OpenDDS

Release 3.28.0

OpenDDS Foundation

Apr 16, 2024

CONTENTS

1 Release Notes **1**
- 1.1 v3.28.0 . . . 1
- 1.2 v3.27.0 . . . 3
- 1.3 v3.26.1 . . . 4
- 1.4 v3.26.0 . . . 5
- 1.5 v3.25.0 . . . 6
- 1.6 v3.24.2 . . . 8
- 1.7 v3.24.1 . . . 9
- 1.8 v3.24.0 . . . 9
- 1.9 Older Releases . . . 11

2 Developer's Guide **13**
- 2.1 About This Guide . . . 13
- 2.2 Quick Start Guides . . . 14
- 2.3 Introduction to DDS . . . 21
- 2.4 Shapes Demo . . . 25
- 2.5 Introduction to OpenDDS . . . 39
- 2.6 Building and Installing . . . 51
- 2.7 Getting Started . . . 97
- 2.8 Quality of Service . . . 114
- 2.9 Conditions and Listeners . . . 135
- 2.10 Content-Subscription Profile . . . 147
- 2.11 Built-in Topics . . . 155
- 2.12 Run-time Configuration . . . 159
- 2.13 opendds_idl . . . 230
- 2.14 The DCPS Information Repository . . . 234
- 2.15 Java Bindings . . . 239
- 2.16 Modeling SDK . . . 247
- 2.17 Alternate Interfaces to Data . . . 261
- 2.18 Safety Profile . . . 266
- 2.19 DDS Security . . . 268
- 2.20 Internet-Enabled RTPS . . . 281
- 2.21 XTypes . . . 288
- 2.22 FAQ . . . 308
- 2.23 Annex . . . 313

3 Internal Documentation **315**
- 3.1 OpenDDS Development Guidelines . . . 315
- 3.2 Documentation Guidelines . . . 327
- 3.3 Unit Tests . . . 341

3.4 GitHub Actions . . . 344
3.5 Running Tests . . . 350
3.6 Bench Performance & Scalability Test Framework . . . 352
3.7 Release Process . . . 367

4 Glossary **375**
4.1 Common Terms . . . 375
4.2 Environment Variables . . . 378

5 Using OpenDDS **379**

6 Other Documentation **381**

Index **383**

CHAPTER

ONE

RELEASE NOTES

These are all the recent releases of OpenDDS.

1.1 v3.28.0

Released 2024-04-16

Download this release on GitHub.

Read the documentation for this release on Read the Docs.

1.1.1 Additions

- Added an XCDR2 value writer that can be used to serialize static and dynamic samples to XCDR2 encoding format. (PR #4421)
- Added utility to *flatten the index* to a multi-dimensional array represented by dynamic data. (PR #4421)
- A new header, `dds/OpenDDSConfig.h` is generated by configure or CMake. (PR #4482, PR #4498)
  - Users manually configuring a build will need to create this file, which may be empty, or add `#define OPENDDS_IGNORE_OPENDDSCONFIG_H_FILE` to their `ace/config.h` file.
  - See `dds/OpenDDSConfig.h.in` for details.
- `ConfigStore`
  - Converted the transport and discovery loading and `domain` section to use `ConfigStore`. (PR #4488, PR #4475, PR #4469, PR #4454)
  - OpenDDS can now be configured with environment variables. (PR #4491)
    - See *Configuration with Environment Variables* for details.
  - OpenDDS now supports multiple config files. (PR #4505)
    - See *Configuration Approach* for details.
  - The ConfigStore is available in Java. (PR #4515)
- The `@value(x)` annotation is now supported on IDL enumerators when using the IDL-to-C++11 mapping. (PR #4519)
  - See *@value(v)* for details.
- The IDL for the Shapes example was updated for interoperability. (PR #4528)
- Added *`[rtps_discovery] SpdpUserTag`*. (PR #4533)

- The data type for the OpenDDS-specific Built-in ParticipantLocation Topic now includes the lease duration. (PR #4545)
  - See *OpenDDSParticipantLocation Topic* for details.
- Allow compile-time configuration of CLOCK_BOOTTIME as the clock used for timers (PR #4568)
  - If the platform supports it, this can be done using `--boottime` when building with the configure script or *`OPENDDS_BOOTTIME_TIMERS`* when building with CMake.

1.1.2 Platform Support and Dependencies

- Building with CMake
  - Fixed building with CMake and Apple Clang on macOS without setting `-DCMAKE_CXX_STANDARD=14` or using ACE 6. (PR #4481, PR #4487)
  - Added support for C++03 and some support for building ACE/TAO with the same compiler and C++ standard as OpenDDS. (PR #4481, PR #4487)
  - Fixed building release builds on Windows at the same time as ACE/TAO (PR #4535)
  - Fixed ACE/TAO build not getting Xerces path when using *`OPENDDS_XERCES3`*. (PR #4572)

1.1.3 Fixes

- The ValueReader and ValueWriter interfaces now use `ACE_CDR::Fixed` as the type of IDL fixed values (PR #4466)
- CMake Config Package
  - Made *`opendds_target_sources(INCLUDE_BASE)`* work correctly in more cases, specifically involving generating an export header. (PR #4489)
    - Added *`opendds_target_sources(EXPORT_HEADER_DIR)`* and *`opendds_export_header(DIR)`* as part of these changes.
- Fixed bug so ConfigStore entries generated by SEDP are cleaned up. (PR #4540, PR #4485)
- Fixed bug where various RtpsDiscoveryConfig setters didn't set. (PR #4540, PR #4485)
- Fixed bug where `vread` for unions used uninitialized memory. (PR #4544)
- Fixed bug where an RTPS Reader gets stuck when heartbeat advances. (PR #4548)
- XCDR2 KeyOnly serialization of union that has no key now has a delimiter for appendable and mutable extensibility. (PR #4554)

1.1.4 Documentation

- *Run-time Configuration* (PR #4464, PR #4570, PR #4467, PR #4588)
  - Restructured configuration properties so they can be linked to directly. Also reviewed each property description to correct or add missing context as needed.
- *Introduction to OpenDDS* (PR #4467)
  - Added *Plugins* to explain generally how discovery, transports, and security libraries must be initialized when statically linking these libraries.
  - Added summaries of important information needed to use the discovery and transport libraries.

- *Quality of Service* (PR #4520)
  - Added *Property QoS*, *Data Representation QoS*, and *Type Consistency Enforcement QoS*.
  - Every policy now has a box that says if it's mutable, if it affects writer-reader association, and a link to the spec definition. Also removed large default value tables and put the default values in these boxes.
  - Added links to the QoS policies.
- Added definitions for *instance*, *unregister*, and *dispose* to the glossary. (PR #4520)
- *DDS Security*
  - Added summary of important information needed to use the security library. (PR #4467)
  - Moved *Fnmatch Expressions* into an "annex" file so it can be common between security and partitions QoS. (PR #4520)
- `ConfigStore`
  - Add *configuration capabilities* to DevGuide. (PR #4556)

1.2 v3.27.0

Released 2024-02-07

Download this release on GitHub.

Read the documentation for this release on Read the Docs.

1.2.1 Additions

- Complete interfaces for dealing with DynamicData and DynamicTypes. (PR #4320, PR #4339)
- It is now possible to specify the *validity for individual publish/subscribe actions* in DDS Security Permission documents. This is an OpenDDS extension. (PR #4344)
- Building with CMake
  - Added new options for *how to get ACE/TAO*. (PR #4346)
- CMake Config Package
  - Added *`OPENDDS_ACE_VERSION`* and *`OPENDDS_TAO_VERSION`*. (PR #4346)
- Add a warning that `@optional` is not supported. (PR #4355)
- Convert discovery configurations (`repository`, static discovery, `rtps_discovery` including templates) to key-value store. (PR #4360, PR #4361, PR #4426, PR #4411, PR #4276, PR #4347)
- Convert ICE configuration to key-value store. (PR #4360, PR #4361, PR #4426, PR #4411, PR #4276, PR #4347)
- Change `transport_template` and `rtps_discovery` template processing to not generate new keys. (PR #4360, PR #4361, PR #4426, PR #4411, PR #4276, PR #4347)

1.2.2 Platform Support and Dependencies

- Improved support for configure script detection of clang on Linux (PR #4449)
- When using Visual C++, OpenDDS can now be configured using `--std=c++NN` (NN = 17 or 20). (PR #4452)

1.2.3 Fixes

- Updated the *read* and *write* semantics of DynamicData for union, expandable collections (sequence and string), and optional member of an aggregated type. (PR #4278)
- Fixed memory leak where instances were not cleaned up with *exclusive ownership*. (PR #4343)
- Removed the special handling for sequence members with length code of 5,6, or 7. (PR #4376)
- Reading data from a dynamic data object for a primitive type now must use `MEMBER_ID_INVALID` id. (PR #4376)
- `create_datawriter` and `create_datareader` check if the topic belongs to the same participant as the publisher/subscriber. (PR #4398)
- Fixed uninitialized `durability_service` in Topic QoS when using QoS-XML. (PR #4424)
- Fixed a bug where compiling IDL with `-Lc++11 -Gequality` produced code outside of a namespace that didn't compile. (PR #4450)
- `SedpLocalAddress` now defaults to *`[common] DCPSDefaultAddress`* to behave like `SpdpLocalAddress` and `local_address`. (PR #4451)

1.2.4 Notes

- `TheParticipantFactory*` will now return a null pointer when *Configuration with a File* doesn't exist. (PR #4372)

1.3 v3.26.1

Released 2023-11-14

Download this release on GitHub.

Read the documentation for this release on Read the Docs.

1.3.1 Fixes

- Building with CMake
  - Fixed Issue #4328, where each run of CMake effectively always appended the MPC features to `default.features` in ACE. (PR #4330)
- Fixed a corner case in RTPS ParameterList parsing (PR #4336)
- Reject some types of invalid RTPS DataFrag submessages (PR #4348)

1.4 v3.26.0

Released 2023-10-23

Download this release on GitHub.

Read the documentation for this release on Read the Docs.

1.4.1 Additions

- OpenDDS can now be built using CMake for most common scenarios. (PR #4203, PR #4214)
  - This is still considered somewhat experimental as it doesn't support *everything that an MPC-built OpenDDS currently can*.
  - See *Building OpenDDS Using CMake* for details.
- Convert transport configurations (`rtps_udp`, `multicast`, `shmem`, `tcp`, `udp`) uses key-value store. (PR #4162, PR #4270, PR #4272, PR #4241, PR #4242, PR #4243, PR #4249, PR #4255)
- CMake Config Package
  - Added *opendds_install_interface_files* to help install IDL files and the files generated from them. (PR #4203, PR #4214)
  - Added *OPENDDS_HOST_TOOLS* and *OPENDDS_ACE_TAO_HOST_TOOLS* to allow cross compiling applications with both MPC and CMake-built OpenDDS. (PR #4203, PR #4214)
  - *opendds_target_sources*:
    * Added *opendds_target_sources(INCLUDE_BASE)* to preserve the directory structure of the IDL files for compiling the resulting generated files and installing everything using *opendds_install_interface_files*. (PR #4203, PR #4214)
    * Added *opendds_target_sources(USE_VERSIONED_NAMESPACE)* as a shortcut to the `-Wb, versioning_*` IDL compiler options. (PR #4203, PR #4214)
- Support sending DynamicDataAdapter sample via DynamicDataWriter (PR #4226)
- Added export macro to ConditionImpl (PR #4295)

1.4.2 Deprecations

- Deprecated *OPENDDS_FILENAME_ONLY_INCLUDES* in favor of *opendds_target_sources(INCLUDE_BASE)*. (PR #4203, PR #4214)

1.4.3 Fixes

- Improved the *subject name* parsing to better conform to the DDS Security spec. (PR #4201)
  - The order of attributes in subject names is now significant when comparing them.
- Remove from TypeLookupService when remote endpoint is removed from SEDP (PR #4216)
- WaitSet is now notified when DataWriter liveliness is lost. (PR #4223)
- ICE doesn't use IPv4-mapped IPv6 addresses anymore. (PR #4230)
- Efficiency: Remove per-element locking in JobQueue (PR #4253)

- RtpsRelay: fixed bug in record_activity's use of remove in GuidAddrSet (PR #4254)
- Fix warnings in typeobject_generator when using TAO 3 (PR #4262)
- Fix null pointer when participant is absent when updating locators (PR #4265)
- Initialize variables in TypeObject to silence warnings (PR #4292)
- RtpsRelay: Use ACE_Message_Block's locking strategy for cached SPDP to fix tsan warning (PR #4293)
- Fix tsan warning in ReactorTask (PR #4298)

1.4.4 Documentation

- Removed documentation for `-Grapidjson` option of `opendds_idl` that was removed in 3.20.0 (PR #4231)
- Remove reference to mailing lists (PR #4234)
- Restructured parts of *DDS Security* page and expanded documentation of some XML security document elements. (PR #4281)
- OS-specific instructions will now be automatically selected based on the browser's user agent. (PR #4281)
- OMG specification section references are now links to that section in the specification PDF. (PR #4281)
- Move build and install instructions to DevGuide (PR #4294)
- Incorporate the quick start guides, FAQ, and shapes demo into the DevGuide. (PR #4297)

1.4.5 Notes

- Using Perl 5.38.0 might prevent TAO from building properly, see here for details.

1.5 v3.25.0

Released 2023-07-20

Download this release on GitHub.

Read the documentation for this release on Read the Docs.

1.5.1 Additions

- The Observer interface now has support for dispose and unregister. (PR #4137)
- OpenDDS now stores configuration information in a key-value store. (PR #4138, PR #4134, PR #4151)
  - Configuration values can be set via API, config file, or command line.
    * Currently applies to the *common* section and common transport configuration.
- Added `encode_to_string`, `encode_to_bytes`, `decode_from_string`, and `decode_from_bytes` to `TypeSupport`. (PR #4144, PR #4122, PR #4133, PR #4135)
  - These methods convert samples to and from other formats.
  - Currently only `OpenDDS::DCPS::JSON_DATA_REPRESENTATION` is supported.
- Add `-Gequality` option to opendds_idl to generate == and != for structs and unions. (PR #4154)

  - The members of the struct or union must have a type that could appear in a DDS topic and be supported by opendds_idl.
  - The motivation for this change was to make the generated code more useful as many users go on to define these operators.

- CMake Config Package
  - Added *executable targets*. (PR #4160)
  - *OPENDDS_CMAKE_VERBOSE* output has been expanded, but now accepts a list of categories to control how much is logged. (PR #4160)
  - Added *opendds_export_header* to generate an export header. (PR #4160)
  - *opendds_target_sources*:
    * Added *opendds_target_sources(GENERATE_SERVER_SKELETONS)* to allow `tao_idl` to generate code for CORBA servers. (PR #4140)
    * Added *opendds_target_sources(AUTO_LINK)* as a fine-grained version of *OPENDDS_AUTO_LINK_DCPS*. (PR #4140)
    * Added *opendds_target_sources(SKIP_TAO_IDL)* to disable `tao_idl`. (PR #4140)
    * Added *opendds_target_sources(SKIP_OPENDDS_IDL)* to disable `opendds_idl`. (PR #4140)
    * Added *opendds_target_sources(USE_EXPORT)* to allow overriding the generated export header with an existing one. (PR #4160)
  - Libraries and features can be passed to `find_package(OpenDDS COMPONENTS)` to change what is required. (PR #4160, PR #4140)
    * See *Components* for details.

1.5.2 Security

- Fixed null pointer exception caused by RTPS Parameters with incorrect zero size. (PR #4197)

1.5.3 Fixes

- CMake Config Package
  - Made linking dependencies and macro definitions closer match using MPC with OpenDDS and TAO. (PR #4140)
  - Fixed issues with passing `OPENDDS_IDL_OPTIONS -SI` to `opendds_target_sources`. (PR #4140)
- Fixed issue deserializing bounded sequences with JSON (PR #4150)
  - The deserialization will fail if the JSON input contains more elements than the bounded sequence can hold.
- Updated the RtpsRelay's tracking of client IP addresses so they are removed when no longer used. (PR #4202)
  - The RtpsRelay configuration option -MaxAddrSetSize was renamed to -MaxIpsPerClient

1.5.4 Documentation

- Moved various markdown files into the Sphinx documentation so that they are now included along with the Developer's Guide: (PR #4139)
  - `INSTALL.md` is now *Building and Installing*.
  - `docs/dependencies.md` is now *Dependencies*.
  - `docs/cmake.md` is now *Using OpenDDS in a CMake Project*.
  - `docs/android.md` is now *Android*.
  - `docs/ios.md` is now *iOS*.
- Restructured how the documentation is presented to cleanly separate the Developer's Guide and internal documentation. (PR #4139)
- Added a *proper main page*. (PR #4139)
- Added *Glossary*. (PR #4139)
- In addition to `NEWS.md`, started adding release notes to *Release Notes*. (PR #4125)

1.5.5 Notes

- CMake Config Package
  - `OPENDDS_TARGET_SOURCES` is now called `opendds_target_sources`. (PR #4140)
    * CMake macros and functions names are case insensitive, so this should have no effect on CMake code.

1.6 v3.24.2

Released 2023-06-30

Download this release on GitHub.

Read the documentation for this release on Read the Docs.

1.6.1 Security

- Fixed a vulnerability in the rtps_udp transport where an acknowledgement sequence number beyond the maximum expected by the writer leads to an assert and incorrect state. (PR #4155)
  - Thanks to Seulbae Kim (@squizz617) for discovering this.

1.6.2 Fixes

- Fixed leaked shared memory by the shared memory transport. (PR ##4171)
  - For a 100% fix, a new ACE version including https://github.com/DOCGroup/ACE_TAO/pull/2077 must be used.
- Fixed bug introduced by PR #4120 (PR #4180, PR #4184)

  - The fix introduced in #4120 causes the TransportClient to silently drop messages when the client's guid is not initialized. This causes issues for TransportClients that send messages to the transport before association. One such example is a DataWriter with liveliness configured. The DataWriter will send liveliness messages to the transport (which will be dropped) and hang waiting for them to be delivered.
  - The solution was set the guid for a TransportClient before calling any method that uses the guid.

1.6.3 Notes

- PR #4180 required changes in InfoRepoDiscovery's IDL, so InfoRepo compatibility with older versions has been broken.

1.7 v3.24.1

Released 2023-04-22

Download this release on GitHub.

Read the documentation for this release on Read the Docs.

1.7.1 Fixes

- Fixed compile warnings in TypeSupport that can happen with GCC and `-O2` or higher (PR #4117)
- Fixed compile error in TypeSupport for IDL that contains a typedef of a typedef (PR #4117)
- Fixed bug in the tcp transport where readers and writers can fail to associate (PR #4120)
- Fixed issue in some headers that could leak `#pragma pack (push, 8)` into user code on Visual Studio (PR #4123)
- Fixed theoretical infinite loop in rtps_udp transport code (PR #4124)

1.7.2 Documentation

- Removed invalid links and references in README and the Developer's Guide and fixed other minor issues (PR #4115, PR #4116, PR #4121, PR #4126)
- Changed theme used by the Sphinx documentation to make the Developer's Guide easier to navigate (PR #4127)
- Added copy buttons to embedded code and code-like examples (PR #4127)

1.8 v3.24.0

Released 2023-04-11

Download this release on GitHub.

Read the documentation for this release on Read the Docs.

1.8.1 Additions

- The OpenDDS Developer's Guide is now available at https://opendds.readthedocs.io/ (PR #4100, PR #4101, PR #4102, PR #4103, PR #4104, PR #4105, PR #4051, PR #4092, PR #4094, PR #4095)
  - The Sphinx/reStructuredText source for this new format is now located in the repo at `docs/devguide`
- DOCGroup ACE6/TAO2 is now the default ACE/TAO for OpenDDS, OCI ACE/TAO is no longer supported (PR #4069)
- Dynamic content subscription (PR #3988)
  - This allows `DynamicDataReaders` to use `QueryCondition` and `ContentFilteredTopic` and allows `DynamicDataWriters` to do filtering on behalf of matched `DataReaders` that use `ContentFilteredTopic`.
- `DynamicData`
  - Can now read and write enum members as strings (PR #4022)
  - `DynamicDataImpl` now uses lazy initialization to reduce memory usage (PR #4024)
  - `get_int64_value` and `get_uint64_value` can now cast from different types (PR #4078)
- Added aliases for IDL types from XTypes spec such as `DDS::UInt32` (PR #3394)
  - See `dds/DdsDcpsCore.idl` for all of them.
- Added PublicationMatchedStatus Current Count To RtpsRelay Statistics (PR #4006)
- Allow reassembly of overlapping fragment ranges in RTPS (PR #4035, PR #4047)
- Added hardening features to RtpsRelay (PR #4045)
  - These are configured with the new options `-MaxAddrSetSize` and `-RejectedAddressDuration`.
- Can now cross-compile on macOS (PR #4048)
- Added `OPENDDS_AUTO_LINK_DCPS` and `OPENDDS_USE_CORRECT_INCLUDE_SCOPE` global options to the CMake package (PR #4071)
- Expanded support for using C++ keywords in IDL (PR #4073)
- IDL file and generated TypeSupport.idl can now be in different directories (PR #4077)
- Improved support for anonymous types in unions branches (PR #4078)

1.8.2 Fixes

- Fixed `rtps_relay_address_change` deadlocks (PR #3989)
- Fixed RtpsUdpTransport data race from `relay_stun_mutex_` (PR #3990)
- Fixed invalid socket handles in RtpsUdpTransport (PR #4002)
- Fixed index increment in `GuidPartitionTable::prepare_relay_partitions` (PR #4005)
- Improved reliability of the shared memory transport (PR #4028)
- Fixed a bug in content filtering with enum comparisons on serialized samples (PR #4038)
- Secure writers and readers in same participant can now associate (PR #4041)
- Fixed transport config and transport instance derived from template conflicting (PR #4058)

- Fixed issue with using `-o` in `tao_idl`/`opendds_idl` options in `OPENDDS_TARGET_SOURCES` and those directories are now automatically included (PR #4071)
- XTypes (PR #4078)
  - `TypeObject`s struct and union members used to be sorted by member ID, but they are now sorted by declaration order as the XTypes spec calls for.

    By default member IDs increment starting at 0, and in that case the `TypeObject`s will be the same. If `@autoid(hash)`, `--default-autoid hash`, or `@id(ID)` are being used then the order could be different. This could cause some reader/writer matching incompatibility with older versions of OpenDDS:

    * Topics with final and appendable structs will no longer match.
    * If `DISALLOW_TYPE_COERCION` QoS is being used, then all topics where the order differ will not longer match. Note that this is true for any time the type hash changes.
    * Pass the *`opendds_idl --old-typeobject-member-order`* to use the non-standard order.
  - The size of XCDR2 member parameters in mutable structs and unions is now correctly interpreted when the "length code" is 5, 6, or 7.
    * This is an optimization that OpenDDS doesn't serialize samples with, so this could only be an issue when dealing with samples from other DDS implementations.
  - `DynamicDataImpl` (`DynamicData` made by `DynamicDataFactory` that can be passed to `DynamicDataWriter`):
    * `get_member_id_at_index` now returns ids for members that haven't been initialized yet.
    * Fixed incorrect serialization of keyed unions for instance registration, disposal, and unregistration samples.
    * Fixed errors from serializing some cases of arrays and sequences.

1.8.3 Notes

- Release files will only be uploaded to GitHub from now on
- `OpenDDS::DCPS::RepoId` has been removed, if needed use `OpenDDS::DCPS::GUID_t` instead (PR #3972)

1.9 Older Releases

Older releases can be found in `NEWS.md`

CHAPTER

TWO

DEVELOPER'S GUIDE

The Developer's Guide explains how to use OpenDDS.

2.1 About This Guide

This Developer's Guide corresponds to OpenDDS version 3.28.0. This guide is primarily focused on the specifics of using and configuring OpenDDS to build distributed publish-subscribe applications. While it does give a general overview of the OMG Data Distribution Service, this guide is not intended to provide comprehensive coverage of the specification. The intent of this guide is to help you become proficient with OpenDDS as quickly as possible. Readers are encouraged to submit corrections to this guide using a GitHub pull request. The source for this guide can be found at `docs/devguide` and *Documentation Guidelines* contains guidance for editing and building it.

2.1.1 Conventions

This guide uses the following conventions:

`Fixed pitch text`	Indicates example code or information a user would enter using a keyboard.
Italic text	Indicates a point of emphasis.
...	An ellipsis indicates a section of omitted text.

2.1.2 `DDS_ROOT`

This guide refers to the *`DDS_ROOT`* environment variable which should point to the base directory of the OpenDDS distribution. Often, this will be written as `$DDS_ROOT` indicating the value of the environment variable.

2.1.3 Examples

The examples in this guide are intended for the learning of the reader and should not be considered to be "production-ready" code. In particular, error handling is sometimes kept to a minimum to help the reader focus on the particular feature or technique that is being presented in the example. The source code for all these examples is available as part of the OpenDDS source code distribution in the `DevGuideExamples` directory. MPC files are provided with the examples for generating build-tool specific files, such as GNU Makefiles or Visual C++ project and solution files. To run an example, execute the `run_test.pl` Perl script.

2.2 Quick Start Guides

2.2.1 Windows

The goal of this guide is help you download and compile OpenDDS and run a simple example.

Build Directions

1. Ensure that your environment has:
   - Visual Studio
   - Perl
   - Optional Java SDK 1.5 or greater for Java JNI binding support

   See *Dependencies* for a complete list of dependencies and `README.md#supported-platforms` for supported platforms.
2. Download and extract the latest zip from the download site
3. Start a Visual Studio Command Prompt
4. Enter the `OpenDDS-<version>` directory
5. ```
   configure
   ```

   To enable Java support, use

   ```
   configure --java
   ```
6. Determine the solution to build from the output of the configure script. The solution will have a `.sln` extension.
7. Start Visual Studio by executing the solution from the command prompt, e.g., `DDS_TAOv2_all.sln`
8. Select **Build** -> **Build Solution**

See Support if you encounter problems with configuration or building.

Run the Messenger Example

1. ```
   setenv
   ```
2. For the C++ example

   ```
   cd DevGuideExamples\DCPS\Messenger
   ```

   For the Java example

   ```
   cd java\tests\messenger
   ```
3. ```
   perl run_test.pl
   ```

The Messenger Example starts an InfoRepo, publisher, and subscriber. The InfoRepo allows the publisher and subscriber to find each other. Once the publisher finds the subscriber, it sends 10 messages to the subscriber and waits 30 seconds for the subscriber to acknowledge the messages.
   ```

Important: The `setenv.cmd` script sets various environment variables needed for building, linking, and running with OpenDDS. Be sure to execute `setenv.cmd` if you start a new Visual Studio Command Prompt.

Next Steps

See *Getting Started* for a detailed explanation of the Messenger C++ Example or *Java Bindings* for the Java Example.

2.2.2 Linux/macOS

The goal of this guide is help you download and compile OpenDDS and run a simple example.

Build Directions

1. Ensure that your environment has:
   - a C++ compiler (GCC or Clang)
   - GNU Make
   - Perl
   - Optional Java SDK 1.5 or greater for Java JNI binding support

   See *Dependencies* for a complete list of dependencies and `README.md#supported-platforms` for supported platforms.
2. Download and extract the latest tar.gz file from the download site
3. Enter the `OpenDDS-<version>` directory
4. ```
   ./configure
   ```

   To enable Java bindings, use

   ```
   ./configure --java
   ```
5. ```
   make
   ```

See Support if you encounter problems with configuration or building.

Run the Messenger Example

1. ```
   source setenv.sh
   ```
2. For the C++ example

   ```
   cd DevGuideExamples/DCPS/Messenger
   ```

   For the Java example

   ```
   cd java/tests/messenger
   ```
   ```

3. `./run_test.pl`

The Messenger Example starts an InfoRepo, publisher, and subscriber. The InfoRepo allows the publisher and subscriber to find each other. Once the publisher finds the subscriber, it sends 10 messages to the subscriber and waits 30 seconds for the subscriber to acknowledge the messages.

Important: The `setenv.sh` script sets various environment variables needed for running OpenDDS tests. Be sure to `source setenv.sh` if you start a new terminal session.

Next Steps

See *Getting Started* for a detailed explanation of the Messenger C++ Example or *Java Bindings* for the Java Example.

2.2.3 Raspberry Pi

The goal of this guide is help you download and compile OpenDDS for Linux on the Raspberry Pi and run a simple example.

Build Directions

For this guide you need a Raspberry Pi set up with Raspbian Bullseye Linux (the Lite variant works) and connected to a local network. You will also need a Linux host system (or virtual machine) connected to the same network where we will build OpenDDS. We have tested with Ubuntu 20.04.3 LTS x86_64 and CentOS Stream 8 x86_64. This guide assumes you know the address and user credentials of the Pi. Perform these all these steps on the host computer:

1. Ensure that your host environment has:
   - a C++ compiler
   - GNU Make
   - Perl
   - CMake if building with DDS Security
   - Optional Java SDK 1.5 or later for Java binding support
2. Download and extract the latest tar.gz file from the download site
3. Download and extract the Linux GCC 10.2 cross-compiler toolchain from the ARM Developer website. Rename the resulting directory from `gcc-arm-10.2-2020.11-x86_64-arm-none-linux-gnueabihf` to `cross-pi-gcc` and move it to `/opt`.
4. If building with *DDS Security*, follow *the steps below* to build OpenSSL and Xerces-C++ for the Pi.
5. Enter the `OpenDDS-<version>` directory
6. Run the following as a single command.

   ```
   ./configure --target=linux-cross --target-compiler=/opt/cross-pi-gcc/bin/arm-none-
   ↪linux-gnueabihf-g++ (additional options)
   ```

   Additional options:

   - If using DDS Security:

```
--security --no-tests --openssl=SSL_ROOT --xerces3=XERCESCROOT
```

Replace `SSL_ROOT` and `XERCESCROOT` with the paths for your system (see *below*).

Note that the Google Test Framework is not supported in this configuration, therefore `--no-tests` is required when using `--security`.

- If using Java bindings:

```
--java
```

7. `make`

See Support if you encounter problems with configuration or building.

Copying OpenDDS to the Pi

There are multiple ways to do this, including using a flash drive. We do not recommend copying the entire build tree, since it can be 2+ GB. The following steps copy the OpenDDS runtime libraries, support scripts, and test executables over the network.

1. Leave the `OpenDDS-<version>` directory:

```
cd ..
```

2.
```
tar czhf OpenDDS-<version>.tar.gz OpenDDS-<version>/build/target/ACE_wrappers/lib␣
↪OpenDDS-<version>/build/target/lib OpenDDS-<version>/build/target/bin OpenDDS-
↪<version>/build/target/ACE_wrappers/bin/PerlACE OpenDDS-<version>/build/target/
↪DevGuideExamples/DCPS/Messenger
```

3. `scp OpenDDS.tar.gz USER@ADDRESS:`

   where `USER` and `ADDRESS` are the username and IP address of your Raspberry Pi. It will ask you for the password for the user on the Pi.

4. `ssh USER@ADDRESS`

   to access the Pi, taking the same information as the previous command.

5. `tar xzf OpenDDSOpenDDS-<version>.tar.gz`

Run the Messenger Example

1. While still in ssh on the Pi, enter the `OpenDDS-<version>` directory

2.
```
export DDS_ROOT="$PWD/build/target"
```

3.
```
export ACE_ROOT="$DDS_ROOT/ACE_wrappers"
```

4.
```
export LD_LIBRARY_PATH=${LD_LIBRARY_PATH}:"$ACE_ROOT/lib":"$DDS_ROOT/lib"
```

5. ```
   export PATH=${PATH}:"$ACE_ROOT/bin":"$DDS_ROOT/bin"
   ```

6. For the C++ example:

   ```
   cd $DDS_ROOT/DevGuideExamples/DCPS/Messenger
   ```

   For the Java example:

   ```
   cd $DDS_ROOT/java/tests/messenger
   ```

7. ```
   ./run_test.pl
   ```

The Messenger Example starts an InfoRepo, publisher, and subscriber. The InfoRepo allows the publisher and subscriber to find each other. Once the publisher finds the subscriber, it sends 10 messages to the subscriber and waits 30 seconds for the subscriber to acknowledge the messages.

Next Steps

See *Getting Started* for a detailed explanation of the Messenger C++ Example or *Java Bindings* for the Java Example.

Building Third-Party Libraries

Setup

1. Create and enter a directory to perform the build.
2. Set the `BUILD_ROOT` shell variable to the working directory.
3. This will be the parent directory for the source repos and "staged" installation directories for the cross-compiled software.

OpenSSL

1. In `$BUILD_ROOT`, download and extract the OpenSSL source archive, and change to that extracted directory. See *OpenSSL* for any version requirements for OpenSSL.
2. ```
   ./Configure --cross-compile-prefix=/opt/cross-pi-gcc/bin/arm-none-linux-gnueabihf-␣
   ↪linux-armv4
   ```
3. ```
   make
   ```
4. ```
   make install DESTDIR=$BUILD_ROOT/pi-openssl
   ```
   ```

Xerces-C++

1. In `$BUILD_ROOT`, create the file `PiToolchain.cmake` with the contents:

```
set(CMAKE_SYSTEM_NAME Linux)
set(CMAKE_SYSTEM_PROCESSOR arm)
set(CMAKE_C_COMPILER /opt/cross-pi-gcc/bin/arm-none-linux-gnueabihf-gcc)
set(CMAKE_CXX_COMPILER /opt/cross-pi-gcc/bin/arm-none-linux-gnueabihf-g++)
set(CMAKE_FIND_ROOT_PATH /opt/cross-pi-gcc/arm-none-linux-gnueabihf)
set(CMAKE_FIND_ROOT_PATH_MODE_PROGRAM NEVER)
set(CMAKE_FIND_ROOT_PATH_MODE_LIBRARY ONLY)
set(CMAKE_FIND_ROOT_PATH_MODE_INCLUDE ONLY)
set(CMAKE_FIND_ROOT_PATH_MODE_PACKAGE ONLY)
set(THREADS_PTHREAD_ARG 2)</pre></li>
```

2. In `$BUILD_ROOT`, download and extract the Xerces-C++ source archive, and change to that extracted directory. See *Xerces* for any version requirements for Xerces.

3. ```
   mkdir build-pi
   cd build-pi
   ```

4. ```
   cmake -DCMAKE_TOOLCHAIN_FILE=$BUILD_ROOT/PiToolchain.cmake -DCMAKE_INSTALL_PREFIX=
   ↪$BUILD_ROOT/pi-xerces ..
   ```

5. ```
   make
   ```

6. ```
   make install
   ```

Using these with OpenDDS

- For `configure` (see *above*)
  - `SSL_ROOT` is `$BUILD_ROOT/pi-openssl/usr/local`
  - `XERCESCROOT` is `$BUILD_ROOT/pi-xerces`
- For runtime loading of shared objects
  - copy `$BUILD_ROOT/pi-openssl/usr/local/lib/libcrypto.so.1.1` to `build/target/lib`
  - copy `$BUILD_ROOT/pi-xerces/lib/libxerces-c-3.2.so` to `build/target/lib`

2.2.4 Docker

This guide will take you through the process of compiling and runnning an OpenDDS application with Docker. Docker images containing a pre-built OpenDDS are available in GitHub Container Registry. An image corresponding to a particular release has a tag of the form `DDS-X.xx`, e.g., `DDS-3.23`.

Prerequisites

Check that `docker` and `docker-compose` are installed.

```
docker --version
docker-compose --version
```

Compile the Messenger Example

1. Enter a container

   ```
   docker run --rm -ti -v "$PWD:/opt/workspace" ghcr.io/opendds/opendds:latest-release
   ```

2. Copy the `Messenger` directory

   ```
   cp -R /opt/OpenDDS/DevGuideExamples/DCPS/Messenger Messenger
   cd Messenger
   ```

3. Configure and build the Messenger example

   ```
   source /opt/OpenDDS/setenv.sh
   mwc.pl -type gnuace
   make
   ```

4. Exit the container

   ```
   exit
   ```

Run the Messenger Example with RTPS

1. Enter the `Messenger` directory

   ```
   cd Messenger
   ```

2. Run the Messenger example with RTPS

   ```
   docker-compose up
   ```

Run the Messenger Example with InfoRepo

1. Enter the `Messenger` directory if not done as part of the previous section

   ```
   cd Messenger
   ```

2. Run the Messenger example with InfoRepo

   ```
   docker-compose -f docker-compose-inforepo.yml up
   ```

3. Use Control-C to kill the InfoRepo process

Next Steps

See *Getting Started* for a detailed explanation of the Messenger C++ Example or *Java Bindings* for the Java Example.

See *Building and Installing* for detailed build instructions.

2.3 Introduction to DDS

The Data Distribution Service (DDS ®) is a specification for distributed systems based on the publish-subscribe paradigm published by the Object Management Group (OMG ®). DDS applications efficiently share data across the network using strongly-typed and asynchronous cache updates based on topics and QoS policies. DDS v1.4 2.2.1.2 Conceptual Outline contains a detailed overview of DDS. Data-Centric Publish-Subscribe (DCPS) is the application model defined by the DDS specification. This section describes the main concepts and entities of the DCPS API and discuss how they interact and work together.

2.3.1 Basic Concepts

This is an overview of the DDS DCPS API:

The following subsections define the concepts shown in the diagram.

Domain

The *domain* is the fundamental partitioning unit within DCPS. Each of the other entities belongs to a domain and can only interact with other entities in that same domain. Application code is free to interact with multiple domains but must do so via separate entities that belong to the different domains. Domains are identified by an integer identifier. There is no entity in the DCPS API that represents the domain.

Entity

An *entity* is an object in a domain that has a QoS policy, status, and can be used with listeners and waitsets. "Entity" is an interface that is implemented by the other concepts in a DCPS domain. The QoS policy for each derived entity is specialized for that entity.

Domain Participant

A *domain participant* or just *participant* is the entry-point for an application to interact within a particular domain. The domain participant is a factory for many of the objects involved in writing or reading data.

Topic

The *topic* is the fundamental means of interaction between publishing and subscribing applications. Each topic has a unique name within the domain that connects publishers to subscribers. Multiple processes can publish on a topic and multiple processes can subscribe to a topic which allows for many-to-many communication. A publishing process specifies the topic when publishing samples and a subscribing process requests samples via the topic.

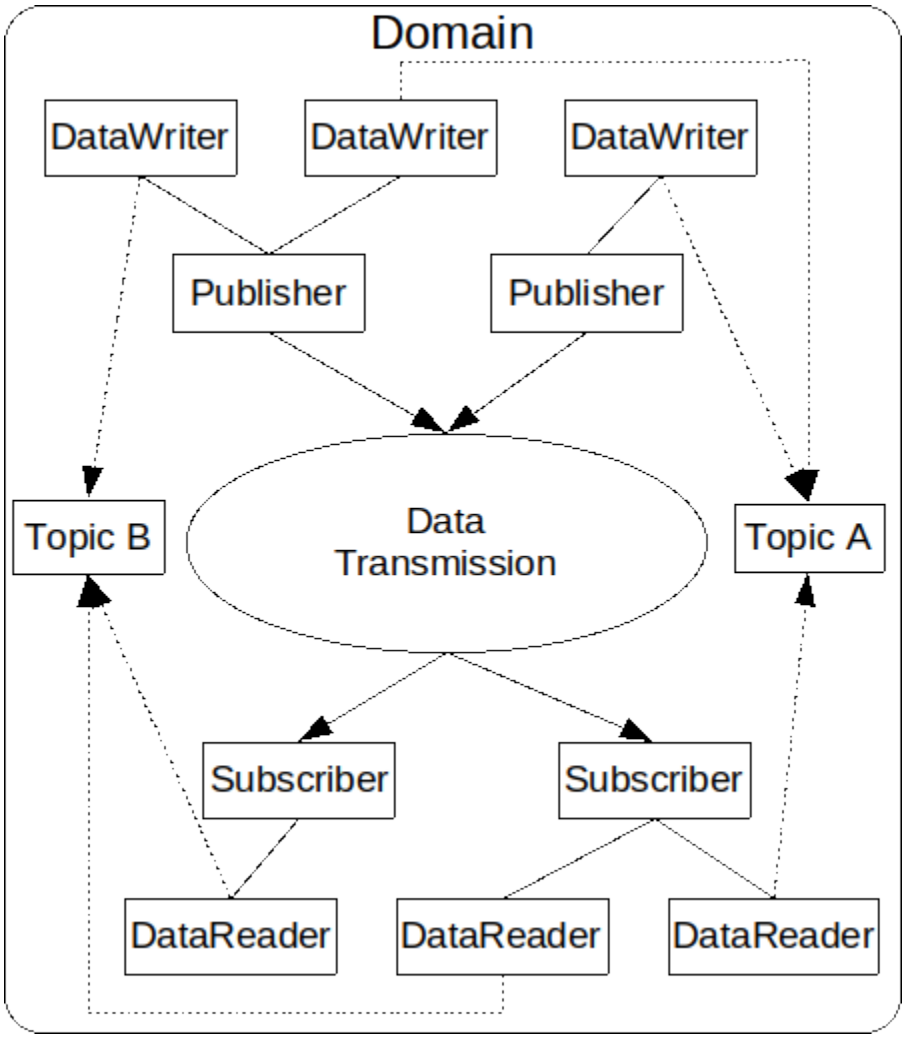


Fig. 1: DCPS Conceptual Overview

Samples, Instances, and Types

In DCPS terminology, an application publishes individual data *samples* for different *instances* on a topic. Each topic has a specific type that describes the samples. Each topic data type can specify zero or more fields that make up its *key*. Each instance is associated with a unique value for the key. A publishing process publishes multiple data samples on the same instance by using the same key value for each sample. Conceptually, a topic data type without a key has a single instance.

A type can be defined at compile-time (static type) or at run-time (dynamic type). An application can use both static types and dynamic types. Static types are defined using OMG Interface Description Language (*IDL*). See *Defining Data Types with IDL* for more information and examples. Dynamic types can be created or acquired via API. (OpenDDS current does not support the creation of dynamic types.)

The type associated with a topic is relative to a participant. That is, two different participants may have different definitions for the same topic type. A feature called *XTypes* allows participants with different topic types to still exchange samples. If XTypes is not used, then the types must match exactly.

DataWriter

A *data writer* is used by the publishing application code to introduce samples for distribution. Each data writer is bound to a particular topic. The application uses the data writer's type-specific interface to publish samples on that topic. The data writer is responsible for marshaling the data and passing it to the publisher for transmission.

Dynamic data writers can be used when code generated from IDL is not available or desired. Dynamic data writers are also type-safe, but type checking happens at runtime.

Publisher

A *publisher* is responsible for taking the published data and disseminating it to all relevant subscribers in the domain. The exact mechanism employed is left to the service implementation. A participant can have multiple publishers and each publisher can have multiple data writers which may be on different topics. A publisher can group a sequence of writes that span multiple data writers so that it appears as a coherent change to subscribers.

Subscriber

A *subscriber* receives the data from the publisher and passes it to any relevant data readers that belong to it. A participant can have multiple subscribers and each subscriber can have multiple data readers which may be on different topics.

DataReader

A *data reader* takes data from the subscriber, demarshals it into the appropriate type for that topic, and delivers the sample to the application. Each data reader is bound to a particular topic. The application uses the data reader's type-specific interfaces to receive the samples.

Dynamic data readers can be used when code generated from IDL is not available or desired. Dynamic data readers are also type-safe, but type checking happens at runtime.

2.3.2 Discovery, Matching, and Association

Discovery is the process whereby a participant learns about the publications and subscriptions offered by other participants. The *Data Distribution Service (DDS) for Real-Time Systems* leaves the details of discovery to the implementation.

After discovering a remote publication and subscription, a participant compares the remote entity with its local entities to determine if they are compatible. This process is called *matching*. A data writer and data reader match if they are on the same topic, they have compatible types, and they have compatible QoS policies.

If a local entity matches a remote entity, then the implementation is configured to allow data to flow from the data writer to the data reader. This is called *association*.

See also:

Discovery
: The discovery impementations availables in OpenDDS.

2.3.3 Quality of Service Policies

The DDS specification defines a number of Quality of Service (QoS) policies that are used by applications to specify their QoS requirements to the service. Participants specify what behavior they require from the service and the service decides how to achieve these behaviors. These policies can be applied to the various DCPS entities (topic, data writer, data reader, publisher, subscriber, domain participant) although not all policies are valid for all types of entities.

Subscribers and publishers are matched using a request-versus-offered (RxO) model. Subscribers *request* a set of policies that are minimally required. Publishers *offer* a set of QoS policies to potential subscribers. The DDS implementation then attempts to match the requested policies with the offered policies; if these policies are compatible then the association is formed.

See also:

Quality of Service
: The QoS policies available in OpenDDS and how to use them.

2.3.4 Conceptual Data Flow

The application on the publishing side initiates the flow of data by writing a sample to the DataWriter which then passes it to its associated Publisher. The Publisher sends the sample to associated Subscribers. Each Subscriber gives the received sample to its DataReaders that are associated with the sending DataWriter. The flow ends when the application on the subscribing side retrieves the data from the DataReader.

Quality of Service (QoS) Policies control the flow of the data through the system. The QoS policies of the Publisher, DataWriter, and Topic control the data on the sending side. The QoS policies of the Subscriber, DataReader, and Topic control the data on the receiving side.

2.3.5 Built-in Topics (BITs)

The DDS specification defines a number of topics that are built-in to the DDS implementation. Subscribing to these *built-in topics* gives application developers access to the state of the domain being used including which topics are registered, which data readers and data writers have been discovered and their status, and the QoS settings of the various entities. While subscribed, the application receives samples indicating changes in the entities within the domain.

See also:

Built-in Topics
The built-in topics available in OpenDDS and how to use them.

2.3.6 Listeners

The DCPS API defines a callback interface for each entity that allows an application to listen for certain state changes or events pertaining to that entity. For example, a Data Reader Listener is notified when there are data values available for reading.

See also:

Listeners
The listeners available in OpenDDS and how to use them.

2.3.7 Conditions

Conditions and *Wait Sets* can also be used to detect events of interest in DDS Entities and are an alternative to listeners. The general pattern is the application creates a specific kind of `Condition` object, such as a `StatusCondition`, and attaches it to a `WaitSet`.

- The application waits on the `WaitSet` until one or more conditions become true.
- The application calls operations on the corresponding entity objects to extract the necessary information.
- The `DataReader` interface also has operations that take a `ReadCondition` argument.
- `QueryCondition` objects are provided as part of the implementation of the *Content-Subscription Profile*. The `QueryCondition` interface extends the `ReadCondition` interface.

See also:

Conditions
The conditions available in OpenDDS and how to use them.

2.4 Shapes Demo

The goal of this guide is to walk through downloading and running the DDS Interoperability Shapes demo program. The Shapes demo is a graphical application that will help you visualize some of the DDS concepts that OpenDDS supports without needing to read or write source code. The application allows you to create publishers and subscribers on topics represented by data payloads shown as simple shapes and see the results of the different quality of service, data partitioning, and filtering options provided. The Shapes demo makes use of the Real-Time Publish-Subscribe Wire Protocol Specification (DDSI-RTPS) that provides interoperable communications between various DDS implementations.

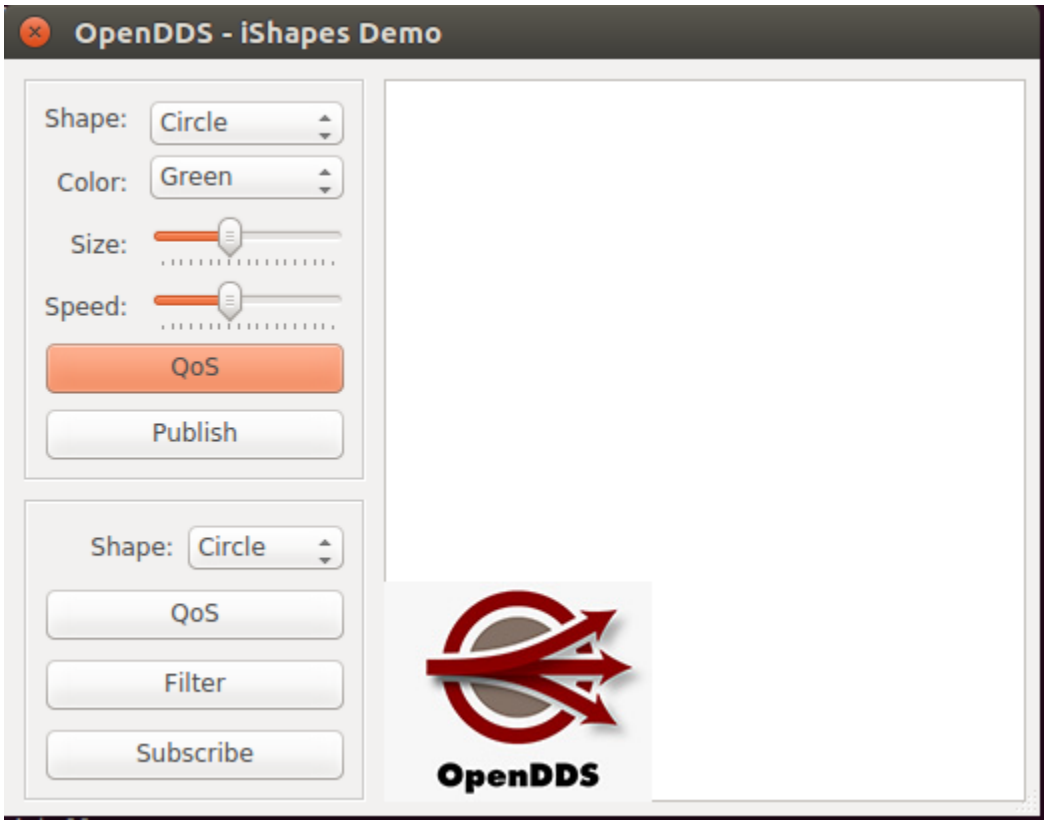
This video demonstrates a few of the scenarios described below.

2.4.1 Environment Prerequisites

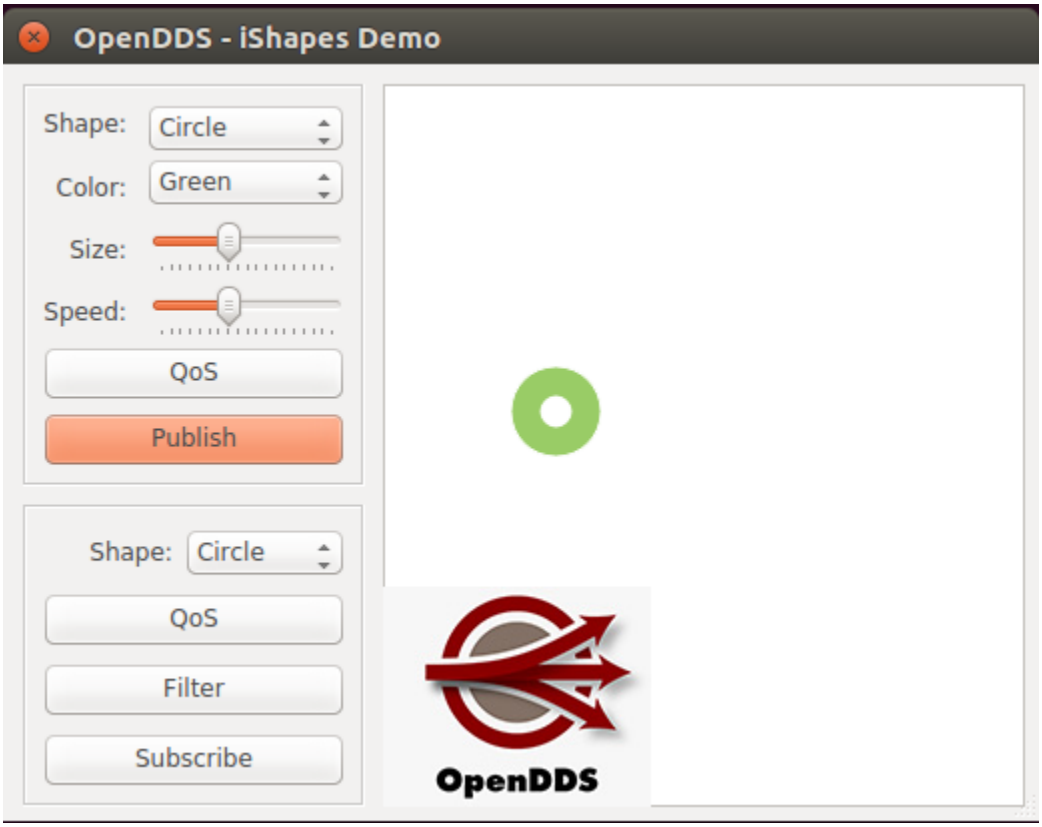
1. Ensure that your environment has Qt5 libraries available:
   - Windows (x64): Use the Qt Installer, or install the qt5 package from vcpkg. The Visual C++ runtime redistributable is also required.
   - Ubuntu (x86_64): Install the `libqt5gui5` package.
2. Download or compile the latest Shapes demo for your operating system:
   - Choose from the "ShapesDemo" assets in the latest release of OpenDDS
   - Alternatively, the Shapes demo can be run from a build from source of OpenDDS with Qt enabled. The demo resides in the `examples/DCPS/ishapes` directory. See *Dependencies* for a complete list of dependencies and `README.md#supported-platforms` for supported platforms.

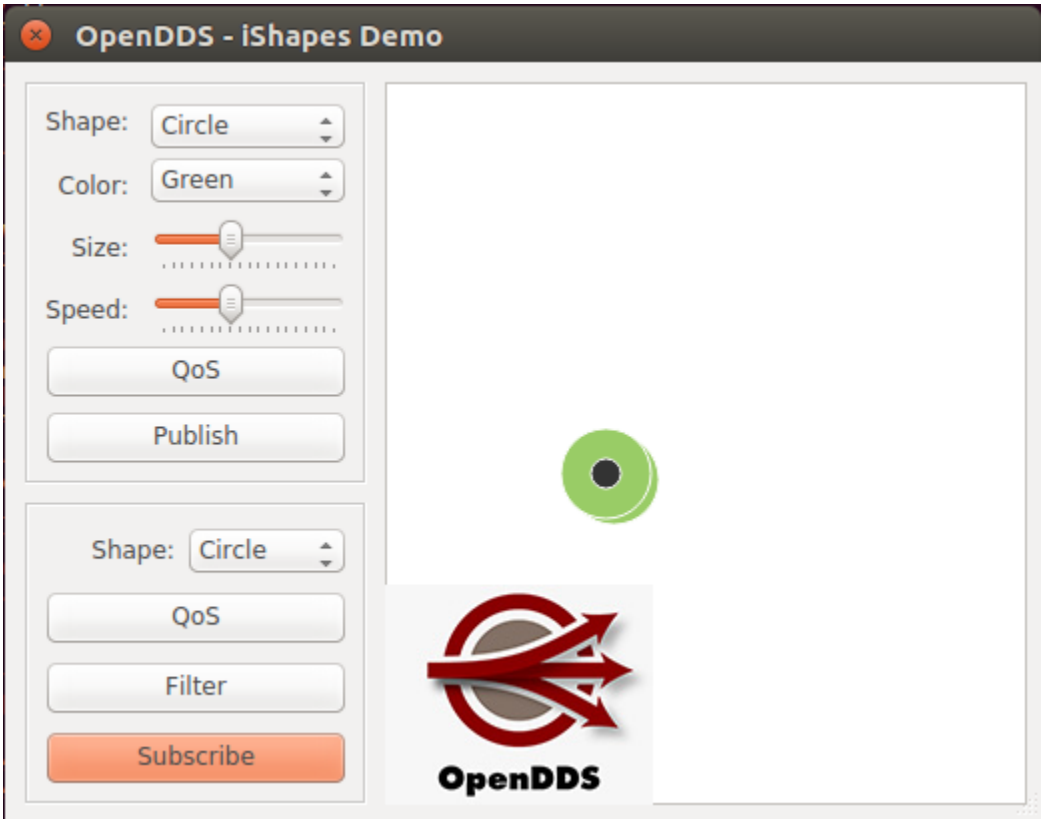
2.4.2 Running the Shapes Demo

1. Locate and run the Shapes demo and you should see a window that looks like this:



2. The most basic example is to simply click the `Publish` button to begin publishing a circle and then click `Subscribe` to begin subscribing to the same circle topic you are publishing. As soon as you begin publishing, you should see a green circle bouncing around the display area with a white center. This indicates that this is a published object, originating at this application.
3. After clicking `Subscribe`, as soon as the subscriber goes live and finds a match in the published circle topic, the center of the circle will go dark to indicate it is an instance of subscribed data, which in this case is being rendered over top the initial published instance.


OpenDDS - iShapes Demo
Shape:
Circle
Color:
Green
Size:
Speed:
QoS
Publish
Shape:
Circle
QoS
Filter
Subscribe
OpenDDS


OpenDDS - iShapes Demo
Shape:
Circle
Color:
Green
Size:
Speed:
QoS
Publish
Shape:
Circle
QoS
Filter
Subscribe
OpenDDS

4. Now that we have confirmed the ability to run an instance of the Shapes demo, let's understand some of the DDS concepts seen at work even in this simple example.

   - Each of the available shapes in the drop-down menu are DDS Topics that can be published on or subscribed to.
   - Each instance on the topic has an instance key represented by the shape's color and the shape itself is a DDS Data type comprised of x and y coordinates as well as a size.

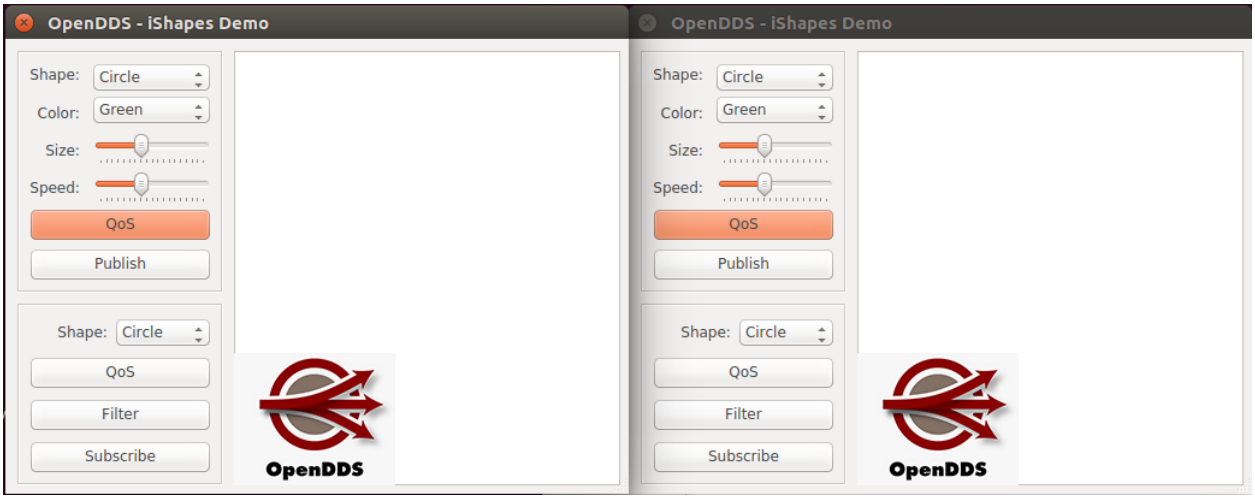
   What may not be apparent in this simple example is that the center of the circle going from white to dark is actually demonstrating the process of discovery, entity matching, publication, and subscription between two DDS entities. The additional example scenarios below make use of multiple shapes demo instances running concurrently to better demonstrate these capabilities.

2.4.3 Example Scenarios

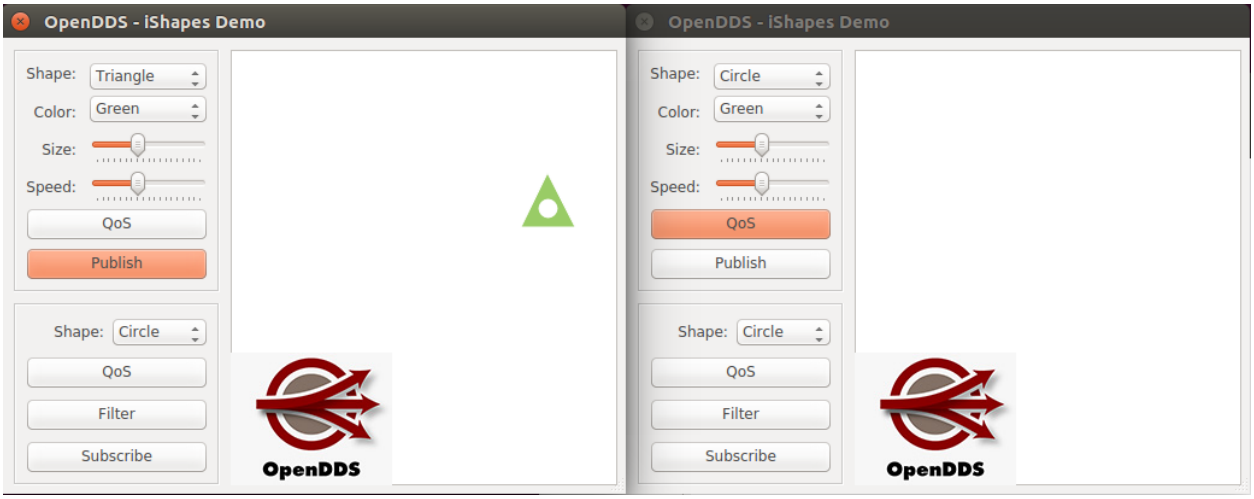
The pages linked below contain example scenarios that demonstrate different features of OpenDDS:

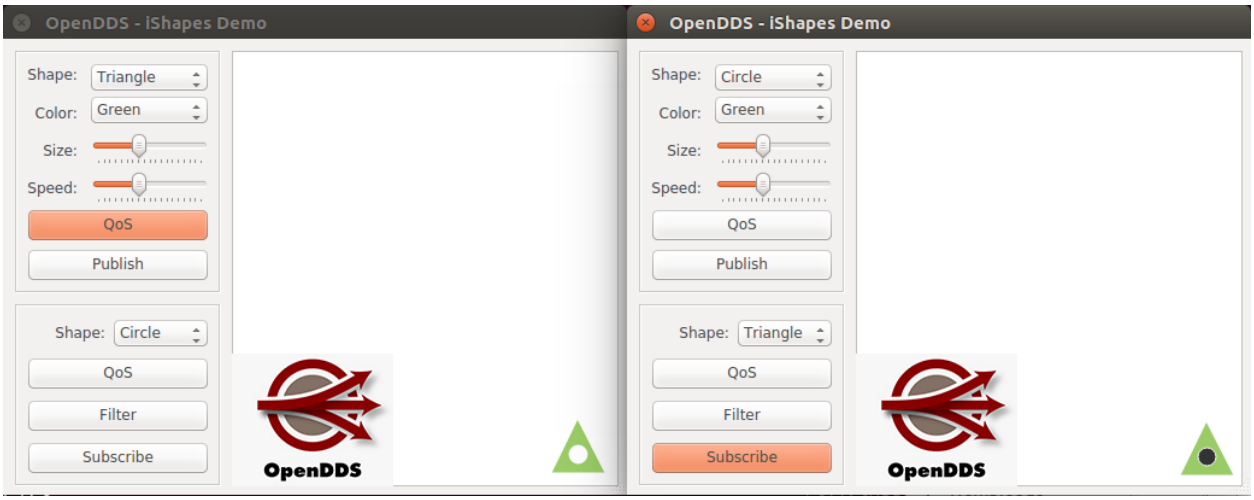
Multiple Instances

1. Start up two instances of the Shapes Demo for this example. You should be able to see two application windows like so:



2. **Publish** - Let's change it up and begin this example by publishing a triangle by selecting `Triangle` from the top Shape dropdown menu. Then click the `Publish` button. You should observe a green triangle bouncing around the application window's display area. The triangle, from a DDS perspective, is a piece of information that is being published to the rest of the system for other entities to receive if they are set up to be interested in triangles.
3. **Subscribe** - In the other application window, select `Triangle` from the bottom Shape dropdown menu. Then click the `Subscribe` button. You should observe the green triangle, published by the first application instance bouncing around the display area in the application window you chose to subscribe in.
4. **Results** - The triangle in the subscriber's window, tracking the initial triangle from the publisher's window, exemplifies the DDS publish/subscribe paradigm for a single publisher to single subscriber. The first application has a single publisher sending information out into the system and the second application has a single subscriber receiving that information.


OpenDDS - iShapes Demo
Shape: Triangle
Color: Green
Size:
Speed:
QoS
Publish
Shape: Circle
QoS
Filter
Subscribe
OpenDDS
OpenDDS - iShapes Demo
Shape: Circle
Color: Green
Size:
Speed:
QoS
Publish
Shape: Circle
QoS
Filter
Subscribe
OpenDDS


OpenDDS - iShapes Demo
Shape: Triangle
Color: Green
Size:
Speed:
QoS
Publish
Shape: Circle
QoS
Filter
Subscribe
OpenDDS
OpenDDS - iShapes Demo
Shape: Circle
Color: Green
Size:
Speed:
QoS
Publish
Shape: Triangle
QoS
Filter
Subscribe
OpenDDS

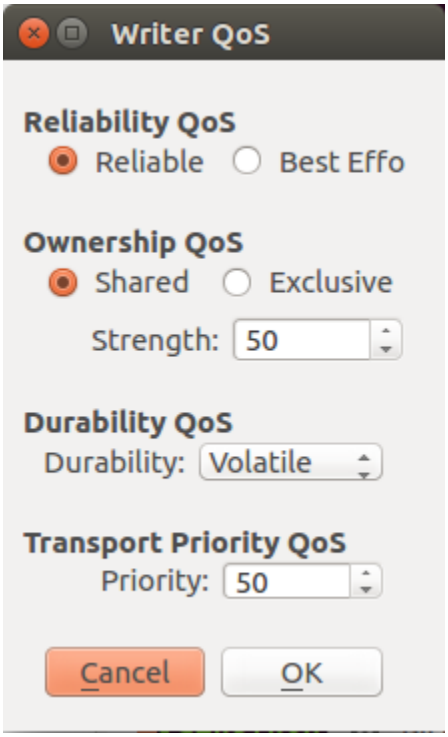
Reliability

See also:

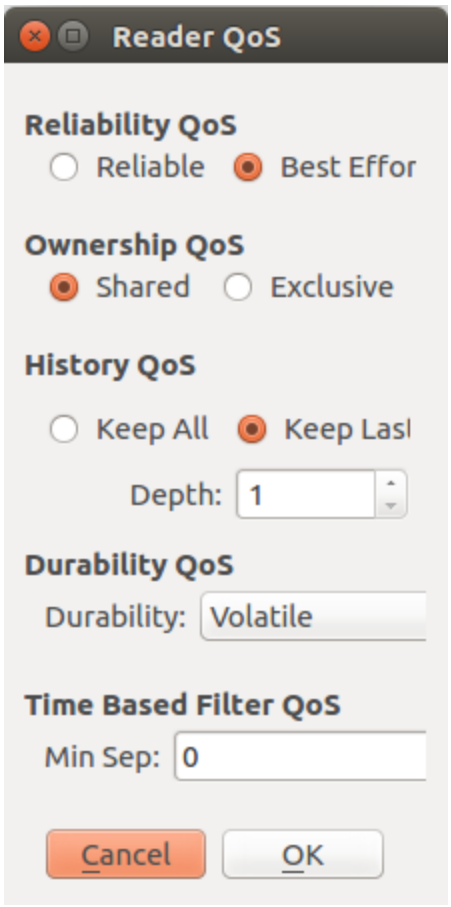
Reliability QoS

In this example, we will begin to look at the DDS concept of reliability as it relates to a publisher's offered quality of service (QoS) and a subscriber's requested QoS. As in the last example, start up two instances of the Shapes Demo.

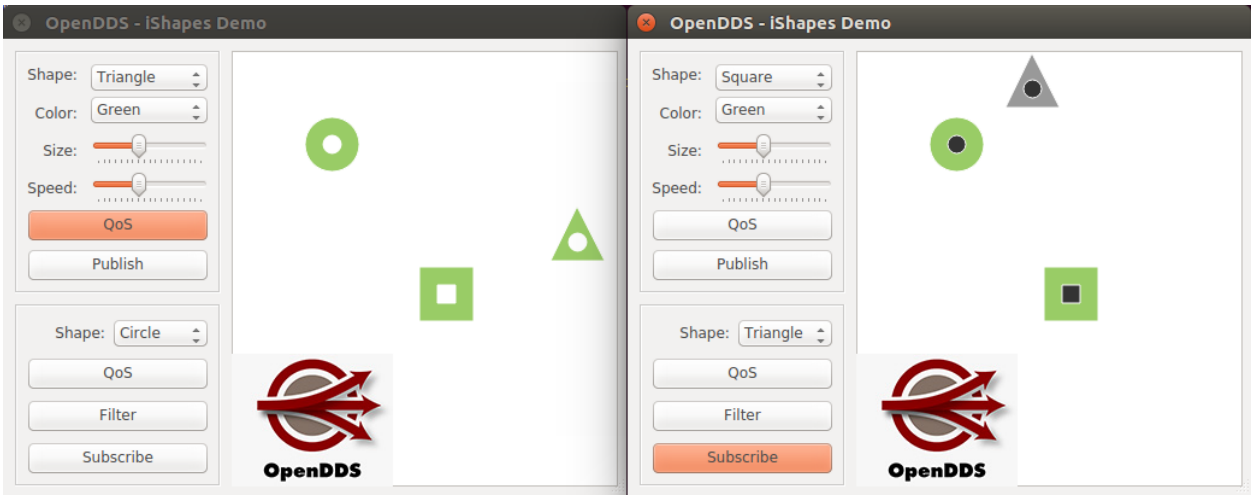
1. **Publisher/Subscriber QoS** - In this example we will publish 3 separate topics, each being configured with QoS settings to demonstrate Reliability QoS compatibility. Use the upper `QoS` button to open a window that will provide you with QoS configuration options for the publisher (Writer QoS). Here you should see the Reliability QoS setting, which defaults to reliable. Likewise, if you click the lower `QoS` button, a window will open which provides configuration options for the subscriber (Reader QoS). As you can see, the subscriber Reliability QoS defaults to best effort.



2. In the first application window, publish one instance of each of the following topics using the QoS menu to set the reliability accordingly before pressing the `Publish` button to begin publishing that topic:
   - Square: RELIABLE
   - Circle: BEST_EFFORT
   - Triangle: BEST_EFFORT
3. In the second application window, subscribe to one instance of each of the following topics using the QoS menu to set the reliability accordingly before pressing the `Subscribe` button to begin subscribing to that topic:
   - Square: RELIABLE
   - Circle: BEST_EFFORT
   - Triangle: RELIABLE
4. **Results** - You should observe in the subscriber application's display window that there are only 2 matched topics - Square and Circle. The subscriber for the Triangle topic did not find a match due to requesting a quality of service


Reader QoS
Reliability QoS
Reliable
Best Effor
Ownership QoS
Shared
Exclusive
History QoS
Keep All
Keep Last
Depth:
1
Durability QoS
Durability:
Volatile
Time Based Filter QoS
Min Sep:
0
Cancel
OK

of RELIABLE, but the only available publisher was only offering BEST_EFFORT. Because the publisher could not guarantee reliable delivery of messages, the subscriber was unable to fulfill its requirement and therefore was unable to find a match. Thus, the unmatched triangle topic on the subscriber's side is grayed out. Your two application windows should look similar to the following:



Durability

See also:

Durability QoS

In this example, we will begin to look at the DDS concept of durability as it relates to a publisher's offered quality of service (QoS) and a subscriber's requested QoS. Durability allows messages sent before a subscriber came online to be delivered to that subscriber. As in the last example, start up two instances of the Shapes Demo.

1. In the first application window, configure the publisher's QoS by opening the QoS menu and setting the following:

   - Durability QoS: TRANSIENT_LOCAL

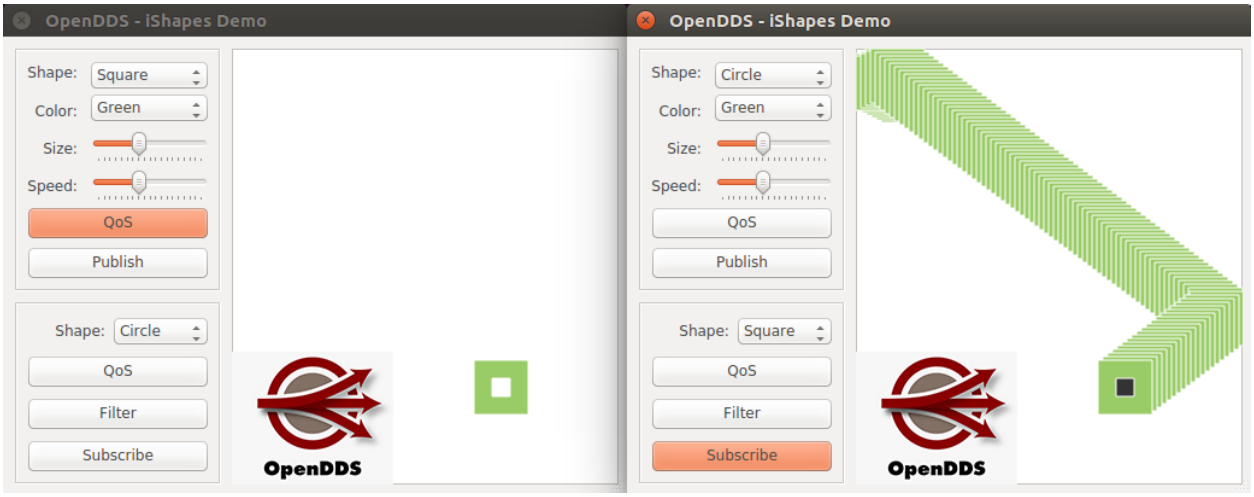
   Then publish one instance of Square.

2. In the second application window, configure the subscriber's QoS by opening the lower QoS menu and setting the following:

   - Reliability QoS: Reliable
   - History QoS Depth: 100
   - Durability QoS: TRANSIENT_LOCAL

   Then subscribe to one instance of Square.

3. **Results** - You should observe a Square with 100 trailing squares bouncing around the subscriber application's display window. This demonstrates that the subscriber is being provided with the durable data that the publisher has made available. The example application windows should look like this (publisher on the left, subscriber on the right):



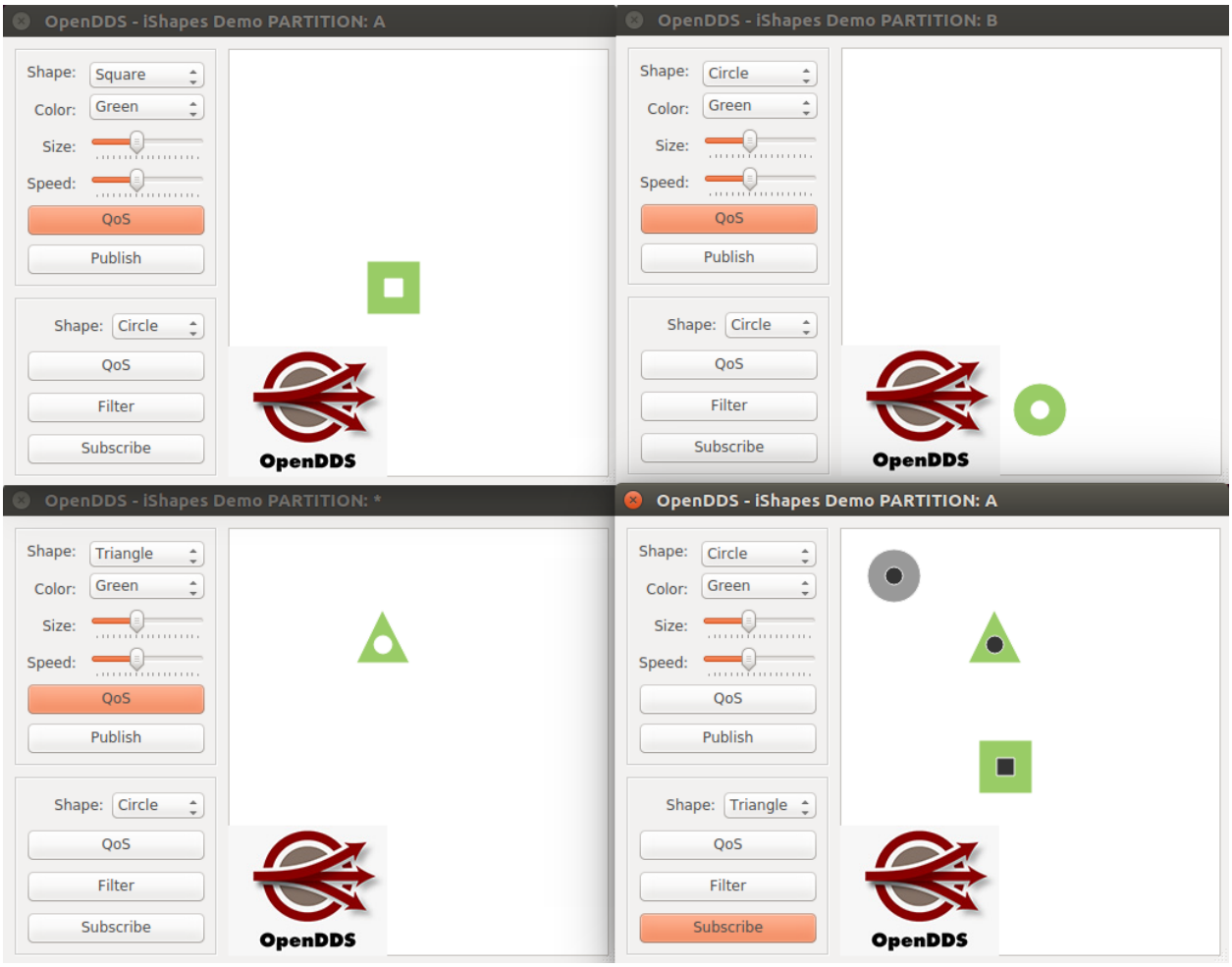
Partition

See also:

Partition QoS

In this example, we will begin to look at the DDS concept of partitions. In this example, 4 instances of the Shapes Demo application will need to be running simultaneously, each instance passed initial parameters to help configure the application's partition. Each step below will describe how one of the instances should be started and configured for publishing/subscribing.

1. **First publisher:** Start an instance of the Shapes demo passing it a command line argument of `-partition "A"`. Then, have this application instance publish a Square. You may leave all the QoS menu items defaulted.
2. **Second publisher:** Start an instance of the Shapes demo passing it a command line argument of `-partition "B"`. Then, have this application instance publish a Circle. You may leave all the QoS menu items defaulted.
3. **Third publisher:** Start an instance of the Shapes demo passing it a command line argument of `-partition "*"`. Then, have this application instance publish a Triangle. You may leave all the QoS menu items defaulted.
4. **Subscriber (fourth instance):** Start an instance of the Shapes demo passing it a command line argument of `-partition "A"`. Then, have this application instance subscribe to Square, Circle, and Triangle. You may leave all the QoS menu items defaulted.
5. **Results** - You should observe that only the Square and Triangle appear in the subscriber application's display area. This is because this subscriber instance matches to both partition `A` and `*`. However, the circle is being published in partition B, which the subscriber does not belong to. Therefore, the circle is grayed out because it is an unmatched subscription currently. The example application windows should look like this (subscriber on the bottom right):


OpenDDS - iShapes Demo PARTITION: A
Shape: Square
Color: Green
Size:
Speed:
QoS
Publish
Shape: Circle
QoS
Filter
Subscribe
OpenDDS
OpenDDS - iShapes Demo PARTITION: B
Shape: Circle
Color: Green
Size:
Speed:
QoS
Publish
Shape: Circle
QoS
Filter
Subscribe
OpenDDS
OpenDDS - iShapes Demo PARTITION: *
Shape: Triangle
Color: Green
Size:
Speed:
QoS
Publish
Shape: Circle
QoS
Filter
Subscribe
OpenDDS
OpenDDS - iShapes Demo PARTITION: A
Shape: Circle
Color: Green
Size:
Speed:
QoS
Publish
Shape: Triangle
QoS
Filter
Subscribe
OpenDDS

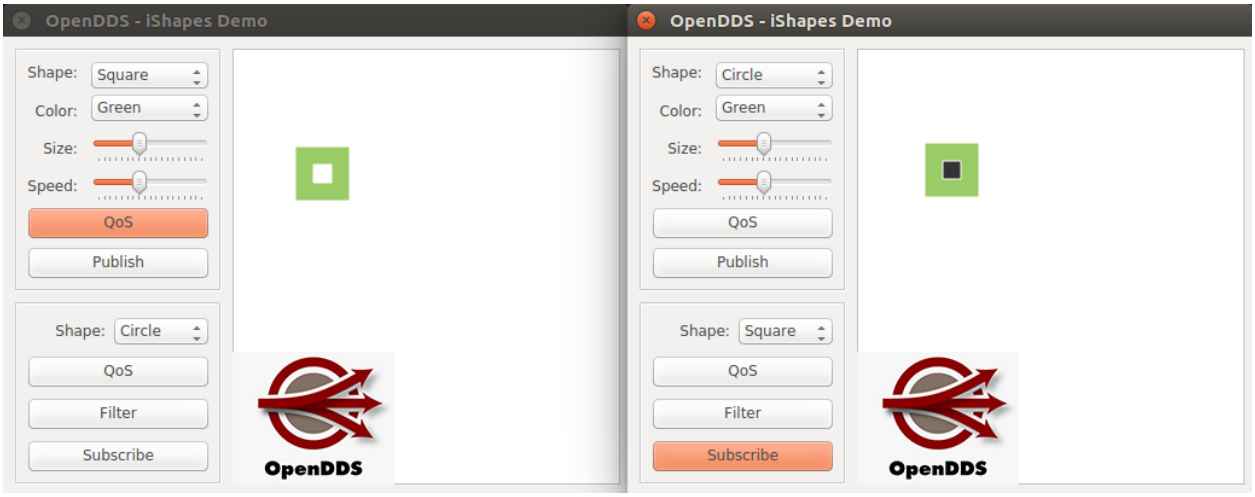
Ownership

See also:

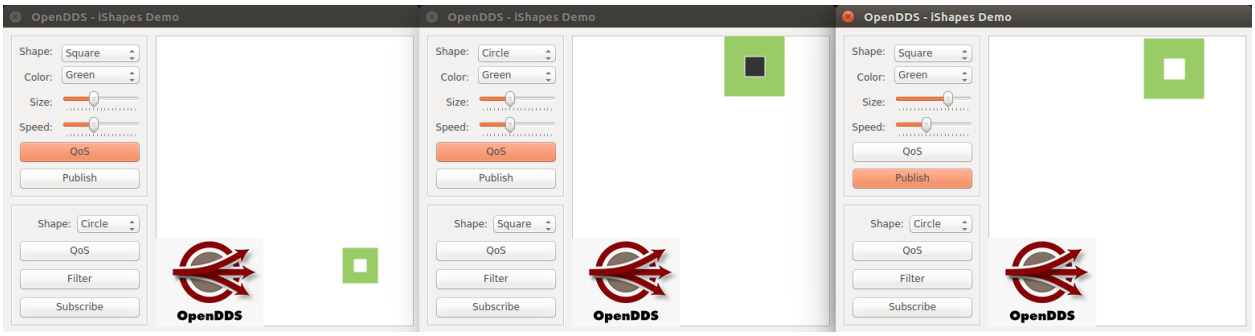
Ownership QoS

In this example, we will begin to look at the DDS concept of Ownership QoS. In this example, 3 instances of the Shapes Demo application will need to be running simultaneously.

1. In the first application window, subscribe to one instance of Square after using the QoS menu to set the Ownership QoS accordingly:
   - Ownership QoS: EXCLUSIVE
2. Now start a second instance of the shapes demo. In this application window, publish one instance of Square after using the QoS menu to set the Ownership QoS accordingly:
   - Ownership QoS: EXCLUSIVE
   - Ownership QoS Strength: 50
3. **Initial Results** - At this point you should observe that the Square has appeared in the subscriber application's display area matching the color, size, and location of the square in the publisher's display area. The example application windows should look like this (publisher on the left, subscriber on the right):



4. Now start a third instance of the shapes demo. In this application window, publish one instance of Square after using the QoS menu to set the Ownership QoS accordingly:
   - Ownership QoS: EXCLUSIVE
   - Ownership QoS Strength: 75
   - **Before clicking "Publish" increase the size of the Square using the size slider.** (This will help make the changes more visible.)
5. **Final Results** - At this point you should observe that the larger Square has appeared in the subscriber application's display area. Since the Ownership QoS has been set to exclusive, only one writer of the topic – the writer with the highest strength – will have its messages find their way to the subscriber. The example application windows should look like this (initial publisher on the left, subscriber on the right, *new* publisher on the right):
6. **Note** - At this point you could simulate a higher strength publisher leaving the system by closing the second publisher application window. Then you should observe the subscriber failing over to the initial publisher's smaller instance of the Square that had a lower ownership strength.



Time-Based Filter

See also:

Time Based Filter QoS

In this example, we will begin to look at the DDS concept of Time Based Filter QoS. In this example, only 2 instances of the Shapes Demo application will be necessary.

