a CA. It will either be directly signed by a root CA (one of the CAs supplied above), by an authority whose certificate has been signed by the root CA, or by a longer chain of certificate authorities. The file must be sorted starting with the certificate to the highest level (root CA). If the certificate is directly signed by a root CA, then this file will only contain the root CA certificate followed by the identity certificate.

Finally, a private key is required. In order to avoid impersonation of an identity, this should be kept private. It can be stored in its own PEM file specified in one of the private key properties, or it can be appended to the certificate chain file.

One complication in the use of DTLS for communication by *Connext DDS* is that even though DTLS is a connectionless protocol, it still has client/server semantics. The *RTI Secure Transport* maps a bidirectional

communication channel between two peer applications into a pair of unidirectional encrypted channels. Both peers are playing the part of a client (when sending data) and a server (when receiving).

41.3.2 Liveliness Mechanism

When a peer shuts down cleanly, the DTLS protocol ensures that resources are released. If a peer crashes or otherwise stops responding, a liveliness mechanism in the DTLS transport cleans up resources. You can configure the DTLS handshake retransmission interval and the connection liveliness interval.

41.4 Certificate Support

Cryptographic certificates are required to use the security features of the WAN transport. This section describes a mechanism to use the OpenSSL command line tool to generate a simple private certificate authority. For more information, see the manual page for the **openssl** tool (http://www.openssl.org/docs/apps/openssl.html) or the book, *"Network Security with OpenSSL"* by Viega, Messier, & Chandra (O'Reilly 2002), or other references on Public Key Infrastructure.

1. Initialize the Certificate Authority:
    a. Create a copy of the openssl.cnf file and edit fields to specify the proper default names and paths.
    b. Create the required CA directory structure:

```
mkdir myCA
mkdir myCA/certs
mkdir myCA/private
mkdir myCA/newcerts
mkdir myCA/crl
touch myCA/index.txt
```

    c. Create a self-signed certificate and CA private key:

```
openssl req -nodes -x509 -days 1095 -newkey rsa:2048 \
     -keyout myCA/private/cakey.pem -out myCA/cacert.pem \
     -config openssl.cnf
```

2. For each identifying certificate:
    a. You may want to create a copy of your customized openssl.cnf file with default identifying information to be used as a template for certificate request creation; the commands below refer to this file as **template.cnf**.
    b. Generate a certificate request and private key:

```
openssl req -nodes -new -newkey rsa:2048 -config template.cnf \
     -keyout peer1key.pem -out peer1req.pem
```

    c. Use the CA to sign the certificate request to generate certificate:

```
openssl ca -create_serial -config openssl.cnf -days 365 \
    -in peer1req.pem -out myCA/newcerts/peer1cert.pem
```

d. Optionally, append the private key to the peer certificate:

```
cat myCA/newcerts/peer1cert.pem peer1key.pem \
       $>${private location}/ peer1.pem
```

41.5 License Issues

The OpenSSL toolkit stays under a dual license, i.e., both the conditions of the OpenSSL License and the original SSLeay license apply to the toolkit. See below for the actual license texts. Actually both licenses are BSD-style Open Source licenses. In case of any license issues related to OpenSSL please contact **openssl-core@openssl.org**.

```
/* ====================================================================
 * Copyright (c) 1998-2007 The OpenSSL Project.  All rights reserved.
 *
 * Redistribution and use in source and binary forms, with or without
 * modification, are permitted provided that the following conditions
 * are met:
 *
 * 1. Redistributions of source code must retain the above copyright
 *    notice, this list of conditions and the following disclaimer.
 * 2. Redistributions in binary form must reproduce the above copyright
 *    notice, this list of conditions and the following disclaimer in
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```

Chapter 42 Configuring RTI Secure WAN Transport

The *Secure WAN Transport* package includes two transports:

- **The WAN Transport** is for use on a WAN and includes security.[1] It must be used with the WAN Server, a separate application that provides additional services needed for *Connext DDS* applications to communicate with each other over a WAN.
- **The Secure Transport** is an alternate transport that provides security on an untrusted LAN. Use of the RTI WAN Server is not required.

There are two ways in which these transports can be configured:

- By setting up predefined strings in the Property QoS Policy of the *DomainParticipant*, on architectures that support dynamic libraries. This process is described in 42.2 Setting Up a Transport with the Property QoS on the next page.

  Dynamic libraries are supported on all architectures except INTEGRITY and certain VxWorks architectures. For VxWorks, dynamic libraries are only supported for architectures that are on Pentium®/Arm® CPUs AND use kernel mode.

- By instantiating a new transport (42.5 Explicitly Instantiating a WAN or Secure Transport Plugin on page 1119) and then registering it with the *DomainParticipant*, see 16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814 (not available in the Java API).

Refer to the API Reference HTML documentation for details on these two approaches.

[1] Security is disabled by default.

42.1 Example Applications

A simple example is available to show how to configure the WAN transport. It includes example settings to enable communication over WAN, and optional settings to enable security (along with example certificate files to use for secure communication). The example is located in **<path to examples>[a]/connext_dds/<*language*>/hello_world_wan**.

As seen in the example, you can configure the properties of either transport by setting the appropriate name/value pairs in the *DomainParticipant's* PropertyQoS, as described in 42.2 Setting Up a Transport with the Property QoS below. This will cause *Connext DDS* to dynamically load the WAN or Secure Transport libraries at run time and then implicitly create and register the transport plugin.

Another way to use the WAN or Secure transports is to explicitly create the plugin and use **register_transport()** to register the transport with *Connext DDS* (see 16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814). This way is *not* shown in the example. See 42.5 Explicitly Instantiating a WAN or Secure Transport Plugin on page 1119.

42.2 Setting Up a Transport with the Property QoS

The 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 allows you to set up name/value pairs of data and attach them to an entity, such as a *DomainParticipant*. This will cause *Connext DDS* to dynamically load the WAN or Secure Transport libraries at run time and then implicitly create and register the transport plugin.

Please refer to 16.6 Setting Builtin Transport Properties with the PropertyQosPolicy on page 795.

To assign properties, use the **add_property()** operation:

```
DDS_ReturnCode_t DDSPropertyQosPolicyHelper::add_property
                (DDS_PropertyQosPolicy policy,
                 const char * name,
                 const char * value,
                 DDS_Boolean  propagate)
```

For more information on **add_property()** and the other operations in the DDSPropertyQosPolicyHelper class, please see Table 7.64 PropertyQoSPolicyHelper Operations, as well as the API Reference HTML documentation.

The 'name' part of the name/value pairs is a predefined string, described in 42.3 WAN Transport Properties on page 1105 and 42.4 Secure Transport Properties on page 1113.

Here are the basic steps, taken from the example Hello World application (for details, please see the example application.)

[a] See **Paths Mentioned in Documentation on page 1**.

1. Get the default *DomainParticipant* QoS from the DomainParticipantFactory.

```
DDSDomainParticipantFactory::get_instance()->
       get_default_participant_qos(participant_qos);
```

2. Disable the builtin transports.

```
participant_qos.transport_builtin.mask =
       DDS_TRANSPORTBUILTIN_MASK_NONE;
```

3. Set up the *DomainParticipant's* Property QoS.
   a. Load the plugin.

```
DDSPropertyQosPolicyHelper::add_property (
      participant_qos.property,
      "dds.transport.load_plugins",
      "dds.transport.wan_plugin.wan",
      DDS_BOOLEAN_FALSE);
```

   b. Specify the transport plugin library.

```
DDSPropertyQosPolicyHelper::add_property (
participant_qos.property,
       "dds.transport.wan_plugin.wan.library",
       "libnddstransportwan.so",
       DDS_BOOLEAN_FALSE);
```

   c. Specify the transport's 'create' function.

```
DDSPropertyQosPolicyHelper::add_property (
       participant_qos.property,
       "dds.transport.wan_plugin.wan.create_function"
       "NDDS_Transport_WAN_create",
       DDS_BOOLEAN_FALSE);
```

   d. Specify the WAN Server and instance ID.

```
DDSPropertyQosPolicyHelper::add_property (
      participant_qos.property
      "dds.transport.wan_plugin.wan.server",
      "192.168.1.1",
      DDS_BOOLEAN_FALSE);
DDSPropertyQosPolicyHelper::add_property (
      participant_qos.property,
      "dds.transport.wan_plugin.wan.transport_instance_id",
      1,
      DDS_BOOLEAN_FALSE);
```

   e. Specify any other properties, as needed.

4. Create the DomainParticipant, using the modified QoS.

```
participant = DDSTheParticipantFactory->create_participant (
       domainId,
        participant_qos,
       NULL /* listener */,
       DDS_STATUS_MASK_NONE);
```

Property changes should be made before the transport is loaded: either before the *DomainParticipant* is enabled, before the first *DataWriter/DataReader* is created, or before the builtin topic reader is looked up, whichever one happens first.

42.3 WAN Transport Properties

Table 42.1 Properties for NDDS_Transport_WAN_Property_t lists the properties that you can set for the WAN Transport.

Table 42.1 Properties for NDDS_Transport_WAN_Property_t

Property Name (prefix with 'dds.transport.WAN.wan1.')[1]	Property Value Description
dds.transport.load_plugins *(note: this does not take a prefix)*	Required Comma-separated strings indicating the prefix names of all plugins that will be loaded by *Connext DDS*. You will use this string as the prefix to the property names. For example: "dds.transport.WAN.wan1". (This assumes you used 'dds.transport.WAN.wan1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins.) This prefix must begin with 'dds.transport.' Note: You can load up to 8 plugins.
library	Required Must set to **nddstransportwan**. This library and the dependent OpenSSL libraries need to be in your library search path (pointed to by the environment variable LD_LIBRARY_PATH on Linux systems, Path on Windows systems, DYLD_LIBRARY_PATH on macOS systems).
create_function	Required Must be "**NDDS_Transport_WAN_create**".

[1] Assuming you used 'dds.transport.WAN.wan1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.1 Properties for NDDS_Transport_WAN_Property_t

Property Name (prefix with 'dds.transport.WAN.wan1.') [1]	Property Value Description
aliases	Used to register the transport plugin returned by **NDDS_Transport_WAN_create()** (as specified by **<WAN_prefix>.create_function**) to the *DomainParticipant*. Aliases should be specified as a comma-separated string, with each comma delimiting an alias. If it is not specified, the prefix–without the leading **"dds.transport"**–is used as the default alias for the plugin. For example, if the <WAN_prefix> is **"dds.transport.mytransport"**, the default alias for the plugin is **"mytransport"**.
verbosity	Specifies the verbosity of log messages from the transport. Possible values: • -1: silent • 0 (default): errors only • 1: errors and warnings • 2: local status • 5 or higher: all messages Note: the logging verbosity is a global property shared across multiple instances of the transport. If you create a new transport instance with a **verbosity** different than -1, the change will affect all the other instances as well.
security_verbosity	Specifies the verbosity of security related log messages from the transport. These are usually messages generated by OpenSSL. Possible values: • -1: silent • 0: errors only • 1: errors and warnings • 2: local status • 5 or higher: all messages Default: If not set, the value is inherited from the **verbosity** property Note: the logging verbosity is a global property shared across multiple instances of the transport. If you create a new transport instance with a **security_verbosity** different than -1, the change will affect all the other instances as well.
parent.parent.properties_ bitmap	A bitmap that defines various properties of the transport to the *Connext DDS* core. Currently, the only property supported is whether or not the transport plugin will always loan a buffer when *Connext DDS* tries to receive a message using the plugin. This is in support of a zero-copy interface.

[1] Assuming you used 'dds.transport.WAN.wan1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.1 Properties for NDDS_Transport_WAN_Property_t

Property Name (prefix with 'dds.transport.WAN.wan1.') [1]	Property Value Description
parent.parent.gather_send_buffer_count_max	Specifies the maximum number of buffers that *Connext DDS* can pass to the **send()** function of the transport plugin. The transport plugin **send()** API supports a gather-send concept, where the **send()** call can take several discontiguous buffers, assemble and send them in a single message. This enables *Connext DDS* to send a message from parts obtained from different sources without first having to copy the parts into a single contiguous buffer. However, most transports that support a gather-send concept have an upper limit on the number of buffers that can be gathered and sent. Setting this value will prevent *Connext DDS* from trying to gather too many buffers into a send call for the transport plugin. *Connext DDS* requires all transport-plugin implementations to support a gather-send of least a minimum number of buffers. This minimum number is defined as NDDS_TRANSPORT_-PROPERTY_GATHER_SEND_BUFFER_COUNT_MIN.
parent.parent.message_size_max	The maximum size of a message in bytes that can be sent or received by the transport plugin. This value must be set before the transport plugin is registered, so that *Connext DDS* can properly use the plugin.
parent.parent.allow_interfaces	A list of strings, each identifying a range of interface addresses. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. If the list is non-empty, this "white" list is applied before the parent.parent.deny_interfaces below list. It is up to the transport plugin to interpret the list of strings passed in. Usually this interpretation will be consistent with **NDDS_Transport_String_To_Address_Fcn_cEA()**. This property is not interpreted by the *Connext DDS* core; it is provided merely as a convenient and standardized way to specify the interfaces for the benefit of the transport plugin developer and user. You must manage the memory of the list. The memory may be freed after the *DomainParticipant* is enabled.
parent.parent.deny_interfaces	A list of strings, each identifying a range of interface addresses. If the list is non-empty, deny the use of these interfaces. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. This "black" list is applied after the parent.parent.allow_interfaces above list and filters out the interfaces that should *not* be used. It is up to the transport plugin to interpret the list of strings passed in. Usually this interpretation will be consistent with **NDDS_Transport_String_To_Address_Fcn_cEA()**. This property is not interpreted by the *Connext DDS* core; it is provided merely as a convenient and standardized way to specify the interfaces for the benefit of the transport plugin developer and user. You must manage the memory of the list. The memory may be freed after the DomainParticipant is enabled.

[1] Assuming you used 'dds.transport.WAN.wan1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.1 Properties for NDDS_Transport_WAN_Property_t

Property Name (prefix with 'dds.transport.WAN.wan1.') [1]	Property Value Description
parent.send_socket_buffer_size	Size in bytes of the send buffer of a socket used for sending. On most operating systems, **setsockopt()** will be called to set the SENDBUF to the value of this parameter. This value must be greater than or equal to parent.parent.message_size_max on the previous page. The maximum value is operating system-dependent. If -1, **setsockopt()** (or equivalent) will not be called to size the send buffer of the socket. The transport will use the OS default. Default: 131072
parent.recv_socket_buffer_size	Size in bytes of the receive buffer of a socket used for receiving. On most operating systems, **setsockopt()** will be called to set the RECVBUF to the value of this parameter. This value must be greater than or equal to parent.parent.message_size_max on the previous page. The maximum value is operating system-dependent. If -1, **setsockopt()** (or equivalent) will not be called to size the receive buffer of the socket. The transport will use the OS default. Default: 131072
parent.unicast_enabled	Allows the transport plugin to use unicast UDP for sending and receiving. By default, it will be turned on. Also by default, it will use all the allowed network interfaces that it finds up and running when the plugin is instanced.
parent.ignore_loopback_interface	Prevents the transport plugin from using the IP loopback interface. Three values are allowed: • 0: Enable local traffic via this plugin. This plugin will only use and report the IP loopback interface only if there are no other network interfaces (NICs) up on the system. • 1: Disable local traffic via this plugin. Do not use the IP loopback interface even if no NICs are discovered. This is useful when you want applications running on the same node to use a more efficient plugin like Shared Memory instead of the IP loopback.

[1] Assuming you used 'dds.transport.WAN.wan1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.1 Properties for NDDS_Transport_WAN_Property_t

Property Name (prefix with 'dds.transport.WAN.wan1.') [1]	Property Value Description
parent.ignore_nonrunning_interfaces	Prevents the transport plugin from using a network interface that is not reported as RUNNING by the operating system. The transport checks the flags reported by the operating system for each network interface upon initialization. An interface which is not reported as UP will not be used. This property allows the same check to be extended to the IFF_RUNNING flag implemented by some operating systems. The RUNNING flag is defined to mean that "all resources are allocated", and may be off if there is no link detected, e.g., the network cable is unplugged. Two values are allowed: • 0: Do not check the RUNNING flag when enumerating interfaces, just make sure the interface is UP. • 1: Check the flag when enumerating interfaces, and ignore those that are not reported as RUNNING. This can be used on some operating systems to cause the transport to ignore interfaces that are enabled but not connected to the network. By default this property is set to 1, so *Connext DDS* will ignore non-running interfaces.
DEPRECATED parent.no_zero_copy	Prevents the transport plugin from doing a zero copy. By default, this plugin will use the zero copy on OSs that offer it. While this is good for performance, it may sometime tax the OS resources in a manner that cannot be overcome by the application. The best example is if the hardware/device driver lends the buffer to the application itself. If the application does not return the loaned buffers soon enough, the node may error or malfunction. In case you cannot reconfigure the H/W, device driver, or the OS to allow the zero copy feature to work for your application, you may have no choice but to turn off zero copy use. By default this is set to 0, so *Connext DDS* will use the zero-copy API if offered by the OS.
parent.send_blocking	**CHANGING THIS FROM THE DEFAULT CAN CAUSE SIGNIFICANT PERFORMANCE PROBLEMS.** Controls the blocking behavior of send sockets. Two values are defined (use the number values only): • 1 (NDDS_TRANSPORT_UDP_BLOCKING_ALWAYS): Sockets are blocking (default socket options for Operating System). • 0 (NDDS_TRANSPORT_UDP_BLOCKING_NEVER): Sockets are modified to make them non-blocking. THIS IS NOT A SUPPORTED CONFIGURATION AND MAY CAUSE SIGNIFICANT PERFORMANCE PROBLEMS.

[1] Assuming you used 'dds.transport.WAN.wan1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.1 Properties for NDDS_Transport_WAN_Property_t

Property Name (prefix with 'dds.transport.WAN.wan1.') [1]	Property Value Description
parent.transport_priority_mask	Mask for the transport priority field. This is used in conjunction with transport_priority_mapping_low/high to define the mapping from DDS transport priority to the IPv4 TOS field. Defines a contiguous region of bits in the 32-bit transport priority value that is used to generate values for the IPv4 TOS field on an outgoing socket. For example, the value 0x0000ff00 causes bits 9-16 (8 bits) to be used in the mapping. The value will be scaled from the mask range (0x0000 - 0xff00 in this case) to the range specified by low and high. If the mask is set to zero, then the transport will not set IPv4 TOS for send sockets.
parent.transport_priority_mapping_low	Sets the low and high values of the output range to IPv4 TOS. These values are used in conjunction with transport_priority_mask to define the mapping from DDS transport priority to the IPv4 TOS field. Defines the low and high values of the output range for scaling. Note that IPv4 TOS is generally an 8-bit value.
parent.transport_priority_mapping_high	
enable_security	Required if you want to use security.
recv_decode_buffer_size	Size of buffer for decoding packets from wire. An extra buffer is required for storage of encrypted data. The minimum value for this property is parent.parent.message_size_max on page 1107. Default: 65507
port_offset	Port offset to allow coexistence with non-secure UDP transport.
dtls_handshake_resend_interval	DTLS handshake retransmission interval in milliseconds. Default: 1000
dtls_connection_liveliness_interval	Liveliness interval (multiple of resend interval) The connection will be dropped if no message from the peer is received in this amount of time. This enables cleaning up state for peers that are no longer responding. A secure keep-alive message will be sent every half-interval if no other sends have occurred for a given DTLS connection during that time. Default: 60
tls.verify.ca_file	A string that specifies the name of file containing Certificate Authority certificates. File should be in PEM format. See the OpenSSL manual page for SSL_load_verify_locations for more information. If you want to use security, tls.verify.ca_file above or tls.verify.ca_path on the next page must be specified; both may be specified.

[1] Assuming you used 'dds.transport.WAN.wan1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.1 Properties for NDDS_Transport_WAN_Property_t

Property Name (prefix with 'dds.transport.WAN.wan1.') [1]	Property Value Description
tls.verify.ca_path	A string that specifies paths to directories containing Certificate Authority certificates. Files should be in PEM format, and follow the OpenSSL-required naming conventions. See the OpenSSL manual page for SSL_CTX_load_verify_locations for more information. The Certificate Authority subject name hash values must be available in the directories. You may generate them by running openssl rehash (available in OpenSSL 1.1.0 or above) or _c_rehash_ in each directory. If you want to use security, tls.verify.ca_file on the previous page or tls.verify.ca_path above must be specified; both may be specified.
tls.verify.verify_depth	Maximum certificate chain length for verification.
tls.verify.verify_peer	If non-zero, use mutual authentication when performing TLS hand-shake (default). If zero, only the reader side will present a certificate, which will be verified by the writer side.
tls.verify.callback	This can be set to one of three values: • "default" selects NDDS_Transport_TLS_default_verify_callback() • "verbose" selects NDDS_Transport_TLS_verbose_verify_callback() • "none" requests no callback be registered
tls.cipher.cipher_list	List of available DTLS ciphers when communicating with *Connext DDS* 6.0.0 or below. See the OpenSSL manual page for SSL_set_cipher_list for more information on the format of this string. Default: NULL

tls.cipher.dh_param_files	List of available Diffie-Hellman (DH) key files. For example: "foo.h:2048,bar.h:1024" means:
	`dh_param_files[0].file = foo.pem,`
	`dh_param_files[0].bits = 2048,`
	`dh_param_files[1].file = bar.pem,`
	`dh_param_files[1].bits = 1024`

tls.cipher.engine_id	String ID of OpenSSL cipher engine to request.
tls.identity.certificate_chain_file	Required if you want to use security. A string that specifies the name of a file containing an identifying certificate chain (in PEM format). An identifying certificate is required for secure communication. The file must be sorted starting with the certificate to the highest level (root CA). If no private key is specified, this file will be used to load a non-RSA private key.
tls.identity.private_key_password	A string that specifies the password for private key.
tls.identity.private_key_file	A string that specifies that name of a file containing private key (in PEM format). If no private key is specified (all values are NULL), this value will default to the same file as the specified certificate chain file.
tls.identity.rsa_private_key_file	A string that specifies that name of a file containing an RSA private key (in PEM format).

[1] Assuming you used 'dds.transport.WAN.wan1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.1 Properties for NDDS_Transport_WAN_Property_t

Property Name (prefix with 'dds.transport.WAN.wan1.') [1]	Property Value Description
transport_instance_id[0] to [NDDS_TRANSPORT_WAN_TRANSPORT_INSTANCE_ID_LENGTH[b]]	Required A set of comma-separated values to specify the elements of the array. This value must be unique for all transport instances communicating with the same WAN Rendezvous Server. If less than the full array is specified, it will be right-aligned. For example, the string "01,02" results in the array being set to: {0,0,0,0,0,0,0,0,0,0,1,2}
interface_address	Locator, as a string
server	Required Server locator, as a string.
server_port	Server port number.
stun_retransmission_interval	STUN request messages requiring a response are resent with this interval. The interval is doubled after each retransmission. Specified in msec.
stun_number_of_retransmissions	Maximum number of times STUN messages are resent unless a response is received.
stun_liveliness_period	Period at which messages are sent to peers to keep NAT holes open; and to the WAN server to refresh bound ports. Specified in msec.
join_multicast_group_timeout	Windows only. On Windows, a network interface may be detected before it is allowed to join a multicast group address. This property adjusts how much time (in milliseconds) to wait for the ADD_MEMBERSHIP multicast operation to succeed before withdrawing. Default: 5000

[1] Assuming you used 'dds.transport.WAN.wan1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

[b] NDDS_TRANSPORT_WAN_TRANSPORT_INSTANCE_ID_LENGTH = 12

Table 42.1 Properties for NDDS_Transport_WAN_Property_t

Property Name (prefix with 'dds.transport.WAN.wan1.') [1]	Property Value Description
property_validation_action	By default, property names given in the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 are validated to avoid using incorrect or unknown names (for example, due to a typo). This property configures the validation of the property names associated with the transport: • VALIDATION_ACTION_EXCEPTION: validate the properties. Upon failure, log errors and fail. • VALIDATION_ACTION_SKIP: skip validation. • VALIDATION_ACTION_WARNING: validate the properties. Upon failure, log warnings and do not fail. If this property is not set, the property validation behavior will be the same as that of the *DomainParticipant*, which by default is VALIDATION_ACTION_EXCEPTION. See 7.5.19.1 Property Validation on page 439 for more information.
thread_name_prefix	You can set this field with your own value, to help you identify the transport thread in a way that's meaningful to you. Do not exceed 8 characters. If you do not set this field, *Connext DDS* creates the following prefix: 'r' + 'Tr' + participant identifier + '\0' Where 'r' indicates this is a thread from RTI, 'Tr' indicates the thread is related to a transport, and participant identifier contains 5 characters as follows: • If **participant_name** is set: The participant identifier will be the first 3 characters and the last 2 characters of the **participant_name**. • If **participant_name** is not set, then the identifier is computed as **domain_id** (3 characters) followed by **participant_id** (2 characters). • If **participant_name** is not set and the **participant_id** is set to -1 (default value), then the participant identifier is computed as the last 5 digits of the **rtps_instance_id** in the participant GUID. See 21.9 Identifying Threads Used by Connext DDS on page 908.

42.4 Secure Transport Properties

Table 42.2 Properties for NDDS_Transport_DTLS_Property_t lists the properties that you can set for the Secure Transport.

[1] Assuming you used 'dds.transport.WAN.wan1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.2 Properties for NDDS_Transport_DTLS_Property_t

Property Name (prefix with 'dds.transport.DTLS.dtls1')[a]	Property Value Description
dds.transport.load_plugins (note: this does not take a prefix)	Required Comma-separated strings indicating the prefix names of all plugins that will be loaded by *Connext DDS*. You will use this string as the prefix to the property names. For example: "dds.transport.DTLS.dtls1". (This assumes you used used 'dds.transport.DTLS.dtls1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins.) This prefix must begin with 'dds.transport.' Note: you can load up to 8 plugins.
library	Only required if linking dynamically Must set to "libnddstransporttls.so" (for Linux systems) or "nddstransporttls.dll" (for Windows systems). This library and the dependent OpenSSL libraries must be in your library search path (pointed to by the environment variable LD_LIBRARY_PATH on Linux systems, Path on Windows systems, DYLD_LIBRARY_PATH on macOS systems).
create_function	Only required if linking dynamically Must be "NDDS_Transport_DTLS_create"
create_function_ptr	Only required if linking statically Defines the function pointer to the DTLS Transport Plugin creation function. Used for loading the DTLS Transport plugin statically. Must be set to the NDDS_Transport_DTLS_create function pointer.
aliases	Used to register the transport plugin returned by NDDS_Transport_DTLS_create() (as specified by <DTLS_prefix>.create_function) to the DomainParticipant. Aliases should be specified as comma-separated strings, with each comma delimiting an alias. If it is not specified, the prefix–without the leading **"dds.transport"**–is used as the default alias for the plugin. For example, if the <TRANSPORT_PREFIX> is **"dds.transport.mytransport"**, the default alias for the plugin is **"mytransport"**.
network_address	The network address at which to register this transport plugin. The least significant transport_in.property.address_bit_count will be truncated. The remaining bits are the network address of the transport plugin. This value overwrites the value returned by the output parameter in NDDS_Transport_create_plugin function as specified in "<DTLS_prefix>.create_function".

[a] Assuming you used 'dds.transport.DTLS.dtls1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.2 Properties for NDDS_Transport_DTLS_Property_t

Property Name (prefix with 'dds.transport.DTLS.dtls1')[a]	Property Value Description
verbosity	Specifies the verbosity of log messages from the transport. Possible values: • -1: silent • 0: errors only • 1: errors and warnings • 2: local status • 5 or higher: all messages Note: the logging verbosity is a global property shared across multiple instances of the transport. If you create a new transport instance with a **verbosity** different than -1, the change will affect all the other instances as well.
security_verbosity	Specifies the verbosity of security related log messages from the transport. These are usually messages generated by OpenSSL. Possible values: • -1: silent • 0: errors only • 1: errors and warnings • 2: local status • 5 or higher: all messages Default: If not set the value is inherited from the property **verbosity** Note: the logging verbosity is a global property shared across multiple instances of the transport. If you create a new transport instance with a **security_verbosity** different than -1, the change will affect all the other instances as well.
parent.properties_bitmap	A bitmap that defines various properties of the transport to the *Connext DDS* core. Currently, the only property supported is whether or not the transport plugin will always loan a buffer when *Connext DDS* tries to receive a message using the plugin. This is in support of a zero-copy interface.
parent.gather_send_buffer_count_max	Specifies the maximum number of buffers that *Connext DDS* can pass to the transport plugin's send() function.
parent.message_size_max	The maximum size of a message in bytes that can be sent or received by the transport plugin. Default and maximum value: 16384. If you attempt to exceed 16384, then the transport will log a warning message and automatically adjust **message_size_max** to be 16384.

[a] Assuming you used 'dds.transport.DTLS.dtls1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.2 Properties for NDDS_Transport_DTLS_Property_t

Property Name (prefix with 'dds.transport.DTLS.dtls1')[a]	Property Value Description
parent.allow_interfaces	A list of strings, each identifying a range of interface addresses. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. If the list is non-empty, this "white" list is applied before the parent.deny_interfaces below list. You must manage the memory of the list. The memory may be freed after the DomainParticipant is enabled.
parent.deny_interfaces	A list of strings, each identifying a range of interface addresses. Interfaces should be specified as comma-separated strings, with each comma delimiting an interface. This "black" list is applied after the parent.allow_interfaces above list and filters out the interfaces that should not be used. You must manage the memory of the list. The memory may be freed after the DomainParticipant is enabled.
disable_interface_tracking	Disables detection of network interface changes. By default, network interfaces changes are propagated in the form of locators to other applications. This is done to support IP mobility scenarios. For example, you could start a application with Wi-Fi and move to a wired connection. In order to continue communicating with other applications this interface change must be propagated. In 5.0 and earlier versions of the product, IP mobility scenarios were not supported. Applications using 5.2 will report errors if they detect locator changes in a *DataWriter* or *DataReader*. You can disable the notification and propagation of interface changes by setting this property to 1. This way, an interface change in a newer application will not trigger errors in an application running 5.2 GAR or earlier. Of course, this will prevent the new application from been able to detect network interface changes.
interface_poll_period	Specifies the period in milliseconds to query for changes in the state of all the interfaces. When possible, the detection of an IP address changes is done asynchronously using the APIs offered by the underlying OS. If there is no mechanism to do that, the detection will use a polling strategy where the polling period can be configured by setting this property.
send_socket_buffer_size	Size in bytes of the send buffer of a socket used for sending. On most operating systems, **setsockopt()** will be called to set the SENDBUF to the value of this parameter. This value must be greater than or equal to **parent.message_size_max**. The maximum value is operating system-dependent. If -1, **setsockopt()** (or equivalent) will not be called to size the send buffer of the socket. The transport will use the OS default. Default: 131072
recv_socket_buffer_size	Size in bytes of the receive buffer of a socket used for receiving. On most operating systems, **setsockopt()** will be called to set the RECVBUF to the value of this parameter. This value must be greater than or equal to **parent.message_size_max**. The maximum value is operating system-dependent. If -1, **setsockopt()** (or equivalent) will not be called to size the receive buffer of the socket. The transport will use the OS default. Default: 131072

[a] Assuming you used 'dds.transport.DTLS.dtls1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.2 Properties for NDDS_Transport_DTLS_Property_t

Property Name (prefix with 'dds.transport.DTLS.dtls1')[a]	Property Value Description
ignore_loopback_interface	Prevents the Transport Plugin from using the IP loopback interface.
ignore_nonrunning_interfaces	Prevents the transport plugin from using a network interface that is not reported as RUNNING by the operating system. The transport checks the flags reported by the operating system for each network interface upon initialization. An interface which is not reported as UP will not be used. This property allows the same check to be extended to the IFF_RUNNING flag implemented by some operating systems. The RUNNING flag is defined to mean that "all resources are allocated", and may be off if there is no link detected, e.g., the network cable is unplugged. Two values are allowed: • 0: Do not check the RUNNING flag when enumerating interfaces, just make sure the interface is UP. • 1: Check the flag when enumerating interfaces, and ignore those that are not reported as RUNNING. This can be used on some operating systems to cause the transport to ignore interfaces that are enabled but not connected to the network.
transport_priority_mask	Mask for use of transport priority field.
transport_priority_mapping_low	Low and high values of output range to IPv4 TOS.
transport_priority_mapping_high	
recv_decode_buffer_size	Size of buffer for decoding packets from wire. An extra buffer is required for storage of encrypted data. The minimum value for this property is parent.message_size_max on page 1115. Default: 65507
port_offset	Port offset to allow coexistence with non-secure UDP transport.
dtls_handshake_resend_interval	DTLS handshake retransmission interval in milliseconds Default: 1000
dtls_connection_liveliness_interval	Liveliness interval (multiple of resend interval) The connection will be dropped if no message from the peer is received in this amount of time. This enables cleaning up state for peers that are no longer responding. A secure keep-alive message will be sent every half-interval if no other sends have occurred for a given DTLS connection during that time. Default: 60
tls.verify.ca_file	A string that specifies the name of file containing Certificate Authority certificates. File should be in PEM format. See the OpenSSL manual page for SSL_load_verify_locations for more information. tls.verify.ca_file above or tls.verify.ca_path on the next page must be specified; both may be specified.

[a] Assuming you used 'dds.transport.DTLS.dtls1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.2 Properties for NDDS_Transport_DTLS_Property_t

Property Name (prefix with 'dds.transport.DTLS.dtls1')[a]	Property Value Description
tls.verify.ca_path	A string that specifies paths to directories containing Certificate Authority certificates. Files should be in PEM format, and follow the OpenSSL-required naming conventions. See the OpenSSL manual page for SSL_CTX_load_verify_locations for more information. The Certificate Authority subject name hash values must be available in the directories. You may generate them by running openssl rehash (available in OpenSSL 1.1.0 or above) or _c_rehash_ in each directory. tls.verify.ca_file on the previous page or tls.verify.ca_path above must be specified; both may be specified.
tls.verify.verify_depth	Maximum certificate chain length for verification.
tls.verify.verify_peer	If non-zero, use mutual authentication when performing TLS hand- shake (default). If zero, only the reader side will present a certificate, which will be verified by the writer side.
tls.verify.callback	This can be set to one of three values: • "default" selects NDDS_Transport_TLS_default_verify_callback() • "verbose" selects NDDS_Transport_TLS_verbose_verify_callback() • "none" requests no callback be registered
tls.cipher.cipher_list	List of available DTLS ciphers when communicating with *Connext DDS* 6.0.0 or below. See the OpenSSL manual page for SSL_set_cipher_list for more information on the format of this string. Default: NULL
tls.cipher.dh_param_files	List of available Diffie-Hellman (DH) key files. For example: "foo.h:2048,bar.h:1024" means: dh_param_files[0].file = foo.pem, dh_param_files[0].bits = 2048, dh_param_files[1].file = bar.pem, dh_param_files[1].bits = 1024
tls.cipher.engine_id	String ID of OpenSSL cipher engine to request.
tls.identity.certificate_chain_file	Required A string that specifies the name of a file containing an identifying certificate chain (in PEM format). An identifying certificate is required for secure communication. The file must be sorted starting with the certificate to the highest level (root CA). If no private key is specified, this file will be used to load a non-RSA private key.
tls.identity.private_key_password	A string that specifies the password for private key.
tls.identity.private_key_file	A string that specifies that name of a file containing private key (in PEM format). If no private key is specified (all values are NULL), this value will default to the same file as the specified certificate chain file.
tls.identity.rsa_private_key_file	A string that specifies that name of a file containing an RSA private key (in PEM format).

[a] Assuming you used 'dds.transport.DTLS.dtls1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 42.2 Properties for NDDS_Transport_DTLS_Property_t

Property Name (prefix with 'dds.transport.DTLS.dtls1')[a]	Property Value Description
join_multicast_group_timeout	Windows only. On Windows, a network interface may be detected before it is allowed to join a multicast group address. This property adjusts how much time (in milliseconds) to wait for the ADD_MEMBERSHIP multicast operation to succeed before withdrawing. Default: 5000
property_validation_action	By default, property names given in the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 are validated to avoid using incorrect or unknown names (for example, due to a typo). This property configures the validation of the property names associated with the transport: • VALIDATION_ACTION_EXCEPTION: validate the properties. Upon failure, log errors and fail. • VALIDATION_ACTION_SKIP: skip validation. • VALIDATION_ACTION_WARNING: validate the properties. Upon failure, log warnings and do not fail. If this property is not set, the property validation behavior will be the same as that of the *DomainParticipant*, which by default is VALIDATION_ACTION_EXCEPTION. See 7.5.19.1 Property Validation on page 439 for more information.
thread_name_prefix	You can set this field with your own value, to help you identify the transport thread in a way that's meaningful to you. Do not exceed 8 characters. If you do not set this field, *Connext DDS* creates the following prefix: 'r' + 'Tr' + participant identifier + '\0' Where 'r' indicates this is a thread from RTI, 'Tr' indicates the thread is related to a transport, and participant identifier contains 5 characters as follows: • If **participant_name** is set: The participant identifier will be the first 3 characters and the last 2 characters of the **participant_name**. • If **participant_name** is not set, then the identifier is computed as **domain_id** (3 characters) followed by **participant_id** (2 characters). • If **participant_name** is not set and the **participant_id** is set to -1 (default value), then the participant identifier is computed as the last 5 digits of the **rtps_instance_id** in the participant GUID. See 21.9 Identifying Threads Used by Connext DDS on page 908.

42.5 Explicitly Instantiating a WAN or Secure Transport Plugin

As described on Page 1102, there are two ways to instantiate a transport plugin. This section describes the mechanism that includes calling **NDDSTransportSupport::register_transport()**. (The other way is to use the Property QoS mechanism, described in 42.2 Setting Up a Transport with the Property QoS on page 1103).

[a] Assuming you used 'dds.transport.DTLS.dtls1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Notes:

- This way of instantiating a transport is not supported in the Java API. If you are using Java, use the Property QoS mechanism, described in 42.2 Setting Up a Transport with the Property QoS on page 1103.
- To use this mechanism, there are **extra libraries that you must link into your program and an additional header file** that you must include. Please see the 42.5.1 Additional Header Files and Include Directories below and 42.5.2 Additional Libraries below for details.

To instantiate a WAN or Secure Transport prior to explicitly registering it with **NDDSTransportSupport::register_transport()**, use one of the following functions:

```
NDDS_Transport_Plugin* NDDS_Transport_WAN_new (
        const struct NDDS_Transport_WAN_Property_t * property_in)
NDDS_Transport_Plugin* NDDS_Transport_DTLS_new (
        const struct NDDS_Transport_DTLS_Property_t * property_in)
```

See the API Reference HTML documentation for details on these functions.

42.5.1 Additional Header Files and Include Directories

- To use the *Secure WAN Transport* API, you must include an extra header file (in addition to those in Table 10.1 Header Files to Include for Connext DDS (All Architectures)).

  ```
  #include "ndds/ndds_transport_secure_wan.h"
  ```

  Assuming that *Secure WAN Transport* is installed in the same directory as *Connext DDS* (see Table 10.2 Include Paths for Compilation (All Architectures)), no additional include paths need to be added for the *Secure WAN Transport* API. If this is not the case, you will need to specify the appropriate include path.

- If you want to access OpenSSL data structures, add the OpenSSL include directory, **<openssl install dir>/<arch>/include**, and include the OpenSSL headers *before* **ndds_transport_secure_wan.h**:

  ```
  #include <openssl/ssl.h>
  #include <openssl/x509.h> (if accessing certificate functions)
  etc.
  ```

  On Windows systems, if you are loading statically: you should also include the OpenSSL file, **applink.c**, in your application. It can be found in the OpenSSL include directory, or included as **<openssl/applink.c>**.

42.5.2 Additional Libraries

To use the *Secure WAN Transport* API, you must link in additional libraries, which are listed in the RTI Connext DDS Core Libraries Platform Notes (in the appropriate section for your architecture). Refer to

10.3.1 Required Libraries on page 676 for the differences between shared and static libraries.

42.5.3 Compiler Flags

No additional compiler flags are required.

Part 7: RTI TCP Transport

RTI TCP Transport is only available on specific architectures. See the RTI Connext DDS Core Libraries Platform Notes for details.

Out of the box, *Connext DDS* uses the UDPv4 and Shared Memory transport to communicate with other DDS applications. This configuration is appropriate for systems running within a single LAN. However, using UDPv4 introduces some problems when *Connext DDS* applications in different LANs need to communicate:

- UDPv4 traffic is usually filtered out by the LAN firewalls for security reasons.
- Forwarded ports are usually TCP ports.
- Each LAN may run in its own private IP address space and use NAT (Network Address Translation) to communicate with other networks.

TCP Transport enables participant discovery and data exchange using the TCP protocol (either on a local LAN, or over the public WAN*). TCP Transport* allows *Connext DDS* to address the challenges of using TCP as a low-level communication mechanism between peers and limits the number of ports exposed to one. (When using the default UDP transport, a *Connext DDS* application uses multiple UDP ports for communication, which may make it unsuitable for deployment across firewalled networks).

Chapter 43 TCP Communication Scenarios

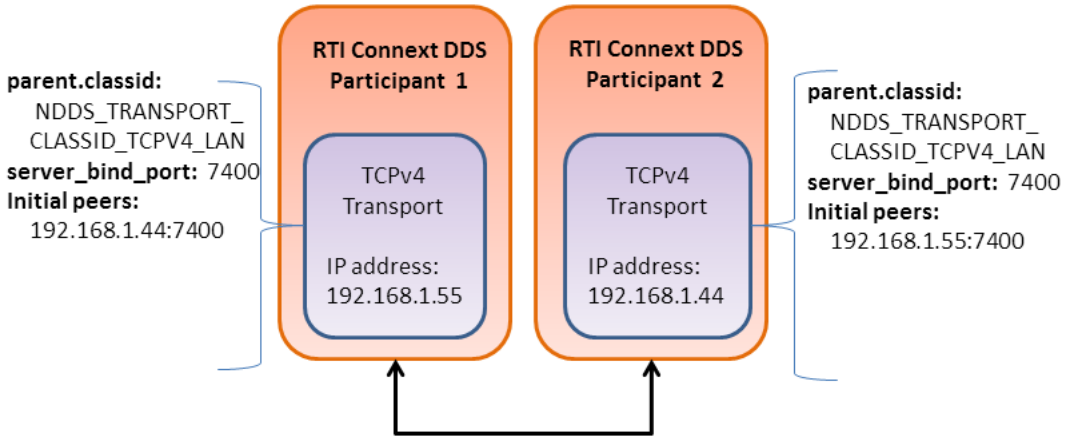
TCP Transport can be used to address multiple communication scenarios—from simple communication within a single LAN, to complex communication scenarios across LANs where NATs and firewalls may be involved. This section describes these scenarios:

- 43.1 Communication Within a Single LAN below
- 43.2 Symmetric Communication Across NATs on the next page
- 43.3 Asymmetric Communication Across NATs on page 1125

43.1 Communication Within a Single LAN

TCP Transport can be used as an alternative to UDPv4 to communicate with *Connext DDS* applications running inside the same LAN. Figure 43.1: Communication within a Single LAN on the next page shows how to configure the TCP transport in this scenario.

Figure 43.1: Communication within a Single LAN



- parent.classid on page 1140 and server_bind_port on page 1145 are transport properties configured using the PropertyQosPolicy of the participant. (Note: When the TCP transport is instantiated, by default it is configured to work in a LAN environment using symmetric communication and binding to port 7400 for incoming connections.) For additional information about these properties, see Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t.
- Initial Peers represents the peers to which the participant will be announced to. Usually, these peers are configured using the DiscoveryQosPolicy of the participant or the environment variable NDDS_DISCOVERY_PEERS. For information on the format of initial peers, see 44.1 Choosing a Transport Mode on page 1128.

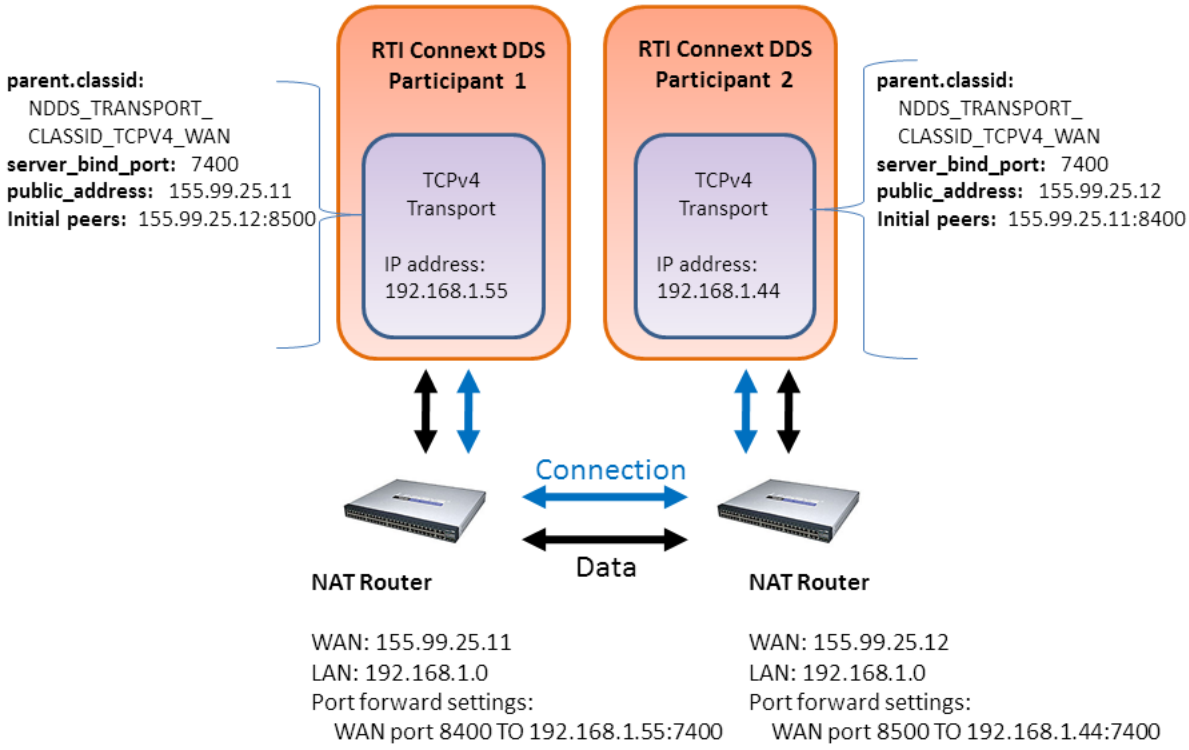
Unlike the UDPv4 transport, **you must specify the initial peers**, because multicast cannot be used with TCP.

43.2 Symmetric Communication Across NATs

In NAT communication scenarios, each one of the LANs has a private IP address space. The communication with other LANs is done through NAT routers that translate private IP addresses and ports into public IP addresses and ports.

In symmetric communication scenarios, any *Connext DDS* application can initiate TCP connections with other applications. Figure 43.2: Symmetric Communication Across NATs on the next page shows how to configure the TCP transport in this scenario.

Figure 43.2: Symmetric Communication Across NATs



Notice that initial peers refer to the public address of the remote LAN where the *Connext DDS* application is deployed and not the private address of the node where the application is running. In addition, the transport associated with a *Connext DDS* instance will have to be configured with its public address (public_address on page 1144) so that this information can be propagated as part of the discovery process.

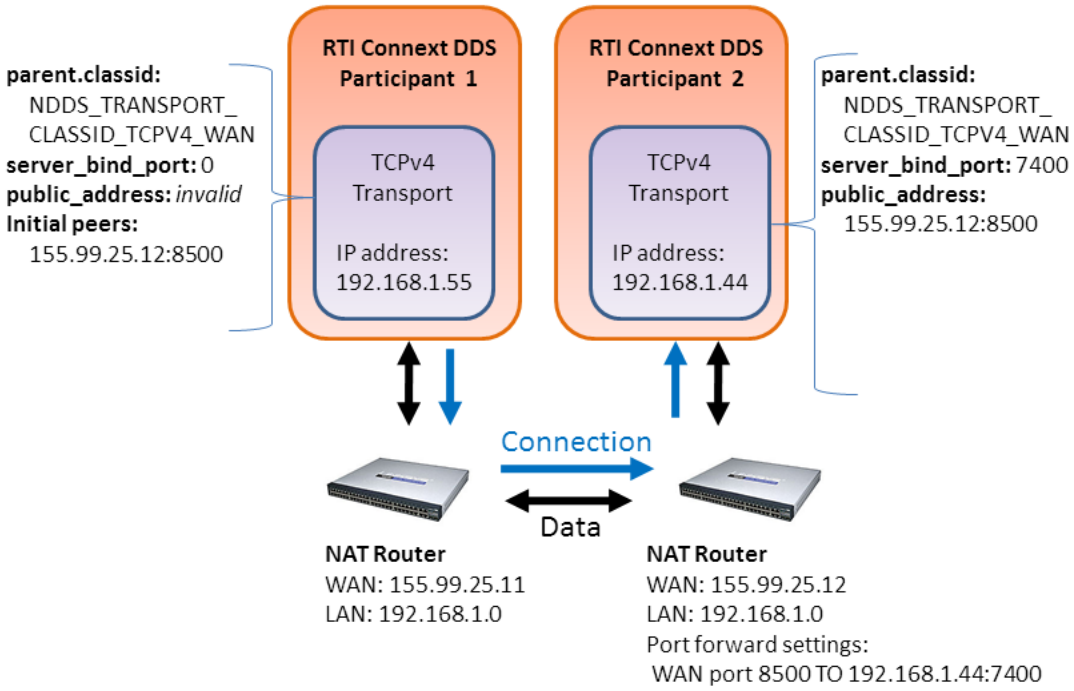
Because the public address and port of the *Connext DDS* instances must be known before the communication is established, the NAT Routers will have to be configured statically to translate (forward) the private server_bind_port on page 1145 into a public port. This process is known as static NAT or port forwarding; it allows traffic originating in outer networks to reach designated peers in the LAN behind the NAT router. You will need to refer to your router's configuration manual to understand how to correctly set up port forwarding.

43.3 Asymmetric Communication Across NATs

This scenario is similar to the previous one, except in this case the TCP connections can be initiated only by the *Connext DDS* instance in LAN1. For security reasons, incoming connections to LAN1 are not allowed. In this case, the peer in LAN1 is considered 'unreachable.' Unreachable peers can publish and subscribe just like any other peer, but communication can occur only to a 'reachable' peer.

Figure 43.3: Asymmetric Communication Across NATs below shows how to configure the TCP transport in this scenario. Notice that the transport property **server_bind_port** is set to 0 to configure the node as unreachable.

Figure 43.3: Asymmetric Communication Across NATs



In an asymmetric configuration, an unreachable peer (that is behind a firewall or NAT without port forwarding) can still publish and subscribe like a reachable peer, but with some important limitations:

- An unreachable peer can only communicate with reachable peers: two unreachable peers cannot establish a direct communication since they are both behind a firewall and/or NAT.

  Note that since *Connext DDS* always relies on a direct connection between peers (even if there is a third node that can be reachable by both unreachable peers), **communication can never occur between unreachable peers**. For example, suppose Peers A and B are unreachable and Peer C is reachable. Communication can take place between A and C, and between B and C, but not between A and B.
- It can take longer to discover unreachable peers than reachable ones. This is because a reachable peer has to wait for the unreachable peer to establish the communication first.

  For example, suppose Peer A (unreachable) starts before Peer B (reachable). The discovery mechanism of A attempts to connect to the (not-yet existing) Peer B. Since it fails, it will retry after *n* seconds. Right after that, B starts. If A would be reachable (and in B's peer list), the discovery

mechanism will immediately contact A. In this case, since A cannot be reached, B needs to wait until the discovery process of A decides to retry.

This effect can be minimized by modifying the QoS that controls the discovery mechanism used by A. In particular, you should set the *DomainParticipant's* DiscoveryConfig QoS policy's **min_initial_participant_announcement_period** to a small value.

Note that the concept of symmetric/asymmetric configuration is a local concept that only describes the communication mechanism between two peers. A reachable peer can be involved in symmetric communication with another reachable peer, and at the same time have asymmetric communication with a unreachable peer. When a peer attempts to communicate with a remote peer, it knows if the remote peer is reachable or not by looking at the transport address provided.

Chapter 44 Configuring the TCP Transport

TCP Transport is distributed as a both shared and static library in **<NDDSHOME>/lib/<architecture>**. The library is called **nddstransporttcp**.

Mechanisms for Configuring the Transport:

- **By explicitly instantiating a new transport** (see 44.2 Explicitly Instantiating the TCP Transport Plugin on the next page) and then registering it with the *DomainParticipant* (see 16.7 Installing Additional Builtin Transport Plugins with register_transport() on page 814). (Not available in the Java and .NET APIs.)
- **Through the Property QoS policy** of the *DomainParticipant* (on Linux and Windows systems only). This process is described in 44.3 Configuring the TCP Transport with the Property QosPolicy on page 1131.

This section describes:

- 44.1 Choosing a Transport Mode below
- 44.2 Explicitly Instantiating the TCP Transport Plugin on the next page
- 44.3 Configuring the TCP Transport with the Property QosPolicy on page 1131
- 44.4 Setting the Initial Peers on page 1134
- 44.6 Support for External Hardware Load Balancers in TCP Transport Plugin on page 1136
- 44.7 TCP/TLS Transport Properties on page 1138

44.1 Choosing a Transport Mode

When you configure the TCP transport, you must choose one of the following types of communication:

- **TCP over LAN** — Communication between the two peers is not encrypted (data is written directly to a TCP socket). Each node can use all the possible interfaces available on that machine to receive connections. The node can only receive connections from machines that are on a local LAN.
- **TCP over WAN** — Communication is not encrypted (data is written directly to a TCP socket). The node can only receive connections from a specific port, which must be configured in the public router of the local network (WAN mode).
- **TLS over LAN** — This is similar to the TCP over LAN, where the node can use all the available network interfaces to TX/RX data (LAN nodes only), but in this mode, the data being written on the physical socket is encrypted first (through the **openssl** library). Performance (throughput and latency) may be less than TCP over LAN since the data needs to be encrypted before going on the wire. Discovery time may be longer with this mode because when the first connection is established, the two peers exchange handshake information to ensure line protection. For more general information on TLS, see 41.3 Datagram Transport-Layer Security (DTLS) on page 1096.
- **TLS over WAN** — The data is encrypted just like TLS over LAN, but it can be sent and received only from a specific port of the router.

Note: To use either TLS mode, you also need *RTI TLS Support*, which is available for purchase as a separate package. *TLS Support* uses TLS 1.3.

An instance of the transport can only communicate with other nodes that use the same transport mode.

You can specify the transport mode in either the NDDS_Transport_TCPv4_Property_t structure (see 44.7 TCP/TLS Transport Properties on page 1138) or in the parent.classid on page 1140 field of the Properties QoS (see 44.3 Configuring the TCP Transport with the Property QosPolicy on page 1131). Your choice of transport mode will also be reflected in the prefix you use for setting the initial peers (see 44.4 Setting the Initial Peers on page 1134).

44.2 Explicitly Instantiating the TCP Transport Plugin

As described on Page 1128, there are two ways to configure a transport plugin. This section describes the way that includes explicitly instantiating and registering a new transport. (The other way is to use the Property QoS mechanism, described in 44.3 Configuring the TCP Transport with the Property QosPolicy on page 1131).

Notes:

This way of instantiating a transport is not supported in the Java and .NET APIs. If you are using Java or .NET, use the Property QoS mechanism described in 44.3 Configuring the TCP Transport with the Property QosPolicy on page 1131.

To use this mechanism, there are **extra libraries that you must link into your program and an additional header file** that you must include. Please see 44.2.1 Additional Header Files and Include Directories on the next page and 44.2.2 Additional Libraries and Compiler Flags on the next page for details.

To instantiate a TCP transport:

Include the extra header file described in 44.2.1 Additional Header Files and Include Directories below.

Instantiate a new transport by calling **NDDS_Transport_TCPv4_new()**:

```
NDDS_Transport_Plugin* NDDS_Transport_TCPv4_new (
        const struct NDDS_Transport_TCPv4_Property_t * property_in)
```

Register the transport by calling **NDDSTransportSupport::register_transport()**.

See the API Reference HTML documentation for details on these functions and the contents of the NDDS_Transport_TCPv4_Property_t structure.

44.2.1 Additional Header Files and Include Directories

To use the TCP Transport API, you must include an extra header file (in addition to those in Table 10.1 Header Files to Include for Connext DDS (All Architectures)):

```
#include "ndds/transport_tcp/transport_tcp_tcpv4.h"
```

Since TCP Transport is in the same directory as Connext DDS (see Table 10.2 Include Paths for Compilation (All Architectures)), no additional include paths need to be added for the TCP Transport API. If this is not the case, you will need to specify the appropriate include path.

44.2.2 Additional Libraries and Compiler Flags

To use the TCP Transport, you must add the **nddstransporttcp** library to the link phase of your application. There are four different kinds of libraries, depending on if you want a debug or release version, and static or dynamic linking with *Connext DDS*.

> **Note:** Make sure your chosen kinds of libraries (static, dynamic, release, or debug) are consistent with the other *Connext DDS* libraries that your application links with. For example, if you are using RTI static core libraries, also use the static TCP Transport libraries. See 10.3.2 Mixing Static and Dynamic Libraries not Supported on page 676.

For Linux systems, the libraries are:

- **libnddstransporttcp.a** — Release version, dynamic libraries
- **libnddstransporttcpd.a** — Debug version, dynamic libraries
- **libnddstransporttcpz.a** — Release version, static libraries
- **libnddstransporttcpzd.a** — Debug version, static libraries

For Windows systems, the libraries are:

- **NDDSTRANSPORTTCP.LIB** — Release version, dynamic libraries
- **NDDSTRANSPORTTCPD.LIB** — Debug version, dynamic libraries
- **NDDSTRANSPORTTCPZ.LIB** — Release version, static libraries
- **NDDSTRANSPORTTCPZD.LIB** — Debug version, static libraries

Notes for using TLS:

To use either TLS mode (see 44.1 Choosing a Transport Mode on page 1128), you also need *RTI TLS Support*, which is available for purchase as a separate package. The TLS library (**libnddstls.so** or **NDDSTLS.LIB**, depending on your platform) must be in your library search path (pointed to by the environment variable LD_LIBRARY_PATH on Linux systems, Path on Windows systems, DYLD_LIBRARY_PATH on macOS systems).

If you already have **$NDDSHOME/lib/<*architecture*>** in your library search path, no extra steps are needed to use TLS once *TLS Support* is installed.

Even if you link everything statically, you must make sure that the location for **$NDDSHOME/lib/<architecture>** (or wherever the TLS library is located) is in your search path. When the TCP Transport Plugin is explicitly instantiated, the TLS library is loaded dynamically, even if you use static linking for everything else. To load TLS libraries statically, please see 44.3 Configuring the TCP Transport with the Property QosPolicy below.

Your search path must also include the location for the OpenSSL library, which is used by the TLS library.

44.3 Configuring the TCP Transport with the Property QosPolicy

The 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 allows you to set up name/value pairs of data and attach them to an entity, such as a *DomainParticipant*.

Like all QoS policies, there are two ways to specify the Property QoS policy:

Programmatically, as described in this section and 4.1.7 Getting, Setting, and Comparing QosPolicies on page 172. This includes using the **add_property()** operation to attach name/value pairs to the Property QosPolicy and then configuring the *DomainParticipant* to use that QosPolicy (by calling **set_qos()** or specifying QoS values when the *DomainParticipant* is created).

With an XML QoS Profile, as described in Configuring QoS with XML (Chapter 19 on page 842). This causes *Connext DDS* to dynamically load the TCP Transport library at runtime and then implicitly create and register the transport plugin.

> **Note:** Dynamically load the TCP Transport library only if your application also links dynamically with the *Connext DDS* core libraries. See 10.3.2 Mixing Static and Dynamic Libraries not Supported on page 676.

To add name/value pairs to the Property QoS policy, use the **add_property()** operation:

```
DDS_ReturnCode_t DDSPropertyQosPolicyHelper::add_property
                (DDS_PropertyQosPolicy policy, const char * name,
                 const char * value, DDS_Boolean propagate)
```

For more information on **add_property()** and the other operations in the DDSPropertyQosPolicyHelper class, see Table 7.64 PropertyQoSPolicyHelper Operations, as well as the API Reference HTML documentation.

The 'name' part of the name/value pairs is a predefined string. The property names for the *TCP Transport* are described in Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t.

Here are the basic steps, taken from the example Hello World application (for details, please see the example application.)

Get the default *DomainParticipant* QoS from the DomainParticipantFactory.

```
DDSDomainParticipantFactory::get_instance()->
    get_default_participant_qos(participant_qos);
```

Disable the builtin transports.