1. In the first application window, publish 4 instances, 2 each of Circle and Square, but vary the colors to be unique. QoS settings on the publisher can remain defaulted. For this demonstration we will publish:
   - Circle - Green
   - Circle - Red
   - Square - Green
   - Square - Blue
2. In the second application window, subscribe to the Square topic using the default QoS settings. Then, subscribe to Circle by first using the QoS configuration menu to set the following:
   - Time Based Filter QoS - Minimum Separation: 2 (seconds)
3. **Results** - Both samples of Square should appear fluidly bouncing around the subscriber's application window. However, you will notice, the Circle samples are being sub-sampled based on the time filter that was configured. Only the most recent sample within the minimum separation is displayed in the subscriber's window. You should notice that each time the time based filter meets its required minimum separation the circle samples are updated and, for an instant, should have the same location as those in the publisher's window. Notice in the following graphics how the circles in the subscriber do not match up perfectly with the position of the circles in the publisher. Here are a couple examples of what your application windows might look like at this point (publisher on the left, subscriber on the right):

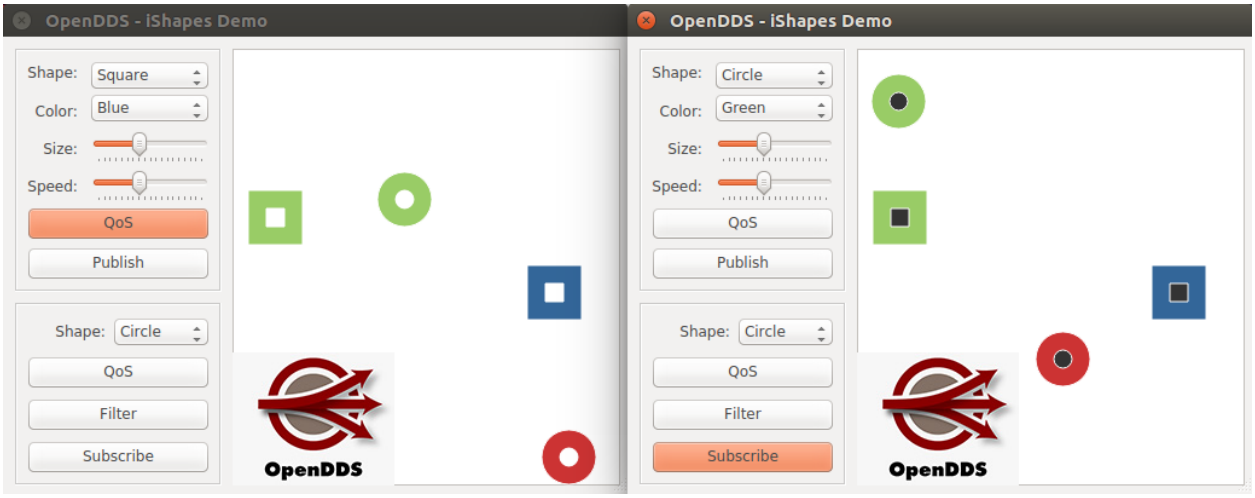
Content-Filtered Topics

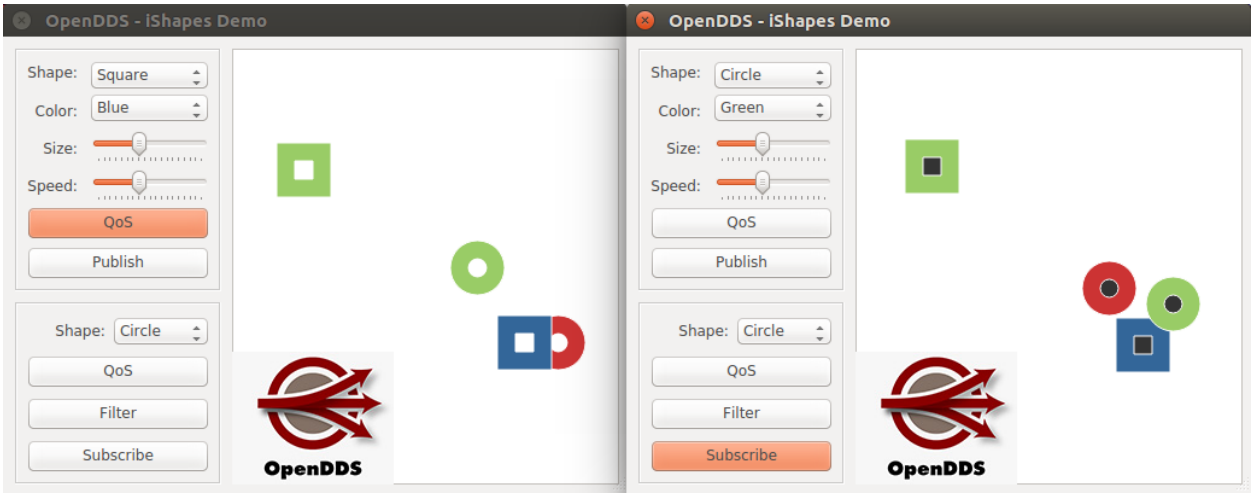
See also:

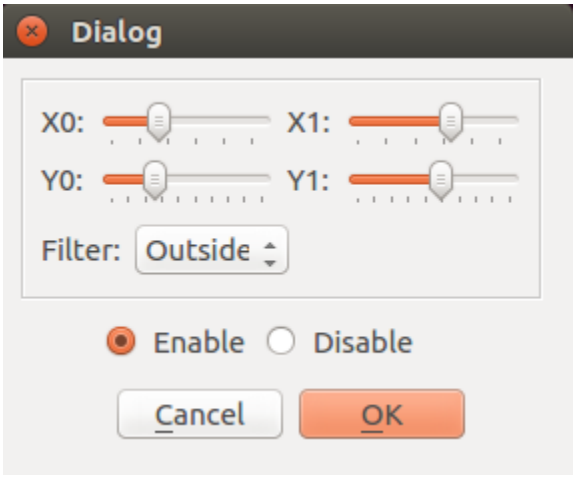
Content-Filtered Topic

In this example we will begin to look at the DDS concept of Content-Filtered Topics. In this example only 2 instances of the Shapes Demo application will be necessary.

1. In the first application window publish a single instance of Square using the default QoS settings.
2. In the second application window you will subscribe to the Square topic. However, the content filter needs to be configured first. So click on the `Filter` button and it should bring up a dialog that looks like this:


OpenDDS - iShapes Demo
Shape: Square
Color: Blue
Size:
Speed:
QoS
Publish
Shape: Circle
QoS
Filter
Subscribe
OpenDDS
OpenDDS - iShapes Demo
Shape: Circle
Color: Green
Size:
Speed:
QoS
Publish
Shape: Circle
QoS
Filter
Subscribe
OpenDDS

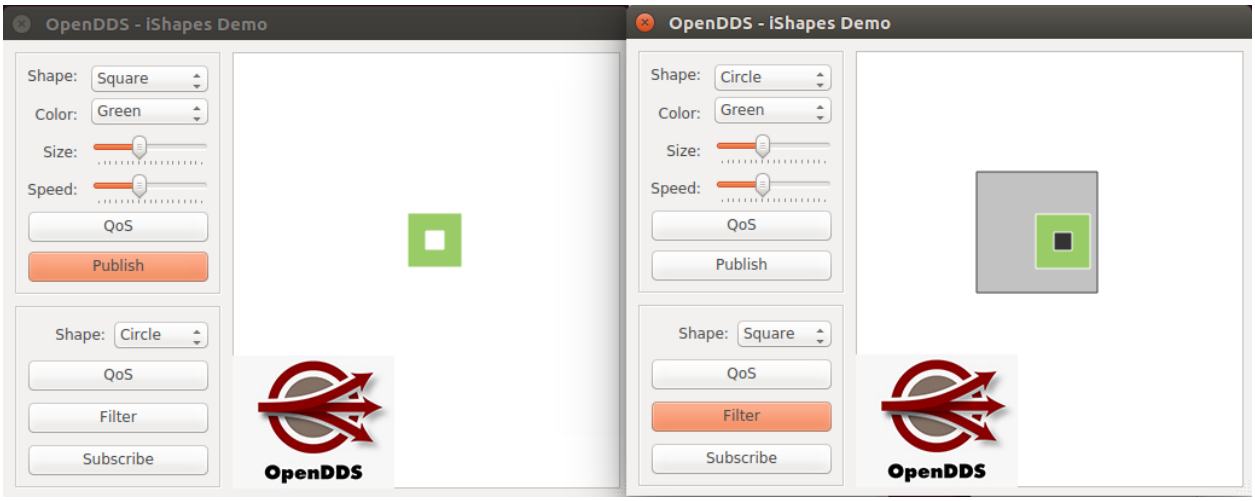

OpenDDS - iShapes Demo
Shape: Square
Color: Blue
Size:
Speed:
QoS
Publish
Shape: Circle
QoS
Filter
Subscribe
OpenDDS
OpenDDS - iShapes Demo
Shape: Circle
Color: Green
Size:
Speed:
QoS
Publish
Shape: Circle
QoS
Filter
Subscribe
OpenDDS


Dialog
X0:
X1:
Y0:
Y1:
Filter: Outside
Enable
Disable
Cancel
OK

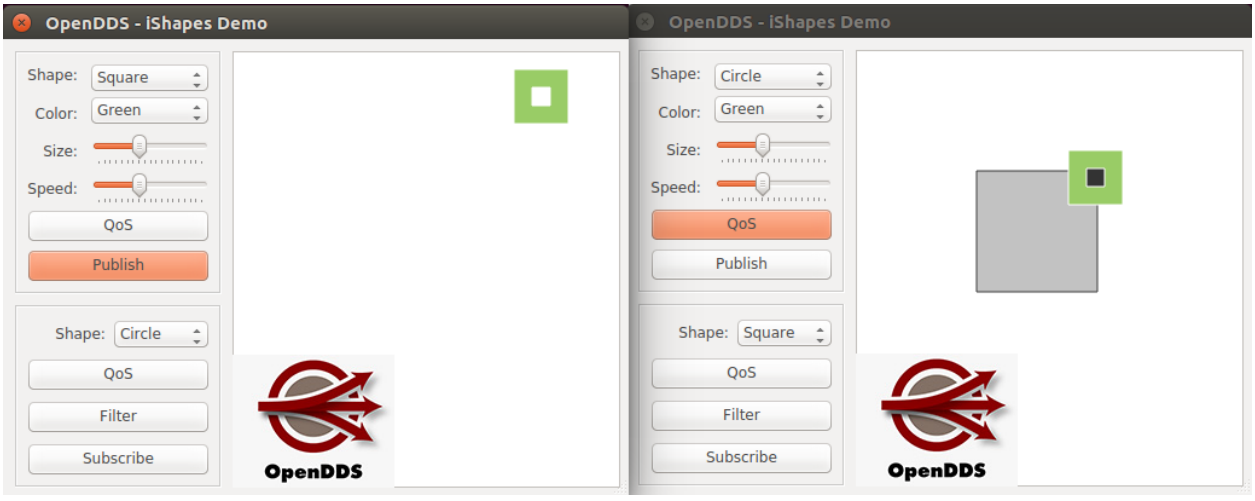
3. For this example we will use the default bounding box for the content filter which is controlled by the x and y slider bars in the menu. We will also use the default filter of **outside** which will tell the subscriber to ignore all samples outside the given bounding box. Then also toggle the filter by selecting `Enable` and finish by clicking the `OK` button.

4. Now that the content filter is set up, subscribe to the Square topic.

5. **Results** - You should be able to observe the square bouncing around the publisher application's display window. On the subscriber's side, however, the square's position and graphic will only be updated when it is within the content filter's bounding box. All samples outside the content filter area are filtered out. Here are a couple of examples of what your application windows might look like at this point (publisher on the left, subscriber on the right):



Here you can see that while the published instance is within the content filter bounds, the subscriber's square updates normally keeping in step with the square on the publisher's side.



Here you can see that when the published instance leaves the confines of the content filter, the subscriber's square remains at the last valid position and no longer updates its position until the published instance once again enters into the bounds of the content filter.

2.4.4 Conclusion

The examples worked through above have demonstrated some of the many Data Distribution Service features provided by OpenDDS. OpenDDS provides a portable and interoperable publish/subscribe infrastructure. You have learned a little about many DDS concepts including:

- Discovery
- Topics and Data Types
- Publish/Subscribe semantics
- One to Many and Many to One communications
- Different Quality of Service (QoS)
  - Reliability
  - Durability
  - Ownership
  - Data Partitioning
  - Time Based Filter
- Content Filtered Topics

Hopefully this has helped provide an understanding of what using OpenDDS to provide a publish/subscribe infrastructure can look like and the different features that can be included in a product using OpenDDS as its communications infrastructure.

2.4.5 Next Steps

Now that you've acquired a conceptual baseline, here are some recommended next steps to continue learning about OpenDDS:

- Work through downloading and building OpenDDS and running a simple example through the other *Quick Start Guides*.
- Find more support information about dependencies and detailed instructions for *Building and Installing*.
- Learn more about *Getting Started* with OpenDDS by walking through an end-to-end example.
- Visit the OpenDDS project on GitHub.

2.5 Introduction to OpenDDS

2.5.1 What is OpenDDS?

OpenDDS is an open-source C++ framework for exchanging data in distributed systems. It is an implementation of *a group of related OMG specifications*. OpenDDS is implemented in C++ and contains support for *Java*. Users in the OpenDDS community have contributed and maintain bindings for other languages that include C#, Node.js, and Python. OpenDDS is sponsored by the OpenDDS Foundation and is available via https://opendds.org and https://github.com/OpenDDS/OpenDDS.

2.5.2 Licensing Terms

OpenDDS is *open source software*. The source code may be freely downloaded and is open for inspection, review, comment, and improvement. Copies may be freely installed across all your systems and those of your customers. There is no charge for development or run-time licenses. The source code is designed to be compiled, and used, across a wide variety of hardware and operating systems architectures. You may modify it for your own needs, within the terms of the license agreements. You must not copyright OpenDDS software. For details of the licensing terms, see the file named `LICENSE` that is included in the OpenDDS source code distribution or visit https://opendds.org/about/license.html.

OpenDDS also utilizes other open source software products including MPC (Make Project Creator), ACE (the ADAPTIVE Communication Environment), and TAO (The ACE ORB).

OpenDDS is open source and the development team welcomes contributions of code, tests, documentation, and ideas. Active participation by users ensures a robust implementation. Contact the OpenDDS Foundation if you are interested in contributing to the development of OpenDDS. Please note that any code or documentation that is contributed to and becomes part of the OpenDDS open source code base is subject to the same licensing terms as the rest of the OpenDDS code base.

2.5.3 Specifications

OpenDDS is an open source implementation of a group of related *OMG* specifications.

Data Distribution Service (DDS) for Real-Time Systems

This specification defines a service for efficiently distributing application data between participants in a distributed application. This is the core functionality implemented by OpenDDS for real-time publish and subscribe applications and is described throughout this document.

The version OpenDDS uses is DDS v1.4. Compliance with the specification is documented in *DDS Compliance*. More information about the DDS itself can be found on the DDS Foundation website.

Real-time Publish-Subscribe (RTPS)

The full name of this specification is the *Real-time Publish-Subscribe Protocol DDS Interoperability Wire Protocol* (DDSI-RTPS), but can also be just called RTPS. This specification describes the requirements for interoperability between DDS implementations. See *RTPS Discovery* for more information.

The version OpenDDS uses is RTPS v2.3. Although the document number is v2.3, it specifies protocol version 2.4. Compliance with the specification is documented in *DDSI-RTPS Compliance*.

DDS Security

This specification extends DDS with capabilities for authentication and encryption. OpenDDS's support for the DDS Security specification is described in *DDS Security*.

The version OpenDDS uses is DDS Security v1.1. Compliance with the specification is documented in *DDS Security Implementation Status*.

Extensible and Dynamic Topic Types for DDS (XTypes)

This specification defines details of the type system used for the data exchanged on DDS Topics, including how schema and data are encoded for network transmission. OpenDDS's support for XTypes is described in *XTypes*.

The version OpenDDS uses is DDS XTypes v1.3. Compliance with the specification is documented in *Unimplemented Features* and *Differences from the specification*.

IDL

IDL is a language that can be used to define data structures and interfaces that can be mapped to multiple programming languages. The parser is implemented as part of *tao_idl*.

The version OpenDDS uses is IDL v4.2. Compliance with the specification is documented in *IDL Compliance*.

IDL to C++03 Language Mapping

This specification defines an *IDL* to C++ mapping. It's generated by *tao_idl*, not *opendds_idl*.

The version OpenDDS uses is IDL to C++03 v1.3.

IDL to C++11 Language Mapping

This specification defines an *IDL* to C++ mapping that takes advantage of C++11 language features and standard library types. OpenDDS's support for IDL to C++11 is described in *Using the IDL-to-C++11 Mapping*.

The version OpenDDS uses is IDL to C++11 v1.5.

IDL to Java Language Mapping

This specification defines an *IDL* to Java mapping and is used for the *Java Bindings*.

The version OpenDDS uses is IDL to Java v1.3.

2.5.4 Compliance

OpenDDS complies with the OMG DDS and the OMG DDSI-RTPS specifications. Details of that compliance follows here. OpenDDS also implements the OMG DDS Security specification. See *Specifications* for how OpenDDS complies with other specifications it implements.

DDS Compliance

Section 2 of the DDS specification defines five compliance points for a DDS implementation:

- Minimum Profile
- Content-Subscription Profile
- Persistence Profile
- Ownership Profile
- Object Model Profile

OpenDDS complies with the entire DDS specification (including all optional profiles). This includes the implementation of all Quality of Service policies with the following notes:

- *Reliability QoS* `RELIABLE_RELIABILITY_QOS` is supported by the *RTPS/UDP Transport*, the *TCP Transport*, and the *Multicast Transport* (when configured as reliable).
- *Transport Priority QoS* is not implemented as changeable.

Although version 1.5 of the DDS specification is not yet published, OpenDDS incorporates some changes planned for that version that are required for a robust implementation:

- OMG Issue DDS15-5 (Member Link): The IDL type `BuiltinTopicKey_t` is a struct containing an array of 16 octets
  - The actual child issue isn't public viewable for some reason, but the member link is https://issues.omg.org/browse/DDS15-257

DDSI-RTPS Compliance

The OpenDDS implementation complies with the requirements of the OMG DDSI-RTPS specification.

OpenDDS RTPS Implementation Notes

The *OMG DDSI-RTPS specification* supplies statements for implementation, but not required for compliance. The following items should be taken into consideration when utilizing the OpenDDS RTPS functionality for transport and/or discovery. Section numbers of the DDSI-RTPS specification are supplied with each item for further reference.

Items not implemented in OpenDDS:

1. Writer-side content filtering (RTPS v2.3 8.7.3 Content-filtered Topics)

   OpenDDS may still drop samples that aren't needed (due to content filtering) by any associated readers – this is done above the transport layer

2. RTPS v2.3 8.7.6 Coherent Sets for *Presentation QoS*
3. RTPS v2.3 8.7.7 Directed Write

   OpenDDS will use the Directed Write parameter if it's present on incoming messages (for example, messages generated by a different DDS implementation)

4. RTPS v2.3 8.7.8 Property Lists
5. RTPS v2.3 8.7.9 Original Writer Info for *Durability QoS*

   This would only be used for transient and persistent durability, which are not supported by the RTPS specification

6. Key Hashes are not generated, but the specification makes them optional
7. `nackSuppressionDuration` (Table 8.47 in RTPS v2.3 8.4.7.1 RTPS Writer) and `heartbeatSuppressionDuration` (Table 8.62 in RTPS v2.3 8.4.10.1 RTPS Reader).

Note: Items 3 and 4 above are described in the DDSI-RTPS specification. However, they do not have a corresponding concept in the DDS specification.

IDL Compliance

OMG IDL is used in a few different ways in the OpenDDS code base and downstream applications that use it:

- Files that come with OpenDDS such as `dds/DdsDcpsTopic.idl` define parts of the API between the middleware libraries and the application. This is known as the OMG IDL Platform Specific Model (PSM).
- Users of OpenDDS author IDL files in addition to source code files in C++ or Java.

This section only describes the latter use.

The IDL specification (version 4.2) uses the term "building block" to define subsets of the overall IDL grammar that may be supported by certain tools. OpenDDS supports the following building blocks, with notes/caveats listed below each:

- Core Data Types
  - Support for the "fixed" data type (fixed point decimal) is incomplete.
- Anonymous Types
  - There is limited support for anonymous types when they appear as sequence/array instantiations directly as struct field types. Using an explicitly-named type is recommended.
- Annotations
  - See *Defining Data Types with IDL* and *IDL Annotations* for details on which built-in annotations are supported.
  - User-defined annotation types are also supported.
- Extended Data Types
  - The integer types `int8`, `uint8`, `int16`, `uin16`, `int32` `uint32`, `int64`, and `uint64` are supported.
  - The rest of the building block is not supported.

2.5.5 Extensions to the DDS Specification

Data types, interfaces, and constants in the `DDS` IDL module (C++ namespace, Java package) correspond directly to the DDS specification with very few exceptions:

- `DDS::SampleInfo` contains an extra field starting with `opendds_reserved`.
- Type-specific DataReaders (including those for Built-in Topics) have additional operations `read_instance_w_condition()` and `take_instance_w_condition()`.

Additional extended behavior is provided by various classes and interfaces in the `OpenDDS` module/namespace/package. Those include features like Recorder and Replayer (*Alternate Interfaces to Data*) and also:

- `OpenDDS::DCPS::TypeSupport` adds the `unregister_type()` operation not found in the DDS spec.
- `OpenDDS::DCPS::ALL_STATUS_MASK`, `NO_STATUS_MASK`, and `DEFAULT_STATUS_MASK` are useful constants for the `DDS::StatusMask` type used by `DDS::Entity`, `DDS::StatusCondition`, and the various `create_*()` operations.

2.5.6 OpenDDS Implementation and Architecture

This section gives a brief overview of the OpenDDS implementation, its features, and some of its components.

Source Code Organization

Relative to *DDS_ROOT*:

- the `dds/` directory contains the source code for OpenDDS.
- the `tests/` directory contains tests.
- the `tools/` directory contains tools and libraries like the DCPSInfoRepo, RtpsRelay, and the Modeling SDK.
- the `DevGuideExamples/` directory contains examples used in this guide.
- the `examples/` directory contains examples *not* used in this guide.
- the `docs/` directory contains documentation for users and developers of OpenDDS.

Design Philosophy

The OpenDDS implementation and API is based on a fairly strict interpretation of the OMG IDL PSM. In almost all cases the OMG's IDL-to-C++ Language Mapping is used to define how the IDL in the DDS specification is mapped into the C++ APIs that OpenDDS exposes to the client.

The main deviation from the OMG IDL PSM is that local interfaces are used for the entities and various other interfaces. These are defined as unconstrained (non-local) interfaces in the DDS specification. Defining them as local interfaces improves performance, reduces memory usage, simplifies the client's interaction with these interfaces, and makes it easier for clients to build their own implementations.

Plugins

OpenDDS puts many implementation details into libraries that are outside the core `OpenDDS_Dcps` library. Making these features modular allows users to build and distribute their applications without building or distributing code their applications won't use. It also makes it easier to replace these libraries with custom ones.

- *transports*:
  - *TCP Transport*
  - *RTPS/UDP Transport*
  - *UDP Transport*
  - *Multicast Transport*
  - *Shared Memory Transport*
- *discovery*[1]:
  - *InfoRepo Discovery*
  - *RTPS Discovery*
- *security*[2]

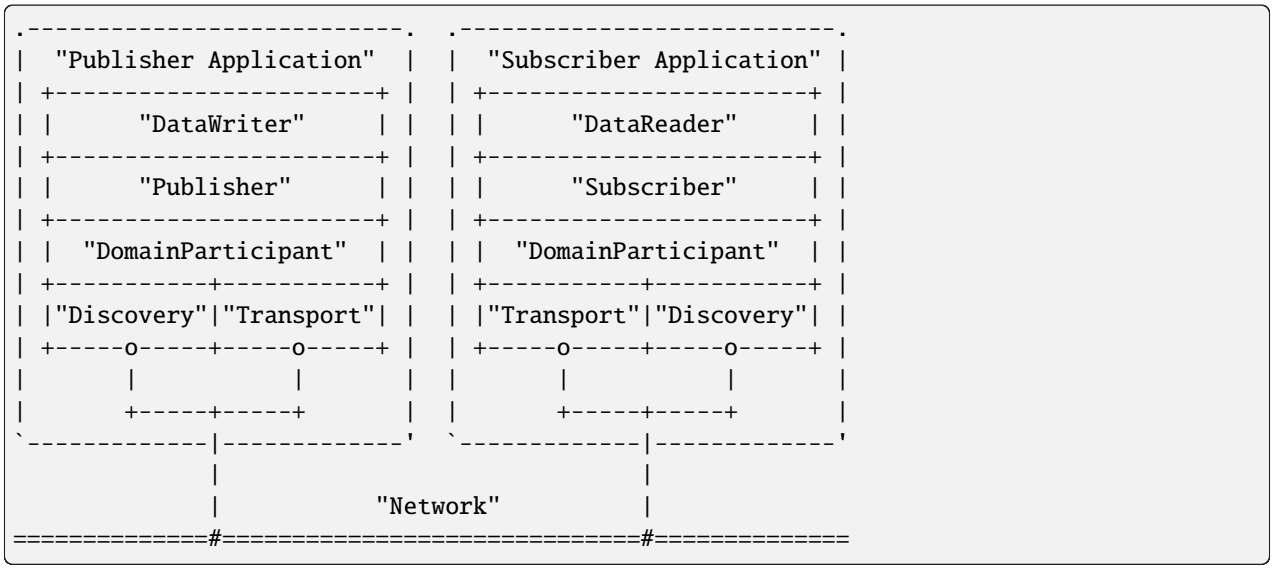
[1] *Static Discovery* is built-in to the core Dcps library, so it doesn't require linking a separate library or including an initialization header.

[2] Within DDS Security there is *a concept of plugins* that is mostly separate from the plugins described here. They are for implementing specific security features such as different encryption methods. The built-in security library is a default implementation of these, but a custom OpenDDS security plugin could implement one or more of these DDS Security plugins.

How to enable and use a particular plugin will differ based on the kind of plugin and the plugin itself, but generally they are enabled by some form of configuration setting, for example using *[transport] transport_type* or *[common] DCPSSecurity* in a configuration file. The plugin will also have to be linked and initialized at runtime. For dynamic libraries (`.dll`, `.dynlib` or, `.so` files) this is done automatically as the OpenDDS will load the dynamic library and then run any initialization the plugin requires. When the plugins are statically linked, then it requires explicit linking and including an initialization header in the application that contains a global object that will initialize the plugin. If OpenDDS was *built using CMake*, then `dds/DCPS/StaticIncludes.h` can be included and the initialization headers will be included automatically based on the *static libraries* that were linked. Explicit linking and initialization headers can also be used with dynamic libraries. This will always load and initialize the plugin when the application starts instead of delaying until the plugin is needed.

Transports

Transmission of *samples* and information related to their management is accomplished via an OpenDDS-specific transport framework that allows the service to be used with a variety of transport protocols. Transports are typically specified via configuration files and are attached to various entities in the publisher and subscriber processes. See *Transport Configuration* for details on configuring transports generally.



Transports are used along with *discovery* to define how OpenDDS communicates.

TCP Transport

The TCP transport (`tcp`) uses TCP as the transmission mechanism. It's the default transport normally. It's *reliable*, regardless of configuration.

Important: Library filename: `OpenDDS_Tcp`

MPC base project name: `dcps_tcp`

CMake target Name: *OpenDDS::Tcp*

Initialization header: `dds/DCPS/transport/tcp/Tcp.h`

[transport] transport_type: *tcp*

Configuration: *TCP Transport Configuration Properties*

RTPS/UDP Transport

The RTPS/UDP transport (`rtps_udp`) uses the UDP-based transport described in *Real-time Publish-Subscribe (RTPS)* as the transmission mechanism. It's interoperable with other DDS implementations when used with *RTPS Discovery*. It's the default transport when *Safety Profile* is being used. It supports *reliability*.

Important: Library filename: `OpenDDS_Rtps_Udp`

MPC base project name: `dcps_rtps_udp`

CMake target Name: *`OpenDDS::Rtps_Udp`*

Initialization header: `dds/DCPS/transport/rtps_udp/RtpsUdp.h`

`[transport] transport_type`: *`rtps_udp`*

Configuration: *RTPS UDP Transport Configuration Properties*

See also:

DDS Security
: For security capabilities that are possible when using *RTPS Discovery* and the *RTPS/UDP Transport*

Internet-Enabled RTPS
: For using *RTPS Discovery* and the *RTPS/UDP Transport* over the internet

UDP Transport

The UDP transport (`udp`) uses unicasted UDP as the transmission mechanism. It doesn't support *reliability* at all.

Important: Library filename: `OpenDDS_Udp`

MPC base project name: `dcps_udp`

CMake target Name: *`OpenDDS::Udp`*

Initialization header: `dds/DCPS/transport/udp/Udp.h`

`[transport] transport_type`: *`udp`*

Configuration: *UDP Transport Configuration Properties*

Multicast Transport

The multicast transport (`mutlicast`) uses multicasted UDP as the transmission mechanism. It supports *reliability*.

Important: Library filename: `OpenDDS_Multicast`

MPC base project name: `dcps_multicast`

CMake target Name: *`OpenDDS::Multicast`*

Initialization header: `dds/DCPS/transport/multicast/Multicast.h`

`[transport] transport_type`: *`multicast`*

Configuration: *Multicast Transport Configuration Properties*

Shared Memory Transport

Note: This transport is not currently supported on macOS because macOS lacks support for POSIX unnamed semaphores.

The shared memory transport (`shmem`) uses shared memory on the local host as the transmission mechanism. It's *reliable*, regardless of configuration.

Important: Library filename: `OpenDDS_Shmem`

MPC base project name: `dcps_shmem`

CMake target Name: *`OpenDDS::Shmem`*

Initialization header: `dds/DCPS/transport/shmem/Shmem.h`

`[transport] transport_type`: *`shmem`*

Configuration: *Shared Memory Transport Configuration Properties*

Custom Transports

The transport framework enables application developers to implement their own customized transports. Implementing a custom transport involves specializing a number of classes defined in the transport framework. The `udp` transport provides a good foundation developers may use when creating their own implementation. See the `dds/DCPS/transport/udp/` directory for details.

Discovery

DDS applications must *discover* one another via some central agent or through some distributed scheme. OpenDDS provides three options for discovery: *InfoRepo Discovery*, *RTPS Discovery*, and *Static Discovery*. The choice of discovery is independent of the choice of transport in most cases. For example, one can use the *TCP Transport* with *RTPS Discovery*. Notable exceptions are:

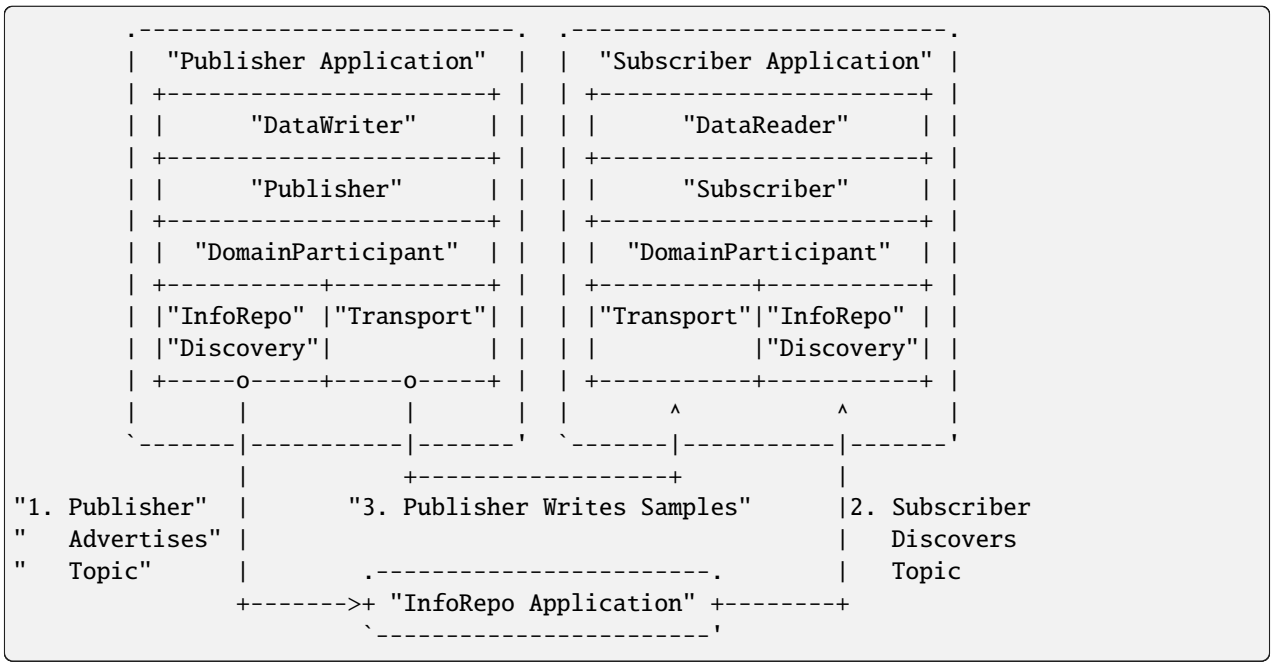
1. *DDS Security* requires using both *RTPS Discovery* and the *RTPS/UDP Transport*.
2. To get the most out of *XTypes*, it's recommended to both *RTPS Discovery* and the *RTPS/UDP Transport*
3. *Static Discovery* requires *RTPS/UDP Transport*.

Like transports, additional discovery implementations can be created and plugged in.

InfoRepo Discovery

Note: InfoRepo discovery is scheduled for deprecation with OpenDDS 4 and scheduled for removal with OpenDDS 5.

OpenDDS contains a standalone CORBA service called *The DCPS Information Repository*. An instance of the DCPSInfoRepo is shared by all the participants in a domain and constitutes a centralized approach to discovery. Each OpenDDS application connects to the DCPSInfoRepo and creates records for its participants, topics, data writers, and data readers. As records for data writers and data readers are created, they are matched against the existing set of records. When matches are found, the DCPSInfoRepo invokes the participant to perform the necessary associations.



Important: Library filename: `OpenDDS_InfoRepoDiscovery`

MPC base project name: `dcps_inforepodiscovery`

CMake target Name: *`OpenDDS::InfoRepoDiscovery`*

Initialization header: `dds/DCPS/InfoRepoDiscovery/InfoRepoDiscovery.h`

Configuration: *Configuring for InfoRepo Discovery*

The DCPSInfoRepo is not involved in data propagation; its role is limited in scope to OpenDDS applications discovering one another. The DCPSInfoRepo populates the *Built-in Topics (BITs)* for a participant if configured to do so. OpenDDS creates its own ORB and a separate thread to run that ORB when using DCPSInfoRepo discovery.

Application developers are free to run multiple information repositories with each managing their own non-overlapping sets of DCPS domains.

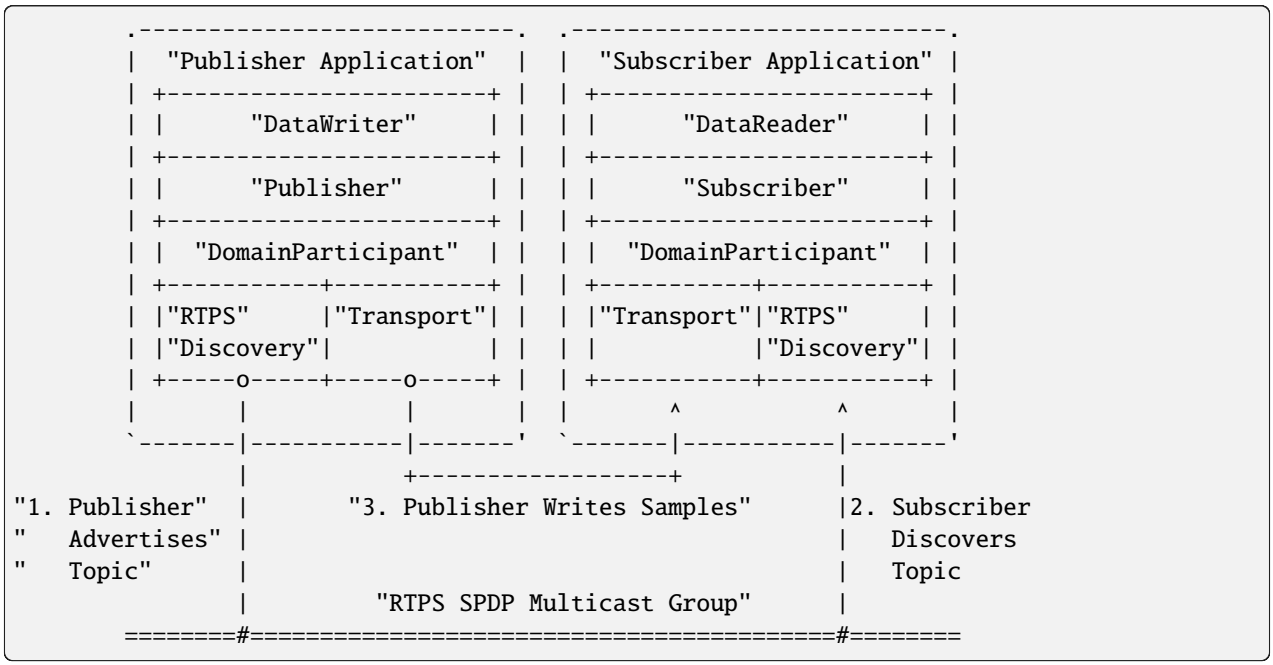
It is also possible to operate domains with more than a single repository, thus forming a distributed virtual repository. This is known as *Repository Federation*. In order for individual repositories to participate in a federation, each one must specify its own federation identifier value (a 32-bit numeric value) upon start-up. See *Repository Federation* for further information about repository federations.

See also:

The DCPS Information Repository
Documentation on the `DCPSInfoRepo` program

RTPS Discovery

RTPS discovery is a peer-to-peer discovery mechanism standardized as part of the RTPS spec. Other DDS implementations can interoperate with OpenDDS when RTPS discovery is used with the *RTPS/UDP Transport*.



Important: Library filename: `OpenDDS_Rtps`

MPC base project name: `dcps_rtps`

CMake target Name: *`OpenDDS::Rtps`*

Initialization header: `dds/DCPS/RTPS/RtpsDiscovery.h`

Configuration: *Configuring for RTPS Discovery*

RTPS Discovery uses the RTPS protocol to advertise and discover participants, data writers, and data readers. RTPS Discovery uses multicast to discover participants and *built-in endpoints* (not to be confused with *built-in topics*) each other without a centralized broker such as InfoRepo. This part of RTPS discovery is called the Simple Participant Discovery Protocol (SPDP). After the built-in endpoints are discovered and associated, they exchange information about data writers and data readers which are called *endpoints*. This part of RTPS discovery is called Simple Endpoint Discovery Protocol (SEDP). RTPS Discovery is a peer-to-peer approach to discovery as each participant interacts directly with other participants to accomplish discovery.

The following are additional implementation limits that developers need to take into consideration when developing and deploying applications that use RTPS discovery:

1. Domain IDs should be between 0 and 231 (inclusive) due to the way UDP ports are assigned to domain IDs. In each OpenDDS process, up to 120 domain participants are supported in each domain.
2. Topic names and type identifiers are limited to 256 characters.

3. The *Multicast Transport* does not work with RTPS Discovery due to the way GUIDs are assigned (a warning will be issued if this is attempted).

See also:

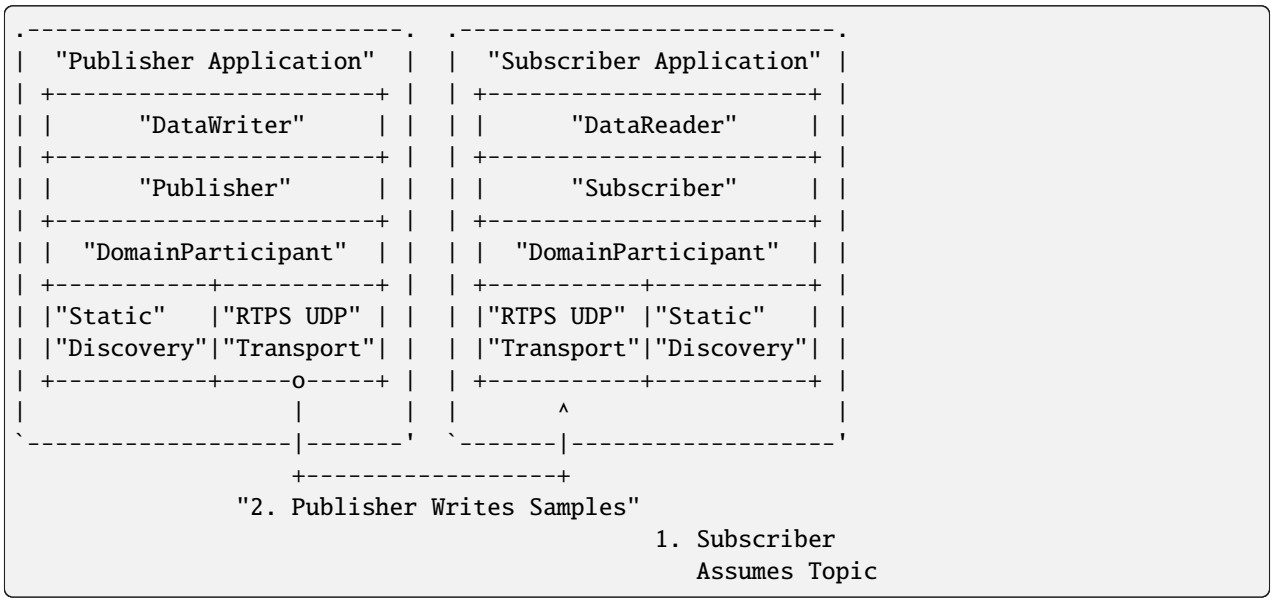
XTypes
For expanded type-system capabilities that are possible when using RTPS discovery

DDS Security
For security capabilities that are possible when using *RTPS Discovery* and the *RTPS/UDP Transport*

Internet-Enabled RTPS
For using *RTPS Discovery* and the *RTPS/UDP Transport* over the internet

Static Discovery

In Static Discovery, each participant starts with a database containing identifiers, QoS settings, and network locators for all participants, topics, data writers, data readers.



Important: The *RTPS/UDP Transport* is the only transport that can be used with Static Discovery.

Static Discovery is built-in to the core Dcps library, so it doesn't require linking a separate library or including an initialization header.

Configuration: *Configuring for Static Discovery*

When an application creates a data writer or data reader, Static Discovery causes it to send out periodic announcements. Upon receiving one of these announcements, Static Discovery consults its local database of entities to look up the details necessary for matching and matches it against local entities.

Static Discovery requires that the *User Data QoS* QoS be configured for each participant, data writer, and data reader. This user data must contain the identifier of the entity that is being created. Thus, the user data QoS is not available for general use when using Static Discovery. Static Discovery also requires that the network locators for all entities be determined up front by configuring the transport with the necessary networking information.

Threading

OpenDDS creates its own threads for handling I/O, timers, asynchronous jobs, and cleanup tasks. These threads are collectively called *service threads*. Applications may receive a callback from these threads via *Listeners* (see *Listeners*).

When publishing a sample, OpenDDS normally attempts to send the sample to any connected subscribers using the calling thread. If the send call would block, then the sample may be queued for sending on a separate service thread. This behavior depends on the QoS policies described in *Quality of Service*.

All incoming data is read by a service thread and queued for reading in DataReaders by the application. If a DataReader has a listener that should be invoked when data is available, then the listener is invoked by the service thread.

Configuration

OpenDDS includes a file-based configuration framework for configuring both global items such as debug level, memory allocation, and discovery, as well as transport implementation details for publishers and subscribers. Configuration can also be achieved directly in code, however, it is recommended that configuration be externalized for ease of maintenance and reduction in runtime errors. The complete set of configuration options are described in *Run-time Configuration*.

2.6 Building and Installing

2.6.1 Dependencies

Required to Build the Core OpenDDS Libraries

Note: Perl is required to run the configure script; MPC, ACE, and TAO will be downloaded automatically by the configure script by default.

Perl

Perl is an interpreted language used in the configure script, the tests, and most other scripting in OpenDDS codebase. Even if the configure script is not used, it is also required to run MPC, so it is required to build OpenDDS.

Perl should be 5.18 or newer and be available on the system `PATH`. Older versions of Perl will probably work, but are not tested anymore. Strawberry Perl is recommended for Windows.

Testing scripts are written in Perl and use the common PerlACE modules provided by ACE. For scripts that will be part of automated testing, don't assume the presence of any non-standard (CPAN) modules. Perl offers many facilities for portability. Shell scripts are by definition non-portable and should not to be committed to the OpenDDS repository.

Perl core modules are a required part of Perl. Some Linux distributions install the Perl interpreter without including core modules. Using OpenDDS with this sort of partial Perl installation may fail unexpectedly when using configure, MPC, `make depend`, or test scripts.

MPC

MPC is the build system used by OpenDDS, used to configure the build and generate platform specific build files (Makefiles, VS solution files, etc.).

The official repository is hosted on Github at DOCGroup/MPC.

It is included in the release archive of ACE/TAO, which is downloaded by the configure script by default.

ACE/TAO

The DOC Group repository for ACE/TAO is hosted on Github at DOCGroup/ACE_TAO.

There are two versions of ACE/TAO that are officially supported by OpenDDS in this release (3.28.0):

DOC Group ACE 6.5.20/TAO 2.5.20
: The configure script will download this version by default. *CMake* will download this version if *OPENDDS_ACE_TAO_KIND* is set to `ace6tao`.

  Pass `--ace-github-latest` to the configure script to clone the `ace6tao2` branch of ACE/TAO as is. This also clones the `master` branch of MPC as is. *CMake* will do the same if *OPENDDS_ACE_TAO_KIND* is set to `ace6tao` and *OPENDDS_ACE_TAO_GIT* is set to `TRUE`.

DOC Group ACE 7.1.3/TAO 3.1.3
: Pass `--doc-group3` to the configure script to download this version. *CMake* will download this version by default.

  This version requires a C++14-capable compiler.

  Pass `--ace-github-latest` to the configure script to clone the `master` branch of ACE/TAO as is. This also clones the `master` branch of MPC as is. *CMake* will do the same if *OPENDDS_ACE_TAO_GIT* is set to `TRUE`.

ACE

ACE is the platform abstraction layer used by OpenDDS. It is used both directly and through TAO. Facilities not provided by the C++ 2003 standard library, for example sockets, threads, and dynamic library loading, are provided by ACE.

Some other features OpenDDS relies on ACE for:

- ACE provides the `gnuace` type used by MPC for generating Makefiles for OpenDDS
- ACE contains a script, `generate_export_file.pl`, which is used (along with MPC) to manage shared libraries' symbol visibility (also known as export/import)
  - See ACE documentation and usage guidelines for details
- ACE logging is used (`ACE_Log_Msg` and related classes).
  - This is used through the `ACE_DEBUG` and `ACE_ERROR` macros.
  - ACE logging uses a formatting string that works like `std::printf()` but not all of the formatting specifiers are the same as `printf()`. Please read the `ACE_Log_Msg` documentation before using.
  - The most commonly misused formatting specifier is `%s`. In `printf` this is for `char*` C strings, but in `ACE_Log_Msg` this is for `ACE_TCHAR*` C strings. `ACE_TCHAR` can be `char` or a wide character depending on how ACE was built (see next point). `%C` should be used for strings that are always `char*`, like `std::string::c_str()`.
- ACE has classes and macros for wide/narrow string conversion. See `docs/design/WCHAR` for details.

- ACE provides support for platforms that have a non-standard program entry point (`main`). All of our `main` functions are `int ACE_TMAIN(int argc, ACE_TCHAR* argv[])`.

TAO

TAO is a C++ CORBA Implementation built on ACE.

- TAO provides the `tao_idl` IDL compiler and non-generated classes which implement the IDL-to-C++ mapping.
- TAO ORBs are only created for interaction with the DCPSInfoRepo, all other uses of TAO are basic types and local interfaces.
- A separate library, `OpenDDS_InfoRepoDiscovery`, encapsulates the participant process's use of the ORB.
  - This is the only library which depends on `TAO_PortableServer`.

The TAO Developer's Guide book can be requested for free from https://objectcomputing.com/products/tao/tao-developers-guide. The CORBA Programmers Guide can be downloaded for free from https://www.remedy.nl/opensource/corbapg.html.

Optional Dependencies

CMake

OpenDDS has a package included for CMake. See *Using OpenDDS in a CMake Project* for how to build OpenDDS applications with CMake and without the need to use MPC in your application.

CMake is required to build *GoogleTest* for OpenDDS tests if a prebuilt GoogleTest is not found or provided. See `tests/gtest_setup.txt` for details.

CMake should be version 3.3 or later for *Using OpenDDS in a CMake Project*. It should be version 3.23 or later for *Building OpenDDS Using CMake*.

GoogleTest

GoogleTest is required for OpenDDS tests.

GoogleTest is a git submodule that will be downloaded automatically if the repository was recursively cloned or submodules were initialized separately.

Note: If OpenDDS is not a git repository or Git isn't available, GoogleTest will have to be downloaded separately and configured manually.

See `tests/gtest_setup.txt` for details.

Java

OpenDDS has optional *Java bindings*. It requires the Java Development Kit (JDK).

There is also support for Java Message Server (JMS) v1.1. In addition to the JDK, it requires Ant and JBoss 4.2.x. See `java/jms/README`.

Qt

Qt5 is used for the `tools/monitor` utility program and the `examples/DCPS/ishapes` RTPS demo.

See `docs/qt.md` for details on configuring OpenDDS to use Qt.

Wireshark

A Wireshark dissector plugin for OpenDDS' non-RTPS transports is included with OpenDDS. The dissector supports Wireshark 1.2 and onwards and supports displaying and filtering by sample contents and from Wireshark 1.12 onwards.

Because of Wireshark's use of Glib, Glib is also required to build the dissector.

See `tools/dissector/README.md` for details.

RapidJSON

RapidJSON is a C++ JSON Library used for sample dissection in the Wireshark dissector and RapidJSON type support. Support for RapidJSON, if available, is enabled by default unless `--no-rapidjson` was passed.

RapidJSON is a git submodule that will be downloaded automatically if the repository was recursively cloned or submodules were initialized separately.

Note: If OpenDDS is not a git repository or Git isn't available, RapidJSON will have to be downloaded separately and configured manually.

Xerces

Apache Xerces ("Xerces 3 C++" specifically) is used for parsing QoS XML and *DDS Security* XML configuration files.

OpenSSL

OpenSSL is used for *DDS Security* for verifying security configurations and encryption and decryption. Versions 1.0, 1.1 and 3.0 (3.0.1 or later) are supported.

Python

Python is used for some scripts where Perl isn't as suitable. Most notably this includes *this Sphinx-based documentation* and processing the results of the CMake tests in `tests/auto_run_tests.pl` if `--cmake` is passed.

Unless noted otherwise, Python should be version 3.10 or later.

Because it's an optional dependency, Python should not be required for any script used for building and testing the core functionality of OpenDDS. Right now only Perl can be used for situations like that.

2.6.2 Using OpenDDS in a CMake Project

See also:

Building OpenDDS Using CMake

OpenDDS can be used with CMake-based projects by using the OpenDDS CMake config package. This package bridges the gap between the MPC build system used by OpenDDS and CMake-based projects by providing *imported library targets* and the ability to add IDL to a target using *`opendds_target_sources`*.

Requirements

CMake version 3.3.2 or greater is required to use the CMake package, but some some features require newer versions.

Using the OpenDDS CMake Package

Examples

Developer's Guide Messenger Example

For a simple quick-start example of a `CMakeLists.txt` using OpenDDS with CMake see the Developer's Guide Messenger example. The following instructions show how to configure and build it:

Make sure the environment is setup by using `source setenv.sh`.

```
cd DevGuideExamples/DCPS/Messenger
mkdir build
cd build
cmake ..
cmake --build .
perl run_test.pl
```

Make sure the environment is setup by using `call setenv.cmd`.

```
cd DevGuideExamples\DCPS\Messenger
mkdir build
cd build
cmake ..
cmake --build .
perl run_test.pl
```

Example Using Installed OpenDDS (Unix only)

The `--prefix` switch can be passed to configure to enable the `install` target, which will install OpenDDS (including the OpenDDS CMake config package) into the specified directory. See *Installation* for details.

Note: Be sure to pass an absolute path to `--prefix`.

```
OPENDDS_PREFIX="$PWD/opendds-install"
DDS_ROOT="$PWD/OpenDDS"
ACE_ROOT="$DDS_ROOT/ACE_wrappers"
cd OpenDDS
./configure --prefix="$OPENDDS_PREFIX"
make -j $(getconf _NPROCESSORS_ONLN)
make install
cd DevGuideExamples/DCPS/Messenger
mkdir build
cd build
cmake -DCMAKE_PREFIX_PATH="$OPENDDS_PREFIX" ..
cmake --build .
PERL5LIB="$DDS_ROOT/bin:$ACE_ROOT/bin" LD_LIBRARY_PATH="$OPENDDS_PREFIX/lib:$LD_LIBRARY_
↪PATH" perl run_test.pl
```

Other Examples

The CMake tests are written primarily as tests, but can also be used as examples for specific features and approaches.

find_package

To use the OpenDDS CMake package, first it has to be loaded using find_package. For example to mandatorily load OpenDDS:

```
find_package(OpenDDS REQUIRED)
```

For this to work, CMake has to be able to find the package. If the OpenDDS build environment variables (from `source setenv.sh` or `call setenv.cmd`) are set then CMake should be able to find it using the `PATH` environment variable. If those environment variables aren't set, OpenDDS was installed to a path CMake doesn't search automatically, or CMake can't otherwise find the OpenDDS package, then CMake has to be told about it explicitly somehow. This can be done a number of ways, which includes adding the OpenDDS source tree or install prefix path to `CMAKE_PREFIX_PATH` or setting `OPENDDS_ROOT` to that path (if using CMake 3.12 or later).

Consult the `find_package` documentation for your CMake version for all the details on how CMake could find OpenDDS. Here is the documentation for the latest version of CMake

Components

New in version 3.25.

By default the package will search for all libraries and executables, but only require the bare minimum for ACE/TAO and OpenDDS. Arguments can be passed to `find_package(OpenDDS COMPONENTS <argument>...)` (or alternatively `find_package(OpenDDS REQUIRED [COMPONENTS] <argument>...)`) add to what's required. These can be:

- *Executables* and *Libraries*

  Example:

  ```
  find_package(OpenDDS REQUIRED OpenDDS::Rtps_Udp OpenDDS::RtpsRelay)
  ```

- *Features*

  Feature names should be the same as the variable, but without the leading `OPENDDS_` and all lowercase. Feature names by themselves will be required to be enabled. If using CMake 3.9 or higher and the name is followed by =, then the CMake boolean value following that determines if the feature must be enabled or disabled.

  Example:

  ```
  find_package(OpenDDS REQUIRED built_in_topics safety_profile=OFF)
  ```

  Note: Passing features to `OPTIONAL_COMPONENTS` is treated as an error. It doesn't make sense to optionally request them because they are fixed.

- `NO_DEFAULTS`

  Passing `NO_DEFAULTS` will only search for and require what is specified. This allows using ACE/TAO without OpenDDS being built, assuming the package is configured correctly. It also allows `OPTIONAL_COMPONENTS` to have an effect because normally everything is treated as optional.

  Example:

  ```
  find_package(OpenDDS REQUIRED NO_DEFAULTS ACE::ACE OPTIONAL_COMPONENTS TAO::TAO)
  ```

  This just makes *ACE::ACE* and optionally *TAO::TAO* available. Normally *ACE::ACE*, *TAO::TAO*, and *OpenDDS::Dcps* are unconditionally searched for and required.

Adding IDL Sources with opendds_target_sources

The CMake config package provides an easy way to add IDL sources to CMake targets using *opendds_target_sources*. Here is how it's used in the Developer's Guide Messenger example:

```
# IDL TypeSupport Library
add_library(messenger_idl)
opendds_target_sources(messenger_idl PUBLIC "Messenger.idl")
target_link_libraries(messenger_idl PUBLIC OpenDDS::Dcps)
```

Here the IDL is added to a library that is shared by the executables, but `opendds_target_sources` can also be used on executables directly.

Note: CMake version 3.10 and below will issue a harmless warning if `add_library` is called without any sources.

See *opendds_target_sources* for all the options it accepts.

Linking OpenDDS Libraries

In addition to C++ types generated from IDL and their type support, OpenDDS applications need discovery and transport to talk to each other. target_link_libraries should be used with all the libraries needed. Here is the usage in the Developer's Guide Messenger example:

```
set(opendds_libs
  OpenDDS::Dcps # Core OpenDDS Library
  OpenDDS::InfoRepoDiscovery OpenDDS::Tcp # For run_test.pl
  OpenDDS::Rtps OpenDDS::Rtps_Udp # For run_test.pl --rtps
  messenger_idl
)

# Publisher
add_executable(publisher
  Publisher.cpp
)
target_link_libraries(publisher ${opendds_libs})

# Subscriber
add_executable(subscriber
  Subscriber.cpp
  DataReaderListenerImpl.cpp
)
target_link_libraries(subscriber ${opendds_libs})
```

See *Libraries* for all the libraries the CMake package can provide.

install(IMPORTED_RUNTIME_ARTIFACTS)

New in version 3.20.

If using CMake 3.21 or later, it's possible to install *executables* and *shared libraries* from OpenDDS, ACE, and TAO in CMake along side the application using install(IMPORTED_RUNTIME_ARTIFACTS). This will just install shared libraries and executables, not static libraries, headers, or anything else required for building applications.

If OpenDDS and ACE/TAO is built with `clang`, the shared libraries might be missing an `SONAME` entry. It is an issue with ACE/TAO. If trying to use `install(IMPORTED_RUNTIME_ARTIFACTS)` in this case, it causes the dynamic linker to ignore the libraries and report that they could not be found. One workaround is to add `SOFLAGS+=-Wl,-h,$(SONAME)` to `$ACE_ROOT/include/makeinclude/platform_macros.GNU` before building. This can be done manually after running the configure script or by passing `--macros=SOFLAGS+=-Wl,-h,\$\(SONAME\)` to the configure script.

opendds_get_library_dependencies is provided to help find out what libraries need to be installed.

See the install Test for an example of using this.

Changed in version 3.25: There are now *executables* that can be installed.

Installing Generated Interface Files

New in version 3.20.

It is possible to install files from the *OPENDDS_*_INTERFACE_FILES target properties* for downstream projects to use. See the install Test for an example of this. It uses install(FILES), but there isn't any restriction on what installation method can be used. For example, the PUBLIC_HEADER target property could be set on target to the desired files from the interface lists. Then they could be installed using install(TARGETS ... PUBLIC_HEADER ...). Another method is provided by `opendds_install_interface_files`.

Manually Creating config.cmake

The configure script is responsible for generating the `config.cmake` file in `cmake`, which has various configuration options. These options provide the OpenDDS CMake package with the required context it needs to integrate with the OpenDDS code generators and libraries.

If you are using OpenDDS libraries that were built without the help of the `configure` script, the `config.cmake` file needs to be created manually. See *Config Variables* for all the possible values to set.

Reference

Targets

Libraries

The CMake package can provide library targets that can be linked using target_link_libraries or installed using *install(IMPORTED_RUNTIME_ARTIFACTS)*.

`OpenDDS::Dcps`
: Required, the core OpenDDS Library

`OpenDDS::Rtps`
: *RTPS Discovery*

`OpenDDS::InfoRepoDiscovery`
: *InfoRepo Discovery*

`OpenDDS::Rtps_Udp`
: *RTPS/UDP Transport*

`OpenDDS::Multicast`
: *Multicast Transport*

`OpenDDS::Shmem`
: *Shared Memory Transport*

`OpenDDS::Tcp`
: *TCP Transport*

`OpenDDS::Udp`
: *UDP Transport*

`OpenDDS::Security`
: *DDS Security*

`OpenDDS::RtpsRelayLib`
: Support library for *OpenDDS::RtpsRelay*.

  New in version 3.25.

`ACE::ACE`
: Required

`ACE::XML_Utils`

`TAO::TAO`
: Required

`TAO::IDL_FE`

`TAO::AnyTypeCode`

`TAO::BiDirGIOP`

`TAO::CodecFactory`

`TAO::IORManip`

`TAO::IORTable`

`TAO::ImR_Client`

`TAO::PI`

`TAO::PortableServer`

`TAO::Svc_Utils`

`TAO::Valuetype`

Executables

New in version 3.25.

The CMake package can provide executable targets that can be called manually from CMake or installed using *install(IMPORTED_RUNTIME_ARTIFACTS)*.

`ACE::ace_gperf`
: Required

`TAO::tao_idl`
: Required, *tao_idl*

`OpenDDS::opendds_idl`
: Required, *opendds_idl*

`OpenDDS::DCPSInfoRepo`
: *The DCPS Information Repository*

`OpenDDS::RtpsRelay`
: *The RtpsRelay*

`OpenDDS::dcpsinfo_dump`
: Utility for *The DCPS Information Repository*

OpenDDS::inspect

tools/inspect/README.rst

OpenDDS::repoctl

Utility for *The DCPS Information Repository*

Functions

opendds_target_sources

```
opendds_target_sources(<target>
  [<idl-file>...]
  [PRIVATE|PUBLIC|INTERFACE <idl-file>...]
  [TAO_IDL_OPTIONS <option>...]
  [OPENDDS_IDL_OPTIONS <option>...]
  [SUPPRESS_ANYS TRUE|FALSE]
  [ALWAYS_GENERATE_LIB_EXPORT_HEADER TRUE|FALSE]
  [USE_EXPORT <export-header>;<export-macro>]
  [USE_VERSIONED_NAMESPACE <vns-header>;<vns-prefix>]
  [GENERATE_SERVER_SKELETONS TRUE|FALSE]
  [AUTO_LINK TRUE|FALSE]
  [INCLUDE_BASE <dir>]
  [SKIP_TAO_IDL]
  [SKIP_OPENDDS_IDL]
)
```

A function that acts like target_sources, but it adds IDL files and the resulting generated code to a target.

`<idl file>...` are IDL files that can be absolute or relative to CMAKE_CURRENT_SOURCE_DIR. Each one will generate code using `tao_idl` and `opendds_idl` that is added to the target. The optional scope-qualifier (`PRIVATE`, `PUBLIC`, `INTERFACE`) sets the scope of the generated files. When it is omitted, *OPENDDS_DEFAULT_SCOPE* is used.

Deprecated since version 3.15: C/C++ files can also be passed along with IDL files, but this has been deprecated.

TAO_IDL_OPTIONS <option>...

Pass options to *tao_idl*. Valid options can be found here

OPENDDS_IDL_OPTIONS <option>...

Pass options to *opendds_idl*. Add `OPENDDS_IDL_OPTIONS -Lc++11` to use the *C++11 IDL Mapping*.

SUPPRESS_ANYS TRUE|FALSE

If `FALSE`, TAO TypeCode for `any` will be generated. The default is set by *OPENDDS_SUPPRESS_ANYS*.

New in version 3.17.

ALWAYS_GENERATE_LIB_EXPORT_HEADER TRUE|FALSE

If `TRUE`, a header for exporting symbols in a shared library will be always generated as long the target is some sort of library. If `FALSE`, then it will only be done if the target is a shared library. The default is set by *OPENDDS_ALWAYS_GENERATE_LIB_EXPORT_HEADER*.

New in version 3.20.

EXPORT_HEADER_DIR <header-dir>

Where the export header is placed relative to the other generated files. The value is passed to *opendds_export_header(DIR)*.

New in version 3.28.

USE_EXPORT <export-header>;<export-macro>

Pass a CMake list (;-delimited) of an existing export header and export macro to use in the generated code. This is the same format as *opendds_export_header(USE_EXPORT_VAR)*, but is intended for use with a custom export header. If there are multiple calls to *opendds_target_sources* on the same target, only the first `USE_EXPORT` is used.

New in version 3.25.

USE_VERSIONED_NAMESPACE <version-ns-header>;<version-ns-prefix>

Pass a CMake list (;-delimited) of an existing versioned namespace header and prefix to use in the generated code.

New in version 3.26.

GENERATE_SERVER_SKELETONS TRUE|FALSE

`tao_idl` generate code for CORBA servers. The default is `FALSE`. `tao_idl` by itself does this by default, but by default `opendds_target_sources` passes `-SS` to suppress this as it's not normally useful to an OpenDDS application.

New in version 3.25.

AUTO_LINK TRUE|FALSE

Automatically link *OpenDDS::Dcps* or other dependencies to the target using the "max" scope. If `FALSE` then dependencies will have to be linked manually. The default is set by *OPENDDS_AUTO_LINK_DCPS*.

New in version 3.25.

INCLUDE_BASE <dir>

Recreates the directory structure of all the passed IDLs relative to the passed base directory in the generated files. This allows using IDL files from multiple directories. *opendds_install_interface_files* is proved to help install generated files that result from this. Any IDL file passed that's outside the include base will cause an error.

The default behavior is the legacy behavior that assumes a flat hierarchy. Starting with OpenDDS 4.0 this will always be enabled and will default to `CMAKE_CURRENT_SOURCE_DIR`.

New in version 3.26.

SKIP_TAO_IDL

Skip invoking `tao_idl` on the IDL files that are passed in. This will still run `tao_idl` on `*TypeSupport.idl` files unless `SKIP_OPENDDS_IDL` is passed in or `-SI` is passed to *opendds_target_sources(OPENDDS_IDL_OPTIONS)*.

New in version 3.25.

SKIP_OPENDDS_IDL

Skip invoking `opendds_idl` on the IDL files.

New in version 3.25.

After `opendds_target_sources` is run on a target, it will have these target properties set on it:

OPENDDS_LANGUAGE_MAPPINGS

This holds the IDL language mappings used in the target based on what is passed to *opendds_target_sources(OPENDDS_IDL_OPTIONS)*.

It will be a list that can contain one or more of the following:

- `"C++03"`
  - IDL-to-C++ mapping generated by default.
- `"C++11"`
  - IDL-to-C++11 mapping available when passing `-Lc++11`.
- `"FACE"`
  - Will appear if `-Lface` is passed.
- `"Java"`
  - Currently unsupported.

If the CMake version is at least 3.12, then this property will be exported with the target.

New in version 3.15.

OPENDDS_GENERATED_DIRECTORY

The is the directory where generated files have been placed. This is an absolute path and is not exported with the target. See *Installing Generated Interface Files* for more information.

New in version 3.20.

The following `OPENDDS_*_INTERFACE_FILES` target properties are used to help with *Installing Generated Interface Files*. Some notes about these properties:

- All paths are absolute.
- All the generated files will be somewhere within the path from the *OPENDDS_GENERATED_DIRECTORY* target property of the target.
- All the properties have the `INTERFACE` in their name, but this includes `PUBLIC` scoped files as `PUBLIC` implies `INTERFACE` in CMake. `PRIVATE` scoped files are excluded from these lists as they shouldn't have a use outside the target.
- These properties are not exported with the target because the paths may not be valid any more if the build directory has been removed or the export is being used on another machine.

OPENDDS_PASSED_IDL_INTERFACE_FILES

The `PUBLIC` and `INTERFACE` scoped IDL files passed.

New in version 3.20.

OPENDDS_GENERATED_IDL_INTERFACE_FILES

The IDL files generated from the IDL files in *OPENDDS_PASSED_IDL_INTERFACE_FILES*.

New in version 3.20.

OPENDDS_ALL_IDL_INTERFACE_FILES

Combination of *OPENDDS_PASSED_IDL_INTERFACE_FILES* and *OPENDDS_GENERATED_IDL_INTERFACE_FILES*.

OPENDDS_GENERATED_HEADER_FILES

The `.h` and `.inl` files generated from *OPENDDS_ALL_IDL_INTERFACE_FILES*.

New in version 3.20.

OPENDDS_ALL_GENERATED_INTERFACE_FILES

Combination of *OPENDDS_GENERATED_IDL_INTERFACE_FILES* and *OPENDDS_GENERATED_HEADER_FILES*.

New in version 3.20.

OPENDDS_ALL_INTERFACE_FILES

All the `INTERFACE` and `PUBLIC` scoped files that were passed in or generated.

New in version 3.20.

Changed in version 3.25: `OPENDDS_TARGET_SOURCES` is now called `opendds_target_sources`, but this shouldn't affect anything because functions and macros are case-insensitive in CMake.

opendds_get_library_dependencies

```
opendds_get_library_dependencies(<output-list-var-name> <target>...)
```

If given targets provided by the CMake package, it will return a list of the targets along with their ACE, TAO, and OpenDDS dependencies. This is provided to help use *install(IMPORTED_RUNTIME_ARTIFACTS)*.

New in version 3.20.

opendds_export_header

```
opendds_export_header(<target>
  [USE_EXPORT_VAR <use-export-var-name>]
  [DIR <dir-path>]
)
```

Generates a header that is compatible with ACE's generate_export_file.pl for exporting symbols in shared libraries. The header will able to be included as `<target>_export.h` and the macro that can be used to export symbols will be named `<target>_Export`. It is the same function *opendds_target_sources* uses so all the same info about *generated files* applies.

USE_EXPORT_VAR <use-export-var-name>

Set a variable with the given name that contains a list with the location of the generated export header and the macro name to export a symbol. These values could be passed to *opendds_target_sources(USE_EXPORT)*, but this shouldn't be necessary because these values are saved on the target on the first call of *opendds_target_sources* or *opendds_export_header*.

DIR <dir-path>

Where the export header is placed relative to the other generated files. By default the generated export header is put in the root of the include base. See *opendds_target_sources(EXPORT_HEADER_DIR)* for how to pass this argument from there.

New in version 3.28: to replace the broken and undocumented `INCLUDE_BASE` argument.

New in version 3.25.

opendds_install_interface_files

```
opendds_install_interface_files(<target>
  [DEST <dir>]
  [INCLUDE_BASE <dir>]
  [EXTRA_GENERATED_FILES <file>...]
)
```

A helper function that installs the files from the *OPENDDS_*_INTERFACE_FILES target properties* of the given target and is meant to be used with *opendds_target_sources(INCLUDE_BASE)*. The install path of a file `idl_file` could be described as `DEST/relative(idl_file,INCLUDE_BASE)/idl_file`.

DEST <dir>

The base directory to install them to. By default this is CMAKE_INSTALL_INCLUDEDIR.

INCLUDE_BASE <dir>

The source directory relative to the source IDL files to define the directory structure of the installed files. This should probably be the same as *opendds_target_sources(INCLUDE_BASE)*. By default this is `CMAKE_CURRENT_SOURCE_DIR`.

EXTRA_GENERATED_FILES <file>...

Extra custom files that are in *OPENDDS_GENERATED_DIRECTORY* to install using the same method.

New in version 3.26.

Variables

Package Options

These variables can be used to override default behavior of the CMake package.

Warning: Except for *OPENDDS_CMAKE_VERBOSE*, do not set these when building OpenDDS using CMake. All the others will either have no effect or break the build.

OPENDDS_CMAKE_VERBOSE

If `TRUE`, then log detailed status information at configure-time. The default for this is `FALSE`.

New in version 3.25: The variable can also contain a list of categories to log more verbosely:

all
Enables all logging

components
Logs what *components* were passed and the exact list of libraries are being searched for and required.

imports
Logs the paths of *executables* and *libraries* that are going to be imported.

opendds_target_sources
Logs the arguments of *opendds_target_sources* and what files will be generated.

OPENDDS_DEFAULT_NESTED

If `TRUE`, then *topic types* must be declared explicitly using *annotations*. The default for this is `TRUE`.

This can also be controlled on a finer level by passing `--default-nested` or `--no-default-nested` to *opendds_target_sources(OPENDDS_IDL_OPTIONS)*. For example:

```
add_library(messenger)
opendds_target_sources(messenger
  PUBLIC
    Messenger.idl
    OPENDDS_IDL_OPTIONS --no-default-nested
)
```

OPENDDS_FILENAME_ONLY_INCLUDES

Setting this to TRUE tells opendds_idl to strip path information from #include lines in generated files. Turning the option on can make it easier to specify build rules for IDL files that include other IDL files. The default for this is FALSE.

New in version 3.15.

Deprecated since version 3.26: *opendds_target_sources(INCLUDE_BASE)* is a better way to handle IDL in multiple nested directories.

OPENDDS_SUPPRESS_ANYS

Default value for *opendds_target_sources(SUPPRESS_ANYS)*. The default for this is TRUE.

New in version 3.17.

OPENDDS_ALWAYS_GENERATE_LIB_EXPORT_HEADER

Default value for *opendds_target_sources(ALWAYS_GENERATE_LIB_EXPORT_HEADER)*. The default for this is FALSE.

New in version 3.20.

OPENDDS_DEFAULT_SCOPE

Default scope of unscoped files in *opendds_target_sources*. It must be PRIVATE, PUBLIC, or INTERFACE. The default for this is PRIVATE.

New in version 3.20.

OPENDDS_AUTO_LINK_DCPS

Default value for *opendds_target_sources(AUTO_LINK)*. The default for this is FALSE.

Note: This is off by default because it's not compatible with any existing usage of target_link_libraries that doesn't specify a scope. The default for this will be TRUE starting in OpenDDS 4.0.

New in version 3.24.

OPENDDS_USE_CORRECT_INCLUDE_SCOPE

If TRUE, then include directories of generated files using the "max" scope specified in *opendds_target_sources*. The default for this is FALSE, which always includes them using the PUBLIC scope.

Note: This is off by default because it could cause "Cannot find source file" errors on TypeSupport.idl files generated in a another directory. This will be fixed in OpenDDS 4.0 by requiring at least CMake 3.20 to get CMP0118. This variable will be removed in OpenDDS 4.0 and the behavior will be the same as if this variable was set to TRUE.

New in version 3.24.

Config Variables

These variables are set by the `configure` script in an MPC-built OpenDDS and normally shouldn't be changed. They can be changed when configuring a *CMake-built OpenDDS* using `-D`, but should not be changed after that.

See also:

Build-Exclusive CMake Variables

Dependencies

OPENDDS_ACE

Path to *ACE*, usually *ACE_ROOT*

OPENDDS_ACE_VERSION

The version of ACE being used.

New in version 3.27.

OPENDDS_TAO

Path to *TAO*, usually *TAO_ROOT*

OPENDDS_TAO_VERSION

The version of TAO being used.

New in version 3.27.

OPENDDS_OPENSSL

Path to *OpenSSL*

OPENDDS_GTEST

Path to *GoogleTest*

OPENDDS_JAVA

Path to *Java* Currently unsupported.

OPENDDS_QT

Path to *Qt*

OPENDDS_RAPIDJSON

Path to *RapidJSON*

OPENDDS_XERCES3

Path to *Xerces*

OPENDDS_HOST_TOOLS

A directory that contains a `bin` directory with `opendds_idl` to be used for cross-compiling.

New in version 3.26.

OPENDDS_ACE_TAO_HOST_TOOLS

A directory that contains a `bin` directory with `tao_idl` and `ace_gperf` to be used for cross-compiling. This isn't set by default unless *OPENDDS_HOST_TOOLS* is set, in which case it defaults to that.

New in version 3.26.

Features

OPENDDS_CXX11

ACE/TAO and OpenDDS were built with C++11 or later. Default depends on the compiler being used. Has no effect when building OpenDDS using CMake.

OPENDDS_CXX_STD

New in version 3.28.

If defined, then this value is prefixed with `cxx_std_` and passed to target_compile_features for all targets. The valid values are the standards in CMAKE_CXX_KNOWN_FEATURES without the leading `cxx_std_`. This is the minimum C++ standard required to use the ACE, TAO, and OpenDDS libraries. When building OpenDDS using CMake, it's also the minimum C++ standard used to build OpenDDS. The default depends on the version of ACE being used.

OPENDDS_DEBUG

Default depends on CMAKE_BUILD_TYPE. When building OpenDDS using CMake `CMAKE_BUILD_TYPE` should be used.

OPENDDS_OPTIMIZE

Default depends on CMAKE_BUILD_TYPE. When building OpenDDS using CMake `CMAKE_BUILD_TYPE` should be used.

OPENDDS_INLINE

`.inl` files are included in header files. Default is `ON` Has no effect when building OpenDDS using CMake.

OPENDDS_VERSIONED_NAMESPACE

ACE/TAO and OpenDDS have versioned namespaces. Default is `OFF`

OPENDDS_STATIC

ACE/TAO are built as static libraries. Default depends on BUILD_SHARED_LIBS. When building OpenDDS using CMake `BUILD_SHARED_LIBS` should be used.

OPENDDS_WCHAR

ACE/TAO prefers using wide characters. Default is `OFF`

OPENDDS_TAO_IIOP

Default is `ON`

OPENDDS_TAO_OPTIMIZE_COLLOCATED_INVOCATIONS

Default is `ON`

OPENDDS_BUILT_IN_TOPICS

Default is `ON`

OPENDDS_OBJECT_MODEL_PROFILE

Default is `ON`

OPENDDS_PERSISTENCE_PROFILE

Default is `ON`

OPENDDS_OWNERSHIP_PROFILE

Default is `ON`

OPENDDS_OWNERSHIP_KIND_EXCLUSIVE

Default is the value of *OPENDDS_OWNERSHIP_PROFILE*.

OPENDDS_CONTENT_SUBSCRIPTION
: Default is `ON`

OPENDDS_CONTENT_FILTERED_TOPIC
: Default is the value of *OPENDDS_CONTENT_SUBSCRIPTION*.

OPENDDS_MULTI_TOPIC
: Default is the value of *OPENDDS_CONTENT_SUBSCRIPTION*.

OPENDDS_QUERY_CONDITION
: Default is the value of *OPENDDS_CONTENT_SUBSCRIPTION*.

OPENDDS_SECURITY
: Default is `OFF`

OPENDDS_SAFETY_PROFILE
: Default is `OFF`

2.6.3 Android

How to build OpenDDS for Android and incorporate OpenDDS into Android apps.

Variables

The following table describes some of the variables of paths that are referenced in this guide.

Note: You don't have to actually set and use these, they are mostly for shorthand.

Variable	Description
`$DDS_ROOT`	OpenDDS being built for Android
`$HOST_DDS`	*OpenDDS host to help build OpenDDS for Android*
`$ACE_ROOT`	ACE being built for Android
`$NDK`	The Android NDK
`$TOOLCHAIN`	The *generated toolchain*
`$SDK`	The *Android SDK* (By default `$HOME/Android/Sdk`)
`$STUDIO`	Android Studio
`$JDK`	The *Java SDK*
`$SSL_ROOT`	Install prefix for cross-compiled *OpenSSL*
`$ABI`	*android_abi*
`$ARCH_ARG`	A *Target architecture* name used by Android NDK
`$MIN_API`	*android_api*, the minimum Android API version number
`$TARGET_API`	*android_target_api*, the target Android API version number

Requirements

To build the core OpenDDS native libraries for Android you will need:

- A development system supported by both OpenDDS and the Android NDK.
  - Windows and Linux were tested, but macOS should work as well.
- Android Native Development Kit (NDK) r18 or higher. *Building with the NDK directly* requires NDK r19 or higher. You can download it separately from https://www.android.com or using the SDK Manager that comes with Android Studio. If you downloaded the NDK using the SDK Manager, then it is located at `$SDK/ndk-bundle`.
- Some knowledge about OpenDDS and Android development will be assumed, but more OpenDDS knowledge will be assumed than Android knowledge.
- Windows users should see *Building on Windows* for additional requirements they might need.

In addition to those, building OpenDDS with *optional dependencies* also have additional requirements listed in their own sections.

The *Using OpenDDS in a Android App* assumes the use of Android Studio, but it will also work when just using the Android SDK if tweaked.

Building on Windows

If using you're using Windows Subsystem for Linux (WSL), Docker, or anything like that, follow the **Linux and macOS** instructions. You can copy the resulting libraries from the virtual environment to Windows and where they can be used in Android Studio as they would be used on Linux.

If you want to build OpenDDS for Android on Windows without WSL or Docker, follow the **Windows** instructions.

In addition to OpenDDS and the Android NDK you will also need the following software:

- MSYS2
  - Building OpenDDS and its dependencies for Android requires various utilities that would normally come on a Unix system. This guide will use MSYS2, which supplies many of those utilities. Install MSYS2 from the official website at https://www.msys2.org and set it up.
  - Follow all the install/update steps from the msys2.org website.
- Strawberry Perl
- OpenDDS Host tools build using Visual Studio
  - In a separate copy of OpenDDS, build OpenDDS as described in *Building and Installing* using Visual Studio, except use the `--host-tools-only` configure script option. This OpenDDS (and the ACE+TAO it uses) must be the same version as the one used to build for Android.
  - If you want to use Java in the Android build, also pass the `--java` configure script option here as described in *Java*. You will also need to pass it to the configure script build for Android when that comes.

Finally, all paths being passed to GNU Make must not contain spaces because ACE's gnuace make scripts don't handle those paths correctly on Windows. This means the NDK, toolchain, MSYS2, JDK, OpenDDS source, OpenDDS host tools, etc. must not contain any spaces in their paths.

Building OpenDDS for Android

As Android targets multiple architectures and has many versions, an architecture and minimum API version to use will have to be decided. As of writing this page lists Android version numbers and their corresponding API versions. You will have to do a separate build for each architecture if you want to build OpenDDS for multiple architectures.

OpenDDS for Android can be built in two ways: *Using the NDK Directly* or *Using a Standalone Toolchain*.

Using the NDK directly is recommended by Google and means that toolchains don't have to be generated for each target architecture.

Using the NDK Directly

Note: Building with the NDK directly requires NDK r19 or later.

Note: If you need to configure OpenDDS with any optional dependencies then read the *relevant sections* before configuring and building OpenDDS.

OpenDDS can be configured and built with the Android NDK using the following commands:

```
./configure --doc-group3 --target=android --macros=android_abi=$ABI --macros=android_api=
↪$MIN_API --macros=android_ndk=$NDK
make # Pass -j/--jobs with an appropriate value or this'll take a while...
```

Using a Standalone Toolchain

To build OpenDDS with with a Android standalone toolchain, a standalone toolchain must first be generated by using:

```
$NDK/build/tools/make_standalone_toolchain.py --arch $ARCH_ARG --api $MIN_API --install-
↪dir $TOOLCHAIN
```

Android NDK includes Python in `prebuilt\windows-x86_64\bin` for 64-bit Windows NDKs. For the example above, assuming `%NDK%` is the location of the NDK and `%TOOLCHAIN%` is the desired location of the toolchain, run this command instead:

```
%NDK%\prebuilt\windows-x86_64\bin\python %NDK%\build\tools\make_standalone_toolchain.py -
↪-arch %ARCH_ARG% --api %MIN_API% --install-dir %TOOLCHAIN%
```

The `--arch` argument for `make_standalone_toolchain.py` and `--macros=android_abi=<ARCH>` argument for the configure script must match according to *this table*.

Note: If you need to configure OpenDDS with any optional dependencies then read the *relevant sections* before configuring and building OpenDDS.

To configure and build OpenDDS after this, run:

```
./configure --target=android --macros=android_abi=$ABI
PATH=$PATH:$TOOLCHAIN/bin make # Pass -j/--jobs with an appropriate value or this'll take␣
↪a while...
```

```
configure --target=android --macros=android_abi=%ABI% --host-tools=%HOST_DDS%
set PATH=%PATH%;%TOOLCHAIN%\bin;C:\msys64\usr\bin
make
REM Pass -j/--jobs with an appropriate value or this'll take a while...
```

Note:

- Pass `--host-tools` with the location of the OpenDDS host tools that were built using Visual Studio must be passed to `configure`.
- You will need MSYS2 utilities in your `%PATH%`.
- Run these commands in a new Visual Studio command prompt that is different from where you configured the host tools.

Configure Script Macros

These are GNU make variables that can be passed using the `--macros` configure script option. They are mostly used by platform_android.GNU.

android_ndk

Location of Android NDK, same as *$NDK*. This is required when *building with the NDK directly*, but not when building with a standalone toolchain.

android_sdk

Location of *Android SDK*, same as *$SDK*. This is only required if enabling OpenDDS to use Android Java APIs.

android_abi

The architecture to cross-target. When using ACE6/TAO2 it is optional as it defaults to `armeabi-v7a`. When using ACE7/ACE3 it is required.

The valid options are:

$ARCH_ARG	android_abi	$ABI_PREFIX	Description
arm	armeabi-v7a	arm-linux-androideabi	32-bit ARM
arm	armeabi-v7a-with-neon	arm-linux-androideabi	32-bit ARM with NEON
arm64	arm64-v8a	aarch64-linux-android	64-bit ARM
x86	x86	i686-linux-android	32-bit x86
x86_64	x86_64	x86_64-linux-android	64-bit x86

android_api

The minimum Android API to target. This is the same as *$MIN_API*. This is required when *building with the NDK*, but not when building with a standalone toolchain.

android_target_api

The Android API being targeted by an application. This is the same as *$TARGET_API*. This is only required if enabling OpenDDS to use Android Java APIs.

Host Tools

To cross-compile OpenDDS, host tools are required to process IDL. These are programs that include *tao_idl* and *opendds_idl* that have to be built to run on the host system, not Android. The example above generates two copies of OpenDDS, one in `OpenDDS/build/host` and another in `OpenDDS/build/target`. If this is the case, then `$HOST_DDS` will be the absolute path to `build/host` and `$DDS_ROOT` will be the absolute path to `build/target`.

If building for more than one architecture, which will be necessary to cover the largest number of Android devices possible, it might make sense to build the OpenDDS host tools separately to cut down on compile time and disk space.

If this is the case, then `$HOST_DDS` will be the location of the static host tools built for the host platform and `$DDS_ROOT` will just be the location of the OpenDDS source code.

This should be done with the same version of OpenDDS and ACE/TAO as what you want to build for Android. Pass `--host-tools-only` to the configure script to generate static host tools. Also pass `--java $JDK` if you plan on using Java.

If you want to just the minimum needed for host OpenDDS tools and get rid of the rest of the source files, you can. These are the binaries that make up the OpenDDS host tools:

- `$HOST_DDS/bin/opendds_idl`
- `$HOST_DDS/bin/idl2jni` (if using the OpenDDS Java API)
- `$HOST_DDS/ACE_TAO/bin/ace_gperf`
- `$HOST_DDS/ACE_TAO/bin/tao_idl`

These files can be separated from the rest of the OpenDDS and ACE/TAO source trees, but the directory structure must be kept. To use these to build OpenDDS for Android, pass `--host-tools $HOST_DDS` to the configure script.

Optional Dependencies

Java

To use OpenDDS in the traditional Android development language, Java, you will need to build the Java bindings when building OpenDDS. See `java/README` for details. For Android you can use the JDK provided with Android Studio, `JDK=$STUDIO/jre`. Pass `--java=$JDK` to the OpenDDS configure script.

Android SDK

OpenDDS can make use of Android's Java SDK. Right now this is just used for allowing OpenDDS to always be notified of *network availability when targeting API 30 and later*.

OpenSSL

OpenSSL is required for OpenDDS Security.

Android preloads the system SSL library (either OpenSSL or BoringSSL) for the Java Android API, so OpenSSL **MUST** be statically linked to the OpenDDS security library. The static libraries will used if the shared libraries are not found. This can be accomplished by either disabling the generation of the shared libraries by passing `no-shared` to OpenSSL's `Configure` script or just deleting the `so` files after building OpenSSL.

To build OpenSSL for Android, read the `NOTES.ANDROID` file that comes with OpenSSL's source code.

Cross-compiling OpenSSL on **Windows**:

1. Start the MSYS2 MSYS development shell using the start menu shortcut or `C:\msys64\msys2_shell.cmd -msys`
2. `cd /c/your/location/of/OpenSSL-source`
3. `export ANDROID_NDK_HOME=/c/your/location/of/ndk-standalone-toolchain`
4. `PATH+=:$ANDROID_NDK_HOME/bin`
5. `./Configure --prefix=$SSL_ROOT android-arm no-tests no-shared` (or replace `-arm` with a different platform like `-arm64`, see OpenSSL's `NOTES.ANDROID` file)
6. `make install_sw`

Xerces

Xerces C++ is also required for OpenDDS Security. It does not support Android specifically, but it comes with a CMake build script that can be paired with the Android NDK's CMake toolchain.

Xerces requires a supported "transcoder" library. For API levels greater than or equal to 28 one of these, GNU libiconv, is included with Android. Before 28 any of the transcoders supported by Xerces would work theoretically but GNU libiconv was the one tested. If GNU libiconv is used, build it as an archive library (`--disable-shared`) so that the users of Xerces (ACE and OpenDDS) don't need to be aware of it as an additional runtime dependency.

Download GNU libiconv version 1.16 source code and extract the archive.

Cross-compiling on Windows

GNU libiconv

1. Start the MSYS2 MSYS development shell using the start menu shortcut or `C:\msys64\msys2_shell.cmd -msys`
2. `cd /c/your/location/of/libiconv-source`
3. `export ANDROID_NDK_HOME=/c/your/location/of/ndk-standalone-toolchain`
4. `PATH+=:$ANDROID_NDK_HOME/bin`
5. `target=arm-linux-androideabi` (or select a different NDK target)

6. `./configure --disable-shared --prefix=/c/your/location/of/installed-libiconv --host=$target CC=$target-clang CXX=$target-clang++ LD=$target-ld CFLAGS="-fPIE -fPIC" LDFLAGS=-pie`
7. `make && make install`

Note: The directory given by `--prefix=` will be created by `make install` and will have `include` and `lib` subdirectories that will be used by the Xerces build.

Xerces

A modified version of Xerces C++ hosted on OpenDDS GitHub organization has support for an external GNU libiconv. Download this version using git (`android` branch) or the via ZIP archive.

Start the Microsoft Visual Studio command prompt for C++ development (for example "x64 Native Tools Command Prompt for VS 2019").

`cmake` and `ninja` should be on the PATH. They can be installed as on option component in the Visual Studio installer (see "C++ CMake tools for Windows"), or downloaded separately.

Set environment variables based on the NDK location and Android configuration selected:

1. `set target=arm-linux-androideabi`
2. `set abi=armeabi-v7a`
3. `set api=16`
4. `set NDK=C:\your\location\of\NDK`
5. `set GNU_ICONV_ROOT=C:\your\location\of\installed-libiconv`

Configure and build with CMake

1. `cd C:\your\location\of\Xerces-for-android`
2. `mkdir build & cd build`
3. `cmake -GNinja -DCMAKE_BUILD_TYPE=Release -DCMAKE_INSTALL_PREFIX=C:\your\location\of\installed-xerces -DCMAKE_TOOLCHAIN_FILE=%NDK%\build\cmake\android.toolchain.cmake -DANDROID_ABI=%abi% -DANDROID_PLATFORM=android-%api% "-DANDROID_CPP_FEATURES=rtti exceptions" ..`
4. `cmake --build . --target install`

Cross-Compiling IDL Libraries

Like all OpenDDS applications, you will need to use type support libraries generated from IDL files to use most of OpenDDS's functionality.

Assuming the library is already setup and works for a desktop platform, then you should be able to run:

```
(source $DDS_ROOT/setenv.sh; opendds_mwc.pl && PATH=$PATH:$TOOLCHAIN/bin make)
```

The resulting native IDL library file must be included with the rest of the native library files.

Java IDL Libraries

Java support for your IDL, assuming OpenDDS was built with Java, will available by inheriting `dcps_java` in your IDL MPC project and will be built along with the native IDL libraries using the command above.

Java IDL libraries consist of two components: a Java `jar` library file and a supporting native library `so` file. This native library must be included with the other native library files, and is different than the regular native IDL type support library.

Using OpenDDS in a Android App

After building OpenDDS and generating the IDL libraries, you will need to set up an app to be able to use OpenDDS.

There is a demo for using OpenDDS over the Internet that includes an Android app built using these instructions.

Adding the OpenDDS Native Libraries to the App

In your app's `build.gradle` (**NOT THE ONE OF THE SAME NAME IN THE ROOT OF THE PROJECT**) add this to the `android` section:

```
sourceSets {
    main {
        jniLibs.srcDirs 'native_libs'
    }
}
```

`native_libs` is not a required name, but it needs to contain subdirectories named after the `android_abi` of the native libraries it contains *ABI/architecture table*.

The exact list of libraries to include depend on what features you're using but the basic list of library file for OpenDDS are as follows:

- Core OpenDDS library and its dependencies:
  - If not already included because of a separate C++ NDK project, you must include the Clang C++ Standard Library. This is located at:
    * Standalone toolchain: `$TOOLCHAIN/sysroot/usr/lib/$ABI_PREFIX/libc++_shared.so`
    * NDK: `$NDK/toolchains/llvm/prebuilt/$HOST_PLATFORM/sysroot/usr/lib/$ABI_PREFIX/libc++_shared.so`
    * `$ABI_PREFIX` is an identifier for the architecture whose possible values can be found in the *ABI/architecture table*.
  - `$ACE_ROOT/lib/libACE.so`
  - `$ACE_ROOT/lib/libTAO.so`
  - `$DDS_ROOT/lib/libOpenDDS_Dcps.so`
- The following are the transport libraries, one for each transport type. You will need at least one of these, depending on the transport(s) you want to use:
  - `$DDS_ROOT/lib/libOpenDDS_Rtps_Udp.so`
    * Depends on `$DDS_ROOT/lib/libOpenDDS_Rtps.so`
  - `$DDS_ROOT/lib/libOpenDDS_Multicast.so`

  - `$DDS_ROOT/lib/libOpenDDS_Shmem.so`
  - `$DDS_ROOT/lib/libOpenDDS_Tcp.so`
  - `$DDS_ROOT/lib/libOpenDDS_Udp.so`
- The *type support libraries for your IDL*.
  - The following are the Discovery libraries. Static discovery is built into `libOpenDDS_Dcps.so`, but most likely you will want one of these:
  - Required to use RTPS Discovery:
    - `$DDS_ROOT/lib/libOpenDDS_Rtps.so`
  - Required to use the DCPSInfoRepo Discovery:
    - `$DDS_ROOT/lib/libOpenDDS_InfoRepoDiscovery.so`
      - Depends on:
        - `$ACE_ROOT/lib/libTAO_PortableServer.so`
        - `$ACE_ROOT/lib/libTAO_AnyTypeCode.so`
        - `$ACE_ROOT/lib/libTAO_BiDirGIOP.so`
        - `$ACE_ROOT/lib/libTAO_CodecFactory.so`
        - `$ACE_ROOT/lib/libTAO_PI.so`
  - Required to use OpenDDS Security:
    - `$ACE_ROOT/lib/libACE_XML_Utils.so`
    - `libxerces-c-3.*.so`
    - `libiconv.so` if it is necessary to include it.
    - `$DDS_ROOT/lib/libOpenDDS_Security.so`
- In addition to the jars listed below, the following native libraries are required for using the Java API:
  - `$DDS_ROOT/lib/libtao_java.so`
  - `$DDS_ROOT/lib/libidl2jni_runtime.so`
  - `$DDS_ROOT/lib/libOpenDDS_DCPS_Java.so`
    - Depends on:
      - `$DDS_ROOT/lib/libOpenDDS_Rtps_Udp.so`
      - `$DDS_ROOT/lib/libOpenDDS_Rtps.so`
      - `$DDS_ROOT/lib/libOpenDDS_Tcp.so`
      - `$DDS_ROOT/lib/libOpenDDS_Udp.so`
      - `$ACE_ROOT/lib/libTAO_PortableServer.so`
      - `$ACE_ROOT/lib/libTAO_AnyTypeCode.so`
      - `$ACE_ROOT/lib/libTAO_BiDirGIOP.so`
      - `$ACE_ROOT/lib/libTAO_CodecFactory.so`
      - `$ACE_ROOT/lib/libTAO_PI.so`
  - The *native part of the Java library for your IDL libraries*.

This list might not be complete, especially if you're using a major feature not listed here.

Adding OpenDDS Java Libraries to the App

In your app's `build.gradle` (**NOT THE ONE OF THE SAME NAME IN THE ROOT OF THE PROJECT**) add this to the `dependencies` section if not already there:

```
implementation fileTree(include: ['*.jar'], dir: 'libs')
```

Copy these jar files from `$DDS_ROOT/lib` to a directory called `libs` in your app's subdirectory. Create `libs` if it doesn't exist Like `native_libs`, the `libs` name isn't required.

- `i2jrt.jar`
- `i2jrt_corba.jar`
- `OpenDDS_DCPS.jar`
- `tao_java.jar`
- The *Java part of the Java library for your IDL libraries*.

Also copy the jar files from your IDL Libraries and sync with Gradle if you're using Android Studio. After this OpenDDS Java API should be able to be used the same as if using OpenDDS with the Hotspot JVM. The exceptions and particulars to how Android can effect OpenDDS are described in the following sections.

Network Permissions and Availability

In `AndroidManifest.xml` you will need to add the network permissions if they are not already there:

```
<uses-permission android:name="android.permission.INTERNET" />
<uses-permission android:name="android.permission.ACCESS_NETWORK_STATE" />
```

Failure to do so will result in ACE failing to access any sockets and OpenDDS will not be able to function.

Network Availability

When not running in an application targeting API 30 or later on Android 10 or later, Android builds of OpenDDS use the `LinuxNetworkConfigMonitor` to reconfigure OpenDDS connections automatically when the device switches from one network (cellular or WiFi) to another.

When running in an application targeting API 30 or later on Android 10, `LinuxNetworkConfigMonitor` can no longer be used, as Netlink sockets are blocked by the OS for security reasons. In the logs this warning shows up as:

> WARNING: LinuxNetworkConfigMonitor::open_i: could not open Netlink socket (this is expected for API>=30, see Android section in the Developer's Guide)

Instead, `NetworkConfigModifier` is utilized. As a consequence of this, two variables are required from the user, *android_sdk*, and *android_target_api*. These correspond to the location of your Android SDK, likely `$HOME/Android/Sdk` on Linux, and the API number you are targeting. The `NetworkConfigModifier` is set up along with the necessary network callbacks when the user uses `TheParticipantFactory.WithArgs`.

Pass the following options to the `configure` script make this possible:

```
--macros=android_sdk=$SDK --macros=android_target_api=$TARGET_API --java
```

Configuration Files

OpenDDS can use several types of configuration files: a main configuration file, security configuration files, and security certificate files, among others. On traditional platforms, distributing and reading these files is usually not an issue at all. On Android however, an app has no traditional files of its own out of the box, so you can't give OpenDDS a path to a file you want to distribute with the app without preparing beforehand.

If you already have a preferred way to include files in your app, then that will work as long as you can give OpenDDS the path to the files.

Android can open a file stream for resource and asset files. Ideally OpenDDS would be able to accept these streams, but it doesn't. One solution to this is reading the streams into memory and then writing them to files in the app's private directory. This example is using assets, but resources will also work with some slight modifications.

```
// ...
    private String copyAsset(String asset_path) {
        File new_file = new File(getFilesDir(), asset_path);
        final String full_path = new_file.getAbsolutePath();
        try {
            InputStream in = getAssets().open(asset_path, AssetManager.ACCESS_BUFFER);
            byte[] buffer = new byte[in.available()];
            in.read(buffer);
            in.close();
            FileOutputStream out = new FileOutputStream(new_file);
            out.write(buffer);
            out.close();
        } catch (FileNotFoundException e) {
            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }
        return full_path;
    }
// ...

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        // ...

        final String config_file = copyAsset("opendds_config.ini");
        String[] args = new String[] {"-DCPSConfigFile", config_file};
        StringSeqHolder argsHolder = new StringSeqHolder(args);
        dpf = TheParticipantFactory.WithArgs(argsHolder);
        // ...
    }
// ...
```

This example works but in production code the error handling should be improved and integrated with the app's initialization. Rewriting the file every time is not ideal, but OpenDDS's files are small and this method ensures the files are up-to-date.

Multithreading

When using a *DataReaderListener*, the callbacks will be using a ACE reactor worker thread, which can't make changes to the Android GUI directly because it's not the main thread. To have these callbacks affect changes in the Android GUI, use something like android.os.Handler:

```
// ...

import android.os.Handler;

// ...

public class DataReaderListenerImpl extends DDS._DataReaderListenerLocalBase {

    private MainActivity context;

    public DataReaderListenerImpl(MainActivity context) {
        super();
        this.context = context;
    }

    public synchronized void on_data_available(DDS.DataReader reader) {
        StatusDataReader mdr = StatusDataReaderHelper.narrow(reader);
        if (mdr == null) {
            return;
        }
        StatusHolder mh = new StatusHolder(new Status());
        SampleInfoHolder sih = new SampleInfoHolder(new SampleInfo(0, 0, 0,
                new DDS.Time_t(), 0, 0, 0, 0, 0, 0, 0, false, 0));
        int status = mdr.take_next_sample(mh, sih);

        if (status == RETCODE_OK.value) {

            // ...

            Handler handler = new Handler(context.getMainLooper());
            handler.post(new Runnable() {
                @Override
                public void run() {
                    context.tryToUpdateThermostat(thermostat_status);
                }
            });
        }
    }
}
```

Android Activity Lifecycle

The Android Activity Lifecycle is something that affects all Android apps. In the case of OpenDDS, the interaction gets more complicated because of the intersection of the similar, but distinct process lifecycle. The process hosts the activity, but isn't guaranteed to be kept alive after `onStop()` is called. What makes this worse for NDK applications is that there doesn't seem to be a way to be warned of the killing of the process the way Java application can rely on `onDestroyed()`. For most OpenDDS applications, this isn't a serious issue.

An easy way to make sure participants are cleaned up is to create participants in `onStart()` as might be expected, and always delete them in `onStop()`, so that they may be created again in `onStart()`. The `DomainParticpantFactory` can be retrieved either in `onStart()` or more perhaps appropriately in Application.onStart(), given the singleton nature of both.

This might not be ideal or efficient though, because deleting and recreating participants will happen every time the app loses focus, like during orientation changes. An alternative to this is to run OpenDDS within an Android Service separate from the main app with the service configured so that it does not stopped when the Application's `onStop()` is called. The service should be specified in `AndroidManifest.xml`.

```
<service
        android:name=".OpenDdsService"
        android:exported="false"
        android:stopWithTask="true">
</service>
```

OpenDDS service classes should extend `Service` and provide an `IBinder` for an application to use when it creates the `ServiceConnection`. For example:

```
public class MainActivity extends AppCompatActivity {
    // ...
    private OpenDdsService svc = null;

    private ServiceConnection ddsServiceConnection = new ServiceConnection() {
        @Override
        public void onServiceConnected(ComponentName name, IBinder service) {
            OpenDdsService.OpenDdsBinder binder = (OpenDdsService.OpenDdsBinder) service␣
↪;
            svc = binder.getService();
            // ...
        }

        @Override
        public void onServiceDisconnected(ComponentName name) {
            // ...
        }
    }
    // ...
}
```

```
public class OpenDdsService extends Service {
    // ...
    private final IBinder binder = new OpenDdsBinder();

    public class OpenDdsBinder extends Binder {
        OpenDdsService getService() {
```

(continues on next page)

(continued from previous page)

```
            return OpenDdsService.this;
        }

        @Override
        public void onCreate() {
            // ...
        }

        @Override
        public int onStartCommand(Intent intent, int flags, int startId) {
            return START_NOT_STICKY;
        }

        @Override
        public IBinder onBind(Intent intent) {
            return binder;
        }

        @Override
        public void onRebind(Intent intent) {
            super.onRebind(intent);
        }

        @Override
        public void onDestroy() {
            super.onDestroy();
            stopSelf();
        }
    }
}
```

See Android's Services overview for more information.

2.6.4 iOS

How to build OpenDDS for iOS and incorporate OpenDDS into iOS apps.

Variables

The following table describes some of the variables of paths that are referenced in this guide.

Note: You don't have to actually set and use all of these, they are mostly for shorthand.

Variable	Description
`$DDS_ROOT`	OpenDDS being built for iOS
`$ACE_ROOT`	ACE being built for iOS
`$HOST_DDS`	*OpenDDS host to help build OpenDDS for iOS*
`$IPHONE_TARGET`	Set to `SIMULATOR` or `HARDWARE`

Requirements

To build the core OpenDDS native libraries for iOS you will need:

- A macOS development system with Xcode and Xcode command-line tools.
- Some knowledge about OpenDDS development and iOS development.

Building OpenDDS with *optional dependencies has additional requirements*.

Building on macOS

OpenDDS has been tested on iOS using Xcode 11, arm64 iPhones (iPhone 5s and later), and x86_64 iOS simulators.

The OpenDDS configure scripts support simulator and hardware builds through the `IPHONE_TARGET` environment variable.

Note: If you need to configure OpenDDS with any optional dependencies then read the *relevant sections* before configuring and building OpenDDS.

To configure OpenDDS for an iOS simulator build, run the configure script in `$DDS_ROOT` from a bash shell:

```
./configure --host=macosx --target=ios --std=c++11 --macros=IPHONE_TARGET=SIMULATOR
```

Configuring a hardware build is similar:

```
./configure --host=macosx --target=ios --std=c++11 --macros=IPHONE_TARGET=HARDWARE
```

Then run make to build the host tools and the target static libraries:

```
make
```

Host Tools

To cross-compile OpenDDS, host tools are required to process IDL. These are programs that include *tao_idl* and *opendds_idl* that have to be built to run on the host system, not iOS. The example above generates two copies of OpenDDS, one in `OpenDDS/build/host` and another in `OpenDDS/build/target`. If this is the case, then `$HOST_DDS` will be the absolute path to `build/host` and `$DDS_ROOT` will be the absolute path to `build/target`.

If building for both iOS simulators and iPhones, it might make sense to build the OpenDDS host tools separately to cut down on compile time and disk space.

If this is the case, then `$HOST_DDS` will be the location of the static host tools built for the host platform and `$DDS_ROOT` will just be the location of the OpenDDS source code.

This should be done with the same version of OpenDDS and ACE/TAO as what you want to build for iOS. Pass `--host-tools-only` to the configure script to generate static host tools.

If you want to just the minimum needed for host OpenDDS tools and get rid of the rest of the source files, you can. These are the binaries that make up the OpenDDS host tools:

- `$HOST_DDS/bin/opendds_idl`
- `$HOST_DDS/ACE_TAO/bin/ace_gperf`
- `$HOST_DDS/ACE_TAO/bin/tao_idl`

These files can be separated from the rest of the OpenDDS and ACE/TAO source trees, but the directory structure must be kept. To use these to build OpenDDS for iOS, pass `--host-tools $HOST_DDS` to the configure script.

OpenDDS's Optional Dependencies

Note: The OpenDDS Java bindings are not supported on iOS, since iOS does not have a Java runtime.

OpenSSL

OpenSSL is required for OpenDDS Security. To configure and build OpenSSL for iPhone targets, use the `ios64-cross` configuration flag, and set the following environment variables:

```
export CC=/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain/
↪usr/bin/clang
export CROSS_TOP=/Applications/Xcode.app/Contents/Developer/Platforms/iPhoneOS.platform/
↪Developer
export CROSS_SDK=iPhoneOS.sdk
export PATH="/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.
↪xctoolchain/usr/bin:$PATH"
```

Run the configure script:

```
./Configure ios64-cross no-shared no-dso no-hw no-engine --prefix=/usr/local/ios/openssl
```

Build with make:

```
make
```

Install with make:

```
make install
```

Set `OPENSSL_ROOT` to the install location:

```
export OPENSSL_ROOT=/usr/local/ios/openssl
```

Note that the directory given by `--prefix=` will be created by `make install` and will have `include` and `lib` subdirectories that will be used by the OpenSSL build.

OpenSSL builds for iOS simulators are not as well-supported, and require a minor modification to the generated makefile. To build OpenSSL for iOS simulators, set the following environment variables:

```
export CC=/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain/
↪usr/bin/clang
export CROSS_TOP=/Applications/Xcode.app/Contents/Developer/Platforms/iPhoneSimulator.
↪platform/Developer
export CROSS_SDK=iPhoneSimulator.sdk
export PATH="/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.
↪xctoolchain/usr/bin:$PATH"
```

Run the configure script in `openssl-1.1.1d/`:

```
./Configure darwin64-x86_64-cc no-shared no-dso no-hw no-engine --prefix=/usr/local/ios/
↪openssl
```

Modify the generated Makefile setting `CNF_CFLAGS`, and `CNF_CXXFLAGS` to:

```
CNF_CFLAGS=-arch x86_64 -miphoneos-version-min=12.0 -isysroot $(CROSS_TOP)/SDKs/$(CROSS_
↪SDK)
```

Build with make:

```
make
```

Install with make:

```
make install
```

Set `OPENSSL_ROOT` to the install location:

```
export OPENSSL_ROOT=/usr/local/ios/openssl
```

Note that the directory given by `--prefix=` will be created by `make install` and will have `include` and `lib` sub-directories that will be used by the OpenSSL build.

OpenDDS security builds need the location of OpenSSL installed headers and static libraries. This location can be passed to the OpenDDS configure script with the `--openssl=\${OPENSSL_ROOT}` flag.

Xerces

Xerces C++ is also required for OpenDDS Security. Xerces builds for iOS use CMake and require passing the cross-compile flags needed by the macOS C and C++ compilers as well as setting the iOS SDK root and other build flags. All setting can be passed on the command line.

A representative simulator build can be configured as:

```
CC="/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain/usr/
↪bin/clang -miphoneos-version-min=12.0 -arch x86_64" \
CXX="/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain/usr/
↪bin/clang++ -miphoneos-version-min=12.0 -arch x86_64" \
cmake . -DBUILD_SHARED_LIBS:BOOL=OFF -Dnetwork:BOOL=OFF -Dtranscoder=iconv \
  -DCMAKE_INSTALL_PREFIX=/usr/local/ios/xerces3 \
  -DCMAKE_OSX_SYSROOT="/Applications/Xcode.app/Contents/Developer/Platforms/
↪iPhoneSimulator.platform/Developer/SDKs/iPhoneSimulator.sdk"
```

After configuring the build, run CMake:

```
cmake --build src
```

Install with make:

```
make install
```

Set `$XERCES_ROOT` to the install location:

```
export XERCES_ROOT=/usr/local/ios/xerces3
```

Note that the directory given by `--prefix=` will be created by `make install` and will have `include` and `lib` subdirectories that will be used by the Xerces build.

Configuring Xerces for a iPhone hardware build is similar to the simulator build. The `--arch` flag changes to `arm64` and the `CMAKE_OS_SYSROOT` changes to the location of the iPhone SDK.

```
CC="/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain/usr/
↪bin/clang -miphoneos-version-min=12.0 -arch arm64" \
CXX="/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain/usr/
↪bin/clang++ -miphoneos-version-min=12.0 -arch arm64" \
cmake . -DBUILD_SHARED_LIBS:BOOL=OFF -Dnetwork:BOOL=OFF -Dtranscoder=iconv \
  -DCMAKE_INSTALL_PREFIX=/usr/local/ios/xerces3 \
  -DCMAKE_OSX_SYSROOT="/Applications/Xcode.app/Contents/Developer/Platforms/iPhoneOS.
↪platform/Developer/SDKs/iPhoneOS.sdk"
```

OpenDDS security builds need the location of Xerces installed headers and static libraries. This location can be passed to the OpenDDS configure script with the `--xerces3=${XERCES_ROOT}` flag.

Cross-Compiling IDL Libraries

Like all OpenDDS applications, you will need to use type support libraries generated from IDL files to use most of OpenDDS's functionality.

Assuming the library is already setup and works for a desktop platform, then you should be able to run the DDS environment setup script from the `OpenDDS/builds/target` directory to set the appropriate iOS build flags:

```
(source $DDS_ROOT/setenv.sh; mwc.pl -type gnuace . && make)
```

The resulting native IDL library file must be included with the rest of the native library files.

Using OpenDDS in an iOS App

Copy the static libraries in `$ACE_ROOT/lib`, `$DDS_ROOT/lib`, and the cross-compiled IDL libraries (and optionally `$OPENSSL_ROOT/lib` and `$XERCES_ROOT/lib`) to the Xcode project or framework directory.

In the Xcode project, add `$ACE_ROOT` and `$DDS_ROOT` the header search paths.

2.6.5 Supported Platforms

The OpenDDS Foundation regularly builds and tests OpenDDS on a wide variety of platforms, operating systems, and compilers. The OpenDDS Foundation continually updates OpenDDS to support additional platforms. See the `README.md#supported-platforms` file in the distribution for the most recent platform support information. See *Cross Compiling* for how to cross compile for other platforms.

2.6.6 Configuring and Building

See also:

Building OpenDDS Using CMake to use CMake instead of a *MPC*-based build.

If not already done, download the source from GitHub.

Use the `configure` script to prepare to build OpenDDS. This script requires *Perl*.

To start the script, change to the root of the OpenDDS source directory and run:

```
./configure
```

Strawberry Perl is recommended for Windows.

To start the script, open a Visual Studio Native Tools Command Prompt or Developer Command Prompt that has C++ tools available, then change to the root of the OpenDDS source directory and run:

```
configure
```

Optionally add `--help` to the command line to see the advanced options available for this script. The configure script will download *ACE/TAO* and configure it for your platform. To use an existing ACE/TAO installation, either set the *ACE_ROOT* and *TAO_ROOT* environment variables or pass the `--ace` and `--tao` (if TAO is not at `$ACE_ROOT/TAO`) options to configure.

See also:

Dependencies for a full list of dependencies including ones that can be configured with the configure script.

If configure runs successfully it will end with a message about the next steps for compiling OpenDDS.

OpenDDS on these platforms must be built using GNU Make:

```
make -j 4
```

OpenDDS supports parallel builds to speed up the build when using Make. Above 4 is used as an example for the max number of parallel jobs. If unsure what this number should be, use the number of CPU cores on the machine.

The configure script creates an environment setup file called `setenv.sh` that sets all the environment variables the build and test steps rely on. The main makefile sets these itself, so `setenv.sh` is not needed when running `make` from the top level. It needs to be sourced before building other projects and running tests:

```
source setenv.sh
```

The configure script will say how to open the solution file for OpenDDS in Visual Studio using `devenv`.

It can also be built directly from the command prompt by using MSBuild. For example, if the configure script was ran without any arguments, to do a Debug x64 build:

```
msbuild -p:Configuration=Debug,Platform=x64 -m DDS_TAOv2.sln
```

See also:

Microsoft MSBuild Documentation

The configure script creates an environment setup file called `setenv.cmd` that sets all the environment variables the build and test steps rely on. For the command prompt that ran the configure script, these variables were set automatically. If running in another command prompt, the variables need to be set again before building other projects and running tests:

```
setenv
```

Java

If you're building OpenDDS for use by *Java applications*, please see the file `java/INSTALL` instead of this one.

Security

DDS Security is disabled by default, and must be enabled by passing `--security` to the configure script. It requires *Xerces* and *OpenSSL*.

Most package managers should have Xerces and OpenSSL packages that can be installed if not already:

- Debian/Ubuntu-based: `sudo apt install libxerces-c-dev libssl-dev`
- Redhat/Fedora-based: `sudo yum install xerces-c-devel openssl-devel`
- Homebrew `brew install xerces-c openssl@3`

Download source and build according to instructions.

If the libraries didn't get installed to `/usr`, then the installation prefixes will have to be passed using `--xerces` and `--openssl`.

Using Microsoft vcpkg

Microsoft vcpkg is a "C++ Library Manager for Windows, Linux, and macOS" which helps developers build/install dependencies. Although it is cross-platform, this guide only discusses vcpkg on Windows.

As of this writing, vcpkg is only supported on Visual Studio 2015 Update 3 and later versions; if using an earlier version of Visual Studio, skip down to the manual setup instructions later in this section.

- If OpenDDS tests will be built, install CMake or put the one that comes with Visual Studio on the `PATH` (see `Common7\IDE\CommonExtensions\Microsoft\CMake`).
- If you need to obtain and install vcpkg, navigate to https://github.com/Microsoft/vcpkg and follow the instructions to obtain vcpkg by cloning the repository and bootstrapping it.
- Fetch and build the dependencies; by default, vcpkg targets x86 so be sure to specify the x64 target if required by specifying it when invoking vcpkg install, as shown here:

  ```
  vcpkg install openssl:x64-windows xerces-c:x64-windows
  ```

- Configure OpenDDS by passing the `--openssl` and `--xerces3` options. As a convenience, it can be helpful to set an environment variable to store the path since it is the same location for both dependencies.

  ```
  set VCPKG_INSTALL=c:\path\to\vcpkg\installed\x64-windows
  configure --security --openssl=%VCPKG_INSTALL% --xerces3=%VCPKG_INSTALL%
  ```

- Compile with `msbuild`:

  ```
  msbuild /m DDS_TAOv2_all.sln
  ```

  Or by launching Visual Studio from this command prompt so it inherits the correct environment variables and building from there:

  ```
  devenv DDS_TAOv2_all.sln
  ```

Note: For all of the build steps listed here, check that each package targets the same architecture (either 32-bit or 64-bit) by compiling all dependencies within the same type of Developer Command Prompt.

Compiling OpenSSL

Official OpenSSL instructions can be found here.

1. Install *Perl* and add it to the `PATH` environment variable.
2. Install Netwide Assembler (NASM). Click through the latest stable release and there is a win32 and win64 directory containing executable installers. The installer does not update the Path environment variable, so a manual entry (`%LOCALAPPDATA%\bin\NASM`) is necessary.
3. Download the required version of OpenSSL by cloning the repository.
4. Open a Developer Command Prompt (32-bit or 64-bit depending on the desired target architecture) and change into the freshly cloned openssl directory.
5. Run the configure script and specify a required architecture (`perl Configure VC-WIN32` or `perl Configure VC-WIN64A`).
6. Run `nmake`
7. Run `nmake install`

Note: If the default OpenSSL location is desired, which will be searched by OpenDDS, open the "Developer Command Prompt" as an administrator before running the install. It will write to `C:\Program Files` or `C:\Program Files (x86)` depending on the architecture.

Compiling Xerces-C++ 3

Official Xerces instructions can be found here.

1. Download/extract the Xerces source files.
2. Create a cmake build directory and change into it (from within the Xerces source tree).

```
mkdir build
cd build
```

3. Run cmake with the appropriate generator. In this case Visual Studio 2017 with 64-bit is being used so:

```
cmake -G "Visual Studio 15 2017 Win64" ..
```

4. Run cmake again with the build switch and install target (this should be done in an administrator command-prompt to install in the default location as mentioned above).

```
cmake --build . --target install
```

Configuring and Building OpenDDS:

1. Change into the OpenDDS root folder and run configure with security enabled.
   - If the default location was used for OpenSSL and Xerces, configure should automatically find the dependencies:

```
configure --security
```

2. If a different location was used (assuming environment variables `NEW_SSL_ROOT` and `NEW_XERCES_ROOT` point to their respective library directories):

```
configure --security --openssl=%NEW_SSL_ROOT% --xerces3=%NEW_XERCES_ROOT%
```

3. Compile with msbuild (or by opening the solution file in Visual Studio and building from there).

```
msbuild /m DDS_TAOv2_all.sln
```

Optional Features

To avoid compiling OpenDDS code that you will not be using, there are certain features than can be excluded from being built. The features are discussed below.

Users requiring a small-footprint configuration or compatibility with safety-oriented platforms should consider using the OpenDDS Safety Profile, which is described in *Safety Profile* of this guide.

Building With a Feature Enabled or Disabled

Most features are supported by the `configure` script. The `configure` script creates config files with the correct content and then runs MPC. If you are using the `configure` script, run it with the `--help` command line option and look for the feature you wish to enable/disable. If you are not using the `configure` script, continue reading below for instructions on running MPC directly.

For the features described below, MPC is used for enabling (the default) a feature or disabling the feature. For a feature named *feature*, the following steps are used to disable the feature from the build:

1. Use the command line `features` argument to MPC:

```
mwc.pl -type type -features feature=0 DDS.mwc
```

   Or alternatively, add the line `feature=0` to the file `$ACE_ROOT/bin/MakeProjectCreator/config/default.features` and regenerate the project files using MPC.

2. If you are using the `gnuace` MPC project type (which is the case if you will be using GNU make as your build system), add line `feature=0` to the file `$ACE_ROOT/include/makeinclude/platform_macros.GNU`.

To explicitly enable the feature, use `feature=1` above.

Note: You can also use the `configure` script to enable or disable features. To disable the feature, pass `--no-feature` to the script, to enable pass `--feature`. In this case `-` is used instead of `_` in the feature name. For example, to disable feature `content_subscription` discussed below, pass `--no-content-subscription` to the configure script.

Disabling the Building of Built-in Topic Support

Feature Name: `built_in_topics`

You can reduce the footprint of the core DDS library by up to 30% by disabling Built-in Topic Support. See *Built-in Topics* for a description of built-in topics.

Disabling the Building of Compliance Profile Features

The DDS specification defines *compliance profiles* to provide a common terminology for indicating certain feature sets that a DDS implementation may or may not support. These profiles are given below, along with the name of the MPC feature to use to disable support for that profile or components of that profile.

Many of the profile options involve QoS settings. If you attempt to use a QoS value that is incompatible with a disabled profile, a runtime error will occur. If a profile involves a class, a compile time error will occur if you try to use the class and the profile is disabled.

Content-Subscription Profile

Feature Name: `content_subscription`

This profile adds the classes `ContentFilteredTopic`, `QueryCondition`, and `MultiTopic` discussed in *Content-Subscription Profile*.

In addition, individual classes can be excluded by using the features given in the table below.

Table 1: Content-Subscription Class Features

Class	Feature
ContentFilteredTopic	`content_filtered_topic`
QueryCondition	`query_condition`
MultiTopic	`multi_topic`

Persistence Profile

Feature Name: `persistence_profile`

This profile adds the *Durability Service QoS* policy and the settings `TRANSIENT` and `PERSISTENT` of the *Durability QoS* policy `kind`.

Ownership Profile

Feature Name: `ownership_profile`

This profile adds:

- the setting `EXCLUSIVE` of *Ownership QoS*
- support for the *Ownership Strength QoS* policy
- setting a `depth > 1` for the *History QoS* policy

Some users may wish to exclude support for the exclusive *Ownership QoS* policy and its associated *Ownership Strength QoS* without impacting use of *History QoS*. In order to support this configuration, OpenDDS also has the MPC feature `ownership_kind_exclusive` (configure script option `--no-ownership-kind-exclusive`).

Object Model Profile

Feature Name: `object_model_profile`

This profile includes support for the *Presentation QoS* `access_scope` setting of `GROUP`.

Note: Currently, the *Presentation QoS* `access_scope` of `TOPIC` is also excluded when `object_model_profile` is disabled.

Cross Compiling

Use the configure script, and set the target platform to one different than the host. For example:

```
./configure --target=lynxos-178
```

Run configure with `--target-help` for details on the supported targets. In this setup, configure will clone the OpenDDS and ACE/TAO source trees for host and target builds. It will do a static build of the host tools (such as `opendds_idl` and `tao_idl`) in the host environment, and a full build in the target environment. Most parameters to configure are then assumed to be target parameters.

Any testing has to be done manually.

Raspberry Pi

The instructions for building for the Raspberry Pi are on opendds.org.

Android

Android support is documented in *Android*.

Apple iOS

Apple iOS support is documented in *iOS*.

2.6.7 Installation

When OpenDDS is built using `make`, if the configure script was run with an argument of `--prefix=<prefix>` the `make install` target is available.

After running `make` (and before `make install`) you have one completely ready and usable OpenDDS. Its `DDS_ROOT` is the top of the source tree – the same directory from which you ran configure and make. That `DDS_ROOT` should work for building application code, and some users may prefer using it this way.

After `make install` there is a second completely ready and usable OpenDDS that's under the installation prefix directory. It contains the required libraries, code generators, header files, IDL files, and associated scripts and documentation.

Note: If configured with RapidJSON, OpenDDS will install the headers for RapidJSON, which might conflict with an existing installation.

Using an Installed OpenDDS

After `make install` completes, the shell script in `<prefix>/share/dds/dds-devel.sh` is used to set the `DDS_ROOT` environment variable. The analogous files for ACE and TAO are `<prefix>/share/ace/ace-devel.sh` and `<prefix>/share/tao/tao-devel.sh`.

The `<prefix>` tree does not contain a tool for makefile generation. To use MPC to generate application makefiles, the `MPC_ROOT` subdirectory from the OpenDDS source tree can be used either in-place or copied elsewhere. To use CMake to generate application makefiles, see *Using OpenDDS in a CMake Project*.

2.6.8 Tests

Tests are not built by default, `--tests` must be passed to the configure script. All tests can be run using `tests/auto_run_tests.pl`. See *Running Tests* for running all tests or individual tests.

2.6.9 Building Applications that use OpenDDS

This section applies to any C++ code that directly or indirectly includes OpenDDS headers. For Java applications, see *Java Bindings*.

C++ source code that includes OpenDDS headers can be built using either build system: MPC or CMake.

MPC: The Makefile, Project, and Workspace Creator

OpenDDS is itself built with MPC, so development systems that are set up to use OpenDDS already have MPC available. The OpenDDS configure script creates a "setenv" script with environment settings (`setenv.cmd` on Windows; `setenv.sh` on Linux/macOS). This environment contains the `PATH` and `MPC_ROOT` settings necessary to use MPC.

MPC's source tree (in `MPC_ROOT`) contains a `docs` directory with both HTML and plain text documentation (`USAGE` and `README` files).

The example walk-through in *Using DCPS* uses MPC as its build system. The OpenDDS source tree contains many tests and examples that are built with MPC. These can be used as starting points for application MPC files.

CMake

Applications can also be built with CMake. See *Using OpenDDS in a CMake Project* for more information.

Custom Build systems

Users of OpenDDS are strongly encouraged to select one of the two options listed above (MPC or CMake) to generate consistent build files on any supported platform. If this is not possible, users of OpenDDS must make sure that all code generator, compiler, and linker settings in the custom build setup result in API- and ABI-compatible code. To do this, start with an MPC or CMake-generated project file (makefile or Visual Studio project file) and make sure all relevant settings are represented in the custom build system. This is often done through a combination of inspecting the project file and running the build with verbose output to see how the toolchain (code generators, compiler, linker) is invoked.

2.6.10 Building OpenDDS Using CMake

New in version 3.26.

OpenDDS can be built with CMake 3.23 or later.

Configuring and Building

If not already done, download the source from GitHub.

To configure and build:

```
cmake -B build -DCMAKE_UNITY_BUILD=TRUE
cmake --build build -- -j 4
```

4 was used as an example for the max number of parallel jobs. If unsure what this number should be, use the number of CPU cores on the machine. This can be combined with unity builds.

```
cmake -B build -DCMAKE_UNITY_BUILD=TRUE
cmake --build build
```

Variables

Unless otherwise noted, the build features and behavior can be controlled by the OpenDDS Config Package *Config Variables*.

ACE/TAO

A prebuilt ACE/TAO can be passed using *OPENDDS_ACE*. In that case *Features* will be automatically derived from ACE's `default.features` file. If *OPENDDS_ACE* is not passed, then ACE/TAO will be built. When building ACE/TAO a release is downloaded by default, but source can also be provided using *OPENDDS_ACE_TAO_SRC* or cloned using *OPENDDS_ACE_TAO_GIT*. *OPENDDS_ACE_TAO_KIND* controls what version of ACE/TAO is downloaded for both releases and *OPENDDS_ACE_TAO_GIT*.

Build-Exclusive CMake Variables

These are all the variables that are exclusive to building OpenDDS with CMake:

OPENDDS_JUST_BUILD_HOST_TOOLS

If true, `opendds_idl` is the only thing built for OpenDDS. If ACE/TAO is also being built, then `ace_gperf`, `tao_idl`, and their dependencies are also built. The build directory for this can be passed to *OPENDDS_HOST_TOOLS*.

OPENDDS_ACE_TAO_SRC

If defined, sets the ACE/TAO to build and use. A prebuilt ACE/TAO can be provided using *OPENDDS_ACE*. By default, a hardcoded release depending on *OPENDDS_ACE_TAO_KIND* is downloaded.

OPENDDS_ACE_TAO_KIND

The default is `ace7tao3` for *ACE 7/TAO 3*. Use `ace6tao2` to get *ACE 6/TAO 2*.

New in version 3.27.

OPENDDS_ACE_TAO_GIT

Implies *OPENDDS_MPC_GIT*. If true clone ACE/TAO from *OPENDDS_ACE_TAO_GIT_TAG* at *OPENDDS_ACE_TAO_GIT_REPO*. By default, a hardcoded release depending on *OPENDDS_ACE_TAO_KIND* is downloaded.

New in version 3.27.

OPENDDS_ACE_TAO_GIT_REPO

Implies *OPENDDS_ACE_TAO_GIT*. The Git repository to clone ACE/TAO from. The default is `https://github.com/DOCGroup/ACE_TAO`.

New in version 3.27.

OPENDDS_ACE_TAO_GIT_TAG

Implies *OPENDDS_ACE_TAO_GIT*. The Git tag to clone ACE/TAO from. The default depends on *OPENDDS_ACE_TAO_KIND*.

New in version 3.27.

OPENDDS_MPC

Path to *MPC*. In most cases this will be provided and automatically detected, unless ACE/TAO was cloned manually and provided using *OPENDDS_ACE_TAO_SRC*.

New in version 3.26,: but documented in 3.27

OPENDDS_MPC_GIT

If true clone MPC from *OPENDDS_MPC_GIT_TAG* at *OPENDDS_MPC_GIT_REPO*.

New in version 3.27.

OPENDDS_MPC_GIT_REPO

Implies *OPENDDS_MPC_GIT*. The Git repository to clone MPC from. The default is `https://github.com/DOCGroup/MPC`.

New in version 3.27.

OPENDDS_MPC_GIT_TAG

Implies *OPENDDS_MPC_GIT*. This is the Git tag to clone MPC from. The default is `master`.

New in version 3.27.

OPENDDS_BUILD_TESTS

Build tests that are currently supported when building OpenDDS with CMake. See *Running Tests* for how to run them. The default for this is `BUILD_TESTING` (usually false).

OPENDDS_BUILD_EXAMPLES

Build examples that are currently supported when building OpenDDS with CMake. See *Running Tests* for how to run them. The default for this is `TRUE`.

OPENDDS_BOOTTIME_TIMERS

New in version 3.28.

OpenDDS uses CLOCK_BOOTTIME when scheduling timers. On some platforms the default is to use CLOCK_MONOTONIC which does not increment when the system is suspended. Enable this option to use CLOCK_BOOTTIME as the timer base clock instead of CLOCK_MONOTONIC. Default is `OFF`.

Speeding up the build

A major speed up supported by all the CMake generators are unity builds. This makes it so that multiple C++ source files are compiled at the same time by a compiler process. This can be enabled by passing `-DCMAKE_UNITY_BUILD=TRUE` to the CMake configure command as shown in the example. If there are problems with building, e.g. redefinition errors, then pass `-DCMAKE_UNITY_BUILD=FALSE` to override the cache variable in an existing build directory and disable unity builds. Fresh build directories default to `CMAKE_UNITY_BUILD=FALSE`.

The Ninja CMake generator can also be used to speed up builds as Ninja was built from scratch for parallel building and build systems like CMake. If Ninja is available, pass `-G Ninja` to have CMake use it. Building ACE/TAO with Ninja requires CMake 3.24 or later. If building ACE/TAO, the CMake build will still use either Visual Studio or GNU Make internally to build ACE/TAO because MPC doesn't support Ninja.

Cross Compiling

Once set up properly, OpenDDS can be cross-compiled with CMake using normal CMake cross compiling. A few things to note:

- Native-built host tools, like *opendds_idl*, have to be configured and built separately and provided to the target build using *OPENDDS_HOST_TOOLS*.
- The host tools will build its own ACE/TAO for the host system, but this can be overridden using *OPENDDS_ACE* on the host build and *OPENDDS_ACE_TAO_HOST_TOOLS* on the target build.
- If the target platform isn't automatically supported, then ACE/TAO will have to be *built separately*.

Android

The following is an example of cross-compiling OpenDDS for Android on Linux using CMake. It assumes the NDK has been downloaded and the location is in an environment variable called `NDK`.

```
# Build Host Tools
cmake -B build-host \
  -DBUILD_SHARED_LIBS=FALSE \
  -DOPENDDS_JUST_BUILD_HOST_TOOLS=TRUE
cmake --build build-host -- -j 4

# Build OpenDDS for Android
cmake -B build-target \
  -DBUILD_SHARED_LIBS=TRUE \
  -DANDROID_ABI=armeabi-v7a -DANDROID_PLATFORM=android-29 \
  --toolchain $NDK/build/cmake/android.toolchain.cmake \
  -DOPENDDS_HOST_TOOLS=$(realpath build-host)
cmake --build build-target-- -j 4
```

Installation

Once built, OpenDDS can be installed using cmake –install. Currently ACE/TAO has to be installed separately and this is only possible with GNU Make.

Using a CMake-built OpenDDS

After building and optionally installing OpenDDS, it can be used through the same *CMake package* as an MPC-built OpenDDS.

Running Tests

`Tests` and `examples` can be run using using ctest. There is also a target for running tests in the build, but the name differs based on the CMake generator used.

Known Limitations

- ACE/TAO can't be automatically built unless there is explicit support for the platform. Currently this only exists for Windows, Linux, macOS, and Android. All other platforms will require configuring and building ACE/TAO separately and passing the path using `OPENDDS_ACE`.
  - See https://www.dre.vanderbilt.edu/~schmidt/DOC_ROOT/ACE/ACE-INSTALL.html for how to manually build ACE/TAO.
- The following features are planned, but not implemented yet:
  - Support for *Safety Profile*
  - Support for *Java Bindings*
  - The ability to use MPC for building user applications with an installed CMake-built OpenDDS

2.7 Getting Started

2.7.1 Using DCPS

This section focuses on an example application using DCPS to distribute data from a single publisher process to a single subscriber process. It is based on a simple messenger application where a single publisher publishes messages and a single subscriber subscribes to them. We use the default QoS properties and the default TCP/IP transport. Full source code for this example may be found under the `DevGuideExamples/DCPS/Messenger/` directory. Additional DDS and DCPS features are discussed in later sections.

Defining Data Types with IDL

In this example, data types for topics will be defined using the OMG Interface Definition Language (IDL). For details on how to build OpenDDS applications that don't use IDL for topic data types, see *DynamicDataWriters and DynamicDataReaders*.

Identifying Topic Types

Each data type used by DDS is defined using OMG Interface Definition Language (IDL). OpenDDS uses IDL annotations[1] to identify the data types that it transmits and processes. These data types are processed by the TAO IDL compiler and the OpenDDS IDL compiler to generate the necessary code to transmit data of these types with OpenDDS. Here is the IDL file that defines our Message data type:

```
module Messenger {

  @topic
  struct Message {
    string from;
    string subject;
    @key long subject_id;
    string text;
    long count;
  };
};
```

The `@topic` annotation marks a data type that can be used as a topic's type. This must be a structure or a union. The structure or union may contain basic types (short, long, float, etc.), enumerations, strings, sequences, arrays, structures, and unions. See *IDL Compliance* for more details on the use of IDL for OpenDDS topic types. The IDL above defines the structure Message in the Messenger module for use in this example.

Keys

The `@key` annotation identifies a field that is used as a key for this topic type. A topic type may have zero or more key fields. These keys are used to identify different DDS Instances within a topic. Keys can be of scalar type, structures or unions containing key fields, or arrays of any of these constructs.

Multiple keys are specified with separate `@key` annotations. In the above example, we identify the `subject_id` member of `Messenger::Message` as a key. Each sample published with a unique `subject_id` value will be defined as belonging to a different DDS Instance within the same topic. Since we are using the default QoS policies, subsequent samples with the same subject_id value are treated as replacement values for that DDS Instance.

`@key` can be applied to a structure field of the following types:

- Any primitive, such as booleans, integers, characters, and strings.
- Other structures that have a defined key or set of keys. For example:

```
struct StructA {
  @key long key;
};

struct StructB {
  @key StructA main_info;
  long other_info;
};

@topic
struct StructC {
```

(continues on next page)

[1] For backwards compatibility, OpenDDS also parses `#pragma` directives which were used before release 3.14. This guide will describe IDL annotations only.

(continued from previous page)

```
  @key StructA keya; // keya.key is one key
  @key StructB keyb; // keyb.main_info.key is another
  DDS::OctetSeq data;
};
```

In this example, every type from the key marked on the topic type down to what primitive data types to use as the key is annotated with `@key`. That isn't strictly necessary though, as the next section shows.

- Other structures that don't have any defined keys. In the following example, it's implied that all the fields in InnerStruct are keys.

```
struct InnerStruct {
  long a;
  short b;
  char c;
};

@topic
struct OuterStruct {
  @key InnerStruct value;
  // value.a, value.b, and value.c are all keys
};
```

If none of the fields in a struct are marked with `@key` or `@key(TRUE)`, then when the struct is used in another struct and marked as a key, all the fields in the struct are assumed to keys. Fields marked with `@key(FALSE)` are always excluded from being a key, such as in this example:

```
struct InnerStruct {
  long a;
  short b;
  @key(FALSE) char c;
};

@topic
struct OuterStruct {
  @key InnerStruct value;
  // Now just value.a and value.b are the keys
};
```

- Unions can also be used as keys if their discriminator is marked as a key. There is an example of a keyed union topic type in the next section, but keep in mind a union being used as a key doesn't have to be a topic type.
- Arrays of any of the previous data types. `@key` can't be applied to sequences, even if the base type would be valid in an array. Also `@key`, when applied to arrays, it makes every element in the array part of the key. They can't be applied to individual array elements.

Union Topic Types

Unions can be used as topic types. Here is an example:

```
enum TypeKind {
  STRING_TYPE,
  LONG_TYPE,
  FLOAT_TYPE
};

@topic
union MyUnionType switch (@key TypeKind) {
case STRING_TYPE:
  string string_value;
case LONG_TYPE:
  long long_value;
case FLOAT_TYPE:
  float float_value;
};
```

Unions can be keyed like structures, but only the union discriminator can be a key, so the set of possible DDS Instances of topics using keyed unions are values of the discriminator. Designating a key for a union topic type is done by putting `@key` before the discriminator type like in the example above. Like structures, it is also possible to have no key fields, in which case `@key` would be omitted and there would be only one DDS Instance.

Topic Types vs. Nested Types

In addition to `@topic`, the set of IDL types OpenDDS can use can also be controlled using `@nested` and `@default_nested`. Types that are "nested" are the opposite of topic types; they can't be used for the top-level type of a topic, but they can be nested inside the top-level type (at any level of nesting). All types are nested by default in OpenDDS to reduce the code generated for type support, but there a number of ways to change this:

- The type can be annotated with `@topic` (see *Identifying Topic Types*), or with `@nested(FALSE)`, which is equivalent to `@topic`.
- The enclosing module can be annotated with `@default_nested(FALSE)`.
- The global default for `opendds_idl` can be changed by adding `--no-default-nested`, in which case it would be as if all valid types were marked with `@topic`. If desired for IDL compatibility with other DDS implementations or based on preference, this can be done through the build system:
  - When using MPC, add `dcps_ts_flags += --no-default-nested` to the project.
  - When using CMake, this can be done by setting either *`OPENDDS_DEFAULT_NESTED`* to `FALSE` or passing `--no-default-nested` to *`opendds_target_sources(OPENDDS_IDL_OPTIONS)`*.

In cases where the module default is not nested, you can reverse this by using `@nested` or `@nested(TRUE)` for structures/unions and `@default_nested` or `@default_nested(TRUE)` for modules. NOTE: the `@topic` annotation doesn't take a boolean argument, so `@topic(FALSE)` would cause an error in the OpenDDS IDL Compiler.

Processing the IDL

This section uses the OMG IDL-to-C++ mapping ("C++ classic") as part of the walk-through. OpenDDS also supports the OMG IDL-to-C++11 mapping, see *Using the IDL-to-C++11 Mapping* for details.

The OpenDDS IDL is first processed by the TAO IDL compiler.

```
tao_idl Messenger.idl
```

In addition, we need to process the IDL file with the OpenDDS IDL compiler to generate the serialization and key support code that OpenDDS requires to marshal and demarshal the Message, as well as the type support code for the data readers and writers. This IDL compiler is located in `bin` and generates three files for each IDL file processed. The three files all begin with the original IDL file name and would appear as follows:

- `<filename>TypeSupport.idl`
- `<filename>TypeSupportImpl.h`
- `<filename>TypeSupportImpl.cpp`

For example, running `opendds_idl` as follows

```
opendds_idl Messenger.idl
```

generates `MessengerTypeSupport.idl`, `MessengerTypeSupportImpl.h`, and `MessengerTypeSupportImpl.cpp`. The IDL file contains the `MessageTypeSupport`, `MessageDataWriter`, and `MessageDataReader` interface definitions. These are type-specific DDS interfaces that we use later to register our data type with the domain, publish samples of that data type, and receive published samples. The implementation files contain implementations for these interfaces. The generated IDL file should itself be compiled with the TAO IDL compiler to generate stubs and skeletons. These and the implementation file should be linked with your OpenDDS applications that use the Message type. The OpenDDS IDL compiler has a number of options that specialize the generated code. These options are described in *opendds_idl*.

Typically, you do not directly invoke the TAO or OpenDDS IDL compilers as above, but let your build system do it for you. Two different build systems are supported for projects that use OpenDDS:

- MPC, the "Make Project Creator" which is used to build OpenDDS itself and the majority of its included tests and examples
- CMake, a build system that's commonly used across the industry

Even if you will eventually use some custom build system that's not one of the two listed above, start by building an example OpenDDS application using one of the supported build systems and then migrate the code generator command lines, compiler options, etc., to the custom build system.

The remainder of this section will assume MPC. For more details on using CMake, see the *Using OpenDDS in a CMake Project*.

The code generation process is simplified when using MPC, by inheriting from the dcps base project. Here is the MPC file section common to both the publisher and subscriber

```
project(*idl): dcps {
  // This project ensures the common components get built first.

  TypeSupport_Files {
    Messenger.idl
  }
  custom_only = 1
}
```

The dcps parent project adds the Type Support custom build rules. The TypeSupport_Files section above tells MPC to generate the Message type support files from `Messenger.idl` using the OpenDDS IDL complier. Here is the publisher section:

```
project(*Publisher): dcpsexe_with_tcp {
  exename = publisher
  after  += *idl

  TypeSupport_Files {
    Messenger.idl
  }

  Source_Files {
    Publisher.cpp
  }
}
```

The `dcpsexe_with_tcp` project links in the DCPS library.

For completeness, here is the subscriber section of the MPC file:

```
project(*Subscriber): dcpsexe_with_tcp {

  exename = subscriber
  after  += *idl

  TypeSupport_Files {
    Messenger.idl
  }

  Source_Files {
    Subscriber.cpp
    DataReaderListenerImpl.cpp
  }
}
```

A Simple Message Publisher

In this section we describe the steps involved in setting up a simple OpenDDS publication process. The code is broken into logical sections and explained as we present each section. We omit some uninteresting sections of the code (such as `#include` directives, error handling, and cross-process synchronization). The full source code for this sample publisher is found in the `Publisher.cpp` and `Writer.cpp` files in `DevGuideExamples/DCPS/Messenger/`.

Initializing the Participant

The first section of `main()` initializes the current process as an OpenDDS participant.

```
int main (int argc, char *argv[]) {
  try {
    DDS::DomainParticipantFactory_var dpf =
      TheParticipantFactoryWithArgs(argc, argv);
    DDS::DomainParticipant_var participant =
```

(continues on next page)

(continued from previous page)

```
      dpf->create_participant(42, // domain ID
                              PARTICIPANT_QOS_DEFAULT,
                              0,  // No listener required
                              OpenDDS::DCPS::DEFAULT_STATUS_MASK);
    if (!participant) {
      std::cerr << "create_participant failed." << std::endl;
      return 1;
    }
    // ...
  }
}
```

The `TheParticipantFactoryWithArgs` macro is defined in `Service_Participant.h` and initializes the Domain Participant Factory with the command line arguments. These command line arguments are used to initialize the ORB that the OpenDDS service uses as well as the service itself. This allows us to pass `ORB_init()` options on the command line as well as OpenDDS configuration options of the form `-DCPS*`. Available OpenDDS options are fully described in *Run-time Configuration*.

The `create_participant()` operation uses the domain participant factory to register this process as a participant in the domain specified by the ID of 42. The participant uses the default QoS policies and no listeners. Use of the OpenDDS default status mask ensures all relevant communication status changes (e.g., data available, liveliness lost) in the middleware are communicated to the application (e.g., via callbacks on listeners).

Users may define any number of domains using IDs in the range (0x0 ~ 0x7FFFFFFF). All other values are reserved for internal use by the implementation.

The Domain Participant object reference returned is then used to register our Message data type.

Registering the Data Type and Creating a Topic

First, we create a `MessageTypeSupportImpl` object, then register the type with a type name using the `register_type()` operation. In this example, we register the type with a nil string type name, which causes the `MessageTypeSupport` interface repository identifier to be used as the type name. A specific type name such as "*Message*" can be used as well.

```
Messenger::MessageTypeSupport_var mts =
  new Messenger::MessageTypeSupportImpl();
if (DDS::RETCODE_OK != mts->register_type(participant, "")) {
  std::cerr << "register_type failed." << std::endl;
  return 1;
}
```

Next, we obtain the registered type name from the type support object and create the topic by passing the type name to the participant in the `create_topic()` operation.

```
CORBA::String_var type_name = mts->get_type_name ();

DDS::Topic_var topic =
  participant->create_topic ("Movie Discussion List",
                             type_name,
                             TOPIC_QOS_DEFAULT,
                             0,  // No listener required
                             OpenDDS::DCPS::DEFAULT_STATUS_MASK);
```

(continues on next page)

(continued from previous page)

```
if (!topic) {
  std::cerr << "create_topic failed." << std::endl;
  return 1;
}
```

We have created a topic named "*Movie Discussion List*" with the registered type and the default QoS policies.

Creating a Publisher

Now, we are ready to create the publisher with the default publisher QoS.

```
DDS::Publisher_var pub =
  participant->create_publisher(PUBLISHER_QOS_DEFAULT,
                                0,  // No listener required
                                OpenDDS::DCPS::DEFAULT_STATUS_MASK);
if (!pub) {
  std::cerr << "create_publisher failed." << std::endl;
  return 1;
}
```

Creating a DataWriter and Waiting for the Subscriber

With the publisher in place, we create the data writer.

```
// Create the datawriter
  DDS::DataWriter_var writer =
    pub->create_datawriter(topic,
                           DATAWRITER_QOS_DEFAULT,
                           0,  // No listener required
                           OpenDDS::DCPS::DEFAULT_STATUS_MASK);
  if (!writer) {
    std::cerr << "create_datawriter failed." << std::endl;
    return 1;
  }
```

When we create the data writer we pass the topic object reference, the default QoS policies, and a null listener reference. We now narrow the data writer reference to a `MessageDataWriter` object reference so we can use the type-specific publication operations.

```
Messenger::MessageDataWriter_var message_writer =
     Messenger::MessageDataWriter::_narrow(writer);
```

The example code uses *conditions* and *wait* sets so the publisher waits for the subscriber to become connected and fully initialized. In a simple example like this, failure to wait for the subscriber may cause the publisher to publish its samples before the subscriber is connected.

The basic steps involved in waiting for the subscriber are:

- Get the status condition from the data writer we created
- Enable the Publication Matched status in the condition
- Create a wait set

- Attach the status condition to the wait set
- Get the publication matched status
- If the current count of matches is one or more, detach the condition from the wait set and proceed to publication
- Wait on the wait set (can be bounded by a specified period of time)
- Loop back around to step *5)*

Here is the corresponding code:

```
// Block until Subscriber is available
DDS::StatusCondition_var condition = writer->get_statuscondition();
condition->set_enabled_statuses(DDS::PUBLICATION_MATCHED_STATUS);

DDS::WaitSet_var ws = new DDS::WaitSet;
ws->attach_condition(condition);

while (true) {
  DDS::PublicationMatchedStatus matches;
  if (writer->get_publication_matched_status(matches) != DDS::RETCODE_OK) {
    std::cerr << "get_publication_matched_status failed!"
              << std::endl;
    return 1;
  }

  if (matches.current_count >= 1) {
    break;
  }

  DDS::ConditionSeq conditions;
  DDS::Duration_t timeout = { 60, 0 };
  if (ws->wait(conditions, timeout) != DDS::RETCODE_OK) {
    std::cerr << "wait failed!" << std::endl;
    return 1;
  }

}

ws->detach_condition(condition);
```

For more details about status, conditions, and wait sets, see *Conditions and Listeners*.

Sample Publication

The message publication is quite straightforward:

```
// Write samples
Messenger::Message message;
message.subject_id = 99;
message.from = "Comic Book Guy";
message.subject = "Review";
message.text = "Worst. Movie. Ever.";
message.count = 0;
```

(continues on next page)

(continued from previous page)

```
for (int i = 0; i < 10; ++i) {
  DDS::ReturnCode_t error = message_writer->write(message, DDS::HANDLE_NIL);
  ++message.count;
  ++message.subject_id;
  if (error != DDS::RETCODE_OK) {
    // Log or otherwise handle the error condition
    return 1;
  }
}
```

For each loop iteration, calling `write()` causes a message to be distributed to all connected subscribers that are registered for our topic. Since the subject_id is the key for Message, each time subject_id is incremented and `write()` is called, a new instance is created (see *Topic*). The second argument to `write()` specifies the instance on which we are publishing the sample. It should be passed either a handle returned by `register_instance()` or `DDS::HANDLE_NIL`. Passing a `DDS::HANDLE_NIL` value indicates that the data writer should determine the instance by inspecting the key of the sample. See *Registering and Using Instances in the Publisher* for details on using instance handles during publication.

Setting up the Subscriber

Much of the subscriber's code is identical or analogous to the publisher that we just finished exploring. We will progress quickly through the similar parts and refer you to the discussion above for details. The full source code for this sample subscriber is found in the `Subscriber.cpp` and `DataReaderListener.cpp` files in `DevGuideExamples/DCPS/Messenger/`.

Initializing the Participant

The beginning of the subscriber is identical to the publisher as we initialize the service and join our domain:

```
int main (int argc, char *argv[])
{
 try {
    DDS::DomainParticipantFactory_var dpf =
      TheParticipantFactoryWithArgs(argc, argv);
    DDS::DomainParticipant_var participant =
      dpf->create_participant(42, // Domain ID
                              PARTICIPANT_QOS_DEFAULT,
                              0,  // No listener required
                              OpenDDS::DCPS::DEFAULT_STATUS_MASK);
    if (!participant) {
      std::cerr << "create_participant failed." << std::endl;
      return 1;
    }
```

Registering the Data Type and Creating a Topic

Next, we initialize the message type and topic. Note that if the topic has already been initialized in this domain with the same data type and compatible QoS, the `create_topic()` invocation returns a reference corresponding to the existing topic. If the type or QoS specified in our `create_topic()` invocation do not match that of the existing topic then the invocation fails. There is also a `find_topic()` operation our subscriber could use to simply retrieve an existing topic.

```
Messenger::MessageTypeSupport_var mts =
  new Messenger::MessageTypeSupportImpl();
if (DDS::RETCODE_OK != mts->register_type(participant, "")) {
  std::cerr << "Failed to register the MessageTypeSupport." << std::endl;
  return 1;
}

CORBA::String_var type_name = mts->get_type_name();

DDS::Topic_var topic =
  participant->create_topic("Movie Discussion List",
                            type_name,
                            TOPIC_QOS_DEFAULT,
                            0,  // No listener required
                            OpenDDS::DCPS::DEFAULT_STATUS_MASK);
if (!topic) {
  std::cerr << "Failed to create_topic." << std::endl;
  return 1;
}
```

Creating the subscriber

Next, we create the subscriber with the default QoS.

```
// Create the subscriber
DDS::Subscriber_var sub =
  participant->create_subscriber(SUBSCRIBER_QOS_DEFAULT,
                                 0,  // No listener required
                                 OpenDDS::DCPS::DEFAULT_STATUS_MASK);
if (!sub) {
  std::cerr << "Failed to create_subscriber." << std::endl;
  return 1;
}
```

Creating a DataReader and Listener

We need to associate a listener object with the data reader we create, so we can use it to detect when data is available. The code below constructs the listener object. The `DataReaderListenerImpl` class is shown in the next subsection.

```
DDS::DataReaderListener_var listener(new DataReaderListenerImpl);
```

The listener is allocated on the heap and assigned to a `DataReaderListener_var` object. This type provides reference counting behavior so the listener is automatically cleaned up when the last reference to it is removed. This usage is

typical for heap allocations in OpenDDS application code and frees the application developer from having to actively manage the lifespan of the allocated objects.

Now we can create the data reader and associate it with our topic, the default QoS properties, and the listener object we just created.

```
// Create the Datareader
DDS::DataReader_var dr =
  sub->create_datareader(topic,
                         DATAREADER_QOS_DEFAULT,
                         listener,
                         OpenDDS::DCPS::DEFAULT_STATUS_MASK);
if (!dr) {
  std::cerr << "create_datareader failed." << std::endl;
  return 1;
}
```

This thread is now free to perform other application work. Our listener object will be called on an OpenDDS thread when a sample is available.

The Data Reader Listener Implementation

Our listener class implements the `DDS::DataReaderListener` interface defined by the DDS specification. The `DataReaderListener` is wrapped within a `DCPS::LocalObject` which resolves ambiguously-inherited members such as `_narrow` and `_ptr_type`. The interface defines a number of operations we must implement, each of which is invoked to inform us of different events. The `OpenDDS::DCPS::DataReaderListener` defines operations for OpenDDS's special needs such as disconnecting and reconnected event updates. Here is the interface definition:

```
module DDS {
  local interface DataReaderListener : Listener {
    void on_requested_deadline_missed(in DataReader reader,
                                      in RequestedDeadlineMissedStatus status);
    void on_requested_incompatible_qos(in DataReader reader,
                                       in RequestedIncompatibleQosStatus status);
    void on_sample_rejected(in DataReader reader,
                            in SampleRejectedStatus status);
    void on_liveliness_changed(in DataReader reader,
                               in LivelinessChangedStatus status);
    void on_data_available(in DataReader reader);
    void on_subscription_matched(in DataReader reader,
                                 in SubscriptionMatchedStatus status);
    void on_sample_lost(in DataReader reader, in SampleLostStatus status);
  };
};
```

Our example listener class stubs out most of these listener operations with simple print statements. The only operation that is really needed for this example is `on_data_available()` and it is the only member function of this class we need to explore.

```
void DataReaderListenerImpl::on_data_available(DDS::DataReader_ptr reader)
{
  ++num_reads_;

  try {
```

(continues on next page)

(continued from previous page)

```
    Messenger::MessageDataReader_var reader_i =
      Messenger::MessageDataReader::_narrow(reader);
    if (!reader_i) {
      std::cerr << "read: _narrow failed." << std::endl;
      return;
    }
```

The code above narrows the generic data reader passed into the listener to the type-specific `MessageDataReader` interface. The following code takes the next sample from the message reader. If the take is successful and returns valid data, we print out each of the message's fields.

```
Messenger::Message message;
DDS::SampleInfo si;
DDS::ReturnCode_t status = reader_i->take_next_sample(message, si);

if (status == DDS::RETCODE_OK) {
  if (si.valid_data) {
      std::cout << "Message: subject = " << message.subject.in() << std::endl
        << "  subject_id = " << message.subject_id << std::endl
        << "  from = " << message.from.in() << std::endl
        << "  count = " << message.count << std::endl
        << "  text = " << message.text.in() << std::endl;
  } else if (si.instance_state == DDS::NOT_ALIVE_DISPOSED_INSTANCE_STATE) {
    std::cout << "instance is disposed" << std::endl;
  } else if (si.instance_state == DDS::NOT_ALIVE_NO_WRITERS_INSTANCE_STATE) {
    std::cout << "instance is unregistered" << std::endl;
  } else {
    std::cerr << "ERROR: received unknown instance state "
              << si.instance_state << std::endl;
  }
} else if (status == DDS::RETCODE_NO_DATA) {
    cerr << "ERROR: reader received DDS::RETCODE_NO_DATA!" << std::endl;
} else {
    cerr << "ERROR: read Message: Error: " << status << std::endl;
}
```

Note the sample read may contain invalid data. The valid_data flag indicates if the sample has valid data. There are two samples with invalid data delivered to the listener callback for notification purposes. One is the *dispose* notification, which is received when the `DataWriter` calls `dispose()` explicitly. The other is the *unregistered* notification, which is received when the `DataWriter` calls `unregister()` explicitly. The dispose notification is delivered with the instance state set to `NOT_ALIVE_DISPOSED_INSTANCE_STATE` and the unregister notification is delivered with the instance state set to `NOT_ALIVE_NO_WRITERS_INSTANCE_STATE`.

If additional samples are available, the service calls this function again. However, reading values a single sample at a time is not the most efficient way to process incoming data. The Data Reader interface provides a number of different options for processing data in a more efficient manner. We discuss some of these operations in *Data Handling Optimizations*.

Cleaning up in OpenDDS Clients

After we are finished in the publisher and subscriber, we can use the following code to clean up the OpenDDS-related objects:

```
participant->delete_contained_entities();
dpf->delete_participant(participant);
TheServiceParticipant->shutdown();
```

The domain participant's `delete_contained_entities()` operation deletes all the topics, subscribers, and publishers created with that participant. Once this is done, we can use the domain participant factory to delete our domain participant.

Since the publication and subscription of data within DDS is decoupled, data is not guaranteed to be delivered if a publication is disassociated (shutdown) prior to all data that has been sent having been received by the subscriptions. If the application requires that all published data be received, the `wait_for_acknowledgments()` operation is available to allow the publication to wait until all written data has been received. Data readers must have *Reliability QoS* set to `RELIABLE_RELIABILITY_QOS` (which is the default) in order for `wait_for_acknowledgments()` to work. This operation is called on individual `DataWriters` and includes a timeout value to bound the time to wait. The following code illustrates the use of `wait_for_acknowledgments()` to block for up to 15 seconds to wait for subscriptions to acknowledge receipt of all written data:

```
DDS::Duration_t shutdown_delay = {15, 0};
DDS::ReturnCode_t result;
result = writer->wait_for_acknowledgments(shutdown_delay);
if (result != DDS::RETCODE_OK) {
  std::cerr << "Failed while waiting for acknowledgment of "
            << "data being received by subscriptions, some data "
            << "may not have been delivered." << std::endl;
}
```

Running the Example

We are now ready to run our simple example. Running each of these commands in its own window should enable you to most easily understand the output.

First we will start a `DCPSInfoRepo` service so our publishers and subscribers can find one another.

Note: This step is not necessary if you are using peer-to-peer discovery by configuring your environment to use RTPS discovery.

The `DCPSInfoRepo` executable is found in `bin/DCPSInfoRepo`. When we start the `DCPSInfoRepo` we need to ensure that publisher and subscriber application processes can also find the started `DCPSInfoRepo`. This information can be provided in one of three ways:

1. Pass arguments on the command line.
2. Connection info generated and placed in a shared file for applications to use.
3. Options put in a configuration file for other processes to use.

For our simple example here we will use option 2 by generating the location properties of the `DCPSInfoRepo` into a file so that our simple publisher and subscriber can read it in and connect to it.

From your current directory type:

```
$DDS_ROOT/bin/DCPSInfoRepo -o simple.ior
```

```
%DDS_ROOT%\bin\DCPSInfoRepo -o simple.ior
```

The `-o` parameter instructs the `DCPSInfoRepo` to generate its connection information to the file `simple.ior` for use by the publisher and subscriber. In a separate window navigate to the same directory that contains the `simple.ior` file and start the subscriber application in our example by typing:

```
./subscriber -DCPSInfoRepo file://simple.ior
```

```
subscriber -DCPSInfoRepo file://simple.ior
```

The command line parameters direct the application to use the specified file to locate the `DCPSInfoRepo`. Our subscriber is now waiting for messages to be sent, so we will now start the publisher in a separate window with the same parameters:

```
./publisher -DCPSInfoRepo file://simple.ior
```

```
publisher -DCPSInfoRepo file://simple.ior
```

The publisher connects to the `DCPSInfoRepo` to find the location of any subscribers and begins to publish messages as well as write them to the console. In the subscriber window, you should also now be seeing console output from the subscriber that is reading messages from the topic demonstrating a simple publish and subscribe application.

You can read more about configuring your application for RTPS and other more advanced configuration options in *Configuring for RTPS Discovery* and *RTPS UDP Transport Configuration Properties* . See *Discovery Configuration* and *The DCPS Information Repository* for configuring and using the `DCPSInfoRepo` . See *Quality of Service* for setting and using QoS features that modify the behavior of your application.

Running Our Example with RTPS

The prior OpenDDS example has demonstrated how to build and execute an OpenDDS application using basic OpenDDS configurations and centralized discovery using the `DCPSInfoRepo` service. The following details what is needed to run the same example using RTPS for discovery and with an interoperable transport. This is important in scenarios when your OpenDDS application needs to interoperate with a non-OpenDDS implementation of the DDS specification or if you do not want to use centralized discovery in your deployment of OpenDDS.

The coding and building of the Messenger example above is not changed for using RTPS, so you will not need to modify or rebuild your publisher and subscriber services. This is a strength of the OpenDDS architecture in that to enable the RTPS capabilities, it is an exercise in configuration. For this exercise, we will enable RTPS for the Messenger example using a configuration file that the publisher and subscriber will share. More details concerning the configuration of all the available transports including RTPS are described in *Run-time Configuration*.

Navigate to the directory where your publisher and subscriber have been built. Create a new text file named `rtps.ini` and populate it with the following content:

```
[common]
DCPSGlobalTransportConfig=$file
DCPSDefaultDiscovery=DEFAULT_RTPS

[transport/the_rtps_transport]
transport_type=rtps_udp
```

The two lines of interest are the one that sets the discovery method and the one that sets the data transport protocol to RTPS.

Now lets re-run our example with RTPS enabled by starting the subscriber process first and then the publisher to begin sending data. It is best to start them in separate windows to see the two working separately.

Start the subscriber with the `-DCPSConfigFile` command line parameter to point to the newly created configuration file...

```
./subscriber -DCPSConfigFile rtps.ini
```

```
subscriber -DCPSConfigFile rtps.ini
```

Now start the publisher with the same parameter...

```
./publisher -DCPSConfigFile rtps.ini
```

```
publisher -DCPSConfigFile rtps.ini
```

Since there is no centralized discovery in the RTPS specification, there are provisions to allow for wait times to allow discovery to occur. The specification sets the default to 30 seconds. When the two above processes are started there may be up to a 30 second delay depending on how far apart they are started from each other. This time can be adjusted in OpenDDS configuration files and is discussed in *Configuring for RTPS Discovery*.

Because the architecture of OpenDDS allows for pluggable discovery and pluggable transports the two configuration entries called out in the `rtps.ini` file above can be changed independently with one using RTPS and the other not using RTPS (e.g. centralized discovery using `DCPSInfoRepo`). Setting them both to RTPS in our example makes this application fully interoperable with other non-OpenDDS implementations.

2.7.2 Data Handling Optimizations

Registering and Using Instances in the Publisher

The previous example implicitly specifies the instance it is publishing via the sample's data fields. When `write()` is called, the data writer queries the sample's key fields to determine the instance. The publisher also has the option to explicitly register the instance by calling `register_instance()` on the data writer:

```
Messenger::Message message;
message.subject_id = 99;
DDS::InstanceHandle_t handle = message_writer->register_instance(message);
```

After we populate the Message structure we called the register_instance() function to register the instance. The instance is identified by the subject_id value of 99 (because we earlier specified that field as the key).

We can later use the returned instance handle when we publish a sample:

```
DDS::ReturnCode_t ret = data_writer->write(message, handle);
```

Publishing samples using the instance handle may be slightly more efficient than forcing the writer to query for the instance and is much more efficient when publishing the first sample on an instance. Without explicit registration, the first write causes resource allocation by OpenDDS for that instance.

Because resource limitations can cause instance registration to fail, many applications consider registration as part of setting up the publisher and always do it when initializing the data writer.

Reading Multiple Samples

The DDS specification provides a number of operations for reading and writing data samples. In the examples above we used the `take_next_sample()` operation, to read the next sample and "take" ownership of it from the reader. The Message Data Reader also has the following take operations.

- `take()` – Take a sequence of up to max_samples values from the reader
- `take_instance()` – Take a sequence of values for a specified instance
- `take_next_instance()` – Take a sequence of samples belonging to the same instance, without specifying the instance.

There are also "read" operations corresponding to each of these "take" operations that obtain the same values, but leave the samples in the reader and simply mark them as read in the `SampleInfo`.

Since these other operations read a sequence of values, they are more efficient when samples are arriving quickly. Here is a sample call to `take()` that reads up to 5 samples at a time.

```
MessageSeq messages(5);
DDS::SampleInfoSeq sampleInfos(5);
DDS::ReturnCode_t status = message_dr->take(messages,
                                            sampleInfos,
                                            5,
                                            DDS::ANY_SAMPLE_STATE,
                                            DDS::ANY_VIEW_STATE,
                                            DDS::ANY_INSTANCE_STATE);
```

The three state parameters potentially specialize which samples are returned from the reader. See the DDS specification for details on their usage.

Zero-Copy Read

The read and take operations that return a sequence of samples provide the user with the option of obtaining a copy of the samples (single-copy read) or a reference to the samples (zero-copy read). The zero-copy read can have significant performance improvements over the single-copy read for large sample types. Testing has shown that samples of 8KB or less do not gain much by using zero-copy reads but there is little performance penalty for using zero-copy on small samples.

The application developer can specify the use of the zero-copy read optimization by calling `take()` or `read()` with a sample sequence constructed with a max_len of zero. The message sequence and sample info sequence constructors both take max_len as their first parameter and specify a default value of zero. The following example code is taken from `DevGuideExamples/DCPS/Messenger_ZeroCopy/DataReaderListenerImpl.cpp`:

```
Messenger::MessageSeq messages;
DDS::SampleInfoSeq info;

// get references to the samples (zero-copy read of the samples)
DDS::ReturnCode_t status = dr->take(messages,
                                    info,
                                    DDS::LENGTH_UNLIMITED,
                                    DDS::ANY_SAMPLE_STATE,
                                    DDS::ANY_VIEW_STATE,
                                    DDS::ANY_INSTANCE_STATE);
```

After both zero-copy takes/reads and single-copy takes/reads, the sample and info sequences' length are set to the number of samples read. For the zero-copy reads, the `max_len` is set to a `value >= length`.

Since the application code has asked for a zero-copy loan of the data, it must return that loan when it is finished with the data:

```
dr->return_loan(messages, info);
```

Calling `return_loan()` results in the sequences' `max_len` being set to 0 and its owns member set to false, allowing the same sequences to be used for another zero-copy read.

If the first parameter of the data sample sequence constructor and info sequence constructor were changed to a value greater than zero, then the sample values returned would be copies. When values are copied, the application developer has the option of calling `return_loan()`, but is not required to do so.

If the `max_len` (the first) parameter of the sequence constructor is not specified, it defaults to 0; hence using zero-copy reads. Because of this default, a sequence will automatically call `return_loan()` on itself when it is destroyed. To conform with the DDS specification and be portable to other implementations of DDS, applications should not rely on this automatic `return_loan()` feature.

The second parameter to the sample and info sequences is the maximum slots available in the sequence. If the `read()` or `take()` operation's `max_samples` parameter is larger than this value, then the maximum samples returned by `read()` or `take()` will be limited by this parameter of the sequence constructor.

Although the application can change the length of a zero-copy sequence, by calling the `length(len)` operation, you are advised against doing so because this call results in copying the data and creating a single-copy sequence of samples.

2.8 Quality of Service

Quality of Service (QoS) policies are sets of requested policies for how *entities* should behave. Each policy defines a structure to specify its data. Each entity supports a subset of the policies and defines a QoS structure that is composed of the supported policy structures. The set of allowable policies for a given entity is constrained by the policy structures nested in its QoS structure. For example, the Publisher's QoS structure is defined in the specification's IDL as follows:

```
module DDS {
  struct PublisherQos {
   PresentationQosPolicy presentation;
   PartitionQosPolicy partition;
   GroupDataQosPolicy group_data;
   EntityFactoryQosPolicy entity_factory;
 };
};
```

Setting policies is as simple as obtaining a structure with the default values already set, modifying the individual policy structures as necessary, and then applying the QoS structure to an entity (usually when it is created). See *Default QoS Policy Values* for examples of how to obtain the default QoS policies for various entity types.

2.8.1 Changing QoS Policies

Applications can change the QoS of any entity by calling the `set_qos()` operation on the entity. If the QoS policy values are either invalid or have conflicting polices, then `set_qos()` returns `DDS::RETCODE_INCONSISTENT_POLICY`. If the application attempts to change a QoS policy that is immutable (not changeable), then `set_qos()` returns `DDS::RETCODE_IMMUTABLE_POLICY`.

If the `set_qos` is successful, existing associations are removed if they are no longer compatible and new associations are added if they become compatible. The policies specify if they are mutable or not and how they affect associations.

The application can detect failed associations caused by incompatible QoS using *Offered Incompatible QoS Status* for writers and *Requested Incompatible QoS Status* for readers.

2.8.2 Default QoS Policy Values

Applications obtain the default QoS policies for an entity by instantiating a QoS structure of the appropriate type for the entity and passing it by reference to the appropriate `get_default_entity_qos()` operation on the appropriate factory entity. (For example, you would use a domain participant to obtain the default QoS for a publisher or subscriber.) The following examples illustrate how to obtain the default policies for publisher, subscriber, topic, domain participant, data writer, and data reader.

```
// Get default Publisher QoS from a DomainParticipant:
DDS::PublisherQos pub_qos;
DDS::ReturnCode_t ret;
ret = domain_participant->get_default_publisher_qos(pub_qos);
if (DDS::RETCODE_OK != ret) {
  std::cerr << "Could not get default publisher QoS" << std::endl;
}

// Get default Subscriber QoS from a DomainParticipant:
DDS::SubscriberQos sub_qos;
ret = domain_participant->get_default_subscriber_qos(sub_qos);
if (DDS::RETCODE_OK != ret) {
  std::cerr << "Could not get default subscriber QoS" << std::endl;
}

// Get default Topic QoS from a DomainParticipant:
DDS::TopicQos topic_qos;
ret = domain_participant->get_default_topic_qos(topic_qos);
if (DDS::RETCODE_OK != ret) {
  std::cerr << "Could not get default topic QoS" << std::endl;
}

// Get default DomainParticipant QoS from a DomainParticipantFactory:
DDS::DomainParticipantQos dp_qos;
ret = domain_participant_factory->get_default_participant_qos(dp_qos);
if (DDS::RETCODE_OK != ret) {
  std::cerr << "Could not get default participant QoS" << std::endl;
}

// Get default DataWriter QoS from a Publisher:
DDS::DataWriterQos dw_qos;
ret = pub->get_default_datawriter_qos(dw_qos);
if (DDS::RETCODE_OK != ret) {
  std::cerr << "Could not get default data writer QoS" << std::endl;
}

// Get default DataReader QoS from a Subscriber:
DDS::DataReaderQos dr_qos;
ret = sub->get_default_datareader_qos(dr_qos);
if (DDS::RETCODE_OK != ret) {
  std::cerr << "Could not get default data reader QoS" << std::endl;
}
```

2.8.3 Policies

Liveliness QoS

The liveliness QoS policy controls when and how the service determines whether participants are considered "alive", meaning they are still reachable and active. This policy applies to the topic, data reader, and data writer entities via the `liveliness` member of their respective QoS structures. Setting this policy on a topic means it is in effect for all data readers and data writers on that topic.

Important: This policy is *immutable* and affects *association*.

IDL:

```
enum LivelinessQosPolicyKind {
  AUTOMATIC_LIVELINESS_QOS,
  MANUAL_BY_PARTICIPANT_LIVELINESS_QOS,
  MANUAL_BY_TOPIC_LIVELINESS_QOS
};

struct LivelinessQosPolicy {
  LivelinessQosPolicyKind kind;
  Duration_t lease_duration;
};
```

Applicable entities	Members	*Default values*
Topic, *DataWriter*, and *DataReader*	`kind`	`AUTOMATIC_LIVELINESS_QOS`
	`lease_duration.sec`	`DURATION_INFINITE_SEC`
	`lease_duration.nanosec`	`DURATION_INFINITE_NSEC`

Specification: DDS v1.4 2.2.3.11 LIVELINESS

The `kind` member setting indicates whether liveliness is asserted automatically by the service or manually by the specified entity. A setting of `AUTOMATIC_LIVELINESS_QOS` means that the service will send a liveliness indication if the participant has not sent any network traffic for the `lease_duration`. The `MANUAL_BY_PARTICIPANT_LIVELINESS_QOS` or `MANUAL_BY_TOPIC_LIVELINESS_QOS` setting means the specified entity (data writer for the "by topic" setting or domain participant for the "by participant" setting) must either write a *sample* or manually assert its liveliness within a specified heartbeat interval. The desired heartbeat interval is specified by the `lease_duration` member. The default lease duration is a pre-defined infinite value, which disables any liveliness testing.

To manually assert liveliness without publishing a sample, the application must call the `assert_liveliness()` operation on the data writer (for the "by topic" setting) or on the domain participant (for the "by participant" setting) within the specified heartbeat interval.

Data writers specify (*offer*) their own liveliness criteria and data readers specify (*request*) the desired liveliness of their writers. Writers that are not heard from within the lease duration (either by writing a sample or by asserting liveliness) cause a change in the *LIVELINESS_CHANGED_STATUS* communication status and notification to the application (e.g., by calling the data reader listener's `on_liveliness_changed()` callback operation or by signaling any related wait sets).

This policy is considered during the establishment of associations between data writers and data readers. The value of both sides of the association must be compatible in order for an association to be established. Compatibility is determined by comparing the data reader's requested liveliness with the data writer's offered liveliness. Both the kind of liveliness (automatic, manual by topic, manual by participant) and the value of the lease duration are considered in

determining compatibility. The writer's offered kind of liveliness must be greater than or equal to the reader's requested kind of liveliness. The liveliness kind values are ordered as follows:

```
MANUAL_BY_TOPIC_LIVELINESS_QOS >
MANUAL_BY_PARTICIPANT_LIVELINESS_QOS >
AUTOMATIC_LIVELINESS_QOS
```

In addition, the writer's offered lease duration must be less than or equal to the reader's requested lease duration. Both of these conditions must be met for the offered and requested liveliness policy settings to be considered compatible and the association established.