```
participant_qos.transport_builtin.mask =
    DDS_TRANSPORTBUILTIN_MASK_NONE;
```

Set up the *DomainParticipant's* Property QoS.

Load the plugin.

```
DDSPropertyQosPolicyHelper::add_property (
    participant_qos.property,
    "dds.transport.load_plugins",
    "dds.transport.TCPv4.tcp1",
    DDS_BOOLEAN_FALSE);
```

Specify the transport plugin library.

```
DDSPropertyQosPolicyHelper::add_property (
    participant_qos.property,
    "dds.transport.TCPv4.tcp1.library",
    "nddstransporttcp",
    DDS_BOOLEAN_FALSE);
```

Specify the transport's 'create' function.

```
DDSPropertyQosPolicyHelper::add_property (
    participant_qos.property,
    "dds.transport.TCPv4.tcp1.create_function",
    "NDDS_Transport_TCPv4_create", DDS_BOOLEAN_FALSE);
```

Set the transport to work in a WAN configuration with a public address:

```
DDSPropertyQosPolicyHelper::add_property (
    participant_qos.property,
```

```
    "dds.transport.TCPv4.tcp1.parent.classid",
    ”NDDS_TRANSPORT_CLASSID_TCPV4_WAN”, DDS_BOOLEAN_FALSE);
DDSPropertyQosPolicyHelper::add_property (
    participant_qos.property,
    "dds.transport.TCPv4.public_address",
    "182.181.2.31",
    DDS_BOOLEAN_FALSE);
```

Specify any other properties, as needed.

Create the *DomainParticipant* using the modified QoS.

```
participant =
    DDSTheParticipantFactory->create_participant (
        domainId,
        participant_qos,
        NULL /* listener */,
        DDS_STATUS_MASK_NONE);
```

Property changes should be made before the transport is loaded—either before the *DomainParticipant* is enabled, before the first *DataWriter/DataReader* is created, or before the builtin topic reader is looked up, whichever one happens first.

44.3.1 Configuring the TCP Transport to be Loaded Statically

Similar to the previous example, here are the basic steps to load the TCP Transport plugin statically.

Note: Statically load the TCP Transport library only if your application also links statically with the *Connext DDS* core libraries. See 10.3.2 Mixing Static and Dynamic Libraries not Supported on page 676.

1. Get the default *DomainParticipant* QoS from the DomainParticipantFactory.

   ```
   DDSDomainParticipantFactory::get_instance()->
       get_default_participant_qos(participant_qos);
   ```

2. Disable the builtin transports.

   ```
   participant_qos.transport_builtin.mask =
       DDS_TRANSPORTBUILTIN_MASK_NONE;
   ```

3. Set up the *DomainParticipant's* Property QoS.

   a. Load the plugin.

   ```
   DDSPropertyQosPolicyHelper::add_property
      (participant_qos.property,
       "dds.transport.load_plugins",
       "dds.transport.TCPv4.tcp1",DDS_BOOLEAN_FALSE);
   ```

   b. Specify the transport's 'create' function pointer.

   ```
   DDSPropertyQosPolicyHelper::add_pointer_property
      (participant_qos.property,
   ```

```
    "dds.transport.TCPv4.tcp1.create_function_ptr",
    (void*)NDDS_Transport_TCPv4_create);
```

c. Set the transport to work in a WAN configuration with a public address:

```
DDSPropertyQosPolicyHelper::add_property
   (participant_qos.property,
   "dds.transport.TCPv4.tcp1.parent.classid",
   ”NDDS_TRANSPORT_CLASSID_TCPV4_WAN”,
   DDS_BOOLEAN_FALSE);
DDSPropertyQosPolicyHelper::add_property
   (participant_qos.property,
    "dds.transport.TCPv4.tcp1.public_address",
    "182.181.2.31",
    DDS_BOOLEAN_FALSE);
```

d. Specify any other properties, as needed.

4. Create the *DomainParticipant* using the modified QoS.

```
participant = DDSTheParticipantFactory->create_participant
    (domainId, participant_qos,
     NULL /* listener */, DDS_STATUS_MASK_NONE);
```

44.3.2 Loading TLS Support Libraries Statically

The process to load TLS Support library statically is similar, but in this case both the **tls_create_function_ptr** and **tls_delete_function_ptr** properties need to be set.

```
DDSPropertyQosPolicyHelper::add_pointer_property
    (participant_qos.property,
     "dds.transport.TCPv4.tcp1.tls_create_function_ptr",
     (void*)RTITLS_ConnectionEndpointFactoryTLSv4_create);
DDSPropertyQosPolicyHelper::add_pointer_property
    (participant_qos.property,
     "dds.transport.TCPv4.tcp1.tls_delete_function_ptr",
     (void*)RTITLS_ConnectionEndpointFactoryTLSv4_delete);
```

44.4 Setting the Initial Peers

Note: You must specify the initial peers (you cannot use the defaults because multicast cannot be used with TCP).

For *TCP Transport*, the addresses of the initial peers (NDDS_DISCOVERY_PEERS) that will be contacted during the discovery process have the following format:

- For WAN communication using TCP: **tcpv4_wan://<IP address or hostname>:<port>**
- For WAN communication using TLS: **tlsv4_wan://<IP address or hostname>:<port>**

- For LAN communication using TCP: **tcpv4_lan://<IP address or hostname>:<port>**
- For LAN communication using TLS: **tlsv4_lan://<IP address or hostname>:<port>**

For example (enter this on one line):

```
export NDDS_DISCOVERY_PEERS=
tcpv4_wan://10.10.1.165:7400,tcpv4_wan://10.10.1.111:7400,tcpv4_lan://192.168.1.1:7500
```

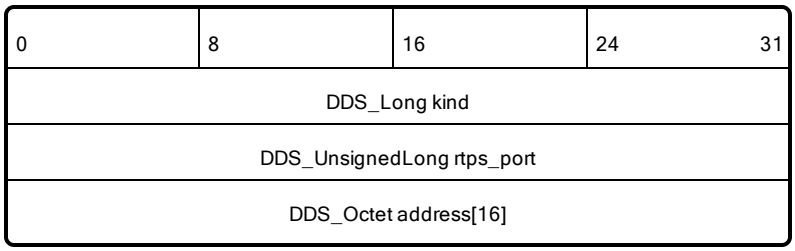
When the TCP transport is configured for LAN communication (with the parent.classid on page 1140 property), the IP address is the LAN address of the peer and the port is the server port used by the transport (the server_bind_port on page 1145 property).

When the TCP transport is configured for WAN communication (with the parent.classid on page 1140 property), the IP address is the WAN or public address of the peer and the port is the public port that is used to forward traffic to the server port in the TCP transport.

44.5 RTPS Locator Format

As described in Chapter 17 RTPS Locators and IP Mobility on page 821, an RTPS locator is an n-tuple (transport, address, port) that describes how to reach a remote endpoint.

The RTI TCP Transport locator has the following format:

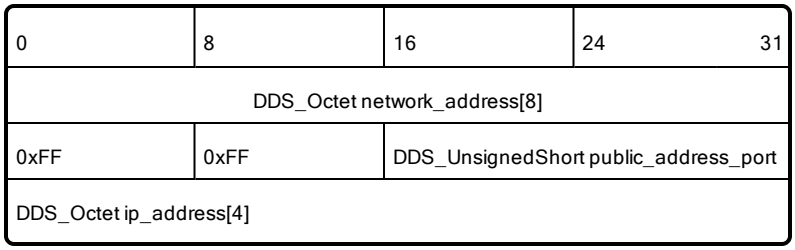


where kind can be one of the following values:

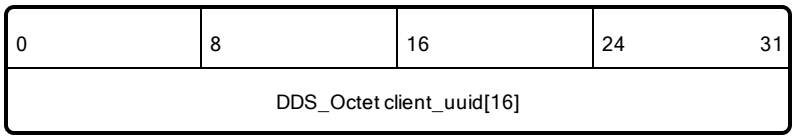
```
#define NDDS_TRANSPORT_CLASSID_TCPV4_LAN  (8)
#define NDDS_TRANSPORT_CLASSID_TCPV4_WAN  (9)
#define NDDS_TRANSPORT_CLASSID_TLSV4_LAN  (10)
#define NDDS_TRANSPORT_CLASSID_TLSV4_WAN  (11)
```

There are two subkinds of RTI TCP locator, which differ in the way the address field is mapped. You can distinguish the two subkinds from each other by comparing bytes address[8] and address[9]:

- If address[8]==0xFF and address[9]==0xFF, the RTI TCP locator is an RTI TCP server locator, and the format of the address[16] is as follows:



- Otherwise, the RTI TCP locator is an RTI TCP client locator, and the format of the address[16] is as follows:



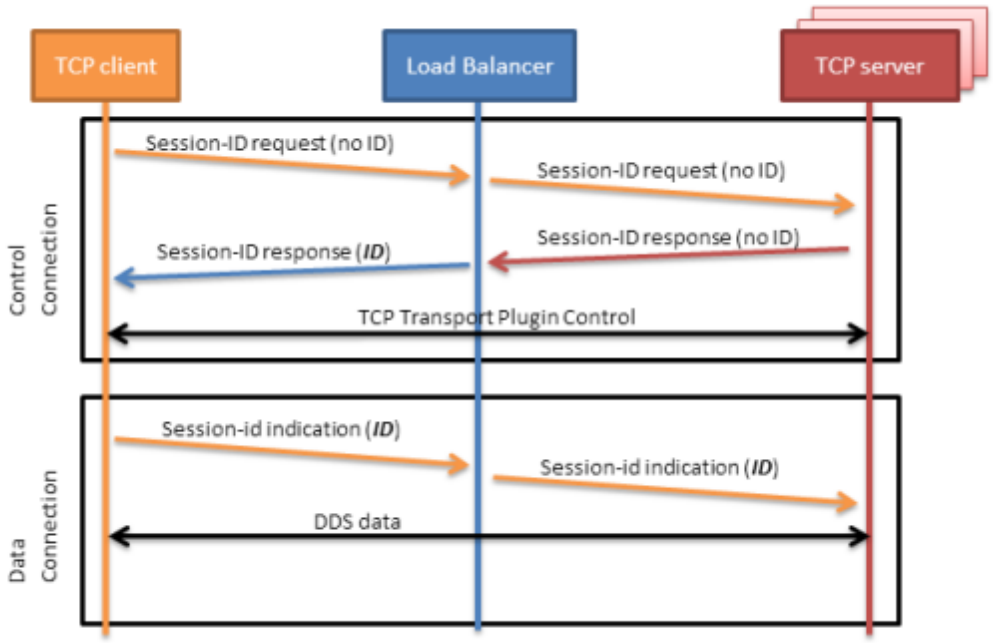
44.6 Support for External Hardware Load Balancers in TCP Transport Plugin

For two *Connext DDS* applications to communicate, the TCP Transport Plugin needs to establish 4-6 connections between the two communicating applications. The plugin uses these connections to exchange DDS data (discovery or user data) and TCP Transport Plugin control messages.

With the default configuration, the TCP Transport Plugin does not support external load balancers. This is because external load balancers do not forward the traffic to a unique TCP Transport Plugin server, but they divide the connections among multiple servers. Because of this behavior, when an application running a TCP Transport Plugin client tries to establish all the connections to an application running a TCP Transport Plugin server, the server may not receive all the required connections.

In order to support external load balancers, the TCP Transport Plugin provides a session-ID negotiation feature. When session-ID negotiation is enabled (by setting the **negotiate_session_id** property to true), the TCP Transport Plugin will perform the negotiation depicted in Figure 44.1: Session-ID Negotiation on the next page.

Figure 44.1: Session-ID Negotiation



During the session-ID negotiation, the TCP Transport Plugin exchanges three types of messages:

Session-ID Request: This message is sent from the client to the server. The server must respond with a session-ID response.

Session-ID Response: This message is sent from the server to the client as a response to a session-ID request. The client will store the session ID contained in this message.

Session-ID Indication: This message is sent from the client to the server; it does not require a response from the server.

The negotiation consists of the following steps:

1. The TCP client sends a session-ID request with the session ID set to zero.
2. The TCP server sends back a session-ID response with the session ID set to zero.
3. The external load balancer modifies the session-ID response, setting the session ID with a value that is meaningful to the load balancer and identifies the session.
4. The TCP client receives the session-ID response and stores the received session ID.
5. For each new connection, the TCP client sends a session-ID indication containing the stored session ID. This will allow the load balancer to redirect to the same server all the connections with the same session ID.

44.6.1 Session-ID Messages

TCP Payload for Session-ID Message below depicts the TCP payload of a session-ID message. The payload consists of 48 bytes. In particular, your load balancer needs to read/modify the following two fields:

CTRLTYPE: This field allows a load balancer to identify session-ID messages. Its value (two bytes) varies according to the session-ID message type: 0x0c05 for a request, 0x0d05 for a response, or 0x0c15 for an indication.

SESSION-ID: This field consists of 16 bytes that the load balancer can freely modify according to its requirements.

TCP Payload for Session-ID Message

00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
RTI reserved				0xDD	0x54	0xDD	0x55	CTRLTYPE		RTI reserved					
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
RTI reserved															
32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
SESSION-ID															

To ensure all the TCP connections within the same session are directed to the same server, you must configure your load balancer to perform the two following actions:

Modify the SESSION-ID field in the *session-id response* with a value that identifies the session within the load balancer.

Make the load-balancing decision according to the value of the SESSION-ID field in the session-ID indication.

44.7 TCP/TLS Transport Properties

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t describes the TCP and TLS transport properties.

Note: To use TLS, you also need *RTI TLS Support*, which is a separate component.

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
dds.transport.load_plugins (Note: this does not take a prefix)	Required Comma-separated strings indicating the prefix names of all plugins that will be loaded by *Connext DDS*. For example: "**dds.transport.TCPv4.tcp1**". You will use this string as the prefix to the property names. Note: you can load up to 8 plugins.
library	Only required if linking dynamically If used, must be "nddstransporttcp". This library must be in your library search path (pointed to by the environment variable LD_LIBRARY_PATH on Linux systems, Path on Windows systems, DYLD_LIBRARY_PATH on macOS systems).
create_function	Only required if linking dynamically If used, must be "NDDS_Transport_TCPv4_create".
create_function_ptr	Only required if linking statically Defines the function pointer to the TCP Transport Plugin creation function. Used for loading TCP Transport Plugin statically. Must be set to the NDDS_Transport_TCPv4_create function pointer.
tls_create_function_ptr	Defines the function pointer to the TLS Support creation function. Used for loading TLS Support libraries statically. Must be set to the RTITLS_ConnectionEndpointFactoryTLSv4_create function pointer. Note: In order to have effect, the **tls_delete_function_ptr** property must also be set.
tls_delete_function_ptr	Defines the function pointer to the TLS Support deletion function. Used for loading TLS Support libraries statically. Must be set to the RTITLS_ConnectionEndpointFactoryTLSv4_delete function pointer. Note: In order to have effect, the **tls_create_function_ptr** property must also be set.
aliases	Used to register the transport plugin returned by **NDDS_Transport_TCPv4_create()** (as specified by **<TCP_prefix>.create_function**) to the *DomainParticipant*. Aliases should be specified as a comma-separated string, with each comma delimiting an alias. If it is not specified, the prefix–without the leading **"dds.transport"**–is used as the default alias for the plugin. For example, if the <TRANSPORT_PREFIX> is **"dds.transport.mytransport"**, the default alias for the plugin is **"mytransport"**.

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
parent.classid	Must be set to one of the following values: • NDDS_TRANSPORT_CLASSID_TCPV4_LAN for TCP communication within a LAN • NDDS_TRANSPORT_CLASSID_TLSV4_LAN for TLS communication within a LAN • NDDS_TRANSPORT_CLASSID_TCPV4_WAN for TCP communication across LANs and firewalls • NDDS_TRANSPORT_CLASSID_TLSV4_WAN for TLS communication across LAN and firewalls Default: **NDDS_TRANSPORT_CLASSID_TCPV4_LAN** **Note:** To use either TLS mode, you also need *RTI TLS Support* which is available for purchase as a separate package.
parent.gather_send_buffer_count_max	Specifies the maximum number of buffers that *Connext DDS* can pass to the **send()** function of the transport plugin. The transport plugin **send()** API supports a gather-send concept, where the **send()** call can take several discontiguous buffers, assemble and send them in a single message. This enables *Connext DDS* to send a message from parts obtained from different sources without first having to copy the parts into a single contiguous buffer. However, most transports that support a gather-send concept have an upper limit on the number of buffers that can be gathered and sent. Setting this value will prevent *Connext DDS* from trying to gather too many buffers into a send call for the transport plugin. Connext DDS requires all transport-plugin implementations to support a gather-send of least a minimum number of buffers. This minimum number is defined as **NDDS_TRANSPORT_PROPERTY_GATHER_SEND_BUFFER_COUNT_MIN**. Default: 128
parent.message_size_max	The maximum size of a message in bytes that can be sent or received by the transport plugin. Default: 65536

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
parent.allow_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name that can be used by the transport. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. For example: 10.10.*, 10.15.* If the list is non-empty, this "white" list is applied before parent.deny_interfaces_list below. Default: All available interfaces are used.
parent.deny_interfaces_list	A list of strings, each identifying a range of interface addresses or an interface name that will not be used by the transport. If the list is non-empty, deny the use of these interfaces. Interfaces must be specified as comma-separated strings, with each comma delimiting an interface. For example: 10.10.* This "black" list is applied after parent.allow_interfaces_list above and filters out the interfaces that should not be used. **Default:** No interfaces are denied
send_socket_buffer_size	Size, in bytes, of the send buffer of a socket used for sending. On most operating systems, **setsockopt()** will be called to set the SENDBUF to the value of this parameter. This value must be greater than or equal to parent.message_size_max on the previous page, or -1. The maximum value is operating system-dependent. When set to -1, **setsockopt()** (or equivalent) will not be called to size the send buffer of the socket. The transport will use the OS default. Default: 131072
recv_socket_buffer_size	Size, in bytes, of the receive buffer of a socket used for receiving. On most operating systems, **setsockopt()** will be called to set the RECVBUF to the value of this parameter. This value must be greater than or equal to parent.message_size_max on the previous page, or -1. The maximum value is operating-system dependent. When set to -1, **setsockopt()** (or equivalent) will not be called to size the receive buffer of the socket. The transport will use the OS default. Default: 131072

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.') [1]	Description
ignore_loopback_interface	Prevents the transport plugin from using the IP loopback interface. This property is ignored when parent.classid on page 1140 is NDDS_TRANSPORT_CLASSID_TCPV4_WAN or NDDS_TRANSPORT_CLASSID_TLSV4_WAN. Two values are allowed: • 0: Enable local traffic via this plugin. The plugin will only use and report the IP loopback interface only if there are no other network interfaces (NICs) up on the system. • 1: Disable local traffic via this plugin. This means "do not use the IP loopback interface, even if no NICs are discovered." This setting is useful when you want applications running on the same node to use a more efficient plugin like shared memory instead of the IP loopback. Default: 1
ignore_nonrunning_interfaces	It prevents the transport plugin from using a network interface that is not reported as RUNNING by the operating system. The transport checks the flags reported by the operating system for each network interface upon initialization. An interface which is not reported as UP will not be used. This property allows the same check to be extended to the IFF_RUNNING flag implemented by some operating systems. The RUNNING flag is defined to mean that "all resources are allocated" and may be off if no link is detected (e.g., the network cable is unplugged). Two values are allowed: • 0: Do not check the RUNNING flag when enumerating interfaces, just make sure the interface is UP. • 1: Check the flag when enumerating interfaces, and ignore those that are not reported as RUNNING. This can be used on some operating systems to cause the transport to ignore interfaces that are enabled but not connected to the network. Default: 1

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
transport_priority_mask	Mask for the transport priority field. This is used in conjunction with transport_priority_mapping_low below/ transport_priority_mapping_high below to define the mapping from DDS transport priority to the IPv4 TOS field. Defines a contiguous region of bits in the 32-bit transport priority value that is used to generate values for the IPv4 TOS field on an outgoing socket. For example, the value 0x0000ff00 causes bits 9-16 (8 bits) to be used in the mapping. The value will be scaled from the mask range (0x0000 -0xff00 in this case) to the range specified by low and high. If the mask is set to zero, then the transport will not set IPv4 TOS for send sockets. Default: 0
transport_priority_mapping_low	Sets the low and high values of the output range to IPv4 TOS. These values are used in conjunction with transport_priority_mask above to define the mapping from DDS transport priority to the IPv4 TOS field. Defines the low and high values of the output range for scaling. Note that IPv4 TOS is generally an 8-bit value. Default transport_priority_mapping_low: 0 Default transport_priority_mapping_high: 0xFF
transport_priority_mapping_high	
interface_poll_period	Specifies the period in milliseconds to query for changes in the state of all the interfaces. See interface_poll_period in 16.6 Setting Builtin Transport Properties with the PropertyQosPolicy on page 795
server_socket_backlog	The backlog parameter determines what is the maximum length of the queue of pending connections. Default: 5

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.') [1]	Description
public_address	**Required for WAN communication (see note below)** Public IP address and port (WAN address and port) (separated with ':') associated with the transport instantiation. For example: 10.10.9.10:4567 This field is used only when parent.classid on page 1140 is NDDS_TRANSPORT_CLASSID_TCPV4_WAN or NDDS_TRANSPORT_CLASSID_TLSV4_WAN. The public address and port are necessary to support communication over WAN that involves Network Address Translators (NATs). Typically, the address is the public address of the IP router that provides access to the WAN. The port is the IP router port that is used to reach the private server_bind_port on the next page inside the LAN from the outside. This value is expressed as a string in the form: **ip[:port]**, where **ip** represents the IPv4 address and port is the external port number of the router. Host names are not allowed in the **public_address** because they may resolve to an internet address that is not what you want (i.e., 'localhost' may map to your local IP or to 127.0.0.1). **Note:** If you are using an asymmetric configuration, **public_address** does not have to be set for the non-public peer.
bind_interface_address	The TCP transport can be configured to bind all sockets to a specified interface. If NULL, the sockets will be bound to the special IP address INADDR_ANY. This address allows the sockets to receive packets destined to any of the interfaces. This field should be set in multi-homed systems communicating across NAT routers.

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.') [1]	Description
server_bind_port	Private IP port (inside the LAN) used by the transport to accept TCP connections. If this property is set to zero (which is only a valid configuration when **parent.classid** is NDDS_TRANSPORT_CLASSID_TCPV4_WAN or NDDS_TRANSPORT_CLASSID_TLSV4_WAN), the transport will operate in "asymmetric mode" and it will disable the internal server socket, making it impossible for external peers to connect to this node. In this case, the node is considered unreachable and will communicate only using the asymmetric mode with other (reachable) peers. For more information about the available modes of operation for the transport, please refer to Chapter 43 TCP Communication Scenarios on page 1123. For WAN communication, if **server_bind_port** is set to a value other than zero, this port must be forwarded to a public port in the NAT-enabled router that connects to the outer network. The **server_bind_port** cannot be shared among multiple participants on a common host. On most operating systems, attempting to reuse the same **server_bind_port** for multiple participants on a common host will result in a "port already in use" error. However, Windows systems will not recognize if the **server_bind_port** is already in use; therefore care must be taken to properly configure Windows systems. Default: 7400
read_buffer_allocation	Allocation settings applied to read buffers. These settings configure the initial number of buffers, the maximum number of buffers and the buffers to be allocated when more buffers are needed. Default: • **read_buffer_allocation.initial_count** = 2 • **read_buffer_allocation.max_count** = -1 (unlimited) • **read_buffer_allocation.incremental_count** = -1 (number of buffers will keep doubling on each allocation until it reaches **max_count**)

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
write_buffer_allocation	Allocation settings applied to buffers used for asynchronous (non-blocking) send. To enable asynchronous send, set the property **force_asynchronous_send** to 1. These settings configure the initial number of buffers, the maximum number of buffers, and the buffers to be allocated when more buffers are needed. Default: • **write_buffer_allocation.initial_count** = 4 • **write_buffer_allocation.max_count** = 32 • **write_buffer_allocation.incremental_count** = 2 The pool of buffers can be configured to be shared across all the TCP connections created by the TCP Transport or to be exclusive for a connection by setting the property **shared_write_buffer_allocation** to 1. The default value is 0. Note that for the write buffer pool, the **max_count** is not set to unlimited. This is to avoid having a fast writer quickly exhaust all the available system memory, in case of a temporary network slowdown. When this write buffer pool reaches the maximum, a new message will replace the oldest message that is not currently in the process of being sent. This guarantees that new messages are prioritized, while at the same time not running into a situation in which messages are not received. Messages that are replaced and not sent may be resent later depending on the application's QoS (if the transport is used for reliable communication, the data will still be sent eventually).
shared_write_buffer_allocation	This property determines whether the pool of buffers created with asynchronous (non-blocking) send is shared or exclusive per TCP connection. Sharing this buffer across connections may lead to less memory consumption. However, high-throughput connections may starve low-throughput connections. This is why the default value is 0. The size of the buffer pool can be configured using the property **write_buffer_allocation**. Default: 0
control_buffer_allocation	Allocation settings applied to buffers used to serialize and send control messages. These settings configure the initial number of buffers, the maximum number of buffers and the buffers to be allocated when more buffers are needed. Default: • **control_buffer_allocation.initial_count** = 2 • **control_buffer_allocation.max_count** = -1 (unlimited) • **control_buffer_allocation.incremental_count** = -1 (number of buffers will keep doubling on each allocation until it reaches **max_count**)

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
control_message_allocation	Allocation settings applied to control messages. These settings configure the initial number of messages, the maximum number of messages and the messages to be allocated when more messages are needed. Default: • **control_message_allocation.initial_count** = 2 • **control_message_allocation.max_count** = -1 (unlimited) • **control_message_allocation.incremental_count** = -1 (number of messages will keep doubling on each allocation until it reaches **max_count**)
control_attribute_allocation	Allocation settings applied to control messages attributes. These settings configure the initial number of attributes, the maximum number of attributes and the attributes to be allocated when more attributes are needed. Default: • **control_attribute_allocation.initial_count** = 2 • **control_attribute_allocation.max_count** = -1 (unlimited) • **control_attribute_allocation.incremental_count** = -1 (number of attributes will keep doubling on each allocation until it reaches **max_count**)
force_asynchronous_send	Forces asynchronous send. When this parameter is set to 0, the TCP Transport will attempt to send data as soon as the internal **send()** function is called. When it is set to 1, the transport will make a copy of the data to send in an internal send buffer and enqueue it. Data will be sent as soon as the low-level socket buffer has space. Setting this option to 0 (default) should provide better latency. However, in high-throughput scenarios, a 0 setting may cause the low-level **send()** function to block until the data is physically delivered to the lower socket buffer. For an application writing data at a very fast rate, the 0 setting may cause the caller thread to block if the send socket buffer is full. This could produce lower throughput in those conditions (the caller thread could prepare the next packet while waiting for the send socket buffer to become available). The size of the buffer pool created by setting this option to 1 can be configured using the property **write_buffer_allocation**. In addition, the TCP Transport can be used to create one buffer pool per connection or a single buffer pool shared across all TCP connections by using the property **shared_write_buffer_allocation**. Default: 0

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
max_packet_size	The maximum size of a TCP segment. This parameter is only supported on Linux architectures. By default, the maximum size of a TCP segment is based on the network MTU for destinations on a local network, or on a default 576 for destinations on non-local networks. This behavior can be changed by setting this parameter to a value between 1 and 65535. Default: -1 (default behavior)
enable_keep_alive	Configures the sending of KEEP_ALIVE messages in TCP. Setting this value to 1, causes a KEEP_ALIVE packet to be sent to the remote peer if a long time passes with no other data sent or received. This feature is implemented only on architectures that provide a low-level implementation of the TCP keep-alive feature. On Windows systems, the TCP keep-alive feature can be globally enabled through the system's registry: **\HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Tcpip\Parameters**. Refer to MSDN documentation for more details. Default: 0
keep_alive_time	Specifies the interval of inactivity in seconds that causes TCP to generate a KEEP_ALIVE message. This parameter is only supported on Linux and Mac architectures. Default: -1 (OS default value)
keep_alive_interval	Specifies the interval in seconds between KEEP_ALIVE retries. This parameter is only supported on Linux architectures. Default: -1 (OS default value)
keep_alive_retry_count	The maximum number of KEEP_ALIVE retries before dropping the connection. This parameter is only supported on Linux architectures. Default: -1 (OS default value)

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
user_timeout	Changes the default OS TCP User Timeout configuration. If set to a value greater than 0, it specifies the maximum amount of time in seconds that transmitted data may remain unacknowledged before TCP will forcibly close the corresponding connection and return ETIMEDOUT to the application. If set to 0, TCP Transport plugin will use the system default. Currently this feature is supported only on Linux 2.6.37 and higher platforms. Default: 0 (use system's default).
connection_liveliness	Configures the connection liveliness feature. See 44.7.1 Connection Liveliness on page 1158. Defaults: • connection_liveliness.enable: 0 • connection_liveliness.lease_duration: 10 • connection_liveliness.assertions_per_lease_duration: 3
event_thread	Configures the event thread used by the TCP Transport plugin for providing some features. Defaults: • event_thread.priority: THREAD_PRIORITY_DEFAULT • event_thread.stack_size: THREAD_STACK_SIZE_DEFAULT • event_thread.mask: PRIORITY_ENFORCE | STDIO
disable_nagle	Disables the TCP nagle algorithm. When this property is set to 1, TCP segments are always sent as soon as possible, which may result in poor network utilization. Default: 0

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.') [1]	Description
logging_verbosity_bitmap	Bitmap that specifies the verbosity of log messages from the transport. Logging values: • -1 (0xffffffff): do not change the current verbosity • 0x00: silence • 0x01: fatal error • 0x02: errors • 0x04: warnings • 0x08: local • 0x10: remote • 0x20: periodic • 0x100: other (used for control protocol tracing) • 13F: all (fatal error, errors, warnings, local, remote, periodic, and other) You can combine these values by logically ORing them together. Default: -1 (meaning, do not change the current verbosity, which is fatal errors, errors, and warnings) Note: the logging verbosity is a global property shared across multiple instances of the TCP Transport. If you create a new TCP Transport instance with **logging_verbosity_bitmap** different than -1, the change will affect all the other instances as well. Note: The option of 0x100 (other) is used only for tracing the internal control protocol. Since the output is very verbose, this feature is enabled only in the debug version of the TCP Transport library (**libnddstransporttcpd.so / LIBNDDSTRANSPORTD.LIB**).

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
security_logging_verbosity_bitmap	Bitmap that specifies the verbosity of security related log messages from the transport. These are usually messages generated by OpenSSL. Logging values: • -1 (0xffffffff): inherit **logging_verbosity_bitmap** value • 0x00: silence • 0x01: fatal error • 0x02: errors • 0x04: warnings • 0x08: local • 0x10: remote • 0x20: periodic You can combine these values by logically ORing them together. Default: -1 (inherit **logging_verbosity_bitmap** value) Note: The security logging verbosity is a global property shared across multiple instances of the TCP Transport. If you create a new TCP Transport instance with a **security_logging_verbosity_bitmap** other than -1, the change will affect all the other instances as well.
socket_monitoring_kind	Configures the socket monitoring API used by the transport. This property can have the following values: • SELECT: The transport uses the POSIX select API to monitor sockets. • WINDOWS_IOCP: The transport uses Windows I/O completion ports to monitor sockets. This value only applies to Windows systems. • WINDOWS_WAITFORMULTIPLEOBJECTS: The transport uses the API WaitForMultipleObjects to monitor sockets. This value only applies to Windows systems. Default: SELECT **Note:** The value selected for this property may affect transport performance and scalability. On Windows systems, using WINDOWS_IOCP provides the best performance and scalability.

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.') [1]	Description
windows_iocp	Configures I/O completion ports when socket_monitoring_kind on the previous page is set to WINDOWS_IOCP. This setting configures the number of threads the plugin creates to process I/O completion packets (thread_pool_size) and the number of those threads that the operating system can allow to concurrently run (concurrency_value). Defaults: windows_iocp.thread_pool_size: 2 windows_iocp.concurrency_value: 1
send_crc	When set to 1, enables the computation of the CRC for sent RTI TCP messages. Default: 0
force_crc_check	When set to 1, forces the checking of the CRC for received RTI TCP messages. By default, the TCP Transport plugin will only validate the CRC if the CRC is present in the received message. If this property is set to 1, TCP Transport will drop messages not including the CRC. Default: 0
negotiate_session_id	When set to 1, the TCP Transport Plugin will perform a session negotiation that will help external load balancers identify all the connections associated with a particular session between two Connext DDS applications. This keeps the connections from being divided among multiple servers and ensures proper communication. For more information about this property, see 44.6 Support for External Hardware Load Balancers in TCP Transport Plugin on page 1136. Default: 0 **Note:** The value of this property must be consistent among all the applications running the TCP Transport Plugin. If two applications have a different value for this property, they may not communicate.
outstanding_connection_cookies	Maximum number of outstanding connection cookies allowed by the transport when acting as server. A connection cookie is a token provided by a server to a client; it is used to establish a data connection. Until the data connection is established, the cookie cannot be reused by the server. To avoid wasting memory, it is good practice to set a cap to the maximum number of connection cookies (pending connections). When the maximum value is reached, a client will not be able to connect to the server until new cookies become available. Range: 1 or higher, or -1 (which means an unlimited number). Default: 100

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
outstanding_connection_cookies_life_span	Maximum lifespan (in seconds) of the cookies associated with pending connections. If a client does not connect to the server before the lifespan of its cookie expires, it will have to request a new cookie. Range: 1 second or higher, or -1 Default: -1, which means an unlimited amount of time (effectively disabling the feature).
send_max_wait_sec	Controls the maximum time (in seconds) the low-level **sendto()** function is allowed to block the caller thread when the TCP send buffer becomes full. If the bandwidth used by the transport is limited, and the sender thread tries to push data faster than the OS can handle, the low-level **sendto()** function will block the caller until there is some room available in the queue. Limiting this delay eliminates the possibility of deadlock and increases the response time of the internal DDS thread. This property affects both CONTROL and DATA streams. It only affects SYNCHRONOUS send operations. Asynchronous sends never block a send operation. For synchronous **send()** calls, this property limits the time the DDS sender thread can block for a full send buffer. If it is set too large, Connext DDS not only won't be able to send more data, it also won't be able to receive any more data because of an internal resource mutex. Setting this property to 0 causes the low-level function to report an immediate failure if the TCP send buffer is full. Setting this property to -1 causes the low-level function to block forever until space becomes available in the TCP buffer. Default: 3 seconds.
client_connection_negotiation_timeout	Timeout (in seconds) for negotiating a client data connection. The TCP Transport plugin requires some negotiation before establishing a connection. This property controls the maximum time (in seconds) a client data connection negotiation can remain in progress. In particular, it controls a maximum timeout for requesting and replying to a server logical port request. If the negotiation of a connection has not completed after the specified timeout, the negotiation will restart, and if there is an associated data connection, it will be closed. This way, the TCP Transport plugin can retry the process of establishing and negotiating that connection. Range: 1 second or higher. Default: 10 seconds

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
server_connection_negotiation_timeout	Timeout (in seconds) for negotiating a server data connection. The TCP Transport plugin requires some negotiation before establishing a connection. This property controls the maximum time (in seconds) a server data connection negotiation can remain in progress. In particular, it controls a maximum timeout for requesting and replying to a client logical port request. If the negotiation of a connection has not completed after the specified timeout, the negotiation will restart, and if there is an associated data connection, it will be closed. This way, the TCP Transport plugin can retry the process of establishing and negotiating that connection. Range: 1 second or higher. Default: 10 seconds
initial_handshake_timeout	Timeout (in seconds) for the initial handshake for a connection. Once a connection is established, TCP transport will exchange some information to identify itself and the connection. This process is known as the initial handshake of a connection, and if using TLS the TCP Transport plugin will also exchange additional information to secure the connection. This property controls the maximum time (in seconds) the initial handshake for a connection can remain in progress. If the handshake has not completed after the specified timeout, the connection will be closed. This way, the TCP Transport plugin can restart the process of establishing and handshaking that connection. Range: 1 second or higher. Default: 10 seconds
tls.verify.ca_file	A string that specifies the name of file containing Certificate Authority certificates. File should be in PEM format. See the OpenSSL manual page for SSL_load_verify_locations for more information. **To enable TLS, ca_file or ca_path is required; both may be specified (at least one is required).**
tls.verify.ca_path	A string that specifies paths to directories containing Certificate Authority certificates. Files should be in PEM format and follow the OpenSSL-required naming conventions. See the OpenSSL manual page for SSL_CTX_load_verify_locations for more information. The Certificate Authority subject name hash values must be available in the directories. You may generate them by running openssl rehash (available in OpenSSL 1.1.0 or above) or _c_rehash_ in each directory. **To enable TLS, ca_file or ca_path is required; both may be specified (at least one is required).**

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
tls.verify.verify_depth	Maximum certificate chain length for verification.
tls.verify.crl_file	Name of the file containing the Certificate Revocation List. File should be in PEM format.
tls.identity.certificate_chain	String containing an identifying certificate (in PEM format) or certificate chain (appending intermediate CA certs in order). **An identifying certificate is required for secure communication.** The string must be sorted starting with the certificate to the highest level (root CA). If this is specified, certificate_chain_file must be empty.
tls.identity.certificate_chain_file	File containing identifying certificate (in PEM format) or certificate chain (appending intermediate CA certs in order). **An identifying certificate is required for secure communication.** The file must be sorted starting with the certificate to the highest level (root CA). If this is specified, **certificate_chain** must be empty. Optionally, a private key may be appended to this file. If no private key option is specified, this file will be used to load a private key.
tls.identity.private_key_password	A string that specifies the password for private key.
tls.identity.private_key	String containing private key (in PEM format). At most one of **private_key** and **private_key_file** may be specified. If no private key is specified (all values are NULL), the private key will be read from the certificate chain file.
tls.identity.private_key_file	File containing private key (in PEM format). At most one of **private_key** and **private_key_file** may be specified. If no private key is specified (all values are NULL), the private key will be read from the certificate chain file.
tls.identity.rsa_private_key	String containing additional RSA private key (in PEM format). For use if both an RSA and non-RSA key are required for the selected cipher. At most one of rsa_private_key and rsa_private_key_file may be specified. At most one of **rsa_private_key** and **rsa_private_key_file** may be specified.
tls.identity.rsa_private_key_file	File containing additional RSA private key (in PEM format). For use if both an RSA and non-RSA key are required for the selected cipher. At most one of rsa_private_key and rsa_private_key_file may be specified. At most one of **rsa_private_key** and **rsa_private_key_file** may be specified.

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.')[1]	Description
tls.cipher.cipher_list	List of available TLS ciphers when communicating with *Connext DDS* 6.0.0 or below. See the OpenSSL manual page for SSL_set_cipher_list for more information on the format of this string. Default: NULL
tls.cipher.ciphersuites	List of available TLS ciphersuites when communicating with *Connext DDS* 6.0.1 or above. See the OpenSSL manual page for SSL_CTX_set_ciphersuites for more information on the format of this string. Default: NULL
tls.cipher.dh_param_files	List of available Diffie-Hellman (DH) key files. For example: "foo.h:2048,bar.h:1024" means: dh_param_files[0].file = foo.pem, dh_param_files[0].bits = 2048, dh_param_files[1].file = bar.pem, dh_param_files[1].bits = 1024
tls.cipher.engine_id	ID of OpenSSL cipher engine to request.
disable_interface_tracking	If this variable is set, the automatic change detection over the system network interfaces will be disabled. See disable_interface_tracking in 16.6 Setting Builtin Transport Properties with the PropertyQosPolicy on page 795
force_interface_ poll_detection	This property forces the interface tracker to use a polling method to detect changes to the network interfaces in IP mobility scenarios. It only applies to operating systems that support asynchronous notifications of interface changes. If set to TRUE, the interface tracker will use a polling method that queries the interfaces periodically to detect the changes. If set to FALSE, the interface tracker will use the operating system's default method. Basically, this property allows you–for an operating system that supports asynchronous notification–to use the polling method instead. Default: FALSE

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t

Property Name (prefix with 'dds.transport.TCPv4.tcp1.') [1]	Description
force_interface_ poll_detection	This property forces the interface tracker to use a polling method to detect changes to the network interfaces in IP mobility scenarios. It only applies to operating systems that support asynchronous notifications of interface changes. If set to TRUE, the interface tracker will use a polling method that queries the interfaces periodically to detect the changes. If set to FALSE, the interface tracker will use the operating system's default method. Basically, this property allows you–for an operating system that supports asynchronous notification–to use the polling method instead. Default: FALSE
property_validation_action	By default, property names given in the 7.5.19 PROPERTY QosPolicy (DDS Extension) on page 436 are validated to avoid using incorrect or unknown names (for example, due to a typo). This property configures the validation of the property names associated with the transport: • VALIDATION_ACTION_EXCEPTION: validate the properties. Upon failure, log errors and fail. • VALIDATION_ACTION_SKIP: skip validation. • VALIDATION_ACTION_WARNING: validate the properties. Upon failure, log warnings and do not fail. If this property is not set, the property validation behavior will be the same as that of the *DomainParticipant*, which by default is VALIDATION_ACTION_EXCEPTION. See 7.5.19.1 Property Validation on page 439 for more information.
thread_name_prefix	You can set this field with your own value, to help you identify the transport thread in a way that's meaningful to you. Do not exceed 8 characters. If you do not set this field, *Connext DDS* creates the following prefix: 'r' + 'Tr' + participant identifier + '\0' Where 'r' indicates this is a thread from RTI, 'Tr' indicates the thread is related to a transport, and participant identifier contains 5 characters as follows: • If **participant_name** is set: The participant identifier will be the first 3 characters and the last 2 characters of the **participant_name**. • If **participant_name** is not set, then the identifier is computed as **domain_id** (3 characters) followed by **participant_id** (2 characters). • If **participant_name** is not set and the **participant_id** is set to -1 (default value), then the participant identifier is computed as the last 5 digits of the **rtps_instance_id** in the participant GUID. See 21.9 Identifying Threads Used by Connext DDS on page 908.

[1] Assuming you used 'dds.transport.TCPv4.tcp1' as the alias to load the plugin. If not, change the prefix to match the string used with dds.transport.load_plugins. This prefix must begin with 'dds.transport.'

44.7.1 Connection Liveliness

The **connection_liveliness** property configures the connection liveliness feature. When enabled, the TCP Transport plugin will periodically exchange some additional control traffic (liveliness requests/responses) over one of the connections between the TCP Client and Server. This traffic allows determining if a that connection is not alive anymore, and thus proceed to its close. This avoids depending on the OS notification about the status of the connection, potentially decreasing the time to reestablish lost connections.

The following parameters can be configured:

- **connection_liveliness.enable**: Enables or disables the feature.
- **connection_liveliness.lease_duration**: In seconds, the timeout by which the connection liveliness must be asserted or the connection will be considered not alive. It is also used as the period between connection liveliness checks. Therefore, the maximum time before a connection is marked as not alive is 2***connection_liveliness.lease_duration**.
- **connection_liveliness.assertions_per_lease_duration**: The number of liveliness requests send per each lease duration. Increasing this value will increase the overhead send into the network, but it will also make the connection liveliness mechanism more robust.

This feature relies on the creation on an additional thread in the TCP Transport Plugin (the event thread). For more information about how to configure this thread, see the **event_thread** in Table 44.1 Properties for NDDS_Transport_TCPv4_Property_t.

> Enabling this feature breaks backwards compatibility with TCP Transport plugins that do not include this feature.

Part 8: RTI Persistence Service

The material in this part of the manual describes *Persistence Service*. It saves DDS data samples so they can be delivered to subscribing applications that join the system at a later time—even if the publishing application has already terminated.

> *Persistence Service* is not available on all platforms. See the RTI Connext DDS Core Libraries Platform Notes.

This section includes:

- Introduction to RTI Persistence Service (Chapter 45 on page 1160)
- Configuring Persistence Service (Chapter 46 on page 1161)
- Running RTI Persistence Service (Chapter 47 on page 1186)
- Administering Persistence Service from a Remote Location (Chapter 48 on page 1191)
- Advanced Persistence Service Scenarios (Chapter 49 on page 1197)

Chapter 45 Introduction to RTI Persistence Service

Persistence Service is a *Connext DDS* application that saves DDS data samples to transient or permanent storage, so they can be delivered to subscribing applications that join the system at a later time—even if the publishing application has already terminated.

Persistence Service runs as a separate application; you can run it on the same node as the publishing application, the subscribing application, or some other node in the network.

When configured to run in PERSISTENT mode, *Persistence Service* can use the filesystem or a relational database that provides an ODBC driver. For each persistent topic, it collects all the data written by the corresponding persistent *DataWriters* and stores them into persistent storage. See the *RTI Persistence Service Release Notes* for the list of platforms and relational databases that have been tested.

When configured to run in TRANSIENT mode, *Persistence Service* stores the data in memory.

The following chapters assume you have a basic understanding of DDS terms such as *DomainParticipants, Publishers, DataWriters, Topics,* and Quality of Service (QoS) policies. For an overview of DDS terms, please see Data-Centric Publish-Subscribe Communications (Chapter 2 on page 14). You should also have already read Mechanisms for Achieving Information Durability and Persistence (Chapter 13 on page 726).

Chapter 46 Configuring Persistence Service

To use *Persistence Service*:

1. Modify your *Connext DDS* applications.
   - The 7.5.9 DURABILITY QosPolicy on page 410 controls whether or not, and how, published DDS samples are stored by *Persistence Service* for delivery to late-joining *DataReaders*. See 13.5 Data Durability on page 743.
     - For each *DataWriter* whose data must be stored, set the Durability QosPolicy's *kind* to DDS_PERSISTENT_DURABILITY_QOS or DDS_TRANSIENT_DURABILITY_QOS.
     - For each *DataReader* that needs to receive stored data, set the Durability QosPolicy's *kind* to DDS_PERSISTENT_DURABILITY_QOS or DDS_TRANSIENT_DURABILITY_QOS.
   - Optionally, modify the 7.5.10 DURABILITY SERVICE QosPolicy on page 414, which can be used to configure *Persistence Service*.

   By default, the History and ResourceLimits QosPolicies for a Persistence Service *DataReader* (PRSTDataReader) and Persistence Service *DataWriter* (PRSTDataWriter) with topic 'A' will be configured using the values specified in the XML file (unless you use the tag <use_durability_service> in the persistence group definition, see 46.8 Creating Persistence Groups on page 1173). Setting the <use_durability_service> tag to true will cause the History and ResourceLimits QosPolicies for a PRSTDataReader and PRSTDataWriter to be configured using the 7.5.10 DURABILITY SERVICE QosPolicy on page 414 of the first-discovered *DataWriter* publishing 'A'. (For more information on the PRSTDataReader and PRSTDataWriter, see 13.5.1 RTI Persistence Service on page 743.)
2. Create a configuration file or edit an existing file, as described in 46.2 XML Configuration File on page 1163.

3. Start *Persistence Service* with your configuration file, as described in 47.1 Starting Persistence Service on page 1186. You can start it on either application's node, or even an entirely different node (provided that node is included in one of the applications' NDDS_DISCOVERY_PEERS lists).

46.1 How to Load the Persistence Service XML Configuration

Persistence Service loads its XML configuration from multiple locations. This section presents the various approaches, listed in load order.

The first three locations only contain QoS Profiles and are inherited from *Connext DDS* (see Configuring QoS with XML (Chapter 19 on page 842)).

- **$NDDSHOME/resource/xml/NDDS_QOS_PROFILES.xml**

  This file contains the DDS default QoS values; it is loaded automatically if it exists. *(First to be loaded.)*

- File specified in the NDDS_QOS_PROFILES Environment Variable

  The files (or XML strings) separated by semicolons referenced in this environment variable are loaded automatically.

- **<*working directory*>/USER_QOS_PROFILES.xml**

  This file is loaded automatically if it exists.

The next locations are specific to *Persistence Service*.

- **<NDDSHOME>/resource/xml/RTI_PERSISTENCE_SERVICE.xml**

  This file contains the default *Persistence Service* configurations; it is loaded if it exists. There are two default configurations: **default** and **defaultDisk**. The **default** configuration persists all the topics into memory. The **defaultDisk** configuration persists all the topics into files located in the current working directory.
- **<*working directory*>/USER_PERSISTENCE_SERVICE.xml**

  This file is loaded automatically if it exists.
- File specified using the command line option, **-cfgFile**

  The command-line option **-cfgFile** (see Table 47.1 Persistence Service Command-Line Options) can be used to specify a configuration file.

46.2 XML Configuration File

The configuration file uses XML format. Let's look at a very basic configuration file, just to get an idea of its contents. You will learn the meaning of each line as you read the rest of this section.

Example Configuration File

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<!-- A Configuration file may be used by several
     persistence services specifying multiple
     <persistence_service> entries
-->
<dds>
    <!-- QoS LIBRARY SECTION -->
    <qos_library name="QosLib1">
        <qos_profile name="QosProfile1">
            <datawriter_qos name="WriterQos1">
                <history>
                    <kind>DDS_KEEP_ALL_HISTORY_QOS</kind>
                </history>
            </datawriter_qos>
            <datareader_qos name="ReaderQos1">
                <reliability>
                    <kind>DDS_RELIABLE_RELIABILITY_QOS</kind>
                </reliability>
                <history>
                    <kind>DDS_KEEP_ALL_HISTORY_QOS</kind>
                </history>
            </datareader_qos>
        </qos_profile>
    </qos_library>
    <!-- PERSISTENCE SERVICE SECTION -->
    <persistence_service name="Srv1">
        <!-- REMOTE ADMINISTRATION SECTION -->
        <administration>
            <domain_id>72</domain_id>
            <distributed_logger>
                <enabled>true</enabled>
            </distributed_logger>
           </administration>
        <!-- PERSISTENT STORAGE SECTION -->
        <persistent_storage>
            <filesystem>
                <directory>/tmp</directory>
                <file_prefix>PS</file_prefix>
            </filesystem>
        </persistent_storage>
        <!-- DOMAINPARTICIPANT SECTION -->
        <participant name="Part1">
            <domain_id>71</domain_id>
            <!-- PERSISTENCE GROUP SECTION -->
            <persistence_group name="PerGroup1" filter="*">
                <single_publisher>true</single_publisher>
                <single_subscriber>true</single_subscriber>
                <datawriter_qos base_name="QosLib1::QosProfile1"/>
                <datareader_qos base_name="QosLib1::QosProfile1"/>
```

```
            </persistence_group>
        </participant>
    </persistence_service>
</dds>
```

46.2.1 Configuration File Syntax

The configuration file must follow these syntax rules:

- The syntax is XML and the character encoding is UTF-8.
- Opening tags are enclosed in <>; closing tags are enclosed in </>.
- A value is a UTF-8 encoded string. Legal values are alphanumeric characters. All leading and trailing spaces are removed from the string before it is processed.

  For example, " **<tag> value </tag>**" is the same as "**<tag>value</tag>**".
- All values are case-sensitive unless otherwise stated.
- Comments are enclosed as follows: **<!-- comment -->**.
- The root tag of the configuration file must be **<dds>** and end with **</dds>**.
- The primitive types for tag values are specified in Table 46.1 Supported Tag Values.

Table 46.1 Supported Tag Values

Type	Format	Notes
DDS_Boolean	yes, 1, true, BOOLEAN_TRUE or DDS_BOOLEAN_TRUE: these all mean TRUE	Not case-sensitive
	no, 0, false, BOOLEAN_FALSE or DDS_BOOLEAN_FALSE: these all mean FALSE	
DDS_Enum	A string. Legal values are those listed in the C or Java API Reference HTML documentation.	Must be specified as a string. (Do not use numeric values.)
DDS_Long	-2147483648 to 2147483647 or 0x80000000 to 0x7fffffff or LENGTH_UNLIMITED or DDS_LENGTH_UNLIMITED	A 32-bit signed integer
DDS_ UnsignedLong	0 to 4294967296 or 0 to 0xffffffff	A 32-bit unsigned integer
String	UTF-8 character string	All leading and trailing spaces are ignored between two tags

46.2.2 XML Validation

46.2.2.1 Validation at Run Time

Persistence Service validates the input XML files using a builtin Document Type Definition (DTD). You can find a copy of the builtin DTD in **<NDDSHOME>**[a]**/resource/schema/rti_persistence_service.dtd**. (This is only a copy of what the *Persistence Service* core uses. Changing this file has no effect unless you specify its path with the DOCTYPE tag, described below.)

You can overwrite the builtin DTD by using the XML tag, **<!DOCTYPE>**. For example, the following indicates that *Persistence Service* must use a different DTD file to perform validation:

```
<!DOCTYPE dds SYSTEM
 "/local/usr/rti/dds/modified_rtipersistenceservice.dtd">
```

If you do not specify the DOCTYPE tag in the XML file, the builtin DTD is used.

The DTD path can be absolute, or relative to the application's current working directory.

46.2.2.2 Validation During Editing

Persistence Service provides DTD and XSD files that describe the format of the XML content. We recommend including a reference to one of these documents in the XML file that contains the persistence service's configuration—this provides helpful features in code editors such as Visual Studio and Eclipse, including validation and auto-completion while you are editing the XML file. Including a reference to the XSD file in the XML documents provides stricter validation and better auto-completion than the corresponding DTD file.

The DTD and XSD definitions of the XML elements are in **<NDDSHOME>/resource/schema** (**rti_persistence_service.dtd** and **rti_persistence_service.xsd**, respectively).

To include a reference to the XSD document in your XML file, use the attribute **xsi:noNamespaceSchemaLocation** in the **<dds>** tag. For example (in the following, replace **<NDDSHOME>** with the *Connext DDS* installation directory, see Paths Mentioned in Documentation on page 1):

```
<?xml version="1.0" encoding="UTF-8"?>
<dds xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation=
"<NDDSHOME>/resource/schema/rti_persistence_service.xsd">
   ...
</dds>
```

To include a reference to the DTD document in your XML file, use the **<!DOCTYPE>** tag. For example (in the following, replace **<NDDSHOME>** with the *Connext DDS* installation directory):

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE dds SYSTEM
"<NDDSHOME>/resource/schema/rti_persistence_service.dtd">
```

[a]See **Paths Mentioned in Documentation on page 1**.

```
<dds>
   ...
</dds>
```

46.3 QoS Configuration

Each persistence group and participant has a set of DDS QoSs. There are six tags:

- **<domain_participant_qos>**
- **<publisher_qos>**
- **<subscriber_qos>**
- **<topic_qos>**
- **<datawriter_qos>**
- **<datareader_qos>**

Each QoS is identified by a name. The QoS can inherit its values from other QoSs described in the XML file. For example:

```
<datawriter_qos name="DerivedWriterQos" base_name="Lib::BaseWriterQos">
    <history>
        <kind>DDS_KEEP_ALL_HISTORY_QOS</kind>
    </history>
</datawriter_qos>
```

In the above example, the writer QoS named 'DerivedWriterQos' inherits the values from the writer QoS 'BaseWriterQos' contained in the library 'Lib'. The HistoryQosPolicy **kind** is set to DDS_KEEP_ALL_HISTORY_QOS.

Each XML tag with an associated name can be uniquely identified by its fully qualified name in C++ style. For more information on tags, see Configuring QoS with XML (Chapter 19 on page 842)

The persistence groups and participants can use QoS libraries and profiles to configure their QoS values. For example:

```
<dds>
  <!- QoS LIBRARY SECTION -->
    <qos_library name="QosLib1">
        <qos_profile name="QosProfile1">
            <datawriter_qos name="WriterQos1">
                <history>
                    <kind>DDS_KEEP_ALL_HISTORY_QOS</kind>
                </history>
            </datawriter_qos>
        </qos_profile>
    </qos_library>
    <!-PERSISTENCE SERVICE SECTION -->
    <persistence_service name="Srv1">
        ...
    <!-PERSISTENCE GROUP SECTION -->
```

```
        <persistence_group name="PerGroup1" filter="*">
            <single_publisher>true</single_publisher>
            <single_subscriber>true</single_subscriber>
            <datawriter_qos base_name="QosLib1::QosProfile1"/>
        </persistence_group>
    </persistence_service>
</dds >
```

For more information about QoS libraries and profiles see Configuring QoS with XML (Chapter 19 on page 842).

46.4 Configuring the Persistence Service Application

Each execution of the *Persistence Service* application is configured using the content of a tag: <persistence_service>. When you start *Persistence Service* (described in 47.1 Starting Persistence Service on page 1186), you must specify which <persistence_service> tag to use to configure the service.

For example:

```
<dds>
    <persistence_service name="Srv1">
        ...
    </persistence_service>
</dds>
```

If you do not specify a service name when you start *Persistence Service*, the service will print the list of available configurations and then exit.

Because a configuration file may contain multiple <persistence_service> tags, one file can be used to configure multiple *Persistence Service* executions.

Table 46.2 Persistence Service Application Tags lists the tags you can specify for a persistence service. Notice that <participant> is required. For default values, please see the API Reference HTML documentation.

Table 46.2 Persistence Service Application Tags

Tags within <persistence_service>	Description	Number of Tags Allowed
<administration>	Enables and configures remote administration. See 46.5 Configuring Remote Administration on the next page.	0 or 1

<annotation>	Provides a description for the persistence service configuration.
	Example:
	`<annotation>`
	`  <documentation>`
	`  Persists in the file system all topics`
	`  published with PERSISTENT durability`
	`  </documentation>`
	`</annotation>`
		0 or 1

Table 46.2 Persistence Service Application Tags

Tags within <persistence_service>	Description	Number of Tags Allowed
<purge_samples_after_acknowledgment>	A DDS_Boolean that indicates whether or not a PRSTDataWriter will purge a DDS sample from its cache once it is acknowledged by all the matching/active *DataReaders* and all the Durable Subscriptions. Default: 0 See 46.9 Configuring Durable Subscriptions in Persistence Service on page 1180.	0 or 1
<participant>	For each <participant> tag, *Persistence Service* creates two *DomainParticipants* on the same domain ID: one to subscribe to changes and one to publish changes. There may be more Participant pairs created when there are multiple versions of a type (see 46.13 Support for Extensible Types on page 1184). The QoS values used to configure both *DomainParticipants* are the same, except for: • The **participant_id** in the 9.5.9 WIRE_PROTOCOL QosPolicy (DDS Extension) on page 664). If **participant_id** is not -1 (the default value, which means automatic selection), *Persistence Service* uses **participant_id** for the first *DomainParticipant* and **participant_id+1** for the second *DomainParticipant*. • The TCP server ports are configured with the properties **dds.transport.tcp.server_bind_port** and **dds.transport.tcp.public_address**. See 44.7 TCP/TLS Transport Properties on page 1138.	1 or more (required)
<persistent_storage>	When this tag is present, the topic data will be persisted to disk. You can select between file storage and relational database storage. See 46.6 Configuring Persistent Storage on the next page.	0 or 1
<synchronization>	Enables synchronization in redundant persistence service instances. See 46.10 Synchronizing of Persistence Service Instances on page 1181. Default: Synchronization is not enabled	0 or 1

46.5 Configuring Remote Administration

You can create a *Connext DDS* application that can remotely control *Persistence Service*. The **<administration>** tag is used to enable remote administration and configure its behavior.

By default, remote administration is turned off in *Persistence Service*.

When remote administration is enabled, *Persistence Service* will create a *DomainParticipant*, *Publisher*, *Subscriber*, *DataWriter*, and *DataReader*. These *Entities* are used to receive commands and send responses. You can configure these entities with QoS tags within the **<administration>** tag.

Table 46.3 Remote Administration Tags lists the tags allowed within **<administration>** tag. Notice that the <domain_id> tag is required.

For more details, please see Administering Persistence Service from a Remote Location (Chapter 48 on page 1191).

Note: The command-line options used to configure remote administration take precedence over the XML configuration (see Table 47.1 Persistence Service Command-Line Options).

Table 46.3 Remote Administration Tags

Tags within <administration>	Description	Number of Tags Allowed

<datareader_qos>	Configures the *DataReader* QoS for remote administration.
	If the tag is not defined, *Persistence Service* will use the DDS defaults with the following changes:
	`reliability.kind = DDS_RELIABLE_RELIABILITY_QOS (this value cannot be changed)`
	`history.kind = DDS_KEEP_ALL_HISTORY_QOS`
	`resource_limits.max_samples = 32`
		0 or 1

<datawriter_qos>	Configures the *DataWriter* QoS for remote administration. If the tag is not defined, *Persistence Service* will use the DDS defaults with the following changes: `history.kind = DDS_KEEP_ALL_HISTORY_QOS` resource_limits.max_samples = 32	0 or 1
<distributed_logger>	Configures *RTI Distributed Logger*.	0 or 1
<domain_id>	Specifies which domain ID *Persistence Service* will use to enable remote administration.	1 (required)
<participant_qos>	Configures the DomainParticipant QoS for remote administration. If the tag is not defined, *Persistence Service* will use the DDS defaults.	0 or 1
<publisher_qos>	Configures the Publisher QoS for remote administration. If the tag is not defined, *Persistence Service* will use the DDS defaults.	0 or 1
<subscriber_qos>	Configures the Subscriber QoS for remote administration. If the tag is not defined, *Persistence Service* will use the DDS defaults.	0 or 1

46.6 Configuring Persistent Storage

The **<persistent_storage>** tag is used to persist DDS samples into permanent storage. If the **<persistence_storage>** tag is not specified, the service will operate in TRANSIENT mode and all the data will be kept in memory. Otherwise, the persistence service will operate in PERSISTENT mode and all the topic data will be stored into the filesystem or into a relational database that provides an ODBC driver.

Table 46.4 Persistent Storage tags lists the tags that you can specify in **<persistent_storage>**.

Relational Database Limitations: The ODBC storage does not support BLOBs. The maximum size for a serialized DDS sample is 65535 bytes in MySQL.

Table 46.4 Persistent Storage tags

Tags within <persistent_storage>	Description	Number of Tags Allowed
<external_database>	When this tag is present, the topic data will be persisted in a relational database. This tag is required if **<filesystem>** is not specified. See Table 46.5 External Database Tags.	0 or 1
<filesystem>	When this tag is present, the topic data will be persisted into files. This tag is required if **<external_database>** is not specified. See Table 46.6 Filesystem tags.	0 or 1
<restore>	This DDS_Boolean (see Table 46.1 Supported Tag Values) indicates if the topic data associated with a previous execution of the persistence service must be restored or not. If the topic data is not restored, it will be deleted from the persistent storage. Default: 1	0 or 1
<type_object_max_serialized_length>	Defines the length in bytes of the database column used to store the TypeObjects associated with PRSTDataWriters and PRSTDataReader. For additional information on TypeObjects, see the RTI Connext DDS Core Libraries Extensible Types Guide. Default: 10488576	0 or 1

Table 46.5 External Database Tags

Tags within <external_database>	Description	Number of Tags Allowed
<dsn>	DSN used to connect to the database using ODBC. You should create this DSN through the ODBC settings on Windows systems, or in your .odbc.ini file on Linux systems. This tag is required.	1 (required)
<odbc_library>	Specifies the ODBC driver to load. By default, *Connext DDS* will try to use the standard ODBC driver manager library (UnixOdbc on Linux systems, the Windows ODBC driver manager on Windows systems).	0 or 1
<password>	Password to connect to the database. Default: no username is used	0 or 1
<username>	Username to connect to the database. Default: no username is used	0 or 1

Table 46.6 Filesystem tags

Tags within <filesystem>	Description	Number of Tags Allowed
<directory>	Specifies the directory of the files in which topic data will be persisted. There will be one file per PRSTDataWriter/PRSTDataReader pair. The directory must exist; otherwise the service will report an error upon start up. Default: current working directory	0 or 1
<file_prefix>	A name prefix associated with all the files created by *Persistence Service*. Default: PS	0 or 1
<journal_mode>	Sets the journal mode of the persistent storage. This tag can take these values: • DELETE: Deletes the rollback journal at the conclusion of each transaction. • TRUNCATE: Commits transactions by truncating the rollback journal to zero-length instead of deleting it. • PERSIST: Prevents the rollback journal from being deleted at the end of each transaction. Instead, the header of the journal is overwritten with zeros. • MEMORY: Stores the rollback journal in volatile RAM. This saves disk I/O. • WAL: Uses a write-ahead log instead of a rollback journal to implement transactions. • OFF: Completely disables the rollback journal. If the application crashes in the middle of a transaction when the OFF journaling mode is set, the files containing the DDS samples will very likely be corrupted. Default: DELETE	0 or 1
<synchronization>	Determines the level of synchronization with the physical disk. This tag can take three values: • FULL: Every DDS sample is written into physical disk as *Persistence Service* receives it. • NORMAL: DDS samples are written into disk at critical moments. • OFF: No synchronization is enforced. Data will be written to physical disk when the OS flushes its buffers. Default: OFF	0 or 1
<trace_file>	Specifies the name of the trace file for debugging purposes. The trace file contains information about all SQL statements executed by the persistence service. Default: No trace file is generated	0 or 1
<vacuum>	Sets the auto-vacuum status of the storage. This tag can take these values: • NONE: When data is deleted from the storage files, the files remain the same size. • FULL: The storage files are compacted every transaction. Default: FULL	0 or 1

46.7 Configuring Participants

An XML <persistence_service> tag will contain a set of <participants>. The persistence service will persist topics published in the domainIDs associated with these participants. For example:

```
<persistence_service name="Srv1">
    <participant name="Part1">
        <domain_id>71</domain_id>
        ...
    </participant>
    <participant name="Part2">
        <domain_id>72</domain_id>
        ...
    </participant>
</persistence_service>
```

Using the above example, the persistence service will create two pairs of *DomainParticipants* on DDS domains 71 and 72, respectively. In each pair, one *DomainParticipant* is used to receive data and the other to publish.

After the *DomainParticipants* are created, the persistence service will monitor the discovery traffic, looking for topics to persist.

Notice that in some cases there may be more than one pair of *DomainParticipants* per domain when there are multiple versions of a type for a given topic. (See 46.13 Support for Extensible Types on page 1184.)

The <domain_id> tag can be specified alternatively as an attribute of <participant>. For example:

```
<persistence_service name="Srv1">
    <participant name="Part1" domain_id="71">
        ...
    </participant>
</persistence_service>
```

Table 46.7 Participant Tagsdescribes the participant tags. Notice that **<persistence_group>** is required.

Table 46.7 Participant Tags

Tags within <participant>	Description	Number of Tags Allowed
<domain_id>	Domain ID associated with the Participant. The domain ID can be specified as an attribute of the participant tag. Default: 0	0 or 1

Table 46.7 Participant Tags

Tags within <participant>	Description	Number of Tags Allowed

<durable_ subscriptions>	Configures a set of Durable Subscriptions for a given topic. This is a sequence of <element> tags, each of which has a <name> (role name in **DDS_EndpointGroup_t**), a <topic_name>, and a <quorum_count> (quorum in **DDS_EndpointGroup_t**). For example:
	`<durable_subscriptions>`
	`<element>`
	`<name>DurSub1</name>`
	`<topic_name>Example MyType</topic_name>`
	`<quorum_count>2</quorum_count>`
	`</element>`
	`<element>`
	`<name>DurSub2</name>`
	`<topic_name>Example MyType</topic_name>`
	`</element>`
	`</durable_subscriptions>`
	Default: Empty list
	See 46.9 Configuring Durable Subscriptions in Persistence Service on page 1180 for additional information
		0 or 1

<participant_ qos>	Participant QoS. Default: DDS defaults	0 or 1
<persistence_ group>	A persistence group describes a set of topics whose data that must be persisted by the persistence service.	1 or more (required)

46.8 Creating Persistence Groups

The topics that must be persisted in a specific domain ID are specified using <persistence_group> tags. A <persistence_group> tag defines a set of topics identified by a POSIX expression.

For example:

```
<participant name="Part1">
    <domain_id>71</domain_id>
    <persistence_group name="PerGroup1" filter="H*">
        ...
    </persistence_group>
</participant>
```

In the above example, the persistence group 'PerGroup1' is associated with all the topics published in DDS domain 71 whose name starts with 'H'.

When a participant discovers a topic that matches a persistence group, it will create a PRSTDataReader and a PRSTDataWriter. The PRSTDataReader and PRSTDataWriter will be configured using the QoS policies associated with the persistence group. The DDS samples received by the PRSTDataReader will be persisted in the queue of the corresponding PRSTDataWriter.

A **<participant>** tag can contain multiple persistence groups; the set of topics that each one represents can intersect.

Table 46.8 Persistence Group Tags further describes the persistence group tags. For default values, please see the API Reference HTML documentation.

Table 46.8 Persistence Group Tags

Tags within <persistence_group>	Description	Number of Tags Allowed
<allow_durable_subscriptions>	A DDS_Boolean (see Table 46.1 Supported Tag Values) that enables support for durable subscriptions in the PRSTDataWriters created in a persistence group. When Durable Subscriptions are not required, setting this property to 0 will increase performance. Default: 1	0 or 1
<content_filter>	Content filter topic expression. A persistence group can subscribe to a specific set of data based on the value of this expression. A filter expression is similar to the WHERE clause in SQL. For more information on the syntax, please see the API Reference Documentation (from the Modules page, select RTI *Connext DDS* DDS API Reference, Queries and Filters Syntax). Default: no expression	0 or 1
<datareader_qos>	PRSTDataReader QoS[1]. See 46.8.1 QoSs on page 1177. Default: DDS defaults	0 or 1
<datawriter_qos>	PRSTDataWriter QoS[2]. See 46.8.1 QoSs on page 1177. Default: DDS defaults	0 or 1
<deny_filter>	Specifies a list of POSIX expressions separated by commas that describe the set of topics to be denied in the persistence group. This "black" list is applied to the topics that pass the filter specified with the <filter> tag Default: *	0 or 1
<filter>	Specifies a list of POSIX expressions separated by commas that describe the set of topics associated with the persistence group. The filter can be specified as an attribute of <persistence_group> as well. Default: *	0 or 1
<memory_management>	This flag configures the memory allocation policy for DDS samples in PRSTDataReaders and PRSTDataWriters. See 46.8.5 Memory Management on page 1179.	0 or 1
<propagate_dispose>	A DDS_Boolean (see Table 46.1 Supported Tag Values) that controls whether or not the persistence service propagates dispose messages from *DataWriters* to DataReaders. Default: 1	0 or 1

[1]These fields cannot be set and are assigned automatically: protocol.virtual_guid, protocol.rtps_object_id, durability.kind.

[2]These fields cannot be set and are assigned automatically: protocol.virtual_guid, protocol.rtps_object_id, durability.kind.

Table 46.8 Persistence Group Tags

Tags within <persistence_group>	Description	Number of Tags Allowed
<propagate_source_timestamp>	A DDS_Boolean (see Table 46.1 Supported Tag Values). When this tag is 1, the DDS data samples sent by the PRSTDataWriters preserve the source timestamp that was associated with them when they were published by the original DataWriter. Default: 0	0 or 1
<propagate_unregister>	A DDS_Boolean (see Table 46.1 Supported Tag Values) that controls whether or not the persistence service propagates unregister messages from *DataWriters* to *DataReaders*. Default: 0	0 or 1
<publisher_qos>	Publisher QoS. See 46.8.1 QoSs on page 1177. Default: DDS defaults	0 or 1
<reader_checkpoint_frequency>	This property controls how often (expressed as a number of DDS samples) the PRSTDataReader state is stored in the database. The PRSTDataReaders are the *DataReaders* created by the persistence service. A high frequency will provide better performance. However, if the persistence service is restarted, it may receive some duplicate DDS samples. The persistence service will send these duplicates DDS samples on the wire but they will be filtered by the *DataReaders* and they will not be propagated to the application. This property is only applicable when the persistence service operates in persistent mode (the <persistent_storage> tag is present). Default: 1	0 or 1
<share_database_connection>	A DDS_Boolean (see Table 46.1 Supported Tag Values) that indicates if the persistence service will create an independent database connection per PRSTDataWriter in the group (0) or per *Publisher* (1) in the group. When <single_publisher> is 0 and <share_database_connection> is 1, there is a single database connection per group. All the PRSTDataWriters will share the same connection. When <single_publisher> is 1 or <share_database_connection> is 0, there is a database connection per PRSTDataWriter. This parameter is only applicable to configurations persisting the data into a relational database using the tag <external_database> in <persistent_storage>. See 46.8.4 Sharing a Database Connection on page 1179 Default: 0	0 or 1
<single_publisher>	A DDS_Boolean (see Table 46.1 Supported Tag Values) that indicates if the persistence service should create one Publisher per persistence group or one *Publisher* per PRSTDataWriter inside the persistence group. See 46.8.3 Sharing a Publisher/Subscriber on page 1178. Default: 1	0 or 1
<single_subscriber>	A DDS_Boolean (see Table 46.1 Supported Tag Values) that indicates if the persistence service should create one Subscriber per persistence group or one *Subscriber* per PRSTDataReader in the persistence group. See 46.8.3 Sharing a Publisher/Subscriber on page 1178. Default: 1	0 or 1
<subscriber_qos>	Subscriber QoS. See 46.8.1 QoSs on page 1177. Default: DDS defaults	0 or 1

Table 46.8 Persistence Group Tags

Tags within <persistence_group>	Description	Number of Tags Allowed
<topic_qos>	Topic QoS. See 46.8.1 QoSs on the next page. Default: DDS defaults	0 or 1
<use_durability_service>	A DDS_Boolean (see Table 46.1 Supported Tag Values) that indicates if the HISTORY and RESOURCE_LIMITS QoS policy of the PRSTDataWriters and PRSTDataReaders should be configured based on the DURABILITY SERVICE value of the discovered DataWriters. See 46.8.2 DurabilityService QoS Policy on page 1178 Default: 0	0 or 1
<writer_ack_period>	Controls how often (expressed in milliseconds) DDS samples are marked as ACK'd in the database by the PRSTDataWriter. Default: 0	0 or 1
<writer_checkpoint_period>	Controls how often (expressed in milliseconds) transactions are committed for a PRSTDataWriter. A value of 0 indicates that transactions will be committed immediately. This is the recommended setting to avoid losing data in the case of an unexpected error in Persistence Service and/or the underlying hardware/software infrastructure. For applications that can tolerate some data losses, setting this tag to a value greater than 0 will increase performance. Default: 0	0 or 1
<writer_checkpoint_volume>	Controls how often (expressed as a number of DDS samples) transactions are committed for a PRSTDataWriter. A value of 1 indicates that DDS samples will be persisted by the PRSTDataWriters immediately. This is the recommended setting to avoid losing data in the case of an unexpected error in persistence service and/or the underlying hardware/software infrastructure. For application that can tolerate some data losses, setting this tag to a value greater than 1 will increase performance. Default: 1	0 or 1
<late_joiner_read_batch>	Defines how many DDS samples will be pre-fetched by a PRSTDataWriter to satisfy requests from late-joiners. When a *DataReader* requests DDS samples from a PRSTDataWriter by sending a NACK message, the PRSTDataWriter may retrieve additional DDS samples from the database to minimize disk access. This parameter determines that amount of DDS samples that will be retrieved preemptively from the database by the PRSTDataWriter. Default: 20000	0 or 1
<sample_logging>	This tag can be used to enable and configure a DDS sample log for the PRSTDataWriters in a persistence group. A DDS sample log is a buffer of DDS samples on disk that, when used in combination with delegate reliability, allow decoupling the original *DataWriters* from slow *DataReaders*. For additional information on the DDS sample log, see 49.3 Scenario: Slow Consumer on page 1200. Default: DDS sample log is disabled	0 or 1

Table 46.8 Persistence Group Tags

Tags within <persistence_group>	Description	Number of Tags Allowed
<writer_in_memory_state>	A DDS_Boolean (see Table 46.1 Supported Tag Values) that determines how much state will be kept in memory by the PRSTDataWriters in order to avoid accessing the persistent storage. The property is only applicable when the persistence service operates in persistent mode (the <persistent_storage> tag is present). If this property is 1, the PRSTDataWriters will keep a copy of all the instances in memory. They will also keep a fixed state overhead of 24 bytes per DDS sample. This mode provides the best performance. However, the restore operation will be slower and the maximum number of DDS samples that a PRSTDataWriter can manage will be limited by the available physical memory. If this property is 0, all the state will be kept in the underlying persistent storage. In this mode, the maximum number of DDS samples that a PRSTDataWriter can manage will not be limited by the available physical memory. Default: If the HistoryQosPolicy's kind is KEEP_LAST or the ResourceLimitsQosPolicy's max_samples != DDS_UNLIMITED_LENGTH, the default is 1. Otherwise, the default is 0.	0 or 1
<use_wait_set>	A DDS_Boolean (see Table 46.1 Supported Tag Values) that indicates if *Persistence Service* will use Waitsets or Listeners to read data from the PRSTDataReaders of the group. By default, the usage of Waitsets is disabled. With this configuration, *Persistence Service* uses the **on_data_available()** listener callback to take the data from the PRSTDataReaders within the persistence group. The write operation in a PRSTDataWriter is called within the listener callback. When Waitsets are enabled, *Persistence Service* will use them to read the data: If <single_subscriber> is set to 1, there will be a single Waitset and a read thread shared across all the PRSTDataReaders in the group. If <single_subscriber> is set to 0, there will be a Waitset and a read thread per PRSTDataReader in the group. The write operation in a PRSTDataWriter is called by the read thread associated with the PRSTDataReader. Default: 0	0 or 1

46.8.1 QoSs

When a persistence service discovers a topic 'A' that matches a specific persistence group, it creates a reader (known as 'PRSTDataReader') and writer ('PRSTDataWriter') to persist that topic. The QoSs associated with these readers and writers, as well as the corresponding publishers and subscribers, can be configured inside the persistence group using QoS tags.

For example:

```
<participant name="Part1">
    <domain_id>71</domain_id>
    <persistence_group name="PerGroup1" filter="*">
         ...
        <publisher_qos base_name="QosLib1::PubQos1"/>
        <subscriber_qos base_name="QosLib1::SubQos1"/>
        <datawriter_qos base_name="QosLib1::WriterQos1"/>
        <datareader_qos base_name="QosLib1::ReaderQos1"/>
         ...
    </persistence_group>
</participant>
```

For instance, the number of DDS samples saved by *Persistence Service* is configurable through the 7.5.12 HISTORY QosPolicy on page 418 of the PRSTDataWriters.

If a QoS tag is not specified, the persistence service will use the corresponding DDS default values (46.8.2 DurabilityService QoS Policy below describes an exception to this rule).

46.8.1.1 DataRepresentation QoS Policy

The PRSTDataReader's DataRepresentation QoS Policy may contain either XCDR_DATA_REPRESENTATION or XCDR2_DATA_REPRESENTATION, but not both. The PRSTDataReader and PRSTDataWriter of a given topic must have identical DataRepresentation QoS Policy values. See 7.5.3 DATA_REPRESENTATION QosPolicy on page 379.

46.8.2 DurabilityService QoS Policy

The 7.5.10 DURABILITY SERVICE QosPolicy on page 414 associated with a *DataWriter* is used to configure the HISTORY and the RESOURCE_LIMITS associated with the PRSTDataReaders and PRSTDataWriters.

By default, the HISTORY and RESOURCE_LIMITS of a PRSTDataReader and *PRSTDataWriter* with topic 'A' will be configured using the values specified in the XML file used to configure *Persistence Service*. To overwrite those values and use the values in the 7.5.10 DURABILITY SERVICE QosPolicy on page 414 of the first discovered *DataWriter* publishing 'A', you can use the tag <use_durability_service> in the persistence group definition:

```
<participant name="Part1">
    <domain_id>71</domain_id>
    <persistence_group name="PerGroup1" filter="*">
           ...
        <use_durability_service/>1</ use_durability_service>
           ...
    </persistence_group>
</participant>
```

46.8.3 Sharing a Publisher/Subscriber

By default, the PRSTDataWriters and PRSTDataReaders associated with a persistence group will share the same Publisher and Subscriber.

To associate a different Publisher and Subscriber with each PRSTDataWriter and PRSTDataReader, use the tags <single_publisher> and <single_subscriber>, as follows:

```
<participant name="Part1">
    <domain_id>71</domain_id>
    <persistence_group name="PerGroup1" filter="*">
        ...
        <single_publisher/>0</single_publisher>
        <single_subscriber/>0</single_subscriber>
        ...
```

```
    </persistence_group>
</participant>
```

46.8.4 Sharing a Database Connection

By default, the persistence service will share a single ODBC database connection to persist the topic data received by each PRSTDataReader.

To associate an independent database connection to the PRSTDataReaders created by the persistence service, use the tag <share_database_connection>, as follows:

```
<participant name="Part1">
    <domain_id>71</domain_id>
    <persistence_group name="PerGroup1" filter="*">
            ...
        <share_database_connection>0</share_database_connection>
            ...
    </persistence_group>
</participant>
```

Sharing a database connection optimizes the resource usage. However, the concurrency of the system decreases because the access to the database connection must be protected.

46.8.5 Memory Management

The DDS samples received and stored by the PRSTDataReaders and PRSTDataWriters are in serialized form.

The serialized size of a DDS sample is the number of bytes required to send the DDS sample on the wire. The maximum serialized size of a DDS sample is the number of bytes that the largest DDS sample for a given type requires on the wire.

By default, the PRSTDataReaders and PRSTDataWriters created by the persistence service try to allocate multiple DDS samples to their maximum serialized size. This may cause memory allocation issues when the maximum serialized size is significantly large.

For PRSTDataReaders, the number of DDS samples in the *DataReader's* queues can be controlled using the QoS values r**esource_qos.resource_limits.max_samples** and **resource_qos.resource_limits.initial_samples**.

The PRSTDataWriters keep a cache of DDS samples so that they do not have to access the database every time. The minimum size of this cache is 32 DDS samples.

In addition, each PRSTDataWriter keeps an additional DDS sample called the DB sample, which is used to move information from the *DataWriter* cache to the database and vice versa

The **<memory_management>** tag in a persistence group can be used to control the memory allocation policy for the DDS samples created by PRSTDataReaders and PRSTDataWriters in the persistence group.

Table 46.9 Memory Management Tags describes the memory management tags.

Table 46.9 Memory Management Tags

Tags within <memory_management>	Description	Number of Tags Allowed
<persistent_sample_buffer_max_size>	This tag is used to control the memory associated with the DB sample in a PRSTDataWriter. The persistence service will not be able to store a DDS sample into persistent storage if the serialized size is greater than this value. Therefore, this parameter must be used carefully. Default: LENGTH_UNLIMITED (DB sample is allocated to the maximum size).	0 or 1
<pool_sample_buffer_max_size>	This tag applies to both PRSTDataReaders and PRSTDataWriters. Its value determines the maximum size (in bytes) of the buffers that will be pre-allocated to store the DDS samples. If the space required for a new DDS sample is greater than this size, the persistence service will allocate the memory dynamically to the exact size required by the DDS sample. This parameter is used to control the memory allocated for the DDS samples in the PRSTDataReaders queues and the PRSTDataWriters caches. The size of the DB sample in the PRSTDataWriters is controlled by the value of the tag **<persistent_sample_buffer_max_size>**. Default: LENGTH_UNLIMITED (DDS samples are allocated to the maximum size).	0 or 1

46.9 Configuring Durable Subscriptions in Persistence Service

This section assumes you are familiar with the concept of 7.3.13 Required Subscriptions on page 322.

A Durable Subscription is a Required Subscription where DDS samples are stored and forwarded by *Persistence Service*.

There are two ways to create a Durable Subscriptions:

1. Programmatically using a *DomainParticipant* API:

   A subscribing application can register a Durable Subscription by providing the topic name and the durable subscription information, consisting of the Durable Subscription **name** (role name in **DDS_EndpointGroup_t**) and the **quorum_count** (quorum in **DDS_EndpointGroup_t**). To register or delete a Durable Subscription, use the *DomainParticipant's* **register_durable_subscription()** and **delete_durable_subscription()** operations, respectively (see Table 9.3 DomainParticipant Operations). The Durable Subscription information is propagated via a built-in topic to *Persistence Service*.
2. Preconfigure *Persistence Service* with a set of Durable Subscriptions:

   Persistence Service can be (pre-)configured with a list of Durable Subscriptions using the **<durable_subscriptions>** XML tag under **<participant>**.

```
<participant name="Participant">
    ...
    <durable_subscriptions>
        <element>
```

```
            <name>Logger</name>
            <topic_name>Track</topic_name>
            <quorum_count>2</quorum_count>
        </element>
        <element>
            <name>Processor</name>
            <topic_name>Track</topic_name>
            <quorum_count>1</quorum_count>
        </element>
    </durable_subscriptions>
</participant>
```

After registering or configuring the persistence service with specific Durable Subscriptions, the persistence service will keep DDS samples until they are acknowledged by all the required Durable Subscriptions. In the above example, the DDS samples must be acknowledged by two *DataReaders* that belong to the "Logger" Durable Subscription and one *DataReader* belonging to the "Processor" Durable Subscription.

46.9.1 DDS Sample Memory Management With Durable Subscriptions

The maximum number of DDS samples that will be kept in a PRSTDataWriter queue is determined by the value of **<resource_limits><max_samples>** in the **<writer_qos>** used to configure the PRSTDataWriter.

By default, a PRSTDataWriter configured with KEEP_ALL **<history><kind>** will keep the DDS samples in its cache until they are acknowledged by all the Durable Subscriptions associated with the PRSTDataWriter. After the DDS samples are acknowledged by the Durable Subscriptions, they will be marked as reclaimable but they will not be purged from the PRSTDataWriter's queue until the *DataWriter* needs these resources for new DDS samples. This may lead to inefficient resource utilization, especially when <**max_samples>** is high or UNLIMITED.

The PRSTDataWriter behavior can be changed to purge DDS samples after they have been acknowledged by all the active/matching *DataReaders* and all the Durable Subscriptions configured for the **<persistence_service>**. To do so, set the tag <purge_samples_after_acknowledgment> under <persistence_service> to TRUE. Notice that this setting is global to the service and applies to all the PRSTDataWriters created by each <persistence_group>.

46.10 Synchronizing of Persistence Service Instances

By default, different *Persistence Service* instances do *not* synchronize with each other. For example, in a scenario with two *Persistence Service* instances, the first persistence service could receive a DDS sample 'S1' from the original *DataWriter* that is not received by the second persistence service. If the disk where the first persistence service stores its DDS samples fails, 'S1' will be lost.

To enable synchronization between *Persistence Servic* instances, use the tag **<synchronization>** under **<persistence_service>.** When it comes to synchronization, there are two different kinds of information that can be synchronized independently:

- Information about Durable Subscriptions and their states (see 46.9 Configuring Durable Subscriptions in Persistence Service on page 1180)
- DDS data samples

Table 46.10 Synchronization Tags

Tags within <synchronization>	Description	Number of Tags Allowed
<synchronize_data>	Enables synchronization of DDS data samples in redundant *Persistence Service* instances. When set to 1, DDS samples lost on the way to one service instance can be repaired by another without impacting the original publisher of that message. To synchronize the instances, the tag <synchronize_data> must be set to 1 in every instance involved in the synchronization. Note: This DDS sample synchronization mechanism is not equivalent to database replication. The extent to which database instances have identical contents depends on the destination ordering and other QoS settings for the *Persistence Service* instances. Default: 0	0 or 1
<synchronize_durable_subscription>	Enables synchronization of Durable Subscriptions in redundant *Persistence Service* instances. When set to 1, the different *Persistence Service* instances will synchronize their Durable Subscription information. This information includes the set of Durable Subscriptions as well as information about the Durable Subscription's state, such as the DDS samples that have already been received by the Durable Subscriptions. Default: 0	0 or 1
<durable_subscription_synchronization_period>	The period (in milliseconds) at which the information about Durable Subscriptions is synchronized. Default: 5000 milliseconds	0 or 1

46.11 Enabling RTI Distributed Logger in Persistence Service

Persistence Service provides integrated support for *RTI Distributed Logger* (see *Part 10: RTI Distributed Logger on page 1219*).

Distributed Logger is included in *Connext DDS* but it is not supported on all platforms; see the RTI Connext DDS Core Libraries Platform Notes to see which platforms support *Distributed Logger*.

When you enable *Distributed Logger, Persistence Service* will publish its log messages to *Connext DDS*. Then you can use *RTI Monitor*[1] to visualize the log message data. Since the data is provided in a *Connext DDS* topic, you can also use *rtiddsspy* or even write your own visualization tool.

To enable *Distributed Logger*, modify the *Persistence Service* XML configuration file. In the <administration> section, add the <distributed_logger> tag as shown in the example below.

[1] *RTI Monitor* is a separate GUI application that can run on the same host as your application or on a different host.

```
<persistence_service name="default">
    ...
    <administration>
        ...
        <distributed_logger>
            <enabled>true</enabled>
        </distributed_logger>
    ...
    </administration>
    ...
</persistence_service>
```

There are more configuration tags that you can use to control *Distributed Logger's* behavior. For example, you can specify a filter so that only certain types of log messages are published. For details, see Enabling Distributed Logger in RTI Services (Chapter 53 on page 1230)

46.12 Enabling RTI Monitoring Library in Persistence Service

Persistence Service provides integrated support for *RTI Monitoring Library* (see Part 9: RTI Monitoring Library on page 1203).

To enable monitoring in *Persistence Service*, you must specify the property **rti.monitor.library** for the participants that you want to monitor. For example:

```
<persistence_service name="monitoring_test">
    <participant name="monitoring_enabled_participant">
       <domain_id>54</domain_id>
       <participant_qos>
               <property>
                   <value>
                     <element>
                       <name>rti.monitor.library</name>
                       <value>rtimonitoring</value>
                       <propagate>false</propagate>
                     </element>
                   </value>
               </property>
        </participant_qos>
        <persistence_group name="persistAll">
         ...
        </persistence_group>
    </participant>
</persistence_service>
```

Since *Persistence Service* is statically linked with *RTI Monitoring Library*, you do *not* need to have it in your library search path.

For details on how to configure the monitoring process, see Configuring Monitoring Library (Chapter 51 on page 1214).

46.13 Support for Extensible Types

Persistence Service includes partial support for the OMG 'Extensible and Dynamic Topic Types for DDS' specification, version 1.3. This section assumes that you are familiar with Extensible Types and you have read the RTI Connext DDS Core Libraries Extensible Types Guide.

Persistence groups can publish and subscribe to topics associated with final, appendable, and mutable types.

46.13.1 TypeConsistencyEnforcementQosPolicy Integration

The service will automatically create different pairs (PRSTDataReader, PRSTDataWriter) for each version of a type discovered for a topic in a persistence group. In *Connext DDS* 5.0, it is not possible to associate more than one type with a topic within a single *DomainParticipant*, therefore each version of a type requires its own *DomainParticipant*.

The 8.6.6 TYPE_CONSISTENCY_ENFORCEMENT QosPolicy on page 589 **kind** for each PRSTDataReader is set to DISALLOW_TYPE_COERCION. This value cannot be overwritten by the user.

For example:

```
struct A {
    long x;
};
struct B {
    long x;
    long y;
};
```

Let's assume that *Persistence Service* is configured as follows and we have two *DataWriters* on Topic "T" publishing type "A" and type "B" and sending TypeObject information.