Reliability QoS

The reliability QoS policy applies to the topic, data reader, and data writer entities via the `reliability` member of their respective QoS structures. This policy controls how data readers and writers treat the *sample*s they process.

Important: This policy is *immutable* and affects *association*.

IDL:

```
enum ReliabilityQosPolicyKind {
  BEST_EFFORT_RELIABILITY_QOS,
  RELIABLE_RELIABILITY_QOS
};

struct ReliabilityQosPolicy {
  ReliabilityQosPolicyKind kind;
  Duration_t max_blocking_time;
};
```

Applicable entities	Members	*Default values*
Topic and *DataReader*	`kind`	`BEST_EFFORT_RELIABILITY_QOS`
	`max_blocking_time.sec`	`DURATION_INFINITE_SEC`
	`max_blocking_time.nanosec`	`DURATION_INFINITE_NSEC`
DataWriter	`kind`	`RELIABLE_RELIABILITY_QOS`[1]
	`max_blocking_time.sec`	`0`
	`max_blocking_time.nanosec`	`100000000` (100 ms)

Specification: DDS v1.4 2.2.3.14 RELIABILITY

The "best effort" value (`BEST_EFFORT_RELIABILITY_QOS`) makes no promises as to the reliability of the samples and could be expected to drop samples under some circumstances. The "reliable" value (`RELIABLE_RELIABILITY_QOS`) indicates that the service should eventually deliver all values to eligible data readers.

The `max_blocking_time` member of this policy is used when the *History QoS* policy is set to "keep all" and the writer is unable to proceed because of *Resource Limits QoS*. When this situation occurs and the writer blocks for more than the specified time, then the write fails with a `DDS::RETCODE_TIMEOUT` return code. The default for this policy for data readers and topics is "best effort", while the default value for data writers is "reliable".

[1] For OpenDDS versions, up to 2.0, the default reliability kind for data writers is best effort. For versions 2.0.1 and later, this is changed to reliable (to conform to the DDS specification).

This policy is considered during the creation of associations between data writers and data readers. The value of both sides of the association must be compatible in order for an association to be created. The reliability kind of data writer must be greater than or equal to the value of data reader. In other words, all combinations are valid except that a reliable reader can only associate with a reliable writer, not a "best effort" one.

History QoS

The history QoS policy determines how *sample*s are held in the data writer and data reader for a particular *instance*. For data writers these samples are held until the publisher retrieves them and successfully sends them to all connected subscribers. For data readers these samples are held until *taken* by the application. This policy applies to the topic, data reader, and data writer entities via the `history` member of their respective QoS structures.

Important: This policy is *immutable* and does not affect association.

IDL:

```
enum HistoryQosPolicyKind {
  KEEP_LAST_HISTORY_QOS,
  KEEP_ALL_HISTORY_QOS
};

struct HistoryQosPolicy {
  HistoryQosPolicyKind kind;
  long depth;
};
```

Applicable entities	Members	*Default values*
Topic, *DataWriter*, and *DataReader*	`kind`	`KEEP_LAST_HISTORY_QOS`
	`depth`	`1`

Specification: DDS v1.4 2.2.3.18 HISTORY

The "keep all" value (`KEEP_ALL_HISTORY_QOS`) specifies that all possible samples for that instance should be kept. When "keep all" is specified and the number of unread samples is equal to the *Resource Limits QoS* field of `max_samples_per_instance` then any incoming samples are rejected.

The "keep last" value (`KEEP_LAST_HISTORY_QOS`) specifies that only the last `depth` values should be kept. When a data writer contains depth samples of a given instance, a write of new samples for that instance are queued for delivery and the oldest unsent samples are discarded. When a data reader contains depth samples of a given instance, any incoming samples for that instance are kept and the oldest samples are discarded.

Durability QoS

The durability QoS policy controls whether data writers should maintain *sample*s after they have been sent to known subscribers. This policy applies to the topic, data reader, and data writer entities via the `durability` member of their respective QoS structures.

Important: This policy is *immutable* and affects *association*.

IDL:

```
enum DurabilityQosPolicyKind {
  VOLATILE_DURABILITY_QOS,          // Least Durability
  TRANSIENT_LOCAL_DURABILITY_QOS,
  TRANSIENT_DURABILITY_QOS,
  PERSISTENT_DURABILITY_QOS         // Greatest Durability
};

struct DurabilityQosPolicy {
  DurabilityQosPolicyKind kind;
};
```

Applicable entities	Members	*Default values*
Topic, *DataWriter*, and *DataReader*	`kind`	`VOLATILE_DURABILITY_QOS`

Specification: DDS v1.4 2.2.3.4 DURABILITY

A durability kind of `VOLATILE_DURABILITY_QOS` means samples are discarded after being sent to all known subscribers. As a side effect, subscribers cannot recover samples sent before they connect.

A durability kind of `TRANSIENT_LOCAL_DURABILITY_QOS` means that data readers that are associated/connected with a data writer will be sent all of the samples in the data writer's history.

A durability kind of `TRANSIENT_DURABILITY_QOS` means that samples outlive a data writer and last as long as the process is alive. The samples are kept in memory, but are not persisted to permanent storage. A data reader subscribed to the same topic and partition within the same domain will be sent all of the cached samples that belong to the same topic/partition.

A durability kind of `PERSISTENT_DURABILITY_QOS` provides basically the same functionality as transient durability except the cached samples are persisted and will survive process destruction.

When transient or persistent durability is specified, the *Durability Service QoS* QoS policy specifies additional tuning parameters for the durability cache.

The durability policy is considered during the creation of associations between data writers and data readers. The value of both sides of the association must be compatible in order for an association to be created. The durability kind value of the data writer must be greater than or equal to the corresponding value of the data reader. The durability kind values are ordered as follows:

```
PERSISTENT_DURABILITY_QOS >
TRANSIENT_DURABILITY_QOS >
TRANSIENT_LOCAL_DURABILITY_QOS >
VOLATILE_DURABILITY_QOS
```

Durability Service QoS

The durability service QoS policy controls deletion of *sample*s in the transient or persistent durability caches. This policy applies to the topic and data writer entities via the `durability_service` member of their respective QoS structures and provides a way to specify *History QoS* and *Resource Limits QoS* for the sample cache.

Important: This policy is *immutable* and does not affect association.

IDL:

```
struct DurabilityServiceQosPolicy {
  Duration_t              service_cleanup_delay;
  HistoryQosPolicyKind    history_kind;
  long                    history_depth;
  long                    max_samples;
  long                    max_instances;
  long                    max_samples_per_instance;
};
```

Applicable entities	Members	*Default values*
Topic and *DataWri*	`service_cleanup_delay.sec`	`DURATION_ZERO_SEC`
	`service_cleanup_delay.nanosec`	`DURATION_ZERO_NSEC`
	`history_kind`	`KEEP_LAST_HISTORY_QOS`
	`history_depth`	`1`
	`max_samples`	`LENGTH_UNLIMITED`
	`max_instances`	`LENGTH_UNLIMITED`
	`max_samples_per_instance`	`LENGTH_UNLIMITED`

Specification: DDS v1.4 2.2.3.5 DURABILITY_SERVICE

The members are analogous to, although independent of, those found in the *History QoS* and *Resource Limits QoS* policies. The `service_cleanup_delay` can be set to a desired value. By default, it is set to zero, which means never clean up cached samples.

Resource Limits QoS

The resource limits determines the amount of resources the service can consume in order to meet the requested QoS. This policy applies to the topic, data reader, and data writer entities via the `resource_limits` member of their respective QoS structures.

Important: This policy is *immutable* and does not affect association.

IDL:

```
struct ResourceLimitsQosPolicy {
  long max_samples;
  long max_instances;
```

(continues on next page)

(continued from previous page)

```
  long max_samples_per_instance;
};
```

Applicable entities	Members	*Default values*
Topic, *DataWriter*, and *DataReader*	`max_samples`	`LENGTH_UNLIMITED`
	`max_instances`	`LENGTH_UNLIMITED`
	`max_samples_per_instance`	`LENGTH_UNLIMITED`

Specification: DDS v1.4 2.2.3.19 RESOURCE_LIMITS

The `max_samples` member specifies the maximum number of samples a single data writer or data reader can manage across all of its instances. The `max_instances` member specifies the maximum number of instances that a data writer or data reader can manage. The `max_samples_per_instance` member specifies the maximum number of samples that can be managed for an individual instance in a single data writer or data reader.

Resources are used by the data writer to queue samples written to the data writer but not yet sent to all data readers because of backpressure from the transport. Resources are used by the data reader to queue samples that have been received, but not yet read/taken from the data reader.

Partition QoS

The partition QoS policy allows the creation of logical partitions within a *domain*. Data readers and data writers can only be associated if they have at least one matched partition string. This policy applies to the publisher and subscriber entities via the `partition` member of their respective QoS structures.

Important: This policy is *mutable* and *affects association*.

IDL:

```
struct PartitionQosPolicy {
  StringSeq name;
};
```

Applicable entities	Members	*Default values*
Publisher and *Subscriber*	`name`	(empty sequence)

Specification: DDS v1.4 2.2.3.13 PARTITION

The default partition name is an empty string and causes the entity to participate in the default partition. The partition names may contain wildcard characters as they are *Fnmatch Expressions*.

The establishment of data reader and data writer associations depends on matching partition strings on the publication and subscription ends. Failure to match partitions is not considered a failure and does not trigger any callbacks or set any status values.

Deadline QoS

The deadline QoS policy allows the application to detect when *sample*s are not written or read within a specified amount of time. This policy applies to the topic, data writer, and data reader entities via the `deadline` member of their respective QoS structures.

Important: This policy is *mutable* and *affects association*.

IDL:

```
struct DeadlineQosPolicy {
  Duration_t period;
};
```

Applicable entities	Members	*Default values*
Topic, *DataWriter*, and *DataReader*	`period.sec` `period.nanosec`	`DURATION_INFINITE_SEC` `DURATION_INFINITE_NSEC`

Specification: DDS v1.4 2.2.3.7 DEADLINE

The default value of the `period` member is infinite, which requires no behavior. When this policy is set to a finite value, then the data writer monitors the changes to data made by the application and indicates failure to honor the policy by setting the corresponding status condition and triggering the `on_offered_deadline_missed()` listener callback. A data reader that detects that the data has not changed before the period has expired sets the corresponding status condition and triggers the `on_requested_deadline_missed()` listener callback.

This policy is considered during the creation of associations between data writers and data readers. The value of both sides of the association must be compatible in order for an association to be created. The deadline period of the data reader must be greater than or equal to the corresponding value of data writer.

The value of this policy may change after the associated entity is enabled. In the case where the policy of a data reader or data writer is made, the change is successfully applied only if the change remains consistent with the remote end of all associations in which the reader or writer is participating. If the policy of a topic is changed, it will only affect data readers and writers that are created after the change has been made. Any existing readers or writers, and any existing associations between them, will not be affected by the topic policy value change.

Lifespan QoS

The lifespan QoS policy allows the application to specify when a *sample* expires. Expired samples will not be delivered to subscribers. This policy applies to the topic and data writer entities via the `lifespan` member of their respective QoS structures.

Important: This policy is *mutable* and does not affect association.

IDL:

```
struct LifespanQosPolicy {
  Duration_t duration;
}
```

Applicable entities	Members	*Default values*
Topic and *DataWriter*	`duration.sec`	`DURATION_INFINITE_SEC`
	`duration.nanosec`	`DURATION_INFINITE_NSEC`

Specification: DDS v1.4 2.2.3.16 LIFESPAN

The default value of the `duration` member is infinite, which means samples never expire.

Note: OpenDDS currently supports expired sample detection on the publisher side when using a *Durability QoS* `kind` other than *VOLATILE_DURABILITY_QOS*. The current OpenDDS implementation may not remove samples from the data writer and data reader caches when they expire after being placed in the cache.

The value of this policy may be changed at any time, but only affects data written after the change.

User Data QoS

The user data QoS policy can be used to attach arbitrary information to the created *entity*. It is not available to the user when using *Static Discovery*. This policy applies to the domain participant, data reader, and data writer entities via the `user_data` member of their respective QoS structures.

Important: This policy is *mutable* and does not affect association.

IDL:

```
struct UserDataQosPolicy {
  sequence<octet> value;
};
```

Applicable entities	Members	*Default values*
DomainParticipant, *DataWriter*, *DataReader*	`value`	(empty sequence)

Specification: DDS v1.4 2.2.3.1 USER_DATA

The value of the policy is available in respective *built-in topic data*. The value's use is defined by the application. For example, the application could attach security credentials via the policy that can be used by the remote application to authenticate the source.[2]

Warning: When using *DDS Security*, the user data of a participant can be leaked in unsecured discovery messages. Enabling *`[rtps_discovery] SecureParticipantUserData`* will only send and provide the real user data when it can be securely sent. This is an OpenDDS-specific extension.

[2] This is an example that was given by the DDS specification. If you actually need to authenticate remote participants in a secure way, it's highly recommended to use *DDS Security*.

Topic Data QoS

The topic data QoS policy can be used to attach arbitrary information to the created *topic*. This policy applies to topic entities via the `topic_data` member of `TopicQoS` structures.

Important: This policy is *mutable* and does not affect association.

IDL:

```
struct TopicDataQosPolicy {
  sequence<octet> value;
};
```

Applicable entities	Members	*Default values*
Topic	`value`	(empty sequence)

Specification: DDS v1.4 2.2.3.2 TOPIC_DATA

The value of the topic data policy is available in data writer, data reader, and topic *built-in topic data*. The value's use is defined by the application.

Group Data QoS

The group data QoS policy can be used to attach arbitrary information to the created *entity*. This policy applies to the publisher and subscriber entities via the `group_data` member of their respective QoS structures.

Important: This policy is *mutable* and does not affect association.

IDL:

```
struct GroupDataQosPolicy {
  sequence<octet> value;
};
```

Applicable entities	Members	*Default values*
Publisher and *Subscriber*	`value`	(empty sequence)

Specification: DDS v1.4 2.2.3.3 GROUP_DATA

The value of the group data policy is propagated via *built-in topics* using the writer built-in topic data for the publisher and the reader built-in topic data for the subscriber. The value's use is defined by the application. This could be used to implement matching mechanisms similar to those of the *Partition QoS* except the decision could be made based on an application-defined policy.

Transport Priority QoS

The transport priority QoS policy is considered a hint to the transport layer to indicate at what priority to send messages. This policy applies to topic and data writer entities via the `transport_priority` member of their respective QoS policy structures.

Important: OpenDDS currently only implements this for the *tcp* and *udp* transports.

This policy is *immutable* and does not affect association. This is opposed to the DDS specification, which specifies that it's mutable. OpenDDS does not currently support modifications of the transport priority policy values after creation of the data writer. This can be worked around by creating new data writers as different priority values are required.

IDL:

```
struct TransportPriorityQosPolicy {
  long value;
};
```

Applicable entities	Members	*Default values*
Topic and *DataWriter*	`value`	`0`

Specification: DDS v1.4 2.2.3.15 TRANSPORT_PRIORITY

Higher values indicate higher priority. OpenDDS maps the priority value directly onto thread and DiffServ codepoint values. A default priority of zero will not modify either threads or codepoints in messages.

OpenDDS will attempt to set the thread priority of the sending transport as well as any associated receiving transport. Transport priority values are mapped from zero (default) through the maximum thread priority linearly without scaling. If the lowest thread priority is different from zero, then it is mapped to the transport priority value of zero. Where priority values on a system are inverted (higher numeric values are lower priority), OpenDDS maps these to an increasing priority value starting at zero. Priority values lower than the minimum (lowest) thread priority on a system are mapped to that lowest priority. Priority values greater than the maximum (highest) thread priority on a system are mapped to that highest priority. On most systems, thread priorities can only be set when the process scheduler has been set to allow these operations. Setting the process scheduler is generally a privileged operation and will require system privileges to perform. On POSIX based systems, the system calls of *`sched_get_priority_min(2)`* and *`sched_get_priority_max(2)`* are used to determine the system range of thread priorities.

OpenDDS will attempt to set the DiffServ codepoint on the socket used to send data for the data writer if it is supported by the transport implementation. If the network hardware honors the codepoint values, higher codepoint values will result in better (faster) transport for higher priority samples. The default value of zero will be mapped to the (default) codepoint of zero. Priority values from 1 through 63 are then mapped to the corresponding codepoint values, and higher priority values are mapped to the highest codepoint value (63).

Latency Budget QoS

The latency budget QoS policy is considered a hint to the transport layer to indicate the urgency of *sample*s being sent. This policy applies to topic, data reader, and data writer entities via the `latency_budget` member of their respective QoS policy structures.

Important: This policy is *mutable* and *affects association*.

IDL:

```
struct LatencyBudgetQosPolicy {
  Duration_t duration;
};
```

Applicable entities	Members	*Default values*
Topic, *DataWriter*, and *DataReader*	`duration.sec` `duration.nanosec`	`DURATION_ZERO_SEC` `DURATION_ZERO_NSEC`

Specification: DDS v1.4 2.2.3.8 LATENCY_BUDGET

The default value of `duration` is zero indicating that the delay should be minimized. OpenDDS uses the value to bound a delay interval for reporting unacceptable delay in transporting samples from publication to subscription. This policy is used for monitoring purposes only at this time. Use *Transport Priority QoS* to modify the sending priority of samples.

There is an OpenDDS-specific *Budget Exceeded Status* that reports when the duration is exceeded.

The data writer policy value is used only for compatibility comparisons and if left at the default value of zero will result in all requested duration values from data readers being matched. The data writer policy value must be greater or equal to a data reader policy value for an association to occur or continue to exist.

Entity Factory QoS

The entity factory QoS policy controls whether *entities* are automatically enabled by their factories when they are created. This policy applies to domain participant factory (as a factory for domain participants), domain participant (as a factory for publishers, subscribers, and topics), publisher (as a factory for data writers), or subscriber (as a factory for data readers).

Important: This policy is *mutable* and does not affect association.

IDL:

```
struct EntityFactoryQosPolicy {
  boolean autoenable_created_entities;
};
```

Applicable entities	Members	*Default values*
`DomainParticipantFactory`, *DomainParticipant*, *Publisher*, and *Subscriber*	`autoenable_created_entit`	`true`

Specification: DDS v1.4 2.2.3.20 ENTITY_FACTORY

Applications that wish to explicitly enable entities some time after they are created should set the value of the `autoenable_created_entities` member of this policy to `false` and apply the policy to the appropriate factory entities. The application must then manually enable the entity by calling the entity's `enable()` operation. One use of setting this policy to `false` is *binding specfic transport configurations to readers and writers*.

The value of this policy may be changed at any time, but this only affects entities created after the change.

Presentation QoS

The presentation QoS policy controls how changes to *instance*s by publishers are presented to data readers. It affects the relative ordering of these changes and the scope of this ordering.

Important: This policy is *immutable* and affects *association*.

IDL:

```
enum PresentationQosPolicyAccessScopeKind {
  INSTANCE_PRESENTATION_QOS,
  TOPIC_PRESENTATION_QOS,
  GROUP_PRESENTATION_QOS
};

struct PresentationQosPolicy {
  PresentationQosPolicyAccessScopeKind access_scope;
  boolean coherent_access;
  boolean ordered_access;
};
```

Applicable entities	Members	*Default values*
Publisher and *Subscriber*	`access_scope`	`INSTANCE_PRESENTATION_QOS`
	`coherent_access`	`0`
	`ordered_access`	`0`

Specification: DDS v1.4 2.2.3.6 PRESENTATION

The scope of these changes (`access_scope`) specifies the level in which an application may be made aware:

- `INSTANCE_PRESENTATION_QOS` (the default) indicates that changes occur to instances independently. Instance access essentially acts as a no-op with respect to `coherent_access` and `ordered_access`. Setting either of these values to true has no observable affect within the subscribing application.
- `TOPIC_PRESENTATION_QOS` indicates that accepted changes are limited to all instances within the same data reader or data writer.
- `GROUP_PRESENTATION_QOS` indicates that accepted changes are limited to all instances within the same publisher or subscriber.

Coherent changes (`coherent_access`) allow one or more changes to an instance be made available to an associated data reader as a single change. If a data reader does not receive the entire set of coherent changes made by a publisher, then none of the changes are made available. The semantics of coherent changes are similar in nature to those found in transactions provided by many relational databases. By default, `coherent_access` is `false`.

Changes may also be made available to associated data readers in the order sent by the publisher (`ordered_access`). This is similar in nature to the *Destination Order QoS* policy, however `ordered_access` permits data to be ordered independently of instance ordering. By default, `ordered_access` is `false`.

Note: This policy controls the ordering and scope of *sample*s made available to the subscriber, but the subscriber application must use the proper logic in reading samples to guarantee the requested behavior. For more details, see DDS v1.4 2.2.2.5.1.9 Data access patterns.

For a reader and writer to associate, all the following must be true:

- The writer's `access_scope` must be greater or equal to the reader's.
- The writer's `coherent_access` must be `false` or else both the reader's and writer's `coherent_access` must both be `true`.
- The writer's `ordered_access` must be `false` or else both the reader's and writer's `ordered_access` must both be `true`.

Destination Order QoS

The destination order QoS policy controls the order in which *sample*s within a given *instance* are made available to a data reader.

Important: This policy is *immutable* and affects *association*.

IDL:

```
enum DestinationOrderQosPolicyKind {
  BY_RECEPTION_TIMESTAMP_DESTINATIONORDER_QOS,
  BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS
};

struct DestinationOrderQosPolicy {
  DestinationOrderQosPolicyKind kind;
};
```

Applicable entities	Members	*Default values*
Topic, *DataWriter*, and *DataReader*	`kind`	`BY_RECEPTION_TIMESTAMP_DESTINATIONORDER_QOS`

Specification: DDS v1.4 2.2.3.17 DESTINATION_ORDER

If a *History QoS* `depth` of one (the default) is specified, the instance will reflect the most recent value written by all data writers to that instance.

The `BY_RECEPTION_TIMESTAMP_DESTINATIONORDER_QOS` value (the default) indicates that samples within an instance are ordered in the order in which they were received by the data reader. Note that samples are not necessarily received in the order sent by the same data writer. To enforce this type of ordering, the `BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS` value should be used.

The `BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS` value indicates that samples within an instance are ordered based on a timestamp provided by the data writer. It should be noted that if multiple data writers write to the same instance, care should be taken to ensure that clocks are synchronized to prevent incorrect ordering on the data reader.

For a reader and writer to associate, the writer's `kind` must be greater or equal to the reader's. In other words, if the reader is `BY_RECEPTION_TIMESTAMP_DESTINATIONORDER_QOS`, then it the writer can be either value. If the reader is `BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS`, then the writer must also be `BY_SOURCE_TIMESTAMP_DESTINATIONORDER_QOS`.

Writer Data Lifecycle QoS

The writer data lifecycle QoS policy controls the lifecycle of *instance*s managed by a *DataWriter*.

Important: This policy is *mutable* and does not affect association.

IDL:

```
struct WriterDataLifecycleQosPolicy {
  boolean autodispose_unregistered_instances;
};
```

Applicable entities	Members	*Default values*
DataWriter	`autodispose_unregistered_instances`	`true`

Specification: DDS v1.4 2.2.3.21 WRITER_DATA_LIFECYCLE

When `autodispose_unregistered_instances` is set to `true` (the default), a data writer *dispose*s an instance when it is *unregister*ed. In some cases, it may be desirable to prevent an instance from being disposed when an instance is unregistered. This policy could, for example, allow an *exclusive ownership* data writer to gracefully defer to the next data writer without affecting the instance state. Deleting a data writer implicitly unregisters all of its instances prior to deletion.

Reader Data Lifecycle QoS

The reader data lifecycle QoS policy controls the lifecycle of *instance*s managed by a *DataReader*.

Important: This policy is *mutable* and does not affect association.

IDL:

```
struct ReaderDataLifecycleQosPolicy {
  Duration_t autopurge_nowriter_samples_delay;
  Duration_t autopurge_disposed_samples_delay;
};
```

Applicable entities	Members	*Default values*
DataRe	`autopurge_nowriter_samples_delay.sec`	`DURATION_INFINITE_SEC`
	`autopurge_nowriter_samples_delay.nanosec`	`DURATION_INFINITE_NSEC`
	`autopurge_disposed_samples_delay.sec`	`DURATION_INFINITE_SEC`
	`autopurge_disposed_samples_delay.nanosec`	`DURATION_INFINITE_NSEC`

Specification: DDS v1.4 2.2.3.22 READER_DATA_LIFECYCLE

Normally, a data reader maintains data for all instances until there are no more associated data writers for the instance, the instance has been *dispose*d, or the data has been *taken* by the user.

In some cases, it may be desirable to constrain the reclamation of these resources. This policy could, for example, permit a late-joining data writer to prolong the lifetime of an instance in fail-over situations.

The `autopurge_nowriter_samples_delay` controls how long the data reader waits before reclaiming resources once an instance transitions to the `NOT_ALIVE_NO_WRITERS` state. By default, `autopurge_nowriter_samples_delay` is infinite.

The `autopurge_disposed_samples_delay` controls how long the data reader waits before reclaiming resources once an instance transitions to the `NOT_ALIVE_DISPOSED` state. By default, `autopurge_disposed_samples_delay` is infinite.

Time Based Filter QoS

The time based filter QoS policy controls how often a *DataReader* may be interested in changes in values to an *instance*.

Important: This policy is *mutable* and does not affect association.

IDL:

```
struct TimeBasedFilterQosPolicy {
  Duration_t minimum_separation;
};
```

Applicable entities	Members	*Default values*
DataReader	`minimum_separation.sec` `minimum_separation.nanosec`	`DURATION_ZERO_SEC` `DURATION_ZERO_NSEC`

Specification: DDS v1.4 2.2.3.12 TIME_BASED_FILTER

An interval (`minimum_separation`) may be specified on the data reader. This interval defines a minimum delay between instance value changes; this permits the data reader to throttle changes without affecting the state of the associated data writer. By default, `minimum_separation` is zero, which indicates that no data is filtered. This QoS policy does not conserve bandwidth as instance value changes are still sent to the subscriber process. It only affects which samples are made available via the data reader.

Ownership QoS

The ownership QoS policy controls whether more than one *DataWriter* is able to write *sample*s for the same *instance*.

Important: This policy is *immutable* and affects *association*.

IDL:

```
enum OwnershipQosPolicyKind {
  SHARED_OWNERSHIP_QOS,
  EXCLUSIVE_OWNERSHIP_QOS
};

struct OwnershipQosPolicy {
  OwnershipQosPolicyKind kind;
};
```

Applicable entities	Members	*Default values*
Topic, *DataWriter*, and *DataReader*	`kind`	`SHARED_OWNERSHIP_QOS`

Specification: DDS v1.4 2.2.3.9 OWNERSHIP

If the kind member is set to `SHARED_OWNERSHIP_QOS`, more than one data writer is allowed to update the same instance. If the kind member is set to `EXCLUSIVE_OWNERSHIP_QOS`, only one data writer is allowed to update a given instance (i.e., the data writer is considered to be the *owner* of the instance) and associated *DataReader*s will only see samples written by that data writer. The owner of the instance is determined by value of the *Ownership Strength QoS* policy; the data writer with the highest value of strength is considered the owner of the instance. Other factors may also influence ownership, such as whether the data writer with the highest strength is "alive" (as defined by the *Liveliness QoS* policy) and has not violated its offered publication deadline constraints (as defined by the *Deadline QoS* policy).

For a reader and writer to associate, the `kind` must be the same.

Ownership Strength QoS

The ownership strength QoS policy is used in conjunction with the *Ownership QoS* `EXCLUSIVE_OWNERSHIP_QOS` policy on *DataWriter*s.

Important: This policy is *mutable* and does not affect association.

IDL:

```
struct OwnershipStrengthQosPolicy {
  long value;
};
```

Applicable entities	Members	*Default values*
DataWriter	`value`	`0`

Specification: DDS v1.4 2.2.3.10 OWNERSHIP_STRENGTH

The `value` member is used to determine which data writer is the *owner* of the *instance*. The default value is zero.

Property QoS

The property QoS policy contains sequences of key-value pairs for the *DomainParticipant*.

Important: This policy is *mutable*, but updates to properties after creating the participant might not an effect. This policy affects association indirectly through security.

IDL:

```
struct Property_t {
  string name;
  string value;
  boolean propagate;
};
typedef sequence<Property_t> PropertySeq;

struct BinaryProperty_t {
  string name;
  OctetSeq value;
  boolean propagate;
};
typedef sequence<BinaryProperty_t> BinaryPropertySeq;

struct PropertyQosPolicy {
  PropertySeq value;
  BinaryPropertySeq binary_value;
};
```

Applicable entities	Members	*Default values*
DomainParticipant	`value`	(empty sequence)
	`binary_value`	(empty sequence)

Specification: DDS Security v1.1 7.2.5 PropertyQosPolicy, DomainParticipantQos, DataWriterQos, and DataReaderQos

---

Right now these are only used for *DDS Security Configuration via Property Qos Policy*.

Data Representation QoS

The data representation QoS policy defines how a *DataWriter* encodes *sample*s and what encodings a *DataReader* will accept. This XTypes concept is explained in detail in *Data Representation*.

Important: This policy is *immutable* and affects *association*.

IDL:

```
module DDS {
  const DataRepresentationId_t XCDR_DATA_REPRESENTATION = 0;
  const DataRepresentationId_t XML_DATA_REPRESENTATION = 1;
  const DataRepresentationId_t XCDR2_DATA_REPRESENTATION = 2;
```

(continues on next page)

(continued from previous page)

```
  typedef sequence<DataRepresentationId_t> DataRepresentationIdSeq;

  struct DataRepresentationQosPolicy {
    DataRepresentationIdSeq value;
  };
};

module OpenDDS {
  module DCPS {
    const DDS::DataRepresentationId_t UNALIGNED_CDR_DATA_REPRESENTATION = -12140;
  };
};
```

Applicable entities	Members	*Default values*
DataWriter using the *RTPS/UDP Transport*	`value`	(empty sequence) – interpreted as a sequence containing `XCDR2_DATA_REPRESENTATION`
DataReader using the *RTPS/UDP Transport*	`value`	(empty sequence) – interpreted as a sequence containing `XCDR_DATA_REPRESENTATION` and `XCDR2_DATA_REPRESENTATION`
DataWriter using other transports	`value`	(empty sequence) – interpreted as a sequence containing `UNALIGNED_CDR_DATA_REPRESENTATION`
DataReader using other transports	`value`	(empty sequence) – interpreted as a sequence containing `XCDR_DATA_REPRESENTATION`, `XCDR2_DATA_REPRESENTATION`, and `UNALIGNED_CDR_DATA_REPRESENTATION`

Specification: DDS XTypes v1.3 7.6.3.1 Data Representation QoS Policy

Warning: The default interpretation of `value` is OpenDDS-specific as of XTypes 1.3. The XTypes specification v1.3 specifies that it should be interpreted as a sequence containing `XCDR_DATA_REPRESENTATION`. This is because OpenDDS defaults to XCDR2 instead of XCDR1 when using the *RTPS/UDP Transport*, the use of unaligned CDR, and the desire to have readers be as compatible as possible by default. See *Data Representation* for details.

For a reader and writer to associate, the first value in the writer's effective `value` must be contained in the reader's effective `value`. Other items values in a writer's `value` are ignored.

Type Consistency Enforcement QoS

The type consistency enforcement QoS policy lets the application fine-tune details of how *topic type*s may differ between *DataWriter*s and *DataReader*s. This XTypes concept is explained in detail in *Type Consistency Enforcement*.

Important: OpenDDS only supports this with *RTPS Discovery*.

This policy is *immutable* and affects *association*.

IDL:

```
enum TypeConsistencyKind {
  DISALLOW_TYPE_COERCION,
  ALLOW_TYPE_COERCION
};

struct TypeConsistencyEnforcementQosPolicy {
  TypeConsistencyEnforcementQosPolicyKind_t kind;
  boolean ignore_sequence_bounds;
  boolean ignore_string_bounds;
  boolean ignore_member_names;
  boolean prevent_type_widening;
  boolean force_type_validation;
};
```

Applicable entities	Members	*Default values*
DataReade	kind	ALLOW_TYPE_COERCION
	ignore_sequence_bounds	true
	ignore_string_bounds	true
	ignore_member_names	false
	prevent_type_widening	false
	force_type_validation	false

Specification: DDS XTypes v1.3 7.6.3.4 Type Consistency Enforcement QoS Policy

Attention: OpenDDS only supports `ignore_member_names`. All other members should be left at their default values.

`ignore_member_names` defaults to `false` so member names (along with member IDs, see *Member ID assignment*) are significant for type compatibility. Changing this to `true` means that only member IDs are used for type compatibility.

2.8.4 Policy Example

The following sample code illustrates some policies being set and applied for a publisher.

```
DDS::DataWriterQos dw_qos;
pub->get_default_datawriter_qos (dw_qos);

dw_qos.history.kind = DDS::KEEP_ALL_HISTORY_QOS;

dw_qos.reliability.kind = DDS::RELIABLE_RELIABILITY_QOS;
dw_qos.reliability.max_blocking_time.sec = 10;
dw_qos.reliability.max_blocking_time.nanosec = 0;

dw_qos.resource_limits.max_samples_per_instance = 100;

DDS::DataWriter_var dw =
  pub->create_datawriter(topic,
                         dw_qos,
                         0,   // No listener
                         OpenDDS::DCPS::DEFAULT_STATUS_MASK);
```

This code creates a publisher with the following qualities:

- *History QoS* set to "keep all"
- *Reliability QoS* set to "reliable" with a maximum blocking time of 10 seconds
- The maximum *sample*s per *instance Resource Limits QoS* set to 100

This means that when 100 samples are waiting to be delivered, the writer can block up to 10 seconds before returning an error code. These same QoS settings on the data reader side would mean that up to 100 unread samples are queued by the framework before any are rejected. Rejected samples are dropped and the *SampleRejectedStatus* is updated.

2.9 Conditions and Listeners

2.9.1 Introduction

The DDS specification defines two separate mechanisms for notifying applications of DCPS communication status changes. Most of the status types define a structure that contains information related to the change of status and can be detected by the application using conditions or listeners. The different status types are described in *Communication Status Types*.

Each *entity* type defines its own corresponding listener interface. Applications can implement this interface and then attach their listener implementation to the entity. Each listener interface contains an operation for each status that can be reported for that entity. The listener is asynchronously called back with the appropriate operation whenever a qualifying status change occurs. Details of the different listener types are discussed in *Listeners*.

Conditions are used in conjunction with Wait Sets to let applications synchronously wait on events. The basic usage pattern for conditions involves creating the condition objects, attaching them to a wait set, and then waiting on the wait set until one of the conditions is triggered. The result of wait tells the application which conditions were triggered, allowing the application to take the appropriate actions to get the corresponding status information. Conditions are described in greater detail in *Conditions*.

2.9.2 Communication Status Types

Each status type is associated with a particular *entity* type. This section is organized by the entity types, with the corresponding statuses described in subsections under the associated entity type.

Most of the statuses below are plain communication statuses. The exceptions are `DATA_ON_READERS` and `DATA_AVAILABLE` which are read statuses. Plain communication statuses define an IDL data structure. Their corresponding section below describes this structure and its fields. The read statuses are simple notifications to the application which then reads or takes the samples as desired.

Incremental values in the status data structure report a change since the last time the status was accessed. A status is considered accessed when a listener is called for that status or the status is read from its entity.

Fields in the status data structure with a type of `InstanceHandle_t` identify an entity by the instance handle used for that entity in the *built-in topics*.

Topic Status Types

Inconsistent Topic Status

The `INCONSISTENT_TOPIC` status indicates that the *topic* being registered has different characteristics than an existing topic with the same name. Typically, the existing topic may have a different type associated with it. The IDL associated with the Inconsistent Topic Status is listed below:

```
struct InconsistentTopicStatus {
  long total_count;
  long total_count_change;
};
```

The `total_count` value is the cumulative count of topics that have been reported as inconsistent. The `total_count_change` value is the incremental count of inconsistent topics since the last time this status was accessed.

Subscriber Status Types

Data On Readers Status

The `DATA_ON_READERS` status indicates that new data is available on some of the data readers associated with the subscriber. This status is considered a read status and does not define an IDL structure. Applications receiving this status can call `get_datareaders()` on the subscriber to get the set of data readers with data available.

Data Reader Status Types

Sample Rejected Status

The `SAMPLE_REJECTED` status indicates that a sample received by the data reader has been rejected. The IDL associated with the Sample Rejected Status is listed below:

```
enum SampleRejectedStatusKind {
  NOT_REJECTED,
  REJECTED_BY_INSTANCES_LIMIT,
  REJECTED_BY_SAMPLES_LIMIT,
  REJECTED_BY_SAMPLES_PER_INSTANCE_LIMIT
```

(continues on next page)

(continued from previous page)

```
};

struct SampleRejectedStatus {
  long total_count;
  long total_count_change;
  SampleRejectedStatusKind last_reason;
  InstanceHandle_t last_instance_handle;
};
```

The `total_count` value is the cumulative count of samples that have been reported as rejected. The `total_count_change` value is the incremental count of rejected samples since the last time this status was accessed. The `last_reason` value is the reason the most recently rejected sample was rejected. The `last_instance_handle` value indicates the instance of the last rejected sample.

Liveliness Changed Status

The `LIVELINESS_CHANGED` status indicates that there have been *liveliness changes* for one or more data writers that are publishing instances for this data reader. The IDL associated with the Liveliness Changed Status is listed below:

```
struct LivelinessChangedStatus {
  long alive_count;
  long not_alive_count;
  long alive_count_change;
  long not_alive_count_change;
  InstanceHandle_t last_publication_handle;
};
```

The `alive_count` value is the total number of data writers currently active on the *topic* this data reader is reading. The `not_alive_count` value is the total number of data writers writing to the data reader's topic that are no longer asserting their liveliness. The `alive_count_change` value is the change in the alive count since the last time the status was accessed. The `not_alive_count_change` value is the change in the not alive count since the last time the status was accessed. The `last_publication_handle` is the handle of the last data writer whose liveliness has changed.

Requested Deadline Missed Status

The `REQUESTED_DEADLINE_MISSED` status indicates that the deadline requested via the *Deadline QoS* policy was not respected for a specific instance. The IDL associated with the Requested Deadline Missed Status is listed below:

```
struct RequestedDeadlineMissedStatus {
  long total_count;
  long total_count_change;
  InstanceHandle_t last_instance_handle;
};
```

The `total_count` value is the cumulative count of missed requested deadlines that have been reported. The `total_count_change` value is the incremental count of missed requested deadlines since the last time this status was accessed. The `last_instance_handle` value indicates the instance of the last missed deadline.

Requested Incompatible QoS Status

The REQUESTED_INCOMPATIBLE_QOS status indicates that one or more *qos* policy values that were requested by a local *DataReader* were incompatible with what was offered by a *DataWriter*. See *Changing QoS Policies* for details. The IDL associated with the Requested Incompatible QoS Status is listed below:

```
struct QosPolicyCount {
  QosPolicyId_t policy_id;
  long count;
};

typedef sequence<QosPolicyCount> QosPolicyCountSeq;

struct RequestedIncompatibleQosStatus {
  long total_count;
  long total_count_change;
  QosPolicyId_t last_policy_id;
  QosPolicyCountSeq policies;
};
```

The total_count value is the cumulative count of times data writers with incompatible QoS have been reported. The total_count_change value is the incremental count of incompatible data writers since the last time this status was accessed. The last_policy_id value identifies one of the QoS policies that was incompatible in the last incompatibility detected. The policies value is a sequence of values that indicates the total number of incompatibilities that have been detected for each QoS policy.

Data Available Status

The DATA_AVAILABLE status indicates that samples are available on the data writer. This status is considered a read status and does not define an IDL structure. Applications receiving this status can use the various take and read operations on the data reader to retrieve the data.

Sample Lost Status

The SAMPLE_LOST status indicates that a sample has been lost and never received by the data reader. The IDL associated with the Sample Lost Status is listed below:

```
struct SampleLostStatus {
  long total_count;
  long total_count_change;
};
```

The total_count value is the cumulative count of samples reported as lost. The total_count_change value is the incremental count of lost samples since the last time this status was accessed.

Subscription Matched Status

The SUBSCRIPTION_MATCHED status indicates that either a compatible data writer has been matched or a previously matched data writer has ceased to be matched. The IDL associated with the Subscription Matched Status is listed below:

```
struct SubscriptionMatchedStatus {
  long total_count;
  long total_count_change;
  long current_count;
  long current_count_change;
  InstanceHandle_t last_publication_handle;
};
```

The total_count value is the cumulative count of data writers that have compatibly matched this data reader. The total_count_change value is the incremental change in the total count since the last time this status was accessed. The current_count value is the current number of data writers matched to this data reader. The current_count_change value is the change in the current count since the last time this status was accessed. The last_publication_handle value is a handle for the last data writer matched.

Data Writer Status Types

Liveliness Lost Status

The LIVELINESS_LOST status indicates that the liveliness that the data writer committed through its Liveliness QoS has not been respected. This means that any connected data readers will consider this data writer no longer active.The IDL associated with the Liveliness Lost Status is listed below:

```
struct LivelinessLostStatus {
  long total_count;
  long total_count_change;
};
```

The total_count value is the cumulative count of times that an alive data writer has become not alive. The total_count_change value is the incremental change in the total count since the last time this status was accessed.

Offered Deadline Missed Status

The OFFERED_DEADLINE_MISSED status indicates that the *deadline* offered by the data writer has been missed for one or more instances. The IDL associated with the Offered Deadline Missed Status is listed below:

```
struct OfferedDeadlineMissedStatus {
  long total_count;
  long total_count_change;
  InstanceHandle_t last_instance_handle;
};
```

The total_count value is the cumulative count of times that deadlines have been missed for an instance. The total_count_change value is the incremental change in the total count since the last time this status was accessed. The last_instance_handle value indicates the last instance that has missed a deadline.

Offered Incompatible QoS Status

The OFFERED_INCOMPATIBLE_QOS status indicates that one or more *qos* policy values offered by a local *DataWriter* were incompatible with what was requested by a *DataReader*. See *Changing QoS Policies* for details. The IDL associated with the Offered Incompatible QoS Status is listed below:

```
struct QosPolicyCount {
  QosPolicyId_t policy_id;
  long count;
};
typedef sequence<QosPolicyCount> QosPolicyCountSeq;

struct OfferedIncompatibleQosStatus {
  long total_count;
  long total_count_change;
  QosPolicyId_t last_policy_id;
  QosPolicyCountSeq policies;
};
```

The total_count value is the cumulative count of times that data readers with incompatible QoS have been found. The total_count_change value is the incremental change in the total count since the last time this status was accessed. The last_policy_id value identifies one of the QoS policies that was incompatible in the last incompatibility detected. The policies value is a sequence of values that indicates the total number of incompatibilities that have been detected for each QoS policy.

Publication Matched Status

The PUBLICATION_MATCHED status indicates that either a compatible data reader has been matched or a previously matched data reader has ceased to be matched. The IDL associated with the Publication Matched Status is listed below:

```
struct PublicationMatchedStatus {
  long total_count;
  long total_count_change;
  long current_count;
  long current_count_change;
  InstanceHandle_t last_subscription_handle;
};
```

The total_count value is the cumulative count of data readers that have compatibly matched this data writer. The total_count_change value is the incremental change in the total count since the last time this status was accessed. The current_count value is the current number of data readers matched to this data writer. The current_count_change value is the change in the current count since the last time this status was accessed. The last_subscription_handle value is a handle for the last data reader matched.

Budget Exceeded Status

This is an OpenDDS-specific listener extension allows for reporting delays in excess of the *Latency Budget QoS*. The `OpenDDS::DCPS::DataReaderListener` interface has an additional operation for notification that samples were received with a measured transport delay greater than the latency budget policy duration. The IDL for this method is:

```
struct BudgetExceededStatus {
  long total_count;
  long total_count_change;
  DDS::InstanceHandle_t last_instance_handle;
};

void on_budget_exceeded(
       in DDS::DataReader reader,
       in BudgetExceededStatus status);
```

To use the extended listener callback you will need to derive the listener implementation from the extended interface, as shown in the following code fragment:

```
class DataReaderListenerImpl
  : public virtual OpenDDS::DCPS::LocalObject<OpenDDS::DCPS::DataReaderListener>
{
  void on_budget_exceeded(
    DDS::DataReader* reader,
    const OpenDDS::DCPS::BudgetExceededStatus& status)
  {
  }
```

Then you must provide a non-null implementation for the `on_budget_exceeded()` operation. Note that you will need to provide empty implementations for the following extended operations as well:

```
void on_subscription_disconnected(
  DDS::DataReader* reader,
  const OpenDDS::DCPS::SubscriptionDisconnectedStatus& status)
{
}

void on_subscription_reconnected(
  DDS::DataReader* reader,
  const OpenDDS::DCPS::SubscriptionReconnectedStatus& status)
{
}

void on_subscription_lost(
  DDS::DataReader* reader,
  const OpenDDS::DCPS::SubscriptionLostStatus& status)
{
}
```

OpenDDS also makes the summary latency statistics available via an extended interface of the data reader. This extended interface is located in the `OpenDDS::DCPS` module and the IDL is defined as:

```
struct LatencyStatistics {
  GUID_t        publication;
```

(continues on next page)

(continued from previous page)

```
  unsigned long n;
  double        maximum;
  double        minimum;
  double        mean;
  double        variance;
};

typedef sequence<LatencyStatistics> LatencyStatisticsSeq;

local interface DataReaderEx : DDS::DataReader {
  /// Obtain a sequence of statistics summaries.
  void get_latency_stats(inout LatencyStatisticsSeq stats);

  /// Clear any intermediate statistical values.
  void reset_latency_stats();

  /// Statistics gathering enable state.
  attribute boolean statistics_enabled;
};
```

To gather this statistical summary data you will need to use the extended interface. You can do so simply by dynamically casting the OpenDDS data reader pointer and calling the operations directly. In the following example, we assume that reader is initialized correctly by calling `DDS::Subscriber::create_datareader()`:

```
DDS::DataReader_var reader;
// ...

// To start collecting new data.
dynamic_cast<OpenDDS::DCPS::DataReaderImpl*>(reader.in())->
  reset_latency_stats();
dynamic_cast<OpenDDS::DCPS::DataReaderImpl*>(reader.in())->
  statistics_enabled(true);

// ...

// To collect data.
OpenDDS::DCPS::LatencyStatisticsSeq stats;
dynamic_cast<OpenDDS::DCPS::DataReaderImpl*>(reader.in())->
  get_latency_stats(stats);
for (unsigned long i = 0; i < stats.length(); ++i) {
  std::cout << "stats[" << i << "]:" << std::endl;
  std::cout << "         n = " << stats[i].n << std::endl;
  std::cout << "       max = " << stats[i].maximum << std::endl;
  std::cout << "       min = " << stats[i].minimum << std::endl;
  std::cout << "      mean = " << stats[i].mean << std::endl;
  std::cout << "  variance = " << stats[i].variance << std::endl;
}
```

2.9.3 Listeners

Each entity defines its own listener interface based on the statuses it can report. Any entity's listener interface also inherits from the listeners of its owned entities, allowing it to handle statuses for owned entities as well. For example, a subscriber listener directly defines an operation to handle Data On Readers statuses and inherits from the data reader listener as well.

Each status operation takes the general form of `on_<status_name>(<entity>, <status_struct>)`, where `<status_name>` is the name of the status being reported, `<entity>` is a reference to the entity the status is reported for, and `<status_struct>` is the structure with details of the status. Read statuses omit the second parameter. For example, here is the operation for the Sample Lost status:

```
void on_sample_lost(in DataReader the_reader, in SampleLostStatus status);
```

Listeners can either be passed to the factory function used to create their entity or explicitly set by calling `set_listener()` on the entity after it is created. Both of these functions also take a status mask as a parameter. The mask indicates which statuses are enabled in that listener. Mask bit values for each status are defined in DdsDcpsInfrastructure.idl:

```
module DDS {
  typedef unsigned long StatusKind;
  typedef unsigned long StatusMask; // bit-mask StatusKind

  const StatusKind INCONSISTENT_TOPIC_STATUS        = 0x0001 << 0;
  const StatusKind OFFERED_DEADLINE_MISSED_STATUS   = 0x0001 << 1;
  const StatusKind REQUESTED_DEADLINE_MISSED_STATUS = 0x0001 << 2;
  const StatusKind OFFERED_INCOMPATIBLE_QOS_STATUS  = 0x0001 << 5;
  const StatusKind REQUESTED_INCOMPATIBLE_QOS_STATUS= 0x0001 << 6;
  const StatusKind SAMPLE_LOST_STATUS               = 0x0001 << 7;
  const StatusKind SAMPLE_REJECTED_STATUS           = 0x0001 << 8;
  const StatusKind DATA_ON_READERS_STATUS           = 0x0001 << 9;
  const StatusKind DATA_AVAILABLE_STATUS            = 0x0001 << 10;
  const StatusKind LIVELINESS_LOST_STATUS           = 0x0001 << 11;
  const StatusKind LIVELINESS_CHANGED_STATUS        = 0x0001 << 12;
  const StatusKind PUBLICATION_MATCHED_STATUS       = 0x0001 << 13;
  const StatusKind SUBSCRIPTION_MATCHED_STATUS      = 0x0001 << 14;
};
```

Simply do a bit-wise "or" of the desired status bits to construct a mask for your listener. Here is an example of attaching a listener to a data reader (for just Data Available statuses):

```
DDS::DataReaderListener_var listener (new DataReaderListenerImpl);
// Create the Datareader
DDS::DataReader_var dr = sub->create_datareader(
  topic,
  DATAREADER_QOS_DEFAULT,
  listener,
  DDS::DATA_AVAILABLE_STATUS);
```

Here is an example showing how to change the listener using `set_listener()`:

```
dr->set_listener(listener,
                 DDS::DATA_AVAILABLE_STATUS | DDS::LIVELINESS_CHANGED_STATUS);
```

When a plain communication status changes, OpenDDS invokes the most specific relevant listener operation. This

means, for example, that a data reader's listener would take precedence over the subscriber's listener for statuses related to the data reader.

A common "gotcha" when using `set_listener` is that the listener is not invoked immediately. Instead, the listener will be invoked for the next status change. Consequently, usages of `set_listener` should 1) invoke the listener manually after calling `set_listener` and 2) ensure that the listener methods are thread safe.

The following sections define the different listener interfaces. For more details on the individual statuses, see *Communication Status Types*.

Topic Listener

```
interface TopicListener : Listener {
  void on_inconsistent_topic(in Topic the_topic,
                             in InconsistentTopicStatus status);
};
```

Data Writer Listener

```
interface DataWriterListener : Listener {
  void on_offered_deadline_missed(in DataWriter writer,
                                  in OfferedDeadlineMissedStatus status);
  void on_offered_incompatible_qos(in DataWriter writer,
                                   in OfferedIncompatibleQosStatus status);
  void on_liveliness_lost(in DataWriter writer,
                          in LivelinessLostStatus status);
  void on_publication_matched(in DataWriter writer,
                              in PublicationMatchedStatus status);
};
```

Publisher Listener

```
interface PublisherListener : DataWriterListener {
};
```

Data Reader Listener

```
interface DataReaderListener : Listener {
  void on_requested_deadline_missed(in DataReader the_reader,
                                    in RequestedDeadlineMissedStatus status);
  void on_requested_incompatible_qos(in DataReader the_reader,
                                     in RequestedIncompatibleQosStatus status);
  void on_sample_rejected(in DataReader the_reader,
                          in SampleRejectedStatus status);
  void on_liveliness_changed(in DataReader the_reader,
                             in LivelinessChangedStatus status);
  void on_data_available(in DataReader the_reader);
  void on_subscription_matched(in DataReader the_reader,
                               in SubscriptionMatchedStatus status);
```

(continues on next page)

(continued from previous page)

```
  void on_sample_lost(in DataReader the_reader,
                      in SampleLostStatus status);
};
```

Subscriber Listener

```
interface SubscriberListener : DataReaderListener {
  void on_data_on_readers(in Subscriber the_subscriber);
};
```

Domain Participant Listener

```
interface DomainParticipantListener : TopicListener,
                                      PublisherListener,
                                      SubscriberListener {
};
```

2.9.4 Conditions

The DDS specification defines four types of condition:

- Status Condition
- Read Condition
- Query Condition
- Guard Condition

Status Condition

Each entity has a status condition object associated with it and a `get_statuscondition()` operation that lets applications access the status condition. Each condition has a set of enabled statuses that can trigger that condition. Attaching one or more conditions to a wait set allows application developers to wait on the condition's status set. Once an enabled status is triggered, the wait call returns from the wait set and the developer can query the relevant status condition on the entity. Querying the status condition resets the status.

Status Condition Example

This example enables the Offered Incompatible QoS status on a data writer, waits for it, and then queries it when it triggers. The first step is to get the status condition from the data writer, enable the desired status, and attach it to a wait set:

```
DDS::StatusCondition_var cond = data_writer->get_statuscondition();
cond->set_enabled_statuses(DDS::OFFERED_INCOMPATIBLE_QOS_STATUS);

DDS::WaitSet_var ws = new DDS::WaitSet;
ws->attach_condition(cond);
```

Now we can wait ten seconds for the condition:

```
DDS::ConditionSeq active;
DDS::Duration_t ten_seconds = {10, 0};
int result = ws->wait(active, ten_seconds);
```

The result of this operation is either a timeout or a set of triggered conditions in the active sequence:

```
if (result == DDS::RETCODE_TIMEOUT) {
  cout << "Wait timed out" << std::endl;
} else if (result == DDS::RETCODE_OK) {
  DDS::OfferedIncompatibleQosStatus incompatibleStatus;
  data_writer->get_offered_incompatible_qos(incompatibleStatus);
  // Access status fields as desired...
}
```

Developers have the option of attaching multiple conditions to a single wait set as well as enabling multiple statuses per condition.

Additional Condition Types

The DDS specification also defines three other types of conditions: read conditions, query conditions, and guard conditions. These conditions do not directly involve the processing of statuses but allow the integration of other activities into the condition and wait set mechanisms. These are other conditions are briefly described here. For more information see the DDS specification or the OpenDDS tests in `tests/`.

Read Conditions

Read conditions are created using the data reader and the same masks that are passed to the read and take operations. When waiting on this condition, it is triggered whenever samples match the specified masks. Those samples can then be retrieved using the `read_w_condition()` and `take_w_condition()` operations which take the read condition as a parameter.

Query Conditions

Query conditions are a specialized form of read conditions that are created with a limited form of an SQL-like query. This allows applications to filter the data samples that trigger the condition and then are read use the normal read condition mechanisms. See *Query Condition* for more information about query conditions.

Guard Conditions

The guard condition is a simple interface that allows the application to create its own condition object and trigger it when application events (external to OpenDDS) occur.

2.10 Content-Subscription Profile

2.10.1 Introduction

The Content-Subscription Profile of DDS consists of three features which enable a data reader's behavior to be influenced by the content of the data samples it receives. These three features are:

- Content-Filtered Topic
- Query Condition
- Multi Topic

The content-filtered topic and multi topic interfaces inherit from the `TopicDescription` interface (and not from the `Topic` interface, as the names may suggest).

Content-filtered topic and query condition allow filtering (selection) of data samples using a SQL-like parameterized query string. Additionally, query condition allows sorting the result set returned from a data reader's `read()` or `take()` operation. Multi topic also has this selection capability as well as the ability to aggregate data from different data writers into a single data type and data reader.

If you are not planning on using the Content-Subscription Profile features in your application, you can configure OpenDDS to remove support for it at build time (*Content-Subscription Profile*).

2.10.2 Content-Filtered Topic

The domain participant interface contains operations for creating and deleting a content-filtered topic. Creating a content-filtered topic requires the following parameters:

- Name

  Assigns a name to this content-filtered topic which could later be used with the `lookup_topicdescription()` operation.

- Related topic

  Specifies the topic that this content-filtered topic is based on. This is the same topic that matched data writers will use to publish data samples.

- Filter expression

  An *SQL-like expression* which defines the subset of samples published on the related topic that should be received by the content-filtered topic's data readers.

- Expression parameters

  The filter expression can contain parameter placeholders. This argument provides initial values for those parameters. The expression parameters can be changed after the content-filtered topic is created (the filter expression cannot be changed).

Once the content-filtered topic has been created, it is used by the subscriber's `create_datareader()` operation to obtain a content-filtering data reader. This data reader is functionally equivalent to a normal data reader except that incoming data samples which do not meet the filter expression's criteria are dropped.

Filter expressions are first evaluated at the publisher so that data samples which would be ignored by the subscriber can be dropped before even getting to the transport. This feature can be turned off by setting *`[common] DCPSPublisherContentFilter`* to `0`. The behavior of non-default *Deadline QoS* or *Liveliness QoS* policies may be affected by this policy. Special consideration must be given to how the "missing" samples impact the QoS behavior, see the document in `docs/design/CONTENT_SUBSCRIPTION`.

Note: *RTPS/UDP Transport* does not always do Writer-side filtering. It does not currently implement transport level filtering, but may be able to filter above the transport layer.

Filter Expressions

The formal grammar for filter expressions is defined in DDS v1.4 Annex B - Syntax for Queries and Filters. This section provides an informal summary of that grammar. *Query expressions* and *topic expressions* are also defined in the DDS specification.

Filter expressions are combinations of one or more predicates. Each predicate is a logical expression taking one of two forms:

- `<arg1> <RelOp> <arg2>`
- – `arg1` and `arg2` are arguments which may be either a literal value (integer, character, floating-point, string, or enumeration), a parameter placeholder of the form `%n` (where n is a zero-based index into the parameter sequence), or a field reference.
  - – At least one of the arguments must be a field reference, which is the name of an IDL struct field, optionally followed by any number of `.` and another field name to represent nested structures.
  - – `RelOp` is a relational operator from the list: =, >, >=, <, <=, <>, and `like`. `like` is a wildcard match using `%` to match any number of characters and _ to match a single character.
  - – Examples of this form of predicate include: `a = 'z'`, `b <> 'str'`, `c < d`, `e = 'enumerator'`, `f >= 3.14e3`, `27 > g`, `h <> i`, `j.k.l like %0`
- `<arg1> [NOT] BETWEEN <arg2> AND <arg3>`
- – In this form, argument 1 must be a field reference and arguments 2 and 3 must each be a literal value or parameter placeholder.

Any number of predicates can be combined through the use of parenthesis and the Boolean operators `AND`, `OR`, and `NOT` to form a filter expression.

Expression Parameters

Expression parameters allow more flexibility since the filter can effectively change at runtime. To use expression parameters, add parameter placeholders in the filter expression wherever a literal would be used. For example, an expression to select all samples that have a string field with a fixed value (`m = 'A'`) could instead use a placeholder which would be written as `m = %0`. Placeholders consist of a percent sign followed by a decimal integer between 0 and 99 inclusive.

Using a filter that contains placeholders requires values for each placeholder which is used in the expression to be provided by the application in the corresponding index of the expression parameters sequence (placeholder `%0` is `sequence[0]`). The application can set the parameter sequence when the content-filtered topic is created (`create_contentfilteredtopic`) or after it already exists by using `set_expression_parameters`. A valid value for each used placeholder must be in the parameters sequence whenever the filter is evaluated, for example when a data reader using the content-filtered topic is enabled.

The type used for the parameters sequence in the DDS-DCPS API is a sequence of strings. The application must format this string based on how the parameter is used:

- For a number (integer or floating point), provide the decimal representation in the same way it would appear as a C++ or Java literal.
- For a character or string, provide the character(s) directly without quoting

- For an enumerated type, provide one of the enumerators as if it was a string

Filtering and Dispose/Unregister Samples

DataReaders without filtering can see samples with the `valid_data` field of `SampleInfo` set to `false`. This happens when the matching DataWriter disposes or unregisters the instance. Content filtering (whether achieved through Content-Filtered Topics, Query Conditions, or Multi Topics) will filter such samples when the filter expression explicitly uses key fields. Filter expressions that don't meet that criteria will result in no such samples passing the filter.

Content-Filtered Topic Example

The code snippet below creates a content-filtered topic for the Message type. First, here is the IDL for Message:

```
module Messenger {
  @topic
  struct Message {
    long id;
  };
};
```

Next we have the code that creates the data reader:

```
CORBA::String_var type_name = message_type_support->get_type_name();
DDS::Topic_var topic = dp->create_topic("MyTopic",
                                        type_name,
                                        TOPIC_QOS_DEFAULT, 0, 0);
DDS::ContentFilteredTopic_var cft =
  participant->create_contentfilteredtopic("MyTopic-Filtered",
                                           topic,
                                           "id > 1",
                                           StringSeq());
DDS::DataReader_var dr =
  subscriber->create_datareader(cft,
                                DATAREADER_QOS_DEFAULT, 0, 0);
```

The data reader `dr` will only receive samples that have values of `id` greater than 1.

2.10.3 Query Condition

The query condition interface inherits from the read condition interface, therefore query conditions have all of the capabilities of read conditions along with the additional capabilities described in this section. One of those inherited capabilities is that the query condition can be used like any other condition with a wait set (*Conditions*).

The `DataReader` interface contains operations for creating (`create_querycondition`) and deleting (`delete_readcondition`) a query condition. Creating a query condition requires the following parameters:

- Sample, view, and instance state masks

  These are the same state masks that would be passed to `create_readcondition()`, `read()`, or `take()`.

- Query expression

  An SQL-like expression (see *Query Expressions*) describing a subset of samples which cause the condition to be triggered. This same expression is used to filter the data set returned from a `read_w_condition()` or `take_w_condition()` operation. It may also impose a sort order (`ORDER BY`) on that data set.

- Query parameters

  The query expression can contain parameter placeholders. This argument provides initial values for those parameters. The query parameters can be changed after the query condition is created (the query expression cannot be changed).

A particular query condition can be used with a wait set (`attach_condition`), with a data reader (`read_w_condition`, `take_w_condition`, `read_next_instance_w_condition`, `take_next_instance_w_condition`), or both. When used with a wait set, the `ORDER BY` clause has no effect on triggering the wait set. When used with a data reader's `read*()` or `take*()` operation, the resulting data set will only contain samples which match the query expression and they will be ordered by the `ORDER BY` fields, if an `ORDER BY` clause is present.

Query Expressions

Query expressions are a super set of filter expressions (*Filter Expressions*). Following the filter expression, the query expression can optionally have an `ORDER BY` keyword followed by a comma-separated list of field references. If the `ORDER BY` clause is present, the filter expression may be empty. The following strings are examples of query expressions:

- `m > 100 ORDER BY n`
- `ORDER BY p.q, r, s.t.u`
- `NOT v LIKE 'z%'`

Query expressions can use parameter placeholders in the same way that filter expressions (for content-filtered topics) use them. See *Expression Parameters* for details.

Query Condition Example

The following code snippet creates and uses a query condition for a type that uses struct `Message` with field `key` (an integral type).

```
DDS::QueryCondition_var dr_qc =
  dr->create_querycondition(DDS::ANY_SAMPLE_STATE,
                            DDS::ANY_VIEW_STATE,
                            DDS::ALIVE_INSTANCE_STATE,
                            "key > 1",
                            DDS::StringSeq());
DDS::WaitSet_var ws = new DDS::WaitSet;
ws->attach_condition(dr_qc);
DDS::ConditionSeq active;
DDS::Duration_t three_sec = {3, 0};
DDS::ReturnCode_t ret = ws->wait(active, three_sec);
  // error handling not shown
ws->detach_condition(dr_qc);
MessageDataReader_var mdr = MessageDataReader::_narrow(dr);
MessageSeq data;
DDS::SampleInfoSeq infoseq;
ret = mdr->take_w_condition(data, infoseq, DDS::LENGTH_UNLIMITED, dr_qc);
  // error handling not shown
dr->delete_readcondition(dr_qc);
```

Any sample received with `key <= 1` would neither trigger the condition (to satisfy the wait) nor be returned in the `data` sequence from `take_w_condition()`.

2.10.4 Multi Topic

Multi topic is a more complex feature than the other two Content-Subscription features, therefore describing it requires some new terminology.

The `MultiTopic` interface inherits from the `TopicDescription` interface, just like `ContentFilteredTopic` does. A data reader created for the multi topic is known as a "multi topic data reader." A multi topic data reader receives samples belonging to any number of regular topics. These topics are known as its "constituent topics." The multi topic has a DCPS data type known as the "resulting type." The multi topic data reader implements the type-specific data reader interface for the resulting type. For example, if the resulting type is Message, then the multi topic data reader can be narrowed to the `MessageDataReader` interface.

The multi topic's topic expression (*Topic Expressions*) describes how the distinct fields of the incoming data (on the constituent topics) are mapped to the fields of the resulting type.

The domain participant interface contains operations for creating and deleting a multi topic. Creating a multi topic requires the following parameters:

- Name

  Assigns a name to this multi topic which could later be used with the `lookup_topicdescription()` operation.

- Type name

  Specifies the resulting type of the multi topic. This type must have its type support registered before creating the multi topic.

- Topic expression (also known as subscription expression)

  An SQL-like expression (*Topic Expressions*) which defines the mapping of constituent topic fields to resulting type fields. It can also specify a filter (`WHERE` clause).

- Expression parameters

  The topic expression can contain parameter placeholders. This argument provides initial values for those parameters. The expression parameters can be changed after the multi topic is created (the topic expression cannot be changed).

Once the multi topic has been created, it is used by the subscriber's `create_datareader()` operation to obtain a multi topic data reader. This data reader is used by the application to receive the constructed samples of the resulting type. The manner in which these samples are constructed is described in *How Resulting Samples are Constructed*.

Topic Expressions

Topic expressions use a syntax that is very similar to a complete SQL query:

```
SELECT <aggregation> FROM <selection> [WHERE <condition>]
```

- The aggregation can be either a `*` or a comma separated list of field specifiers. Each field specifier has the following syntax:
- – `<constituent_field> [[AS] <resulting_field>]]`
  – `constituent_field` is a field reference (*Filter Expressions*) to a field in one of the constituent topics (which topic is not specified).
  – The optional resulting_field is a field reference to a field in the resulting type. If present, the `resulting_field` is the destination for the constituent_field in the constructed sample. If absent, the `constituent_field` data is assigned to a field with the same name in the resulting type. The optional `AS` has no effect.

  - If a * is used as the aggregation, each field in the resulting type is assigned the value from a same-named field in one of the constituent topic types.

- The selection lists one or more constituent topic names. Topic names are separated by a `join` keyword (all 3 join keywords are equivalent):
-
  - `<topic> [{NATURAL INNER | NATURAL | INNER NATURAL} JOIN <topic>]...`
  - Topic names must contain only letters, digits, and dashes (but may not start with a digit).
  - The natural join operation is commutative and associative, thus the order of topics has no impact.
  - The semantics of the natural join are that any fields with the same name are treated as "join keys" for the purpose of combining data from the topics in which those keys appear. The join operation is described in more detail in subsequent sections.
- The condition has the exact same syntax and semantics as the filter expression (*Filter Expressions*). Field references in the condition must match field names in the resulting types, not field names in the constituent topic types. The condition in the topic expression can use parameter placeholders in the same way that filter expressions (for content-filtered topics) use them. See *Expression Parameters* for details.

Usage Notes

Join Keys and DCPS Data Keys

The concept of DCPS data keys (`@key`) has already been discussed in *Defining Data Types with IDL*. Join keys for the multi topic are a distinct but related concept.

A join key is any field name that occurs in the struct for more than one constituent topic. The existence of the join key enforces a constraint on how data samples of those topics are combined into a constructed sample (*How Resulting Samples are Constructed*). Specifically, the value of that key must be equal for those data samples from the constituent topics to be combined into a sample of the resulting type. If multiple join keys are common to the same two or more topics, the values of all keys must be equal in order for the data to be combined.

The DDS specification requires that join key fields have the same type. Additionally, OpenDDS imposes two requirements on how the IDL must define DCPS data keys to work with multi topics:

1. Each join key field must also be a DCPS data key for the types of its constituent topics.
2. The resulting type must contain each of the join keys, and those fields must be DCPS data keys for the resulting type.

The example in *IDL and Topic Expression* meets both of these requirements. Note that it is not necessary to list the join keys in the aggregation (`SELECT` clause).

How Resulting Samples are Constructed

Although many concepts in multi topic are borrowed from the domain of relational databases, a real-time middleware such as DDS is not a database. Instead of processing a batch of data at a time, each sample arriving at the data reader from one of the constituent topics triggers multi-topic-specific processing that results in the construction of zero, one, or many samples of the resulting type and insertion of those constructed samples into the multi topic data reader.

Specifically, the arrival of a sample on constituent topic `A` with type `TA` results in the following steps in the multi topic data reader (this is a simplification of the actual algorithm):

1. A sample of the resulting type is constructed, and fields from `TA` which exist in the resulting type and are in the aggregation (or are join keys) are copied from the incoming sample to the constructed sample.

2. Each topic `B` which has at least one join key in common with `A` is considered for a join operation. The join reads `READ_SAMPLE_STATE` samples on topic `B` with key values matching those in the constructed sample. The result of the join may be zero, one, or many samples. Fields from `TB` are copied to the resulting sample as described in step 1.
3. Join keys of topic `B` (connecting it to other topics) are then processed as described in step 2, and this continues to all other topics that are connected by join keys.
4. Any constituent topics that were not visited in steps 2 or 3 are processed as "cross joins" (also known as cross-product joins). These are joins with no key constraints.
5. If any constructed samples result, they are inserted into the multi topic data reader's internal data structures as if they had arrived via the normal mechanisms. Application listeners and conditions are notified.

Use with Subscriber Listeners

If the application has registered a subscriber listener for read condition status changes (`DATA_ON_READERS_STATUS`) with the same subscriber that also contains a multi topic, then the application must invoke `notify_datareaders()` in its implementation of the subscriber listener's `on_data_on_readers()` callback method. This requirement is necessary because the multi topic internally uses data reader listeners, which are preempted when a subscriber listener is registered.

Multi Topic Example

This example is based on the example topic expression used in Annex A section A.3 of the DDS specification. It illustrates how the properties of the multi topic join operation can be used to correlate data from separate topics (and possibly distinct publishers).

IDL and Topic Expression

Often times we will use the same string as both the topic name and topic type. In this example we will use distinct strings for the type names and topic names, in order to illustrate when each is used.

Here is the IDL for the constituent topic data types:

```
@topic
struct LocationInfo {
  @key unsigned long flight_id;
  long x;
  long y;
  long z;
};

@topic
struct PlanInfo {
  @key unsigned long flight_id;
  string flight_name;
  string tailno;
};
```

Note that the names and types of the key fields match, so they are designed to be used as join keys. The resulting type (below) also has that key field.

Next we have the IDL for the resulting data type:

```
@topic
struct Resulting {
  @key unsigned long flight_id;
  string flight_name;
  long x;
  long y;
  long height;
};
```

Based on this IDL, the following topic expression can be used to combine data from a topic `Location` which uses type `LocationInfo` and a topic `FlightPlan` which uses type `PlanInfo`:

```
SELECT flight_name, x, y, z AS height FROM Location NATURAL JOIN FlightPlan WHERE height
↪< 1000 AND x <23
```

Taken together, the IDL and the topic expression describe how this multi topic will work. The multi topic data reader will construct samples which belong to instances keyed by `flight_id`. The instance of the resulting type will only come into existence once the corresponding instances are available from both the `Location` and `FlightPlan` topics. Some other domain participant or participants within the domain will publish data on those topics, and they don't even need to be aware of one another. Since they each use the same `flight_id` to refer to flights, the multi topic can correlate the incoming data from disparate sources.

Creating the Multi Topic Data Reader

Creating a data reader for the multi topic consists of a few steps. First the type support for the resulting type is registered, then the multi topic itself is created, followed by the data reader:

```
ResultingTypeSupport_var ts_res = new ResultingTypeSupportImpl;
ts_res->register_type(dp, "");
CORBA::String_var type_name = ts_res->get_type_name();
DDS::MultiTopic_var mt =
  dp->create_multitopic("MyMultiTopic",
                        type_name,
                        "SELECT flight_name, x, y, z AS height "
                          "FROM Location NATURAL JOIN FlightPlan "
                          "WHERE height < 1000 AND x<23",
                        DDS::StringSeq());
DDS::DataReader_var dr =
  sub->create_datareader(mt,
                         DATAREADER_QOS_DEFAULT,
                         NULL,
                         OpenDDS::DCPS::DEFAULT_STATUS_MASK);
```

Reading Data with the Multi Topic Data Reader

From an API perspective, the multi topic data reader is identical to any other typed data reader for the resulting type. This example uses a wait set and a read condition in order to block until data is available.

```
DDS::WaitSet_var ws = new DDS::WaitSet;
DDS::ReadCondition_var rc =
  dr->create_readcondition(DDS::ANY_SAMPLE_STATE,
                           DDS::ANY_VIEW_STATE,
                           DDS::ANY_INSTANCE_STATE);
ws->attach_condition(rc);
DDS::Duration_t infinite = {DDS::DURATION_INFINITE_SEC,
                            DDS::DURATION_INFINITE_NSEC};
DDS::ConditionSeq active;
ws->wait(active, infinite); // error handling not shown
ws->detach_condition(rc);
ResultingDataReader_var res_dr = ResultingDataReader::_narrow(dr);
ResultingSeq data;
DDS::SampleInfoSeq info;
res_dr->take_w_condition(data, info, DDS::LENGTH_UNLIMITED, rc);
```

2.11 Built-in Topics

2.11.1 Introduction

In OpenDDS, built-in topics are created and published by default to exchange information about DDS participants operating in the deployment. When OpenDDS is *InfoRepo Discovery*, the built-in topics are published by this service. For *RTPS Discovery*, the internal OpenDDS implementation instantiated in a process populates the caches of the built-In topic DataReaders.

The IDL struct `BuiltinTopicKey_t` is used by the built-in topics. This structure contains an array of 16 octets (bytes) which corresponds to an InfoRepo identifier or a DDSI-RTPS GUID.

2.11.2 Built-in Topics for DCPSInfoRepo Configuration

When starting the `DCPSInfoRepo` a command line option of `-NOBITS` may be used to suppress publication of built-in topics.

Four separate topics are defined for each domain. Each is dedicated to a particular entity (domain participant *DCPSParticipant Topic*, topic *DCPSParticipant Topic*, data writer *DCPSPublication Topic*, data reader *DCPSSubscription Topic*) and publishes instances describing the state for each entity in the domain.

Subscriptions to built-in topics are automatically created for each domain participant. A participant's support for built-in topics can be toggled via the *`[common] DCPSBit`* configuration option. To view the built-in topic data, simply obtain the built-in Subscriber and then use it to access the Data Reader for the built-in topic of interest. The Data Reader can then be used like any other Data Reader.

See *Built-in Topic Subscription Example* for an example showing how to read from a built-in topic.

If you are not planning on using built-in topics in your application, you can configure OpenDDS to remove built-in topic support at build time. Doing so can reduce the footprint of the core DDS library by up to 30%. See *Disabling the Building of Built-in Topic Support* for information on disabling built-in topic support.

2.11.3 DCPSParticipant Topic

The `DCPSParticipant` topic publishes information about the Domain Participants of the Domain. Here is the IDL that defines the structure published for this topic:

```
struct ParticipantBuiltinTopicData {
  BuiltinTopicKey_t key;
  UserDataQosPolicy user_data;
};
```

Each Domain Participant is defined by a unique key and is its own instance within this topic.

2.11.4 DCPSTopic Topic

Note: OpenDDS does not support this built-in topic when configured for *RTPS Discovery*.

The `DCPSTopic` topic publishes information about the topics in the domain. Here is the IDL that defines the structure published for this topic:

```
struct TopicBuiltinTopicData {
  BuiltinTopicKey_t key;
  string name;
  string type_name;
  DurabilityQosPolicy durability;
  QosPolicy deadline;
  LatencyBudgetQosPolicy latency_budget;
  LivelinessQosPolicy liveliness;
  ReliabilityQosPolicy reliability;
  TransportPriorityQosPolicy transport_priority;
  LifespanQosPolicy lifespan;
  DestinationOrderQosPolicy destination_order;
  HistoryQosPolicy history;
  ResourceLimitsQosPolicy resource_limits;
  OwnershipQosPolicy ownership;
  TopicDataQosPolicy topic_data;
};
```

Each topic is identified by a unique key and is its own instance within this built-in topic. The members above identify the name of the topic, the name of the topic type, and the set of QoS policies for that topic.

2.11.5 DCPSPublication Topic

The `DCPSPublication` topic publishes information about the Data Writers in the Domain. Here is the IDL that defines the structure published for this topic:

```
struct PublicationBuiltinTopicData {
  BuiltinTopicKey_t key;
  BuiltinTopicKey_t participant_key;
  string topic_name;
  string type_name;
```

(continues on next page)

(continued from previous page)

```
  DurabilityQosPolicy durability;
  DeadlineQosPolicy deadline;
  LatencyBudgetQosPolicy latency_budget;
  LivelinessQosPolicy liveliness;
  ReliabilityQosPolicy reliability;
  LifespanQosPolicy lifespan;
  UserDataQosPolicy user_data;
  OwnershipStrengthQosPolicy ownership_strength;
  PresentationQosPolicy presentation;
  PartitionQosPolicy partition;
  TopicDataQosPolicy topic_data;
  GroupDataQosPolicy group_data;
};
```

Each Data Writer is assigned a unique key when it is created and defines its own instance within this topic. The fields above identify the Domain Participant (via its key) that the Data Writer belongs to, the topic name and type, and the various QoS policies applied to the Data Writer.

2.11.6 DCPSSubscription Topic

The `DCPSSubscription` topic publishes information about the Data Readers in the Domain. Here is the IDL that defines the structure published for this topic:

```
struct SubscriptionBuiltinTopicData {
  BuiltinTopicKey_t key;
  BuiltinTopicKey_t participant_key;
  string topic_name;
  string type_name;
  DurabilityQosPolicy durability;
  DeadlineQosPolicy deadline;
  LatencyBudgetQosPolicy latency_budget;
  LivelinessQosPolicy liveliness;
  ReliabilityQosPolicy reliability;
  DestinationOrderQosPolicy destination_order;
  UserDataQosPolicy user_data;
  TimeBasedFilterQosPolicy time_based_filter;
  PresentationQosPolicy presentation;
  PartitionQosPolicy partition;
  TopicDataQosPolicy topic_data;
  GroupDataQosPolicy group_data;
};
```

Each Data Reader is assigned a unique key when it is created and defines its own instance within this topic. The fields above identify the Domain Participant (via its key) that the Data Reader belongs to, the topic name and type, and the various QoS policies applied to the Data Reader.

2.11.7 Built-in Topic Subscription Example

The following code uses a domain participant to get the built-in subscriber. It then uses the subscriber to get the Data Reader for the `DCPSParticipant` topic and subsequently reads samples for that reader.

```
Subscriber_var bit_subscriber = participant->get_builtin_subscriber();
DDS::DataReader_var dr =
  bit_subscriber->lookup_datareader(BUILT_IN_PARTICIPANT_TOPIC);
DDS::ParticipantBuiltinTopicDataDataReader_var part_dr =
  DDS::ParticipantBuiltinTopicDataDataReader::_narrow(dr);

DDS::ParticipantBuiltinTopicDataSeq part_data;
DDS::SampleInfoSeq infos;
DDS::ReturnCode_t ret = part_dr->read(part_data, infos, 20,
                                      DDS::ANY_SAMPLE_STATE,
                                      DDS::ANY_VIEW_STATE,
                                      DDS::ANY_INSTANCE_STATE);

// Check return status and read the participant data
```

The code for the other built-in topics is similar.

2.11.8 OpenDDS-specific Built-in Topics

OpenDDSParticipantLocation Topic

The built-in topic `OpenDDSParticipantLocation` is published by the DDSI-RTPS discovery implementation to give applications visibility into the details of how each remote participant is connected over the network. If the RtpsRelay (*The RtpsRelay*) and/or IETF ICE (*Interactive Connectivity Establishment (ICE) for RTPS*) are enabled, their usage is reflected in the OpenDDSParticipantLocation topic data. The topic type ParticipantLocationBuiltinTopicData is defined in `dds/OpenddsDcpsExt.idl` in the `OpenDDS::DCPS` module:

- `guid` (key) – The GUID of the remote participant. Also, a key into the DCPSParticipant topic.
- `location` – A bit-mask indicating which fields are populated.
- `change_mask` – A bit-mask indicating which fields changed.
- `local_addr` – SPDP address of the remote participant for a local connection.
- `local_timestamp` – Time that `local_addr` was set.
- `ice_addr` – SPDP address of the remote participant for an ICE connection.
- `ice_timestamp` – Time that `ice_addr` was set.
- `relay_addr` – SPDP address of the remote participant using the RtpsRelay.
- `relay_timestamp` – Time that `relay_addr` was set.
- `local6_addr`, `local6_timestamp`, `ice6_addr`, `ice6_timestamp`, `relay6_addr`, and `relay6_timestamp` – Are the IPV6 equivalents.
- `lease_duration` – The remote participant's *[rtps_discovery] LeaseDuration*

OpenDDSConnectionRecord Topic

The built-in topic `OpenDDSConnectionRecord` is published by the DDSI-RTPS discovery implementation and RTPS_UDP transport implementation to give applications visibility into the details of a participant's connection to an RtpsRelay instance. Security must be enabled in the build of OpenDDS (*Building OpenDDS with Security Enabled*) to use this topic.

The topic type ConnectionRecord is defined in `dds/OpenddsDcpsExt.idl` in the `OpenDDS::DCPS` module:

- `guid` (key) – The GUID of the remote participant. Also, a key into the DCPSParticipant topic.
- `address` (key) – The address of the remote participant.
- `protocol` (key) – The method used to determine connectivity. Currently, "RtpsRelay:STUN" is the only supported protocol.
- `latency` – A measured round-trip latency for protocols that support it.

OpenDDSInternalThread Topic

The built-in topic `OpenDDSInternalThread` is published when OpenDDS is configured with *`[common] DCPSThreadStatusInterval`*. When enabled, the DataReader for this built-in topic will report the status of threads created and managed by OpenDDS within the current process. The timestamp associated with samples can be used to determine the health (responsiveness) of the thread.

The topic type InternalThreadBuiltinTopicData is defined in `dds/OpenddsDcpsExt.idl` in the `OpenDDS::DCPS` module:

- `thread_id` (key) – A string identifier for the thread.
- `utilization` – Estimated utilization of this thread (0.0-1.0).

2.12 Run-time Configuration

OpenDDS configuration is concerned with three main areas:

1. **Common Configuration Properties** – configure the behavior of DCPS entities at a global level. This allows separately deployed processes in a computing environment to share common settings for the specified behavior (e.g. all readers and writers should use RTPS discovery). See *Common Configuration Properties* for details.
2. **Discovery Configuration Properties** – configure the behavior of the *discovery mechanism(s)*. OpenDDS supports multiple approaches for discovering and associating writers and readers as detailed in *Discovery Configuration*.
3. **Transport Configuration Properties** – configure the *transport framework* which abstracts the transport layer from the DCPS layer of OpenDDS. Each pluggable transport can be configured separately. See *Transport Configuration* for details.

2.12.1 Configuration Approach

Most of OpenDDS is configured through a key-value store. Keys are strings that are converted to a canonical form before being stored by 1) converting camel case to snake case, 2) capitalizing all alphabetic characters, 3) replacing all non-alphanumeric characters with underscores, and 4) stripping leading, trailing, and duplicate underscores. For example, the key `!SectionInstance__PROPERTY` is canonicalized into `SECTION_INSTANCE_PROPERTY` before being stored. Values are stored as strings and converted to other types as necessary. The documentation for each key contains its canonical name.

A key has the following parts:

1. **section** – The section describes the area of functionality that is being configured.
2. **instance** – (optional) The instance names a particular collection of configuration values. Configuration keys that do not have an instance imply a singleton or global.
3. **property** – The property names a variable relative to the section and instance.

Sections, instances, and properties can contain underscores meaning that underscores are not used as delimiters to separate the section, instance, and property. This ambiguity is resolved by the following rules:

- Sections are known by OpenDDS. For example, OpenDDS will look for *RTPS Discovery* instances under keys prefixed by `RTPS_DISCOVERY`.
- Instances must be introduced by a special key-value pair where the value is prefixed by `@`. For example, `RTPS_DISCOVERY_MY_DISCOVERY=@MY_DISCOVERY` introduces an instance named `MY_DISCOVERY` under the `RTPS_DISCOVERY` section.

Suppose the configuration store contains the following key-pairs: `RTPS_DISCOVERY_MY_DISCOVERY=@MY_DISCOVERY` and `RTPS_DISCOVERY_MY_DISCOVERY_RESEND_PERIOD=5`. In this case, the `MY_DISCOVERY` instance of `RTPS_DISCOVERY` will have a `RESEND_PERIOD` with a value of `5` (seconds).

This table shows a list of the available configuration section types as they relate to the area of OpenDDS that they configure.

Table 2: Configuration Sections

Focus Area	Section Title
Global Settings	*[common]*
Discovery Configuration	*[domain]*
Configuring for InfoRepo Discovery	*[repository]*
Configuring for RTPS Discovery	*[rtps_discovery]*
Configuring for Static Discovery	*[endpoint]* *[topic]* *[datawriterqos]* *[datareaderqos]* *[publisherqos]* *[subscriberqos]*
Transport Configuration	*[config]* *[transport]*
Other	*[ice]*

The configuration store can be populated in a number of ways:

- *Environment variables*
- *Command-line arguments*

- *Configuration file(s)*
- *Specific and generic APIs*

By default and for backwards compatibility, the different configuration mechanisms are processed in the following order:

1. Environment variables
2. Command-line arguments (will overwrite configuration from environment variables)
3. Configuration file (will not overwrite configuration from environment variables or command-line arguments)
4. APIs called by the user (will overwrite existing configuration)

However, multiple configuration files can be processed by setting `DCPS_SINGLE_CONFIG_FILE=0`. This can be done with an environment variable `OPENDDS_DCPS_SINGLE_CONFIG_FILE=0` or a command-line argument `-DCPSSingleConfigFile 0`. This causes the different configuration mechanisms to be processed in the following order:

1. Environment variables
2. Command-line arguments and configuration files are processed sequentially and overwrite existing configuration
3. APIs called by the user (which also overwrite existing configuration)

Users can store configuration data for their applications in the configuration store. Users taking advantage of this capability should use the section names of `APP` and `USER` which are reserved for this purpose.