```
<persistence_service name="XTypes">
    <participant name="XTypesParticipant">
        <persistence_group name="XTypesPersistenceGroup">
            <filter>T</filter>
        </persistence_group>
    </participant>
</persistence_service>
```

When *Persistence Service* discovers the first *DataWriter* with type "A", it will create a *DataReader* (PRSTDataReader) to read DDS samples from that *DataWriter,* and a *DataWriter* (PRSTDataWriter) to publish and store the received DDS samples so they can be available to late-joiners.

When *Persistence Service* discovers the second *DataWriter* with type "B", it will see that type "B" is not equal to type "A"; then it will create a new pair (PRSTDataReader, PRSTDataWriter) to receive and store DDS samples from the second *DataWriter*.

Since the PRSTDataReaders are created with the TypeConsistencyEnforcementQosPolicy's **kind** set to DISALLOW_TYPE_COERCION, the PRSTDataReader with type "A" will not match the *DataWriter* with type "B". Likewise, the PRSTDataReader with type "B" will not match the *DataWriter* with type "A".

46.13.1.1 Type Version Discrimination

Persistence Service uses the rules described in the *RTI Connext DDS Core Libraries Extensible Types Guide* to decide whether or not to create a new pair (PRSTDataReader, PRSTDataWriter) when it discovers a *DataWriter* for a topic "T".

For *DataWriters* created with previous *Connext DDS* releases, *Persistence Service* will select the first pair (PRSTDataReader, PRSTDataWriter) with a registered type name equal to the discovered registered type name since *DataWriters* created with previous *Connext DDS* releases (before 5.0) do not send TypeObject information.

46.13.2 DataRepresentationQosPolicy Integration

There are some restrictions on how the 7.5.3 DATA_REPRESENTATION QosPolicy on page 379 is configured for the PRSTDataReader and PRSTDataWriter in a persistence group:

- A PRSTDataReader cannot be configured to request two or more data representations. For example, it is not possible to request XCDR and XCDR2. Subscribing to a *Topic* in which data is published in XCDR and XCDR2 format requires creating two different persistence groups.
- The data representation requested by a PRSTDataReader has to be equal to the data representation offered by the corresponding PRSTDataWriter.

46.14 TCP Transport Support in Persistence Service

You can configure *Persistence Service's* Participants to use the TCP Transport. To do so, enable the TCP Transport under the proper XML Persistence Service's **<participant_qos>** tag.

> Make sure the string prefix passed in the property **dds.transport.load_plugins** is "**dds.transport.tcp**". For more information about how to enable the TCP Transport, please see 44.7 TCP/TLS Transport Properties on page 1138.

Note that the *Persistence Service's* **participant_qos** will be used at least by two Participants: one for sending data and another for receiving data. Consequently, at least two TCP Transport plugins will be instantiated when enabling the TCP Transport. In order to avoid port collisions, *Persistence Service* will automatically assign consecutive ports. For a base, it will use the values set for **dds.transport.tcp.server_bind_port** (only when it is non-zero) and **dds.transport.tcp.public_address** (only if it is set). Consequently, the Participants creating a TCP Transport running as a server will open a minimum of two TCP ports.

Chapter 47 Running RTI Persistence Service

This chapter describes how to start and stop *Persistence Service*.

You can run *Persistence Service* on any node in the network. It does not have to be run on the same node as the publishing or subscribing applications for which it is saving/delivering data. If you run it on a separate node, make sure that the other applications can find it during the discovery process—that is, it must be in one of the NDDS_DISCOVERY_PEERS lists.

47.1 Starting Persistence Service

The script to run *Persistence Service's* executable is located in **<NDDSHOME>/bin**.

> To run this service executable on a *target* system (not your host development platform), you must first select the target architecture. To do so, either:
> Set the environment variable **CONNEXTDDS_ARCH** to the name of the target architecture. (Do this for each command shell you will be using.)
> Or set the variable **connextdds_architecture** in the file **rticommon_config.[sh/bat]**[a] to the name of the target architecture. If the **CONNEXTDDS_ARCH** environment variable is set, the architecture in this file will be ignored.

Run **rtipersistenceservice -help** to see the syntax:

```
RTI Persistence Service
Usage: rtipersistenceservice [options]
Options:
 -cfgFile                      <file>  Configuration file. This parameter is optional
                                       since the configuration can be loaded from
                                       other locations
```

[a]This file is resource/scripts/rticommon_config.sh on Linux or macOS systems, resource/scripts/rticommon_config.bat on Windows systems.

```
 -cfgName                        <name>  Configuration name. This parameter is required
                                         and it is used to find a <persistence_service>
                                         matching tag in the configuration files
 -appName                        <name>  Application name. Used to identify this
                                         execution
                                         for remote administration and to name the
                                         DomainParticipants
                                         Default: -cfgName
 -identifyExecution                      Appends the host name and process ID to the
                                         appName to help ensure unique names
 -domainId                       <int>   domain ID for the DomainParticipants created
                                         by the service
                                         Default: Use XML value
 -remoteAdministrationDomainId           <int>   Enables remote administration and sets
                                         the domain ID for the communication
                                         Default: Use XML value
 -restore                        <0|1>   Indicates whether or not persistence service
                                         must restore its state from the persistent
                                         storage
                                          Default: Use XML value
 -noAutoStart                            Use this option if you plan to start RTI
                                         Persistence Service remotely
 -infoDir                        <dir>   The info directory of the running persistence
                                         service. The service writes a ps.pid file into
                                         this directory when is started. When the
                                         service finalizes the file is deleted
                                         Default: None
 -maxObjectsPerThread            <int>   Sets the maximum number of objects that can
                                         be stored per thread for a
                                         DomainParticipantFactory
                                          Default: Connext DDS default
 -serviceThreadStackSize         <int>   Service thread stack size
                                         Default: OS default
-disableDatabaseLocking                 Disable database locking
                                         Default: Enabled
-heapSnapshotPeriod              <sec>   Enables heap monitoring. Persistence Service
                                         will generate a heap snapshot every <sec>
                                         Default: heap monitoring is disabled
                                         Valid range: [1, 86400]
-heapSnapshotDir                 <dir>   When heap monitoring is enabled this parameter
                                         configures the directory where the snapshots
                                         will be stored. The snapshot file
                                         name format is
                                         PS_heap_<appName>_<processId>_<index>.log
                                         Default: current working directory
 -verbosity                      [0-6]   RTI Persistence Service verbosity
                                          * 0 - silent
                                          * 1 - exceptions (Core Libraries and Service)
                                          * 2 - warnings (Service)
                                          * 3 - information (Service)
                                          * 4 - warnings (Core Libraries and Service)
                                          * 5 - tracing (Service)
                                          * 6 - tracing (Core Libraries and Service)
                                          Default: 1 (exceptions)
 -version                                Prints RTI Persistence Service version
 -help                                   Displays this information
```

The command-line options are described with more detail in Table 47.1 Persistence Service Command-Line Options

Table 47.1 Persistence Service Command-Line Options

Command-line Option	Description
-appName <string>	Assigns a name to the execution of *Persistence Service*. Remote commands will refer to the persistence service using this name. In addition, the name of the *DomainParticipants* created by *Persistence Service* will be based on this name as follows: RTI Persistence Service: <appName>: <participantName>(<pub|sub>) Default: The name given with **-cfgName** if present, otherwise it is "RTI_Persistence_Service"
-cfgFile <string>	Specifies an XML configuration file for the *Persistence Service*. The parameter is optional since the *Persistence Service* configuration can be loaded from other locations. See 46.1 How to Load the Persistence Service XML Configuration on page 1162 for further details.
-cfgName <string>	Required. Selects a *Persistence Service* configuration. The same configuration files can be used to configure multiple persistence services. Each *Persistence Service* instance will load its configuration from a different <persistence_service> tag based on the name specified with this option. If not specified, *Persistence Service* will print the list of available configurations and then exit.
-identifyExecution	Appends the host name and process ID to the service name provided with the **-appName** option. This helps ensure unique names for remote administration.
-disableDatabaseLocking	Disables database locking. If *Persistence Service* is started with this flag, the database locking mechanism used to detect other instances using the same database will be disabled. This feature only has effect when <persistent_storage> is used. Default: Database locking is enabled by default
-domainId <ID>	Sets the domain ID for the *DomainParticipants* created by *Persistence Service*. If not specified, the value in the <participant> XML tag (see Table 46.7 Participant Tags) is used.
-remoteAdministrationDomainId <ID>	Enables remote administration and sets the domain ID for remote communication. When remote administration is enabled, *Persistence Service* will create a *DomainParticipant*, *Publisher*, *Subscriber*, *DataWriter*, and *DataReader* in the designated DDS domain. This option overwrites the value of the tag **<domain_id>** within **<administration>**. Default: Use the value **<domain_id>** under **<administration>.**
-help	Prints the *Persistence Service* version and list of command-line options.
-licenseFile <file>	Specifies the license file (path and filename). Only applicable to licensed versions of *Persistence Service*. If not specified, *Persistence Service* looks for the license as described in the RTI Connext DDS Installation Guide.

Table 47.1 Persistence Service Command-Line Options

Command-line Option	Description
-restore <0|1>	Indicates whether or not *Persistence Service* must restore its state from the persistent storage. 0 = do not restore; 1 = do restore. If this option is not specified, the corresponding XML value in the <persistent_storage> tag (see Table 46.4 Persistent Storage tags) is used.
-noAutoStart	Indicates that *Persistence Service* will not be started when the process is executed. Use this option if you plan to start *Persistence Service* remotely, as described in Administering Persistence Service from a Remote Location (Chapter 48 on page 1191).
-infoDir <dir>	The info directory of the running *Persistence Service*. Using this command line option, *Persistence Service* can be configured to create a file used to monitor the status of the last shutdown. At startup, the *Persistence Service* instance will create a file called **ps.pid** into the directory specified by **-infoDir**. If *Persistence Service* is shutdown gracefully, the file will be deleted before the process exists. If *Persistence Service* is not shutdown gracefully, the file will not be deleted. You can detect the shutdown state of *Persistence Service* by checking for the presence of the **ps.pid** file. If the file is present and *Persistence Service* is no longer running, the previous shutdown was not graceful. If *Persistence Service* is started and a **ps.pid** file exists, *Persistence Service* will immediately shutdown. In this case, you must remove the file before *Persistence Service* can be restarted again. Default: The file **ps.pid** will not be generated.
-maxObjectsPerThread <int>	Parameter used to configure the maximum objects per thread in the DomainParticipantFactory created by *Persistence Service*. Default: DDS default
-serviceThreadStackSize <int>	Service thread stack size. Default: DDS default
-verbosity	*Persistence Service* verbosity: 0 - No verbosity 1 - Exceptions (Core Libraries and *Persistence Service*) (default) 2 - Warning (*Persistence Service*) 3 - Information (*Persistence Service*) 4 - Warning (Core Libraries and *Persistence Service*) 5 - Tracing (*Persistence Service*) 6 - Tracing (Core Libraries and *Persistence Service*) Each verbosity level, *n*, includes all the verbosity levels smaller than *n*.
-version	Prints the *Persistence Service* version.

47.2 Stopping Persistence Service

To stop Persistence Service: Press **Ctrl-C**.

Persistence Service will close all files and perform a clean shutdown. It can also be stopped and shutdown remotely (see Administering Persistence Service from a Remote Location (Chapter 48 on page 1191)).

Chapter 48 Administering Persistence Service from a Remote Location

Persistence Service can be controlled remotely by sending commands through a special Topic. Any *Connext DDS* application can be implemented to send these commands and receive the corresponding responses. A shell application that sends/receives these commands is provided with *Persistence Service*.

The script for the shell application is **$NDDSHOME/bin/rtipssh**.

Entering **rtipssh -help** will show you the command-line options:

```
RTI Persistence Service Shell v6.1.0
Usage: rtipssh [options]...
Options:
 -domainId  <integer>   Domain ID for the remote configuration
 -timeout   <seconds>   Max time to wait a remote response
 -cmdFile   <file>      Run commands in this file
 -help                  Displays this information
```

48.1 Enabling Remote Administration

By default, remote administration is disabled in *Persistence Service*.

To enable remote administration you can use the **<administration>** tag (see 46.5 Configuring Remote Administration on page 1168) or the **-remoteAdministrationDomainId** command-line parameter (see Table 47.1 Persistence Service Command-Line Options), which enables remote administration and sets the domain ID for remote communication.

When remote administration is enabled, *Persistence Service* will create a *DomainParticipant*, *Publisher*, *Subscriber*, *DataWriter*, and *DataReader* in the designated DDS domain. (The QoS values for these entities are described in 46.5 Configuring Remote Administration on page 1168.)

48.2 Remote Commands

This section describes the remote commands using the shell interface; 48.3 Accessing Persistence Service from a Connext DDS Application on the next page explains how to use remote administration from a *Connext DDS* application.

Remote commands:

```
48.2.1   start below <target_persistence_service>
48.2.2   stop below <target_persistence_service>
48.2.3   shutdown below <target_persistence_service>
48.2.4   status on the next page <target_persistence_service>
```

Parameters:

<target_persistence_service> can be:

- The application name of a persistence service, such as "**MyPersistenceService1**", as specified at start-up with the command-line option **-appName**
- A wildcard expression[1] for a persistence service name, such as **"MyPersistenceService*"**

48.2.1 start

```
start <target_persistence_service>
```

The **start** command starts the persistence service instance. DDS samples will not be persisted until the persistence service is started.

By default, the persistence service is started automatically when the process is executed. To start the service remotely use the command line option **-noAutoStart** (see Table 47.1 Persistence Service Command-Line Options).

48.2.2 stop

```
stop <target_persistence_service>
```

The **stop** command stops the persistence service instance.

An instance that has been stopped can be started again using the command start.

48.2.3 shutdown

```
shutdown <target_persistence-_service>
```

The command **shutdown** stops the persistence service instance and finalizes the process

[1] As defined by the POSIX fnmatch API (1003.2-1992 section B.6)

48.2.4 status

```
status <target_persistence_service>
```

The **status** command gets the status of a running persistence service instance. Possible values are STARTED and STOPPED.

48.3 Accessing Persistence Service from a Connext DDS Application

You can send commands to control a Persistence Service instance from your own *Connext DDS* application. You will need to create a *DataWriter* for a specific topic and type. Then, you can send a DDS sample that contains a command and its parameters. Optionally, you can create a *DataReader* for a specific topic to receive the results of the execution of your commands.

The topics are:

- rti/persistence_service/administration/command_request
- rti/persistence_service/administration/command_response

The types are:

- RTI::PersistenceService::Administration::CommandRequest
- RTI::PersistenceService::Administration::CommandResponse

You can find the IDL definitions for these types in:

<NDDSHOME>/resource/idl/PersistenceServiceAdministration.idl.

The QoS configuration of your *DataWriter* and *DataReader* must be compatible with the one used by the persistence service (see how this QoS is configured in 46.5 Configuring Remote Administration on page 1168).

The following example in C shows how to send a command to shutdown a persistence service instance:

```
/*********************************************************/
/*** Create the Entities needed to send command request ****/
/*********************************************************/
participant = DDS_DomainParticipantFactory_create_participant(
                DDS_TheParticipantFactory, domainId,
                &DDS_PARTICIPANT_QOS_DEFAULT, NULL,
                DDS_STATUS_MASK_NONE);
if (participant == NULL)
{ /* Error */ }
if (publisher == NULL)
{ /* Error */ }

subscriber = DDS_DomainParticipant_create_subscriber(
                participant, &DDS_SUBSCRIBER_QOS_DEFAULT,
                NULL, DDS_STATUS_MASK_NONE);
```

```
publisher = DDS_DomainParticipant_create_publisher(
               participant, &DDS_PUBLISHER_QOS_DEFAULT,
               NULL, DDS_STATUS_MASK_NONE);
if (publisher == NULL)
{ /* Error */ }

typeName =
RTI_PersistenceService_Administration_CommandRequestTypeSupport_get_type_name();
retcode =
RTI_PersistenceService_Administration_CommandRequestTypeSupport_register_type(
               participant, typeName);
if (retcode != DDS_RETCODE_OK)
{ /* Error */ }

topicCmd = DDS_DomainParticipant_create_topic(
               participant,
                "rti/persistence_service/administration/command_request",
               typeName, &DDS_TOPIC_QOS_DEFAULT,
               NULL, DDS_STATUS_MASK_NONE);
if (topicCmd == NULL)
{ /* Error */ }

typeName =
RTI_PersistenceService_Administration_CommandResponseTypeSupport_get_type_name();
retcode =
RTI_PersistenceService_Administration_CommandResponseTypeSupport_register_type(
                participant, typeName);
if (retcode != DDS_RETCODE_OK)
{ /* Error */ }

topicResponse = DDS_DomainParticipant_create_topic(
               participant,
               "rti/persistence_service/administration/command_response",
               typeName, &DDS_TOPIC_QOS_DEFAULT, NULL,
               DDS_STATUS_MASK_NONE);
if (topicResponse == NULL)
{ /* Error */ }

writerQos.reliability.kind = DDS_RELIABLE_RELIABILITY_QOS;
writerQos.history.kind = DDS_KEEP_ALL_HISTORY_QOS;
writer = DDS_Publisher_create_datawriter(
               publisher, topicCmd, &writerQos,
                NULL /* listener */,
               DDS_STATUS_MASK_NONE);
if (writer == NULL)
{ /* Error */ }

readerQos.reliability.kind = DDS_RELIABLE_RELIABILITY_QOS;
readerQos.history.kind     = DDS_KEEP_ALL_HISTORY_QOS;
reader = DDS_Subscriber_create_datareader(
               subscriber,
               DDS_Topic_as_topicdescription(topicResponse),
               &readerQos, NULL, DDS_STATUS_MASK_NONE);
if (reader == NULL)
{ /* Error */ }

/*****************************************************************/
```

```
/*** Wait for discovery ********************************************/
/*****************************************************************/
/* Wait until we discover one reader and one writer matching
 * with the command request DataWriter and the command response
 * DataReader */
while (count < maxPollPeriods)
{
  retcode = DDS_DataWriter_get_publication_matched_status(
              writer, &pubMatchStatus);
  if (retcode != DDS_RETCODE_OK)
  { /* Error */ }

  retcode = DDS_DataReader_get_subscription_matched_status(
              reader, &subMatchStatus);
  if (retcode != DDS_RETCODE_OK) { /* Error */ }

  if (pubMatchStatus.total_count == 1 &&
    subMatchStatus.total_count == 1)
  { break; }
  count++;
  NDDS_Utility_sleep(&pollPeriod);
}
if (count == maxPollPeriods)
{ /* Error */ }

/*****************************************************************/
/*** Send the command request **************************************/
/*****************************************************************/
request =
       RTI_PersistenceService_Administration_CommandRequestTypeSupport_create_data();
if (request == NULL)
{ /* Error */ }

/* request->id provides an unique way to identify a request so that
 * it can be correlated with a response. Although one of the fields is
 * called host it does not necessarily has to contain the IP address of
 * the host. Same applies to app */
request->id.host = 0;
request->id.app = 0;
request->id.invocation = 0;
strcpy(request->target_ps, "MyPersistenceService");
request->command._d = RTI_PERSISTENCE_SERVICE_COMMAND_SHUTDOWN;
retcode = RTI_PersistenceService_Administration_CommandRequestDataWriter_write(
       (RTI_PersistenceService_Administration_CommandRequestDataWriter *) writer,
       request, &instance_handle);
if (retcode != DDS_RETCODE_OK)
{ /* Error */ }

/*****************************************************************/
/*** Wait for response  ********************************************/
/*****************************************************************/
response =
        RTI_PersistenceService_Administration_CommandResponseTypeSupport_create_data();
if (response == NULL)
{ /* Error */ }
count = 0;
while (count < maxPollPeriods) {
```