Configuration with Environment Variables

OpenDDS reads environment variables that begin with `OPENDDS_` to populate the configuration store. An environment variable `OPENDDS_KEY=VALUE` causes `KEY=VALUE` to be saved in the configuration store. `KEY` is canonicalized before being stored.

To set the `ResendPeriod` on an `rtps_discovery` instance named `MyDiscovery` to 5 seconds using environment variables, one would set the following:

- `OPENDDS_RTPS_DISCOVERY_MY_DISCOVERY=@MY_DISCOVERY`
- `OPENDDS_RTPS_DISCOVERY_MY_DISCOVERY_RESEND_PERIOD=5`

Configuration with Command-line Arguments

This section describes the command-line arguments that are relevant to OpenDDS and how they are processed. Command-line arguments are passed to the service participant singleton when initializing the domain participant factory. This is accomplished by using the `TheParticipantFactoryWithArgs` macro:

```
#include <dds/DCPS/Service_Participant.h>

int main(int argc, char* argv[])
{
  DDS::DomainParticipantFactory_var dpf =
    TheParticipantFactoryWithArgs(argc, argv);
  // ...
}
```

Command-line arguments are parsed in two phases. The following arguments are parse in the first phase:

1. *[common] ORBLogFile*

2. *[common] ORBVerboseLogging*
3. `-DCPSSingleConfigFile 0|1` - Enables/disables the legacy behavior of a single configuration file that is processed after environment variables and command-line arguments and does not overwrite existing configuration (default 1). When disabled, arguments processed in the second phase are processed as they are encountered and overwrite existing configuration.

The following arguments are processed in the second phase:

1. `-DCPSConfigFile <path>` - Causes configuration to be read from the file indicated by `<path>`. It is processed immediately if `-DCPSSingleConfigFile 0` and deferred to the end of argument processing, otherwise.
2. `-OpenDDSKEY VALUE` - Causes `KEY=VALUE` to be saved in the configuration store. The key `KEY` is canonicalized before being stored. To set the *[rtps_discovery] ResendPeriod* on an *[rtps_discovery]* instance named `MyDiscovery` to 5 seconds using environment variables, one could use the following arguments:
   - `-OpenDDS_rtps_discovery_MyDiscovery @MY_DISCOVERY`
   - `-OpenDDS_rtps_discovery_MyDiscovery_ResendPeriod 5`
3. `-DCPSx VALUE` - Causes `COMMON_DCPS_x=VALUE` to be saved in the configuration store. The key `COMMON_DCPS_x` is canonicalized before being stored.
4. `-FederationX VALUE` - Causes `COMMON_FEDERATION_X=VALUE` to be saved in the configuration store. The key `COMMON_FEDERATION_X` is canonicalized before being stored.

Configuration with a File

The `-DCPSConfigFile <path>` argument described above causes OpenDDS to read configuration from a human-readable ini-style text file. For example:

```
./publisher -DCPSConfigFile pub.ini
```

```
publisher -DCPSConfigFile pub.ini
```

For each of the section types with the exception of *[common]* and `[ice]`, the syntax of a section header takes the form of `[<section_type>/<instance_name>]`. For example, a `[repository]` section type would always be used in a configuration file like so: `[repository/repo_1]` where `repository` is the section type and `repo_1` is an instance name of a repository configuration.

Using instances to configure discovery and transports is explained further in *Discovery Configuration* and *Transport Configuration* respectively.

To set a default configuration file to load, use `TheServiceParticipant->default_configuration_file(ACE_TCHAR* path)`, like in the following example:

```
#include <dds/DCPS/Service_Participant.h>

int main(int argc, char* argv[])
{
  TheServiceParticipant->default_configuration_file(ACE_TEXT("pub.ini"));

  DDS::DomainParticipantFactory_var dpf =
    TheParticipantFactoryWithArgs(argc, argv);
  // ...
}
```

`pub.ini` would be used unless `-DCPSConfigFile` is passed to override the default configuration file.

If there is a directory with multiple configuration files, then *OPENDDS_CONFIG_DIR* can be used to make `-DCPSConfigFile` relative to that directory. For example, the following commands would have the same effect:

```
./publisher -DCPSConfigFile /pretend/this/is/a/long/path/a.ini
./subscriber -DCPSConfigFile /pretend/this/is/a/long/path/b.ini

export OPENDDS_CONFIG_DIR=/pretend/this/is/a/long/path
./publisher -DCPSConfigFile a.ini
./subscriber -DCPSConfigFile b.ini
```

Configuration with API

ConfigStore API

The configuration store API allows any configuration value to be set and retrieved. The interface for the ConfigStore is intentionally generic to facilitate multiple language bindings without specific support for every configuration property. See `dds/DdsDcpsInfrastructure.idl` and `dds/DCPS/ConfigStoreImpl.h` for more details.

```
#include <dds/DCPS/Service_Participant.h>

int main(int argc, char* argv[])
{
  // ...
  TheServiceParticipant->config_store()->set_string(
     "RTPS_DISCOVERY_MY_DISCOVERY", "@MY_DISCOVERY");
  TheServiceParticipant->config_store()->set_string(
     "RTPS_DISCOVERY_MY_DISCOVERY_RESEND_PERIOD", "5");
  // ...
}
```

```
import OpenDDS.DCPS.TheServiceParticipant;
import OpenDDS.DCPS.ConfigStore;
// ...
ConfigStore cs = TheServiceParticipant.config_store();
cs.set_string("RTPS_DISCOVERY_MY_DISCOVERY", "@MY_DISCOVERY");
cs.set_string("RTPS_DISCOVERY_MY_DISCOVERY_RESEND_PERIOD", "5");
// ...
```

Specific APIs

Various classes provide methods that allow an application to configure OpenDDS.

- See `Service_Participant` in `dds/DCPS/Service_Participant.h`
- See `InfoRepoDiscovery` in `dds/DCPS/InfoRepoDiscovery/InfoRepoDiscovery.h`
- See `RtpsDiscoveryConfig` in `dds/DCPS/RTPS/RtpsDiscoveryConfig.h`
- See `TransportRegistry` in `dds/DCPS/transport/framework/TransportRegistry.h`
- See `RtpsUdpInst` in `dds/DCPS/transport/rtps_udp/RtpsUdpInst.h`
- See `TcpInst` in `dds/DCPS/transport/tcp/TcpInst.h`

- See ShmemInst in dds/DCPS/transport/shmem/ShmemInst.h

2.12.2 Common Configuration Properties

The *[common]* section of an OpenDDS configuration file contains options such as the debugging output level, the location of the DCPSInfoRepo process, and memory preallocation settings. A sample [common] section follows:

```
[common]
DCPSDebugLevel=0
DCPSInfoRepo=localhost:12345
DCPSLivelinessFactor=80
DCPSChunks=20
DCPSChunksAssociationMultiplier=10
DCPSBitLookupDurationMsec=2000
DCPSPendingTimeout=30
```

It is not necessary to specify every option.

Option values in the [common] section with names that begin with DCPS or ORB[1] can be overridden by a command-line argument. The command-line argument has the same name as the configuration option with a - prepended to it. For example:

```
subscriber -DCPSInfoRepo localhost:12345
```

[common]

DCPSBidirGIOP=<boolean>

Config store key: COMMON_DCPS_BIDIR_GIOP
Default: 1 (enabled)

Note: This property is only applicable when using *InfoRepo Discovery*.

Use TAO's BiDirectional GIOP feature for interaction with the *The DCPS Information Repository*. With BiDir enabled, fewer sockets are needed since the same socket can be used for both client and server roles.

DCPSBit=<boolean>

Config store key: COMMON_DCPS_BIT
Default: 1 (enabled)

Controls if *Built-in Topics* are enabled.

[1] *[common] ORBLogFile* and *[common] ORBVerboseLogging* start with "ORB" because they are inherited from *TAO*. They are implemented directly by OpenDDS (not passed to TAO) and are supported either on the command line (using a "-" prefix) or in the configuration file. Other command-line options that begin with -ORB are passed to TAO's ORB_init if *InfoRepo Discovery* is used.

DCPSBitLookupDurationMsec=<msec>

Config store key: COMMON_DCPS_BIT_LOOKUP_DURATION_MSEC
Default: 2000 (2 seconds)

The maximum duration in milliseconds that the framework will wait for latent *Built-in Topics* information when retrieving BIT data given an instance handle. The participant code may get an instance handle for a remote entity before the framework receives and processes the related BIT information. The framework waits for up to the given amount of time before it fails the operation.

DCPSBitTransportIPAddress=<addr>

Config store key: COMMON_DCPS_BIT_TRANSPORT_IP_ADDRESS
Default: INADDR_ANY

Note: This property is only applicable when using *InfoRepo Discovery*.

IP address identifying the local interface to be used by *TCP Transport* for the *Built-in Topics*.

DCPSBitTransportPort=<port>

Config store key: COMMON_DCPS_BIT_TRANSPORT_PORT
Default: 0

Note: This property is only applicable when using *InfoRepo Discovery*.

Port used by the *TCP Transport* for *Built-in Topics*. If the default of 0 is used, the operating system will choose a port to use.

DCPSChunkAssociationMultiplier=<n>

Config store key: COMMON_DCPS_CHUNK_ASSOCIATION_MULTIPLIER
Default: 10

Multiplier for the *DCPSChunks* or the max_samples value in *Resource Limits QoS* to determine the total number of shallow copy chunks that are preallocated. Set this to a value greater than the number of connections so the preallocated chunk handles do not run out. A sample written to multiple data readers will not be copied multiple times but there is a shallow copy handle to that sample used to manage the delivery to each data reader. The size of the handle is small so there is not great need to set this value close to the number of connections.

DCPSChunks=<n>

Config store key: COMMON_DCPS_CHUNKS
Default: 20

Configurable number of chunks that a data writer's and reader's cached allocators will preallocate when the *Resource Limits QoS* value is infinite. When all of the preallocated chunks are in use, OpenDDS allocates from the heap. This feature of allocating from the heap when the preallocated memory is exhausted provides flexibility but performance will decrease when the preallocated memory is exhausted.

DCPSDebugLevel=<n>

Config store key: COMMON_DCPS_DEBUG_LEVEL
Default: 0 (disabled)

Integer value that controls the amount of *debug information the DCPS layer logs*. Valid values are 0 through 10.

DCPSDefaultAddress=<addr>

Config store key: COMMON_DCPS_DEFAULT_ADDRESS
Default: 0.0.0.0

Default value for the host portion of `local_address` in transport instances and some other host address values:

- *[transport] local_address (tcp)*
- *[transport] local_address (udp)*
- *[transport] local_address (multicast)*
- *[transport] local_address (rtps_udp)*
- *[transport] ipv6_local_address (rtps_udp)*
- *[transport] multicast_interface (rtps_udp)*
- *[rtps_discovery] SedpLocalAddress*
- *[rtps_discovery] SpdpLocalAddress*
- *[rtps_discovery] MulticastInterface*

DCPSDefaultDiscovery=DEFAULT_REPO|DEFAULT_RTPS|DEFAULT_STATIC|<name>

Config store key: COMMON_DCPS_DEFAULT_DISCOVERY
Default: *DEFAULT_REPO*

Specifies a discovery configuration to use for any domain not explicitly configured.

DEFAULT_REPO

Uses a default *InfoRepo Discovery* configuration.

DEFAULT_RTPS

Uses a default *RTPS Discovery* configuration.

DEFAULT_STATIC

Uses a default *Static Discovery* configuration.

<**name**>

Name of a user-defined discovery configuration. This can either be a *[repository]* or *[rtps_discovery]* section

See *Discovery Configuration* for details about configuring discovery.

DCPSGlobalTransportConfig=<name>|$file

Config store key: COMMON_DCPS_GLOBAL_TRANSPORT_CONFIG
Default: The default configuration is used as described in *Overview*.

The *transport configuration* that should be used as the global default one.

<**name**>

Name of a user-defined *[config]* sections.

$file

$file uses a transport configuration that includes all transport instances defined in the configuration file.

DCPSInfoRepo=<objref>

Config store key: COMMON_DCPS_INFO_REPO
Default: file://repo.ior

Object reference for locating the *The DCPS Information Repository* in *InfoRepo Discovery*. This value is passed to CORBA::ORB::string_to_object() and can be any Object URL type understandable by *TAO* (file, IOR, corbaloc, corbaname). A simplified endpoint description of the form <host>:<port> is also accepted, which is equivalent to corbaloc::<host>:<port>/DCPSInfoRepo.

DCPSLivelinessFactor=<n>

Config store key: COMMON_DCPS_LIVELINESS_FACTOR
Default: 80

Percent of the *Liveliness QoS* lease duration after which a liveliness message is sent. A value of 80 implies a 20% cushion of latency from the last detected heartbeat message.

DCPSLogLevel=none|error|warning|notice|info|debug

Config store key: COMMON_DCPS_LOG_LEVEL
Default: *warning*

General logging control.

none
See *none log level*

error
See *error log level*

warning
See *warning log level*

notice
See *notice log level*

info
See *info log level*

debug
See *debug log level*

See *Logging* for details.

DCPSMonitor=<boolean>

Config store key: COMMON_DCPS_MONITOR
Default: 0

Use the Monitor library to publish data on monitoring topics (see dds/monitor/README).

DCPSPendingTimeout=<sec>

Config store key: COMMON_DCPS_PENDING_TIMEOUT
Default: 0

The maximum duration in seconds a data writer will block to allow unsent samples to drain on deletion. The default, 0, blocks indefinitely.

DCPSPersistentDataDir=<path>

Config store key: COMMON_DCPS_PERSISTENT_DATA_DIR
Default: OpenDDS-durable-data-dir

The path to a directory on where durable data will be stored for *PERSISTENT_DURABILITY_QOS*. If the directory does not exist it will be created automatically.

DCPSPublisherContentFilter=<boolean>

Config store key: COMMON_DCPS_PUBLISHER_CONTENT_FILTER
Default: 1

Controls the filter expression evaluation policy for *content filtered topics*. When the value is 1 the publisher may drop any samples, before handing them off to the transport when these samples would have been ignored by all subscribers.

DCPSSecurity=<boolean>

Config store key: COMMON_DCPS_SECURITY
Default: 0

This setting is only available when OpenDDS is compiled with *DDS Security*. If set to 1, enable DDS Security framework and built-in plugins. Each Domain Participant using security must be created with the correct *property QoS*.

See *DDS Security* for more information.

DCPSSecurityDebug=<cat>[,<cat>]...

Config store key: COMMON_DCPS_SECURITY_DEBUG
Default: 0 (No security logging)

This setting is only available when OpenDDS is compiled with *DDS Security* enabled. This controls the *security debug logging* granularity by category.

DCPSSecurityDebugLevel=<n>

Config store key: COMMON_DCPS_SECURITY_DEBUG_LEVEL
Default: 0 (No security logging)

This setting is only available when OpenDDS is compiled with *DDS Security* enabled. This controls the *security debug logging* granularity by debug level.

DCPSSecurityFakeEncryption=<boolean>

Config store key: COMMON_DCPS_SECURITY_FAKE_ENCRYPTION
Default: 0 (Real encryption when that's setup)

This setting is only available when OpenDDS is compiled with *DDS Security* enabled. This option, when set to `1`, disables all encryption by making encryption and decryption no-ops. OpenDDS still generates keys and performs other security bookkeeping, so this option is useful for debugging the security infrastructure by making it possible to manually inspect all messages.

DCPSThreadStatusInterval=<sec>

Config store key: `COMMON_DCPS_THREAD_STATUS_INTERVAL`
Default: `0` (disabled)

Enable *internal thread status reporting* using the specified reporting interval, in seconds.

DCPSTransportDebugLevel=<n>

Config store key: `COMMON_DCPS_TRANSPORT_DEBUG_LEVEL`
Default: `0` (disabled)

Integer value that controls the amount of *debug information the transport layer logs*. Valid values are `0` through `5`.

DCPSTypeObjectEncoding=`Normal|WriteOldFormat|ReadOldFormat`

Config store key: `COMMON_DCPS_TYPE_OBJECT_ENCODING`
Default: *`Normal`*

From when *XTypes* was first implemented in OpenDDS from 3.16.0 until 3.18.0, there was a bug in the encoding and decoding of `TypeObject` and related data types for *representing user types*. This was fixed in 3.18.0, but if an application needs to be compatible with an application built with 3.16 or 3.17, then it can use this option to do that and migrate to the correct encoding without taking everything down all at once.

`WriteOldFormat`

This setting makes OpenDDS use the incorrect encoding. To start to migrate an existing set of OpenDDS applications, this should be the setting of applications using OpenDDS 3.18 or later.

`ReadOldFormat`

This setting allows OpenDDS to read the incorrect encoding, but it will always write the correct one. Once all application using OpenDDS 3.16 or 3.17 have been upgraded to OpenDDS 3.18 or later, `WriteOldFormat` can be set to communicate with `ReadOldFormat` and `Normal`.

`Normal`

The default, correct encoding is used. Once all applications are using both OpenDDS 3.18 or later and `ReadOldFormat`, then `Normal` can be used.

ORBLogFile=<path>

Config store key: `COMMON_ORB_LOG_FILE`
Default: Output to standard error stream on most platforms

Change *log* message destination to the file specified, which is opened in appending mode.[Page 164, 1]

ORBVerboseLogging=0|1|2

Config store key: COMMON_ORB_VERBOSE_LOGGING
Default: 0

Add a prefix to each *log* message, using a format defined by the *ACE* library:[Page 164, 1]

0

No prefix

1

Verbose "lite", adds timestamp and priority

2

Verbose, in addition to "lite" has host name, PID, program name

pool_size=<n_bytes>

Config store key: COMMON_POOL_SIZE
Default: 41943040 bytes (40 MiB)

Size of *Safety Profile* memory pool, in bytes.

pool_granularity=<n_bytes>

Config store key: COMMON_POOL_GRANULARITY
Default: 8

Granularity of *Safety Profile* memory pool in bytes. Must be multiple of 8.

Scheduler=SCHED_RR|SCHED_FIFO|SCHED_OTHER

Config store key: COMMON_SCHEDULER
Default: *SCHED_OTHER*

Selects the scheduler to use for transport sending threads. Setting the scheduler to a value other than the default requires privileges on most systems.

SCHED_RR

Round robin scheduling algorithm

SCHED_FIFO

Allows each thread to run until it either blocks or completes before switching to a different thread

SCHED_OTHER

The default scheduler on most systems

See also:

sched(7)

Transport Priority QoS

scheduler_slice=<usec>

Config store key: COMMON_SCHEDULER_SLICE
Default: 0

Some operating systems require a time slice value to be set when selecting a *Scheduler* other than the default. For those systems, this option can be used to set a value in microseconds.

2.12.3 Discovery Configuration

In DDS implementations, participants are instantiated in application processes and must discover one another in order to communicate. A DDS implementation uses the feature of domains to give context to the data being exchanged between DDS participants in the same domain. When DDS applications are written, participants are assigned to a domain and need to ensure their configuration allows each participant to discover the other participants in the same domain.

OpenDDS offers a centralized discovery mechanism, a peer-to-peer discovery mechanism, and a static discovery mechanism. The centralized mechanism uses a separate service running a DCPSInfoRepo process. The RTPS peer-to-peer mechanism uses the DDSI-RTPS discovery protocol standard to achieve non-centralized discovery. The static discovery mechanism uses the configuration file to determine which writers and readers should be associated and uses the underlying transport to determine which writers and readers exist. A number of configuration options exist to meet the deployment needs of DDS applications. Except for static discovery, each mechanism uses default values if no configuration is supplied either via the command line or configuration file.

The following sections show how to configure the advanced discovery capabilities. For example, some deployments may need to use multiple DCPSInfoRepo services or DDSI-RTPS discovery to satisfy interoperability requirements.

Domain Configuration

An OpenDDS configuration file uses the [domain] section type to configure one or more discovery domains with each domain pointing to a discovery configuration in the same file or a default discovery configuration. OpenDDS applications can use a centralized discovery approach using the DCPSInfoRepo service or a peer-to-peer discovery approach using the RTPS discovery protocol standard or a combination of the two in the same deployment. A single domain can refer to only one type of discovery section.

See *Configuring for InfoRepo Discovery* for configuring InfoRepo Discovery, *Configuring for RTPS Discovery* for configuring RTPS Discovery, and *Configuring for Static Discovery* for configuring Static Discovery.

Ultimately a domain is assigned an integer value and a configuration file can support this in two ways. The first is to simply make the instance value the integer value assigned to the domain as shown here:

```
[domain/1]
DiscoveryConfig=DiscoveryConfig1
(more properties...)
```

Our example configures a single domain identified by the `domain` keyword and followed by an instance value of `/1`. The instance value after the slash in this case is the integer value assigned to the domain. An alternative syntax for this same content is to use a more recognizable (friendly) name instead of a number for the domain name and then add the *[domain] DomainId* property to the section to give the integer value. Here is an example:

```
[domain/books]
DomainId=1
DiscoveryConfig=DiscoveryConfig1
```

The domain is given a friendly name of books. The *[domain] DomainId* property assigns the integer value of 1 needed by a DDS application reading the configuration. Multiple domain instances can be identified in a single configuration file in this format.

Once one or more domain instances are established, the discovery properties must be identified for that domain. The *[domain] DiscoveryConfig* property must either point to another section that holds the discovery configuration or specify one of the internal default values for discovery. The instance name in our example is `DiscoveryConfig1`. This instance name must be associated with a section type of either *[repository]* or *[rtps_discovery]*.

Here is an extension of our example:

```
[domain/1]
DiscoveryConfig=DiscoveryConfig1

[repository/DiscoveryConfig1]
RepositoryIor=host1.mydomain.com:12345
```

In this case our domain points to a `[repository]` section which is used for an OpenDDS `DCPSInfoRepo` service. See *Configuring for InfoRepo Discovery* for more details.

There are going to be occasions when specific domains are not identified in the configuration file. For example, if an OpenDDS application assigns a domain ID of 3 to its participants and the above example does not supply a configuration for domain id of 3 then the following can be used:

```
[common]
DCPSInfoRepo=host3.mydomain.com:12345
DCPSDefaultDiscovery=DEFAULT_REPO

[domain/1]
DiscoveryConfig=DiscoveryConfig1

[repository/DiscoveryConfig1]
RepositoryIor=host1.mydomain.com:12345
```

The *[common] DCPSDefaultDiscovery* and *[common] DCPSInfoRepo* properties tell the application that every participant that doesn't have a domain id found in the configuration file to use the *The DCPS Information Repository* at `host3.mydomain.com:12345`.

As shown in *Common Configuration Properties* the `DCPSDefaultDiscovery` property has three other values that can be used. The `DEFAULT_RTPS` constant value informs participants that don't have a domain configuration to use RTPS discovery to find other participants. Similarly, the `DEFAULT_STATIC` constant value informs the participants that don't have a domain configuration to use static discovery to find other participants.

The final option for the `DCPSDefaultDiscovery` property is to tell an application to use one of the defined discovery configurations to be the default configuration for any participant domain that isn't called out in the file. Here is an example:

```
[common]
DCPSDefaultDiscovery=DiscoveryConfig2

[domain/1]
DiscoveryConfig=DiscoveryConfig1

[repository/DiscoveryConfig1]
RepositoryIor=host1.mydomain.com:12345

[domain/2]
DiscoveryConfig=DiscoveryConfig2

[repository/DiscoveryConfig2]
RepositoryIor=host2.mydomain.com:12345
```

By adding the `DCPSDefaultDiscovery` property to the `[common]` section, any participant that hasn't been assigned to a domain id of `1` or `2` will use the configuration of `DiscoveryConfig2`. For more explanation of a similar configuration for RTPS discovery see *Configuring for RTPS Discovery*.

`[domain/<id>]`

DomainId=<n>

Config store key: `DOMAIN_<id>_DOMAIN_ID`
Required

An integer value representing a domain being associated with a repository.

DomainRepoKey=<k>

Config store key: `DOMAIN_<id>_DOMAIN_REPO_KEY`

Key value of the mapped repository

Deprecated since version Provided: for backward compatibility.

DiscoveryConfig=<name>

Config store key: `DOMAIN_<id>_DISCOVERY_CONFIG`
Default: *`[common] DCPSDefaultDiscovery`*

Sets the discovery configuration for this domain. It uses the same values as *`[common] DCPSDefaultDiscovery`*.

DefaultTransportConfig=<name>

Config store key: `DOMAIN_<id>_DEFAULT_TRANSPORT_CONFIG`

A user-defined string that refers to the instance name of a `[config]` section. See *Transport Configuration*.

Configuring for InfoRepo Discovery

This section describes the configuration properties for the *InfoRepo Discovery*. Assume for example that the *The DCPS Information Repository* is started on a host and port of `myhost.mydomain.com:12345`. Applications can make their OpenDDS participants aware of how to find this service through command line options or by reading a configuration file.

In *Running the Example* the executables were given a command line parameter to find the `DCPSInfoRepo` service like so:

```
publisher -DCPSInfoRepo file://repo.ior
```

This assumes that the `DCPSInfoRepo` has been started with the following syntax:

```
$DDS_ROOT/bin/DCPSInfoRepo -o repo.ior
```

```
%DDS_ROOT%\bin\DCPSInfoRepo -o repo.ior
```

The `DCPSInfoRepo` service generates its location object information in this file and participants need to read this file to ultimately connect. The use of file based IORs to find a discovery service, however, is not practical in most production environments, so applications instead can use a command line option like the following to simply point to the host and port where the `DCPSInfoRepo` is running.

```
publisher -DCPSInfoRepo myhost.mydomain.com:12345
```

The above assumes that the `DCPSInfoRepo` has been started on a host (`myhost.mydomain.com`) as follows:

```
$DDS_ROOT/bin/DCPSInfoRepo -ORBListenEndpoints iiop://:12345
```

```
%DDS_ROOT%\bin\DCPSInfoRepo -ORBListenEndpoints iiop://:12345
```

If an application needs to use a configuration file for other settings, it would become more convenient to place discovery content in the file and reduce command line complexity and clutter. The use of a configuration file also introduces the opportunity for multiple application processes to share common OpenDDS configuration. The above example can easily be moved to the `[common]` section of a configuration file (assume a file of `pub.ini`):

```
[common]
DCPSInfoRepo=myhost.mydomain.com:12345
```

The command line to start our executable would now change to the following:

```
publisher -DCSPConfigFile pub.ini
```

A configuration file can specify domains with discovery configuration assigned to those domains. In this case the *`[repository] RepositoryIor`* property is used to take the same information that would be supplied on a command line to point to a running `DCPSInfoRepo` service. Two domains are configured here:

```
[domain/1]
DiscoveryConfig=DiscoveryConfig1

[repository/DiscoveryConfig1]
RepositoryIor=myhost.mydomain.com:12345
```

(continues on next page)

(continued from previous page)

```
[domain/2]
DiscoveryConfig=DiscoveryConfig2

[repository/DiscoveryConfig2]
RepositoryIor=host2.mydomain.com:12345
```

The *[domain] DiscoveryConfig* property under `[domain/1]` instructs all participants in domain 1 to use the configuration defined in an instance called `DiscoveryConfig1`. In the above, this is mapped to a `[repository]` section that gives the `RepositoryIor` value of `myhost.mydomain.com:12345`.

Finally, when configuring a `DCPSInfoRepo` the `DiscoveryConfig` property under a domain instance entry can also contain the value of `DEFAULT_REPO` which instructs a participant using this instance to use the definition of the property `DCPSInfoRepo` wherever it has been supplied. Consider the following configuration file as an example:

```
[common]
DCPSInfoRepo=localhost:12345

[domain/1]
DiscoveryConfig=DiscoveryConfig1

[repository/DiscoveryConfig1]
RepositoryIor=myhost.mydomain.com:12345

[domain/2]
DiscoveryConfig=DEFAULT_REPO
```

In this case any participant in domain 2 would be instructed to refer to the discovery property of *[common] DCPSInfoRepo*, which is defined in the `[common]` section of our example. If the `DCPSInfoRepo` value is not supplied in the `[common]` section, it could alternatively be supplied as a parameter to the command line like so:

```
publisher -DCPSInfoRepo localhost:12345 -DCPSConfigFile pub.ini
```

This sets the value of `DCPSInfoRepo` such that if participants reading the configuration file pub.ini encounters `DEFAULT_REPO`, there is a value for it. If `DCPSInfoRepo` is not defined in a configuration file or on the command line, then the OpenDDS default value for `DCPSInfoRepo` is `file://repo.ior`. As mentioned prior, this is not likely to be the most useful in production environments and should lead to setting the value of `DCPSInfoRepo` by one of the means described in this section.

Configuring for Multiple DCPSInfoRepo Instances

The DDS entities in a single OpenDDS process can be associated with multiple DCPS information repositories (`DCPSInfoRepo`).

The repository information and domain associations can be configured using a configuration file, or via application API. Internal defaults, command line arguments, and configuration file options will work as-is for existing applications that do not want to use multiple `DCPSInfoRepo` associations.

The following is an example of a process that uses multiple `DCPSInfoRepo` repositories.

Processes `A` and `B` are typical application processes that have been configured to communicate with one another and discover one another in `InfoRepo_1`. This is a simple use of basic discovery. However, an additional layer of context has been applied with the use of a specified domain (Domain 1). DDS entities (data readers/data writers) are restricted to communicate to other entities within that same domain. This provides a useful method of separating traffic when

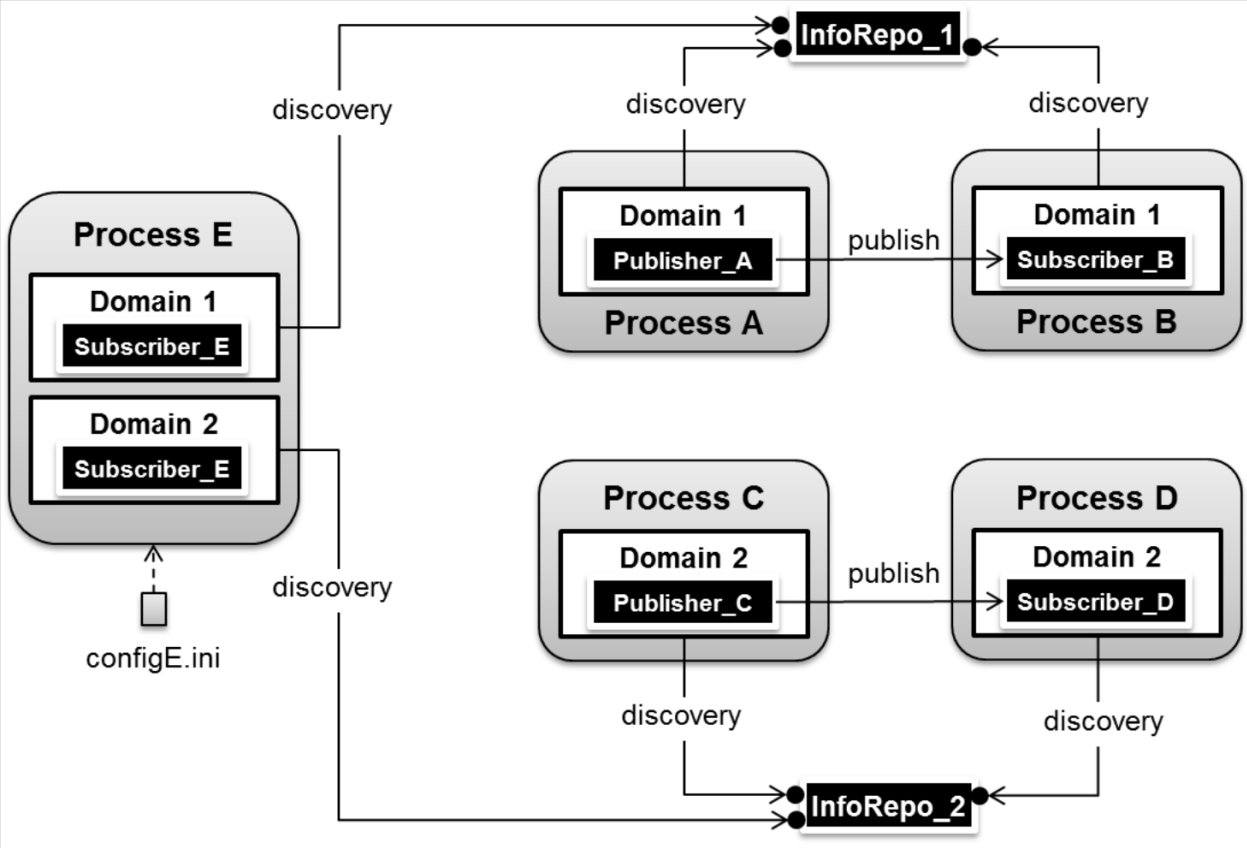


Fig. 2: Multiple DCPSInfoRepo Configuration

needed by an application. Processes C and D are configured the same way, but operate in Domain 2 and use InfoRepo_2. The challenge comes when you have an application process that needs to use multiple domains and have separate discovery services. This is Process E in our example. It contains two subscribers, one subscribing to publications from InfoRepo_1 and the other subscribing to publications in InfoRepo_2. What allows this configuration to work can be found in the configE.ini file.

We will now look at the configuration file (referred to as configE.ini) to demonstrate how Process E can communicate to both domains and separate DCPSInfoRepo services. For this example we will only show the discovery aspects of the configuration and not show transport content.

```
[domain/1]
DiscoveryConfig=DiscoveryConfig1

[repository/DiscoveryConfig1]
RepositoryIor=host1.mydomain.com:12345

[domain/2]
DiscoveryConfig=DiscoveryConfig2

[repository/DiscoveryConfig2]
RepositoryIor=host2.mydomain.com:12345
```

When Process E reads in the above configuration it finds the occurrence of multiple domain sections. As described in *Domain Configuration* each domain has an instance integer and a property of *[domain] DiscoveryConfig* defined.

For the first domain ([domain/1]), the DiscoveryConfig property is supplied with the user-defined name of DiscoveryConfig1 value. This property causes the OpenDDS implementation to find a section title of either repository or rtps_discovery and an instance name of DiscoveryConfig1. In our example, a [repository/DiscoveryConfig1] section title is found and this becomes the discovery configuration for domain instance [domain/1] (integer value 1). The section found now tells us that the address of the DCPSInfoRepo that this domain should use can be found by using the RepositoryIor property value. In particular it is host1.mydomain.com and port 12345. The values of the RepositoryIor can be a full CORBA IOR or a simple host:port string.

A second domain section title [domain/2] is found in this configuration file along with it's corresponding repository section [repository/DiscoveryConfig2] that represents the configuration for the second domain of interest and the InfoRepo_2 repository. There may be any number of repository or domain sections within a single configuration file.

Note: Domains not explicitly configured are automatically associated with the default discovery configuration.

Note: Individual DCPSInfoRepos can be associated with multiple domains, however domains cannot be shared between multiple DCPSInfoRepos.

Here are the valid properties for a [repository] section:

[**repository**/<inst_name>]

RepositoryIor=<ior>

Config store key: REPOSITORY_<inst_name>_REPOSITORY_IOR

Repository IOR or host:port

RepositoryKey=<key>

Config store key: REPOSITORY_<inst_name>_REPOSITORY_KEY

Unique key value for the repository

Deprecated since version Provided: for backward compatibility.

Configuring for RTPS Discovery

This section describes the configuration properties for the *RTPS Discovery*. The RTPS specification gives the following simple description that forms the basis for the discovery approach used by OpenDDS and the two different protocols used to accomplish the discovery operations. The excerpt from the RTPS v2.3 8.5.1 Overview is as follows:

> The RTPS specification splits up the discovery protocol into two independent protocols:
>
> 1. Participant Discovery Protocol
> 2. Endpoint Discovery Protocol
>
> A Participant Discovery Protocol (PDP) specifies how Participants discover each other in the network. Once two Participants have discovered each other, they exchange information on the Endpoints they contain using an Endpoint Discovery Protocol (EDP). Apart from this causality relationship, both protocols can be considered independent.

The configuration options discussed in this section allow a user to specify property values to change the behavior of the *Simple Participant Discovery Protocol* (SPDP) and/or the *Simple Endpoint Discovery Protocol* (SEDP) default settings.

RTPS discovery can be configured for a single domain or for multiple domains as was done in *Configuring for Multiple DCPSInfoRepo Instances*.

A simple configuration is achieved by specifying a property in the `[common]` section of our example configuration file.

```
[common]
DCPSDefaultDiscovery=DEFAULT_RTPS
```

All default values for RTPS discovery are adopted in this form. A variant of this same basic configuration is to specify a section to hold more specific parameters of RTPS discovery. The following example uses the `[common]` section to point to an instance of an `[rtps_discovery]` section followed by an instance name of `TheRTPSConfig` which is supplied by the user.

```
[common]
DCPSDefaultDiscovery=TheRTPSConfig

[rtps_discovery/TheRTPSConfig]
ResendPeriod=5
```

The instance `[rtps_discovery/TheRTPSConfig]` is now the location where properties that vary the default RTPS settings get specified. In our example the *`ResendPeriod=5`* entry sets the number of seconds between periodic announcements of available data readers / data writers and to detect the presence of other data readers / data writers on the network. This would override the default of 30 seconds.

If your OpenDDS deployment uses multiple domains, the following configuration approach combines the use of the *`[domain]`* section title with *`[rtps_discovery]`* to allow a user to specify particular settings by domain. It might look like this:

```
[common]
DCPSDebugLevel=0

[domain/1]
DiscoveryConfig=DiscoveryConfig1

[rtps_discovery/DiscoveryConfig1]
ResendPeriod=5

[domain/2]
DiscoveryConfig=DiscoveryConfig2

[rtps_discovery/DiscoveryConfig2]
ResendPeriod=5
SedpMulticast=0
```

Some important implementation notes regarding RTPS discovery in OpenDDS are as follows:

1. Domain IDs should be between 0 and 231 (inclusive) due to the way UDP ports are assigned to domain IDs. In each OpenDDS process, up to 120 domain participants are supported in each domain.
2. The *Multicast Transport* does not work with RTPS Discovery due to the way GUIDs are assigned (a warning will be issued if this is attempted).

The OMG RTPS specification details several properties that can be adjusted from their defaults that influence the behavior of RTPS discovery. Those properties, along with options specific to OpenDDS's RTPS discovery implementation, are listed below.

[**rtps_discovery**/<inst_name>]

ResendPeriod=<sec>

Config store key: RTPS_DISCOVERY_<inst_name>_RESEND_PERIOD
Default: 30

The number of seconds that a process waits between the announcement of participants (see RTPS v2.3 8.5.3 The Simple Participant Discovery Protocol).

MinResendDelay=<msec>

Config store key: RTPS_DISCOVERY_<inst_name>_MIN_RESEND_DELAY
Default: 100

The minimum time in milliseconds between participant announcements.

QuickResendRatio=<frac>

Config store key: RTPS_DISCOVERY_<inst_name>_QUICK_RESEND_RATIO
Default: 0.1

Tuning parameter that configures local SPDP resends as a fraction of the resend period.

LeaseDuration=<sec>

Config store key: RTPS_DISCOVERY_<inst_name>_LEASE_DURATION
Default: 300 (5 minutes)

Sent as part of the participant announcement. It tells the peer participants that if they don't hear from this participant for the specified duration, then this participant can be considered "not alive".

LeaseExtension=<sec>

Config store key: RTPS_DISCOVERY_<inst_name>_LEASE_EXTENSION
Default: 0

Extends the lease of discovered participants by the set amount of seconds. Useful on spotty connections to reduce load on the *RtpsRelay*.

PB=<port>

Config store key: RTPS_DISCOVERY_<inst_name>_PB
Default: 7400

This number sets the starting point for deriving port numbers used for Simple Endpoint Discovery Protocol (SEDP). This property is used in conjunction with *DG*, *PG*, *D0* (or *DX*), and *D1* to construct the necessary Endpoints for RTPS discovery communication. See RTPS v2.3 9.6.1.1 Discovery traffic for how these Endpoints are constructed.

DG=<n>

Config store key: RTPS_DISCOVERY_<inst_name>_DG
Default: 250

An integer value representing the Domain Gain. This is a multiplier that assists in formulating Multicast or Unicast ports for RTPS.

PG=<n>

Config store key: RTPS_DISCOVERY_<inst_name>_PG
Default: 2

An integer that assists in configuring SPDP Unicast ports and serves as an offset multiplier. Participants are assigned addresses using the formula:

$$PB + DG \times domainId + d1 + PG \times participantId$$

See RTPS v2.3 9.6.1.1 Discovery traffic for how these Endpoints are constructed.

D0=<n>

Config store key: RTPS_DISCOVERY_<inst_name>_D0
Default: The value of the OPENDDS_RTPS_DEFAULT_D0 environment variable if set, else 0

An integer value that assists in providing an offset for calculating an assignable port in SPDP Multicast configurations. The formula used is:

$$PB + DG \times domainId + d0$$

See RTPS v2.3 9.6.1.1 Discovery traffic for how these Endpoints are constructed.

D1=<n>

Config store key: RTPS_DISCOVERY_<inst_name>_D1
Default: 10

An integer value that assists in providing an offset for calculating an assignable port in SPDP Unicast configurations. The formula used is:

$$PB + DG \times domainId + d1 + PG \times participantId$$

See RTPS v2.3 9.6.1.1 Discovery traffic for how these Endpoints are constructed.

DX=<n>

Config store key: RTPS_DISCOVERY_<inst_name>_DX
Default: 2

An integer value that assists in providing an offset for calculating a port in SEDP Multicast configurations. This is only valid when *SedpMulticast=1*. The formula used is:

$$PB + DG \times domainId + dx$$

This is an OpenDDS extension and not part of the OMG DDSI-RTPS specification.

SpdpRequestRandomPort=<boolean>

Config store key: RTPS_DISCOVERY_<inst_name>_SPDP_REQUEST_RANDOM_PORT
Default: 0

Use a random port for SPDP.

SedpMaxMessageSize=<n>

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_MAX_MESSAGE_SIZE
Default: 65466 (maximum worst-case UDP payload size)

Set the maximum SEDP message size.

See *[transport] max_message_size (rtps_udp)*.

SedpMulticast=<boolean>

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_MULTICAST
Default: 1

Determines whether Multicast is used for the SEDP traffic. When set to 1, Multicast is used. When set to 0, Unicast is used.

SedpLocalAddress=<addr>:[<port>]

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_LOCAL_ADDRESS
Default: *[common] DCPSDefaultAddress*

Configure the transport instance created and used by SEDP to bind to the specified local address and port. In order to leave the port unspecified, it can be omitted from the setting but the trailing : must be present.

SpdpLocalAddress=<addr>[:<port>]

Config store key: RTPS_DISCOVERY_<inst_name>_SPDP_LOCAL_ADDRESS
Default: *[common] DCPSDefaultAddress*

Address of a local interface, which will be used by SPDP to bind to that specific interface.

SedpAdvertisedLocalAddress=<addr>:[<port>]

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_ADVERTISED_LOCAL_ADDRESS

Sets the address advertised by SEDP. Typically used when the participant is behind a firewall or NAT. In order to leave the port unspecified, it can be omitted from the setting but the trailing : must be present.

SedpSendDelay=<msec>

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_SEND_DELAY
Default: 10

Time in milliseconds for a built-in SEDP Writer to wait before sending data.

SedpHeartbeatPeriod=<msec>

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_HEARTBEAT_PERIOD
Default: 200

Time in milliseconds for a built-in SEDP Writer to announce the availability of data.

SedpNakResponseDelay=<msec>

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_NAK_RESPONSE_DELAY
Default: 100

Time in milliseconds for a built-in SEDP Writer to delay the response to a negative acknowledgment.

SpdpSendAddrs=<host>:<port>[,<host>:<port>]...

Config store key: RTPS_DISCOVERY_<inst_name>_SPDP_SEND_ADDRS

A list (comma or whitespace separated) of <host>:<port> pairs used as destinations for SPDP content. This can be a combination of Unicast and Multicast addresses.

MaxSpdpSequenceMsgResetChecks=<n>

Config store key: RTPS_DISCOVERY_<inst_name>_MAX_SPDP_SEQUENCE_MSG_RESET_CHECKS
Default: 3

Remove a discovered participant after this number of SPDP messages with earlier sequence numbers.

PeriodicDirectedSpdp=<boolean>

Config store key: RTPS_DISCOVERY_<inst_name>_PERIODIC_DIRECTED_SPDP
Default: 0 (disabled)

A boolean value that determines whether directed SPDP messages are sent to all participants once every resend period. This setting should be enabled for participants that cannot use multicast to send SPDP announcements, e.g., an RtpsRelay.

UndirectedSpdp=<boolean>

Config store key: RTPS_DISCOVERY_<inst_name>_UNDIRECTED_SPDP
Default: 1 (enabled)

A boolean value that determines whether undirected SPDP messages are sent. This setting should be disabled for participants that cannot use multicast to send SPDP announcements, e.g., an RtpsRelay.

InteropMulticastOverride=<group_address>

Config store key: RTPS_DISCOVERY_<inst_name>_INTEROP_MULTICAST_OVERRIDE

A network address specifying the multicast group to be used for SPDP discovery. This overrides the interoperability group of the specification, `239.255.0.1` It can be used, for example, to specify use of a routed group address to provide a larger discovery scope.

TTL=n

Config store key: RTPS_DISCOVERY_<inst_name>_TTL
Default: 1 (all data is restricted to the local network)

The value of the Time-To-Live (TTL) field of multicast datagrams sent as part of discovery. This value specifies the number of hops the datagram will traverse before being discarded by the network.

MulticastInterface=<iface>

Config store key: RTPS_DISCOVERY_<inst_name>_MULTICAST_INTERFACE
Default: *[common] DCPSDefaultAddress*

Specifies the network interface to be used by this discovery instance. This uses a platform-specific format that identifies the network interface, but can be address assigned to that interface on most platforms.

GuidInterface=<iface>

Config store key: RTPS_DISCOVERY_<inst_name>_GUID_INTERFACE
Default: The system / ACE library default is used

Specifies the network interface to use when determining which local MAC address should appear in a GUID generated by this node.

SpdpRtpsRelayAddress=<host>:<port>

Config store key: RTPS_DISCOVERY_<inst_name>_SPDP_RTPS_RELAY_ADDRESS

Specifies the address of the *RtpsRelay* for SPDP messages.

SpdpRtpsRelaySendPeriod=<sec>

Config store key: RTPS_DISCOVERY_<inst_name>_SPDP_RTPS_RELAY_SEND_PERIOD

Default: `30` seconds

Specifies the interval between SPDP announcements sent to the *RtpsRelay*.

SedpRtpsRelayAddress=host:port

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_RTPS_RELAY_ADDRESS

Specifies the address of the *RtpsRelay* for SEDP messages.

RtpsRelayOnly=<boolean>

Config store key: RTPS_DISCOVERY_<inst_name>_RTPS_RELAY_ONLY
Default: `0` (disabled)

Only send RTPS message to the *RtpsRelay* (for debugging).

UseRtpsRelay=<boolean>

Config store key: RTPS_DISCOVERY_<inst_name>_USE_RTPS_RELAY
Default: `0` (disabled)

Send messages to the *RtpsRelay*. Messages will only be sent if *SpdpRtpsRelayAddress* and/or *SedpRtpsRelayAddress* are set.

SpdpStunServerAddress=<host>:<port>

Config store key: RTPS_DISCOVERY_<inst_name>_SPDP_STUN_SERVER_ADDRESS

Specifies the address of the STUN server to use for SPDP when using *ICE*.

SedpStunServerAddress=<host>:<port>

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_STUN_SERVER_ADDRESS

Specifies the address of the STUN server to use for SEDP when using *ICE*.

UseIce=<boolean>

Config store key: RTPS_DISCOVERY_<inst_name>_USE_ICE
Default: `0` (disabled)

Enable or disable *ICE* for both SPDP and SEDP.

MaxAuthTime=<sec>

Config store key: RTPS_DISCOVERY_<inst_name>_MAX_AUTH_TIME
Default: 300 seconds (5 minutes)

Set the maximum time for authentication with *DDS Security*.

AuthResendPeriod=<sec>

Config store key: RTPS_DISCOVERY_<inst_name>_AUTH_RESEND_PERIOD
Default: 1 second

Resend authentication messages for *DDS Security* after this amount of seconds. It is a floating point value, so fractions of a second can be specified.

SecureParticipantUserData=<boolean>

Config store key: RTPS_DISCOVERY_<inst_name>_SECURE_PARTICIPANT_USER_DATA
Default: 0 (disabled)

If *DDS Security* is enabled, the *Participant's USER_DATA QoS* is omitted from unsecured discovery messages.

UseXTypes=no|minimal|complete

Config store key: RTPS_DISCOVERY_<inst_name>_USE_X_TYPES
Default: *no*

Enables discovery extensions from the XTypes specification. Participants exchange topic type information in endpoint announcements and extended type information using the Type Lookup Service.

See *Representing Types with TypeObject and DynamicType* for more information on CompleteTypeObject and its use in the dynamic binding.

no

XTypes isn't taken into consideration during discovery. 0 can also be used for backwards compatibility.

minimal

XTypes is used for discovery when possible and only the MinimalTypeObject is provided to remote participants if available. 1 can also be used for backwards compatibility.

complete

XTypes is used for discovery when possible and only the CompleteTypeObject is provided to remote participants if available. This requires that *opendds_idl -Gxtypes-complete* was used when compiling the IDL. 2 can also be used for backwards compatibility.

TypeLookupServiceReplyTimeout=<msec>

Config store key: RTPS_DISCOVERY_<inst_name>_TYPE_LOOKUP_SERVICE_REPLY_TIMEOUT
Default: 5000 milliseconds (5 seconds).

If *UseXTypes* is enabled, then this sets the timeout for waiting for replies to remote Type Lookup Service requests.

SedpResponsiveMode=<boolean>

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_RESPONSIVE_MODE
Default: 0 (disabled)

Causes the built-in SEDP endpoints to send additional messages which may reduce latency.

SedpPassiveConnectDuration=<msec>

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_PASSIVE_CONNECT_DURATION
Default: 60000 milliseconds (1 minute)

Sets the duration that a passive endpoint will wait for a connection.

SendBufferSize=<bytes>

Config store key: RTPS_DISCOVERY_<inst_name>_SEND_BUFFER_SIZE
Default: 0 (system default value is used)

Socket send buffer size for both SPDP and SEDP.

RecvBufferSize=<bytes>

Config store key: RTPS_DISCOVERY_<inst_name>_RECV_BUFFER_SIZE
Default: 0 (system default value is used)

Socket receive buffer size for both SPDP and SEDP.

MaxParticipantsInAuthentication=<n>

Config store key: RTPS_DISCOVERY_<inst_name>_MAX_PARTICIPANTS_IN_AUTHENTICATION
Default: 0 (no limit)

This setting is only available when OpenDDS is compiled with *DDS Security* enabled. Limits the number of peer participants that can be concurrently in the process of authenticating – that is, not yet completed authentication.

SedpReceivePreallocatedMessageBlocks=<n>

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_RECEIVE_PREALLOCATED_MESSAGE_BLOCKS
Default: 0 (use *[transport] receive_preallocated_message_blocks*'s default)

Configure the *[transport] receive_preallocated_message_blocks* attribute of SEDP's transport.

SedpReceivePreallocatedDataBlocks=<n>

Config store key: RTPS_DISCOVERY_<inst_name>_SEDP_RECEIVE_PREALLOCATED_DATA_BLOCKS
Default: 0 (use *[transport] receive_preallocated_data_blocks*'s default)

Configure the *[transport] receive_preallocated_data_blocks* attribute of SEDP's transport.

CheckSourceIp=<boolean>

Config store key: RTPS_DISCOVERY_<inst_name>_CHECK_SOURCE_IP
Default: 1 (enabled)

Incoming participant announcements (SPDP) are checked to verify that their source IP address matches one of:

- An entry in the metatraffic locator list
- The configured *RtpsRelay* (if any)
- An *ICE* AgentInfo parameter

Announcements that don't match any of these are dropped if this check is enabled.

SpdpUserTag=<i>

Config store key: RTPS_DISCOVERY_<inst_name>_SPDP_USER_TAG
Default: 0 (disabled)

Add the OpenDDS-specific UserTag RTPS submessage to the start of SPDP messages. If <i> is 0 (the default), the submessage is not added. Otherwise this submessage's contents is the 4-byte unsigned integer <i>.

Additional DDSI-RTPS Discovery Features

The DDSI_RTPS discovery implementation creates and manages a transport instance – specifically an object of class `RtpsUdpInst`. In order for applications to access this object and enable advanced features (*Additional RTPS_UDP Features*), the `RtpsDiscovery` class provides the method `sedp_transport_inst(domainId, participant)`.

Configuring for Static Discovery

Static discovery may be used when a DDS domain has a fixed number of processes and data readers/writers that are all known *a priori*. Data readers and writers are collectively known as *endpoints*. Using only the configuration file, the static discovery mechanism must be able to determine a network address and the QoS settings for each endpoint. The static discovery mechanism uses this information to determine all potential associations between readers and writers. A domain participant learns about the existence of an endpoint through hints supplied by the underlying transport.

Note: Currently, static discovery can only be used for endpoints using the *RTPS/UDP Transport*.

Static discovery introduces the following configuration file sections:

- The *[topic]* section is used to introduce a topic.
- The *[datawriterqos]*, *[datareaderqos]*, *[publisherqos]*, and *[subscriberqos]* sections are used to describe a QoS of the associated type.
- The *[endpoint]* section describes a data reader or writer.

Data reader and writer objects must be identified by the user so that the static discovery mechanism can associate them with the correct *[endpoint]* section in the configuration file. This is done by setting the *User Data QoS* of the `DomainParticipantQos` to an octet sequence of length 6. The representation of this octet sequence occurs in the *[endpoint] participant* as a string with two hexadecimal digits per octet. Similarly, the `user_data` of the `DataReaderQos` or `DataWriterQos` must be set to an octet sequence of length 3 corresponding to the `entity` value in the `[endpoint/*]` section. For example, suppose the configuration file contains the following:

```
[topic/MyTopic]
type_name=TestMsg::TestMsg

[endpoint/MyReader]
type=reader
topic=MyTopic
config=MyConfig
domain=34
participant=0123456789ab
entity=cdef01

[config/MyConfig]
transports=MyTransport

[transport/MyTransport]
transport_type=rtps_udp
use_multicast=0
local_address=1.2.3.4:30000
```

The corresponding code to configure the `DomainParticipantQos` is:

```
DDS::DomainParticipantQos dp_qos;
domainParticipantFactory->get_default_participant_qos(dp_qos);
dp_qos.user_data.value.length(6);
dp_qos.user_data.value[0] = 0x01;
dp_qos.user_data.value[1] = 0x23;
dp_qos.user_data.value[2] = 0x45;
dp_qos.user_data.value[3] = 0x67;
dp_qos.user_data.value[4] = 0x89;
dp_qos.user_data.value[5] = 0xab;
```

The code to configure the DataReaderQos is similar:

```
DDS::DataReaderQos qos;
subscriber->get_default_datareader_qos(qos);
qos.user_data.value.length(3);
qos.user_data.value[0] = 0xcd;
qos.user_data.value[1] = 0xef;
qos.user_data.value[2] = 0x01;
```

The domain id, which is 34 in the example, should be passed to the call to `create_participant`.

In the example, the endpoint configuration for `MyReader` references `MyConfig` which in turn references `MyTransport`. Transport configuration is described in *Transport Configuration*. The important detail for static discovery is that at least one of the transports contains a known network address (`1.2.3.4:30000`). An error will be issued if an address cannot be determined for an endpoint. The static discovery implementation also checks that the QoS of a data reader or data writer object matches the QoS specified in the configuration file.

[**topic**/<inst_name>]

name=<name>

Config store key: TOPIC_<inst_name>_NAME
Default: The <inst_name> of the topic section

Use this to override the name of the topic in the DDS API.

type_name=<name>

Config store key: TOPIC_<inst_name>_TYPE_NAME
Required

Identifier which uniquely defines the sample type. This is typically a CORBA interface repository type name.

[**datawriterqos**/<inst_name>]

durability.kind=VOLATILE|TRANSIENT_LOCAL

Config store key: DATAWRITERQOS_<inst_name>_DURABILITY_KIND

See *Durability QoS*.

deadline.period.sec=<numeric>|DURATION_INFINITE_SEC

Config store key: DATAWRITERQOS_<inst_name>_DEADLINE_PERIOD_SEC

See *Deadline QoS*.

deadline.period.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key: DATAWRITERQOS_<inst_name>_DEADLINE_PERIOD_NANOSEC

See *Deadline QoS*.

latency_budget.duration.sec=<numeric>|DURATION_INFINITE_SEC

Config store key: DATAWRITERQOS_<inst_name>_LATENCY_BUDGET_DURATION_SEC

See *Latency Budget QoS*.

latency_budget.duration.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key: DATAWRITERQOS_<inst_name>_LATENCY_BUDGET_DURATION_NANOSEC

See *Latency Budget QoS*.

liveliness.kind=AUTOMATIC|MANUAL_BY_TOPIC|MANUAL_BY_PARTICIPANT

Config store key: DATAWRITERQOS_<inst_name>_LIVELINESS_KIND

See *Liveliness QoS*.

liveliness.lease_duration.sec=<numeric>|DURATION_INFINITE_SEC

Config store key: DATAWRITERQOS_<inst_name>_LIVELINESS_LEASE_DURATION_SEC

See *Liveliness QoS*.

liveliness.lease_duration.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key: DATAWRITERQOS_<inst_name>_LIVELINESS_LEASE_DURATION_NANOSEC

See *Liveliness QoS*.

reliability.kind=BEST_EFFORT|RELIABILE

Config store key: DATAWRITERQOS_<inst_name>_RELIABILITY_KIND

See *Reliability QoS*.

reliability.max_blocking_time.sec=<numeric>|DURATION_INFINITE_SEC

Config store key: DATAWRITERQOS_<inst_name>_RELIABILITY_MAX_BLOCKING_TIME_SEC

See *Reliability QoS*.

reliability.max_blocking_time.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key: DATAWRITERQOS_<inst_name>_RELIABILITY_MAX_BLOCKING_TIME_NANOSEC

See *Reliability QoS*.

destination_order.kind=BY_SOURCE_TIMESTAMP|BY_RECEPTION_TIMESTAMP

Config store key: DATAWRITERQOS_<inst_name>_DESTINATION_ORDER_KIND

See *Destination Order QoS*.

history.kind=KEEP_LAST|KEEP_ALL

Config store key: DATAWRITERQOS_<inst_name>_HISTORY_KIND

See *History QoS*.

history.depth=<numeric>

Config store key: DATAWRITERQOS_<inst_name>_HISTORY_DEPTH

See *History QoS*.

resource_limits.max_samples=<numeric>

Config store key: DATAWRITERQOS_<inst_name>_RESOURCE_LIMITS_MAX_SAMPLES

See *Resource Limits QoS*.

resource_limits.max_instances=<numeric>

Config store key: DATAWRITERQOS_<inst_name>_RESOURCE_LIMITS_MAX_INSTANCES

See *Resource Limits QoS*.

resource_limits.max_samples_per_instance=<numeric>

Config store key: DATAWRITERQOS_<inst_name>_RESOURCE_LIMITS_MAX_SAMPLES_PER_INSTANCE

See *Resource Limits QoS*.

transport_priority.value=<numeric>

Config store key: DATAWRITERQOS_<inst_name>_TRANSPORT_PRIORITY_VALUE

See *Transport Priority QoS*.

lifespan.duration.sec=<numeric>|DURATION_INFINITE_SEC

Config store key: DATAWRITERQOS_<inst_name>_LIFESPAN_DURATION_SEC

See *Lifespan QoS*.

lifespan.duration.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key: DATAWRITERQOS_<inst_name>_LIFESPAN_DURATION_NANOSEC

See *Lifespan QoS*.

ownership.kind=SHARED|EXCLUSIVE

Config store key: DATAWRITERQOS_<inst_name>_OWNERSHIP_KIND

See *Ownership QoS*.

ownership_strength.value=<numeric>

Config store key: DATAWRITERQOS_<inst_name>_OWNERSHIP_STRENGTH_VALUE

See *Ownership Strength QoS*.

[**datareaderqos**/<inst_name>]

durability.kind=VOLATILE|TRANSIENT_LOCAL

Config store key: DATAREADERQOS_<inst_name>_DURABILITY_KIND

See *Durability QoS*.

deadline.period.sec=<numeric>|DURATION_INFINITE_SEC

Config store key: DATAREADERQOS_<inst_name>_DEADLINE_PERIOD_SEC

See *Deadline QoS*.

deadline.period.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key: DATAREADERQOS_<inst_name>_DEADLINE_PERIOD_NANOSEC

See *Deadline QoS*.

latency_budget.duration.sec=<numeric>|DURATION_INFINITE_SEC

Config store key: DATAREADERQOS_<inst_name>_LATENCY_BUDGET_DURATION_SEC

See *Latency Budget QoS*.

latency_budget.duration.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key: DATAREADERQOS_<inst_name>_LATENCY_BUDGET_DURATION_NANOSEC

See *Latency Budget QoS*.

liveliness.kind=AUTOMATIC|MANUAL_BY_TOPIC|MANUAL_BY_PARTICIPANT

Config store key: DATAREADERQOS_<inst_name>_LIVELINESS_KIND

See *Liveliness QoS*.

liveliness.lease_duration.sec=<numeric>|DURATION_INFINITE_SEC

Config store key: DATAREADERQOS_<inst_name>_LIVELINESS_LEASE_DURATION_SEC

See *Liveliness QoS*.

liveliness.lease_duration.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key: DATAREADERQOS_<inst_name>_LIVELINESS_LEASE_DURATION_NANOSEC

See *Liveliness QoS*.

reliability.kind=BEST_EFFORT|RELIABILE

Config store key: DATAREADERQOS_<inst_name>_RELIABILITY_KIND

See *Reliability QoS*.

reliability.max_blocking_time.sec=<numeric>|DURATION_INFINITE_SEC

Config store key: DATAREADERQOS_<inst_name>_RELIABILITY_MAX_BLOCKING_TIME_SEC

See *Reliability QoS*.

reliability.max_blocking_time.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key: DATAREADERQOS_<inst_name>_RELIABILITY_MAX_BLOCKING_TIME_NANOSEC

See *Reliability QoS*.

destination_order.kind=BY_SOURCE_TIMESTAMP|BY_RECEPTION_TIMESTAMP

Config store key: DATAREADERQOS_<inst_name>_DESTINATION_ORDER_KIND

See *Destination Order QoS*.

history.kind=KEEP_LAST|KEEP_ALL

Config store key: DATAREADERQOS_<inst_name>_HISTORY_KIND

See *History QoS*.

history.depth=<numeric>

Config store key: DATAREADERQOS_<inst_name>_HISTORY_DEPTH

See *History QoS*.

resource_limits.max_samples=<numeric>

Config store key: DATAREADERQOS_<inst_name>_RESOURCE_LIMITS_MAX_SAMPLES

See *Resource Limits QoS*.

resource_limits.max_instances=<numeric>

Config store key: DATAREADERQOS_<inst_name>_RESOURCE_LIMITS_MAX_INSTANCES

See *Resource Limits QoS*.

resource_limits.max_samples_per_instance=<numeric>

Config store key: DATAREADERQOS_<inst_name>_RESOURCE_LIMITS_MAX_SAMPLES_PER_INSTANCE

See *Resource Limits QoS*.

time_based_filter.minimum_separation.sec=<numeric>|DURATION_INFINITE_SEC

Config store key: DATAREADERQOS_<inst_name>_TIME_BASED_FILTER_MINIMUM_SEPARATION_SEC

See *Time Based Filter QoS*.

time_based_filter.minimum_separation.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key:
DATAREADERQOS_<inst_name>_TIME_BASED_FILTER_MINIMUM_SEPARATION_NANOSEC

See *Time Based Filter QoS*.

reader_data_lifecycle.autopurge_nowriter_samples_delay.sec=<numeric>|DURATION_INFINITE_SEC

Config store key:
DATAREADERQOS_<inst_name>_READER_DATA_LIFECYCLE_AUTOPURGE_NOWRITER_SAMPLES_DELAY_SEC

See *Reader Data Lifecycle QoS*.

reader_data_lifecycle.autopurge_nowriter_samples_delay.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key: DATAREADERQOS_<inst_name>_READER_DATA_LIFECYCLE_AUTOPURGE_NOWRITER_SAMPLES_DELAY_NANOSEC

See *Reader Data Lifecycle QoS*.

reader_data_lifecycle.autopurge_dispose_samples_delay.sec=<numeric>|DURATION_INFINITE_SEC

Config store key: DATAREADERQOS_<inst_name>_READER_DATA_LIFECYCLE_AUTOPURGE_DISPOSE_SAMPLES_DELAY_SEC

See *Reader Data Lifecycle QoS*.

reader_data_lifecycle.autopurge_dispose_samples_delay.nanosec=<numeric>|DURATION_INFINITE_NANOSEC

Config store key: DATAREADERQOS_<inst_name>_READER_DATA_LIFECYCLE_AUTOPURGE_DISPOSE_SAMPLES_DELAY_NANOSEC

See *Reader Data Lifecycle QoS*.

[**publisherqos**/<inst_name>]

presentation.access_scope=INSTANCE|TOPIC|GROUP

Config store key: PUBLISHERQOS_<inst_name>_PRESENTATION_ACCESS_SCOPE

See *Presentation QoS*.

presentation.coherent_access=true|false

Config store key: PUBLISHERQOS_<inst_name>_PRESENTATION_COHERENT_ACCESS

See *Presentation QoS*.

presentation.ordered_access=true|false

Config store key: PUBLISHERQOS_<inst_name>_PRESENTATION_ORDERED_ACCESS

See *Presentation QoS*.

partition.name=<name>[,<name>]...

Config store key: PUBLISHERQOS_<inst_name>_PARTITION_NAME

See *Partition QoS*.

[**subscriberqos**/<inst_name>]

presentation.access_scope=INSTANCE|TOPIC|GROUP

Config store key: SUBSCRIBERQOS_<inst_name>_PRESENTATION_ACCESS_SCOPE

See *Presentation QoS*.

presentation.coherent_access=true|false

Config store key: SUBSCRIBERQOS_<inst_name>_PRESENTATION_COHERENT_ACCESS

See *Presentation QoS*.

presentation.ordered_access=true|false

Config store key: SUBSCRIBERQOS_<inst_name>_PRESENTATION_ORDERED_ACCESS

See *Presentation QoS*.

partition.name=<name>[,<name>]...

Config store key: SUBSCRIBERQOS_<inst_name>_PARTITION_NAME

See *Partition QoS*.

[**endpoint**/<inst_name>]

domain=<numeric>

Config store key: ENDPOINT_<inst_name>_DOMAIN
Required

Domain id for endpoint in range 0-231. Used to form GUID of endpoint.

participant=<hexstring>

Config store key: ENDPOINT_<inst_name>_PARTICIPANT
Required

String of 12 hexadecimal digits. Used to form GUID of endpoint. All endpoints with the same domain/participant combination should be in the same process.

entity=<hexstring>

Config store key: ENDPOINT_<inst_name>_ENTITY
Required

String of 6 hexadecimal digits. Used to form GUID of endpoint. The combination of domain/participant/entity should be unique.

type=reader|writer

Config store key: ENDPOINT_<inst_name>_TYPE
Required

Determines if the entity is a data reader or data writer.

topic=<inst_name>

Config store key: ENDPOINT_<inst_name>_TOPIC
Required

The *[topic]* to use.

datawriterqos=<inst_name>

Config store key: ENDPOINT_<inst_name>_DATAWRITERQOS

The *[datawriterqos]* to use.

datareaderqos=<inst_name>

Config store key: ENDPOINT_<inst_name>_DATAREADERQOS

The *[datareaderqos]* to use.

publisherqos=<inst_name>

Config store key: ENDPOINT_<inst_name>_PUBLISHERQOS

The *[publisherqos]* to use.

subscriberqos=<inst_name>

Config store key: ENDPOINT_<inst_name>_SUBSCRIBERQOS

The *[subscriberqos]* to use.

config=<inst_name>

Config store key: ENDPOINT_<inst_name>_CONFIG

The *[config]* to use.

2.12.4 Transport Configuration

Beginning with OpenDDS 3.0, a new transport configuration design has been implemented. The basic goals of this design were to:

- Allow simple deployments to ignore transport configuration and deploy using intelligent defaults (with no transport code required in the publisher or subscriber).
- Enable flexible deployment of applications using only configuration files and command line options.
- Allow deployments that mix transports within individual data writers and writers. Publishers and subscribers negotiate the appropriate transport implementation to use based on the details of the transport configuration, QoS settings, and network reachability.
- Support a broader range of application deployments in complex networks.
- Support optimized transport development (such as collocated and shared memory transports - note that these are not currently implemented).
- Integrate support for the *Reliability QoS* policy with the underlying transport.
- Whenever possible, avoid dependence on the ACE Service Configurator and its configuration files.

Unfortunately, implementing these new capabilities involved breaking of backward compatibility with OpenDDS transport configuration code and files from previous releases. See `docs/OpenDDS_3.0_Transition.txt` for information on how to convert your existing application to use the new transport configuration design.

Overview

Transport Concepts

This section provides an overview of the concepts involved in transport configuration and how they interact.

Each data reader and writer uses a *Transport Configuration* consisting of an ordered set of *Transport Instances*. Each transport instance specifies a *transport implementation* and can customize the configuration parameters defined by that transport. Transport Configurations and Transport Instances are managed by the *Transport Registry* and can be created via configuration files or through programming APIs.

Transport Configurations can be specified for Domain Participants, Publishers, Subscribers, Data Writers, and Data Readers. When a Data Reader or Writer is enabled, it uses the most specific configuration it can locate, either directly bound to it or accessible through its parent entity. For example, if a Data Writer specifies a Transport Configuration, it always uses it. If the Data Writer does not specify a configuration, it tries to use that of its Publisher or Domain Participant in that order. If none of these entities have a transport configuration specified, the *Global Transport Configuration* is obtained from the Transport Registry. The Global Transport Configuration can be specified by the user via either configuration file, command line option, or a member function call on the Transport Registry. If not defined by the user, a default transport configuration is used which contains all available transport implementations with their default configuration parameters. If you don't specifically load or link in any other transport implementations, OpenDDS uses the *TCP Transport* for all communication.

How OpenDDS Selects a Transport

Currently, the behavior for OpenDDS is that Data Writers actively connect to Data Readers, which are passively awaiting those connections. Data Readers "listen" for connections on each of the Transport Instances that are defined in their Transport Configuration. Data Writers use their Transport Instances to "connect" to those of the Data Readers. Because the logical connections discussed here don't correspond to the physical connections of the transport, OpenDDS often refers to them as *Data Links*.

When a Data Writer tries to connect to a Data Reader, it first attempts to see if there is an existing data link that it can use to communicate with that Data Reader. The Data Writer iterates (in definition order) through each of its Transport Instances and looks for an existing data link to the Transport Instances that the reader defined. If an existing data link is found it is used for all subsequent communication between the Data Writer and Reader.

If no existing data link is found, the Data Writer attempts to connect using the different Transport Instances in the order they are defined in its Transport Configuration. Any Transport Instances not "matched" by the other side are skipped. For example, if the writer specifies udp and tcp transport instances and the reader only specifies tcp, the udp transport instance is ignored. Matching algorithms may also be affected by *QoS*, configuration of the instances, and other specifics of the transport implementation. The first pair of Transport Instances that successfully "connect" results in a data link that is used for all subsequent data sample publication.

Configuration File Examples

The following examples explain the basic features of transport configuration via files and describe some common use cases. These are followed by full reference documentation for these features.

Single Transport Configuration

The simplest way to provide a transport configuration for your application is to use the OpenDDS configuration file. Here is a sample configuration file that might be used by an application running on a computer with two network interfaces that only wants to communicate using one of them:

```
[common]
DCPSGlobalTransportConfig=myconfig

[config/myconfig]
transports=mytcp

[transport/mytcp]
transport_type=tcp
local_address=myhost
```

This file does the following (starting from the bottom up):

1. Defines a transport instance named `mytcp` with a transport type of tcp and the local address specified as `myhost`, which is the host name corresponding to the network interface we want to use.
2. Defines a transport configuration named `myconfig` that uses the transport instance `mytcp` as its only transport.
3. Makes the transport configuration named `myconfig` the global transport configuration for all entities in this process.

A process using this configuration file utilizes our customized transport configuration for all Data Readers and Writers created by it (unless we specifically bind another configuration in the code as described in *Using Multiple Configurations*).

Using Mixed Transports

This example configures an application to primarily use multicast and to "fall back" to tcp when it is unable to use multicast. Here is the configuration file:

```
[common]
DCPSGlobalTransportConfig=myconfig

[config/myconfig]
transports=mymulticast,mytcp

[transport/mymulticast]
transport_type=multicast

[transport/mytcp]
transport_type=tcp
```

The transport configuration named `myconfig` now includes two transport instances, `mymulticast` and `mytcp`. Neither of these transport instances specify any parameters besides *`[transport] transport_type`*, so they use the default configuration of these transport implementations. Users are free to use any of the transport-specific configuration parameters that are listed in the following reference sections.

Assuming that all participating processes use this configuration file, the application attempts to use multicast to initiate communication between data writers and readers. If the initial multicast communication fails for any reason (possibly because an intervening router is not passing multicast traffic) tcp is used to initiate the connection.

Using Multiple Configurations

For many applications, one configuration is not equally applicable to all communication within a given process. These applications must create multiple Transport Configurations and then assign them to the different entities of the process.

For this example consider an application hosted on a computer with two network interfaces that requires communication of some data over one interface and the remainder over the other interface. Here is our configuration file:

```
[common]
DCPSGlobalTransportConfig=config_a

[config/config_a]
transports=tcp_a

[config/config_b]
transports=tcp_b

[transport/tcp_a]
transport_type=tcp
local_address=hosta

[transport/tcp_b]
transport_type=tcp
local_address=hostb
```

Assuming `hosta` and `hostb` are the host names assigned to the two network interfaces, we now have separate configurations that can use tcp on the respective networks. The above file sets the `config_a` configuration as the default, meaning we must manually bind any entities we want to use the other side to the `config_b` configuration.

OpenDDS provides two mechanisms to assign configurations to entities:

- Via source code by attaching a configuration to an *entity*
- Via configuration file by associating a configuration with a domain

Here is the source code mechanism (using a domain participant):

```
 DDS::DomainParticipant_var dp =
        dpf->create_participant(MY_DOMAIN,
                                PARTICIPANT_QOS_DEFAULT,
                                DDS::DomainParticipantListener::_nil(),
                                OpenDDS::DCPS::DEFAULT_STATUS_MASK);

OpenDDS::DCPS::TransportRegistry::instance()->bind_config("config_b", dp);
```

Any Data Writers or Readers owned by this Domain Participant should now use the `config_b` configuration.

When directly binding a configuration to a data writer or reader, the `bind_config` call must occur before the reader or writer is enabled. This is because the configuration is fixed on `enable()` and this is done automatically by default when an entity is created. This is not an issue when binding configurations to domain participants, publishers, or subscribers. Setting *Entity Factory QoS* `autoenable_created_entities` on the publisher or subscriber to `false` is required to use `bind_config` succesfully on a reader or writer. For example:

```
DDS::PublisherQos pub_qos;
participant->get_default_publisher_qos(pub_qos);
pub_qos.entity_factory.autoenable_created_entities = false;
```

(continues on next page)

(continued from previous page)

```
DDS::Publisher_var publisher = participant->create_publisher(pub_qos, /*...*/);
DDS::DataWriter_var datawriter1 = publisher->create_datawriter(/*...*/);
TheTransportRegistry->bind_config("tcp1", datawriter1);
datawriter1->enable();
```

The QoS can also be set on the domain participant or the service participant instead of the publisher or subscriber, but that requires manually calling `enable()` all the child entities of that entity.

Transport Registry Example

OpenDDS allows developers to also define transport configurations and instances via C++ APIs. The `OpenDDS::DCPS::TransportRegistry` class is used to construct `OpenDDS::DCPS::TransportConfig` and `OpenDDS::DCPS::TransportInst` objects. The `TransportConfig` and `TransportInst` classes contain public data member corresponding to the options defined below. This section contains the code equivalent of the simple transport configuration file described in . First, we need to include the correct header files:

```
#include <dds/DCPS/transport/framework/TransportRegistry.h>
#include <dds/DCPS/transport/framework/TransportConfig.h>
#include <dds/DCPS/transport/framework/TransportInst.h>
#include <dds/DCPS/transport/tcp/TcpInst.h>

using namespace OpenDDS::DCPS;
```

Next we create the transport configuration, create the transport instance, configure the transport instance, and then add the instance to the configuration's collection of instances:

```
TransportConfig_rch cfg = TheTransportRegistry->create_config("myconfig");
TransportInst_rch inst = TheTransportRegistry->create_inst("mytcp", // name
                                                           "tcp");  // type

// Must cast to TcpInst to get access to transport-specific options
TcpInst_rch tcp_inst = dynamic_rchandle_cast<TcpInst>(inst);
tcp_inst->local_address_str_ = "myhost";

// Add the inst to the config
cfg->instances_.push_back(inst);
```

Lastly, we can make our newly defined transport configuration the global transport configuration:

```
TheTransportRegistry->global_config(cfg);
```

This code should be executed before any Data Readers or Writers are enabled.

See the header files included above for the full list of public data members and member functions that can be used. See the option descriptions in the following sections for a full understanding of the semantics of these settings.

Stepping back and comparing this code to the original configuration file from, the configuration file is much simpler than the corresponding C++ code and has the added advantage of being modifiable at run-time. It is easy to see why we recommend that almost all applications should use the configuration file mechanism for transport configuration.

Transport Configuration Properties

Transport Configurations are specified in the OpenDDS configuration file via sections with the format of `[config/<name>]`, where `<name>` is a unique name for that configuration within that process.

`[config/<inst_name>]`

transports=<inst_name>|<template_name>[,<inst_name>|<template_name>...]

Config store key: CONFIG_<inst_name>_TRANSPORTS
Required

The ordered list of *transport instance* or *transport template* names that this configuration will utilize. This field is required for every transport configuration.

swap_bytes=<boolean>

Config store key: CONFIG_<inst_name>_SWAP_BYTES
Default: `0` (disabled)

A value of `0` causes DDS to serialize data in the source machine's native endianness; a value of `1` causes DDS to serialize data in the opposite endianness. The receiving side will adjust the data for its endianness so there is no need to match this option between machines. The purpose of this option is to allow the developer to decide which side will make the endian adjustment, if necessary.

passive_connect_duration=<msec>

Config store key: CONFIG_<inst_name>_PASSIVE_CONNECT_DURATION
Default: `10000` (10 sec)

Timeout (milliseconds) for initial passive connection establishment. A value of `0` would wait indefinitely (not recommended).

Without a suitable connection timeout, the subscriber endpoint can potentially enter a state of deadlock while waiting for the remote side to initiate a connection. Because there can be multiple transport instances on both the publisher and subscriber side, this option needs to be set to a high enough value to allow the publisher to iterate through the combinations until it succeeds.

In addition to the user-defined configurations, OpenDDS can implicitly define two transport configurations. The first is the default configuration and includes all transport implementations that are linked into the process. If none are found, then only *[transport] transport_type=tcp* is used. Each of these transport instances uses the default configuration for that transport implementation. This is the global transport configuration used when the user does not define one.

The second implicit transport configuration is defined whenever an OpenDDS configuration file is used. It is given the same name as the file being read and includes all the transport instances defined in that file, in the alphabetical order of their names. The user can most easily utilize this configuration by using the *[common] DCPSGlobalTransportConfig=$file* option in the same file.

Transport Instance Properties

Transport instances are specified in the OpenDDS configuration file via sections with the format of `[transport/<name>]`, where `<name>` is a unique name for that instance within that process. Each transport instance must specify the *`[transport] transport_type=tcp`* option with a valid transport implementation type. The following sections list the other options that can be specified, starting with those options common to all transport types and following with those specific to each transport type.

When using dynamic libraries, the OpenDDS transport libraries are dynamically loaded whenever an instance of that type is defined in a configuration file. When using custom transport implementations or static linking, the application developer is responsible for ensuring that the transport implementation code is linked with their executables. See *Plugins* for more information.

`[transport/<inst_name>]`

`transport_type``=tcp|udp|multicast|shmem|rtps_udp`

Config store key: `TRANSPORT_<inst_name>_TRANSPORT_TYPE`
Required

Type of the transport; the list of available transports can be extended programmatically via the transport framework.

`tcp`

Use the *TCP Transport*. See *TCP Transport Configuration Properties* for properties specific to this transport.

`udp`

Use the *UDP Transport*. See *UDP Transport Configuration Properties* for properties specific to this transport.

`multicast`

Use the *Multicast Transport*. See *Multicast Transport Configuration Properties* for properties specific to this transport.

`shmem`

Use the *Shared Memory Transport*. See *Shared Memory Transport Configuration Properties* for properties specific to this transport.

`rtps_udp`

Use the *RTPS/UDP Transport*. See *RTPS UDP Transport Configuration Properties* for properties specific to this transport.

`max_packet_size``=<n>`

Config store key: `TRANSPORT_<inst_name>_MAX_PACKET_SIZE`
Default: `2147481599`

The maximum size of a transport packet, including its transport header, sample header, and sample data.

max_samples_per_packet=<n>

Config store key: TRANSPORT_<inst_name>_MAX_SAMPLES_PER_PACKET
Default: 10

Maximum number of samples in a transport packet.

optimum_packet_size=<n>

Config store key: TRANSPORT_<inst_name>_OPTIMUM_PACKET_SIZE
Default: 4096 (4 KiB)

Transport packets greater than this size will be sent over the wire even if there are still queued samples to be sent. This value may impact performance depending on your network configuration and application nature.

thread_per_connection=<boolean>

Config store key: TRANSPORT_<inst_name>_THREAD_PER_CONNECTION
Default: 0 (disabled)

Enable or disable the thread per connection send strategy. This option will increase performance when writing to multiple data readers on different process as long as the overhead of thread context switching does not outweigh the benefits of parallel writes. This balance of network performance to context switching overhead is best determined by experimenting. If a machine has multiple network cards, it may improve performance by creating a transport for each network card.

datalink_release_delay=<msec>

Config store key: TRANSPORT_<inst_name>_DATALINK_RELEASE_DELAY
Default: 10000 (10 sec)

This is the delay in milliseconds that a datalink will be released after having no associations. Increasing this value may reduce the overhead of re-establishment when reader/writer associations are added and removed frequently.

datalink_control_chunks=<n>

Config store key: TRANSPORT_<inst_name>_DATALINK_CONTROL_CHUNKS
Default: 32

The number of chunks used to size allocators for transport control samples.

receive_preallocated_message_blocks=<n>

Config store key: TRANSPORT_<inst_name>_RECEIVE_PREALLOCATED_MESSAGE_BLOCKS
Default: 0 (use default)

Set to a positive number to override the number of message blocks that the allocator reserves memory for eagerly (on startup).

receive_preallocated_data_blocks=<n>

Config store key: TRANSPORT_<inst_name>_RECEIVE_PREALLOCATED_DATA_BLOCKS
Default: 0 (use default)

Set to a positive number to override the number of data blocks that the allocator reserves memory for eagerly (on startup).

TCP Transport Configuration Properties

This section describes the configuration properties for the *TCP Transport*. A properly configured transport provides added resilience to underlying stack disturbances. Almost all of the options available to customize the connection and reconnection strategies have reasonable defaults, but ultimately these values should to be chosen based upon a careful study of the quality of the network and the desired QoS in the specific DDS application and target environment.

You can also configure the publisher and subscriber transport implementations programmatically, as described in *Transport Registry Example*. Configuring subscribers and publishers should be identical, but different addresses/ports should be assigned to each Transport Instance.

[**transport**/<inst_name>] **(tcp)**

active_conn_timeout_period=<msec>

Config store key: TRANSPORT_<inst_name>_ACTIVE_CONN_TIMEOUT_PERIOD
Default: 5000 (5 sec)

The time period (milliseconds) for the active connection side to wait for the connection to be established. If not connected within this period then the on_publication_lost() callbacks will be called.

conn_retry_attempts=<n>

Config store key: TRANSPORT_<inst_name>_CONN_RETRY_ATTEMPTS
Default: 3

Number of reconnect attempts before giving up and calling the on_publication_lost() and on_subscription_lost() callbacks.

conn_retry_initial_delay=<msec>

Config store key: TRANSPORT_<inst_name>_CONN_RETRY_INITIAL_DELAY
Default: 500

Initial delay (milliseconds) for reconnect attempt. As soon as a lost connection is detected, a reconnect is attempted. If this reconnect fails, a second attempt is made after this specified delay.

conn_retry_backoff_multiplier=<n>

Config store key: TRANSPORT_<inst_name>_CONN_RETRY_BACKOFF_MULTIPLIER
Default: 2.0

The backoff multiplier for reconnection tries. After the initial delay described above, subsequent delays are determined by the product of this multiplier and the previous delay. For example, with a *conn_retry_initial_delay* of 500 and a *conn_retry_backoff_multiplier* of 1.5, the second reconnect attempt will be 0.5 seconds after the first retry connect fails; the third attempt will be 0.75 seconds after the second retry connect fails; the fourth attempt will be 1.125 seconds after the third retry connect fails.

enable_nagle_algorithm=<boolean>

Config store key: TRANSPORT_<inst_name>_ENABLE_NAGLE_ALGORITHM
Default: 0 (disabled)

Enable or disable the Nagle's algorithm. Enabling the Nagle's algorithm may increase throughput at the expense of increased latency.

local_address=<host>:<port>

Config store key: TRANSPORT_<inst_name>_LOCAL_ADDRESS
Default: *[common] DCPSDefaultAddress*

Hostname and port of the connection acceptor. If only the host is specified and the port number is omitted, the : is still required on the host specifier.

The *local_address* option is used by the peer to establish a connection. By default, the TCP transport selects an ephemeral port number on the NIC with the FQDN (fully qualified domain name) resolved. Therefore, you may wish to explicitly set the address if you have multiple NICs or if you wish to specify the port number. When you configure inter-host communication, *local_address* can not be localhost and should be configured with an externally visible address (i.e. 192.168.0.2), or you can leave it unspecified in which case the FQDN and an ephemeral port will be used.

FQDN resolution is dependent upon system configuration. In the absence of a FQDN (e.g. example.opendds.org), OpenDDS will use any discovered short names (e.g. example). If that fails, it will use the name resolved from the loopback address (e.g. localhost).