```
    retcode =
      RTI_PersistenceService_Administration_CommandResponseDataReader_take_next_sample(
        (RTI_PersistenceService_Administration_CommandResponseDataReader*) reader,
        response, &sampleInfo);
    if (retcode == DDS_RETCODE_OK) {
        break;
    } else if (retcode != DDS_RETCODE_NO_DATA) {
       /* Error */
    }
    NDDS_Utility_sleep(&pollPeriod);
    count++;
}
if (count == maxPollPeriods) {
    printf("No response received\n");
} else {
    printf("Response received: %s\n",response->message);
}
```

Chapter 49 Advanced Persistence Service Scenarios

This section covers several advanced scenarios for using *Persistence Service*.

49.1 Scenario: Load-balanced Persistence Services

Each running instance of the *Persistence Service* executes as a single process in a single computer. In high-throughput scenarios the *Persistence Service* may become a bottleneck. The main reasons are:

- If the *Persistence Service* is configured to persist its DDS samples to durable storage (a disk or a database) this will further limit the throughput of DDS samples that can be persisted to what the database and/or disk can handle. Depending on computer hardware, the disk or database this limit may be in the order of tens of thousands of DDS samples per second which is far less than what could be communicated system-wide.
- Depending on the CPU there will be limits on the throughput of DDS samples that can be received by a single process.
- The computer running the *Persistence Service* is typically connected to the network via a single network interface so the data that can be persisted will be limited to the throughput that flows though a single interface which is typically far less that the aggregated throughput that can flow on the complete network.

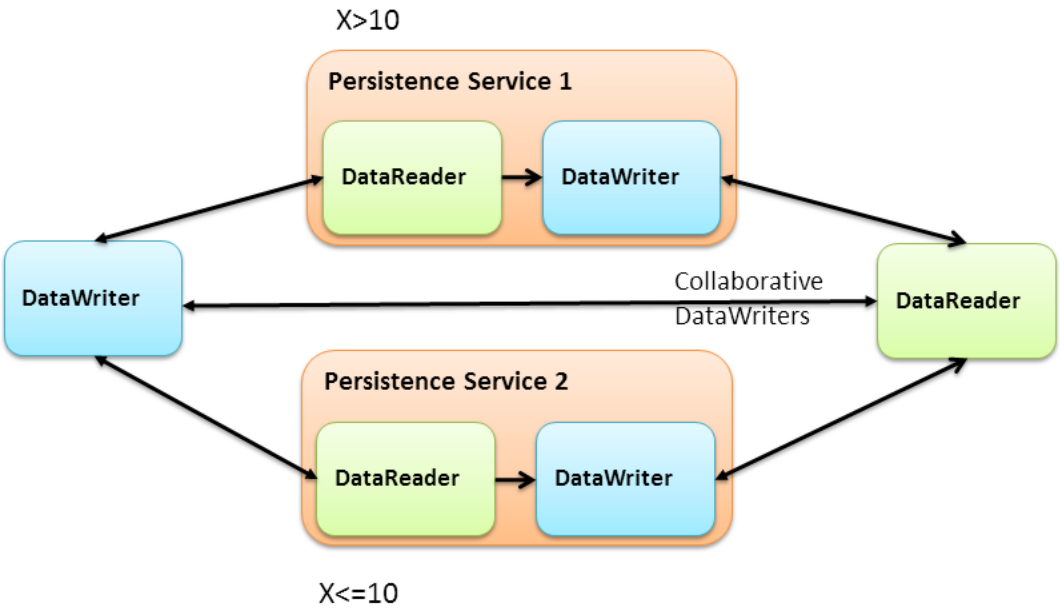
To overcome these limits multiple instances of the RTI *Persistence Service* can be run in parallel. These instances may run in multiple machines and be configured in a "load balancing" fashion such that each *Persistence Service* process is only responsible for persisting a subset of the data published on the DDS domain.

Multiple strategies for partitioning the data stored by each *Persistence Service* instance are possible:

- **Balance *Persistence Services* by Topic name**. This strategy configures each persistence service to persist different Topic names. This is accomplished by associating a filter expression with the declaration of the persistent groups used to configure each *Persistence Service* (see 46.8 Creating Persistence Groups on page 1173). The filter expression is applied to the Topic names, so for example one *Persistence Service* could be configured with the filter "[A-Z]*" filter in the name of the Topics that it will persist and the second with the filter "[a-z]*". With this configuration the first *Persistence Service* will persist data produced by DataWriters that specify durability TRANSIENT or PERSISTENT and have a Topic name that starts with a capital letter and the second Persistence *Service* will do the same for Topics that start with a lower-case letter.
- **Balance *Persistence Services* by data content**. In some scenarios the data published on a single Topic is too much for a single *Persistence Service* to handle. In this case the *Persistence Services* can also be configured with filter expressions based on the content of the data. This is accomplished by associating a content filter with the declaration of the persistent groups used to configure each *Persistence Service* (see 46.8 Creating Persistence Groups on page 1173).

When multiple instances of *Persistence Service* are used to store data on the same Topic, it becomes possible for DDS samples from the same original *DataWriter* to be stored in separate instances of *Persistence Service.* In this situation, *Connext DDS DataReaders* automatically merge the data from the multiple *Persistence Services* such that the relative order of the DDS samples from the original *DataWriter* is preserved. This *Connext DDS* capability is called *Collaborative Datawriters* because multiple *DataWriters*, in this case the ones for different *Persistence Services,* collaborate to reconstruct the original stream. (See Collaborative DataWriters (Chapter 12 on page 721)).

Figure 49.1: Load-Balanced Persistence Services Scenario



49.2 Scenario: Delegated Reliability

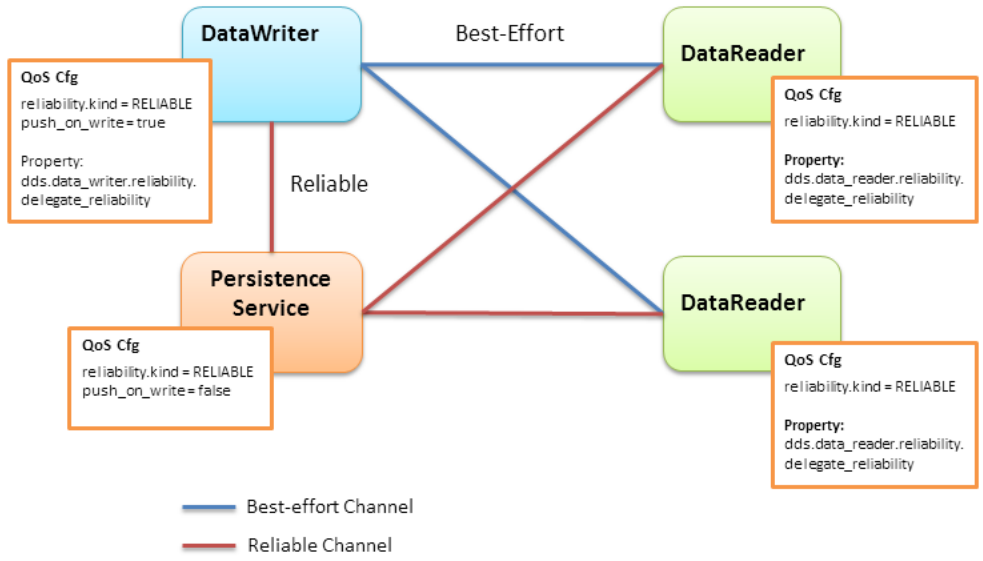
The DDS-RTPS reliability protocol requires the *DataWriter* to periodically send HeartBeat messages to the *DataReaders,* process their ACKs and NACK messages, keep track of the *DataReader* state, and send the necessary repairs. The additional load caused by the reliability protocol increases with the number of reliable *DataReaders* matched with the *DataWriter*. Even if the data is sent via multicast the number of ACKs and NACKs will increase with the number of *DataReaders*.

In situations where there many *DataReaders* are subscribing to the same Topic, the reliability and repair traffic may become too much for the *DataWriter* to handle and negatively impact its performance. To address this situation, *Connext DDS* provides the ability to configure the *DataWriter* so that it delegates the reliability task to a separate service. This approach is known as *delegated reliability.*

To take advantage of *delegated reliability,* both the original *DataWriter* and *DataReader* must be configured to enable an external service to ensure the reliability on their behalf. This is done by setting both the **dds.data_writer.reliability.delegate_reliability** property on the *DataWriter* and the **dds.data_reader.reliability.delegate_reliability** property on the *DataReader* to 1.

With this configuration, the *DataWriter* creates a reliable channel to *Persistence Service*, yet sends data using 'best-effort' reliability to the *DataReaders* directly. If a DDS sample is dropped, *Persistence Service* will repair the DDS sample. *Persistence Service* is configured with **push_on_write** (in the 7.5.5 DATA_WRITER_PROTOCOL QosPolicy (DDS Extension) on page 388) set to false. This way, DDS samples will only be sent from *Persistence Service* to the *DataReaders* when they are explicitly NACKed by the *DataReader*.

Figure 49.2: Delegated Reliability Scenario

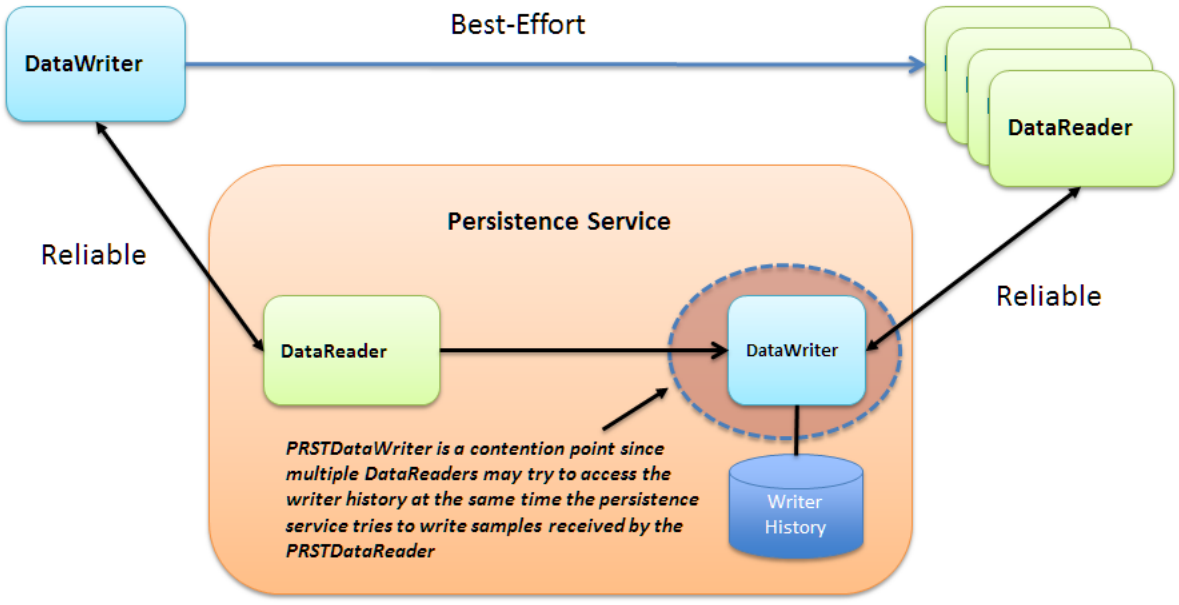


49.3 Scenario: Slow Consumer

Unless special measures are taken, the presence of slow consumers can impact the overall behavior of the system. If a *DataReader* is not keeping up with the DDS samples being sent by the *DataWriter,* it will apply back-pressure to the *DataWriter* to slow the rate at which the *DataWriter* can write DDS samples. With *delegated reliability* (see 49.2 Scenario: Delegated Reliability on the previous page), the original *DataWriter* can offload the processing of the ACK/NACK messages generated by the *DataReaders* to a *PRSTDataWriter.* However, the original *DataWriter* still has a reliable channel with the *PRSTDataReader* that can slow it down.

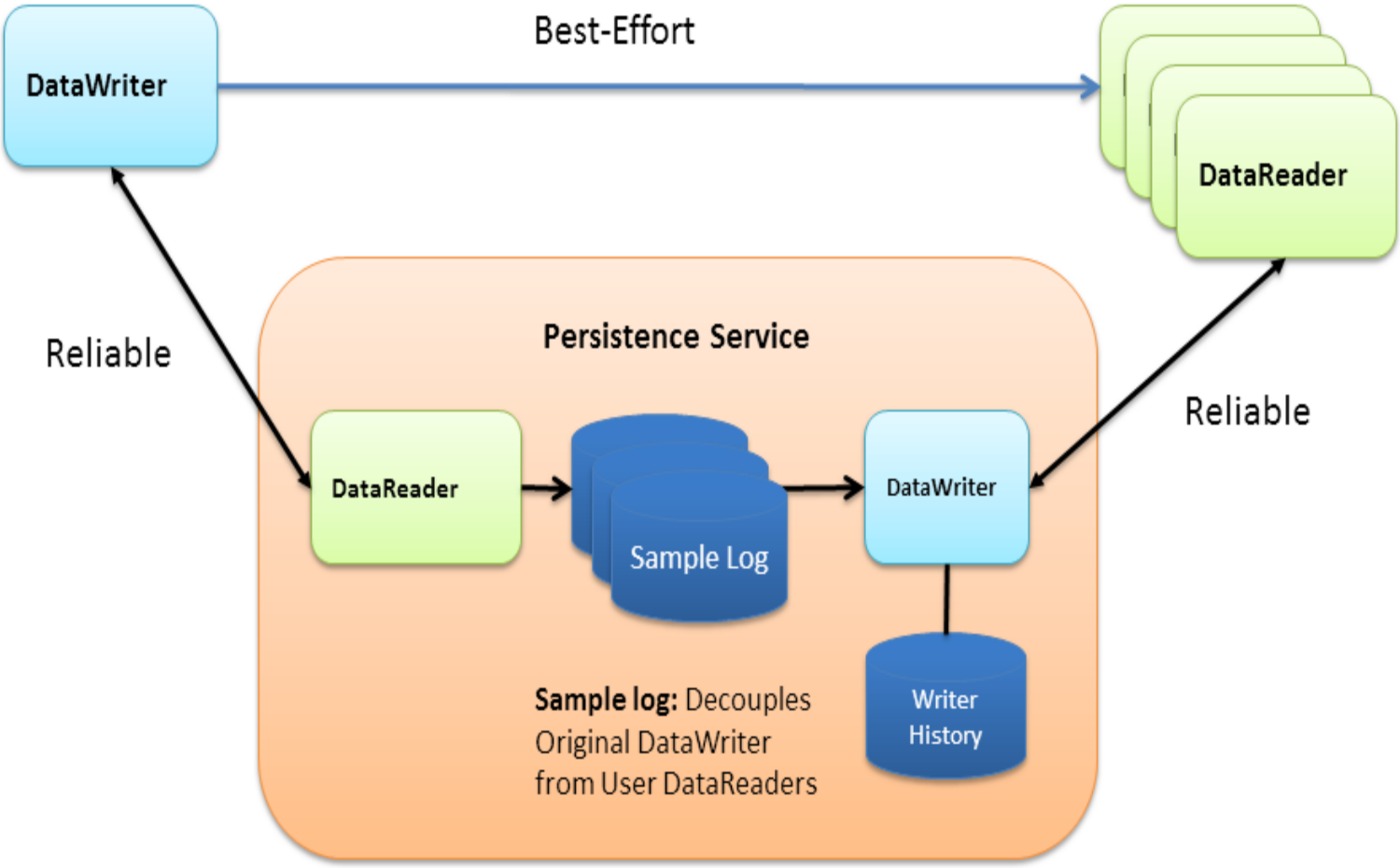
By default, *Persistence Service* uses the *Connext DDS* receive thread to read DDS samples from the PRStDataReaders, write the DDS samples to the PRSTDataWriters history, and send ACKs to the original *DataWriter*. With this configuration, a PRSTDataReader does not ACK DDS samples to the original *DataWriter* until they are written into the corresponding PRSTDataWriter's history. Since multiple *DataReaders* may be accessing the PRSTDataWriter history at the same time that the persistence service is trying to write new DDS samples, the PRSTDataWriter history becomes a contention point that can indirectly slow down the original *DataWriter* (see Figure 49.3: Slow-Consumer Scenario with Delegated Reliability below).

Figure 49.3: Slow-Consumer Scenario with Delegated Reliability



To remove this contention point and decouple the slow consumer from the original *DataWriter*, *Persistence Service* supports a mode where DDS samples can be buffered prior to being added to the *PRSTDataWriter's* queue (see Figure 49.4: Slow Consumer Scenario with Delegated Reliability and DDS Sample Log on the next page).

Figure 49.4: Slow Consumer Scenario with Delegated Reliability and DDS Sample Log



If the PRSTDataWriter slows down due to the presence of slow consumers, the buffer will hold DDS samples such that the original *DataWriter* and the rest of the system are not impacted. This buffer is called the *Persistence Service sample log*. The persistence service creates a separate DDS sample log per PRSTDataWriter in the group. In addition to the DDS sample log, the persistence service creates a thread (write thread) whose main function is to read DDS samples from the log and write them to the associated *PRSTDataWriter.* There is one thread per PRSTDataWriter.

> *Persistence Service* currently does not allow multiple DDS sample logs to share the same write thread.

Persistence Service can be configured to enable DDS sample logging per persistence group using the **<sample_logging>** XML tag to specify the log's configuration parameters—see Table 49.1 Sample Logging Tags..

Table 49.1 Sample Logging Tags

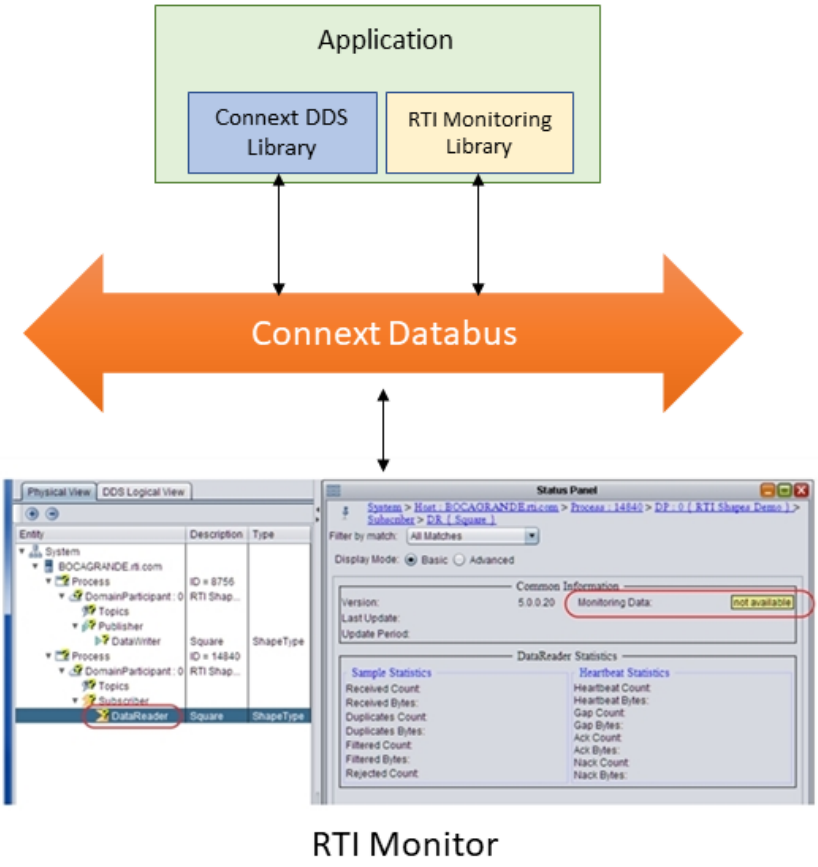
Tags within <sample_logging>	Description	Number of Tags Allowed
<enable>	A DDS_Boolean (see Table 46.1 Supported Tag Values) that indicates whether or not DDS sample logging is enabled in the container persistence group. Default: 0	0 or 1
<log_file_size>	Specifies the maximum size of a DDS sample log file in Mbytes. When a log file becomes full, Persistence Service creates a new log file. Default: 60 MB	0 or 1
<log_flush_period>	The period (in milliseconds) at which Persistence Service removes DDS sample log files whose full content have been written into the PRSTDataWriter by the DDS sample log write thread. Default: 10000 milliseconds	0 or 1
<log_read_batch>	Determines how many DDS samples should be read and processed at once by the DDS sample log write thread. Default: 100 DDS samples	0 or 1
<log_bookmark_period>	DDS samples in the DDS sample log are identified by two attributes: • The file ID • The row ID (position within the file) The read bookmark indicates the most recently processed DDS sample. This tag indicates how often (in milliseconds) the read bookmark is persisted into disk. Default: 1000 milliseconds	0 or 1

Enabling DDS sample logging in a persistence group is expensive. For every PRSTDataWriter, *Persistence Service* will create a write thread and an event thread that will be in charge of flushing the log files and storing the read bookmark. Therefore, DDS sample logging should be enabled only for the persistence groups where it is needed based on the potential presence of slow consumers and/or the expected data rate in the persistence group. Small data rates will likely not require a DDS sample log.

Part 9: RTI Monitoring Library

RTI Monitoring Library is a plug-in that enables *Connext DDS* applications to provide monitoring data. The monitoring data can be visualized with *RTI Monitor*, a separate GUI application that can run on the same host as *Monitoring Library* or on a different host.

Connext DDS notifies *Monitoring Library* every time an entity is created/deleted or a QoS is changed. *Monitoring Library* periodically queries the status of all *Connext DDS* entities. You can enable/disable monitoring by setting values in the *DomainParticipant's* PropertyQosPolicy (programmatically or through an XML QoS profile).



RTI Monitor

This part of the *User's Manual* includes:

- Using Monitoring Library in Your Application (Chapter 50 on page 1204)
- Configuring Monitoring Library (Chapter 51 on page 1214)

Chapter 50 Using Monitoring Library in Your Application

50.1 Enabling Monitoring

There are two ways to enable monitoring in your application:

- 50.1.1 Method 1—Change the Participant QoS to Automatically Load the Dynamic Monitoring Library on the next page
- 50.1.2 Method 2—Change the Participant QoS to Specify the Monitoring Library Create Function Pointer and Explicitly Load the Monitoring Library on page 1206

Notes:

- The libraries that you will need for Monitoring are listed in the RTI Connext DDS Core Libraries Platform Notes.
- If your original application has made modifications to the ParticipantQos **resource_limits.type_code_max_serialized_length**, ParticipantQos **resource_limits.type_object_max_serialized_length,** or any of the transport's default settings to enable large type code or large data, refer to 50.3 What Monitoring Topics are Published? on page 1211 for additional QoS modifications that may be needed.
- *Monitoring Library* creates internal *DataWriters* to publish monitoring data by making modifications based on the default *DataWriter* QoS settings. If you have made changes to the default *DataWriter* QoS, especially if you have increased/decreased the initial or maximum DDS sample/instance values, *Monitoring Library* may have trouble creating *DataWriters* to publish monitoring data, or it may limit the number of statistics that you can publish through the internal monitoring writers. If this is true for your case, you may want to specify the **qos_library** and **qos_profile** that will be used to create these internal writers for publishing mon-

itoring data, to avoid being impacted by default *DataWriter* QoS settings. See Configuring Monitoring Library (Chapter 51 on page 1214) for details.

50.1.1 Method 1–Change the Participant QoS to Automatically Load the Dynamic Monitoring Library

If all of the following are true, you can enable monitoring simply by changing your participant QoS (otherwise, use 50.1.2 Method 2—Change the Participant QoS to Specify the Monitoring Library Create Function Pointer and Explicitly Load the Monitoring Library on the next page):

- Your application is linked to *dynamic Connext DDS* libraries (see 10.3.2 Mixing Static and Dynamic Libraries not Supported on page 676), or you are using Java or .Net, and
- You will run your application on a platform that is *not* VxWorks or INTEGRITY (which don't support this), and
- You are NOT linking in an additional monitoring library into your application at link time (you let the middleware load the monitoring library for you automatically as needed).

If you change the QoS in an XML file as shown below, you can enable/disable monitoring without recompiling. If you change the QoS in your source code, you may need to recompile every time you enable/disable monitoring.

If you need to change the participant QoS by hand, refer to the definition of **BuiltinQosLib::Generic.Monitoring.Common** in **<NDDSHOME>/resource/xml/BuiltinProfiles.documentationONLY.xml** for the values you should set.

Example XML to enable monitoring:

```
<domain_participant_qos>
    <property>
        <value>
            <element>
               <name>rti.monitor.library</name>
               <value>rtimonitoring</value>
            </element>
            <element>
                <name>rti.monitor.create_function</name>
                <value>RTIDefaultMonitor_create</value>
            </element>
        </value>
    </property>
</domain_participant_qos>
```

50.1.2 Method 2–Change the Participant QoS to Specify the Monitoring Library Create Function Pointer and Explicitly Load the Monitoring Library

If any of the following are true, you must change the Participant QoS to enable monitoring and explicitly load the correct version of *Monitoring Library* at compile time:

- Your application is linked to the static version of *Connext DDS* libraries. (See 10.3.2 Mixing Static and Dynamic Libraries not Supported on page 676.)
- You will run your application on a VxWorks or INTEGRITY platform.
- You want to explicitly link in the monitoring library (static or dynamic) into your application.

There are two ways to do this:

- 50.1.2.1 Method 2-A: Change the Participant QoS by Specifying the Monitoring Library Create Function Pointer in Source Code on the next page: Applies to most users who cannot use Method 1 and do not mind changing/recompiling source code every time you enable/disable monitoring, or whose system does not support setting environment variables programmatically. Participant QoS must be defined in source code with this approach.
- 50.1.2.2 Method 2-B: Change the Participant QoS by Specifying the Monitoring Library Create Function Pointer in an Environment Variable on page 1210: Applies to users who cannot use Method 1 *and* want to specify the create function pointer via an environment variable. This approach allows the Participant QoS to be defined in an XML file or in source code.

50.1.2.1 Method 2-A: Change the Participant QoS by Specifying the Monitoring Library Create Function Pointer in Source Code

1. Modify your *Connext DDS* application based on the following examples.

Traditional C++ Example:

```
#include "ndds/ndds_cpp.h"
#include "monitor/monitor_common.h"
extern "C" int publisher_main(int domainId, int sample_count)
{
    ...
    DDSDomainParticipant *participant = NULL;
    DDS_DomainParticipantQos participant_qos;

    /* Get default QoS */
    retcode =
    DDSTheParticipantFactory->get_default_participant_qos(
        participant_qos);
    if (retcode != DDS_RETCODE_OK) {
        /*Error*/
    }
    /* This property indicates that the DomainParticipant
       has monitoring turned on. The property name MUST be
       "rti.monitor.library". The value can be anything.*/
    retcode = DDSPropertyQosPolicyHelper::add_property(
       participant_qos.property,
       "rti.monitor.library", "rtimonitoring", DDS_BOOLEAN_FALSE);
    if (retcode != DDS_RETCODE_OK) {
        /*Error*/
    }
    /* The property name "rti.monitor.create_function"
       indicates the entry point for the monitoring library.
       The value MUST be the value of the function pointer of
       RTIDefaultMonitor_create */

    retcode = DDSPropertyQosPolicyHelper::add_pointer_property(
        participant_qos.property,
        "rti.monitor.create_function_ptr",
        (void *) RTIDefaultMonitor_create);
    if (retcode!= DDS_RETCODE_OK) {
        /* Error */
    }
    /* Create DomainParticipant with participant_qos */
    participant = DDSTheParticipantFactory->create_participant(
       domainId, participant_qos,NULL /* listener */,
       DDS_STATUS_MASK_NONE);
    if (participant == NULL) {
        /* Error */
    }
    ...
```

Modern C++ Example:

```
#include "rti/rti.hpp" // include all the modern C++ API
#include "monitor/monitor_common.h" // for RTIDefaultMonitor_create
//...
using rti::core::policy::Property;

// Get property policy from default DomainParticipantQos
auto participant_qos =
    dds::core::QosProvider::Default().participant_qos();
auto property_policy = participant_qos.policy<Property>();

// This property turns monitoring on
property_policy.set(Property::Entry("rti.monitor.library",
    "rtimonitoring"));

// This property specifies the entry point (function
// pointer) for the monitoring library.
std::ostringstream monitor_function_to_str;
monitor_function_to_str <<
    reinterpret_cast<void*>(RTIDefaultMonitor_create);
property_policy.set(Property::Entry(
    "rti.monitor.create_function_ptr",
    monitor_function_to_str.str()));

participant_qos << property_policy;

// Create a DomainParticipant with Qos
dds::domain::DomainParticipant participant(0, participant_qos);

...
```

C Example:

```
#include "ndds/ndds_c.h"
#include "monitor/monitor_common.h"
...
extern "C" int publisher_main(int domainId, int sample_count)
{
       DDS_DomainParticipantFactory *factory = NULL;
      struct DDS_DomainParticipantQos participantQos =
      DDS_DomainParticipantQos_INITIALIZER;

      DDS_DomainParticipant *participant = NULL;
      factory = DDS_DomainParticipantFactory_get_instance();
      if (factory == NULL) {
              /* error */
      }
```

```
if (DDS_DomainParticipantFactory_get_default_participant_qos(
    factory, &participantQos) != DDS_RETCODE_OK) {
        /* error */
}
/* This property indicates that the DomainParticipant has
    monitoring turned on. The property name MUST be
        "rti.monitor.library". The value can be anything.*/
if (DDS_PropertyQosPolicyHelper_add_property(
        &participantQos.property,
         "rti.monitor.library", "rtimonitoring",
         DDS_BOOLEAN_FALSE) != DDS_RETCODE_OK) {
                /* error */
}
/* The property name "rti.monitor.create_function_ptr"
    indicates the entry point for the monitoring library.
    The value MUST be the value of the function pointer
    of RTIDefaultMonitor_create */

if (DDS_PropertyQosPolicyHelper_add_pointer_property(
        &participantQos.property,
        "rti.monitor.create_function_ptr",RTIDefaultMonitor_create)
         != DDS_RETCODE_OK) {
            /* error */
}
/* create DomainParticipant with participantQos */
participant=
        DDS_DomainParticipantFactory_create_participant(
                factory, domainId, &participantQos,
                 NULL /* listener */,
                DDS_STATUS_MASK_NONE);
if (participant == NULL) {
        /* error */
}
DDS_DomainParticipantQos_finalize(&participantQos);
...
```

Note:

- In the above code, you may notice that **valueBuffer** is initialized to 17 characters. This is because a pointer (RTIDefaultMonitor_create) is at most 8 bytes (on a 64-bit system) and it takes two characters to represent a byte in hex. So the total size must be:

  ```
  (2 * 8 characters) + 1 null-termination character = 17 characters
  ```

2. Link the *Monitoring Library* for your platform into your application at compile time (the Monitoring libraries are listed in the RTI Connext DDS Core Libraries Platform Notes).

   The kind of monitoring library that you link into your application at compile time must be consistent with the kind of *Connext DDS* libraries that you are linking into your application (static/dynamic, release/debug version of the libraries).

On Windows systems: If you are linking a static monitoring library, you will also need to link in **Psapi.lib** at compile time.

50.1.2.2 Method 2-B: Change the Participant QoS by Specifying the Monitoring Library Create Function Pointer in an Environment Variable

This is similar to Method 2-A, but if you specify the function pointer value for **rti.monitor.create_function_ptr** in an environment variable that is set programmatically, you can specify your QoS either in an XML file or in source code. If you specify the QoS in an XML file, you can enable/disable monitoring without recompiling. If you change the QoS in your source code, you may need to recompile every time you enable/disable monitoring.

1. In XML, enable monitoring by setting the **rti.monitor.create_function_ptr** property to an environment variable. In our example, the variable is named RTIMONITORFUNCPTR.

```
<participant_qos>
    <property>
       <value>
           <element>
               <name>rti.monitor.library</name>
               <value>rtimonitoring</value>
           </element>
           <element>
               <name>rti.monitor.create_function_ptr</name>
               <value>$(RTIMONITORFUNCPTR)</value>
           </element>
       </value>
    </property>
</participant_qos>
```

2. In the DDS application that links in the monitoring library, get the function pointer of **RTIDefaultMonitor_create** and write it to the same environment variable you named in Step 1 and create a *DomainParticipant* by using the XML profile specified in Step 1. (Setting of the environment variable must appear in the application *before* it creates the *DomainParticipant* using the profile from Step 1.)

   Here is an example in C:

```
#include <stdio.h>
#include <stdlib.h>
#include "monitor/monitor_common.h"
...
char putenvBuffer[34];
int putenvReturn;
putenvBuffer[0] = '\0';
sprintf(putenvBuffer, "RTIMONITORFUNCPTR=%p",
         RTIDefaultMonitor_create);
putenvReturn = putenv(putenvBuffer);
if (putenvReturn) {
    printf(
    "Error: couldn't set env variable for RTIMONITORFUNCPTR. "
    "error code: %d\n",  putenvReturn );
```

```
}
...
/* create DomainParticipant using XML profile from Step 1 */
...
```

Note: In the above code, you may notice that **putenvBuffer** is initialized to 34 characters. This is because a pointer (RTIDefaultMonitor_create) is at most 8 bytes (on a 64-bit system) and it takes 2 characters to represent a byte in hex. So the total size must be: strlen(RTIMONITORFUNCPTR) + (2 * 8 characters) + 1 null-termination character = 17 + 16 + 1 = 34 characters

3. Link the *Monitoring Library* for your platform into your application at compile time (the Monitoring libraries are listed in the RTI Connext DDS Core Libraries Platform Notes).

   The kind of monitoring library that you link into your application at compile time must be consistent with the kind of *Connext DDS* libraries that you are linking into your application (static/dynamic, release/debug version of the libraries).

   On Windows systems: If you are linking a static monitoring library, you will also need to link in **Psapi.lib** at compile time.

50.2 How does Monitoring Library Work?

Monitoring Library works by creating DDS Topics that publish information about the other DDS entities contained in the same operating system process. The Topics can be created inside of the first *DomainParticipant* that enables the library (the default). Or they may be created in a separate *DomainParticipant* if the **rti.monitor.config.new_participant_domain_id** property is used. Use cases for this latter configuration include controlling the domain ID on which this information is exchanged (for example to ensure that this data does not interfere with production topics) as well as the ability to specify the QoS that is used for the *DomainParticipant* (through the **rti.monitor.config.qos_library** and **rti.monitor.config.qos_profile** properties). It may be desirable to specify the QoS for *Monitoring Library's DomainParticipant* if the information will be consumed on a different transport or simply to enable the feature but keep it as isolated from the production system as possible.

50.3 What Monitoring Topics are Published?

Two categories of predefined monitoring topics are sent out:

- *Descriptions* are published when an entity is created or deleted, or there are QoS changes (see Table 50.1 Descriptions (QoS and Other Static System Information)).
- *Entity Statistics* are published periodically (see Table 50.2 Entity Statistics (Statuses, Aggregated Statuses, CPU and Memory Usage)).

Table 50.1 Descriptions (QoS and Other Static System Information)

Topic Name	Topic Contents
rti/dds/monitoring/domainParticipantDescription	*DomainParticipant* QoS and other static information
rti/dds/monitoring/topicDescription	*Topic* QoS and other static information
rti/dds/monitoring/publisherDescription	*Publisher* QoS and other static information
rti/dds/monitoring/subscriberDescription	*Subscriber* QoS and other static information
rti/dds/monitoring/dataReaderDescription	*DataReader* QoS and other static information
rti/dds/monitoring/dataWriterDescription	*DataWriter* QoS and other static information

Table 50.2 Entity Statistics (Statuses, Aggregated Statuses, CPU and Memory Usage)

Topic Name	Topic Contents
rti/dds/monitoring/domainParticipantEntityStatistics	Number of entities discovered in the system, CPU and memory usage of the process
rti/dds/monitoring/dataReaderEntityStatistics	*DataReader* statuses
rti/dds/monitoring/dataWriterEntityStatistics	*DataWriter* statuses
rti/dds/monitoring/topicEntityStatistics	*Topic* statuses
rti/dds/monitoring/ dataReaderEntityMatchedPublicationStatistics	*DataReader* statuses calculated on a per discovered matching writer basis
rti/dds/monitoring/ dataWriterEntityMatchedSubscriptionStatistics	*DataWriter* statuses calculated on a per discovered matching reader basis
rti/dds/monitoring/ dataWriterEntityMatchedSubscriptionWithLocatorStatistics	*DataWriter* statuses calculated on a per sending destination basis

All monitoring data are sent out using specially created *DataWriters* with the above topics.

You can configure some aspects of *Monitoring Library's* behavior, such as which monitoring topics to turn on, which user topics to monitor, how often to publish the statistics topics, and whether to publish monitoring data using (a) the participant created in the user's application that has monitoring turned on or (b) a separate participant created just for publishing monitoring data. See Configuring Monitoring Library (Chapter 51 on page 1214).

50.4 Enabling Support for Large Type-Code (Optional)

Some monitoring topics have large type-code (larger than the default maximum type code serialized size setting). If you use *Monitor* to display all the monitoring data, it already has all the monitoring types built-

in and therefore it uses the default maximum type-code serialized size in the *Connext DDS* application and there is no problem. However, if you are using any other tools to display monitoring data (such as *RTI Spreadsheet Add-in for Microsoft Excel*, *rtiddsspy,* or writing your own application to subscribe to monitoring data), or if your user data-type has large type-code, you may need to increase the maximum type-object serialized size setting in the DomainParticipantResourceLimitsQosPolicy.

50.5 Troubleshooting Monitoring

50.5.1 Buffer Allocation Error

Monitoring Library obtains the default *DataWriter* QoS from the *Connext DDS* application's *DomainParticipant*. If the application has changed the default QoS Profile, either through application code or in an XML file, *Monitoring Library* will use this new default QoS. In specific scenarios, the new default QoS may cause your Connext DDS application to run out of memory and report error messages similar to these:

```
REDAFastBufferPool_growEmptyPoolEA: !allocate buffer of 1210632000 bytes
[D0012|ENABLE]REDAFastBufferPool_newWithNotification:!create fast buffer pool buffers
[D0012|ENABLE]PRESTypePluginDefaultEndpointData_createWriterPool:!create writer buffer pool
[D0012|ENABLE]WriterHistorySessionManager_new:!create newAllocator
[D0012|ENABLE]WriterHistoryMemoryPlugin_createHistory:!create sessionManager
[D0012|ENABLE]PRESWriterHistoryDriver_new:!create _whHnd
[D0012|ENABLE]PRESPsService_enableLocalEndpointWithCursor:!create WriterHistoryDriver
[D0012|ENABLE]PRESPsService_enableAllLocalEndpointsInGroupWithCursor:!enable endpoint
[D0012|ENABLE]PRESPsService_enableGroupWithCursor:!enableAllLocalEndpointsInGroupWithCursor
[D0012|ENABLE]PRESPsService_enableGroup:!enableGroupWithCursor
[D0012|ENABLE]RTIDefaultMonitorPublisher_enableEntitiesAndStartThreadI:!create enable publisher
[D0012|ENABLE]RTIDefaultMonitorPublisher_onEventNotify:!create enable entities
```

To resolve this problem, either:

- Configure *Monitoring Library* to use a non-default QoS Profile. For details, see Configuring Monitoring Library (Chapter 51 on page 1214).
- Change the default QoS to have a lower value for *DataWriter*'s **initial_samples**; this field is part of the ResourceLimitsQosPolicy.

Chapter 51 Configuring Monitoring Library

You can control some aspects of *Monitoring Library's* behavior by setting the PropertyQosPolicy of the *DomainParticipant*, either via an XML QoS profile or in your application's code prior to creating the *DomainParticipant*.

Two example QoS profiles are provided in **<path to examples>/connext_dds/qos/MONITORING_LIBRARY_QOS_PROFILES.xml** (see Paths Mentioned in Documentation on page 1):

- CustomerExampleMonitoringLibrary::CustomerExampleMonitoringProfile

  This is an example of how to enable *Monitoring Library* for your applications. It can be used as a guide to enabling *Monitoring Library* quickly in your applications.

- RTIMonitoringQosLibrary::RTIMonitoringQosProfile

  This profile documents the QoS used by *Monitoring Library*. It can also be used as a starting point if you want to tune QoS for *Monitoring Library* (normally not necessary). Use cases for this include customizing *DomainParticipant* QoS (often the transports) to accommodate preferences or environment. This same profile can also be used to subscribe to the *Monitoring Library* Topics. This is useful in situations where the *Monitoring Library* information can be used directly by system components or it is not possible to use the *RTI Monitor* tool.

<NDDSHOME>/resource/xml/RTI_MONITOR_QOS_PROFILES.xml is used by the *RTI Monitor* tool. See *Changing Transport Settings in the Configuration File*, in the RTI Monitor User's Manual for more information.

See the qos_library on page 1216 and qos_profile on page 1216 properties in Table 51.1 Configuration Properties for Monitoring Library for further information on when to use the example profiles in **MONITORING_LIBRARY_QOS_PROFILES.xml**.

Table 51.1 Configuration Properties for Monitoring Library lists the configuration properties that you can set for *Monitoring Library*. These properties are immutable; they cannot be changed after the *DomainParticipant* is created.

Table 51.1 Configuration Properties for Monitoring Library

Property Name (all must be prepended with "rti.monitor.config.")	Property Value
get_process_statistics	This boolean value specifies whether or not *Monitoring Library* should collect CPU and memory usage statistics for the process in the topic **rti/dds/monitoring/domainParticipantDescription**. This property is only applicable for platforms that support obtaining CPU and memory usage from monitoring data. CPU and memory usage is not available on these platforms:VxWorks, INTEGRITY. CPU usage is reported in terms of time spent since the process has been started. It can be longer than the actual running time of the process on a multi-core machine. Default: true if unspecified
new_participant_domain_id	To create a separate participant that will be used to publish monitoring information in the application, set this to the domain ID that you want to use for the newly created participant. The new participant is created with the default Qos (for example, that defined in USER_QOS_PROFILES.xml), unless the qos_library on the next page and qos_profile on the next page properties are set. Default: Not set (means you want to reuse the participant in your application that has monitoring turned on to publish statistics information for that participant)
publish_period	Period of time to sample and publish all monitoring topics, in units of seconds. Default: 5 if unspecified
publish_thread_priority	Priority of the thread used to sample and publish monitoring data. This value is architecture dependent. Default if unspecified: same as the default used in *Connext DDS* for the event thread: Windows systems: -2 Linux systems: -999999 (meaning use OS-default priority)
publish_thread_stacksize	Stack size used for the thread that samples and publishes monitoring data. This value is architecture dependent. Default if unspecified: same as the default used in *Connext DDS* for the event thread: Windows systems: -1 (meaning use the default size for the executable). Linux systems: -1 (meaning use OS's default value).

Table 51.1 Configuration Properties for Monitoring Library

Property Name (all must be prepended with "rti.monitor.config.")	Property Value
publish_thread_options	Describes the type of thread. Supported values (may be combined with by OR'ing with '|' as seen in the default below): • **FLOATING_POINT**: Code executed within the thread may perform floating point operations • **STDIO**: Code executed within the thread may access standard • **REALTIME_PRIORITY**: The thread will be scheduled on a real-time basis • **PRIORITY_ENFORCE**: Strictly enforce this thread's priority Default: **FLOATING_POINT|STDIO** (same as the default used in *Connext DDS* for the event thread)
qos_library	Specifies the name of the QoS library that will be used to create the monitoring library *DomainParticipant*, *Publisher*, and *DataWriters*. Default: Not set. If you don't set this property, the entities are created with the following QoS values: • The *DomainParticipant* uses the default DomainParticipantQos (for example, that defined in USER_QOS_PROFILES.xml). • The *Publisher* and the *DataWriters* use a specific QoS configuration that can be found in the library **RTIMonitoringQosLibrary** in **<path to examples>/connext_dds/qos/MONITORING_LIBRARY_QOS_PROFILES.xml**. (Note that the *Publisher* and *DataWriters* use the values reproduced in this .xml file, but modifying the file has no effect; it is for reference only.)
qos_profile	Specifies the name of the QoS profile that will be used to create the monitoring library *DomainParticipant*, *Publisher*, and *DataWriters*. Default: Not set. If you don't set this property, the entities are created with the following QoS values: • The *DomainParticipant* uses the default DomainParticipantQos (for example, that defined in USER_QOS_PROFILES.xml). • The *Publisher* and the *DataWriters* use a specific QoS configuration that can be found in the library **RTIMonitoringQosLibrary** in **<path to examples>/connext_dds/qos/MONITORING_LIBRARY_QOS_PROFILES.xml**. (Note that the *Publisher* and *DataWriters* use the values reproduced in this .xml file, but modifying the file has no effect; it is for reference only.)
reset_status_change_counts	*Monitoring Library* obtains all statuses of all entities in the *Connext DDS* application. This boolean value controls whether or not the change counts in those statuses are reset by *Monitoring Library*. If set to true, the change counts are reset each time *Monitoring Library* is done accessing them. If set to false, the change counts truly reflect what users will see in their application and are unaffected by the access of the monitoring library. Default: false

Table 51.1 Configuration Properties for Monitoring Library

Property Name (all must be prepended with "rti.monitor.config.")	Property Value
skip_monitor_entities	This boolean value controls whether or not the entities created internally by *Monitoring Library* should be included in the entity counts published by the participant entity statistics topic. If set to true, the internal monitoring entities will not be included in the count. (Thirteen internal writers are created by the monitoring library by default.) Default: true
skip_participant_ properties	If set to true, *DomainParticipant* PropertyQosPolicy name and value pairs will not be sent out through the domainParticipantDescriptionTopic. This is necessary if you are linking with *Monitoring Library* and any of these conditions occur: • The PropertyQosPolicy of a *DomainParticipant* has more than 32 properties. • Any of the properties in PropertyQosPolicy of a *DomainParticipant* has a name longer than 127 characters or a value longer than 511 characters. Default: false if unspecified
skip_reader_ properties	If set to true, *DataReader* PropertyQosPolicy name and value pairs will not be sent out through the dataReaderDescriptionTopic. This is necessary if you are linking with *Monitoring Library* and any of these conditions occur: • The PropertyQosPolicy of a *DataReader* has more than 32 properties. • Any of the properties in PropertyQosPolicy of a *DataReader* has a name longer than 127 characters or a value longer than 511 characters. Default: false if unspecified
skip_writer_properties	If set to true, *DataWriter* PropertyQosPolicy name and value pairs will not be sent out through the dataWriterDescriptionTopic. This is necessary if you are linking with *Monitoring Library* and any of these conditions occur: • The PropertyQosPolicy of a *DataWriter* has more than 32 properties. • Any of the properties in PropertyQosPolicy of a *DataWriter* has a name longer than 127 characters or a value longer than 511 characters. Default: false if unspecified
topics	Filter for monitoring topics, with regular expression matching syntax as specified in the *Connext DDS* documentation (similar to the POSIX fnmatch syntax). For example, if you only want to send description topics and the entity statistics topics, but NOT the matching statistics topics, you can specify **"*Description,*EntityStatistics"**. Default: ***** if unspecified
usertopics	Filter for user topics, with regular expression matching syntax as specified in the *Connext DDS* documentation (similar to the POSIX fnmatch syntax). For example, if you only want to send monitoring information for reader/writer/topic entities for topics that start with Foo or Bar, you can specify **"Foo*,Bar*"**. Default: ***** if unspecified

Table 51.1 Configuration Properties for Monitoring Library

Property Name (all must be prepended with "rti.monitor.config.")	Property Value
verbosity	Sets the verbosity on the monitoring library for debugging purposes (does not affect the topic/data that is sent out). • -1: Silent • 0: Exceptions only • 1: Warnings • 2 and up: Higher verbosity level Default: 1 if unspecified
writer_pool_buffer_max_size	Controls the threshold at which dynamic memory allocation is used, expressed as a number of bytes. If the serialized size of the data to be sent is smaller than this size, a pre-allocated writer buffer pool is used to obtain the memory. If the serialized size of the data is larger than this value, the memory is allocated dynamically. This setting can be used to control memory consumption of the monitoring library, at the cost of performance, when the maximum serialized size of the data type is large (which is the case for some description topics' data types) or if you have several participants on the same machine. The default setting is -1, meaning memory is always obtained from the writer buffer pool, whose size is determined by the maximum serialized size.

Part 10: RTI Distributed Logger

RTI Distributed Logger is a library that enables applications to publish their log messages to *Connext DDS*. The log message data can be visualized with *RTI Monitor* and *RTI Admin Console*. Since the data is provided in a *Topic*, you can also use *rtiddsspy* or even write your own visualization tool.

Distributed Logger can also send *Connext DDS* errors, warnings and other internal messages from its own builtin logging system as a DDS *Topic*. In fact, *Distributed Logger* provides a remote command topic so that its behavior can be remotely controlled at run time.

This part of the *User's Manual* includes:

- Using Distributed Logger in a Connext DDS Application (Chapter 52 on page 1220)
- Enabling Distributed Logger in RTI Services (Chapter 53 on page 1230)

Chapter 52 Using Distributed Logger in a Connext DDS Application

There are two ways to use *Distributed Logger*: directly through its API or by attaching it to an existing logging framework as an 'appender' or a 'handler.' Using the API directly is straightforward, but keep in mind that *Distributed Logger* is not intended to be a full-featured logging library. Rather, it is primarily intended to be integrated into third-party logging infrastructures.

The libraries that you will need for *Distributed Logger* are listed in 52.1 Distributed Logger Libraries below.

Distributed Logger comes with third-party integrations for the open-source project log4j (http://-logging.apache.org/log4j/) as well as Java's built-in logging library (java.util.logging). Please see 52.3 Examples on the next page for examples that illustrate these integrations.

Distributed Logger captures and forwards *Connext DDS* internal information, warning, and error messages using a DDS topic. It monitors these messages using the same mechanism as user log messages.

These *Connext DDS* log messages are sent over DDS automatically as soon as you initialize *Distributed Logger* (by calling **RTI_DL_DistLogger_getInstance()** in C or C++, or **Logger.getLogger(...)** in Java; see the API Reference HTML documentation for details).

52.1 Distributed Logger Libraries

Table 52.1 Required Libraries lists the additional libraries you will need in order to use *Distributed Logger*.

Table 52.1 Required Libraries

Platform	Language	Static		Dynamic	
		Release	Debug	Release	Debug
Linux®	C	librtidlcz.a	librtidlczd.a	librtidlc.so	librtidcd.so
	C++	librtidlcz.a librtidlcppz.a	librtidlczd.a librtidlcppzd.a	librtidlc.so librtidlcpp.so	librtidlcd.so librtidlcppd.so
	Java	N/A	N/A	distlog.jar distlogdatamodel.jar	distlogd.jar distlogdatamodeld.jar
QNX	C	librtidlcz.a	librtidlczd.a	librtidlc.so	librtidcd.so
	C++	librtidlcz.a librtidlcppz.a	librtidlczd.a librtidlcppzd.a	librtidlc.so librtidlcpp.so	librtidlcd.so librtidlcppd.so
VxWorks™	C	librtidlcz.a	librtidlczd.a	librtidlc.so	librtidcd.so
	C++	librtidlcz.a librtidlcppz.a	librtidlczd.a librtidlcppzd.a	librtidlc.so librtidlcpp.s	librtidlcd.so librtidlcppd.s
Windows®	C	rtidlcz.lib	rtidlczd.lib	rtidlc.dll	rtidlcd.dll
	C++	rtidlcz.lib rtidlcppz.lib	rtidlczd.lib rtidlcppzd.lib	rtidlc.dll rtidlcpp.dll	rtidlcd.dll rtidlcppd.dll
	Java	N/A	N/A	distlog.jar distlogdatamodel.jar	distlogd.jar distlogdatamodeld.jar

52.2 Using the API Directly

Details on using the *Distributed Logger* APIs are provided in the API Reference HTML documentation: **<NDDSHOME>/doc/api/connext_dds/distributed_logger/<language>**. Start by opening **index.html**. (See Paths Mentioned in Documentation on page 1

If you plan to use the *Distributed Logger*'s API directly, please be aware of the following notes. To configure the options, create an options object and update its fields. Once your updates are complete, set the options on *Distributed Logger*. It is important that this be done **before** *Distributed Logger* is instantiated. *Distributed Logger* acts as a singleton and there is no way to change the options after it has been created.

When your application is ready to exit, use the 'delete' method. This will delete all Entities and threads associated with *Distributed Logger*.

52.3 Examples

Distributed Logger includes several examples in **<path to examples>/distributed_logger** (see Paths Mentioned in Documentation on page 1):

- **c/hello_distributed_logger**

  This is a simple example of how to use the API directly and does not publish or subscribe to any Topics except the ones related to *Distributed Logger*.

- **c++/hello_distributed_logger**

  This is a simple example of how to use the API directly and does not publish or subscribe any Topics except the ones related to *Distributed Logger*.

- **java/hello_direct_usage**

  This is a simple example of how to use the API directly and does not publish or subscribe any Topics except the ones related to *Distributed Logger*.

- **java/hello_file_logger**

  This example shows how an application can use the information provided by *Distributed Logger*. As the name suggests, this example subscribes to log messages and writes them to a file. Multiple DDS domains can be subscribed to simultaneously if desired. The example is meant to strike a balance between simplicity and function. Certainly more features could be added to make it a production-ready application but that would obscure the goal of the example.

- **java/hello_java_util_logging**

  In this example, all System.{out/err} invocations are replaced with Java logging library equivalents. It adds *Distributed Logger* through a configuration file.

- **java/hello_log4j_logging**

  In this example, all System.{out/err} invocations are replaced with log4j library equivalents. It adds *Distributed Logger* through a configuration file.

Each example has a **READ_ME.txt** file which explains how to build and run it.

52.4 Data Type Resource

You can find the data types used by *Distributed Logger* in **<NDDSHOME>/resource/idl/distog.idl**. (See Paths Mentioned in Documentation on page 1.)

If you want to generate code and interact with *Distributed Logger* through Topics, you can use this file to do so. You will need to provide extra command-line arguments to *RTI Code Generator* (*rtiddsgen*). (This allows us to accommodate multiple language bindings within the same file. As a consequence, we've used preprocessor definitions to achieve this functionality.) The command-line options which must be added to *rtiddsgen* are as follows:

- For C or C++: **–D LANGUAGE_C**
- For Java: **–D LANGUAGE_JAVA**
- For .Net: **–D LANGUAGE_DOTNET**

If you plan to use the generated code in your application (to subscribe to log messages, for instance) be aware that the type names used might not match the default ones. *Do not* use the generated type names obtained when calling **get_type_name()** or found in **distlogSupport.h**. Use the variables in Table 52.2 Registration Names for each Distributed Logger Type instead.

Table 52.2 Registration Names for each Distributed Logger Type

Type	Registered Typename	Variable
Log Message	com::rti::dl::LogMessage	C/C++: RTI_DL_LOG_MESSAGE_TYPE_NAME Java: LOG_MESSAGE_TYPE_NAME.VALUE
Administration State	com::rti::dl::admin::State	C/C++: RTI_DL_STATE_TYPE_NAME Java: STATE_TYPE_NAME.VALUE
Administration Command Request	com::rti::dl::admin:: CommandRequest	C/C++: RTI_DL_COMMAND_REQUEST_TYPE_NAME Java: COMMAND_REQUEST_TYPE_NAME.VALUE
Administration Command Response	com::rti::dl::admin:: CommandResponse	C/C++: RTI_DL_COMMAND_RESPONSE_TYPE_NAME Java: COMMAND_RESPONSE_TYPE_NAME.VALUE

For instance, to subscribe to log messages in C you will need to do the following:

```
retcode = RTI_DL_LogMessageTypeSupport_register_type(
                participant, RTI_DL_LOG_MESSAGE_TYPE_NAME);
```

52.5 Distributed Logger Topics

Distributed Logger uses four Topics to publish log messages, state, and command responses and one topic to subscribe to command requests. These are detailed in Table 52.3 Topics Used by Distributed Logger.

Table 52.3 Topics Used by Distributed Logger

Topic	Type Name	Quality of Service

Table 52.3 Topics Used by Distributed Logger

rti/distlog	com::rti::dl::LogMessage	Reliable Transient Local
rti/distlog/administration/state	com::rti::dl::admin::State	Reliable Transient Local
rti/distlog/administration/command_request	com::rti::dl::admin::CommandRequest	Reliable
rti/distlog/administration/command_response	com::rti::dl::admin::CommandResponse	Reliable

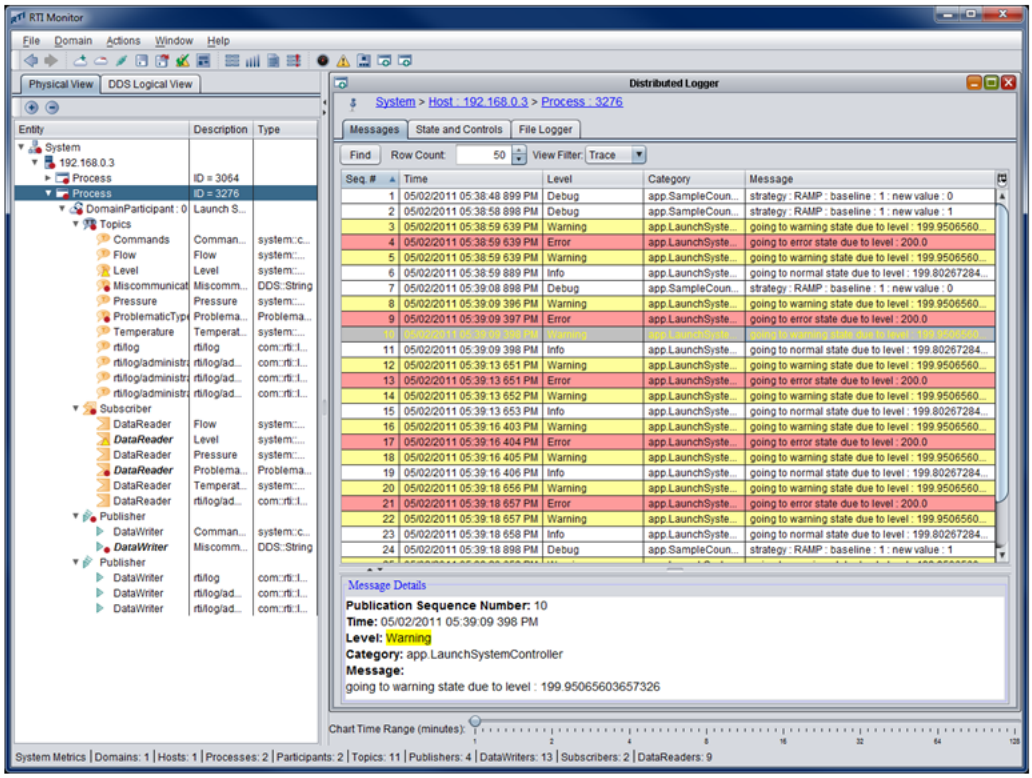
52.6 Distributed Logger IDL

The IDL describing the types used for Topics created by *Distributed Logger* are in **<NDDSHOME>/resource/idl/distlog.idl**. (See Paths Mentioned in Documentation on page 1.) You can use this IDL to create custom applications that use the data provided by *Distributed Logger* and/or to remotely control any *Distributed Logger* instances that are running in your system. The IDL has been designed to take advantage of the latest type-support features in *Connext DDS*.

52.7 Viewing Log Messages

One way to see the messages from *Distributed Logger* is to use *RTI Monitor*.

Figure 52.1: Viewing Log Messages with RTI Monitor



Other ways to see the log messages include using *rtiddsspy* or writing your own visualization tool. If you want to write your own application that interacts with *Distributed Logger*, you can find the IDL in **<NDDSHOME>/resource/idl/distlog.idl**. (See Paths Mentioned in Documentation on page 1.)

52.8 Logging Levels

Log levels in *Distributed Logger* are organized as shown in Table 52.4 Mapping between Distributed Logger and Connext DDS Builtin Logging System (ordered by importance). This table also shows the mapping between logging levels in the *Connext DDS* builtin logging system and *Distributed Logger*.

Table 52.4 Mapping between Distributed Logger and *Connext DDS* Builtin Logging System

Connext DDS Builtin Logging System Log Level	Distributed Logger Log Level
NDDS_CONFIG_LOG_FATAL_ERROR	RTI_DL_FATAL_LEVEL
NDDS_CONFIG_LOG_LEVEL_ERROR	RTI_DL_ERROR_LEVEL
NDDS_CONFIG_LOG_LEVEL_WARNING	RTI_DL_WARNING_LEVEL
NDDS_CONFIG_LOG_LEVEL_STATUS_LOCAL	RTI_DL_NOTICE_LEVEL

Connext DDS Builtin Logging System Log Level	Distributed Logger Log Level
NDDS_CONFIG_LOG_LEVEL_STATUS_REMOTE	RTI_DL_INFO_LEVEL
NDDS_CONFIG_LOG_LEVEL_DEBUG	RTI_DL_DEBUG_LEVEL

52.9 Distributed Logger Quality of Service Settings

To ensure that *Distributed Logger* works correctly with other RTI tools, some QoS settings are hard-coded and cannot be modified by customized profiles. Table 52.5 QoS Values Used by Distributed Logger lists the QoS values that are set in *Distributed Logger*. Values in bold are hard-coded; therefore even if they appear in an XML profile, they remain as noted in the table.

Table 52.5 QoS Values Used by Distributed Logger

Entity	Property	Value
Subscriber	**Presentation.access_scope**	**PRES_INSTANCE_PRESENTATION_QOS**
	Presentation.coherent_access	**false**
	Presentation.ordered_access	**false**
Publisher	**Presentation.access_scope**	**PRES_INSTANCE_PRESENTATION_QOS**
	Presentation.coherent_access	**false**
	Presentation.ordered_access	**false**
Log Message Topic	**Reliability.kind**	**DDS_RELIABLE_RELIABILITY_QOS**
	Durability.kind	**DDS_TRANSIENT_LOCAL_DURABILITY_QOS**
Administration State Topic	**Reliability.kind**	**DDS_RELIABLE_RELIABILITY_QOS**
	Durability.kind	**DDS_TRANSIENT_LOCAL_DURABILITY_QOS**
Administration Command Request Topic	**Reliability.kind**	**DDS_RELIABLE_RELIABILITY_QOS**
Administration Command Response Topic	**Reliability.kind**	**DDS_RELIABLE_RELIABILITY_QOS**

Table 52.5 QoS Values Used by Distributed Logger

Entity	Property	Value
Log Message DataWriter	**Ownership.kind**	**DDS_SHARED_OWNERSHIP_QOS**
	Latency_budget.duration.sec	**0**
	Latency_budget.duration.nanosec	**0**
	Liveliness.kind	**DDS_AUTOMATIC_LIVELINESS_QOS**
	Destination_order.kind	**DDS_BY_RECEPTION_TIMESTAMP_ DESTINATIONORDER_QOS**
	Reliability.kind	**DDS_RELIABLE_RELIABILITY_QOS**
	Durability.kind	**DDS_TRANSIENT_LOCAL_DURABILITY_QOS**
	History.kind	DDS_KEEP_LAST_HISTORY_QOS
	History.depth	10
Administration State DataWriter	**Ownership.kind**	**DDS_SHARED_OWNERSHIP_QOS**
	Latency_budget.duration.sec	**0**
	Latency_budget.duration.nanosec	**0**
	Liveliness.kind	**DDS_AUTOMATIC_LIVELINESS_QOS**
	Destination_order.kind	**DDS_BY_RECEPTION_TIMESTAMP_ DESTINATIONORDER_QOS**
	Reliability.kind	**DDS_RELIABLE_RELIABILITY_QOS**
	Durability.kind	**DDS_TRANSIENT_LOCAL_DURABILITY_QOS**
	History.kind	DDS_KEEP_LAST_HISTORY_QOS
	History.depth	1
Administration Command Response DataWriter	**Ownership.kind**	**DDS_SHARED_OWNERSHIP_QOS**
	Latency_budget.duration.sec	**0**
	Latency_budget.duration.nanosec	**0**
	Liveliness.kind	**DDS_AUTOMATIC_LIVELINESS_QOS**
	Destination_order.kind	**DDS_BY_RECEPTION_TIMESTAMP_ DESTINATIONORDER_QOS**
	Reliability.kind	**DDS_RELIABLE_RELIABILITY_QOS**
	History.kind	DDS_KEEP_LAST_HISTORY_QOS
	History.depth	10

Table 52.5 QoS Values Used by Distributed Logger

Entity	Property	Value
Administration Command Request DataReader	**Ownership.kind**	**DDS_SHARED_OWNERSHIP_QOS**
	Latency_budget.duration.sec	**DDS_DURATION_INFINITE_SEC**
	Latency_budget.duration.nanosec	**DDS_DURATION_INFINITE_NSEC**
	Deadline.period.sec	**DDS_DURATION_INFINITE_SEC**
	Deadline.period.nanosec	**DDS_DURATION_INFINITE_NSEC**
	Liveliness.kind	**DDS_AUTOMATIC_LIVELINESS_QOS**
	Destination_order.kind	**DDS_BY_RECEPTION_TIMESTAMP_ DESTINATIONORDER_QOS**
	Reliability.kind	**DDS_RELIABLE_RELIABILITY_QOS**
	History.kind	DDS_KEEP_LAST_HISTORY_QOS
	History.depth	10

52.10 Troubleshooting

52.10.1 Message Losses

In some cases, some of the messages logged with *Distributed Logger* can be lost, especially when the log message generation rate is high.

You can detect losses by inspecting the **LogMessage.messageId** field when subscribing to log messages. If the difference between two consecutive log messages coming from the same **LogMessage.hostAndAppId** is greater than 1, then some messages were lost.

Messages can be lost for two reasons:

- The queue that *Distributed Logger* uses to temporarily store log messages from the application until they can be written to *Connext DDS* is full.
- A log message published by *Distributed Logger* is replaced on the *Connext DDS DataWriter* queue before the *DataReaders* have a chance to receive it.

To minimize losses in the *Distributed Logger* queue, increase the queue size by using the API **RTI_DLOptions::setQueueSize**.

To minimize losses in the *DataWriter* that publishes the log messages, increase the number of messages that the *DataWriter* is caching for the process where *Distributed Logger* is running. To increase this number, configure **writer_qos.history.depth**. You can change the history depth in the QoS profile that you

use to configure *Distributed Logger*, by invoking the APIs **RTI_DLOptions::setQosLibrary** and **RTI_DLOptions::setQosProfile**.

52.10.2 Logger Device not Working

If you enable *Distributed Logger*, any previously created logger device will not be used. This is because you cannot have more than one logger device installed. When you enable *Distributed Logger*, it overwrites any previously created logger device.

Suppose *Distributed Logger* is enabled, and you are using a profile that configures *Connext DDS* to print the log messages to a file, such as:

```
<qos_profile name="..." is_default_qos="true">
    <participant_factory_qos>
        <logging>
            <output_file>/path/to/log/file/log.txt</output_file>
        </logging>
    </participant_factory_qos>
    ...
```

In this case, messages will be printed by *Distributed Logger*, they will not be sent to the log file.

If you want messages to be printed to the log file, you need to disable *Distributed Logger* first.

Chapter 53 Enabling Distributed Logger in RTI Services

Many RTI components provide integrated support for *Distributed Logger* (check the component's *Release Notes*) and include the *Distributed Logger* library in their distribution. To enable *Distributed Logger* in these components, modify their XML configuration file. In the <administration> section, add the <distributed_logger> tag as shown in this example:

```
<persistence_service name="default">
    <administration>
        <domain_id>10</domain_id>
        <distributed_logger>
            <enabled>true</enabled>
            <filter_level>DEBUG</filter_level>
            <queue_size>2048</queue_size>
            <thread>
               <priority>
                    THREAD_PRIORITY_BELOW_NORMAL
               </priority>
               <stack_size>8192</stack_size>
               <cpu_list>
                    <element>0</element>
                    <element>1</element>
                </cpu_list>
                <cpu_rotation>
                    THREAD_SETTINGS_CPU_NO_ROTATION
                </cpu_rotation>
            </thread>
        </distributed_logger>
    </administration>
    ...
</persistence_service>
```

The tags supported within the <distributed_logger> tag are described in Table 53.1 Distributed Logger Tags.

Table 53.1 Distributed Logger Tags

Tags within <distributed_logger>	Description	Number of Tags Allowed
<enabled>	Controls whether or not *Distributed Logger* should be enabled at start up. This field is required. Allowed values: TRUE or FALSE	**1** (required)
<filter_level>	The filter level for the log messages to be sent. *Distributed Logger* uses the filter level to discard log messages before they can be sent from the application/service. This is the minimum log level that will be sent out over the network. For example, when using the NOTICE level, any INFO, DEBUG and TRACE-level log messages will be filtered out and not sent from the application/service to *Connext DDS*. See important information in 53.1 Relationship Between Service Verbosity and Filter Level on page 1233. Can be set to these values: • SILENT • FATAL • SEVERE • ERROR • WARNING • NOTICE • INFO • DEBUG • TRACE (most verbose level, default)	0 or 1
<queue_size>	The size of an internal message queue used to store log messages before they are written to DDS. Default, 128 log messages.	0 or 1
<echo_to_stdout>	Controls whether or not Distributed Logger should echo log messages to standard output (true) or not (false). Allowed values: TRUE or FALSE Default: TRUE	0 or 1
<log_infrastructure_messages>	Controls whether or not Distributed Logger should log infrastructure messages Allowed values: TRUE or FALSE Default: TRUE	0 or 1
<thread>	See Table 53.2 Distributed Logger Thread Tags.	0 or 1

Table 53.2 Distributed Logger Thread Tags

Tags within <distributed_logger>/<thread>	Description	Number of Tags Allowed

<cpu_list>	Each **<element>** specifies a processor on which the Distributed Logger thread may run.
	`<cpu_list>`
	`  <element>value</element>`
	`</cpu_list>`
	Only applies to platforms that support controlling CPU core affinity (see the RTI Connext DDS Core Libraries Platform Notes).
		0 or 1

<cpu_rotation>	Determines how the CPUs in **<cpu_list>** will be used by the Distributed Logger thread. The value can be either: • THREAD_SETTINGS_CPU_NO_ROTATION The thread can run on any listed processor, as determined by OS scheduling. • THREAD_SETTINGS_CPU_RR_ROTATION The thread will be assigned a CPU from the list in round-robin order. Only applies to platforms that support controlling CPU core affinity (see the RTI Connext DDS Core Libraries Platform Notes).	0 or 1
<mask>	A collection of flags used to configure threads of execution. Not all of these options may be relevant for all operating systems. May include these bits: • STDIO • FLOATING_POINT • REALTIME_PRIORITY • PRIORITY_ENFORCE It can also be set to a combination of the above bits by using the "or" symbol (|), such as STDIO|FLOATING_POINT. Default: MASK_DEFAULT	0 or 1
<priority>	Thread priority. The value can be specified as an unsigned integer or one of the following strings. • THREAD_PRIORITY_DEFAULT • THREAD_PRIORITY_HIGH • THREAD_PRIORITY_ABOVE_NORMAL • THREAD_PRIORITY_NORMAL • THREAD_PRIORITY_BELOW_NORMAL • THREAD_PRIORITY_LOW When using an unsigned integer, the allowed range is platform-dependent.	0 or 1
<stack_size>	Thread stack size, specified as an unsigned integer or set to the string THREAD_STACK_SIZE_DEFAULT. The allowed range is platform-dependent.	0 or 1

53.1 Relationship Between Service Verbosity and Filter Level

A service's verbosity influences the way the log messages reach *Distributed Logger* and their quantity. If a service (such as *RTI Persistence Service*, *RTI Routing Service,* or another service that is integrated with *Distributed Logger*) is configured with a low verbosity, it will not pass a lot of messages to *Distributed Logger*, even if the *Distributed Logger* filter level is set to a very verbose one (such as TRACE). On the contrary, a high verbosity will work better, because it will pass more messages to *Distributed Logger;* in this case the filter level will have more effect.

Note: Since *Distributed Logger* uses a separate thread to send log messages, there is little impact on performance with more verbose filter levels. However, there is some performance penalty in services that use a higher verbosity.