Note: OpenDDS IPv6 support requires that the underlying ACE/TAO components be built with IPv6 support enabled. The *local_address* needs to be an IPv6 decimal address or a FQDN with port number. The FQDN must be resolvable to an IPv6 address.

max_output_pause_period=<msec>

Config store key: TRANSPORT_<inst_name>_MAX_OUTPUT_PAUSE_PERIOD
Default: 0 (disabled)

Maximum period (milliseconds) of not being able to send queued messages. If there are samples queued and no output for longer than this period then the connection will be closed and on_*_lost() callbacks will be called. The default value of 0 means that this check is not made.

passive_reconnect_duration=<msec>

Config store key: TRANSPORT_<inst_name>_PASSIVE_RECONNECT_DURATION
Default: 2000 (2 seconds)

The time period (milliseconds) for the passive connection side to wait for the connection to be reconnected. If not reconnected within this period then the on_*_lost() callbacks will be called.

pub_address=<host>:<port>

Config store key: TRANSPORT_<inst_name>_PUB_ADDRESS

Override the address sent to peers with the configured string. This can be used for firewall traversal and other advanced network configurations.

TCP Reconnection Properties

When a TCP connection gets closed OpenDDS attempts to reconnect. The reconnection process is (a successful reconnect ends this sequence):

- Upon detecting a lost connection immediately attempt to reconnect.
- If that fails, then wait *[transport] conn_retry_initial_delay (tcp)* milliseconds and attempt reconnect.
- While we have not tried more than *[transport] conn_retry_attempts (tcp)*, wait (previous wait time * *[transport] conn_retry_backoff_multiplier (tcp)*) milliseconds and attempt to reconnect.

UDP Transport Configuration Properties

This section describes the configuration properties for the *UDP Transport*.

`[transport/<inst_name>] (udp)`

local_address=<host>:<port>

Config store key: TRANSPORT_<inst_name>_LOCAL_ADDRESS
Default: *[common] DCPSDefaultAddress*

Hostname and port of the listening socket. The port can be omitted, in which case the value should end in `:`.

send_buffer_size=<n>

Config store key: TRANSPORT_<inst_name>_SEND_BUFFER_SIZE
Default: Platform value of ACE_DEFAULT_MAX_SOCKET_BUFSIZ

Total send buffer size in bytes for UDP payload.

rcv_buffer_size=<n>

Config store key: TRANSPORT_<inst_name>_RCV_BUFFER_SIZE
Default: Platform value of ACE_DEFAULT_MAX_SOCKET_BUFSIZ

Total receive buffer size in bytes for UDP payload.

Multicast Transport Configuration Properties

This section describes the configuration properties for the *Multicast Transport*.

This transport has the following restrictions:

- *At most*, one DDS domain may be used per multicast group;
- A given participant may only have a single `multicast` transport attached per multicast group; if you wish to send and receive samples on the same multicast group in the same process, independent participants must be used.

`[transport/<inst_name>] (multicast)`

default_to_ipv6=<boolean>

Config store key: TRANSPORT_<inst_name>_DEFAULT_TO_IPV6
Default: `0` (disabled)

The `default_to_ipv6` and *port_offset* options affect how default multicast group addresses are selected. If `default_to_ipv6` is set to 1 (enabled), then the default IPv6 address will be used (`[FF01::80]`).

group_address=<host>:<port>

Config store key: TRANSPORT_<inst_name>_GROUP_ADDRESS
Default: `224.0.0.128:,[FF01::80]:`

This property may be used to manually define a multicast group to join to exchange data. Both IPv4 and IPv6 addresses are supported. OpenDDS IPv6 support requires that the underlying ACE/TAO components be built with IPv6 support enabled.

local_address=<address>

Config store key: TRANSPORT_<inst_name>_LOCAL_ADDRESS
Default: *[common] DCPSDefaultAddress*

If non-empty, address of a local network interface which is used to join the multicast group. On hosts with multiple network interfaces, it may be necessary to specify that the multicast group should be joined on a specific interface.

nak_delay_intervals=<n>

Config store key: TRANSPORT_<inst_name>_NAK_DELAY_INTERVALS
Default: 4

The number of intervals between naks after the initial nak.

nak_depth=<n>

Config store key: TRANSPORT_<inst_name>_NAK_DEPTH
Default: 32

The number of datagrams to retain in order to service repair requests (reliable only).

nak_interval=<msec>

Config store key: TRANSPORT_<inst_name>_NAK_INTERVAL
Default: 500

The minimum number of milliseconds to wait between repair requests (reliable only). This interval is randomized to prevent potential collisions between similarly associated peers. Use this option so that naks will be not be sent repeatedly for unrecoverable packets before *nak_timeout*.

nak_max=<n>

Config store key: TRANSPORT_<inst_name>_NAK_MAX
Default: 3

The maximum number of times a missing sample will be nak'ed. The *maximum* delay between repair requests is bounded to double the minimum value.

nak_timeout=<msec>

Config store key: TRANSPORT_<inst_name>_NAK_TIMEOUT
Default: 30000 (30 sec)

The maximum number of milliseconds to wait before giving up on a repair response (reliable only).

port_offset=<n>

Config store key: TRANSPORT_<inst_name>_PORT_OFFSET
Default: 49152

Used to set the port number when not specifying a group address. When a group address is specified, the port number within it is used. If no group address is specified, the port offset is used as a port number. This value should not be set less than 49152.

rcv_buffer_size=<n>

Config store key: TRANSPORT_<inst_name>_RCV_BUFFER_SIZE
Default: 0 (system default buffer size)

The size of the socket receive buffer in bytes. A value of zero indicates that the system default value is used.

reliable=<boolean>

Config store key: TRANSPORT_<inst_name>_RELIABLE
Default: 1 (enabled)

Enables reliable communication.

syn_backoff=<n>

Config store key: TRANSPORT_<inst_name>_SYN_BACKOFF
Default: 2.0

The exponential base used during handshake retries; smaller values yield shorter delays between attempts.

Given the values of *syn_backoff* and *syn_interval*, it is possible to calculate the delays between handshake attempts (bounded by *syn_timeout*):

```
delay = syn_interval * syn_backoff ^ number_of_retries
```

For example, if the default configuration options are assumed, the delays between handshake attempts would be: 0, 250, 1000, 2000, 4000, and 8000 milliseconds respectively.

syn_interval=<msec>

Config store key: TRANSPORT_<inst_name>_SYN_INTERVAL
Default: 250

The minimum number of milliseconds to wait between handshake attempts during association.

syn_timeout=<msec>

Config store key: TRANSPORT_<inst_name>_SYN_TIMEOUT
Default: 30000 (30 sec)

The maximum number of milliseconds to wait before giving up on a handshake response during association.

ttl=<n>

Config store key: TRANSPORT_<inst_name>_TTL
Default: 1 (all data is restricted to the local network)

The value of the time-to-live (TTL) field of any datagrams sent. This value specifies the number of hops the datagram will traverse before being discarded by the network.

async_send=<boolean>

Config store key: TRANSPORT_<inst_name>_ASYNC_SEND
Default: 0 (disabled)

Send datagrams using asynchronous I/O on platforms that support it efficiently.

RTPS UDP Transport Configuration Properties

This section describes the configuration properties for the *RTPS/UDP Transport*.

To provide an RTPS variant of the single configuration example from *Single Transport Configuration*, the configuration file below simply introduces the `myrtps` transport and sets *`[transport] transport_type=rtps_udp`*. All other items remain the same.

```
[common]
DCPSGlobalTransportConfig=myconfig

[config/myconfig]
transports=myrtps

[transport/myrtps]
transport_type=rtps_udp
local_address=myhost
```

To extend our examples to a mixed transport configuration as shown in *Using Mixed Transports*, below shows the use of an `rtps_udp` transport mixed with a *TCP Transport* transport. The interesting pattern that this allows for is a deployed OpenDDS application that can be, for example, communicating using `tcp` with other OpenDDS participants while communicating in an interoperability configuration with a non-OpenDDS participant using `rtps_udp`.

```
[common]
DCPSGlobalTransportConfig=myconfig

[config/myconfig]
transports=mytcp,myrtps

[transport/myrtps]
transport_type=rtps_udp

[transport/mytcp]
transport_type=tcp
```

Some implementation notes related to using the `rtps_udp` transport protocol are as follows:

1. RTPS v2.3 8.7.2.2.7 WRITER_DATA_LIFECYCLE notes that the same Data sub-message should *dispose* and *unregister* an instance. OpenDDS may use two Data sub-messages.
2. RTPS UDP transport instances can not be shared by different Domain Participants. *Configuration templates* can be used to workaround this.
3. Transport auto-selection (negotiation) is partially supported with RTPS such that the `rtps_udp` transport goes through a handshaking phase only in reliable mode.

[transport/<inst_name>**] (rtps_udp)**

use_multicast=<boolean>

Config store key: TRANSPORT_<inst_name>_USE_MULTICAST
Default: 1 (enabled)

The `rtps_udp` transport can use Unicast or Multicast. When set to `0` (false) the transport uses Unicast, otherwise a value of `1` (true) will use Multicast.

multicast_group_address=<host>:<port>

Config store key: TRANSPORT_<inst_name>_MULTICAST_GROUP_ADDRESS
Default: 239.255.0.2:7401

When *use_multicast* is enabled, this is the multicast network address that should be used. If <port> is not specified for the network address, port 7401 will be used.

ipv6_multicast_group_address=<network_address>

Config store key: TRANSPORT_<inst_name>_IPV6_MULTICAST_GROUP_ADDRESS
Default: [FF03::2]:7401

When the transport is set to multicast, this is the multicast network address that should be used. If <port> is not specified for the network address, port 7401 will be used.

multicast_interface=<iface>

Config store key: TRANSPORT_<inst_name>_MULTICAST_INTERFACE
Default: *[common] DCPSDefaultAddress*

Specifies the network interface to be used by this transport instance. This uses a platform-specific format that identifies the network interface.

local_address=<addr>:[<port>]

Config store key: TRANSPORT_<inst_name>_LOCAL_ADDRESS
Default: *[common] DCPSDefaultAddress*

Bind the socket to the given address and port. Port can be omitted but the trailing : is required.

ipv6_local_address=<addr>:[<port>]

Config store key: TRANSPORT_<inst_name>_IPV6_LOCAL_ADDRESS
Default: *[common] DCPSDefaultAddress*

Bind the socket to the given address and port. Port can be omitted but the trailing : is required.

advertised_address=<addr>:[<port>]

Config store key: TRANSPORT_<inst_name>_ADVERTISED_ADDRESS

Sets the address advertised by the transport. Typically used when the participant is behind a firewall or NAT. Port can be omitted but the trailing `:` is required.

ipv6_advertised_address=<addr>:[<port>]

Config store key: TRANSPORT_<inst_name>_IPV6_ADVERTISED_ADDRESS

Sets the address advertised by the transport. Typically used when the participant is behind a firewall or NAT. Port can be omitted but the trailing `:` is required.

send_delay=<msec>

Config store key: TRANSPORT_<inst_name>_SEND_DELAY
Default: 10

Time in milliseconds for an RTPS Writer to wait before sending data.

nak_depth=<n>

Config store key: TRANSPORT_<inst_name>_NAK_DEPTH
Default: 32

The number of data samples to retain in order to service repair requests (reliable only).

nak_response_delay=<msec>

Config store key: TRANSPORT_<inst_name>_NAK_RESPONSE_DELAY
Default: 200

Protocol tuning parameter that allows the RTPS Writer to delay the response (expressed in milliseconds) to a request for data from a negative acknowledgment.

See RTPS v2.3 8.4.7.1 RTPS Writer for more information.

heartbeat_period=<msec>

Config store key: TRANSPORT_<inst_name>_HEARTBEAT_PERIOD
Default: 1000 (1 sec)

Protocol tuning parameter that specifies in milliseconds how often an RTPS Writer announces the availability of data.

See RTPS v2.3 8.4.7.1 RTPS Writer for more information.

ResponsiveMode=<boolean>

Config store key: TRANSPORT_<inst_name>_RESPONSIVE_MODE
Default: 0 (disabled)

Causes reliable writers and readers to send additional messages which may reduce latency.

max_message_size=<n>

Config store key: TRANSPORT_<inst_name>_MAX_MESSAGE_SIZE
Default: 65466 (maximum worst-case UDP payload size)

The maximum message size.

ttl=<n>

Config store key: TRANSPORT_<inst_name>_TTL
Default: 1 (all data is restricted to the local network)

The value of the time-to-live (TTL) field of any multicast datagrams sent. This value specifies the number of hops the datagram will traverse before being discarded by the network.

DataRtpsRelayAddress=<host>:<port>

Config store key: TRANSPORT_<inst_name>_DATA_RTPS_RELAY_ADDRESS

Specifies the address of the *RtpsRelay* for RTPS messages.

RtpsRelayOnly=<boolean>

Config store key: TRANSPORT_<inst_name>_RTPS_RELAY_ONLY
Default: 0

Only send RTPS message to the *RtpsRelay* (for debugging).

UseRtpsRelay=<boolean>

Config store key: TRANSPORT_<inst_name>_USE_RTPS_RELAY
Default: 0

Send messages to the *RtpsRelay*. Messages will only be sent if *DataRtpsRelayAddress* is set.

DataStunServerAddress=<host>:<port>

Config store key: TRANSPORT_<inst_name>_DATA_STUN_SERVER_ADDRESS

Specifies the address of the STUN server to use for RTPS when using *ICE*.

UseIce=<boolean>

Config store key: TRANSPORT_<inst_name>_USE_ICE
Default: 0

Enable or disable *ICE* for this transport instance.

Additional RTPS UDP Features

The RTPS UDP transport implementation has capabilities that can only be enabled by API. These features cannot be enabled using configuration files.

The `RtpsUdpInst` class has a method `count_messages(bool flag)` via inheritance from `TransportInst`. With `count_messages` enabled, the transport will track various counters and make them available to the application using the method `append_transport_statistics(TransportStatisticsSequence& seq)`. The elements of that sequence are defined in IDL: `OpenDDS::DCPS::TransportStatistics` and detailed in the tables below.

Table 3: `TransportStatistics`

Type	Name	Description
string	transport	The name of the transport.
MessageCount	message_cou	Set of message counts grouped by remote address. See the MessageCount table below.
GuidCountSe	writer_rese	Map of counts indicating how many times a local writer has resent a data sample. Each element in the sequence is a structure containing a GUID and a count.
GuidCountSe	reader_nack	Map of counts indicating how many times a local reader has requested a sample to be resent.

Table 4: `MessageCount`

Type	Name	Description
Locator_t	locator	A byte array containing an IPv4 or IPv6 address.
MessageCountKin	kind	Key indicating the type of message count for transports that use multiple protocols.
boolean	relay	Indicates that the locator is a relay.
uint32	send_count	Number of messages sent to the locator.
uint32	send_bytes	Number of bytes sent to the locator.
uint32	send_fail_coun	Number of sends directed at the locator that failed.
uint32	send_fail_byte	Number of bytes directed at the locator that failed.
uint32	recv_count	Number of messages received from the locator.
uint32	recv_bytes	Number of bytes received from the locator.

Shared Memory Transport Configuration Properties

This section describes the configuration properties for the *Shared Memory Transport*. This transport type is supported Unix-like platforms with POSIX/XSI shared memory and on Windows platforms. The shared memory transport type can only provide communication between transport instances on the same host. As part of *transport negotiation*, if there are multiple transport instances available for communication between hosts, the shared memory transport instances will be skipped so that other types can be used.

`[transport/<inst_name>] (shmem)`

pool_size=<bytes>

Config store key: `TRANSPORT_<inst_name>_POOL_SIZE`
Default: `16777216` (16 MiB)

The size of the single shared-memory pool allocated.

datalink_control_size=<bytes>

Config store key: `TRANSPORT_<inst_name>_DATALINK_CONTROL_SIZE`
Default: `4096` (4 KiB)

The size of the control area allocated for each data link. This allocation comes out of the shared-memory pool defined by *pool_size*.

host_name=<host>

Config store key: `TRANSPORT_<inst_name>_HOST_NAME`
Default: Uses fully qualified domain name

Override the host name used to identify the host machine.

2.12.5 ICE Configuration

The *[ice]* section of an OpenDDS configuration file contains settings for the ICE Agent. See *Interactive Connectivity Establishment (ICE) for RTPS* for details about OpenDDS's implementation of ICE. A sample `[ice]` section follows:

```
[ice]
Ta=50
ConnectivityCheckTTL=300
ChecklistPeriod=10
IndicationPeriod=15
NominatedTTL=300
ServerReflexiveAddressPeriod=30
ServerReflexiveIndicationCount=10
DeferredTriggeredCheckTTL=300
ChangePasswordPeriod=300
```

`[ice]`

Ta=<msec>

Config store key: ICE_TA
Default: 50

Minimum interval between ICE sends.

ConnectivityCheckTTL=<sec>

Config store key: ICE_CONNECTIVITY_CHECK_TTL
Default: 300 (5 minutes)

Maximum duration of connectivity check.

ChecklistPeriod=<sec>

Config store key: ICE_CHECKLIST_PERIOD
Default: 10

Attempt to cycle through all of the connectivity checks for a candidate in this amount of time.

IndicationPeriod=<sec>

Config store key: ICE_INDICATION_PERIOD
Default: 15

Send STUN indications to peers to maintain NAT bindings at this period.

NominatedTTL=<sec>

Config store key: ICE_NOMINATED_TTL
Default: 300 (5 minutes)

Forget a valid candidate if an indication is not received in this amount of time.

ServerReflexiveAddressPeriod=<sec>

Config store key: ICE_SERVER_REFLEXIVE_ADDRESS_PERIOD
Default: 30

Send a messages to the STUN server at this period.

ServerReflexiveIndicationCount=<integer>

Config store key: ICE_SERVER_REFLEXIVE_INDICATION_COUNT
Default: 10

Send this many indications before sending a new binding request to the STUN server.

DeferredTriggeredCheckTTL=<sec>

Config store key: ICE_DEFERRED_TRIGGERED_CHECK_TTL
Default: 300 (5 minutes)

Purge deferred checks after this amount of time.

ChangePasswordPeriod=<sec>

Config store key: ICE_CHANGE_PASSWORD_PERIOD
Default: 300 (5 minutes)

Change the ICE password after this amount of time.

2.12.6 Discovery and Transport Configuration Templates

OpenDDS supports dynamic configuration of *RTPS Discovery* and *Transports* by means of configuration templates in OpenDDS configuration files. This feature adds 3 optional file sections, *[DomainRange]*, *[Customization]*, and *[transport_template]*. Configuration templates are processed at application startup; however, creation of domain, discovery, and transport objects is deferred until a participant is created in a corresponding domain.

Without templates an OpenDDS application with participants using RTPS discovery in 5 different domains will have a configuration file with 5 separate, but nearly identical, *[domain]* sections. The same functionality can be accomplished with a single [DomainRange/1-5] section using templates.

Configuring Discovery for a Set of Similar Domains

[**DomainRange**/<minimum_domain_id>-<maximum_domain_id>]

Domain ranges must have a minimum and maximum domain, such as [DomainRange/1-5]. *[DomainRange]* sections are templates for the *[domain]* sections and accept all [domain] configuration properties and the following configuration properties:

DiscoveryTemplate=<rtps_discovery_inst_name>

Config store key:
DOMAIN_RANGE_<minimum_domain_id>-<maximum_domain_id>_DISCOVERY_TEMPLATE
Required

Domain ranges uses this rather than the *[domain] DiscoveryConfig* property to denote the corresponding *[rtps_discovery]* section.

Customization=<customization_name>

Config store key: DOMAIN_RANGE_<minimum_domain_id>-<maximum_domain_id>_CUSTOMIZATION

Use this *[Customization]* section.

See *Example Configuration File* for a [DomainRange] example.

Configuring a Set of Similar Transports

[**transport_template**/<template_name>]

[transport_template] sections are templates for the *[transport]* sections and accept all [transport] configuration properties and the following configuration properties:

instantiation_rule=|per_participant

Config store key: TRANSPORT_TEMPLATE_<template_name>_INSTANTIATION_RULE

Default: (empty string, a transport instance is created for each domain)

per_participant

A separate *transport instance* will be created for each *DomainParticipant*. This allows applications to have multiple participants per domain when using *RTPS Discovery*.

Customization=<customization_name>

Config store key: TRANSPORT_TEMPLATE_<template_name>_CUSTOMIZATION

Use this *[Customization]* section.

To associate a transport template with a domain range in a configuration file, set the *[common] DCPSGlobalTransportConfig* property to the name of the *[config]* whose *[config] transports* property is the name of the *[transport_template]*. For example, for a global config setting:

```
[common]
DCPSGlobalTransportConfig=primary_config
```

a corresponding config could be:

```
[config/primary_config]
transports=auto_config_rtps
```

and the partial transport template would be:

```
[transport_template/auto_config_rtps]
transport_type=rtps_udp
```

Domain participants that belong to a domain that is configured by a template can bind to non-global transport configurations using the `bind_config` function. See *Using Multiple Configurations* for a discussion of `bind_config`.

If *[transport_template] instantiation_rule=per_participant*, a separate transport instance will be created for each participant in the domain.

See *Example Configuration File* for a `[transport_template]` example.

Adding Customizations

`[Customization/<customization_name>]`

This section can be used to modify values based the on the domain ID so they are unique for each domain.

multicast_group_address=|add_domain_id_to_ip_addr|add_domain_id_to_port

Config store key: CUSTOMIZATION_<customization_name>_MULTICAST_GROUP_ADDRESS
Default: (empty string, not modified)

Modifies *[transport] multicast_group_address (rtps_udp)*.

add_domain_id_to_ip_addr
Adds the domain ID to the last octet of the multicast group address.

add_domain_id_to_port
Use the domain ID in the port calculation for the multicast group address.

InteropMulticastOverride=|AddDomainId

Config store key: CUSTOMIZATION_<customization_name>_INTEROP_MULTICAST_OVERRIDE
Default: (empty string, not modified)

Modifies *[rtps_discovery] InteropMulticastOverride*.

AddDomainId
Adds the domain id to the last octet of the multicast address used for SPDP.

Example Configuration File

The following is an example configuration file for domains 2 through 10. It includes customizations to add the domain ID to *[rtps_discovery] InteropMulticastOverride* and *[transport] multicast_group_address (rtps_udp)*.

```
[common]
DCPSGlobalTransportConfig=the_config

[DomainRange/2-10]
DiscoveryTemplate=DiscoveryConfigTemplate

[Customization/discovery_customization]
InteropMulticastOverride=AddDomainId
```

(continues on next page)

(continued from previous page)

```
[Customization/transport_customization]
multicast_group_address=add_domain_id_to_ip_addr,add_domain_id_to_port

[rtps_discovery/DiscoveryConfigTemplate]
InteropMulticastOverride=239.255.4.0
Customization=discovery_customization
SedpMulticast=1

[config/the_config]
transports=auto_config_rtps

[transport_template/auto_config_rtps]
transport_type=rtps_udp
instantiation_rule=per_participant
Customization=transport_customization
multicast_group_address=239.255.2.0
```

2.12.7 Logging

By default, the OpenDDS framework will only log serious errors and warnings that can't be conveyed to the user in the API. An OpenDDS user may increase the amount of logging via the log level and debug logging via controls at the DCPS, Transport, or Security layers.

The default destination of these log messages is the process's standard error stream. See *Common Configuration Properties* for options controlling the destination and formatting of log messages.

The highest level logging is controlled by the general log levels listed in the following table.

Table 5: :header-rows: 1

Level	Values	Description
N/A	*[common] DCPSLogLevel=none* `log_level: LogLevel::None` `ACE_Log_Priority`: N/A	Disables all logging.
Error	*[common] DCPSLogLevel=error* `log_level: LogLevel::Error` `ACE_Log_Priority: LM_ERROR`	Logs issues that may prevent OpenDDS from functioning properly or functioning as configured.
Warning	*[common] DCPSLogLevel=warning* `log_level: LogLevel::Warning` `ACE_Log_Priority: LM_WARNING`	Log issues that should probably be addressed, but don't prevent OpenDDS from functioning. This is the default.
Notice	*[common] DCPSLogLevel=notice* `log_level: LogLevel::Notice` `ACE_Log_Priority: LM_NOTICE`	Logs details of issues that are returned to the user via the API, for example through a `DDS::ReturnCode_t`.
Info	*[common] DCPSLogLevel=info* `log_level: LogLevel::Info` `ACE_Log_Priority: LM_INFO`	Logs a small amount of basic information, such as the version of OpenDDS being used.
Debug	*[common] DCPSLogLevel=debug* `log_level: LogLevel::Debug` `ACE_Log_Priority: LM_DEBUG`	This level doesn't directly control any logging but will enable at least DCPS and security debug level 1. For backwards compatibility, setting *DCPS debug logging* to greater than zero will set this log level. Setting the log level to below this level will disable all debug logging.

The log level can be set a number of ways. To do it with command line arguments, pass:

```
-DCPSLogLevel notice
```

Using a configuration file option is similar:

```
[common]
DCPSLogLevel=notice
```

Doing this from code can be done using an enumerator or a string:

```
OpenDDS::DCPS::log_level.set(OpenDDS::DCPS::LogLevel::Notice);
OpenDDS::DCPS::log_level.set_from_string("notice");
```

Passing invalid levels to the text-based methods will cause warning messages to be logged unconditionally, but will not

cause the `DomainParticipantFactory` to fail to initialize.

DCPS Layer Debug Logging

Debug logging in the DCPS layer of OpenDDS is controlled by the *[common] DCPSDebugLevel* configuration option and command-line option. It can also be set in application code using:

```
OpenDDS::DCPS::set_DCPS_debug_level(level)
```

The *level* defaults to a value of 0 and has values of 0 to 10 as defined below:

- 0 – debug logging is disabled
- 1 – logs that should happen once per process
- 2 – logs that should happen once per DDS entity
- 4 – logs that are related to administrative interfaces
- 6 – logs that should happen every Nth sample write/read
- 8 – logs that should happen once per sample write/read
- 10 – logs that may happen more than once per sample write/read

Transport Layer Debug Logging

OpenDDS transport debug layer logging is controlled via the *[common] DCPSTransportDebugLevel* configuration option. For example, to add transport layer logging to any OpenDDS application that uses `TheParticipantFactoryWithArgs`, add the following option to the command line:

```
-DCPSTransportDebugLevel level
```

The transport layer logging level can also be configured by setting the variable:

```
OpenDDS::DCPS::Transport_debug_level = level;
```

Valid transport logging levels range from 0 to 5 with increasing verbosity of output.

Note: Transport logging level 6 is available to generate system trace logs. Using this level is not recommended as the amount of data generated can be overwhelming and is mostly of interest only to OpenDDS developers. Setting the logging level to 6 requires defining the `DDS_BLD_DEBUG_LEVEL` macro to 6 and rebuilding OpenDDS.

There are additional debug logging options available through the `transport_debug` object that are separate from the logging controlled by the transport debug level. For the moment this can only be configured using C++; for example:

```
OpenDDS::DCPS::transport_debug.log_progress = true;
```

Table 6: Transport Debug Logging Categories

Option	Description
log_progress	Log progress for RTPS entity discovery and association.
log_dropped_mes	Log received RTPS messages that were dropped.
log_nonfinal_me	Log non-final RTPS messages send or received. Useful to gauge lost messages and resends.
log_fragment_st	Log fragment reassembly process for transports where that applies. Also logged when the transport debug level is set to the most verbose.
log_remote_coun	Log number of associations and pending associations of RTPS entities.

Security Debug Logging

When OpenDDS is compiled with security enabled, debug logging for security can be enabled using *[common] DCPSSecurityDebug*. Security logging is divided into categories, although *[common] DCPSSecurityDebugLevel* is also provided, which controls the categories in a similar manner and using the same scale as *[common] DCPSDebugLevel*.

Table 7: Security Debug Logging Categories

Option	Debug Level	Description
N/A	0	The default. Security related messages are not logged.
access_erro	1	Log errors from permission and governance file parsing.
new_entity_	1	Log security-related errors that prevented a DDS entity from being created.
cleanup_err	1	Log errors from cleaning up DDS entities in the security plugins.
access_warn	2	Log warnings from permission and governance file parsing.
auth_warn	3	Log warnings from the authentication and handshake that happen when two secure participants discover each other.
encdec_erro	3	Log errors from the encryption and decryption of RTPS messages.
new_entity_	3	Log security-related warnings from creating a DDS entity.
bookkeeping	4	Log generation of crypto handles and keys for local DDS entities and tracking crypto handles and keys for remote DDS entities.
auth_debug	4	Log debug information from the authentication and handshake that happen when two secure participants discover each other.
encdec_warn	4	Log warnings from the encryption and decryption of RTPS messages.
encdec_debu	8	Log debug information from the encryption and decryption of RTPS messages.
showkeys	9	Log the whole key when generating it, receiving it, and using it.
chlookup	10	Very verbosely prints the steps being taken when looking up a crypto handle for decrypting. This is most useful to see what keys a participant has.
all	10	Enable all the security related logging.

Categories are passed to `DCPSSecurityDebug` using a comma limited list:

```
-DCPSSecurityDebug=access_warn,showkeys
```

Unknown categories will cause warning messages, but will not cause the `DomainParticipantFactory` to fail to initialize.

Like the other debug levels, security logging can also be programmatically configured. All the following are equivalent:

```
OpenDDS::DCPS::security_debug.access_warn = true;
OpenDDS::DCPS::security_debug.set_debug_level(1);
OpenDDS::DCPS::security_debug.parse_flags(ACE_TEXT("access_warn"));
```

2.13 opendds_idl

`opendds_idl` is one of the code generators used in the process of building OpenDDS and OpenDDS applications. It can be used in a number of different ways to customize how source code is generated from *IDL* files. See *Processing the IDL* for an overview of the default usage pattern.

The OpenDDS IDL compiler is invoked using the `opendds_idl` executable, located in `bin/` (on the `PATH`). It parses a single IDL file and generates the serialization and key support code that OpenDDS requires to marshal and demarshal the types described in the IDL file, as well as the type support code for the data readers and writers. For each IDL file processed, such as `xyz.idl`, it generates three files: `xyzTypeSupport.idl`, `xyzTypeSupportImpl.h`, and `xyzTypeSupportImpl.cpp`. In the typical usage, `opendds_idl` is passed a number of options and the IDL file name as a parameter. For example,

```
opendds_idl [options...] Foo.idl
```

Subsequent sections describe all of the command-line options and the ways that `opendds_idl` can be used to generate alternate mappings.

2.13.1 opendds_idl Command Line Options

`--help, -h`
: Prints a help message and exits.

`-v`
: Enables verbose/debug logging.

`--version, -V`
: Prints version numbers of both TAO and OpenDDS.

`--idl-version` `VERSION`
: Set the version of the *IDL specification* to use. The default is `4`.

`--list-idl-versions`
: List the versions of IDL at least partially supported and exits.

`--syntax-only`
: Just check syntax of input files and exit without generating any code.

`-Wb,export_macro``=MACRO`
: Use the export macro for generating C++ implementation code named *MACRO*. By default export macros are not used. `--export` is an alias for this.

`-Wb,export_include``=FILE`
: Add an additional header *FILE* to `#include` in generated code that has the export macro.

`-Wb,pch_include``=FILE`
: Include a pre-compiled header *FILE* in generated C++ files.

-Dname[=value]

Define a preprocessor macro named *name* optionally with value *value* for IDL.

-Idir

Adds *dir* to the preprocessor include path for IDL.

-o OUTPUT_PATH

Output directory where generated files are put. By default this is the current working directory.

-Wb,java

Generate Java Bindings for generated `TypeSupport` implementation classes. See *Java Bindings* for more information.

-Gitl

Generate "Intermediate Type Language" descriptions of topic types. These files are used by the Wireshark dissector or other external applications.

-GfaceTS

Generate FACE (Future Airborne Capability Environment) Transport Services API. See *Safety Profile* for more information.

-Gv8

Generate type support for converting data samples to/from V8 JavaScript objects `-Wb,v8` is an alias for this.

-Gxtypes-complete

Generate complete XTypes TypeObjects which can be used to provide type information to applications that don't have compile-time knowledge of the IDL. By default only minimal TypeObjects are generated. See *Dynamic Language Binding* for more information.

-Gequality

Generate == and != for structs and unions. The members of the struct or union must have a type that could appear in a DDS topic and be supported by `opendds_idl`.

-Lface

Generates IDL-to-C++ mapping for FACE. See *Safety Profile* for more information.

-Lspcpp

Generates IDL-to-C++ mapping for *Safety Profile*.

-Lc++11

Generates *IDL-to-C++11 mapping*.

-Wb,tao_include_prefix=S

Prefix the string *S* to `#include` directives meant to include headers generated by `tao_idl`.

-St

Suppress generation of IDL TypeCodes when one of the `-L` options are present.

--unknown-annotations REACTION

Control the reaction to unknown IDL annotations. *REACTION* can be:

- `warn-once` – the default, warn once per annotation with the same name.
- `warn-all` – warn for every use of an unknown annotation.
- `error` – similar to `warn-all`, but causes the compiler to exit with an error status when finished.
- `ignore` – ignore all unknown annotations.

`--no-dcps-data-type-warnings`

Don't warn about `#pragma DCPS_DATA_TYPE`. See *Identifying Topic Types* for more information.

`--[no-]default-nested`

Un-annotated types/modules are treated as nested. By default all types are nested by default See *Topic Types vs. Nested Types* for details.

`--default-extensibility EXT`

Set the *default XTypes extensibility*. *EXT* can be:

- `final`
- `appendable` (default)
- `mutable`

`--default-autoid VALUE`

Set the default *XTypes auto member-id assignment strategy*. *VALUE* can be `sequential` (the default) or `hash`.

`--default-try-construct VALUE`

Set the default *XTypes try-construct strategy*. *VALUE* can be `discard` (the default), `use-default`, or `trim`.

`--old-typeobject-encoding`

New in version 3.18.

Use the pre-3.18 encoding of `TypeObject`s when deriving `TypeIdentifier`s.

`--default-enum-extensibility-zero`

New in version 3.22.

Do not set the type flags for enums. This flag is for simulating the behavior of OpenDDS before 3.22.

`--old-typeobject-member-order`

New in version 3.24.

Use the pre-3.24 struct and union member order for `TypeObject`s, which is ordered by member id instead of declared order. See *3.24.0 news entry* for more info.

The code generation options allow the application developer to use the generated code in a wide variety of environments. Since IDL may contain preprocessing directives (`#include`, `#define`, etc.), the C++ preprocessor is invoked by `opendds_idl`. The `-I` and `-D` options allow customization of the preprocessing step. The `-Wb,export_macro` option lets you add an export macro to your class definitions. This is required if the generated code is going to reside in a shared library and the compiler (such as Visual C++ or GCC) uses the export macro (`dllexport` on Visual C++ / overriding hidden visibility on GCC). The `-Wb,pch_include` option is required if the generated implementation code is to be used in a project that uses precompiled headers.

2.13.2 Using the IDL-to-C++11 Mapping

The *IDL-to-C++11 Mapping* is a separate specification from the OMG. Like the "classic" IDL-to-C++ Mapping, IDL-to-C++11 describes how IDL constructs (structs, sequences, unions, etc.) should appear in C++. Since the IDL-to-C++11 Mapping assumes a C++11 (or higher) compiler and standard library, the code generated is easier to use and looks more natural to C++ developers who are not familiar with the classic mapping. For example, IDL strings, arrays, and sequences map to their equivalents in the `std` namespace: `string`, `array`, and `vector`. All of the details of the mapping are spelled out in the specification document (available at https://www.omg.org/spec/CPP11), however the easiest way to get started with the mapping is to generate code from IDL and examine the generated header file.

In the default mode of `opendds_idl` (as described in *Processing the IDL*), responsibility for generating the language mapping is delegated to `tao_idl` (using the IDL-to-C++ classic mapping). In this case, `opendds_idl` is only responsible for generating the OpenDDS-specific additions such as `TypeSupport.idl` and the marshal/demarshal functions.

Contrast this with using `opendds_idl` for IDL-to-C++11. In this case, `opendds_idl` takes over responsibility for generating the language mapping. This is indicated by the `-Lc++11` command-line option.

Starting with a user-written file `Foo.idl`, running `opendds_idl -Lc++11 <other options> Foo.idl` generates these output files:

- `FooTypeSupport.idl`
  - IDL local interfaces for `*TypeSupport`, `*DataWriter`, `*DataReader`
- `FooC.h`
  - IDL-to-C++11 language mapping
- `FooTypeSupportImpl.h and .cpp`
  - Additional source code needed for OpenDDS

FooTypeSupport.idl is the same as it was when using the classic mapping. After it's generated by `opendds_idl`, it needs to be processed by `tao_idl` to generate `FooTypeSupportC.h`, `FooTypeSupportC.inl`, and `FooTypeSupportC.cpp`.

Unlike when using the classic mapping, `Foo.idl` is not processed by `tao_idl`.

`Foo.idl` can contain the following IDL features:

- modules, typedefs, and constants
- basic types
- constructed types: enums, structs and unions
  - Note that setting a union value through a modifier method automatically sets the discriminator. In cases where there are multiple possible values for the discriminator, a 2-argument modifier method is provided. Using this is preferred to using `_d()`.
  - If you chose to use the `_d()` method of the generated union types, take note that it can only be used to set a value that selects the same union member as the one that's currently selected. OpenDDS treats this as a precondition (it is not checked within the implementation).
- strings (narrow and wide), sequences, and arrays
  - Bounded strings and sequences are supported, but bounds checks are not currently enforced. Due to this limitation, distinct types are not used for bounded instantiations.
- annotations – see *Defining Data Types with IDL* and *IDL Annotations*
- `#include`s of IDL files that are also used with the IDL-to-C++11 mapping

When using MPC to generate projects, the `opendds_cxx11` base project should be used to inherit the correct settings for code generation. If the generated code will be part of a shared library, use the `-Wb,export_include` option (in addition to `-Wb,export_macro`) so that the generated headers have an `#include` for the export header.

When using CMake to generate projects, see *Using OpenDDS in a CMake Project*.

2.14 The DCPS Information Repository

The DCPS Information Repository is a non-interoperable and OpenDDS-specific service to distribute discovery information. See *Configuring for RTPS Discovery* for interoperable discovery. The DCPS Information Repository is scheduled for deprecation with OpenDDS 4 and scheduled for removal with OpenDDS 5.

There is no interoperability guarantee between multiple OpenDDS releases when you are using the DCPS Information Repository. All applications using a specific DCPS Information Repository must use the same OpenDDS release as that DCPS Information Repository.

2.14.1 DCPS Information Repository Options

The table below shows the command line options for the `DCPSInfoRepo` server:

Table 8: DCPS Information Repository Options

Option	Description	Default
`-o file`	Write the IOR of the `DCPSInfo` object to the specified file	`repo.ior`
`-NOBITS`	Disable the publication of built-in topics	Built-in topics are published
`-a address`	Listening address for built-in topics (when built-in topics are published).	Random port
`-z`	Turn on verbose transport logging	Minimal transport logging.
`-r`	Resurrect from persistent file	1 (true)
`-Federatio <id>`	Unique identifier for this repository within any federation. This is supplied as a 32 bit decimal numeric value.	N/A
`-FederateW <ref>`	Repository federation reference at which to join a federation. This is supplied as a valid CORBA object reference in string form: stringified IOR, file: or corbaloc: reference string.	N/A
`-?`	Display the command line usage and exit	N/A

OpenDDS clients often use the IOR file that `DCPSInfoRepo` outputs to locate the service. The `-o` option allows you to place the IOR file into an application-specific directory or file name. This file can subsequently be used by clients with the `file://` IOR prefix.

Applications that do not use built-in topics may want to disable them with `-NOBITS` to reduce the load on the server. If you are publishing the built-in topics, then the `-a` option lets you pick the listen address of the tcp transport that is used for these topics.

Using the `-z` option causes the invocation of many transport-level debug messages. This option is only effective when the DCPS library is built with the `DCPS_TRANS_VERBOSE_DEBUG` environment variable defined.

The `-FederationId` and `-FederateWith` options are used to control the federation of multiple `DCPSInfoRepo` servers into a single logical repository. See *Repository Federation* for descriptions of the federation capabilities and how to use these options.

File persistence is implemented as an ACE Service object and is controlled via service config directives. Currently available configuration options are:

Table 9: InfoRepo persistence directives

Options	Description	Defaults
`-file`	Name of the persistent file	`InforepoPersist`
`-reset`	Wipe out old persistent data.	`0` (false)

The following directive:

```
static PersistenceUpdater_Static_Service "-file info.pr -reset 1"
```

will persist `DCPSInfoRepo` updates to local file `info.pr`. If a file by that name already exists, its contents will be erased. Used with the command-line option `-r`, the `DCPSInfoRepo` can be reincarnated to a prior state. When using persistence, start the `DCPSInfoRepo` process using a TCP fixed port number with the following command line option. This allows existing clients to reconnect to a restarted InfoRepo.

```
-ORBListenEndpoints iiop://:<port>
```

2.14.2 Repository Federation

Note: Repository federation should be considered an experimental feature.

Repository Federation allows multiple DCPS Information Repository servers to collaborate with one another into a single federated service. This allows applications obtaining service metadata and events from one repository to obtain them from another if the original repository is no longer available.

While the motivation to create this feature was the ability to provide a measure of fault tolerance to the DDS service metadata, other use cases can benefit from this feature as well. This includes the ability of initially separate systems to become federated and gain the ability to pass data between applications that were not originally reachable. An example of this would include two platforms which have independently established internal DDS services passing data between applications; at some point during operation the systems become reachable to each other and federating repositories allows data to pass between applications on the different platforms.

The current federation capabilities in OpenDDS provide only the ability to statically specify a federation of repositories at startup of applications and repositories. A mechanism to dynamically discover and join a federation is planned for a future OpenDDS release.

OpenDDS automatically detects the loss of a repository by using the *Liveliness QoS* policy on a Built-in Topic. When a federation is used, the liveliness QoS policy is modified to a non-infinite value. When liveliness is lost for a Built-in Topic an application will initiate a failover sequence causing it to associate with a different repository server. Because the federation implementation currently uses a Built-in Topic `ParticipantDataDataReaderListener` entity, applications should not install their own listeners for this topic. Doing so would affect the federation implementation's capability to detect repository failures.

The federation implementation distributes repository data within the federation using a reserved DDS domain. The default domain used for federation is defined by the constant `Federator::DEFAULT_FEDERATIONDOMAIN`.

Currently only static specification of federation topology is available. This means that each DCPS Information Repository, as well as each application using a federated DDS service, needs to include federation configuration as part of its configuration data. This is done by specifying each available repository within the federation to each participating process and assigning each repository to a different key value in the configuration files as described in *Configuring for Multiple DCPSInfoRepo Instances*.

Each application and repository must include the same set of repositories in its configuration information. Failover sequencing will attempt to reach the next repository in numeric sequence (wrapping from the last to the first) of the

repository key values. This sequence is unique to each application configured, and should be different to avoid overloading any individual repository.

Once the topology information has been specified, then repositories will need to be started with two additional command line arguments. These are shown in *DCPS Information Repository Options*. One, `-FederationId <value>`, specifies the unique identifier for a repository within the federation. This is a 32 bit numeric value and needs to be unique for all possible federation topologies.

The second command line argument required is `-FederateWith <ref>`. This causes the repository to join a federation at the <ref> object reference after initialization and before accepting connections from applications.

Only repositories which are started with a federation identification number may participate in a federation. The first repository started should not be given a `-FederateWith` command line directive. All others are required to have this directive in order to establish the initial federation. There is a command line tool (`federation`) supplied that can be used to establish federation associations if this is not done at startup. See *Federation Management* for a description. It is possible, with the current static-only implementation, that the failure of a repository before a federation topology is entirely established could result in a partially unusable service. Due to this current limitation, it is highly recommended to always establish the federation topology of repositories prior to starting the applications.

Federation Management

A new command line tool has been provided to allow some minimal run-time management of repository federation. This tool allows repositories started without the `-FederateWith` option to be commanded to participate in a federation. Since the operation of the federated repositories and failover sequencing depends on the presence of connected topology, it is recommended that this tool be used before starting applications that will be using the federated set of repositories.

The command is named `repoctl` and is located in the `bin/` directory. It has a command format syntax of:

```
repoctl <cmd> <arguments>
```

Some options contain endpoint information. This information consists of an optional host specification, separated from a required port specification by a colon. This endpoint information is used to create a CORBA object reference using the corbaloc: syntax in order to locate the 'Federator' object of the repository server.

Table 10: repoctl Repository Management Command

Com-manc	Syntax	Description
join	repoctl join <target> <peer> [<federation domain>]	Calls the <peer> to join <target> to the federation. <federation domain> is passed if present, or the default Federation Domain value is passed.
leave	repoctl leave <target>	Causes the <target> to gracefully leave the federation, removing all managed associations between applications using <target> as a repository with applications that are not using <target> as a repository.
shutc	repoctl shutdown <target>	Causes the <target> to shutdown without removing any managed associations. This is the same effect as a repository which has crashed during operation.
kill	repoctl kill <target>	Kills the <target> repository regardless of its federation status.
help	repoctl help	Prints a usage message and quits.

A join command specifies two repository servers (by endpoint) and asks the second to join the first in a federation:

```
repoctl join 2112 otherhost:1812
```

This generates a CORBA object reference of `corbaloc::otherhost:1812/Federator` that the federator connects to and invokes a join operation. The join operation invocation passes the default Federation Domain value (because we did not specify one) and the location of the joining repository which is obtained by resolving the object reference `corbaloc::localhost:2112/Federator`.

Table 11: Federation Management Command Arguments

Option	Description
<target>	This is endpoint information that can be used to locate the `Federator::Manager` CORBA interface of a repository which is used to manage federation behavior. This is used to command leave and shutdown federation operations and to identify the joining repository for the join command.
<peer>	This is endpoint information that can be used to locate the `Federator::Manager` CORBA interface of a repository which is used to manage federation behavior. This is used to command join federation operations.
<federation domain>	This is the domain specification used by federation participants to distribute service metadata amongst the federated repositories. This only needs to be specified if more than one federation exists among the same set of repositories, which is currently not supported. The default domain is sufficient for single federations.

Federation Example

To illustrate the setup and use of a federation, this section walks through a simple example that establishes a federation and a working service that uses it.

This example is based on a two repository federation, with the simple Message publisher and subscriber from *Using DCPS* configured to use the federated repositories.

Configuring the Federation Example

There are two configuration files to create for this example one each for the message publisher and subscriber.

The Message Publisher configuration `pub.ini` for this example is as follows:

```
[common]
DCPSDebugLevel=0

[domain/information]
DomainId=42
DomainRepoKey=1

[repository/primary]
RepositoryKey=1
RepositoryIor=corbaloc::localhost:2112/InfoRepo

[repository/secondary]
RepositoryKey=2
RepositoryIor=file://repo.ior
```

Note that the `DCPSInfo` attribute/value pair has been omitted from the `[common]` section. The user domain is 42, so that domain is configured to use the primary repository for service metadata and events.

The `[repository/primary]` and `[repository/secondary]` sections define the primary and secondary repositories to use within the federation (of two repositories) for this application. The `RepositoryKey` attribute is an internal

key value used to uniquely identify the repository (and allow the domain to be associated with it, as in the preceding `[domain/information]` section). The `RepositoryIor` attributes contain string values of resolvable object references to reach the specified repository. The primary repository is referenced at port 2112 of the `localhost` and is expected to be available via the TAO `IORTable` with an object name of `/InfoRepo`. The secondary repository is expected to provide an IOR value via a file named `repo.ior` in the local directory.

The subscriber process is configured with the `sub.ini` file as follows:

```
[common]
DCPSDebugLevel=0

[domain/information]
DomainId=42
DomainRepoKey=1

[repository/primary]
RepositoryKey=1
RepositoryIor=file://repo.ior

[repository/secondary]
RepositoryKey=2
RepositoryIor=corbaloc::localhost:2112/InfoRepo
```

Note that this is the same as the `pub.ini` file except the subscriber has specified that the repository located at port 2112 of the `localhost` is the secondary and the repository located by the `repo.ior` file is the primary. This is opposite of the assignment for the publisher. It means that the publisher is started using the repository at port 2112 for metadata and events while the subscriber is started using the repository located by the IOR contained in the file. In each case, if a repository is detected as unavailable the application will attempt to use the other repository if it can be reached.

The repositories do not need any special configuration specifications in order to participate in federation, and so no files are required for them in this example.

Running the Federation Example

The example is executed by first starting the repositories and federating them, then starting the application publisher and subscriber processes the same way as was done in the example of *Running the Example*.

Start the first repository as:

```
$DDS/bin/DCPSInfoRepo -o repo.ior -FederationId 1024
```

The `-o repo.ior` option ensures that the repository IOR will be placed into the file as expected by the configuration files. The `-FederationId 1024` option assigns the value 1024 to this repository as its unique id within the federation.

Start the second repository as:

```
$DDS/bin/DCPSInfoRepo \
  -ORBListenEndpoints iiop://localhost:2112 \
  -FederationId 2048 -FederateWith file://repo.ior
```

Note that this is all intended to be on a single command line. The `-ORBListenEndpoints iiop://localhost:2112` option ensures that the repository will be listening on the port that the previous configuration files are expecting. The `-FederationId 2048` option assigns the value 2048 as the repositories unique id within the federation. The `-FederateWith file://repo.ior` option initiates federation with the repository located at the IOR contained within the named file - which was written by the previously started repository.

Once the repositories have been started and federation has been established (this will be done automatically after the second repository has initialized), the application publisher and subscriber processes can be started and should execute as they did for the previous example in *Running the Example*.

2.15 Java Bindings

2.15.1 Introduction

OpenDDS provides JNI bindings. Java applications can make use of the complete OpenDDS middleware just like C++ applications.

See the `java/INSTALL` file for information on getting started, including the prerequisites and dependencies.

Java versions 9 and up use the Java Platform Module System. To use OpenDDS with one of these Java versions, set the MPC feature java_pre_jpms to 0. OpenDDS's configure script will attempt to detect the Java version and set this automatically.

See the `java/FAQ` file for information on common issues encountered while developing applications with the Java bindings.

2.15.2 IDL and Code Generation

The OpenDDS Java binding is more than just a library that lives in one or two .jar files. The DDS specification defines the interaction between a DDS application and the DDS middleware. In particular, DDS applications send and receive messages that are strongly-typed and those types are defined by the application developer in IDL.

In order for the application to interact with the middleware in terms of these user-defined types, code must be generated at compile-time based on this IDL. C++, Java, and even some additional IDL code is generated. In most cases, application developers do not need to be concerned with the details of all the generated files. Scripts included with OpenDDS automate this process so that the end result is a native library (`.so` or `.dll`) and a Java library (`.jar` or just a `classes` directory) that together contain all of the generated code.

Below is a description of the generated files and which tools generate them. In this example, `Foo.idl` contains a single struct `Bar` contained in module `Baz` (IDL modules are similar to C++ namespaces and Java packages). To the right of each file name is the name of the tool that generates it, followed by some notes on its purpose.

Table 12: Generated files descriptions

File	Generation Tool
`Foo.idl`	Developer-written description of the DDS sample type
`Foo{C,S}.{h,inl,cpp}`	`tao_idl`: C++ representation of the IDL
`FooTypeSupport.idl`	`opendds_idl`: DDS type-specific interfaces
`FooTypeSupport{C,S}.{h,inl,cpp}`	`tao_idl`
`Baz/BarSeq{Helper,Holder}.java`	`idl2jni`
`Baz/BarData{Reader,Writer}*.java`	`idl2jni`
`Baz/BarTypeSupport*.java`	`idl2jni` (except TypeSupportImpl, see below)
`FooTypeSupportJC.{h,cpp}`	`idl2jni`: JNI native method implementations
`FooTypeSupportImpl.{h,cpp}`	`opendds_idl`: DDS type-specific C++ impl.
`Baz/BarTypeSupportImpl.java`	`opendds_idl`: DDS type-specific Java impl.
`Baz/Bar*.java`	`idl2jni`: Java representation of IDL struct
`FooJC.{h,cpp}`	`idl2jni`: JNI native method implementations

Foo.idl:

```
module Baz {
  @topic
  struct Bar {
    long x;
  };
};
```

2.15.3 Setting up an OpenDDS Java Project

These instructions assume you have completed the installation steps in the `java/INSTALL` document, including having the various environment variables defined.

1. Start with an empty directory that will be used for your IDL and the code generated from it. `java/tests/messenger/messenger_idl/` is set up this way.
2. Create an IDL file describing the data structure you will be using with OpenDDS. See `Messenger.idl` for an example. This file will contain at least struct/union annotated with `@topic`. For the sake of these instructions, we will call the file `Foo.idl`.
3. The C++ generated classes will be packaged in a shared library to be loaded at run-time by the JVM. This requires the packaged classes to be exported for external visibility. ACE provides a utility script for generating the correct export macros. The script usage is shown here:

   ```
   $ACE_ROOT/bin/generate_export_file.pl Foo > Foo_Export.h
   ```

   ```
   %ACE_ROOT%\bin\generate_export_file.pl Foo > Foo_Export.h
   ```

4. Create an MPC file, Foo.mpc, from this template:

   ```
   project: dcps_java {
     idlflags += -Wb,stub_export_include=Foo_Export.h \
       -Wb,stub_export_macro=Foo_Export
     dcps_ts_flags += -Wb,export_macro=Foo_Export
     idl2jniflags += -Wb,stub_export_include=Foo_Export.h \
       -Wb,stub_export_macro=Foo_Export
     dynamicflags += FOO_BUILD_DLL

     specific {
       jarname = DDS_Foo_types
     }

    TypeSupport_Files {
       Foo.idl
     }
   }
   ```

   You can leave out the `specific {...}` block if you do not need to create a jar file. In this case you can directly use the Java .class files which will be generated under the classes subdirectory of the current directory.

5. Run MPC to generate platform-specific build files.

   ```
   $ACE_ROOT/bin/mwc.pl -type gnuace
   ```

```
%ACE_ROOT%\bin\mwc.pl -type [CompilerType]
```

CompilerType can be any supported MPC type (such as "vs2019")

Make sure this is running ActiveState Perl or Strawberry Perl.

6. Compile the generated C++ and Java code

```
make
```

Build the generated `.sln` (Solution) file using your preferred method. This can be either the Visual Studio IDE or one of the command-line tools. If you use the IDE, start it from a command prompt using `devenv` so that it inherits the environment variables. Command-line tools for building include ms `build` and invoking the IDE (`devenv`) with the appropriate arguments.

When this completes successfully you have a native library and a Java `.jar` file. The native library names are `Foo.dll` (Release) or `Food.dll` (Debug) on Windows and `libFoo.so` on Linux.

You can change the locations of these libraries (including the `.jar` file) by adding a line such as the following to the `Foo.mpc` file:

```
libout = $(PROJECT_ROOT)/lib
```

where `PROJECT_ROOT` can be any environment variable defined at build-time.

7. You now have all of the Java and C++ code needed to compile and run a Java OpenDDS application. The generated `.jar` file needs to be added to your `classpath`, along with the `.jar` files that come from OpenDDS (in the `lib` directory). The generated C++ library needs to be available for loading at run-time:

   Add the directory containing `libFoo.so` to the `LD_LIBRARY_PATH`.

   Add the directory containing `Foo.dll` (or `Food.dll`) to the `PATH`. If you are using the debug version (`Food.dll`) you will need to inform the OpenDDS middleware that it should not look for `Foo.dll`. To do this, add `-Dopendds.native.debug=1` to the Java VM arguments.

   See the publisher and subscriber directories in `java/tests/messenger/` for examples of publishing and subscribing applications using the OpenDDS Java bindings.

8. If you make subsequent changes to `Foo.idl`, start by re-running MPC (step #5 above). This is needed because certain changes to `Foo.idl` will affect which files are generated and need to be compiled.

2.15.4 A Simple Message Publisher

This section presents a simple OpenDDS Java publishing process. The complete code for this can be found at `java/tests/messenger/publisher/TestPublisher.java`. Uninteresting segments such as imports and error handling have been omitted here. The code has been broken down and explained in logical subsections.

Initializing the Participant

DDS applications are boot-strapped by obtaining an initial reference to the Participant Factory. A call to the static method `TheParticipantFactory.WithArgs()` returns a Factory reference. This also transparently initializes the C++ Participant Factory. We can then create Participants for specific domains.

```
public static void main(String[] args) {

    DomainParticipantFactory dpf =
        TheParticipantFactory.WithArgs(new StringSeqHolder(args));
    if (dpf == null) {
      System.err.println ("Domain Participant Factory not found");
      return;
    }
    final int DOMAIN_ID = 42;
    DomainParticipant dp = dpf.create_participant(DOMAIN_ID,
      PARTICIPANT_QOS_DEFAULT.get(), null, DEFAULT_STATUS_MASK.value);
    if (dp == null) {
      System.err.println ("Domain Participant creation failed");
      return;
    }
```

Object creation failure is indicated by a null return. The third argument to `create_participant()` takes a Participant events listener. If one is not available, a null can be passed instead as done in our example.

Registering the Data Type and Creating a Topic

Next we register our data type with the `DomainParticipant` using the `register_type()` operation. We can specify a type name or pass an empty string. Passing an empty string indicates that the middleware should simply use the identifier generated by the IDL compiler for the type.

```
MessageTypeSupportImpl servant = new MessageTypeSupportImpl();
if (servant.register_type(dp, "") != RETCODE_OK.value) {
  System.err.println ("register_type failed");
  return;
}
```

Next we create a topic using the type support servant's registered name.

```
Topic top = dp.create_topic("Movie Discussion List",
                            servant.get_type_name(),
                            TOPIC_QOS_DEFAULT.get(), null,
                            DEFAULT_STATUS_MASK.value);
```

Now we have a topic named "*Movie Discussion List*" with the registered data type and default QoS policies.

Creating a Publisher

Next, we create a publisher:

```
Publisher pub = dp.create_publisher(
  PUBLISHER_QOS_DEFAULT.get(),
  null,
  DEFAULT_STATUS_MASK.value);
```

Creating a DataWriter and Registering an Instance

With the publisher, we can now create a DataWriter:

```
DataWriter dw = pub.create_datawriter(
  top, DATAWRITER_QOS_DEFAULT.get(), null, DEFAULT_STATUS_MASK.value);
```

The `DataWriter` is for a specific topic. For our example, we use the default `DataWriter` QoS policies and a null `DataWriterListener`.

Next, we narrow the generic `DataWriter` to the type-specific `DataWriter` and register the instance we wish to publish. In our data definition IDL we had specified the subject_id field as the key, so it needs to be populated with the instance id (99 in our example):

```
MessageDataWriter mdw = MessageDataWriterHelper.narrow(dw);
Message msg = new Message();
msg.subject_id = 99;
int handle = mdw.register(msg);
```

Our example waits for any peers to be initialized and connected. It then publishes a few messages which are distributed to any subscribers of this topic in the same domain.

```
msg.from = "OpenDDS-Java";
msg.subject = "Review";
msg.text = "Worst. Movie. Ever.";
msg.count = 0;
int ret = mdw.write(msg, handle);
```

2.15.5 Setting up the Subscriber

Much of the initialization code for a subscriber is identical to the publisher. The subscriber needs to create a participant in the same domain, register an identical data type, and create the same named topic.

```
public static void main(String[] args) {

    DomainParticipantFactory dpf =
        TheParticipantFactory.WithArgs(new StringSeqHolder(args));
    if (dpf == null) {
      System.err.println ("Domain Participant Factory not found");
      return;
    }
    DomainParticipant dp = dpf.create_participant(42,
      PARTICIPANT_QOS_DEFAULT.get(), null, DEFAULT_STATUS_MASK.value);
```

(continues on next page)

(continued from previous page)

```
    if (dp == null) {
      System.err.println("Domain Participant creation failed");
      return;
    }

    MessageTypeSupportImpl servant = new MessageTypeSupportImpl();
                    if (servant.register_type(dp, "") != RETCODE_OK.value) {
      System.err.println ("register_type failed");
      return;
    }
    Topic top = dp.create_topic("Movie Discussion List",
                                servant.get_type_name(),
                                TOPIC_QOS_DEFAULT.get(), null,
                                DEFAULT_STATUS_MASK.value);
```

Creating a Subscriber

As with the publisher, we create a subscriber:

```
Subscriber sub = dp.create_subscriber(
  SUBSCRIBER_QOS_DEFAULT.get(), null, DEFAULT_STATUS_MASK.value);
```

Creating a DataReader and Listener

Providing a `DataReaderListener` to the middleware is the simplest way to be notified of the receipt of data and to access the data. We therefore create an instance of a `DataReaderListenerImpl` and pass it as a `DataReader` creation parameter:

```
DataReaderListenerImpl listener = new DataReaderListenerImpl();
 DataReader dr = sub.create_datareader(
   top, DATAREADER_QOS_DEFAULT.get(), listener,
   DEFAULT_STATUS_MASK.value);
```

Any incoming messages will be received by the Listener in the middleware's thread. The application thread is free to perform other tasks at this time.

2.15.6 The DataReader Listener Implementation

The application defined `DataReaderListenerImpl` needs to implement the specification's `DDS.DataReaderListener` interface. OpenDDS provides an abstract class `DDS._DataReaderListenerLocalBase`. The application's listener class extends this abstract class and implements the abstract methods to add application-specific functionality.

Our example `DataReaderListener` stubs out most of the Listener methods. The only method implemented is the message available callback from the middleware:

```
public class DataReaderListenerImpl extends DDS._DataReaderListenerLocalBase {

    private int num_reads_;
```

(continues on next page)

(continued from previous page)

```
    public synchronized void on_data_available(DDS.DataReader reader) {
        ++num_reads_;
        MessageDataReader mdr = MessageDataReaderHelper.narrow(reader);
        if (mdr == null) {
          System.err.println ("read: narrow failed.");
          return;
        }
```

The Listener callback is passed a reference to a generic `DataReader`. The application narrows it to a type-specific `DataReader`:

```
MessageHolder mh = new MessageHolder(new Message());
SampleInfoHolder sih = new SampleInfoHolder(new SampleInfo(0, 0, 0,
    new DDS.Time_t(), 0, 0, 0, 0, 0, 0, 0, false));
int status  = mdr.take_next_sample(mh, sih);
```

It then creates holder objects for the actual message and associated `SampleInfo` and takes the next sample from the `DataReader`. Once taken, that sample is removed from the `DataReader`'s available sample pool.

```
        if (status == RETCODE_OK.value) {

          System.out.println ("SampleInfo.sample_rank = "+ sih.value.sample_rank);
          System.out.println ("SampleInfo.instance_state = "+
                              sih.value.instance_state);

          if (sih.value.valid_data) {

            System.out.println("Message: subject    = " + mh.value.subject);
            System.out.println("         subject_id = " + mh.value.subject_id);
            System.out.println("         from       = " + mh.value.from);
            System.out.println("         count      = " + mh.value.count);
            System.out.println("         text       = " + mh.value.text);
            System.out.println("SampleInfo.sample_rank = " +
                               sih.value.sample_rank);
          }
          else if (sih.value.instance_state ==
                     NOT_ALIVE_DISPOSED_INSTANCE_STATE.value) {
            System.out.println ("instance is disposed");
          }
          else if (sih.value.instance_state ==
                     NOT_ALIVE_NO_WRITERS_INSTANCE_STATE.value) {
            System.out.println ("instance is unregistered");
          }
          else {
            System.out.println ("DataReaderListenerImpl::on_data_available: "+
                                "received unknown instance state "+
                                sih.value.instance_state);
          }

        } else if (status == RETCODE_NO_DATA.value) {
          System.err.println ("ERROR: reader received DDS::RETCODE_NO_DATA!");
        } else {
```

(continues on next page)

(continued from previous page)

```
            System.err.println ("ERROR: read Message: Error: "+ status);
        }
    }

}
```

The `SampleInfo` contains meta-information regarding the message such as the message validity, instance state, etc.

2.15.7 Cleaning up OpenDDS Java Clients

An application should clean up its OpenDDS environment with the following steps:

```
dp.delete_contained_entities();
```

Cleans up all topics, subscribers and publishers associated with that `Participant`.

```
dpf.delete_participant(dp);
```

The `DomainParticipantFactory` reclaims any resources associated with the `DomainParticipant`.

```
TheServiceParticipant.shutdown();
```

Shuts down the `ServiceParticipant`. This cleans up all OpenDDS associated resources. Cleaning up these resources is necessary to prevent the `DCPSInfoRepo` from forming associations between endpoints which no longer exist.

2.15.8 Configuring the Example

OpenDDS offers a file-based configuration mechanism. The syntax of the configuration file is similar to a Windows INI file. The properties are divided into named sections corresponding to common and individual transports configuration.

The Messenger example has common properties for the `DCPSInfoRepo` objects location and the global transport configuration:

```
[common]
DCPSInfoRepo=file://repo.ior
DCPSGlobalTransportConfig=$file
```

and a transport instance section with a transport type property:

```
[transport/1]
transport_type=tcp
```

The `[transport/1]` section contains configuration information for the transport instance named `1`. It is defined to be of type `tcp`. The global transport configuration setting above causes this transport instance to be used by all readers and writers in the process.

See *Run-time Configuration* for a complete description of all OpenDDS configuration parameters.

2.15.9 Running the Example

To run the Messenger Java OpenDDS application, use the following commands:

```
$DDS_ROOT/bin/DCPSInfoRepo -o repo.ior

$JAVA_HOME/bin/java -ea -cp classes:$DDS_ROOT/lib/i2jrt.jar:$DDS_ROOT/lib/OpenDDS_DCPS.
↪jar:classes TestPublisher -DCPSConfigFile pub_tcp.ini

$JAVA_HOME/bin/java -ea -cp classes:$DDS_ROOT/lib/i2jrt.jar:$DDS_ROOT/lib/OpenDDS_DCPS.
↪jar:classes TestSubscriber -DCPSConfigFile sub_tcp.ini
```

The `-DCPSConfigFile` command-line argument passes the location of the OpenDDS configuration file.

2.15.10 Java Message Service (JMS) Support

OpenDDS provides partial support for JMS version 1.1. Enterprise Java applications can make use of the complete OpenDDS middleware just like standard Java and C++ applications.

See the `INSTALL` file in the `java/jms/` directory for information on getting started with the OpenDDS JMS support, including the prerequisites and dependencies.

2.16 Modeling SDK

The OpenDDS Modeling SDK is a modeling tool that can be used by the application developer to define the required middleware components and data structures as a UML model and then generate the code to implement the model using OpenDDS. The generated code can then be compiled and linked with the application to provide seamless middleware support to the application.

2.16.1 Overview

Model Capture

UML models defining DCPS elements and policies along with data definitions are captured using the graphical model capture editors included in the Eclipse plug-ins. The elements of the UML models follow the structure of the DDS UML Platform Independent Model (PIM) defined in the DDS specification (OMG: `formal/2015-04-10`).

Opening a new OpenDDS model within the plug-ins begins with a top level main diagram. This diagram includes any package structures to be included in the model along with the local QoS policy definitions, data definitions, and DCPS elements of the model. Zero or more of the policy or data definition elements can be included. Zero or one DCPS elements definition can be included in any given model.

Creating separate models for QoS policies only, data definitions only, or DCPS elements only is supported. References to other models allows externally defined models to be included in a model. This allows sharing of data definitions and QoS policies among different DCPS models as well as including externally defined data in a new set of data definitions.

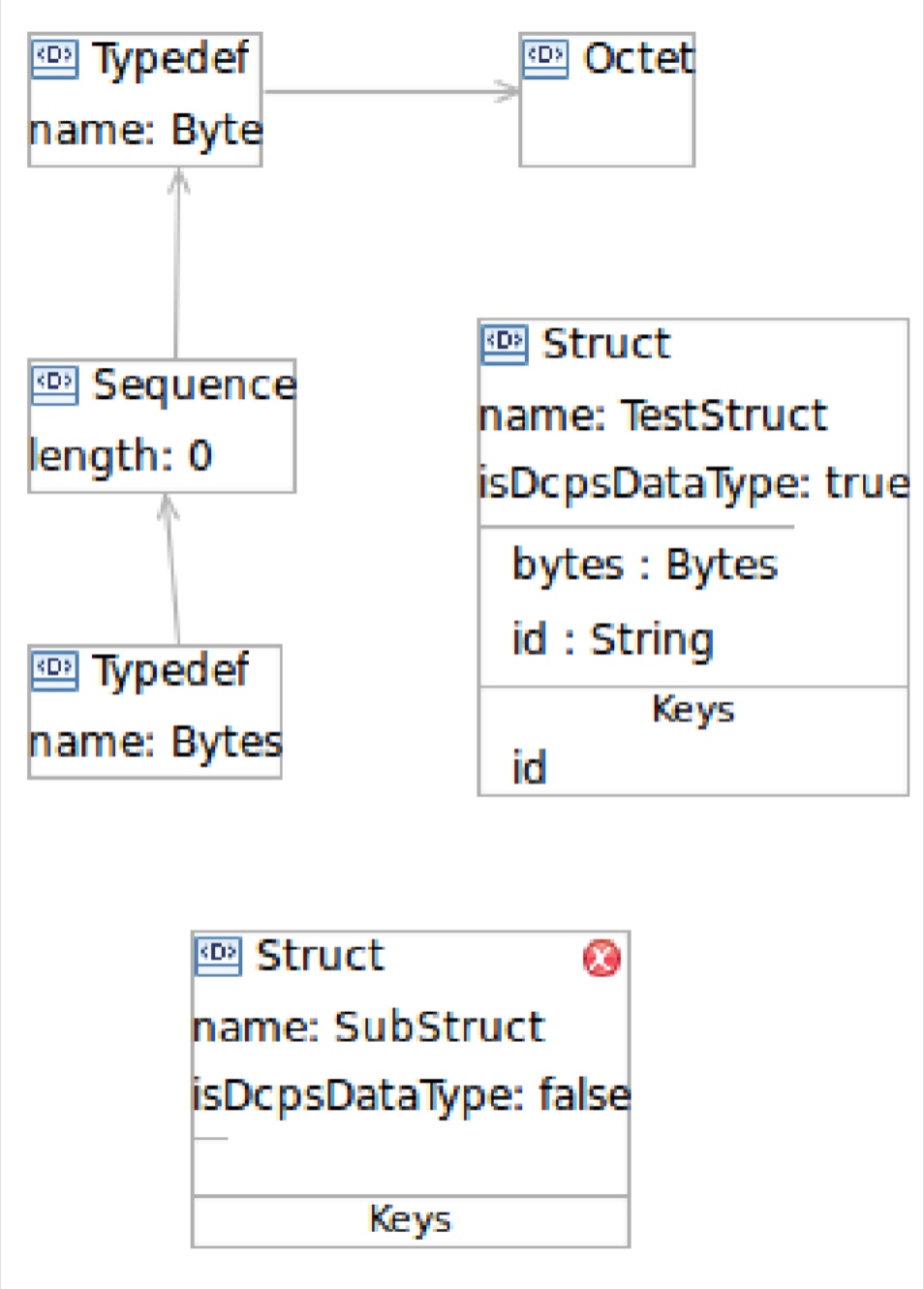


Fig. 3: Graphical modeling of the data definitions

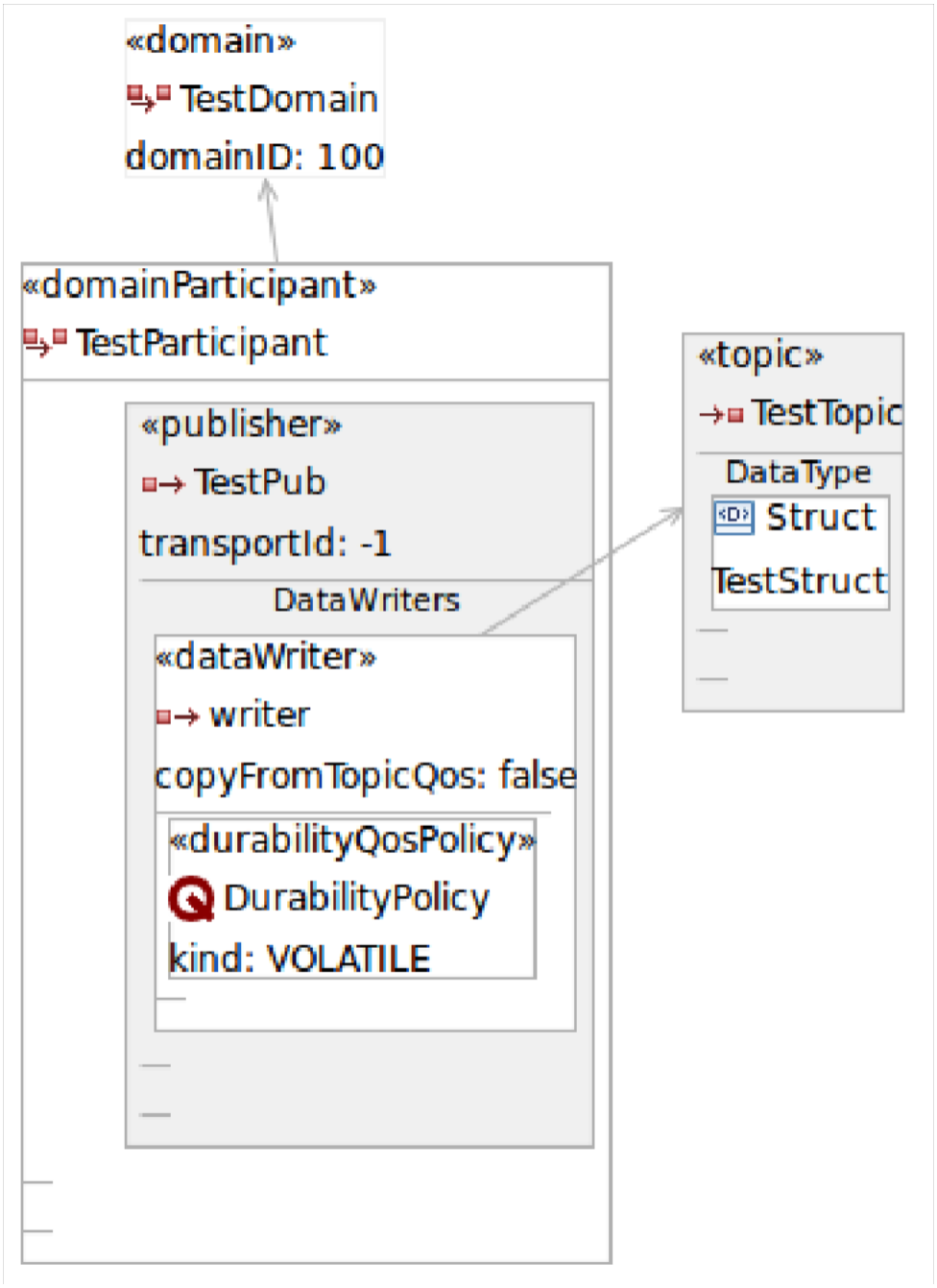


Fig. 4: Graphical modeling of the DCPS entities

Code Generation

Once models have been captured, source code can be generated from them. This source code can then be compiled into link libraries providing the middleware elements defined in the model to applications that link the library. Code generation is done using a separate forms based editor.

Specifics of code generation are unique to the individual generation forms and are kept separate from the models for which generation is being performed. Code generation is performed on a single model at a time and includes the ability to tailor the generated code as well as specifying search paths to be used for locating resources at build time.

It is possible to generate model variations (distinct customizations of the same model) that can then be created within the same application or different applications. It is also possible to specify locations to search for header files and link libraries at build time. See *Generated Code* for details.

Programming

In order to use the middleware defined by models, applications need to link in the generated code. This is done through header files and link libraries. Support for building applications using the MPC portable build tool is included in the generated files for a model. See *Developing Applications* for details.

2.16.2 Installation and Getting Started

Unlike the OpenDDS Middleware which is compiled from source code by the developer, the compiled Modeling SDK is available for download via an Eclipse Update Site.

Prerequisites

- Java Runtime Environment (JRE)
- Eclipse IDE

Installation

1. From Eclipse, open the "Help" menu and select "Install New Software".
2. Click the hyperlink for "Available Software Sites".
3. The standard `eclipse.org` sites (Eclipse Project Updates and Galileo) should be enabled. If they are disabled, enable them now.
4. Add a new Site entry named OpenDDS with URL http://download.opendds.org/modeling/eclipse_44/
5. Click OK to close the Preferences dialog and return to the Install dialog.
6. In the "Work with" combo box, select the new entry for OpenDDS.
7. Select the "OpenDDS Modeling SDK" and click Next.
8. Review the "Install Details" list and click Next. Review the license, select Accept (if you do accept it), and click Finish.
9. Eclipse will download the OpenDDS plug-ins and various plug-ins from `eclipse.org` that they depend on. There will be a security warning because the OpenDDS plug-ins are not signed. There also may be a prompt to accept a certificate from `eclipse.org`.
10. Eclipse will prompt the user to restart in order to use the newly installed software.

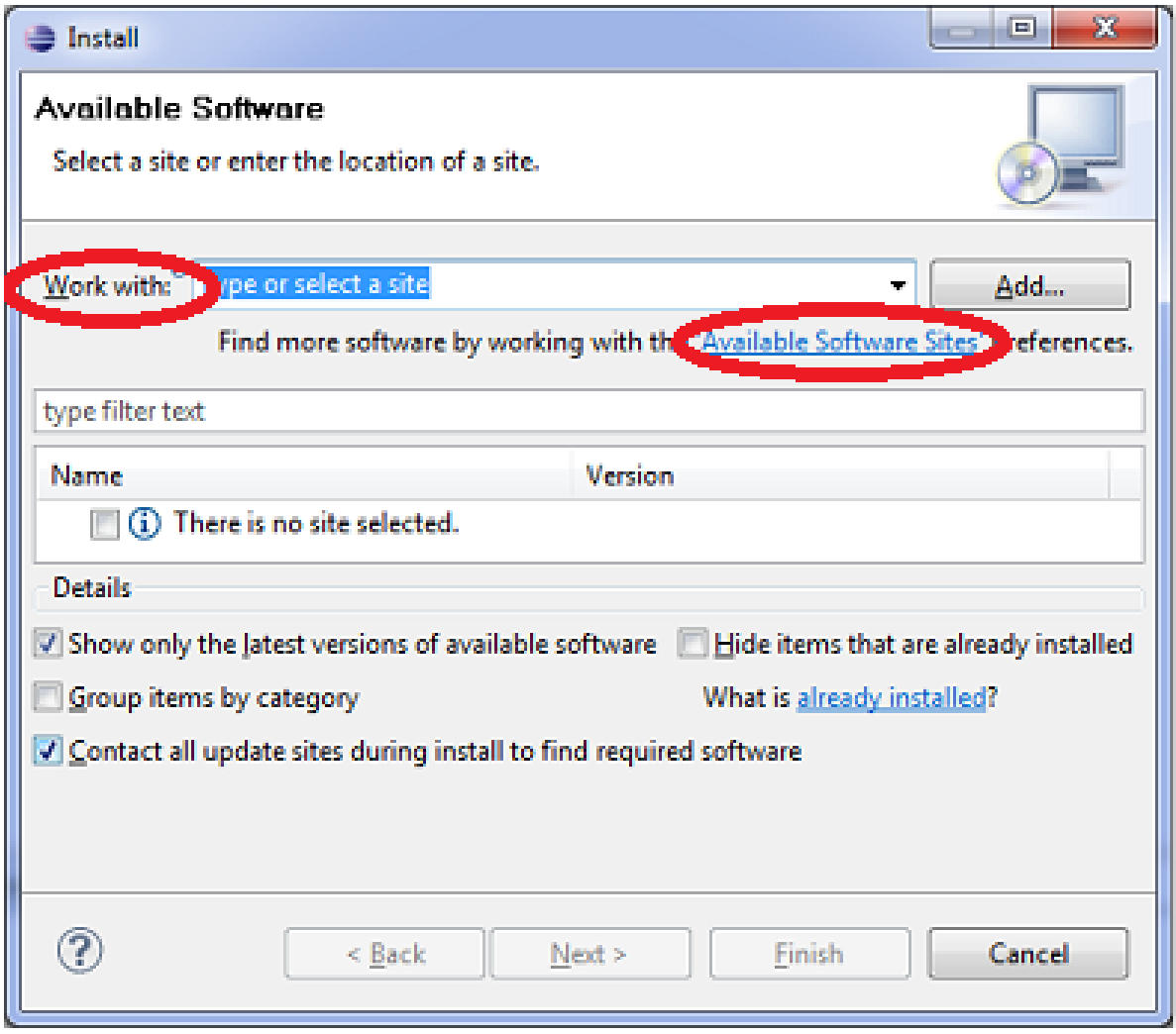


Fig. 5: Eclipse Software Installation Dialog

Getting Started

The OpenDDS Modeling SDK contains an Eclipse Perspective. Open it by going to the Window menu and selecting Open Perspective -> Other -> OpenDDS Modeling.

To get started using the OpenDDS Modeling SDK, see the help content installed in Eclipse. Start by going to the Help menu and selecting Help Contents. There is a top-level item for `OpenDDS Modeling SDK Guide` that contains all of the OpenDDS-specific content describing the modeling and code generation activities.

2.16.3 Developing Applications

In order to build an application using the OpenDDS Modeling SDK, one must understand a few key concepts. The concepts concern:

1. The support library
2. Generated model code
3. Application code

Modeling Support Library

The OpenDDS Modeling SDK includes a support library, found at `tools/modeling/codegen/model`. This support library, when combined with the code generated by the Modeling SDK, greatly reduces the amount of code needed to build an OpenDDS application.

The support library is a C++ library which is used by an OpenDDS Modeling SDK application. Two classes in the support library that most developers will need are the Application and Service classes.

The Application Class

The `OpenDDS::Model::Application` class takes care of initialization and finalization of the OpenDDS library. It is required for any application using OpenDDS to instantiate a single instance of the `Application` class, and further that the `Application` object not be destroyed while communicating using OpenDDS.

The `Application` class initializes the factory used to create OpenDDS participants. This factory requires the user-provided command line arguments. In order to provide them, the `Application` object must be provided the same command line arguments.

The Service Class

The `OpenDDS::Model::Service` class is responsible for the creation of OpenDDS entities described in an OpenDDS Modeling SDK model. Since the model can be generic, describing a much broader domain than an individual application uses, the Service class uses lazy instantiation to create OpenDDS entities.

In order to properly instantiate these entities, it must know:

- The relationships among the entities
- The transport configuration used by entities

Generated Code

The OpenDDS Modeling SDK generates model-specific code for use by an OpenDDS Modeling SDK application. Starting with a .codegen file (which refers to an `.opendds` model file), the files described in the table below. The process of generating code is documented in the Eclipse help.

File Name	Description
`<ModelName>.idl`	Data types from the model's `DataLib`
`<ModelName>_T.h`	C++ class from the model's `DcpsLib`
`<ModelName>_T.cpp`	C++ implementation of the model's `DcpsLib`
`<ModelName>.mpc`	MPC project file for the generated C++ library
`<ModelName>.mpb`	MPC base project for use by the application
`<ModelName>_paths.mpb`	MPC base project with paths, see *Dependencies Between Models*
`<ModelName>Traits.h`	Transport configuration from the .codegen file
`<ModelName>Traits.cpp`	Transport configuration from the .codegen file

The DCPS Model Class

The DCPS library models relationships between DDS entities, including `Topics`, `DomainParticipants`, `Publishers`, `Subscribers`, `DataWriters` and `DataReaders`, and their corresponding Domains.

For each DCPS library in your model, the OpenDDS Modeling SDK generates a class named after the DCPS library. This DCPS model class is named after the DCPS library, and is found in the `<ModelName>_T.h` file in the code generation target directory.

The model class contains an inner class, named Elements, defining enumerated identifiers for each DCPS entity modeled in the library and each type referenced by the library's Topics. This Elements class contains enumeration definitions for each of:

- DomainParticipants
- Types
- Topics
- Content Filtered Topics
- Multi Topics
- Publishers
- Subscribers
- Data Writers
- Data Readers

In addition, the DCPS model class captures the relationships between these entities. These relationships are used by the Service class when instantiating DCPS entities.

The Traits Class

Entities in a DCPS model reference their transport configuration by name. The Model Customization tab of the Codegen file editor is used to define the transport configuration for each name.

There can be more than one set of configurations defined for a specific code generation file. These sets of configurations are grouped into instances, each identified by a name. Multiple instances may be defined, representing different deployment scenarios for models using the application.

For each of these instances, a `Traits` class is generated. The traits class provides the transport configuration modeled in the Codegen editor for a specific transport configuration name.

The Service Typedef

The Service is a template which needs two parameters: (1) the entity model, in the DCPS model `Elements` class, (2) transport configuration, in a `Traits` class. The OpenDDS Modeling SDK generates one typedef for each combination of DCPS library and transport configuration model instance. The typedef is named `<InstanceName><DCPSLibraryName>Type`.

Data Library Generated Code

From the data library, IDL is generated, which is processed by the IDL compilers. The IDL compilers generate type support code, which is used to serialize and deserialize data types.

QoS Policy Library Generated Code

There are no specific compilation units generated from the QoS policy library. Instead, the DCPS library stores the QoS policies of the entities it models. This QoS policy is later queried by the Service class, which sets the QoS policy upon entity creation.

Application Code Requirements

Required headers

The application will need to include the `Traits` header, in addition to the `Tcp.h` header (for static linking). These will include everything required to build a publishing application. Here is the `#include` section of an example publishing application, `MinimalPublisher.cpp`.

```
#ifdef ACE_AS_STATIC_LIBS
#include <dds/DCPS/transport/tcp/Tcp.h>
#endif

#include "model/MinimalTraits.h"
```

Exception Handling

It is recommended that Modeling SDK applications catch both `CORBA::Exception` objects and `std::exception` objects.

```
int ACE_TMAIN(int argc, ACE_TCHAR* argv[])
{
  try {
    // Create and use OpenDDS Modeling SDK (see below)
  } catch (const CORBA::Exception& e) {
    // Handle exception and return non-zero
  } catch (const OpenDDS::DCPS::Transport::Exception& te) {
    // Handle exception and return non-zero
  } catch (const std::exception& ex) {
    // Handle exception and return non-zero
  }
  return 0;
}
```

Instantiation

As stated above, an OpenDDS Modeling SDK application must create an `OpenDDS::Model::Application` object for the duration of its lifetime. This `Application` object, in turn, is passed to the constructor of the Service object specified by one of the typedef declarations in the traits headers.

The service is then used to create OpenDDS entities. The specific entity to create is specified using one of the enumerated identifiers specified in the `Elements` class. The Service provides this interface for entity creation:

```
DDS::DomainParticipant_var participant(Elements::Participants::Values part);
DDS::TopicDescription_var topic(Elements::Participants::Values part,
                                Elements::Topics::Values topic);
DDS::Publisher_var publisher(Elements::Publishers::Values publisher);
DDS::Subscriber_var subscriber(Elements::Subscribers::Values subscriber);
DDS::DataWriter_var writer(Elements::DataWriters::Values writer);
DDS::DataReader_var reader(Elements::DataReaders::Values reader);
```

It is important to note that the service also creates any required intermediate entities, such as `DomainParticipants`, `Publishers`, `Subscribers`, and `Topics`, when necessary.

Publisher Code

Using the `writer()` method shown above, `MinimalPublisher.cpp` continues:

```
int ACE_TMAIN(int argc, ACE_TCHAR* argv[])
{
  try {
    OpenDDS::Model::Application application(argc, argv);
    MinimalLib::DefaultMinimalType model(application, argc, argv);

    using OpenDDS::Model::MinimalLib::Elements;
    DDS::DataWriter_var writer = model.writer(Elements::DataWriters::writer);
```

What remains is to narrow the `DataWriter` to a type-specific data writer, and send samples.

```
data1::MessageDataWriter_var msg_writer =
  data1::MessageDataWriter::_narrow(writer);
data1::Message message;
// Populate message and send
message.text = "Worst. Movie. Ever.";
DDS::ReturnCode_t error = msg_writer->write(message, DDS::HANDLE_NIL);
if (error != DDS::RETCODE_OK) {
  // Handle error
}
```

In total our publishing application, `MinimalPublisher.cpp`, looks like this:

```
#ifdef ACE_AS_STATIC_LIBS
#include <dds/DCPS/transport/tcp/Tcp.h>
#endif

#include "model/MinimalTraits.h"

int ACE_TMAIN(int argc, ACE_TCHAR* argv[])
{
  try {
    OpenDDS::Model::Application application(argc, argv);
    MinimalLib::DefaultMinimalType model(application, argc, argv);

    using OpenDDS::Model::MinimalLib::Elements;
    DDS::DataWriter_var writer = model.writer(Elements::DataWriters::writer);

    data1::MessageDataWriter_var msg_writer =
      data1::MessageDataWriter::_narrow(writer);
    data1::Message message;
    // Populate message and send
    message.text = "Worst. Movie. Ever.";
    DDS::ReturnCode_t error = msg_writer->write(message, DDS::HANDLE_NIL);
    if (error != DDS::RETCODE_OK) {
      // Handle error
    }
  } catch (const CORBA::Exception& e) {
    // Handle exception and return non-zero
  } catch (const std::exception& ex) {
    // Handle exception and return non-zero
  }
  return 0;
}
```

Note this minimal example ignores logging and synchronization, which are issues that are not specific to the OpenDDS Modeling SDK.

Subscriber Code

The subscriber code is much like the publisher. For simplicity, OpenDDS Modeling SDK subscribers may want to take advantage of a base class for Reader Listeners, called `OpenDDS::Modeling::NullReaderListener`. The `NullReaderListener` implements the entire `DataReaderListener` interface and logs every callback.

Subscribers can create a listener by deriving a class from `NullReaderListener` and overriding the interfaces of interest, for example on_data_available.

```
#ifdef ACE_AS_STATIC_LIBS
#include <dds/DCPS/transport/tcp/Tcp.h>
#endif

#include "model/MinimalTraits.h"
#include <model/NullReaderListener.h>

class ReaderListener : public OpenDDS::Model::NullReaderListener {
public:
  virtual void on_data_available(DDS::DataReader_ptr reader)
    ACE_THROW_SPEC((CORBA::SystemException)) {
    data1::MessageDataReader_var reader_i =
      data1::MessageDataReader::_narrow(reader);

    if (!reader_i) {
      // Handle error
      ACE_OS::exit(-1);
    }

    data1::Message msg;
    DDS::SampleInfo info;

    // Read until no more messages
    while (true) {
      DDS::ReturnCode_t error = reader_i->take_next_sample(msg, info);
      if (error == DDS::RETCODE_OK) {
        if (info.valid_data) {
          std::cout << "Message: " << msg.text.in() << std::endl;
        }
      } else {
        if (error != DDS::RETCODE_NO_DATA) {
          // Handle error
        }
        break;
      }
    }
  }
};
```

In the main function, create a data reader from the service object:

```
DDS::DataReader_var reader = model.reader(Elements::DataReaders::reader);
```

Naturally, the `DataReaderListener` must be associated with the data reader in order to get its callbacks.

```
DDS::DataReaderListener_var listener(new ReaderListener);
reader->set_listener(listener, OpenDDS::DCPS::DEFAULT_STATUS_MASK);
```

The remaining subscriber code has the same requirements of any OpenDDS Modeling SDK application, in that it must initialize the OpenDDS library through an `OpenDDS::Modeling::Application` object, and create a Service object with the proper DCPS model Elements class and traits class.

An example subscribing application, `MinimalSubscriber.cpp`, follows.

```
#ifdef ACE_AS_STATIC_LIBS
#include <dds/DCPS/transport/tcp/Tcp.h>
#endif

#include "model/MinimalTraits.h"
#include <model/NullReaderListener.h>

class ReaderListener : public OpenDDS::Model::NullReaderListener {
public:
  virtual void on_data_available(DDS::DataReader_ptr reader)
  ACE_THROW_SPEC((CORBA::SystemException)) {
    data1::MessageDataReader_var reader_i =
      data1::MessageDataReader::_narrow(reader);

    if (!reader_i) {
      // Handle error
      ACE_OS::exit(-1);
    }

    data1::Message msg;
    DDS::SampleInfo info;

    // Read until no more messages
    while (true) {
      DDS::ReturnCode_t error = reader_i->take_next_sample(msg, info);
      if (error == DDS::RETCODE_OK) {
        if (info.valid_data) {
          std::cout << "Message: " << msg.text.in() << std::endl;
        }
      } else {
        if (error != DDS::RETCODE_NO_DATA) {
          // Handle error
        }
        break;
      }
    }
  }
};

int ACE_TMAIN(int argc, ACE_TCHAR* argv[])
{
  try {
    OpenDDS::Model::Application application(argc, argv);
    MinimalLib::DefaultMinimalType model(application, argc, argv);
```

(continues on next page)

(continued from previous page)

```
    using OpenDDS::Model::MinimalLib::Elements;

    DDS::DataReader_var reader = model.reader(Elements::DataReaders::reader);

    DDS::DataReaderListener_var listener(new ReaderListener);
    reader->set_listener(listener, OpenDDS::DCPS::DEFAULT_STATUS_MASK);

    // Call on_data_available in case there are samples which are waiting
    listener->on_data_available(reader);

    // At this point the application can wait for an exteral "stop" indication
    // such as blocking until the user terminates the program with Ctrl-C.

  } catch (const CORBA::Exception& e) {
    e._tao_print_exception("Exception caught in main():");
    return -1;
  } catch (const std::exception& ex) {
    // Handle error
    return -1;
  }
  return 0;
}
```

MPC Projects

In order to make use of the OpenDDS Modeling SDK support library, OpenDDS Modeling SDK MPC projects should inherit from the dds_model project base. This is in addition to the dcpsexe base from which non-Modeling SDK projects inherit.

```
project(*Publisher) : dcpsexe, dds_model {
  // project configuration
}
```

The generated model library will generate an MPC project file and base project file in the target directory, and take care of building the model shared library. OpenDDS modeling applications must both (1) include the generated model library in their build and (2) ensure their projects are built after the generated model libraries.

```
project(*Publisher) : dcpsexe, dds_model {
  // project configuration
  libs  += Minimal
  after += Minimal
}
```

Both of these can be accomplished by inheriting from the model library's project base, named after the model library.

```
project(*Publisher) : dcpsexe, dds_model, Minimal {
  // project configuration
}
```

Note that the `Minimal.mpb` file must now be found by MPC during project file creation. This can be accomplished through the -include command line option.

Using either form, the MPC file must tell the build system where to look for the generated model library.

```
project(*Publisher) : dcpsexe, dds_model, Minimal {
  // project configuration
  libpaths += model
}
```

This setting based upon what was provided to the Target Folder setting in the Codegen file editor.

Finally, like any other MPC project, its source files must be included:

```
Source_Files {
  MinimalPublisher.cpp
}
```

The final MPC project looks like this for the publisher:

```
project(*Publisher) : dcpsexe, dds_model, Minimal {
  exename   = publisher
  libpaths += model

  Source_Files {
    MinimalPublisher.cpp
  }
}
```

And similar for the subscriber:

```
project(*Subscriber) : dcpsexe, dds_model, Minimal {
  exename   = subscriber
  libpaths += model

  Source_Files {
    MinimalSubscriber.cpp
  }
}
```

Dependencies Between Models

One final consideration – the generated model library could itself depend on other generated model libraries. For example, there could be an external data type library which is generated to a different directory.

This possibility could cause a great deal of maintenance of project files, as models change their dependencies over time. To help overcome this burden, the generated model library records the paths to all of its externally referenced model libraries in a separate MPB file named `<ModelName>_paths.mpb`. Inheriting from this paths base project will inherit the needed settings to include the dependent model as well.

Our full MPC file looks like this:

```
project(*Publisher) : dcpsexe, dds_model, Minimal, Minimal_paths {
  exename   = publisher
  libpaths += model

  Source_Files {
```

(continues on next page)

(continued from previous page)

```
    MinimalPublisher.cpp
  }
}

project(*Subscriber) : dcpsexe, dds_model, Minimal, Minimal_paths {
  exename   = subscriber
  libpaths += model

  Source_Files {
    MinimalSubscriber.cpp
  }
}
```

2.17 Alternate Interfaces to Data

The DDS-DCPS approach to data transfer using synchronization of strongly-typed caches (DataWriter and DataReader) is not appropriate for all applications. Therefore OpenDDS provides two different alternate interface approaches which are described in this section. These are not defined by OMG specifications and may change in future releases of OpenDDS, including minor updates. The two approaches are:

- Recorder and Replayer
  - These interfaces allow the application to create untyped stand-ins for DataReaders and/or DataWriters
  - Recorder can be used with the Dynamic Language Binding XTypes features (*Dynamic Language Binding*) to access typed data samples through a reflection-based API
- Observer
  - Observers play a role similar to the spec-defined Listeners (attached to DataReaders and/or DataWriters). Unlike the Listeners, Observers don't need to interact with the DataReader/Writer caches to access the data samples.

The XTypes Dynamic Language Binding (*Dynamic Language Binding*) provides a set of related features that can be used to create DataWriters and DataReaders that work with a generic data container (DynamicData) instead of a specific IDL-generated data type.

2.17.1 Recorder and Replayer

The Recorder feature of OpenDDS allows applications to record samples published on arbitrary topics without any prior knowledge of the data type used by that topic. Analogously, the Replayer feature allows these recorded samples to by re-published back into the same or other topics. What makes these features different from other Data Readers and Writers are their ability to work with any data type, even if unknown at application build time. Effectively, the samples are treated as if each one contains an opaque byte sequence.

The purpose of this section is to describe the public API for OpenDDS to enable the recording/replaying use-case.

API Structure

Two new user-visible classes (that behave somewhat like their DDS Entity counterparts) are defined in the `OpenDDS::DCPS` namespace, along with the associated Listener interfaces. Listeners may be optionally implemented by the application. The `Recorder` class acts similarly to a `DataReader` and the `Replayer` class acts similarly to a `DataWriter`.

Both `Recorder` and `Replayer` make use of the underlying OpenDDS discovery and transport libraries as if they were `DataReader` and `DataWriter`, respectively. Regular OpenDDS applications in the domain will "see" the `Recorder` objects as if they were remote `DataReaders` and `Replayers` as if they were `DataWriters`.

Usage Model

The application creates any number of `Recorders` and `Replayers` as necessary. This could be based on using the *built-in topics* to dynamically discover which topics are active in the Domain. Creating a `Recorder` or `Replayer` requires the application to provide a topic name and type name (as in `DomainParticipant::create_topic()`) and also the relevant QoS data structures. The `Recorder` requires SubscriberQos and DataReaderQos whereas the `Replayer` requires PublisherQos and DataWriterQos. These values are used in discovery's reader/writer matching. See the section on QoS processing below for how the `Recorder` and `Replayer` use QoS. Here is the code needed to create a recorder:

```
OpenDDS::DCPS::Recorder_var recorder =
    service_participant->create_recorder(domain_participant,
                                         topic.in(),
                                         sub_qos,
                                         dr_qos,
                                         recorder_listener);
```

Data samples are made available to the application via the `RecorderListener` using a simple "one callback per sample" model. The sample is delivered as an `OpenDDS::DCPS::RawDataSample` object. This object includes the timestamp for that data sample as well as the marshaled sample value. Here is a class definition for a user-defined Recorder Listener.

```
class MessengerRecorderListener : public OpenDDS::DCPS::RecorderListener
{
public:
  MessengerRecorderListener();

  virtual void on_sample_data_received(OpenDDS::DCPS::Recorder*,
                                       const OpenDDS::DCPS::RawDataSample& sample);

  virtual void on_recorder_matched(OpenDDS::DCPS::Recorder*,
                                   const DDS::SubscriptionMatchedStatus& status );

};
```

The application can store the data wherever it sees fit (in memory, file system, database, etc.). At any later time, the application can provide that same sample to a `Replayer` object configured for the same topic. It's the application's responsibility to make sure the topic types match. Here is an example call that replays a sample to all readers connected on a replayer's topic:

```
replayer->write(sample);
```

Because the stored data is dependent on the definition of the data structure, it can't be used across different versions of OpenDDS or different versions of the IDL used by the OpenDDS participants.

QoS Processing

The lack of detailed knowledge about the data sample complicates the use of many normal DDS QoS properties on the `Replayer` side. The properties can be divided into a few categories:

- Supported
  - Liveliness
  - Time-Based Filter
  - Lifespan
  - Durability (transient local level, see details below)
  - Presentation (topic level only)
  - Transport Priority (pass-thru to transport)
- Unsupported
  - Deadline (still used for reader/writer match)
  - History
  - Resource Limits
  - Durability Service
  - Ownership and Ownership Strength (still used for reader/writer match)
- Affects reader/writer matching and *built-in topics* but otherwise ignored
  - Partition
  - Reliability (still used by transport negotiation)
  - Destination Order
  - Latency Budget
  - User/Group Data

Durability details

On the `Recorder` side, transient local durability works just the same as any normal `DataReader`. Durable data is received from matched `DataWriters`. On the `Replayer`side there are some differences. As opposed to the normal DDS `DataWriter`, `Replayer` is not caching/storing any data samples (they are simply sent to the transport). Because instances are not known, storing data samples according to the usual History and Resource Limits rules is not possible. Instead, transient local durability can be supported with a "pull" model whereby the middleware invokes a method on the `ReplayerListener` when a new remote `DataReader` is discovered. The application can then call a method on the `Replayer` with any data samples that should be sent to that newly-joined `DataReader`. Determining which samples these are is left to the application.

Recorder With XTypes Dynamic Language Binding

The Recorder class includes support for the Dynamic Language Binding from XTypes (*Dynamic Language Binding*). Type information for each matched DataWriter (that supports XTypes complete TypeObjects) is stored in the Recorder. Users can call `Recorder::get_dynamic_data`, passing a `RawDataSample` to get back a `DynamicData` object which includes type information – see `DynamicData::type()`.

A tool called `inspect`, uses the Recorder and Dynamic Language Binding allow for the printing of any type, so long as the topic name, type name, and domain ID are known. The DataWriter must include code generation for complete TypeObjects. See `tools/inspect/Inspect.cpp` for this tool's source code. It can be used as a standalone tool or an example for developing your own applications using these APIs.

2.17.2 Observer

To observe the most important events happening within OpenDDS, applications can create classes that derive from the Observer base class (in `dds/DCPS/Observer.h`). The design of Observer is intended to allow applications to have a single Observer object observing many Entities, however this is flexible to allow many different use cases. The following events can be observed:

- DataWriter/Reader enabled, deleted
- DataWriter/Reader QoS changed
- DataWriter/Reader peer associated, disassociated
- DataWriter sample sent, instance disposed, instance unregistered
- DataReader sample received (enters the cache), read, taken, instance disposed, instance unregistered

Attaching Observers to Entities

Entity is the spec-defined base interface of the following types:

- DataWriter, DataReader
  - As seen above in *Observer*, the Observer events originate in the DataWriter and DataReader Entities
- DomainParticipant, Publisher, Subscriber
  - Among their other roles, these Entities act as containers (either directly or indirectly) for DataWriters and DataReaders.
  - If a smaller-scoped Entity (such as a DataWriter) has no Observer for the event in question, its containing Entity (in this example, a Publisher) is checked for an Observer.
- Topic
  - Although it is an Entity, no Observer events are generated by Topics or Entities they contain (since they don't contain any Entities)

The class `EntityImpl` (in `dds/DCPS/EntityImpl.h`) is OpenDDS's base class for all Entity types. `EntityImpl` includes public methods for Observer registration: `set_observer` and `get_observer`. These methods are not part of the IDL interfaces, so invoking them the requires a cast to the implementation (Impl) of Entity.

```
DDS::DataWriter_var dw = /* ... */;
EntityImpl* entity = dynamic_cast<EntityImpl*>(dw.in());
Observer_rch observer = make_rch<MyObserver>();
entity->set_observer(observer, Observer::e_SAMPLE_SENT);
```

Note that since the `Observer` class is an internal (not IDL) interface, it uses the "RCH" (Reference Counted Handle) smart pointer classes. Observer itself inherits from `RcObject`, and uses of `Observer`-derived classes should use the `RcHandle` template and its associated functions, as in the example above. See `dds/DCPS/RcHandle_T.h` for details.

Writing Observer-Derived Classes

The virtual methods in the `Observer` class are divided into 3 groups based on the general category of events they observe:

1. Operations on the observed `Entity` itself
   - `on_enabled`, `on_deleted`, `on_qos_changed`
   - The only parameter to these methods is the `Entity`, so the `Observer` implementation can use the public methods on the `Entity`.
2. Events relating to associating with remote matched endpoints
   - `on_associated`, `on_disassociated`
   - In addition to the `Entity`, the `Observer` implementation receives a `GUID_t` structure which is the internal representation of remote `Entity` identity. The `GUID_t` values from `on_associated` could be stored or logged to correlate them with the values from `on_disassociated`.
3. Events relating to data samples moving through the system
   - `on_sample_sent`, `on_sample_received`, `on_sample_read`, `on_sample_taken`, `on_disposed`, `on_unregistered`
   - In addition to the `Entity`, the `Observer` implementation receives an instance of the `Sample` structure. The definition of this structure is nested within `Observer`. See below for details.

The Observer::Sample structure

The `Observer::Sample` structure contains the following fields:

- `instance` and `instance_state`
  - Describe the instance that this sample belongs to, using the spec-defined types
- `timestamp` and `sequence_number`
  - Attributes of the sample itself: `timestamp` uses a spec-defined type whereas `sequence_number` uses the OpenDDS internal type for DDSI-RTPS 64-bit sequence numbers.
- `data` and `data_dispatcher`
  - Since `Observer` is an un-typed interface, the contents of the data sample itself are represented only as a void pointer
  - Implementations that need to process this data can use the `data_dispatcher` object to interpret it. See the class definition of `ValueDispatcher` in `dds/DCPS/ValueDispatcher.h` for more details.

2.18 Safety Profile

2.18.1 Overview

The Safety Profile configuration allows OpenDDS to be used in environments that have a restricted set of operating system and standard library functions available and that require dynamic memory allocation to occur only at system start-up.

OpenDDS Safety Profile (and the corresponding features in ACE) were developed for the Open Group's FACE specification, edition 2.1. It can be used along with the support for FACE Transport Services to create FACE-conformant DDS applications, or it can be used by general DDS applications that are not written to the FACE Transport Services APIs. This latter use-case is described by this section of the developer's guide. For more information on the former use-case see the file `FACE/README.txt` in the source distribution.

2.18.2 Safety Profile Subset of OpenDDS

The following features of OpenDDS are not available when it is configured for Safety Profile:

- DCPSInfoRepo and its associated libraries and tools
- Transport types: tcp, udp, multicast, shared memory
  - The rtps_udp transport type is available (uses UDP unicast or multicast)
- OpenDDS Monitor library and monitoring GUI

When developing the Safety Profile, the following DDS Compliance Profiles were disabled:

- content_subscription
- ownership_kind_exclusive
- object_model_profile
- persistence_profile

See *Disabling the Building of Compliance Profile Features* for more details on compliance profiles. It is possible that enabling any of these compliance profiles in a Safety Profile build will result in a compile-time or run-time error.

To build OpenDDS Safety Profile, pass the command line argument `--safety-profile` to the configure script along with any other arguments needed for your platform or configuration. When safety profile is enabled in the configure script, the four compliance profiles listed above default to disabled. See *Installation* for more information about the configure script.

2.18.3 Safety Profile Configurations of ACE

OpenDDS uses ACE as its platform abstraction library, and in OpenDDS's Safety Profile configuration, one of the following safety profile configurations must be enabled in ACE:

- FACE Safety Base (always uses the memory pool)
- FACE Safety Extended with Memory Pool
- FACE Safety Extended with Standard C++ Dynamic Allocation

OpenDDS's configure script will automatically configure ACE. Pass the command line argument `--safety-profile=base` to select the Safety Base profile. Otherwise a `--safety-profile` (no equals sign) configuration will default to Safety Extended with Memory Pool.

The Safety Extended with Standard C++ Dynamic Allocation configuration is not automatically generated by the configure script, but the file `build/target/ACE_wrappers/ace/config.h` can be edited after it is generated by configure (and before running make). Remove the macro definition for `ACE_HAS_ALLOC_HOOKS` to disable the memory pool.

ACE's safety profile configurations have been tested on Linux and on LynxOS-178 version 2.3.2+patches. Other platforms may work too but may require additional configuration.

2.18.4 Run-time Configurable Options

The memory pool used by OpenDDS can be configured by setting values in the `[common]` section of the configuration file. See *`[common] pool_size`* and *`[common] pool_granularity`*.

2.18.5 Running ACE and OpenDDS Tests

After configuring and building OpenDDS Safety Profile, note that there are two sub-directories of the top level that each contain some binary artifacts:

- `build/host` has the build-time code generators tao_idl and opendds_idl
- `build/target` has the run-time libraries for safety profile ACE and OpenDDS and the OpenDDS tests

Therefore, testing needs to be relative to the `build/target` sub-directory. Source-in the generated file `build/target/setenv.sh` to get all of the needed environment variables.

ACE tests are not built by default, but once this environment is set up all it takes to build them is generating makefiles and running make:

1. `cd $ACE_ROOT/tests`
2. `$ACE_ROOT/bin/mwc.pl -type gnuace`
3. `make`

Run ACE tests by changing to the `$ACE_ROOT/tests` directory and using `run_test.pl`. Pass any `-Config XYZ` options required for your configuration (use `run_test.pl -h` to see the available Config options).

Run OpenDDS tests by changing to the `$DDS_ROOT` and using `tests/auto_run_tests.pl`. Pass `-Config OPENDDS_SAFETY_PROFILE`, `-Config SAFETY_BASE` (if using safety base), `-Config RTPS`, and `-Config` options corresponding to each disabled compliance profile, by default: `-Config DDS_NO_OBJECT_MODEL_PROFILE -Config DDS_NO_OWNERSHIP_KIND_EXCLUSIVE -Config DDS_NO_PERSISTENCE_PROFILE -Config DDS_NO_CONTENT_SUBSCRIPTION`.

Alternatively, an individual test can be run using `run_test.pl` from that test's directory. Pass the same set of `-Config` options to `run_test.pl`.

2.18.6 Using the Memory Pool in Applications

When the Memory Pool is enabled at build time, all dynamic allocations made by code in OpenDDS or in ACE (methods invoked by OpenDDS) go through the pool. Since the pool is a general purpose dynamic allocator, it may be desirable for application code to use the pool too. Since these APIs are internal to OpenDDS, they may change in future releases.

The class `OpenDDS::DCPS::MemoryPool` (`dds/DCPS/MemoryPool.h`) contains the pool implementation. However, most client code shouldn't interact directly with it. The class `OpenDDS::DCPS::SafetyProfilePool` (`dds/DCPS/SafetyProfilePool.h`) adapts the pool to the ACE_Allocator interface. `OpenDDS::DCPS::PoolAllocator<T>` (`dds/DCPS/PoolAllocator.h`) adapts the pool to the C++ Allocator concept (C++03). Since the `PoolAllocator` is stateless, it depends on the `ACE_Allocator`'s singleton. When OpenDDS is configured with the memory pool, `ACE_Allocator`'s singleton instance will point to an object of class SafetyProfilePool.

Application code that makes use of C++ Standard Library classes can either use `PoolAllocator` directly, or make use of the macros defined in `dds/DCPS/PoolAllocator.h` (for example `String`).

Application code that allocates raw (untyped) buffers of dynamic memory can use `SafetyProfilePool` either directly or via the `ACE_Allocator::instance()` singleton.

Application code that allocates objects from the heap can use the `PoolAllocator<T>` template.

Classes written by the application developer can derive from `PoolAllocationBase` (see `dds/DCPS/PoolAllocationBase.h`) to inherit class-scoped operators `new` and `delete`, thus redirecting all dynamic allocation of these classes to the pool.

2.19 DDS Security

OpenDDS includes an implementation of the *DDS Security specification*. This allows participants to encrypt messages and to authenticate remote participants before engaging with them.

Important: Library filename: `OpenDDS_Security`

MPC base project name: `opendds_security`

CMake target Name: *`OpenDDS::Security`*

Initialization header: `dds/DCPS/security/BuiltInPlugins.h`

2.19.1 Building OpenDDS with Security Enabled

OpenDDS isn't built with security enabled by default. See *Security* for more information.

2.19.2 Architecture of the DDS Security Specification

The DDS Security specification defines plugin APIs for Authentication, Access Control, and Cryptographic operations. These APIs provide a level of abstraction for DDS implementations as well as allowing for future extensibility and version control. Additionally, the specification defines Built-In implementations of each of these plugins, which allows for a baseline of functionality and interoperability between DDS implementations. OpenDDS implements these Built-In plugins, and this document assumes that the Built-In plugins are being used. Developers using OpenDDS may also implement their own custom plugins, but those efforts are well beyond the scope of this document.

2.19.3 Terms and Background Info

DDS Security uses current industry standards and best-practices in security. As such, this document makes use of several security concepts which may warrant additional research by OpenDDS users.

Term Group	References
Public Key Cryptography (including Private Keys)	• Public Key Cryptography • RSA • Elliptic Curve Cryptography
Public Key Certificate	• Public Key Certificate • Certificate Authority • X.509 • PEM
Signed Documents	• Digital Signature

2.19.4 Required DDS Security Artifacts

Per-Domain Artifacts

These are shared by all participants within the secured DDS Domain:

- Identity CA Certificate
- Permissions CA Certificate (may be same as Identity CA Certificate)
- Governance Document
  - Signed by Permissions CA using its private key

Per-Participant Artifacts

These are specific to the individual Domain Participants within the DDS Domain:

- Identity Certificate and its Private Key
  - Issued by Identity CA (or a CA that it authorized to act on its behalf)
- Permissions Document
  - Contains a "subject name" which matches the participant certificate's Subject
  - Signed by Permissions CA using its private key

2.19.5 Required OpenDDS Configuration

The following configuration steps are required to enable OpenDDS Security features:

1. Select RTPS Discovery and the RTPS-UDP Transport; because DDS Security only works with these configurations, both must be specified for any security-enabled participant.
2. Enable OpenDDS security-features, which can be done two ways:
   - Via API: `TheServiceParticipant->set_security(true);` or
   - Via config file: setting *`[common] DCPSSecurity`* to 1.

DDS Security Configuration via Property Qos Policy

When the application creates a *DomainParticipant*, the `DomainParticipantQos` passed to the `create_participant()` method contains *Property QoS*, which has a sequence of name-value pairs. The following properties must be included to enable security. Except where noted, these values take the form of a URI starting with either the scheme `file:` followed by a filesystem path (absolute or relative) or the scheme `data:`, followed by the literal data.

Name	Value	Notes
`dds.sec.auth.identity_ca`	Certificate PEM file	Can be the same as `permissions_ca`
`dds.sec.access.permissions_ca`	Certificate PEM file	Can be the same as `identity_ca`
`dds.sec.access.governance`	Signed XML (.p7s)	Signed by `permissions_ca`
`dds.sec.auth.identity_certificate`	Certificate PEM file	Signed by `identity_ca`
`dds.sec.auth.private_key`	Private Key PEM file	Private key for `identity_certificate`
`dds.sec.auth.password`	Private Key Password (not a URI)	Optional, Base64 encoded
`dds.sec.access.permissions`	Signed XML (.p7s)	Signed by `permissions_ca`

Example Code

Below is an example of code that sets the Participant QoS's *Property QoS* in order to configure DDS Security.

```
// DDS Security artifact file locations
const char auth_ca_file[] = "file:identity_ca_cert.pem";
const char perm_ca_file[] = "file:permissions_ca_cert.pem";
const char id_cert_file[] = "file:test_participant_01_cert.pem";
const char id_key_file[] = "file:test_participant_01_private_key.pem";
const char governance_file[] = "file:governance_signed.p7s";
const char permissions_file[] = "file:permissions_01_signed.p7s";

// DDS Security property names
const char DDSSEC_PROP_IDENTITY_CA[] = "dds.sec.auth.identity_ca";
const char DDSSEC_PROP_IDENTITY_CERT[] = "dds.sec.auth.identity_certificate";
const char DDSSEC_PROP_IDENTITY_PRIVKEY[] = "dds.sec.auth.private_key";
const char DDSSEC_PROP_PERM_CA[] = "dds.sec.access.permissions_ca";
const char DDSSEC_PROP_PERM_GOV_DOC[] = "dds.sec.access.governance";
const char DDSSEC_PROP_PERM_DOC[] = "dds.sec.access.permissions";

void append(DDS::PropertySeq& props, const char* name, const char* value)
{
  const DDS::Property_t prop = {name, value, false /*propagate*/};
  const unsigned int len = props.length();
  props.length(len + 1);
  props[len] = prop;
}

int main(int argc, char* argv[])
{
  DDS::DomainParticipantFactory_var dpf =
```

(continues on next page)

(continued from previous page)

```
  TheParticipantFactoryWithArgs(argc, argv);

// Start with the default Participant QoS
DDS::DomainParticipantQos part_qos;
dpf->get_default_participant_qos(part_qos);

// Add properties required by DDS Security
DDS::PropertySeq& props = part_qos.property.value;
append(props, DDSSEC_PROP_IDENTITY_CA, auth_ca_file);
append(props, DDSSEC_PROP_IDENTITY_CERT, id_cert_file);
append(props, DDSSEC_PROP_IDENTITY_PRIVKEY, id_key_file);
append(props, DDSSEC_PROP_PERM_CA, perm_ca_file);
append(props, DDSSEC_PROP_PERM_GOV_DOC, governance_file);
append(props, DDSSEC_PROP_PERM_DOC, permissions_file);

// Create the participant
participant = dpf->create_participant(4, // DomainID
                                      part_qos,
                                      0, // No listener
                                      OpenDDS::DCPS::DEFAULT_STATUS_MASK);
```

Identity Certificates and Certificate Authorities

All certificate inputs to OpenDDS, including self-signed CA certificates, are expected to be an X.509 v3 certificate in PEM format for either a 2048-bit RSA key or a 256-bit Elliptic Curve key (using the prime256v1 curve).

Identity, Permissions, and Subject Names

The "subject_name" element for a signed permissions XML document must match the "Subject:" field provided by the accompanying Identity Certificate which is transmitted during participant discovery, authentication, and authorization. This ensures that the permissions granted by the Permissions CA do, in fact, correspond to the identity provided.

Examples in the OpenDDS Source Code Repository

Examples to demonstrate how the DDS Security features are used with OpenDDS can be found in the OpenDDS GitHub repository.

The following table describes the various examples and where to find them in the source tree.

Example	Source Location
C++ application that configures security QoS policies via command-line parameters	`tests/DCPS/Messenger/publisher.cpp`
Identity CA Certificate (along with private key)	`tests/security/certs/identity/identity_ca_cert.pem`
Permissions CA Certificate (along with private key)	`tests/security/certs/permissions/permissions_ca_cert.pem`
Participant Identity Certificate (along with private key)	`tests/security/certs/identity/test_participant_01_cert.pem`
Governance XML Document (alongside signed document)	`tests/DCPS/Messenger/governance.xml`
Permissions XML Document (alongside signed document)	`tests/DCPS/Messenger/permissions_1.xml`

Using OpenSSL Utilities for OpenDDS

To generate certificates using the `openssl` command, a configuration file `openssl.cnf` is required (see below for example commands). Before proceeding, it may be helpful to review OpenSSL's man pages to get help with the file format. In particular, configuration file format and ca command's documentation and configuration file options.

An example OpenSSL CA-Config file used in OpenDDS testing can be found here: `tests/security/certs/identity/identity_ca_openssl.cnf`

Creating Self-Signed Certificate Authorities

Generate a self-signed 2048-bit RSA CA:

```
openssl genrsa -out ca_key.pem 2048
openssl req -config openssl.cnf -new -key ca_key.pem -out ca.csr
openssl x509 -req -days 3650 -in ca.csr -signkey ca_key.pem -out ca_cert.pem
```

Generate self-signed 256-bit Elliptic Curve CA:

```
openssl ecparam -name prime256v1 -genkey -out ca_key.pem
openssl req -config openssl.cnf -new -key ca_key.pem -out ca.csr
openssl x509 -req -days 3650 -in ca.csr -signkey ca_key.pem -out ca_cert.pem
```

Creating Signed Certificates with an Existing CA

Generate a signed 2048-bit RSA certificate:

```
openssl genrsa -out cert_1_key.pem 2048
openssl req -new -key cert_1_key.pem -out cert_1.csr
openssl ca -config openssl.cnf -days 3650 -in cert_1.csr -out cert_1.pem
```

Generate a signed 256-bit Elliptic Curve certificate:

```
openssl ecparam -name prime256v1 -genkey -out cert_2_key.pem
openssl req -new -key cert_2_key.pem -out cert_2.csr
openssl ca -config openssl.cnf -days 3650 -in cert_2.csr -out cert_2.pem
```

Signing Documents with SMIME

Sign a document using existing CA & CA private key:

```
openssl smime -sign -in doc.xml -text -out doc_signed.p7s -signer ca_cert.pem -inkey ca_
↪private_key.pem
```

2.19.6 Common XML Elements

These are elements that are common to all the XML documents.

Domain Id Set

A list of domain ids and/or domain id ranges of domains impacted by the current domain rule. This is the type of `domains` in the *governance document* and in the *permissions document*.

The set is made up of `<id>` tags or `<id_range>` tags. An `<id>` tag simply contains the domain id that are part of the set. An `<id_range>` tag can be used to add multiple ids at once. It must contain a `<min>` tag to say where the range starts and may also have a `<max>` tag to say where the range ends. If the `<max>` tag is omitted then the set includes all valid domain ids starting at `<min>`.

If the domain rule or permissions grant should to apply to all domains, use the following:

```
<domains>
  <id_range><min>0</min></id_range>
</domains>
```

If there's a need to be selective about what domains are chosen, here's an annotated example:

```
<domains>
  <id>2</id>
  <id_range><min>4</min><max>6</max></id_range> <!-- 4, 5, 6 -->
  <id_range><min>10</min></id_range> <!-- 10 and onward -->
</domains>
```

2.19.7 Domain Governance Document

The signed governance document is used by the DDS Security built-in access control plugin in order to determine both per-domain and per-topic security configuration options for specific domains. For full details regarding the content of the governance document, see DDS Security v1.1 9.4.1.2 Domain Governance Document.

Global Governance Model

It's worth noting that the DDS Security Model expects the governance document to be globally shared by all participants making use of the relevant domains described within the governance document. Even if this is not the case, the local participant will verify incoming authentication and access control requests as if the remote participant shared the same governance document and accept or reject the requests accordingly.

Key Governance Elements

The following types and values are used in configuring both per-domain and per-topic security configuration options. We summarize them here to simplify discussion of the configuration options where they're used, found below.

Boolean

A boolean value indicating whether a configuration option is enabled or not. Recognized values are: `TRUE`/`true`/`1` and `FALSE`/`false`/`0`

Protection Kind

The method used to protect domain data (message signatures or message encryption) along with the ability to include origin authentication for either protection kind.

Recognized values are:

- `NONE`
- `SIGN`
- `ENCRYPT`
- `SIGN_WITH_ORIGIN_AUTHENTICATION`
- `ENCRYPT_WITH_ORIGIN_AUTHENTICATION`

> **Attention:** Currently, OpenDDS doesn't implement origin authentication. So while the `_WITH_ORIGIN_AUTHENTICATION` options are recognized, the underlying configuration is unsupported.

Basic Protection Kind

The method used to protect domain data (message signatures or message encryption). Recognized values are `NONE`, `SIGN`, and `ENCRYPT`

Domain Rule Configuration Options

The following XML elements are used to configure domain participant behaviors.

domains

A *Domain Id Set* of domains impacted by the current domain rule.

allow_unauthenticated_participants

A *Boolean* value which determines whether to allow unauthenticated participants for the current domain rule

enable_join_access_control

A *Boolean* value which determines whether to enforce domain access controls for authenticated participants

discovery_protection_kind

The discovery protection element specifies the *Protection Kind* used for the built-in DataWriter(s) and DataReader(s) used for secure endpoint discovery messages

liveliness_protection_kind

The liveliness protection element specifies the *Protection Kind* used for the built-in DataWriter and DataReader used for secure liveliness messages

rtps_protection_kind

Indicate the *Protection Kind* for the whole RTPS message. Very little RTPS data exists outside the "metadata protection" envelope (see topic rule configuration options), and so for most use cases topic-level "data protection" or "metadata protection" can be combined with discovery protection and/or liveliness protection in order to secure domain data adequately. One item that is not secured by "metadata protection" is the timestamp, since RTPS uses a separate InfoTimestamp submessage for this. The timestamp can be secured by using `rtps_protection_kind`

Topic Rule Configuration Options

The following XML elements are used to configure topic endpoint behaviors:

topic_expression

A *fnmatch expression* of the topic names to match. A default rule to catch all previously unmatched topics can be made with: `<topic_expression>*</topic_expression>`

enable_discovery_protection

A *Boolean* to enable the use of secure discovery protections for matching user topic announcements.

enable_read_access_control

A *Boolean* to enable the use of access control protections for matching user topic DataReaders.

enable_write_access_control

A *Boolean* to enable the use of access control protections for matching user topic DataWriters.

metadata_protection_kind

Specifies the *Protection Kind* used for the RTPS SubMessages sent by any DataWriter and DataReader whose associated Topic name matches the rule's topic expression.

data_protection_kind

Specifies the *Basic Protection Kind* used for the RTPS SerializedPayload SubMessage element sent by any DataWriter whose associated Topic name matches the rule's topic expression.

Governance XML Example

```
<?xml version="1.0" encoding="utf-8"?>
<dds xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation=
↪"http://www.omg.org/spec/DDS- Security/20170801/omg_shared_ca_domain_governance.xsd">
  <domain_access_rules>
    <domain_rule>
      <domains>
        <id>0</id>
        <id_range>
          <min>10</min>
          <max>20</max>
        </id_range>
      </domains>
      <allow_unauthenticated_participants>FALSE</allow_unauthenticated_participants>
      <enable_join_access_control>TRUE</enable_join_access_control>
      <rtps_protection_kind>SIGN</rtps_protection_kind>
      <discovery_protection_kind>ENCRYPT</discovery_protection_kind>
      <liveliness_protection_kind>SIGN</liveliness_protection_kind>
      <topic_access_rules>
        <topic_rule>
          <topic_expression>Square*</topic_expression>
          <enable_discovery_protection>TRUE</enable_discovery_protection>
          <enable_read_access_control>TRUE</enable_read_access_control>
          <enable_write_access_control>TRUE</enable_write_access_control>
          <metadata_protection_kind>ENCRYPT</metadata_protection_kind>
          <data_protection_kind>ENCRYPT</data_protection_kind>
        </topic_rule>
        <topic_rule>
          <topic_expression>Circle</topic_expression>
          <enable_discovery_protection>TRUE</enable_discovery_protection>
          <enable_read_access_control>FALSE</enable_read_access_control>
          <enable_write_access_control>TRUE</enable_write_access_control>
          <metadata_protection_kind>ENCRYPT</metadata_protection_kind>
          <data_protection_kind>ENCRYPT</data_protection_kind>
        </topic_rule>
```

(continues on next page)

(continued from previous page)

```
        <topic_rule>
          <topic_expression>Triangle</topic_expression>
          <enable_discovery_protection>FALSE</enable_discovery_protection>
          <enable_read_access_control>FALSE</enable_read_access_control>
          <enable_write_access_control>TRUE</enable_write_access_control>
          <metadata_protection_kind>NONE</metadata_protection_kind>
          <data_protection_kind>NONE</data_protection_kind>
        </topic_rule>
        <topic_rule>
          <topic_expression>*</topic_expression>
          <enable_discovery_protection>TRUE</enable_discovery_protection>
          <enable_read_access_control>TRUE</enable_read_access_control>
          <enable_write_access_control>TRUE</enable_write_access_control>
          <metadata_protection_kind>ENCRYPT</metadata_protection_kind>
          <data_protection_kind>ENCRYPT</data_protection_kind>
        </topic_rule>
      </topic_access_rules>
    </domain_rule>
  </domain_access_rules>
</dds>
```

2.19.8 Participant Permissions Document

The signed permissions document is used by the DDS Security built-in access control plugin in order to determine participant permissions to join domains and to create endpoints for reading, writing, and relaying domain data. For full details regarding the content of the permissions document, see DDS Security v1.1 9.4.1.3 DomainParticipant permissions document.

Key Permissions Elements

Each permissions file consists of one or more permissions grants. Each grant bestows access control privileges to a single subject name for a limited validity period.

subject_name

This is a X.509 subject name field. In order for permissions checks to successfully validate for both local and remote participants, the supplied identity certificate subject name must match the subject name of one of the grants included in the permissions file.

This will look something like:

```
<subject_name>emailAddress=cto@acme.com, CN=DDS Shapes Demo, OU=CTO Office, O=ACME Inc.,␣
↪L=Sunnyvale, ST=CA, C=US</subject_name>
```

Changed in version 3.25.0: The order of attributes in subject names is now significant.

validity

Each grant's validity section contains a start date and time (<not_before>) and an end date and time (<not_after>) to indicate the period of time during which the grant is valid.

The format of the date and time, which is like ISO-8601, must take one of the following forms:

1. `YYYY-MM-DDThh:mm:ss`

   Example: `2020-10-26T22:45:30`

2. `YYYY-MM-DDThh:mm:ssZ`

   Example:`2020-10-26T22:45:30Z`

3. `YYYY-MM-DDThh:mm:ss+hh:mm`

   Example:`2020-10-26T23:45:30+01:00`

4. `YYYY-MM-DDThh:mm:ss-hh:mm`

   Example:`2020-10-26T16:45:30-06:00`

All fields shown must include leading zeros to fill out their full width, as shown in the examples. `YYYY-MM-DD` is the date and `hh:mm:ss` is the time in 24-hour format. The date and time must be able to be represented by the `time_t` (C standard library) type of the system. The seconds field can also include a variable length fractional part, like `00.0` or `01.234`, but it will be ignored because `time_t` represents a whole number of seconds. Examples #1 and #2 are both interpreted using UTC. To put the date and time in a local time, a time zone offset can to be added that says how far the local timezone is ahead of (using + as in example #3) or behind (using - as in example #4) UTC at that date and time.

allow_rule and deny_rule

Grants will contain one or more allow / deny rules to indicate which privileges are being applied. When verifying that a particular operation is allowed by the supplied grant, rules are checked in the order they appear in the file. If the domain, partition, and (when implemented) data tags for an applicable topic rule match the operation being verified, the rule is applied (either allow or deny). Otherwise, the next rule is considered. Special Note: If a grant contains any allow rule that matches a given domain (even one with no publish / subscribe / relay rules), the grant may be used to join a domain with join access controls enabled.

domains

Every allow or deny rule must contain a set of domain ids to which it applies. The syntax is the same as the domain id set found in the governance document. See *Domain Id Set* for details.

publish, subscribe, and relay Rules (PSR rules)

Every allow or deny rule may optionally contain a list of publish, subscribe, or relay rules bestowing privileges to publish, subscribe, or relay data (respectively). Each rule applies to a collection of topics in a set of partitions with a particular set of data tags. As such, each rule must then meet these three conditions (topics, partitions, and (when implemented) data tags) in order to apply to a given operation. These conditions are governed by their relevant subsection, but the exact meaning and default values will vary depending on the both the PSR type (publish, subscribe, relay) as well as whether this is an allow rule or a deny rule. Each condition is summarized below. See the DDS Security specification for full details. OpenDDS does not currently support relay-only behavior and consequently ignores allow and deny relay rules for both local and remote entities. Additionally, OpenDDS does not currently support data tags, and so the data tag condition applied is always the "default" behavior described below.

topics

The list of topics and/or topic expressions for which a rule applies. Topic names and expressions are matched using *Fnmatch Expressions*. If the triggering operation matches any of the topics listed, the topic condition is met. The topic section must always be present for a PSR rule, so there there is no default behavior.

partitions

The partitions list contains the set of partition names for which the parent PSR rule applies. Similarly to topics, partition names and expressions are matched using *Fnmatch Expressions*. For "allow" PSR rules, the DDS entity of the associated triggering operation must be using a strict subset of the partitions listed for the rule to apply. When no partition list is given for an "allow" PSR rule, the "empty string" partition is used as the default value. For "deny" PSR rules, the rule will apply if the associated DDS entity is using any of the partitions listed. When no partition list is given for a "deny" PSR rule, the wildcard expression "*" is used as the default value.

data_tags

Attention: Data tags are an optional part of the DDS Security specification and are not currently implemented by OpenDDS. If they were implemented, the condition criteria for data tags would be similar to partitions.

For "allow" PSR rules, the DDS entity of the associated triggering operation must be using a strict subset of the data tags listed for the rule to apply. When no data tag list is given for an "allow" PSR rule, the empty set of data tags is used as the default value. For "deny" PSR rules, the rule will apply if the associated DDS entity is using any of the data tags listed. When no data tag list is given for a "deny" PSR rule, the set of "all possible tags" is used as the default value.

validity

Attention: This is an OpenDDS extension.

This structure defines the validity of a particular publish or subscribe action. Thus, it is possible to declare that an action is valid for some subset of the grant's validity. The format for *validity* is the same as *validity*.

default_rule

The default rule is the rule applied if none of the grant's allow rules or deny rules match the incoming operation to be verified. Recognized values are `ALLOW` and `DENY`.

Permissions XML Example

```
<?xml version="1.0" encoding="UTF-8"?>
<dds xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation=
↪"http://www.omg.org/spec/DDS-Security/20170801/omg_shared_ca_permissions.xsd">
  <permissions>
    <grant name="ShapesPermission">
      <subject_name>emailAddress=cto@acme.com, CN=DDS Shapes Demo, OU=CTO Office, O=ACME␣
↪Inc., L=Sunnyvale, ST=CA, C=US</subject_name>
      <validity>
        <not_before>2015-10-26T00:00:00</not_before>
        <not_after>2020-10-26T22:45:30</not_after>
      </validity>
      <allow_rule>
        <domains>
          <id>0</id>
        </domains>
      </allow_rule>
      <deny_rule>
        <domains>
          <id>0</id>
        </domains>
        <publish>
          <topics>
            <topic>Circle1</topic>
          </topics>
        </publish>
        <publish>
          <topics>
            <topic>Square</topic>
          </topics>
          <partitions>
            <partition>A_partition</partition>
          </partitions>
        </publish>
        <subscribe>
          <topics>
            <topic>Square1</topic>
          </topics>
        </subscribe>
        <subscribe>
          <topics>
            <topic>Tr*</topic>
          </topics>
          <partitions>
            <partition>P1*</partition>
          </partitions>
        </subscribe>
      </deny_rule>
      <default>DENY</default>
    </grant>
  </permissions>
</dds>
```

2.19.9 DDS Security Implementation Status

The following DDS Security features are not implemented in OpenDDS.

1. Optional parts of the DDS Security v1.1 specification
   - Ability to write a custom plugin in C or in Java (C++ is supported)
   - Logging Plugin support
   - Built-in Logging Plugin
   - Data Tagging
2. Use of RTPS KeyHash for encrypted messages
   - OpenDDS doesn't use KeyHash, so it meets the spec requirements of not leaking secured data through KeyHash
3. Immutability of Publisher's Partition QoS, see OMG Issue DDSSEC12-49 (Member Link)
4. Use of multiple plugin configurations (with different Domain Participants)
5. CRL (**RFC 5280**) and OCSP (**RFC 2560**) support
6. Certain plugin operations not used by built-in plugins may not be invoked by middleware
7. Origin Authentication
8. PKCS#11 for certificates, keys, passwords
9. Relay as a permissions "action" (Publish and Subscribe are supported)
10. Legacy matching behavior of permissions based on Partition QoS
11. 128-bit AES keys (256-bit is supported)
12. Configuration of Built-In Crypto's key reuse (within the DataWriter) and blocks-per-session
13. Signing (without encrypting) at the payload level, see OMG Issue DDSSEC12-59 (Member Link)

The following features are OpenDDS extensions:

1. Validity of publish/subscribe actions *validity*.

2.20 Internet-Enabled RTPS

2.20.1 Overview

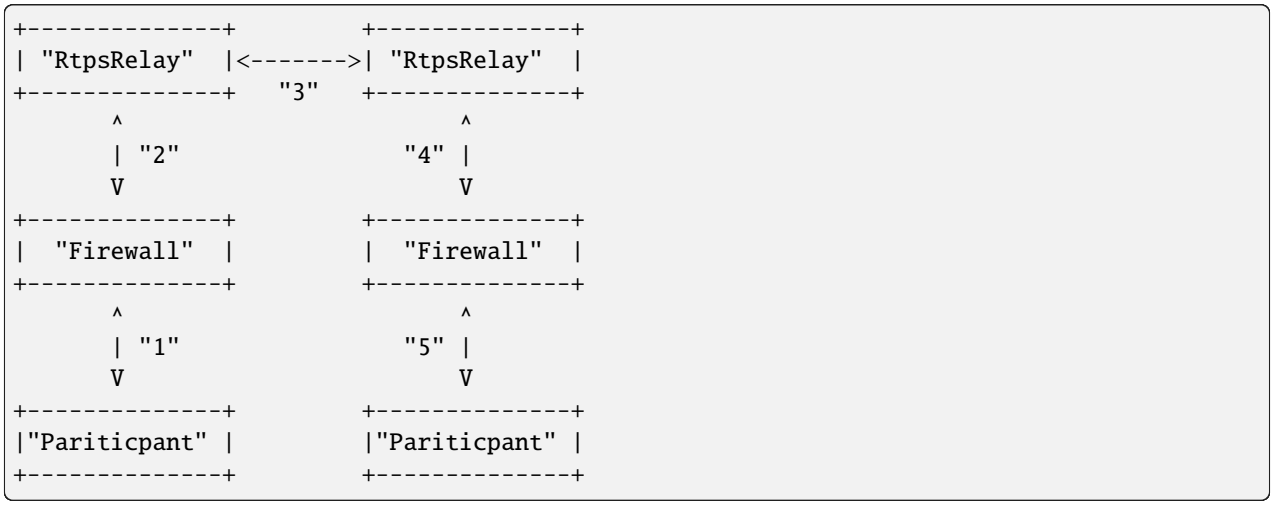
Like any specification, standard, or system, RTPS was designed with certain assumptions. Two of these assumptions severely limit the ability to use RTPS in modern network environments. First, RTPS, or more specifically, SPDP uses multicast for discovery. Multicast is not supported on the public Internet which precludes the use of RTPS for Internet of Things (IoT) applications and Industrial Internet of Things (IIoT) applications. Second, SPDP and SEDP advertise locators (IP and port pairs) for endpoints (DDS readers and writer). If the participant is behind a firewall that performs network address translation, then the locators advertised by the participant are useless to participants on the public side of the firewall.

This section describes different tools and techniques for getting around these limitations. First, we introduce the *RtpsRelay* as a service for forwarding RTPS messages according to application-defined groups. The RtpsRelay can be used to connect participants that are deployed in environments that don't support multicast and whose packets are subject to NAT. Second, we introduce Interactive Connection Establishment (ICE) for RTPS. Adding ICE to RTPS is an

optimization that allows participants that are behind firewalls that perform NAT to exchange messages directly. ICE requires a back channel for distributing discovery information and is typically used with the RtpsRelay.

2.20.2 The RtpsRelay

The RtpsRelay is designed to allow participants to exchange RTPS datagrams when separated by a firewall that performs network address translation (NAT) and/or a network that does not support multicast like the public Internet. The RtpsRelay supports both IPv4 and IPv6. A participant that uses an RtpsRelay Instance is a *client* of that instance. Each RtpsRelay instance contains two participants: the *Application Participant* and the *Relay Participant*. The Application Participant runs in the domain of the application. The RtpsRelay reads the built-in topics to discover Participants, DataReaders, and DataWriters. It then shares this information with other RtpsRelay instances using the Relay Participant. Each RtpsRelay instance maintains a map of associated readers and writers. When a client sends an RTPS datagram to its RtpsRelay instance, the RtpsRelay instance uses the association table to forward the datagram to other clients and other RtpsRelay instances so that they can deliver it to their clients. Clients send RTPS datagrams via unicast which is generally supported and compatible with NAT. The RtpsRelay can be used in lieu of or in addition to conventional RTPS discovery.



The preceding diagram illustrates how the RtpsRelay can be used to connect participants that are behind firewalls that may be performing NAT. First, a Participant sends an RTPS datagram to its associated RtpsRelay (1). This datagram is intercepted by the firewall, the source address and port are replaced by the external IP address and port of the firewall, and then the datagram is sent to the RtpsRelay (2). The relationship between the source address and external IP address and port selected by the firewall is called a NAT binding. The RtpsRelay instance forwards the datagram to other RtpsRelay instances (3). The RtpsRelays then forward the datagram to all of the destination participants (4). Firewalls on the path to the participants intercept the packet and replace the destination address (which is the external IP and port of the firewall) with the address of the Participant according to a previously created NAT binding (5).

The RTPS implementation in OpenDDS uses a port for SPDP, a port for SEDP, and a port for conventional RTPS messages. The relay mirrors this idea and exposes three ports to handle each type of traffic.

To keep NAT bindings alive, clients send STUN binding requests and indications periodically to the RtspRelay ports. Participants using ICE may use these ports as a STUN server for determining a server reflexive address. The timing parameters for the periodic messages are controlled via the ICE configuration variables for server reflexive addresses.

Using the RtpsRelay

Support for the RtpsRelay is activated via configuration. See *[rtps_discovery]* and *[transport] (rtps_udp)* for details. As an example:

```
[common]
DCPSGlobalTransportConfig=$file

[domain/4]
DiscoveryConfig=rtps

[rtps_discovery/rtps]
SpdpRtpsRelayAddress=1.2.3.4:4444
SedpRtpsRelayAddress=1.2.3.4:4445
UseRtpsRelay=1

[transport/the_rtps_transport]
transport_type=rtps_udp
DataRtpsRelayAddress=1.2.3.4:4446
UseRtpsRelay=1
```

Each participant should use a single RtpsRelay instance due to the way NAT bindings work. Most firewalls will only forward packets received from the destination address that was originally used to create the NAT binding. That is, if participant A is interacting with relay A and participant B is interacting with relay B, then a message from A to B must go from A to relay A, to relay B, and finally to B. Relay A cannot send directly to B since that packet will not be accepted by the firewall.

Usage

The RtpsRelay itself is an OpenDDS application. The source code is located in `tools/rtpsrelay`. Security must be enabled to build the RtpsRelay. See *Building OpenDDS with Security Enabled*. Each RtpsRelay process has a set of ports for exchanging RTPS messages with the participants called the "vertical" ports and a set of ports for exchanging RTPS messages with other relays called the "horizontal" ports.

The RtpsRelay contains an embedded webserver called the meta discovery server. The webserver has the following endpoints:

- `/config`

  Responds with configured content and content type. See -MetaDiscovery options below. Potential client participants can download the necessary configuration from this endpoint.

- `/healthcheck`

  Responds with HTTP 200 (OK) or 503 (Service Unavailable) if *thread monitoring is enabled* and the RtpsRelay is not admitting new client participants. Load balancers can use this endpoint to route new client participants to an available RtpsRelay instance.

The command-line options for the RtpsRelay:

-Id <string>

This option is mandatory and is a unique id associated with all topics published by the relay.

-HorizontalAddres <address>

Determines the base network address used for receiving RTPS message from other relays. By default, the relay listens on the first IP network and uses port 11444 for SPDP messages, 11445 for SEDP messages, and 11446 for data messages.

-VerticalAddress <address>

Determines the base network address used for receiving RTPS messages from the participants. By default, the relay listens on 0.0.0.0:4444 for SPDP messages, 0.0.0.0:4445 for SEDP messages, and 0.0.0.0.4446 for data messages.

-RelayDomain <domain>

Sets the DDS domain used by the Relay Participant. The default is 0.

-ApplicationDomain <domain>

Sets the DDS domain used by the Application Participant. The default is 1.

-UserData <string>

Set the contents of the Application Participant's *UserData QoS policy* to the provided string.

-BufferSize <integer>

Send of send and receive buffers in bytes

-Lifespan <seconds>

RtpsRelay will only forward a datagram to a client if it has received a datagram from the client in this amount of time. Otherwise, participant is marked as not alive. The default is 60 seconds.

-InactivePeriod <seconds>

RtpsRelay will mark participant as not active if does not receive a datagram from the client in this amount of time. The default is 60 seconds.

-AllowEmptyPartition 0|1

Allow client participants with no partitions. Defaults to 1 (true).

-IdentityCA <path>

Provide identity CA file for *DDS Security*.

-PermissionsCA <path>

Provide permissions CA file for *DDS Security*.

-IdentityCertificate <path>

Provide identity certificate file for *DDS Security*.

-IdentityKey <path>

Provide identity key file for *DDS Security*.

-Governance <path>

Provide governance file for *DDS Security*.

-Permissions <path>

Provide permissions file for *DDS Security*.

-RestartDetection 0|1

Setting to 1 causes the relay to track clients by the first 6 bytes of their RTPS GUID and source IP address and clean up older sessions with the same key. The default is 0 (false).

-LogWarnings 0|1

Enable/disable logging of warning events.

-LogDiscovery 0|1

Enable/disable logging of discovery events.

-LogActivity 0|1

Enable/disable logging of activity events.

-LogRelayStatistics <seconds>

-LogHandlerStatistics <seconds>

-LogParticipantStatistics <seconds>

Write statistics for the various event types to the log at the given interval, defaults to 0 (disabled).

-PublishRelayStatistics <seconds>

-PublishHandlerStatistics <seconds>

-PublishParticipantStatistics <seconds>

Configure the relay to publish usage statistics on DDS topics at the given interval, defaults to 0 (disabled).

-LogThreadStatus 0|1

If *thread monitoring is enabled*, log the status of the threads in the RtpsRelay, defaults to 0 (disabled).

-ThreadStatusSafetyFactor <integer>

Restart if *thread monitoring is enabled* and a thread has not checked in for this many reporting intervals, default 3.

-UtilizationLimit <decimal>

If *thread monitoring is enabled*, the RtpsRelay will not accept new client participants if the CPU utilization of any thread is above this limit, default .95.

-PublishRelayStatus <seconds>

Setting this to a positive integer causes the relay to publish its status at that interval.

-PublishRelayStatusLiveliness <seconds>

Setting this to a positive integer causes the relay to set the *Liveliness QoS* on the relay status topic.

-MetaDiscoveryAddress <host>:<port>

Listening address for the meta discovery server, default is `0.0.0.0:8080`.

-MetaDiscoveryContentType <content-type>

The HTTP content type to report for the meta discovery config endpoint, default is `application/json`.

-MetaDiscoveryContentPath <content>

-MetaDiscoveryContent <content>

The content returned by the meta discovery config endpoint, default `{}`. If a path is specified, the content of the file will be used.

-MaxIpsPerClient <integer>

The maximum number of IP addresses that the RtpsRelay will maintain for a client participant, defaults to 0 (infinite).

-RejectedAddressDuration <seconds>

Amount of time to reject messages from client participants that show suspicious behavior, e.g., those that send messages from the RtpsRelay back to the RtpsRelay. The default is 0 (disabled).

Deployment Considerations

Running an RtpsRelay relay cluster with RTPS in the cloud leads to a bootstrapping problem since multicast is not supported in the cloud. One option is to not use RTPS for discovery. Another option is to run a single well-known relay that allows the other relays to discover each other. A third option is to use a program translates multicast to unicast.

RTPS uses UDP which typically cannot be load balanced effectively due to the way NAT bindings work. Consequently, each RtpsRelay server must have a public IP address. Load balancing can be achieved by having the participants choose a relay according to a load balancing policy. To illustrate, each relay could also run an HTTP server which does nothing but serve the public IP address of the relay. These simple web servers would be exposed via a centralized load balancer. A participant, then, could access the HTTP load balancer to select a relay.

2.20.3 Interactive Connectivity Establishment (ICE) for RTPS

Interactive Connectivity Establishment (ICE) is protocol for establishing connectivity between a pair of hosts that are separated by at least one firewall that performs network address translation. ICE can be thought of as an optimization for situations that require an RtpsRelay. The success of ICE depends on the firewall(s) that separate the hosts.

The ICE protocol has three steps. First, a host determines its public IP address by sending a STUN binding request to a public STUN server. The STUN server sends a binding success response that contains the source address of the request. If the host has a public IP address, then the address returned by STUN will match the IP address of the host. Otherwise, the address will be the public address of the outermost firewall. Second, the hosts generate and exchange candidates (which includes the public IP address determined in the first step) using a side channel. A candidate is an IP and port that responds to STUN messages and sends datagrams. Third, the hosts send STUN binding requests to the candidates in an attempt to generate the necessary NAT bindings and establish connectivity.

For OpenDDS, ICE can be used to potentially establish connectivity between SPDP endpoints, SEDP endpoints, and ordinary RTPS endpoints. SPDP is used as the side channel for SEDP and SEDP is used as the side channel for the ordinary RTPS endpoints. To this, we added two parameters to the RTPS protocol for sending general ICE information and ICE candidates and added the ability to execute the ICE protocol and process STUN messages to the RTPS transports.

ICE is defined in **RFC 8445**. ICE utilizes the STUN protocol that is defined in **RFC 5389**. The ICE implementation in OpenDDS does not use TURN servers.

ICE is enabled through configuration. The minimum configuration involves setting the *[rtps_discovery] UseIce* and *[transport] UseIce (rtps_udp)* flags and providing addresses for the STUN servers. See *[rtps_discovery]* and *[transport] (rtps_udp)* for details.

```
[common]
DCPSGlobalTransportConfig=$file
DCPSDefaultDiscovery=DEFAULT_RTPS

[transport/the_rtps_transport]
transport_type=rtps_udp
DataRtpsRelayAddress=5.6.7.8:4446
UseIce=1
DataStunServerAddress=1.2.3.4:3478

[domain/42]
DiscoveryConfig=DiscoveryConfig1

[rtps_discovery/DiscoveryConfig1]
SpdpRtpsRelayAddress=5.6.7.8:4444
SedpRtpsRelayAddress=5.6.7.8:4445
```

(continues on next page)

(continued from previous page)

```
UseIce=1
SedpStunServerAddress=1.2.3.4:3478
```

2.20.4 Security Considerations

The purpose of this section is to inform users about potential security issues when using OpenDDS. Users of OpenDDS are encouraged to perform threat modeling, security reviews, assessments, testing, etc. to ensure that their applications meet their security objectives.

Use DDS Security

Most applications have common objectives with respect to data security:

- Authentication - The identity of every process that participates in the DDS domain can be established.
- Authorization - Only authorized writers of a topic may generate samples for a topic and only authorized readers may consume samples for a topic.
- Integrity - The content of a sample cannot be altered without detection.
- Privacy - The content of a sample cannot be read by an unauthorized third party.

If an application is subject to any of these security objectives, then it should use the DDS Security features described in *DDS Security*. Using a non-secure discovery mechanism or a non-secure transport leaves the application exposed to data security breaches.

Understand the Weaknesses of (Secure) RTPS Discovery

Secure RTPS Discovery has a behavior that can be exploited to launch a denial of service attack (see https://www.cisa.gov/news-events/ics-advisories/icsa-21-315-02). Basically, an attacker can send a fake SPDP message to a secure participant which will cause it to begin authentication with a non-existent participant. The authentication messages are repeated resulting in amplification. An attacker could manipulate a group of secure participants to launch a denial of service attack against a specific host or group of hosts. RTPS (without security) has the same vulnerability except that messages come from the other built-in endpoints. For this reason, consider the mitigation features below before making an OpenDDS participant publicly accessible.

The weakness in RTPS Discovery can be mitigated but currently does not have a solution. OpenDDS includes the following features for mitigation:

- Compare the source IP of the SPDP message to the locators. For most applications, the locators advertised by SPDP should match the source IP of the SPDP message.
  - See *[rtps_discovery] CheckSourceIp*
- Use the participant lease time from secure discovery and bound it otherwise. By default, OpenDDS will attempt authentication for the participant lease duration specified in the SPDP message. However, this data can't be trusted so a smaller maximum lease time can be specified to force authentication or discovery to terminate before the lease time.
  - See *[rtps_discovery] MaxAuthTime*
- Limit the number of outstanding secure discoveries. The number of discovered but not-yet-authenticated participants is capped when using secure discovery.
  - See *[rtps_discovery] MaxParticipantsInAuthentication*

Run Participants in a Secure Network

One approach to a secure application without DDS Security is to secure it at the network layer instead of the application layer. A physically secure network satisfies this by construction. Another approach is to use a virtual private network (VPN) or a secure overlay. These approaches have a simple security model when compared to DDS Security and are not interoperable.

2.21 XTypes

2.21.1 Overview

The DDS specification defines a way to build distributed applications using a data-centric publish and subscribe model. In this model, publishing and subscribing applications communicate via Topics and each Topic has a data type. An assumption built into this model is that all applications agree on data type definitions for each Topic that they use. This assumption is not practical as systems must be able to evolve while remaining compatible and interoperable.

The DDS XTypes (Extensible and Dynamic Topic Types) specification loosens the requirement on applications to have a common notion of data types. Using XTypes, the application developer adds IDL annotations that indicate where the types may vary between publisher and subscriber and how those variations are handled by the middleware.

OpenDDS implements the *XTypes specification* at the Basic Conformance level, with a partial implementation of the Dynamic Language Binding. Some features described by the specification are not yet implemented in OpenDDS - those are noted in *Unimplemented Features*. This includes IDL annotations that are not yet implemented (*Annotations*). See *Differences from the specification* for situations where the implementation of XTypes in OpenDDS departs from or infers something about the specification. Specification issues have been raised for these situations.

2.21.2 Features

Extensibility

There are 3 kinds of extensibility for types:

Appendable
: Appendable denotes a constructed type which may have additional members added onto or removed from the end, but not both at the same time. Appendable is the default extensibility. A type can be explicitly marked as appendable with the *@appendable* annotation.

Mutable
: Mutable denotes a constructed type that allows for members to be added, removed, and reordered so long as the keys and the required members of the sender and receiver remain. Mutable extensibility is accomplished by assigning a stable identifier to each member. A type can be marked as mutable with the *@mutable* annotation.

Final
: Final denotes a constructed type that can not add, remove, or reorder members. This can be considered a non-extensible constructed type, with behavior similar to that of a type created before XTypes. A type can be marked as final with the *@final* annotation.

The default extensibility can be changed with `opendds_idl --default-extensibility`.

Structs, unions, and enums are the only types which can use any of the extensibilities.

The default extensibility for enums is "appendable" and is not governed by `--default-extensibility`. TypeObjects for received enums that do not set any flags are treated as a wildcard.

Assignability

Assignability describes the ability of values of one type to be coerced to values of a possibility different type.

Assignability between the type of a writer and reader is checked as part of discovery. If the types are assignable but not identical, then the *"try construct"* mechanism will be used to coerce values of the writer's type to values of the reader's type.

In order for two constructed types to be assignable they must

- Have the same extensibility.
- Have the same set of keys.

Each member of a constructed type has an identifier. This identifier may be assigned automatically or explicitly.

Union assignability depends on two dimensions. First, unions are only assignable if their discriminators are assignable. Second, for any branch label or default that exists in both unions, the members selected by that branch label must be assignable.

Interoperability with non-XTypes Implementations

Communication with a non-XTypes DDS (either an older OpenDDS or another DDS implementation which has RTPS but not XTypes 1.2+) requires compatible IDL types and the use of RTPS Discovery. Compatible IDL types means that the types are structurally equivalent and serialize to the same bytes using XCDR version 1.

Additionally, the XTypes-enabled participant needs to be set up as follows:

- Types cannot use mutable extensibility
- Data Writers must have their Data Representation QoS policy set to `DDS::XCDR_DATA_REPRESENTATION`
- Data Readers must include `DDS::XCDR_DATA_REPRESENTATION` in the list of data representations in their Data Representation QoS (true by default)

Data Representation shows how to change the data representation. *XCDR1 Support* details XCDR1 support.

Dynamic Language Binding

Before the XTypes specification, all DDS applications worked by mapping the topic's data type directly into the programming language and having the data handling APIs such as read, write, and take, all defined in terms of that type. As an example, topic type A (an IDL structure) caused code generation of IDL interfaces ADataWriter and ADataReader while topic type B generated IDL interfaces BDataWriter and BDataReader. If an application attempted to pass an object of type A to the BDataWriter, a compile-time error would occur (at least for statically typed languages including C++ and Java). Advantages to this design include efficiency and static type safety, however, the code generation required by this approach is not desirable for every DDS application.

The XTypes Dynamic Language Binding defines a generic data container DynamicData and the interfaces DynamicDataWriter and DynamicDataReader. Applications can create instances of DynamicDataWriter and DynamicDataReader that work with various topics in the domain without needing to incorporate the generated code for those topics' data types. The system is still type safe but the type checks occur at runtime instead of at compile time. The Dynamic Language Binding is described in detail in *Dynamic Language Binding*.

2.21.3 Examples and Explanation

Suppose you are in charge of deploying a set of weather stations that publish temperature, pressure, and humidity. The following examples show how various features of XTypes may be applied to address changes in the schema published by the weather station. Specifically, without XTypes, one would either need to create a new type with its own DataWriters/DataReaders or update all applications simultaneously. With proper planning and XTypes, one can simply modify the existing type (within limits) and writers and readers using earlier versions of the topic type will remain compatible with each other and be compatible with writers and readers using new versions of the topic type.

Mutable Extensibility

The type published by the weather stations can be made extensible with the `@mutable` annotation:

```
// Version 1
@topic
@mutable
struct StationData {
  short temperature;
  double pressure;
  double humidity;
};
```

Suppose that some time in the future, a subset of the weather stations are upgraded to monitor wind speed and direction:

```
enum WindDir {N, NE, NW, S, SE, SW, W, E};
// Version 2
@topic
@mutable
struct StationData {
  short temperature;
  double pressure;
  double humidity;
  short wind_speed;
  WindDir wind_direction;
};
```

When a Version 2 writer interacts with a Version 1 reader, the additional fields will be ignored by the reader. When a Version 1 writer interacts with a Version 2 reader, the additional fields will be initialized to a "logical zero" value for its type (empty string, `FALSE` boolean) - see Table 9 of the XTypes specification for details.

Assignability

The first and second versions of the `StationData` type are *assignable* meaning that it is possible to construct a version 2 value from a version 1 value and vice-versa. The assignability of non-constructed types (e.g., integers, enums, strings) is based on the types being identical or identical up to parameterization, i.e., bounds of strings and sequences may differ. The assignability of constructed types like structs and unions is based on finding corresponding members with assignable types. Corresponding members are those that have the same id.

A type marked as `@mutable` allows for members to be added, removed, or reordered so long as member ids are preserved through all of the mutations.

Member IDs

Member ids are assigned using various annotations. A policy for a type can be set with either `@autoid(SEQUENTIAL)` or `@autoid(HASH)`:

```
// Version 3
@topic
@mutable
@autoid(SEQUENTIAL)
struct StationData {
  short temperature;
  double pressure;
  double humidity;
};

// Version 4
@topic
@mutable
@autoid(HASH)
struct StationData {
  short temperature;
  double pressure;
  double humidity;
};
```

`SEQUENTIAL` causes ids to be assigned based on the position in the type. `HASH` causes ids to be computed by hashing the name of the member. If no `@autoid` annotation is specified, the policy is `SEQUENTIAL`.

Suppose that Version 3 was used in the initial deployment of the weather stations and the decision was made to switch to `@autoid(HASH)` when adding the new fields for wind speed and direction. In this case, the ids of the pre-existing members can be set with `@id`:

```
enum WindDir {N, NE, NW, S, SE, SW, W, E};

// Version 5
@topic
@mutable
@autoid(HASH)
struct StationData {
  @id(0) short temperature;
  @id(1) double pressure;
  @id(2) double humidity;
  short wind_speed;
  WindDir wind_direction;
};
```

See the *Member ID assignment* for more details.

Appendable Extensibility

Mutable extensibility requires a certain amount of overhead both in terms of processing and network traffic. A more efficient but less flexible form of extensibility is appendable. Appendable is limited in that members can only be added to or removed from the end of the type. With appendable, the initial version of the weather station IDL would be:

```
// Version 6
@topic
@appendable
struct StationData {
  short temperature;
  double pressure;
  double humidity;
};
```

And the subsequent addition of the wind speed and direction members would be:

```
enum WindDir {N, NE, NW, S, SE, SW, W, E};

// Version 7
@topic
@appendable
struct StationData {
  short temperature;
  double pressure;
  double humidity;
  short wind_speed;
  WindDir wind_direction;
};
```

As with mutable, when a Version 7 Writer interacts with a Version 6 Reader, the additional fields will be ignored by the reader. When a Version 6 Writer interacts with a Version 7 Reader, the additional fields will be initialized to default values based on Table 9 of the XTypes specification.

Appendable is the default extensibility.

Final Extensibility

The third kind of extensibility is final. Annotating a type with `@final` means that it will not be compatible with (assignable to/from) a type that is structurally different. The `@final` annotation can be used to define types for pre-XTypes compatibility or in situations where the overhead of mutable or appendable is unacceptable.

Try Construct

From a reader's perspective, there are three possible scenarios when attempting to initialize a member. First, the member type is identical to the member type of the reader. This is the trivial case the value from the writer is copied to the value for the reader. Second, the writer does not have the member. In this case, the value for the reader is initialized to a default value based on Table 9 of the XTypes specification (this is the "logical zero" value for the type). Third, the type offered by the writer is assignable but not identical to the type required by the reader. In this case, the reader must try to construct its value from the corresponding value provided by the writer.

Suppose that the weather stations also publish a topic containing station information:

```
typedef string<8> StationID;
typedef string<256> StationName;

// Version 1
@topic
@mutable
struct StationInfo {
  @try_construct(TRIM) StationID station_id;
  StationName station_name;
};
```

Eventually, the pool of station IDs is exhausted so the IDL must be refined as follows:

```
typedef string<16> StationID;
typedef string<256> StationName;

// Version 2
@topic
@mutable
struct StationInfo {
  @try_construct(TRIM) StationID station_id;
  StationName station_name;
};
```

If a Version 2 writer interacts with a Version 1 reader, the station ID will be truncated to 8 characters. While perhaps not ideal, it will still allow the systems to interoperate.

There are two other forms of try-construct behavior. Fields marked as `@try_construct(USE_DEFAULT)` will receive a default value if value construction fails. In the previous example, this means the reader would receive an empty string for the station ID if it exceeds 8 characters. Fields marked as `@try_construct(DISCARD)` cause the entire sample to be discarded. In the previous example, the Version 1 reader will never see a sample from a Version 2 writer where the original station ID contains more than 8 characters. `@try_construct(DISCARD)` is the default behavior.

2.21.4 Data Representation

Data representation is the way a data sample can be encoded for transmission.

The possible data representations are:

XML
: This isn't currently supported.

  The `DataRepresentationId_t` value is `DDS::XML_DATA_REPRESENTATION`

  The annotation is *@OpenDDS::data_representation(XML)*.

XCDR1
: This is the pre-XTypes standard CDR extended with XTypes features. Support is limited to non-XTypes features, see *XCDR1 Support* for details.

  The `DataRepresentationId_t` value is `DDS::XCDR_DATA_REPRESENTATION`

  The annotation is *@OpenDDS::data_representation(XCDR1)*.

XCDR2
: This is default for writers when using the RTPS-UDP transport and should be preferred in most cases. It is a more robust and efficient version of XCDR1.

The `DataRepresentationId_t` value is `DDS::XCDR2_DATA_REPRESENTATION`

The annotation is *@OpenDDS::data_representation(XCDR2)*.

Unaligned CDR

This is a OpenDDS-specific encoding that is the default for writers using only non-RTPS-UDP transports. It can't be used by a DataWriter using the RTPS-UDP transport.

The `DataRepresentationId_t` value is `OpenDDS::DCPS::UNALIGNED_CDR_DATA_REPRESENTATION`

The annotation is *@OpenDDS::data_representation(UNALIGNED_CDR)*.

Use *Data Representation QoS* to define what representations writers and readers should use. Writers can only encode samples using only one data representation, but readers can accept multiple data representations. *@OpenDDS::data_representation* can be used to restrict what data representation can be used for a topic type in IDL.

Warning: Because writers default to XCDR2 instead of XCDR1, they aren't likely to be compatible with readers from OpenDDS versions before 3.16 and other DDS implementations by default. Either the remote readers will have to set to use XCDR2 if they support it or OpenDDS writers will have to be set to use XCDR1.

The example below shows a possible configuration for an XCDR1 DataWriter.

```
DDS::DataWriterQos qos;
pub->get_default_datawriter_qos(qos);
qos.representation.value.length(1);
qos.representation.value[0] = DDS::XCDR_DATA_REPRESENTATION;
DDS::DataWriter_var dw = pub->create_datawriter(topic, qos, 0, 0);
```

Note that the IDL constant used for XCDR1 is `XCDR_DATA_REPRESENTATION` (without the digit).

2.21.5 Type Consistency Enforcement

When a reader/writer match is happening, type consistency enforcement checks that the two types are compatible according to the type objects if they are available. This check will not happen if OpenDDS has been *configured not to generate or use type objects* or if the remote DDS doesn't support type objects. Some parts of the compatibility check can be controlled on the reader side using *Type Consistency Enforcement QoS*. The full type object compatibility check is too detailed to reproduce here. It can be found in DDS XTypes v1.3 7.2.4 Type Compatibility. In general though two topic types and their nested types are compatible if:

- Extensibilities of shared types match
- Extensibility rules haven't been broken, for example:
  - Changing a `@final` struct
  - Adding a member in the middle of an `@appendable` struct
- Length bounds of strings and sequences are the same or greater
- Lengths of arrays are exactly the same
- The keys of the types match exactly
- Shared member IDs match when required, like when they are final or are being used as keys

If the type objects are compatible then the match goes ahead. If one or both type objects are not available, then OpenDDS falls back to checking the names each entity's `TypeSupport` was given. This is the name passed to the `register_type` method of a `TypeSupport` object or if that string is empty then the name of the topic type in IDL.

An interesting side effect of these rules is when type objects are always available, then the topic type names passed to `register_type` are only used within that process. This means they can be changed and remote readers and writers will still match, assuming the new name is used consistently within the process and the types are still compatible.

2.21.6 IDL Annotations

Indicating Which Types Can Be Topic Types

@topic

Applies To: struct or union type declarations

The topic annotation marks a topic type for samples to be transmitted from a publisher or received by a subscriber. A topic type may contain other topic and non-topic types. See *Defining Data Types with IDL* for more details.

@nested

Applies To: struct or union type declarations

The `@nested` annotation marks a type that will always be contained within another. This can be used to prevent a type from being used as in a topic. One reason to do so is to reduce the amount of code generated for that type.

@default_nested

Applies To: modules

The `@default_nested(TRUE)` or `@default_nested(FALSE)` sets the default nesting behavior for a module. Types within a module marked with `@default_nested(FALSE)` can still set their own behavior with `@nested`.

Specifying allowed Data Representations

If there are `@OpenDDS::data_representation` annotations are on the topic type, then the representations are limited to ones the specified in the annotations, otherwise all representations are allowed. Trying to create a reader or writer with the disallowed representations will result in an error. See *Data Representation* for more information.

@OpenDDS::data_representation(XML)

Applies To: topic types

Limitations: XML is not currently supported

@OpenDDS::data_representation(XCDR1)

Applies To: topic types

Limitations: XCDR1 doesn't support XTypes features See *Data Representation* for details

@OpenDDS::data_representation(XCDR2)

Applies To: topic types

XCDR2 is currently the recommended data representation for most cases.

@OpenDDS::data_representation(UNALIGNED_CDR)

Applies To: topic types

Limitations: OpenDDS specific, can't be used with RTPS-UDP, and doesn't support XTypes features See *Data Representation* for details

Standard @data_representation

`tao_idl` doesn't support bitset, which the standard `@data_representation` requires. Instead use `@OpenDDS::data_representation` which is similar, but doesn't support bitmask value chaining like `@data_representation(XCDR|XCDR2)`. The equivalent would require two separate annotations:

```
@OpenDDS::data_representation(XCDR1)
@OpenDDS::data_representation(XCDR2)
```

Determining Extensibility

The extensibility annotations can explicitly define the *extensibility* of a type. If no extensibility annotation is used, then the type will have the default extensibility. This will be *appendable* unless the *opendds_idl --default-extensibility* is used to override the default.

@mutable

Alias: `@extensibility(MUTABLE)`

Applies To: type declarations

This annotation indicates a type may have non-key or non-must-understand members removed. It may also have additional members added.

@appendable

Alias: `@extensibility(APPENDABLE)`

Applies To: type declarations

This annotation indicates a type may have additional members added or members at the end of the type removed.

Limitations: Appendable is not currently supported when XCDR1 is used as the data representation.

@final

Alias: `@extensibility(FINAL)`

Applies To: type declarations

This annotation marks a type that cannot be changed and still be compatible. Final is most similar to pre-XTypes.

Customizing XTypes per-member

Try Construct annotations dictate how members of one object should be converted from members of a different but assignable object. If no try construct annotation is added, it will default to discard.

@try_construct(USE_DEFAULT)

Applies to: structure and union members, sequence and array elements

The use_default try construct annotation will set the member whose deserialization failed to a default value which is determined by the XTypes specification. Sequences will be of length 0, with the same type as the original sequence. Primitives will be set equal to 0. Strings will be replaced with the empty string. Arrays will be of the same length but have each element set to the default value. Enums will be set to the first enumerator defined.

@try_construct(TRIM)

Applies to: structure and union members, sequence and array elements

The trim try construct annotation will, if possible, shorten a received value to one fitting the receiver's bound. As such, trim only makes logical sense on bounded strings and bounded sequences.

@try_construct(DISCARD)

Applies to: structure and union members, sequence and array elements

The discard try construct annotation will "throw away" the sample if an element fails to deserialize.

Member ID assignment

If no explicit id annotation is used, then member IDs will automatically be assigned sequentially.

@id(value)

Applies to: structure and union members

`value` is an unsigned 32-bit integer which assigns that member's ID.

@autoid(value)

Applies to: module declarations, structure declarations, union declarations

The autoid annotation can take two values, `HASH` or `SEQUENTIAL`. `SEQUENTIAL` states that the identifier shall be computed by incrementing the preceding one. `HASH` states that the identifier should be calculated with a hashing algorithm - the input to this hash is the member's name. `HASH` is the default value of `@autoid`.

@hashid(value)

Applies to: structure and union members

The `@hashid` sets the identifier to the hash of the `value` parameter, if one is specified. If the `value` parameter is omitted or is the empty string, the member's name is used as if it was the `value`.

Determining the Key Fields of a Type

@key

Applies to: structure members, union discriminator

The `@key` annotation marks a member used to determine the Instances of a topic type. See *Keys* for more details on the general concept of a Key. For XTypes specifically, two types can only be compatible if each contains the members that are keys within the other.

Customizing the values of enumerators

@value(v)

Applies to: enumerators (only when *Using the IDL-to-C++11 Mapping*)

Without annotations, the enumerators of each enum type take on consecutive integer values starting at 0. The `@value(v)` annotation customizes the integer value of an individual enumerator. The parameter `v` is an integer constant (signed, 4 bytes wide). Any enumerators that are not annotated take on the integer value one higher than the value of the previously-declared enumerator, with the first declared taking value 0.

```
enum MyAnnotionEnabledEnum {
  ZERO,
  @value(3) THREE,
  FOUR,
```

(continues on next page)

(continued from previous page)

```
  @value(2) TWO
};
```

2.21.7 Dynamic Language Binding

For an overview of the Dynamic Language Binding, see *Dynamic Language Binding*. This section describes the features of the Dynamic Language Binding that OpenDDS supports.

There are two main usage patterns supported:

- Applications can receive DynamicData from a Recorder object (*Recorder and Replayer*)
- Applications can use XTypes DynamicDataWriter and/or DynamicDataReader (*DynamicDataWriters and DynamicDataReaders*)

To use DynamicDataWriter and/or DynamicDataReader for a given topic, the data type definition for that topic must be available to the local DomainParticipant. There are a few ways this can be achieved, see *Obtaining DynamicType and Registering TypeSupport* for details.

Representing Types with TypeObject and DynamicType

In XTypes, the types of the peers may not be identical, as in the case of appendable or mutable extensibility. In order for a peer to be aware of its remote peer's type, there must be a way for the remote peer to communicate its type. TypeObject is an alternative to IDL for representing types, and one of the purposes of TypeObject is to communicate the peers' types.

There are two classes of TypeObject: MinimalTypeObject and CompleteTypeObject. A MinimalTypeObject object contains minimal information about the type that is sufficient for a peer to perform type compatibility checking. However, MinimalTypeObject may not contain all information about the type as represented in the corresponding user IDL file. In cases where the complete information about the type is required, CompleteTypeObject should be used. When XTypes is enabled, peers communicate their TypeObject information during the discovery process automatically. Internally, the local and received TypeObjects are stored in a TypeLookupService object, which is shared between the entities in the same DomainParticipant.

In the Dynamic Language Binding, each type is represented using a DynamicType object, which has a TypeDescriptor object that describes all the information needed to correctly process the type. Likewise, each member in a type is represented using a DynamicTypeMember object, which has a MemberDescriptor object that describes any information needed to correctly process the type member. DynamicType is converted from the corresponding CompleteTypeObject internally by the system.

Enabling Use of CompleteTypeObjects

To enable use of `CompleteTypeObject`s needed for the dynamic binding, they must be generated and OpenDDS must be configured to use them. To generate them, use `opendds_idl -Gxtypes-complete`. For MPC, this can be done by adding this to the opendds_idl arguments for idl files in the project, like this:

```
TypeSupport_Files {
  dcps_ts_flags += -Gxtypes-complete
  Messenger.idl
}
```

To do the same for CMake:

```
opendds_target_sources(target
  Messenger.idl
  OPENDDS_IDL_OPTIONS -Gxtypes-complete
)
```

Once set up to be generated, OpenDDS has to be configured to send and receive the `CompleteTypeObjects`. This can be done by setting *[rtps_discovery] UseXTypes* or programmatically using the `OpenDDS::RTPS::RtpsDiscovery::use_xtypes()` setter methods.

Interpreting Data Samples with DynamicData

Together with DynamicType, DynamicData allows users to interpret a received data sample and read individual fields from it. Each DynamicData object is associated with a type, represented by a DynamicType object, and the data corresponding to an instance of that type. Consider the following example:

```
@appendable
struct NestedStruct {
  @id(1) short s_field;
};

@topic
@mutable
struct MyStruct {
  @id(1) long l_field;
  @id(2) unsigned short us_field;
  @id(3) float f_field;
  @id(4) NestedStruct nested_field;
  @id(5) sequence<unsigned long> ul_seq_field;
  @id(6) double d_field[10];
  @id(7) long mdim_field[2][3];
};
```

The samples for MyStruct are written by a normal, statically-typed DataWriter. The writer application needs to have the IDL-generated code including the "complete" form of TypeObjects. Use a command-line option to opendds_idl to enable CompleteTypeObjects since the default is to generate MinimalTypeObjects (*opendds_idl Command Line Options*).

One way to obtain a DynamicData object representing a data sample received by the participant is using the Recorder and RecorderListener classes (*Recorder and Replayer*). Recorder's get_dynamic_data can be used to construct a DynamicData object for each received sample from the writer. Internally, the CompleteTypeObjects received from discovering that writer are converted to DynamicTypes and they are then used to construct the DynamicData objects. Once a DynamicData object for a MyStruct sample is constructed, its members can be read as described in the following sections. Another way to obtain a DynamicData object is from a DynamicDataReader (*Creating and Using a DynamicDataWriter or DynamicDataReader*).

Reading Basic Types

DynamicData provides methods for reading members whose types are basic such as integers, floating point numbers, characters, boolean. See the XTypes specification for a complete list of basic types for which DynamicData provides an interface. To call a correct method for reading a member, we need to know the type of the member as well as its id. For our example, we first want to get the number of members that the sample contains. In these examples, the `data` object is an instance of DynamicData.

```
DDS::UInt32 count = data.get_item_count();
```

Then, each member's id can be read with `get_member_id_at_index`. The input for this function is the index of the member in the sample, which can take a value from `0` to `count - 1`.

```
XTypes::MemberId id = data.get_member_id_at_index(0);
```

The `MemberDescriptor` for the corresponding member then can be obtained as follows.

```
XTypes::MemberDescriptor md;
DDS::ReturnCode_t ret = data.get_descriptor(md, id);
```

The returned `MemberDescriptor` allows us to know the type of the member. Suppose id is 1, meaning that the member at index 0 is `l_field`, we now can get its value.

```
DDS::Int32 int32_value;
ret = data.get_int32_value(int32_value, id);
```

After the call, `int32_value` contains the value of the member `l_field` from the sample. The method returns `DDS::RETCODE_OK` if successful. In case the type has an optional member and it is not present in the DynamicData instance, `DDS::RETCODE_NO_DATA` is returned.

Similarly, suppose we have already found out the types and ids of the members `us_field` and `f_field`, their values can be read as follows.

```
DDS::UInt16 uint16_value;
ret = data.get_uint16_value(uint16_value, 2); // Get the value of us_field
DDS::Float32 float32_value;
ret = data.get_float32_value(float32_value, 3); // Get the value of f_field
```

Reading members from union is a little different as there is at most one active branch at any time. In general, DynamicData in OpenDDS follows the IDL-to-C++ mappings for union. Consider the following union as an example.

```
@mutable
union MyUnion switch (short) {
case 1:
case 2:
  @id(1) short s_field;
case 3:
  @id(2) long l_field;
case 4:
  @id(3) string str_field;
};
```

The discriminator can be read using the appropriate method for the discriminator type and id `XTypes::DISCRIMINATOR_ID` (see `dds/DCPS/XTypes/TypeObject.h`).

```
DDS::Int32 disc_value;
ret = data.get_int16_value(disc_val, XTypes::DISCRIMINATOR_ID);
```

Using the value of the discriminator, user can decide which branch is activated and read its value in a similar way as reading a struct member. Reading a branch that is not activated returns `DDS::RETCODE_PRECONDITION_NOT_MET`.

At any time, a DynamicData instance of a union represents a valid state of that union. A special case is an empty DynamicData instance. In this case, the discriminator takes the default value of the discriminator type (the XTypes specification specifies the default value for each type). If that discriminator value selects a branch, the selected branch also takes the default value corresponding to its type. If it doesn't select a branch, the union contains only the discriminator.

Reading Collections of Basic Types

Besides a list of methods for getting values of members of basic types, DynamicData also defines methods for reading sequence members. In particular, for each method that reads value from a basic type, there is a counterpart that reads a sequence of the same basic type. For instance, `get_int32_value` reads the value from a member of type `int32/long`, and `get_int32_values` reads the value from a member of type `sequence<int32>`. For the member `ul_seq_field` in our example, its value can be read as follows.

```
DDS::UInt32Seq my_ul_seq;
ret = data.get_uint32_values(my_ul_seq, id); // id is 5
```

Because `ul_seq_field` is a sequence of unsigned 32-bit integers, the `get_uint32_values` method is used. Again, the second argument is the id of the requested member, which is 5 for `ul_seq_field`. When successful, `my_ul_seq` contains values of all elements of the member `ul_seq_field` in the sample.

To get the values of the array member `d_field`, we first need to create a separate DynamicData object for it, and then read individual elements of the array using the new DynamicData object.

```
DDS::DynamicData_var array_data;
DDS::ReturnCode_t ret = data.get_complex_value(array_data, id); // id is 6

const DDS::UInt32 num_items = array_data->get_item_count();
for (DDS::UInt32 i = 0; i < num_items; ++i) {
  const XTypes::MemberId my_id = array_data->get_member_id_at_index(i);
  DDS::Float64 my_double;
  ret = array_data->get_float64_value(my_double, my_id);
}
```

In the example code above, `get_item_count` returns the number of elements of the array. Inside the for loop, the index of each element is converted to an id within the array using `get_member_id_at_index`. Then, this id is used to read the element's value into `my_double`. Note that the second parameter of the interfaces provided by DynamicData must be the id of the requested member. In case of collection, elements are considered members of the collection. However, the collection element doesn't have a member id. And thus, we need to convert its index into an id before calling a get_*_value (or get_*_values) method.

Accessing a multi-dimensional array is a little different as `get_member_id_at_index` accepts a single index as its sole argument. OpenDDS provides function `flat_index` to convert an index to a multi-dimensional array to a flat index that can then be passed to `get_member_id_at_index`.

```
DDS::DynamicData_var mdim_arr_data;
DDS::ReturnCode_t ret = data.get_complex_value(mdim_arr_data, id); // id is 7
DDS::DynamicType_var mdim_type = mdim_arr_data->type();
```

(continues on next page)

(continued from previous page)

```
DDS::TypeDescriptor_var mdim_td;
ret = mdim_type->get_descriptor(mdim_td);
const DDS::BoundSeq& bound = mdim_td->bound();

DDS::UInt32Seq index_vec;
index_vec.length(2);
for (DDS::UInt32 i = 0; i < bound[0]; ++i) {
    index_vec[0] = i;
    for (DDS::UInt32 j = 0; j < bound[1]; ++j) {
        index_vec[1] = j;
        DDS::UInt32 flat_idx;
        ret = OpenDDS::XTypes::flat_index(flat_idx, index_vec, bound);
        const XTypes::MemberId id = mdim_arr_data->get_member_id_at_index(flat_idx);
        DDS::Int32 my_long;
        ret = mdim_arr_data->get_int32_value(my_long, id);
    }
}
```

`flat_index` takes as input an index vector to the multi-dimensional array and the dimensions of the array and returns a flat index. The same function is used when serializing the dynamic data object to make sure the mapping from index to id is consistent and conforms to the XTypes spec regarding the order of the elements.

Reading Members of More Complex Types

For a more complex member such as a nested structure or union, the discussed DynamicData methods are not suitable. And thus, users first need to get a new DynamicData object that represents the sole data of the member with get_complex_value. This new DynamicData object can then be used to get the values of the inner members of the nested member. For example, a DynamicData object for the nested_field member of the MyStruct sample can be obtained as follows.

```
DDS::DynamicData_var nested_data;
DDS::ReturnCode_t ret = data.get_complex_value(nested_data, id); // id is 4
```

Recall that nested_field has type NestedStruct which has one member s_field with id 1. Now the value of s_field can be read from nested_data using get_int16_value, since s_field has type short.

```
DDS::Int16 my_short;
ret = nested_data->get_int16_value(my_short, id); // id is 1
```

The get_complex_value method is also suitable for any other cases where the value of a member cannot be read directly using the get_*_value or get_*_values methods. As an example, suppose we have a struct MyStruct2 defined as follows.

```
@appendable
struct MyStruct2 {
  @id(1) sequence<NestedStruct> seq_field;
};
```

And suppose we already have a DynamicData object, called data, that represents a sample of MyStruct2. To read the individual elements of seq_field, we first get a new DynamicData object for the seq_field member.

```
DDS::DynamicData_var seq_data;
DDS::ReturnCode_t ret = data.get_complex_value(seq_data, id); // id is 1
```

Since the elements of seq_field are structures, for each of them we create another new DynamicData object to represent it, which can be used to read its member.

```
const DDS::UInt32 num_elems = seq_data->get_item_count();
for (DDS::UInt32 i = 0; i < num_elems; ++i) {
  const XTypes::MemberId my_id = seq_data->get_member_id_at_index(i);
  DDS::DynamicData_var elem_data; // Represent each element.
  ret = seq_data->get_complex_value(elem_data, my_id);
  DDS::Int16 my_short;
  ret = elem_data->get_int16_value(my_short, 1);
}
```

Populating Data Samples With DynamicData

DynamicData objects can be created by the application and populated with data so that they can be used as data samples which are written to a DynamicDataWriter (*Creating and Using a DynamicDataWriter or DynamicDataReader*).

To create a DynamicData object, use the DynamicDataFactory API defined by the XTypes spec:

```
DDS::DynamicData_var dynamic =
  DDS::DynamicDataFactory::get_instance()->create_data(type);
```

Like other data types defined by IDL interfaces (for example, the `*TypeSupportImpl` types), the "dynamic" object's lifetime is managed with a smart pointer - in this case `DDS::DynamicData_var`.

The "type" input parameter to `create_data()` is an object that implements the `DDS::DynamicType` interface. The DynamicType representation of any type that's supported as a topic data type is available from its corresponding TypeSupport object (*Obtaining DynamicType and Registering TypeSupport*) using the `get_type()` operation. Once the application has access to that top-level type, the DynamicType interface can be used to obtain complete information about the type including nested and referenced data types. See the file `dds/DdsDynamicData.idl` in OpenDDS for the definition of the DynamicType and related interfaces.

Once the application has created the DynamicData object, it can be populated with data members of any type. The operations used for this include the DynamicData operations named "set_*" for the various data types. They are analogous to the "get_*" operations that are described in *Interpreting Data Samples with DynamicData*. When populating the DynamicData of complex data types, use get_complex_value() (*Reading Members of More Complex Types*) to navigate from DynamicData representing containing types to DynamicData representing contained types.

Setting the value of a member of a DynamicData union using a `set_*` method implicitly 1) activates the branch corresponding to the member and 2) sets the discriminator to a value corresponding to the active branch. For example, the `l_field` member of `MyUnion` above can be set as follows:

```
DDS::Int32 l_field_value = 12;
data.set_int32_value(id, l_field_value); // id is 2
```

The discriminator can also be set directly in the following two cases. First, the new discriminator value selects the same branch that is currently activated. Second, the new discriminator value selects no branch. In all other cases, `DDS::RETCODE_PRECONDITION_NOT_MET` is returned. As an example for the first case, suppose the union currently has the discriminator value of 1 and the member *s_field* is active. We can set the discriminator value to 2 as it selects the same member.

```
DDS::Int16 new_disc_value = 2;
data.set_int16_value(XTypes::DISCRIMINATOR_ID, new_disc_value);
```

For the second case, setting the discriminator to any value that doesn't select a member will succeed. After that, the union contains only the discriminator.

```
DDS::Int16 new_disc_value = 5; // does not select any branch
data.set_int16_value(XTypes::DISCRIMINATOR_ID, new_disc_value);
```

Unions start in an "empty" state as described in *Interpreting Data Samples with DynamicData*. Consequently, at the point of serialization, empty and non-empty unions are not differentiated.

Expandable collection types such as sequences or strings can be extended one element at a time. To extend a sequence (or string), we first get the id of the new element at index equal to the current length of the sequence using the `get_member_id_at_index` operation. The length of the sequence can be got using `get_item_count`. After we obtain the id, we can write the new element using the `set_*` operation as usual.

DynamicDataWriters and DynamicDataReaders

DynamicDataWriters and DynamicDataReaders are designed to work like any other DataWriter and DataReader except that their APIs are defined in terms of the DynamicData type instead of a type generated from IDL. Each DataWriter and DataReader has an associated Topic and that Topic has a data type (represented by a TypeSupport object). Behavior related to keys, QoS policies, discovery and built-in topics, DDS Security, and transport is not any different for a DynamicDataWriter or DynamicDataReader. One exception is that in the current implementation, *Content-Subscription Profile* is not supported for DynamicDataWriters and DynamicDataReaders.

Obtaining DynamicType and Registering TypeSupport

OpenDDS currently supports two usage patterns for obtaining a TypeSupport object that can be used with the Dynamic Language Binding:

- Dynamically load a library that has the IDL-generated code
- Get the DynamicType of a peer DomainParticipant that has CompleteTypeObjects

The XTypes specification also describes how an application can construct a new type at runtime, but this is not yet implemented in OpenDDS.

To use a shared library (`*.dll` on Windows, `*.so` on Linux, `*.dylib` on macOS, etc.) as a type support plug-in, an application simply needs to load the library into its process. This can be done with the ACE cross-platform support library that OpenDDS itself uses, or using a platform-specific function like LoadLibrary or dlopen. The application code does not need to include any generated headers from this IDL. This makes the type support library a true plug-in, meaning it can be loaded into an application that had no knowledge of it when that application was built.

Once the shared library is loaded, an internal singleton class in OpenDDS called Registered_Data_Types can be used to obtain a reference to the TypeSupport object.

```
DDS::TypeSupport_var ts_static = Registered_Data_Types->lookup(0, "TypeName");
```

This TypeSupport object `ts_static` is not registered with the DomainParticipant and is not set up for the Dynamic Language Binding. But, crucially, it does have the DynamicType object that we'll need to set up a second TypeSupport object which is registered with the DomainParticipant.

```
DDS::DynamicType_var type = ts_static->get_type();
DDS::DynamicTypeSupport_var ts_dynamic = new DynamicTypeSupport(type);
DDS::ReturnCode_t ret = ts_dynamic->register_type(participant, "");
```

Now the type support object `ts_dynamic` can be used in the usual DataWriter/DataReader setup sequence (creating a Topic first, etc.) but the created DataWriters and DataReaders will be DynamicDataWriters and DynamicDataReaders (*Creating and Using a DynamicDataWriter or DynamicDataReader*).

The other approach to obtaining TypeSupport objects for use with the Dynamic Language Binding is to have DDS discovery's built-in endpoints get TypeObjects from remote domain participants. To do this, use the `get_dynamic_type` method on the singleton `Service_Participant` object.

```
DDS::DynamicType_var type; // NOTE: passed by reference below
DDS::ReturnCode_t ret = TheServiceParticipant->get_dynamic_type(type, participant, key);
```

The two input parameters to `get_dynamic_type` are the `participant` (an object reference to the DomainParticipant that will be used to register our TypeSupport and create Topics, DataWriters, and/or DataReders) and the `key` which is the `DDS::BuiltinTopicKey_t` that identifies the remote entity which has the data type that we'll use. This key can be obtained from the Built-In Publications topic (which identifies remote DataWriters) or the Built-In Subscriptions topic (which identifies remote DataReaders). See *Built-in Topics* for details on using the Built-In Topics.

The type obtained from `get_dynamic_type` can be used to create and register a TypeSupport object.

```
DDS::DynamicTypeSupport_var ts_dynamic = new DynamicTypeSupport(type);
DDS::ReturnCode_t ret = ts_dynamic->register_type(participant, "");
```

Creating and Using a DynamicDataWriter or DynamicDataReader

Following the steps in *Obtaining DynamicType and Registering TypeSupport*, a DynamicTypeSupport object is registered with the domain participant. The type name used to register with the participant may be the default type name (used when an empty string is passed to the `register_type` operation), or some other type name. If the default type name was used, the application can access that name by invoking the `get_type_name` operation on the TypeSupport object.

The registered type name is then used as one of the input parameters to `create_topic`, just like when creating a topic for the Plain (non-Dynamic) Language Binding. Once a Topic object exists, create a DataWriter or DataReader using this Topic. They can be narrowed to the DynamicDataWriter or DynamicDataReader IDL interface:

```
DDS::DynamicDataWriter_var w = DDS::DynamicDataWriter::_narrow(writer);
DDS::DynamicDataReader_var r = DDS::DynamicDataReader::_narrow(reader);
```

The IDL interfaces are defined in `dds/DdsDynamicTypeSupport.idl` in OpenDDS. They provides the same operations as any other DataWriter or DataReader, but with DynamicData as their data type. See *Populating Data Samples With DynamicData* for details on creating DynamicData objects for use with the DynamicDataWriter interface. See *Interpreting Data Samples with DynamicData* for details on using DynamicData objects obtained from the DynamicDataReader interface.

Limitations of the Dynamic Language Binding

The Dynamic Language Binding doesn't currently support:

- Access from Java applications
- Content-Subscription Profile features (Content-Filtered Topics, Multi Topics, Query Conditions)
- XCDRv1 Data Representation
- Constructing types at runtime

2.21.8 Unimplemented Features

OpenDDS implements the *XTypes specification* at the Basic Conformance level, with a partial implementation of the Dynamic Language Binding (supported features of which are described in *Dynamic Language Binding*). Specific unimplemented features listed below. The two optional profiles, XTypes 1.1 Interoperability (XCDR1) and XML, are not implemented.

XCDR1 Support

Pre-XTypes standard CDR is fully supported, but the XTypes-specific features are not fully supported and should be avoided. Types can be marked as final or appendable, but all types should be treated as if they were final. Nothing should be marked as mutable. Readers and writers of topic types that are mutable or contain nested types that are mutable will fail to initialize.

Type System

- IDL map type
- IDL bitmask type
- Struct and union inheritance

Annotations

IDL4 defines many standardized annotations and XTypes uses some of them. The Annotations recognized by XTypes are in Table 21 in DDS XTypes v1.3 7.3.1.2.2 Using Built-in Annotations. Of those listed in that table, the following are not supported in OpenDDS. They are listed in groups defined by the rows of that table. Some annotations in that table, and not listed here, can only be used with new capabilities of the *Type System*.

- Struct members
  - `@optional`
  - `@must_understand`
  - `@non_serialized`
- Struct or union members
  - `@external`
- Enums
  - `@bit_bound`
  - `@default_literal`
  - `@value`
- `@verbatim`
- `@data_representation`
  - See *Standard @data_representation* for details.

2.21.9 Differences from the specification

- Inconsistent topic status isn't set for reader/reader or writer/writer in non-XTypes use cases
- Define the encoding and extensibility used by Type Lookup Service (Member Link)
- Enums must have the same "bit bound" to be assignable (Member Link)
- Default data representation is XCDR2 (Member Link)
- Type Lookup Service when using DDS Security (Member Link)
- Anonymous types in Strongly Connected Components (Member Link)
- Meaning of ignore_member_names in TypeConsistencyEnforcement (Member Link)

2.22 FAQ

2.22.1 General

What's a PRF?

"PRF" refers to the PROBLEM-REPORT-FORM, i.e., `PROBLEM-REPORT-FORM`.

The odds of getting questions answered, bugs fixed, etc., goes up significantly when you report problems using the PRF because it insures that developers and support personnel get the most commonly required information right away. Failure to use the PRF means that those folks have to spend valuable time (yours and theirs) having a conversation to get that information just to start debugging. Unless you've got a paid support contract, there's even a chance that nobody will answer!

So, always use the PRF!

Is there a mailing list or forum or usenet group for discussion of OpenDDS?

Yes. The GitHub Discussions for OpenDDS can be used to ask questions and get help. Please remember to use the *Problem Report Form* when posting questions (and not just "problems").

Which platforms does OpenDDS support?

Please refer to `README.md#supported-platforms` for a complete list of supported platforms.

Is OpenDDS interoperable with other DDS implementations?

Starting with version 3.1, OpenDDS contains an implementation of the RTPS (Real Time Publish-Subscribe) specification required for interoperability. It is not enabled by default. See *Configuring for RTPS Discovery* for configuration details.

Does OpenDDS use CORBA?

OpenDDS uses CORBA when configured to use the DCPSInfoRepo for discovery, which is the default. See *Configuring for InfoRepo Discovery*. CORBA is never used in the distribution of application data. When configured for RTPS peer-to-peer discovery, the CORBA libraries (TAO) are present but not used for any inter-process communication at all. When configured for Safety Profile, which uses RTPS, no TAO libraries are used at runtime.

Summarize the network connections established by OpenDDS in a two participant scenario.

This scenario has two participants (one only publishes and the other only subscribes) using the TCP transport with no Built-In Topics. The DCPSInfoRepo is used for discovery. Here, we would expect to see three established TCP connections at each participant:

- The participant contacts the InfoRepo over IIOP (CORBA). The endpoint used for this connection can be supplied as `-DCPSInfoRepo HOST:PORT` or a similar setting in the .ini file. The HOST is the host where the InfoRepo is running. The PORT for the InfoRepo can be controlled by passing an argument to the InfoRepo process: `-ORBListenEndpoints iiop://:PORT`.

  Another option that's useful for port-forwarding solutions such as NAT traversal and SSH tunneling is `hostname_in_ior`. This gets appended to the endpoint like so `-ORBListenEndpoints iiop://:PORT/hostname_in_ior=HOST_ALIAS` where HOST_ALIAS is a hostname (or dotted-decimal IP) that can be used by the client to contact the server. In the NAT traversal example, the HOST_ALIAS would be the external side of the NAT and the PORT would be the port that's forwarded to the host running the server.

  You can also specify more than one endpoint (just repeating the `-ORBListenEndpoints` will work) so you can provide endpoints that will work for both "inside" and "outside" clients.

- The InfoRepo will make an IIOP connection *back* to the participant. This is just the inverse of connection #1, but there is no equivalent to the `-DCPSInfoRepo corbaloc:...` option. It's not necessary because the InfoRepo knows how to find the participant already (from data transmitted over connection #1). To control the endpoint here, use the same `-ORBListenEndpoints ...` option but this time with the participant and not the InfoRepo.

- Once the publishing participant and the subscribing participant have been associated, they connect directly using the tcp transport (by default) instance in each one. Here the endpoint is determined by the subscriber's transport config (the `local_address` value). Unfortunately there is no equivalent to the `hostname_in_ior` for DDS transports.

2.22.2 Obtaining and building OpenDDS

How do I obtain, configure, and build OpenDDS?

Please refer to *Building and Installing* for complete requirements and build steps.

What could be causing std lib related build failures on Linux?

We have seen gcc 4.0.x-series compiler users see this problem the most often. The visibility feature in this compiler still seems to be in a state of flux. If you see these errors, we recommend turning off the visibility feature by adding `no_hidden_visibility=1` to your platform_macros.GNU file and rebuilding all of ACE+TAO and OpenDDS.

2.22.3 Configuring OpenDDS

Does OpenDDS support broadcast or multicast? If so, how do you set it up?

Reliable multicast has been available in OpenDDS since the 0.12 release (unreliable multicast since 0.11 release). A broadcast based transport is currently not available. Please see *Multicast Transport Configuration Properties* for how to configure the multicast transport. See the `tests/DCPS/Messenger` test for an example that can use the multicast transport. Using `run_test.pl multicast` to run the test with the multicast transport. Also, see *RTPS UDP Transport Configuration Properties* for details of the interoperable RTPS transport that supports multicast and unicast.

Why did a subscriber did not receive all samples sent by the publisher?

While there can be multiple reasons that the samples are lost or dropped, a common problem is that the publisher starts sending samples before the subscriber is ready to receive. To synchronize, the publisher can use a WaitSet before writing. This ensures the subscriber is ready to receive samples. Here is the example code:

```
DDS::StatusCondition_var cond = writer->get_statuscondition();
cond->set_enabled_statuses(DDS::PUBLICATION_MATCHED_STATUS);

DDS::WaitSet_var ws = new DDS::WaitSet;
ws->attach_condition(cond);

while (true) {
  DDS::PublicationMatchedStatus matches;
  if (writer->get_publication_matched_status(matches) != DDS::RETCODE_OK) {
    // failure
  } else if (matches.current_count >= 1) {
    break;
  }

  DDS::ConditionSeq conditions;
  DDS::Duration_t timeout =
    { DDS::DURATION_INFINITE_SEC, DDS::DURATION_INFINITE_NSEC };
  if (ws->wait(conditions, timeout) != DDS::RETCODE_OK) {
    // failure
  }
}

ws->detach_condition(cond);
```

Why can't my publisher establish a connection with a remote subscriber?

While there can be multiple reasons for inter-host communication failure, this entry deals with connection establishment failures due to improper endpoint configuration.

The configuration option `local_address` represents the endpoint address. This host/port tuple is used by the publisher to initiate connection establishment. In order to allow inter-host communication, make sure the endpoint address is publicly visible.

A common mistake is to re-use the configuration provided in the exercises without modifications. Since the examples are intended to be run on an intra-host environment, they generally use the 'localhost' interface. This configuration will fail when the test is run in an inter-host setting.

2.22.4 Built-In Topics (BITs)

What is the status of BIT support in OpenDDS?

Support for Built-In-Topics is complete since the 0.12 release. This means that BITs will now work as specified. BIT support is now turned on by default.

How do I turn off BIT support at build-time?

It is possible to build OpenDDS without BIT support which will reduce overall footprint. For this, you will need to generate new project files:

```
mwc.pl -type <yourtype> -features built_in_topics=0 DDS.mwc
```

If `yourtype` happens to be `gnuace`, add `built_in_topics=0` to the `platform_macros.GNU` file or the `MAKEFLAGS` environment variable. Alternatively, use the configure script with `--no-built-in-topics`.

How do I turn off BIT support at run-time?

Turning off BIT support involves it being turned off in the DCPS Information Repository and any associated participants.

The DCPSInfoRepo option `-NOBITS` disables BIT support for the InfoRepo.

The option `-DCPSBit 0` will disable BIT support for all participants in the process.

2.22.5 Using IDL

How do I use sequences of built-in types in IDL?

If you'd like to use a sequence of one of the following IDL built-in types:

- boolean, octet
- char, wchar, string, wstring
- float, double, long double
- short, long, long long
- unsigned short, unsigned long, unsigned long long

TAO already has a typedef for these sequences. The typedef name is the name of the built-in type in CamelCase with a "Seq" suffix. Unsigned types use a "U" prefix as in "ULongSeq".

To use the existing typedef, add an `#include` for the pidl file from the tao directory:

```
#include <tao/LongSeq.pidl>
```

The typedefs are in the "CORBA" IDL module, so the typedef for LongSeq could be used as:

```
struct X {
  CORBA::LongSeq seq;
};
```

2.22.6 Using the OpenDDS Modeling SDK

How do I obtain the OpenDDS Modeling SDK?

Please refer to the *Modeling SDK* for complete installation instructions.

Make sure that Eclipse's list of Available Software Sites contains an enabled site for the Eclipse release itself. Version 3.5 uses URL: http://download.eclipse.org/releases/galileo. If not, you need to add the correct update site for your version of Eclipse.

Why can't I see the element I added to my figure?

If auto-sizing isn't enabled for the figure and depending on the figure's size, an element added to one of the figure's compartments may not be immediately visible. By increasing the size of the figure, the element should appear. See the OpenDDS Modeling SDK Guide > Tasks > Working with Diagrams > Creating Figures in the Eclipse help for information on how to make the figure automatically re-size to accommodate additional content.

How to I open a library (for example a DataLib) on the main diagram?

Double clicking on the library should open the library in a subdiagram. However, sometimes no action will be taken after double clicking. An alternative way to open a library is to select the library and then press the Enter key. This topic, along with other topics related to libraries, is in the Eclipse help content under OpenDDS Modeling SDK Guide > Tasks > Modeling > Working with OpenDDS Models.

2.22.7 Using the DDS DCPS API

How should I override a specific QoS policy and leave others defaulted?

1. Create an empty QoS variable of the proper type (for example `DDS::DataWriterQos dw_qos`).
2. Call the parent's `get_default_*_qos()` method (for example `Publisher::get_default_datawriter_qos(dw_qos)`.
3. Modify the QoS and pass it to the proper `create_*` method.

Note that the default QoS returned by `get_default_*_qos()` can be changed with `set_default_*_qos()`.

The `TheServiceParticipant` also has methods to return the code default QoS for different entities, e.g., `TheServiceParticipant->initial_DataWriterQos()`.

OpenDDS contains various `*QosPolicyBuilder` classes that can be used to configure QoS policies using a builder pattern. The QoS returned by a default constructed `*QosPolicyBuilder` corresponds to the code default. Here's an example using a builder that sets transient local durability for a DataWriter:

```
#include <dds/DCPS/Qos_Helper.h>

...

DDS::DataWriter_var writer =
   publisher->create_datawriter(topic,
                                DataWriterQosBuilder().durability_transient_local(),
                                0,
                                OpenDDS::DCPS::DEFAULT_STATUS_MASK);
```

What are the *_QOS_DEFAULT macros?

These macros (for example DATAWRITER_QOS_DEFAULT) are placeholders used only to provide a default value to the create_* methods. These macros themselves do not expand to QoS structure instances that can be used for any purpose other than passing to the create_* methods. This includes DATAWRITER_QOS_USE_TOPIC_QOS, DATAREADER_QOS_DEFAULT, etc. In Java, they are classes in the DDS package that have a public static get() method and not macros.

Why do I get samples with invalid data in them?

Make sure the call to read/take returns a status of RETCODE_OK and the SampleInfo's valid_data is set to true. Both of these conditions are required for the sample to be valid. If valid_data is not true, then the sample could be indicating an unregister and/or dispose.

What could account for increasing memory usage in subscribing processes?

If the subscribing process contains Data Readers which have received many instances from the corresponding Data Writers, it will need some resources to track each instance. This can be bounded by the *Resource Limits QoS* policy and by the subscribing application taking samples from the Data Reader. The *Reader Data Lifecycle QoS* policy may also be helpful.

2.23 Annex

2.23.1 Fnmatch Expressions

A wildcard-capable string used to match one or more names from a set. This is used in *Partition QoS* and in *DDS Security* documents. Recognized values will conform to POSIX fnmatch() function as specified in POSIX 1003.2-1992, Section B.6. This is a subset of UNIX shell file matching and is similar to, but separate from standard regular expressions.

Simplified, this consists of the following:

?
: Will match any single character. For example ab? matches abc and abb.

*****
: Will match any zero or more characters. For example * will match anything and a* matches a, abc, and aaaaa.

[]
: Will match a single character specified in the brackets. For example a[bc] matches ab and ac. Can also use ranges, for example a[b-d] matches ab, ac, and ad.

****
: Will escape the following character. For example \? just matches ? and \\ matches \.

CHAPTER

THREE

INTERNAL DOCUMENTATION

This documentation is for those who want to contribute to OpenDDS and those who are just curious!

3.1 OpenDDS Development Guidelines

This document organizes our current thoughts around development guidelines in a place that's readable and editable by the overall user and maintainer community. It's expected to evolve as different maintainers get a chance to review and contribute to it.

Although ideally all code in the repository would already follow these guidelines, in reality the code has evolved over many years by a diverse group of developers. At one point an automated re-formatter was run on the codebase, migrating from the GNU C style to the current, more conventional style, but automated tools can only cover a subset of the guidelines.

3.1.1 Repository

The repository is hosted on Github at OpenDDS/OpenDDS and is open for pull requests.

3.1.2 Testing

If a pull request fixes a bug that's not covered in an existing test it should be added to the tests. This should be in an existing test if possible. If a new integration test is required, see `tests/DCPS/HelloWorld` for a template. Pull requests will be tested automatically using GitHub Actions.

See also:

Running Tests for how tests are run in general.

Unit Tests for guidance on the unit tests.

GitHub Actions for how building and testing is done with GitHub Actions.

3.1.3 Dependencies

- MPC is the build system, used to configure the build and generate platform specific build files (Makefiles, VS solution files, etc.).
- ACE is a library used for cross-platform compatibility, especially networking and event loops. It is used both directly and through TAO.
- TAO is a C++ CORBA implementation built on ACE.
  - It's used to communicate with DCPSInfoRepo, which is one option for Discovery.
  - TAO's data types and support for the OMG IDL-to-C++ mapping are also used in the End User DDS API.
  - The TAO IDL compiler is used internally and by the end user to allow OpenDDS to use user-defined IDL types as topic data.
- Perl is an interpreted language used in the configure script, the tests, and any other scripting in OpenDDS codebase.
- Google Test is required for OpenDDS tests. By default, CMake will be used to build a specific version of Google Test that we have as a submodule. An appropriate prebuilt or system Google Test can also be used.

See also:

Dependencies for all dependencies and details on how these are used in OpenDDS.

3.1.4 Text File Formatting

All text files in the source code repository follow a few basic rules. These apply to C++ source code, Perl scripts, MPC files, and any other plaintext file.

- A text file is a sequence of lines, each ending in the "end-of-line" character (AKA Unix line endings).
- Based on this rule, all files end with the end-of-line character.
- The character before end-of-line is a non-whitespace character (no trailing whitespace).
- Tabs are not used.
  - One exception, MPC files may contain literal text that's inserted into Makefiles which could require tabs.
  - In place of a tab, use a set number of spaces, depending on what type of file it is:
    * C++ and everywhere else unless otherwise noted should always be 2 spaces.
    * Perl is usually 2 spaces, but some files are defiant and use 4 spaces. See *Perl Coding Style* for details.
    * Python should always be 4 spaces. See *Python Coding Style* for details.
- Keep line length reasonable. I don't think it makes sense to strictly enforce an 80-column limit, but overly long lines are harder to read. Try to keep lines to roughly 80 characters.

The *lint script* will help check for most of these in a PR.

There is also a `.editorconfig` file that allows contributors to follow most of these rules automatically. EditorConfig support is built-in to some editors (including Visual Studio) with plugins available for others.

3.1.5 Lint Script

The lint script is a Perl script that is run on every PR. It checks for mistakes in both coding and style. It can also be run locally to check for issues before committing. If it is ran without arguments it does the default set of checks and also runs ACE's `fuzz.pl` if available. To see a list of the default checks with descriptions, run the script with `--list`. Passing `--try-fix` will try to fix some of those issues. The script also has ways to skip some or all checks for single lines or whole files. Pass `--help` for more information.

3.1.6 Documentation

Guidelines for building and editing documentation like the Developer's Guide and this document are covered in *Documentation Guidelines*.

If a pull request makes a change that should be included in the release notes, the entry should be specified using the method described in *News*.

3.1.7 C++ Standard

The base C++ standard used in OpenDDS is C++03. There are some optional features that are only built when a newer C++ standard level is used. See uses of the MPC feature `no_cxx11` and the base project `MPC/config/opendds_cxx11.mpb`.

Avoid using implementation-defined extensions (including `#pragma`). Exceptions are:

- `#pragma once` which only impacts preprocessing and is understood across all supported compilers, or harmlessly ignored if not understood
- `#pragma pack` can only be used on POD structs to influence alignment/padding

Use the C++ standard library as much as possible. The standard library should be preferred over ACE, which in turn should be preferred over system-specific libraries.

The C++ standard library includes the C standard library by reference, making those identifiers available in namespace `std`. Using C's standard library identifiers in namespace `std` is preferred over the global namespace – `#include <cstring>` instead of `#include <string.h>`. Not all supported platforms have standard library support for wide characters (`wchar_t`) but this is rarely needed. Preprocessor macro `DDS_HAS_WCHAR` can be used to detect those platforms.

3.1.8 C++ Coding Style

- C++ code in OpenDDS must compile under the compilers listed in the `README.md` file.
- Commit code in the proper style from the start, so follow-on commits to adjust style don't clutter history.
- C++ source code is a plaintext file, so the guidelines in *Text File Formatting* apply.
- A modified Stroustrup style is used (see `tools/scripts/style`).
  - Warning: not everything in `tools/scripts/style` represents the current guidelines.
- Sometimes the punctuation characters are given different names, this document will use:
  - Parentheses `( )`
  - Braces `{ }`
  - Brackets `[ ]`

Example

```
template<typename T>
class MyClass : public Base1, public Base2 {
public:
  bool method(const OtherClass& parameter, int idx = 0) const;
};

template<typename T>
bool MyClass<T>::method(const OtherClass& parameter, int) const
{
  if (parameter.foo() > 42) {
    return member_data_;
  } else {
    for (int i = 0; i < some_member_; ++i) {
      other_method(i);
    }
    return false;
  }
}
```

Punctuation

The punctuation placement rules can be summarized as:

- Open brace appears as the first non-whitespace character on the line to start function definitions.
- Otherwise the open brace shares the line with the preceding text.
- Parentheses used for control-flow keywords (`if`, `while`, `for`, `switch`) are separated from the keyword by a single space.
- Otherwise parentheses and brackets are not preceded by spaces.

Whitespace

- Each "tab stop" is two spaces.
- Namespace scopes that span most or all of a file do not cause indentation of their contents.
- Otherwise lines ending in `{` indicate that subsequent lines should be indented one more level until `}`.
- Continuation lines (when a statement spans more than one line) can either be indented one more level, or indented to nest "under" an `(` or similar punctuation.
- Add space around binary operators and after commas: `a + b, c`
- Do not add space around parentheses for function calls, a properly formatted function call looks like `func(arg1, arg2, arg3);`
- Do not add space around brackets for indexing, instead it should look like: `mymap[key]`
- For code that includes multiple braces appearing together in the same expression (such as initializer lists), there are two approved styles:
  - spaces between braces and their enclosed (non-empty) sub-expression: `const GUID_t GUID_UNKNOWN = { { 0 }, { { 0 }, 0 } };` or `{ a + b, {} }`

  - no such spaces: `const GUID_t GUID_UNKNOWN = {{0}, {{0}, 0}};` or `{a + b, {}}`

- Do not add extra spaces to make syntax elements (that span lines/statements) line up; this only causes unnecessary changes in adjacent lines as the code evolves.
- In general, do not add extra spaces unless doing so is covered by the rules above.

Language Usage

- Add braces following control-flow keywords even when they are optional.
- `this->` is not used unless required for disambiguation or to access members of a template-dependent base class.
- Declare local variables at the latest point possible.
- `const` is a powerful tool that enables the compiler to help the programmer find bugs. Use `const` everywhere possible, including local variables.
- Modifiers like `const` appear left of the types they modify, like: `const char* cstring = ...`. `char const*` is equivalent but not conventional.
- For function arguments that are not modified by the callee, pass by value for small objects (8 bytes?) and pass by const-reference for everything else. Function argument that is passed by value should not have `const` qualifier in the function declaration; use of `const` in the definition is optional.
- Arguments unused by the implementation have no names (in the definition that is, the declarations still have names), or a `/*commented-out*/` name.
- Use `explicit` constructors unless implicit conversions are intended and desirable.
- Use the constructor initializer list and make sure its order matches the declaration order.
- Prefer pre-increment/decrement (`++x`) to post-increment/decrement (`x++`) for both objects and non-objects.
- All currently supported compilers use the template inclusion mechanism. Thus function/method template definitions may not be placed in normal `*.cpp` files, instead they can go in `_T.cpp` (which are `#included` and not separately compiled), or directly in the `*.h`. In this case, `*_T.cpp` takes the place of `*.inl` (except it is always inlined). See ACE for a description of `*.inl` files.

Pointers and References

Pointers and references go along with the type, not the identifier. For example:

```
int* intPtr = &someInt;
```

Watch out for multiple declarations in one statement. `int* c, b;` does not declare two pointers! It's best just to break these into separate statements:

```
int* c;
int* b;
```

In code targeting C++03, `0` should be used as the null pointer. For C++11 and later, `nullptr` should be used instead. `NULL` should never be used.

Naming

(For library code that the user may link to)

- Preprocessor macros visible to user code must begin with `OPENDDS_`
- C++ identifiers are either in top-level namespace `DDS` (OMG spec defined) or `OpenDDS` (otherwise)
- Within the `OpenDDS` namespace there are some nested namespaces:
  - `DCPS`: anything relating to the implementation of the DCPS portion of the DDS spec
  - `RTPS`: types directly tied to the RTPS spec
  - `Federator`: DCPSInfoRepo federation
  - `FileSystemStorage`: reusable component for persistent storage
- Naming conventions
  - `ClassesAreCamelCaseWithInitialCapital`
  - `methodsAreCamelCaseWithInitialLower` OR `methods_are_lower_case_with_underscores`
  - `member_data_use_underscores_and_end_with_an_underscore_`
  - `ThisIsANamespaceScopedOrStaticClassMemberConstant`

Note: For CMake <*https://cmake.org/cmake/help/latest/prop_tgt/UNITY_BUILD.html*> are nominally supported. This may cause unexpected build issues in CI builds when a name in one file happens to clash with another source file in the same source file batch.

Comments

- Add comments only when they will provide MORE information to the reader.
- Describing the code verbatim in comments doesn't add any additional information.
- If you start out implementation with comments describing what the code will do (or pseudocode), review all comments after implementation is done to make sure they are not redundant.
- Do not add a comment before the constructor that says `// Constructor`. We know it's a constructor. The same note applies to any redundant comment.

Documenting Code for Doxygen

This is a simple guide that shows how to use Doxygen in OpenDDS.

See also:

The Doxygen manual for a complete guide to using Doxygen.

Doxygen supports multiple styles of documenting comments but this style should be used in non-trivial situations:

```
/**
 * This sentence is the brief description.
 *
 * Everything else is the details.
 */
```

(continues on next page)

(continued from previous page)

```
class DoesStuff {
// ...
};
```

For simple things, a single line documenting comment can be made like:

```
/// Number of bugs in the code
unsigned bug_count = -1; // Woops
```

The extra * on the multiline comment and / on the single line comment are important. They inform Doxygen that comment is the documentation for the following declaration.

If referring to something that happens to be a namespace or other global object (like DDS, OpenDDS, or RTPS), you should precede it with a %. If not it will turn into a link to that object.

Preprocessor

- If possible, use other language features things like inlining and constants instead of the preprocessor.
- Prefer `#ifdef` and `#ifndef` to `#if defined` and `#if !defined` when testing if a single macro is defined.
- Leave parentheses off preprocessor operators. For example, use `#if defined X && defined Y` instead of `#if defined(X) && defined(Y)`.
- As stated before, preprocessor macros visible to user code must begin with `OPENDDS_`.
- See section *C++ Standard* above for notes on `#pragma`.
- Ignoring the header guard if there is one, preprocessor statements should be indented using two spaces starting at the pound symbol, like so:

```
#if defined X && defined Y
#  if X > Y
#    define Z 1
#  else
#    define Z 0
#  endif
#else
#  define Z -1
#endif
```

Includes

Order

As a safeguard against headers being dependant on a particular order, includes should be ordered based on a hierarchy going from local headers to system headers, with spaces between groups of includes. Generated headers from the same directory should be placed last within these groups. This order can be generalized as the following:

1. Pre-compiled header if it is required for a `.cpp` file by Visual Studio.
2. The corresponding header to the source file (`Foo.h` if we were in `Foo.cpp`).
3. Headers from the local project.
4. Headers from external OpenDDS-based libraries.

5. Headers from dds/DCPS.
6. dds/*C.h Headers
7. Headers from external TAO-based libraries.
8. Headers from TAO.
9. Headers from external ACE-based libraries.
10. Headers from ACE.
11. Headers from external non-ACE-based libraries.
12. Headers from system and C++ standard libraries.

There can be exceptions to this list. For example if a header from ACE or the system library was needed to decide if another header should be included.

Path

Headers should only use local includes (`#include "foo/Foo.h"`) if the header is relative to the file. Otherwise system includes (`#include <foo/Foo.h>`) should be used to make it clear that the header is on the system include path.

In addition to this, includes for a file that will always be relative to the including file should have a relative include path. For example, a dds/DCPS/bar.cpp should include dds/DCPS/bar.h using `#include "bar.h"`, not `#include <dds/DCPS/bar.h>` and especially not `#include "dds/DCPS/bar.h"`.

Example

For a Doodad.cpp file in dds/DCPS, the includes could look like:

```
#include <DCPS/DdsDcps_pch.h>

#include "Doodad.h"

#include <ace/config-lite.h>
#ifndef ACE_CPP11
#  include "ConditionVariable.h"
#endif
#include "ReactorTask.h"
#include "transport/framework/DataLink.h"

#include <dds/DdsDcpsCoreC.h>

#include <tao/Version.h>

#include <ace/Version.h>

#include <openssl/opensslv.h>

#include <unistd.h>
#include <stdlib.h>
```

Initialization

Note that OpenDDS applications require ACE to be initialized to work correctly. For many OpenDDS applications, `ACE::init()` and `ACE::fini()` will be called automatically, either by interaction with the ACE or TAO libraries, or due to ACE's redefinition of executable entry points (e.g. `main`) which wrap normal execution with calls to those functions. However, be advised that on some platforms, the helper macros to catch entry points may change names to suit compiler options. For example, for Visual C++ builds on Windows with wide-character support enabled, the helper macro changes from `main` to `wmain`. Applications either need to handle these differences in order to correctly ensure initialization or they need to use an entrypoint helper macro such as `ACE_TMAIN` which isn't vulnerable to this issue.

Time

Measurements of time can be broken down into two basic classes: A specific point in time (Ex: 00:00 January 1, 1970) and a length or duration of time without context (Ex: 134 Seconds). In addition, a computer can change its clock while a program is running, which could mess up any time lapses being measured. To solve this problem, operating systems provide what's called a monotonic clock that runs independently of the normal system clock.

ACE can provide monotonic clock time and has a class for handling time measurements, `ACE_Time_Value`, but it doesn't differentiate between specific points in time and durations of time. It can differentiate between the system clock and the monotonic clock, but it does so poorly. OpenDDS provides three classes that wrap `ACE_Time_Value` to fill these roles: `TimeDuration`, `MonotonicTimePoint`, and `SystemTimePoint`. All three can be included using `dds/DCPS/TimeTypes.h`. Using `ACE_Time_Value` is discouraged unless directly dealing with ACE code which requires it and using `ACE_OS::gettimeofday()` or `ACE_Time_Value().now()` in C++ code in `dds/DCPS` treated as an error by the *lint script*.

`MonotonicTimePoint` should be used when tracking time elapsed internally and when dealing with `ACE_Time_Value`s being given by the `ACE_Reactor` in OpenDDS. `ACE_Condition`s, like all ACE code, will default to using system time. Therefore the `Condition` class wraps it and makes it so it always uses monotonic time like it should. Like `ACE_OS::gettimeofday()`, referencing `ACE_Condition` in `dds/DCPS` will be treated as an error by the *lint script*.

More information on using monotonic time with ACE can be found here.

`SystemTimePoint` should be used when dealing with the DDS API and timestamps on incoming and outgoing messages.

Logging

ACE Logging

Logging is done via ACE's logging macro functions, `ACE_DEBUG` and `ACE_ERROR`, defined in `ace/Log_Msg.h`. The logging macros arguments to both are:

- A `ACE_Log_Priority` value
  - This is an enum defined in `ace/Log_Priority.h` to say what the priority or severity of the message is.
- The format string
  - This is similar to the format string for the standard `printf`, where it substitutes sequences starting with `%`, but the format of theses sequences is different. For example `char*` values are substituted using `%C` instead of `%s`. See the documenting comment for `ACE_Log_Msg::log` in `ace/Log_Msg.h` for what the format of the string is.
- The variable number of arguments

  - Like `printf` the variable arguments can't be whole objects, like a `std::string` value. In the case of `std::string`, the format and arguments would look like: `"%C", a_string.c_str()`.

Note that all the `ACE_DEBUG` and `ACE_ERROR` arguments must be surrounded by two sets of parentheses.

```
ACE_DEBUG((LM_DEBUG, "Hello, %C!\n", "world"));
```

ACE logs to `stderr` by default on conventional platforms, but can log to other places.

Usage in OpenDDS

Logging Conditions and Priority

In OpenDDS `ACE_DEBUG` and `ACE_ERROR` are used directly most of the time, but sometimes they are used indirectly, like with the transport framework's `VDBG` and `VDBG_LVL`. They also should be conditional on one of the logging control systems in OpenDDS.

See also:

See *Logging* for the user perspective.

The logging conditions are as follows:

Message Kind	Macro	Priority	Condition
Unrecoverable error	`ACE_ERRO`	`LM_ERROR`	`log_level >= LogLevel::Error`
Unreportable recoverable error	`ACE_ERRO`	`LM_WARNIN`	`log_level >= LogLevel::Warning`
Reportable recoverable error	`ACE_ERRO`	`LM_NOTICE`	`log_level >= LogLevel::Notice`
Informational message	`ACE_DEBU`	`LM_INFO`	`log_level >= LogLevel::Info`
Debug message	`ACE_DEBU`	`LM_DEBUG`	Based on `DCPS_debug_level` or one of the other debug systems *listed below*[1]

An *unrecoverable error* indicates that OpenDDS is in a state where it cannot function as intended. This may be the result of a defect, misconfiguration, or interference.

A *recoverable error* indicates that OpenDDS could not perform a desired action but remains in a state where it can function as intended.

A *reportable error* indicates that OpenDDS can report the error via the API through something like an exception or return value.

An *informational message* gives high level information mostly at startup, like the version of OpenDDS being used.

A *debug message* gives lower level information, such as if a message is being sent. These are directly controlled by one of a few debug logging control systems.

- `DCPS_debug_level` should be used for all debug logging that doesn't fall under the other systems. It is an unsigned integer value which ranges from 0 to 10. See `dds/DCPS/debug.h` for details.
- `Transport_debug_level` should be used in the transport layer. It is an unsigned integer value which ranges from 0 to 6. See `dds/DCPS/transport/framework/TransportDebug.h` for details.
- `security_debug` should be used for logging in related to DDS Security. It is an object with `bool` members that make up categories of logging messages that allow fine control. See `dds/DCPS/debug.h` for details.

[1] Debug messages don't rely on both *LogLevel::Debug* and a debug control system. The reason is that it results in a simpler check and the log level already loosely controls all the debug control systems. See the `LogLevel::set` function in `dds/DCPS/debug.cpp` for exactly what it does.

For number-based conditions like `DCPS_debug_level` and `Transport_debug_level`, the number used should be the log level the message starts to become active at. For example for `DCPS_debug_level >= 6` should be used instead of `DCPS_debug_level > 5`.

Message Content

- Log messages should take the form:

```
(%P|%t) [ERROR:|WARNING:|NOTICE:|INFO:] FUNCTION_NAME: MESSAGE\n
```

  - Use `ERROR:`, `WARNING:`, `NOTICE:`, and `INFO:` if using the corresponding log priorities.
  - `CLASS_NAME::METHOD_NAME` should be used instead of just the function name if it's part of a class. It's at the developer's discretion to come up with a meaningful name for members of overload sets, templates, and other more complex cases.
  - `security_debug` and `transport_debug` log messages should indicate the category name, for example:

```
if (security_debug.access_error) {
  ACE_ERROR((LM_ERROR, "(%P|%t) ERROR: {access_error} example_function: Hello,␣
↪World!\n"));
}
```

- Format strings should not be wrapped in `ACE_TEXT`. We shouldn't go out of our way to replace it in existing logging points, but it should be avoided it in new ones.
  - `ACE_TEXT`'s purpose is to wrap strings and characters in `L` on builds where `uses_wchar=1`, so they become the wide versions.
  - While not doing it might result in a performance hit for character encoding conversion at runtime, the builds where this happens are rare, so it's outweighed by the added visual noise to the code and the possibility of bugs introduced by improper use of `ACE_TEXT`.
- Avoid new usage of `ACE_ERROR_RETURN` in order to not hide the return statement within a macro.

Examples

```
if (log_level >= LogLevel::Error) {
  ACE_ERROR((LM_ERROR, "(%P|%t) ERROR: example_function: Hello, World!\n"));
}

if (log_level >= LogLevel::Warning) {
  ACE_ERROR((LM_WARNING, "(%P|%t) WARNING: example_function: Hello, World!\n"));
}

if (log_level >= LogLevel::Notice) {
  ACE_ERROR((LM_NOTICE, "(%P|%t) NOTICE: example_function: Hello, World!\n"));
}

if (log_level >= LogLevel::Info) {
  ACE_DEBUG((LM_INFO, "(%P|%t) INFO: example_function: Hello, World!\n"));
}

if (DCPS_debug_level >= 1) {
```

(continues on next page)

(continued from previous page)

```
  ACE_DEBUG((LM_DEBUG, "(%P|%t) example_function: Hello, World!\n"));
}
```

3.1.9 Perl Coding Style

The Perl style guide should be generally followed, as long as it doesn't conflict with *Text File Formatting*. Some additional notes and exceptions:

- New files should use 2 space indents, while existing 4 space indent files should stay that way for the most part.
- The style of `if`/`elsif`/`else` should be this:

  ```
  if (x) {
  }
  elsif (y) {
  }
  else {
  }
  ```

  This is most likely what the Perl style guide refers to when it says "Uncuddled elses".
- Prefer calling functions with parentheses around the arguments where possible.
- The Perl style guide says to add spaces to line things up across multiple lines, but do not do this. The reason is the same as in C++ and that is that it reduces the flexibility of the code.
- Put the following at the start of a Perl file as soon as possible:

  ```
  use strict;
  use warnings;
  ```

  They should go before the imports, so that they can help reveal as many problems as possible.

3.1.10 Python Coding Style

In the world of Python usage of some form of **PEP 8** is basically universal. It should be generally followed, including indents being 4 spaces, as long as it doesn't conflict with *Text File Formatting*.

3.1.11 CMake Coding Style

The vcpkg CMake style guide should be generally followed, as long as it doesn't conflict with *Text File Formatting*. Some additional notes and exceptions:

- vcpkg-specific things can be ignored.
- Whitespace:
  - Indents are 2 spaces.
  - There should not be spaces before parentheses in flow control and function declarations and calls. For example use `if(value)`, not `if (value)`.
- Naming:
  - Global variables and properties should be the only names in all caps.

  - Prefix public global variables with `OPENDDS_`.
  - Prefix private global variables with `_OPENDDS_`.
  - Prefix public functions and macros with `opendds_`.
  - Prefix private functions and macros with `_opendds_`.
- Prefer defining or clearing a variable before use instead of assuming that it will always be undefined.
- Don't create new macros if a function will also work. Functions can use `set(name value PARENT_SCOPRE)` to set a value in the caller's scope. Helper macros inside of functions are okay.

3.2 Documentation Guidelines

This Sphinx-based documentation is hosted on Read the Docs and can be located here. It can also be built locally. To do this follow the steps in the following section.

3.2.1 Building

Run `docs/build.py`, passing the kinds of documentation desired. Multiple kinds can be passed, and they are documented in the following sections.

Requirements

The script requires Python 3.10 or later and an internet connection if the script needs to download dependencies or check the validity of external links. It will also try to download extra information for things like *`omgspec`*, but it shouldn't be a fatal error if there's not an internet connection.

You might receive a message like this when running for the first time:

```
build.py: Creating venv...
The virtual environment was not created successfully because ensurepip is not
available.  On Debian/Ubuntu systems, you need to install the python3-venv
package using the following command.

    apt install python3.9-venv
```

If you do, then follow the directions it gives, remove the `docs/.venv` directory, and try again.

HTML

HTML documentation can be built and viewed using `docs/build.py html -o`. If it was built successfully, then the front page will be at `docs/_build/html/index.html`.

A single page variant is also available using `docs/build.py singlehtml -o` If it was built successfully, then the page will be at `docs/_build/singlehtml/index.html`.

Dash

Documentation can be built for Dash, Zeal, and other Dash-compatible applications using doc2dash. The command for this is `docs/build.py dash`. This will create a `docs/_build/OpenDDS.docset` directory that must be manually moved to where other docsets are stored.

PDF

Note: The PDF output is currently much less optimized than the HTML-based outputs.

Note: The Sphinx PDF builder has additional dependencies on LaTeX that are documented here.

PDF documentation can be built and viewed using `docs/build.py pdf -o`. If it was built successfully, then the PDF file will be at `docs/_build/latex/opendds.pdf`.

Strict Checks

`docs/build.py strict` will promote Sphinx warnings to errors and check to see if links resolve to a valid web page.

Note: The documentation includes dynamic links to files in the GitHub repo created by *ghfile*. These links will be invalid until the git commit they were built under is pushed to a Github fork of OpenDDS. This also means running will cause those links to marked as broken. A workaround for this is to pass `-c master` or another commit, branch, or tag that is desired.

Building Manually

It is recommended to use `build.py` to build the documentation as it will handle dependencies automatically. If necessary though, Sphinx can be ran directly.

To build the documentation the dependencies need to be installed first. Run this from the `docs` directory to do this:

```
pip3 install -r requirements.txt
```

Then `sphinx-build` can be ran. For example to build the HTML documentation:

```
sphinx-build -M html . _build
```

3.2.2 RST/Sphinx Usage

- See Sphinx reStructuredText Primer for basic RST usage.
- Inline code such as class names like `DataReader` and other symbolic text such as commands like `ls` should use double backticks: ``` ``TEXT`` ```. This distinguishes it as code, makes it easier to distinguish characters, and reduces the chance of needing to escape characters if they happen to be special for RST.
- One sentence per line should be perfered. This makes it easier to see what changed in a `git diff` or GitHub PR and easier to move sentences around in editors like Vim. It also avoids inconsistencies involving what the

maximum line length is. This might make it more annoying to read the documentation raw, but that's not the intended way to do so anyway.

Special Links

There are a few shortcuts for linking to GitHub and OMG that are custom to OpenDDS. These come in the form of RST roles and are implemented in `docs/sphinx_extensions/links.py`.

`:ghfile:`

```
:ghfile:`README.md`

:ghfile:`the \`\`README.md\`\` File <README.md>`

:ghfile:`the support section of the \`\`README.md\`\` File <README.md#support>`

:ghfile:`check out the available support <README.md#support>`

:ghfile:`java/docs/overview.html`
```

Turns into:

README.md#support

README.md

the README.md File

the support section of the README.md File

check out the available support

java/docs/overview.html (View as HTML)

The path passed must exist, be relative to the root of the repository, and will have to be committed, if it's not already. If there is a URL fragment in the path, like `README.md#support`, then it will appear in the link URL.

It will try to point to the most specific version of the file:

- If `-c` or `--gh-links-commit` was passed to `build.py`, then it will use the commit, branch, or tag that was passed along with it.
- Else if the OpenDDS is a release it will calculate the release tag and use that.
- Else if the OpenDDS is in a git repository it will use the commit hash.
- Else it will use `master`.

If the file ends in `.html`, there will be an additional link to the file that uses https://htmlpreview.github.io/ so the file can be viewed directly in a web browser.

`:ghissue:`

```
:ghissue:`213`

:ghissue:`this is the issue <213>`

:ghissue:`this is **the issue** <213>`
```

Turns into:

Issue #213

this is the issue

this is **the issue**

:ghpr:

```
:ghpr:`1`

:ghpr:`this is the PR <1>`

:ghpr:`this is **the PR** <1>`
```

Turns into:

PR #1

this is the PR

this is **the PR**

:ghrelease:

`ghrelease` links to a release on Github using the git tag. Note that this behaves differently than the other roles here. Without the syntax `` `Link text <TARGET>` `` syntax, it uses the contents as link text and link to the release tag for the current version, assuming there is one. This syntax should only be used in a `.. ifconfig:: is_release` directive. Also it never parses the contents as inline markup.

```
:ghrelease:`This is the release`

:ghrelease:`This is the release <DDS-3.24>`
```

Turns into:

This is the release

This is the release

:acetaorel:

`acetaorel` accepts the ACE/TAO major version nickname from `acetao.ini` and makes a link to that release this version of OpenDDS uses.

```
See :acetaorel:`ace6tao2`

Also see :acetaorel:`this <ace7tao3>`
```

Turns into:

See ACE 6.5.20/TAO 2.5.20

Also see this

:omgissue:

```
:omgissue:`DDSXTY14-29`

:omgissue:`this is the issue <DDSXTY14-29>`

:omgissue:`this is **the issue** <DDSXTY14-29>`
```

Turns into:

OMG Issue DDSXTY14-29 (Member Link)

this is the issue (Member Link)

this is **the issue** (Member Link)

:omgspec:

The OMG specs are published as PDFs and it would be nice to be able to link to subsections within the specs using something like `DDS.pdf#2.2.2`. It's possible for the OMG to enable that when the PDF is created, but they don't. This role works around that by downloading the PDFs and extracting sections from the table of contents to generate links that that can be used by browsers. If a spec PDF can't be downloaded, the link will be just to the spec PDF.

```
:omgspec:`dds`

:omgspec:`dds:2.2.2`

:omgspec:`dds:2.2.2 PIM Description`

:omgspec:`dds:Annex B`

:omgspec:`Somewhere in the XTypes spec <xtypes>`

:omgspec:`Exactly here in the XTypes spec <xtypes:2.2.2>`

:omgspec:`TypeObject IDL <xtypes:Annex B>`
```

Turns into:

DDS v1.4

DDS v1.4 2.2.2 PIM Description

DDS v1.4 2.2.2 PIM Description

DDS v1.4 Annex B - Syntax for Queries and Filters

Somewhere in the XTypes spec

Exactly here in the XTypes spec

TypeObject IDL

The format of the target is `SPEC[:SECTION]`.

Valid specs are:

- DDS 1.4 (`dds`)
- RTPS 2.3 (`rtps`)
- DDS Security 1.1 (`sec`)
- DDS XTypes 1.3 (`xtypes`)
- IDL 4.2 (`idl`)
- IDL to C++03 1.3 (`cpp03`)
- IDL to C++11 1.5 (`cpp11`)
- IDL to Java 1.3 (`java`)

These are defined in docs/conf.py.

Valid sections can be named one of two ways:

- Section that start with section numbers, such as `2.2.2`. This is based on the start of the full name of the section in the table of contents.
- All others can be linked using the section title, either part or whole, such as `Annex B` or `Annex B - Syntax for Queries and Filters`. This can be used to link to sections that don't have section numbers, but can be ambiguous, so should be most or all of the title. It can also be used to link to numbered sections in case the numbers change, such as `2.2.2 PIM Description`.

See here for all the possible sections.

Custom Domains

Sphinx domains are a way to document collections of hierarchical definitions such as APIs. Sphinx has a number of built-in domains such as Python and C++, but it helps to have custom ones. Custom domains in OpenDDS should use classes derived from the ones in docs/sphinx_extensions/custom_domain.py.

All of the custom domain directives can and should have RST content nested in them. They all support the `:no-index:`, `:no-index-entry:`, and `:no-contents-entry:` directive options. See Basic Markup for more information.

CMake Domain

For *Using OpenDDS in a CMake Project* there's a custom CMake Sphinx domain in docs/sphinx_extensions/cmake_domain.py. There is an official CMake domain used by CMake for their own documentation, but it would be impractical for us to use because it requires a separate RST file for every property and variable.

.. cmake:func:: <name>

Use to document public CMake functions.

```
.. cmake:func:: opendds_cmake_function

  ::

    opendds_cmake_function(<target> [ARG <value>])

  This is a function.

  .. cmake:func:arg:: target

    This is a positional argument

  .. cmake:func:arg:: ARG <value>

    This is a keyword argument
```

Turns into:

opendds_cmake_function

```
opendds_cmake_function(<target> [ARG <value>])
```

This is a function.

target
This is a positional argument

ARG <value>
This is a keyword argument

.. cmake:func:arg:: <name> [<subargument>...]

Use to document arguments and options for public CMake functions. Should be nested in *cmake:func* of the function the argument belongs to.

:cmake:func:

Use to reference a *cmake:func* by name or reference a *cmake:func:arg* by function name followed by argument name in parentheses. For example:

```
:cmake:func:`opendds_cmake_function`

:cmake:func:`opendds_cmake_function(target)`

:cmake:func:`opendds_cmake_function(ARG)`
```

Turns into:

opendds_cmake_function

opendds_cmake_function(target)

opendds_cmake_function(ARG)

.. cmake:var:: <name>

Use to document public variables.

```
.. cmake:var:: OPENDDS_CMAKE_VARIABLE

  This is a variable
```

Turns into:

OPENDDS_CMAKE_VARIABLE
This is a variable

:cmake:var:

Use to reference a *cmake:var* by name.

```
:cmake:var:`OPENDDS_CMAKE_VARIABLE`
```

Turns into:

OPENDDS_CMAKE_VARIABLE

.. cmake:prop:: <name>

Use to document properties on CMake targets, or possibly other kinds of properties, that we're looking for or creating for the user.

```
.. cmake:prop:: OPENDDS_CMAKE_PROPERTY

  This is a property
```

Turns into:

OPENDDS_CMAKE_PROPERTY

This is a property

:cmake:prop:

Use to reference a *cmake:prop* by name.

```
:cmake:prop:`OPENDDS_CMAKE_PROPERTY`
```

Turns into:

OPENDDS_CMAKE_PROPERTY

.. cmake:tgt:: <name>

Use to document a library or executable CMake target meant to users that can be imported or exported.

```
.. cmake:tgt:: OpenDDS::MessengerPigeonTransport

  Transport for IP over messenger pigeon (:rfc:`1149`)
```

Turns into:

OpenDDS::MessengerPigeonTransport

Transport for IP over messenger pigeon (**RFC 1149**)

:cmake:tgt:

Use to reference a *cmake:tgt* by name.

```
:cmake:tgt:`OpenDDS::MessengerPigeonTransport`
```

Turns into:

OpenDDS::MessengerPigeonTransport

Config Domain

For *Run-time Configuration* there's a custom configuration Sphinx domain in docs/sphinx_extensions/config_domain.py.

.. cfg:sec:: <name>[@<discriminator>][/<argument>]

Use to document a configuration section that can contain *cfg:prop* and most other RST content. <discriminator> is an optional extension of the name to document cases where the available properties depend on something. Using discriminators requires separate *cfg:sec* entires. <arguments> is just for display and has no restrictions on the contents.

:cfg:sec:

Use to reference a *cfg:sec* by name and optional discriminator. If the section has a discriminator, it must be separated by a @ symbol. Do not include arguments if it has arguments in the directive. The possible formats are <sect_name> and <sect_name>@<disc_name>.

.. cfg:prop:: <name>=<values>

Use to document a configuration property that can contain *cfg:val* and most other RST content. Must be in a *cfg:sec*. <values> describe what sort of text is accepted. It is just for display and has no restrictions on the contents, but should follow the following conventions to describe the accepted values:

- | indicates an OR
- [] indicates an optional part of the value

- `...` indicates the previous part can be repeated
- Words surrounded angle brackets (ex: `<prop_name>`) indicate placeholders.
- Everything else should be considered literal.

For example: `log_level=none|error|warn|debug`, `memory_limit=<uint64>`, `addresses=<ip>[:<port>],...`.

:required:

Indicates the property is required for the section

:default:

The default value of the property if omitted

:cfg:prop:

Use to reference a *cfg:prop* by name. Do not include values if it has values in the directive. The possible formats are:

- `<prop_name>`

  Inside of a *cfg:sec*, it refers to a property in that section. Outside of a *cfg:sec*, the property is assumed to be `common`.

- `[<sect_name>]<prop_name>`
- `[<sect_name>@<disc_name>]<prop_name>`

.. cfg:val:: `[<]<name>[>]`

Use to document a part of what a configuration property accepts. Must be in a *cfg:prop*. The optional angle brackets (<>) are just for display and are meant to help distinguish between the value being a literal and a placeholder.

:cfg:val:

Use to reference a *cfg:val* by name. Do not include brackets if it has brackets in the directive. The possible formats are:

- `<val_name>`

  This must be inside a *cfg:prop*.

- `<prop_name>=<val_name>`

  Inside of a *cfg:sec*, it refers to a value of a property in that section. Outside of a *cfg:sec*, the property is assumed to be `common`.

- `[<sect_name>]<prop_name>=<val_name>`
- `[<sect_name>@<disc_name>]<prop_name>=<val_name>`

Example

This is a example made up for the following INI file:

```
[server/Alpha]
os=windows

[server/Beta]
os=linux
distro=Debian
```

```
Outside their sections, references to properties and values must be complete:␣
↪:cfg:val:`[server]os=linux`, :cfg:prop:`[server@linux]distro`

Otherwise the ``common`` section will be assumed.

.. cfg:sec:: server/<name>

  A property or value's section can be omitted from references within their sections:␣
↪:cfg:prop:`os`, :cfg:val:`os=windows`

  .. cfg:prop:: os=windows|linux
    :required:

    A value's property can be omitted from references within their properties:␣
↪:cfg:val:`linux`

    .. cfg:val:: windows

      Implied titles will be shortened within their scopes: :cfg:prop:`[server]os`,␣
↪:cfg:val:`[server]os=windows`

    .. cfg:val:: linux

      Sections with discriminators require them in the reference targets:␣
↪:cfg:sec:`server@linux`, :cfg:prop:`[server@linux]distro`

.. cfg:sec:: server@linux/<name>

  .. cfg:prop:: distro=<name>
    :default: ``Ubuntu``
```

Turns into:

Outside their sections, references to properties and values must be complete: *[server] os=linux*, *[server] distro (linux)*

Otherwise the common section will be assumed.

[**server**/<name>]

A property or value's section can be omitted from references within their sections: *os*, *os=windows*

os=windows|linux

Config store key: SERVER_<name>_OS
Required

A value's property can be omitted from references within their properties: *linux*

windows

Implied titles will be shortened within their scopes: *os*, *windows*

linux

Sections with discriminators require them in the reference targets: *[server] (linux)*, *[server] distro (linux)*

[server/<name>**] (linux)**

distro=<name>

Config store key: SERVER_<name>_DISTRO
Default: Ubuntu

3.2.3 News

The *news for a release (aka release notes)* is created from separate reStructuredText files called *fragments*. This makes it possible to change the news without everyone editing one file. Managing the news fragments is handled as part of the Sphinx documentation to make it easy to link to other relevant documents and files in the source code. It also makes it possible to easily preview the news before a release.

News Fragments

To add content to the news for a release, a fragment file with the content must be created in `docs/news.d`. It can be named anything as long as it's reasonably unique, doesn't start with an underscore, and has an `.rst` file extension. The branch name of the PR for this change might be a good name, for example: `fix_rtps_segfault.rst`.

The following is a simple news fragment example:

Listing 1: `docs/news.d/_example.rst`

```
# This is a news fragment example. Copy this file in this directory and change
# it to have content added to the release notes for the next release.
# See https://opendds.readthedocs.io/en/master/internal/docs.html#news for details

# This will have to be replaced with the PR number after the PR is created:
.. news-prs: 0

.. news-start-section: Additions
- This is an addition we made.

  - This is detailed information about the addition.
    This is some more.

.. news-end-section
```

Fragments contain RST content for the news along with some RST directive-like metadata. Lines starting with # are ignored as comments. Content for the news must be formatted as a list. It will usually be one list item, but can be multiple items if they are separate changes from a user perspective.

Note: If using nested lists, reStructuredText requires these to have empty lines before and after as shown in the example above.

Content must be contained somewhere within a section, indicated by `news-start-section` and `news-end-section`. Having text outside sections that isn't a comment or a special news directive is an error.

Content should provide a reasonable amount of context to users so they can figure out if and how a change will impact or benefit them. Some of this can be achieved through *subsections*. Content should link to the rest of the Sphinx documentation and to source files using `:ghfile:` if relevant.

PRs will usually have just have one fragment file, but can have more then one. For example, say there is a PR that is making changes associated with an existing fragment file, but also has changes that are separate from the PRs in that fragment. This might indicate a new PR should be made for those changes, but if that's impractical, a new separate fragment file for those changes can be made.

Directives

news-prs

`news-prs` should declare all the PRs that make up the changes to OpenDDS described in the fragment. It's an error to omit `news-prs` from a fragment or to have more than one `news-prs` directive. Do not add `#` at the start of the PR numbers. Please add follow-on PRs separated by spaces as they are created.

```
.. news-prs: 1002 1003 1008
```

If the changes don't have a PR associated with them, such as a policy change, then put `none` instead:

```
.. news-prs: none
```

news-start-section and news-end-section

`news-start-section` and `news-end-section` directives contain the news content and define how they're grouped. All sections with the same name across all the fragments are merged together in the final result. The top-level sections must be one of the following:

`Additions`
: New user-relevant features

`Platform Support and Dependencies`
: Additional support or changes to support for OS, C++ standards, compilers, and dependencies.

`Deprecations`
: User-relevant features that are being planned on being removed, but removing now would break a significant number of user's use cases. This marks them for removal in the next major version.

`Removals`
: User-relevant features removed that were either deprecated, "experimental", or "internal" that users might be relying on anyways.

`Security`
: Fixes for issues that might compromise the security of a system using OpenDDS. This doesn't need to be related to *DDS Security*.

`Fixes`
: User-relevant fixes not related to security or documentation.

`Documentation`
: Significant changes to documentation, either in the primary Sphinx documentation or in secondary documentation. This can be documenting an existing feature or major changes to existing documentation. Documentation

for a new feature should be linked in the news item for it, not here. Minor corrections like spelling and changes to internal documentation probably don't need to be mentioned in the news.

Notes
: Changes that might be relevant to users, but might not fit in any of the other sections. This could be a change in policy or change outside the OpenDDS source code that doesn't have a PR associated with it.

Sections can be nested as subsections. There is no requirement for subsections or restrictions on their names, but it's suggested to group otherwise separate changes if they are all impact the same part of OpenDDS. For example:

```
.. news-start-section: Fixes
- Non-RTPS Fix
.. news-start-section: RTPS
- RTPS Fix
.. news-start-section: RTPS Relay
- RTPS Relay Fix
- Another RTPS Relay Fix
.. news-end-section
- Another RTPS Fix
.. news-end-section
- Another Non-RTPS Fix
.. news-end-section
```

Will result in:

- Non-RTPS Fix (PR #1000)
- RTPS
  - RTPS Fix (PR #1000)
  - RTPS Relay
    * RTPS Relay Fix (PR #1000)
    * Another RTPS Relay Fix (PR #1000)
  - Another RTPS Fix (PR #1000)
- Another Non-RTPS Fix (PR #1000)

This will allow other fragments to add to "RTPS" or "RTPS Relay".

news-rank

Rank is an integer used to help sort content and sections. Setting the rank higher using `news-rank` can headline a change within a section. This is optional and if omitted or if rank is the same, then items are ranked by the oldest PR number.

Once used, `news-rank` applies to both subsections and content directly in the section between the `news-start-section` and the `news-end-section`. Content in subsections will need a separate `news-rank` to change the order, as sorting of subsections is separate. When sections have different ranks across fragments (or even in the same fragment), then the largest of ranks is used.

For an example of all that, let us say we had the following fragments:

Listing 2: These are the older changes

```
.. news-prs: 1111
.. news-start-section: Additions
# Rank 0 because it's a new section
- Improved logging in some cases.
# Lets give XTypes as a section some priority
.. news-rank: 20
.. news-start-section: XTypes
# Rank 0 because it's a new section
- Added ability to randomize ``DynamicData``
.. news-rank: 10
- Added lossless casting from any type to any other type in ``DynamicData``.
.. news-end-section
# This gets the same rank 20 as the XTypes section
- Made logging worse in some cases.
.. news-end-section
```

Listing 3: These are the newer changes

```
.. news-prs: 2222
.. news-start-section: Additions
# Rank 0, the rank 0 older item in the other fragment will get priority
- Unoptimized all code that's not related to pigeons
# Let's say we want to give this highest priority
.. news-rank: 50
- Added a new transport for IP over messenger pigeon (:rfc:`1149`)
# This will be overruled by the rank 20 XTypes in the other fragment
.. news-rank: 10
.. news-start-section: XTypes
.. news-rank: 100
- New pigeon-based ``DynamicData``
.. news-end-section
.. news-end-section
```

These will result in:

- Added a new transport for IP over messenger pigeon (**RFC 1149**) (PR #2222) [Rank 50]
- Made logging worse in some cases. (PR #1111) [Rank 20]
- XTypes [Rank 20]
  - New pigeon-based `DynamicData` (PR #2222) [Rank 100]
  - Added lossless casting from any type to any other type in `DynamicData`. (PR #1111) [Rank 10]
  - Added ability to randomize `DynamicData` (PR #1111) [Rank 0]
- Improved logging in some cases. (PR #1111) [Rank 0]
- Unoptimized all code that's not related to pigeons (PR #2222) [Rank 0]

The ranks are included in previews of the news as an aid to deciding what the rank of new news content should be. The preview can be viewed in *Release Notes* or alternatively by running `docs/news.py preview`. The ranks are not included in the final news for a release.

One final thing to note is that top-level sections, like "Additions", have a fixed rank that can't be changed so they always appear in the same order.

Generating the News

Before a release, a preview of the whole news for the next release will always be available in *Release Notes*. It's also possible to see the source of that preview by running `docs/news.py preview` or `docs/news.py preview-all`. During a release the fragments are permanently committed to `docs/news.d/_releases` and `NEWS.md` and the fragment files in `docs/news.d` are removed.

See also:

Release Process

3.3 Unit Tests

3.3.1 The Goals of Unit Testing

The primary goal of a unit test is to provide informal evidence that a piece of code performs correctly. An alternative to unit testing is writing formal proofs. However, formal proofs are difficult, expensive, and unmaintainable given the changing nature of software. Unit tests, while necessarily incomplete, are a practical alternative.

Unit tests document how to use various algorithms and data structures and serve as an informal set of requirements. As such, a unit test should be developed with the idea that it will serve as a reference for future developers. Clarity in unit tests serve to accomplish their primary goal of establishing correctness. That is, a unit test that is difficult to understand casts doubt that the code being tested is correct. Consequently, unit tests should be clear and concise.

The confidence one has in a piece of code is often related to the number of code paths explored in it. This is often approximated by "code coverage." That is, one can run the unit test with a coverage tool to see which code paths were exercised by the unit test. Code with higher coverage tends to have fewer bugs because the tester has often considered various corner-cases. Consequently, unit tests should aim for high code coverage.

Unit tests should be executed frequently to provide developers with instant feedback. This applies to the feature under development and the system as a whole. That is, developers should frequently execute all of the unit tests to make sure they haven't broken functionality elsewhere in the system. The more frequently the tests are run, the smaller the increment of development and the easier it is to identify a breaking change. Thus, unit tests should execute quickly.

Code that is difficult to test will most likely be difficult to use. Code that is difficult to use correctly will lead to bugs in code that uses it. Consequently, unit tests are vital to the design of useful software as developing a unit test provides feedback on the design of the code under test. Often, when developing a unit test, one will find parts of the design that can be improved.

Unit tests should promote and not inhibit development. A robust set of unit tests allows a developer to aggressively refactor since the correctness of the system can be checked after the refactoring. However, unit tests do produce drag on development since they must be maintained as the code evolves. Thus, it is important that the unit test code be properly maintained so that they are an asset and not a liability.

Some of the goals mentioned above are in conflict. Adding code to increase coverage may make the tests less maintainable, slower, and more difficult to understand. The following metrics can be generated to measure the utility of the unit tests:

- Code coverage
- Test compilation time
- Test execution time
- Test code size vs. code size
- Defect rate vs. code coverage (Are bugs appearing in code that is not tested as well?)

3.3.2 Unit Test Organization

The most basic unit when testing is the *test case*. A test case typically has four phases.

1. Setup - The system is initialized to a known state.
2. Exercise - The code under test is invoked.
3. Check - The resulting state of the system and outputs are checked.
4. Teardown - Any resources allocated in the test are deallocated.

Test cases are grouped into a *test suite*.

Test suites are organized into *a test plan*.

We adopt file boundaries for organizing the unit tests for OpenDDS. That is, the unit tests for a file group `dds/DCPS/SomeFile.(h|cpp)` will be located in `tests/unit-tests/dds/DCPS/SomeFile.cpp`. The file `tests/unit-tests/dds/DCPS/SomeFile.cpp` is a test suite containing all of the test cases for `dds/DCPS/SomeFile.(h|cpp)`. The test plan for OpenDDS will execute all of the test suites under `tests/unit-tests`. When the complete test plan takes too much time to execute, it will be sub-divided along module boundaries.

In regards to coverage, the coverage of `dds/DCPS/SomeFile.(h|cpp)` is measured by executing the tests in its test suite `tests/unit-tests/dds/DCPS/SomeFile.cpp`. The purpose of this is to avoid indirect testing where a piece of code may get full coverage without ever being intentionally tested.

3.3.3 Unit Test Scope

A unit test should be completely deterministic with respect to the code paths that it exercises. This means the test code must have control over all relevant inputs, i.e., inputs that influence the code paths. To illustrate, the current time is relevant when testing algorithms that perform date related functions, e.g., code that is conditioned on a certificate being expired, while it is not relevant if it is only used when printing log messages. Sources of non-determinism include time, random numbers, schedulers, and the network. A dependency on the time is typically mitigated by mocking the service that return the time. Random numbers can be handled the same way. A unit test should never sleep. Avoiding schedulers means a unit test should not have multiple processes and should not have multiple threads unless they cannot impact the code paths being tested. The network can be avoided by defining a suitable abstraction and mocking.

Code that relies on event dispatching may use a mock dispatcher to control the sequence of events. One design that makes it possible to unit test in this way is to organize a module as a set of atomic event handlers around a plain old data structure core. The core should be easy to test. Event handlers are called for timers, I/O readiness, and method calls into the module. Event handlers update the core and can perform I/O and call into other modules. Inter-module calls are problematic in that they create the possibility for deadlock and other hazards. In the simplest designs, each module has a single lock that is acquired at the beginning of each event handler. The non-deterministic part of the module can be tested by isolating its dependencies on the operating system and other modules; typically by providing mock objects.

To illustrate the other side of determinism, consider other kinds of tests. Integration tests often use operating system services, e.g., threads and networking, to test partial or whole system functionality. A stress test executes the same code over and over hoping that non-determism results in a different outcome. Performance tests may or may not admit non-determinism and focuses on aggregate behavior as opposed to code-level correctness. Unit tests should focus on code-level correctness.

3.3.4 Isolating Dependencies

More often than not, the code under test will have dependencies on other objects. For each dependency, the test can either pass in a real object or a stand-in. Test stand-ins have a variety of names including mocks, spies, dummies, etc. depending on their function. Some take the position that everything should be mocked. The author takes the position that real objects should be preferred for the following reasons:

- Less code to maintain
- The design of the real objects improves to accommodate testing
- Tests break in a more meaningful way when dependencies change, i.e., over time, a test stand-in may no longer behave in a realistic way

However, there are cases when a test stand-in is justified:

- It is difficult to configure the real object
- The real object lacks the necessary API for testing and adding it cannot be justified

The use of a mock assumes that an interface exists for the stand-in.

3.3.5 Writing a New Unit Test

1. Add the test to the appropriate file under `tests/unit-tests`.
2. Name the test after the code it is meant to cover. For example, the `tests/unit-tests/dds/DCPS/security/AccessControlBuiltInImpl.cpp` unit test covers the `dds/DCPS/security/AccessControlBuiltInImpl.(h|cpp)` files.
3. Update the `tests/unit-tests/UnitTests.mpc` file if necessary.

3.3.6 Using GTest

The main unit test driver is based on GTest. GTest provides you with many helpful tools to simplify the writing of unit tests. To use GTest in a test, add `#include <gtest/gtest.h>` to the unit test source file. A basic unit test has the following form

```
TEST(TestModule, TestSubmodule)
{
}
```

All tests in a unit test source file must have the same TestModule which is name of the unit under test with underscores, e.g., `dds_DCPS_security_AccessControlBuiltInImpl`. This naming convention is required for intentional unit test coverage. The TestSubmodule can be any identifier, however, it should typical describe the class, function, or scenario being tested.

Each test contains evaluators. The most common evaluators are `EXPECT_EQ`, `EXPECT_TRUE`, `EXPECT_FALSE`.

```
EXPECT_EQ(X, 2)
EXPECT_EQ(Y, 3)
```

This will mark the test as a failure if either `X` does not equal 2, or `Y` does not equal 3.

`EXPECT_TRUE` and `EXPECT_FALSE` are equivalence checks to a boolean value. In the following examples we pass `X` to a function `is_even` that returns true if the passed value is an even number and returns false otherwise.

```
EXPECT_TRUE(is_even(X));
```

This will mark the test as a failure if `is_even(X)` returns false.

```
EXPECT_FALSE(is_even(X));
```

This will mark the test as a failure if `is_even(X)` returns true.

There are more EXPECT_* and ASSERT_*, but these are the most common ones. The difference between EXPECT and ASSERT is that an ASSERT will cease the test upon failure, whereas EXPECTS continue to run. For example if you have multiple `EXPECT_EQ`, they will all always run.

For more information, visit the google test documentation: https://github.com/google/googletest/blob/main/docs/primer.md.

3.3.7 Code Coverage

To enable code coverage, one needs to disable the *dds_non_coverage* feature, e.g., `./configure ... --features=dds_non_coverage=0`.

The script `$DDS_ROOT/tools/scripts/unit_test_coverage.sh` will execute unit tests and generate an intentional unit test coverage report. It can be called with no arguments to generate a report for all of the units or it can be called with a list of units to test. For example, `$DDS_ROOT/tools/scripts/unit_test_coverage.sh dds/DCPS/Serializer`.

3.3.8 Final Word

Ignore anything in this document that prevents you from writing unit tests.

3.4 GitHub Actions

3.4.1 Overview

GitHub Actions is the continuous integration solution currently being used to evaluate the readiness of pull requests. It builds OpenDDS and runs the test suite across a wide variety of operation systems and build configurations.

3.4.2 Legend for GitHub Actions Build Names

Operating System

- u20/u22 - Ubuntu 20.04/22.04
- w19/w22 - Windows Server 2019/Windows Server 2022
- m11/m12 - macOS 11/12

See also:

GitHub Runner Images

Build Configuration

- x86 - Windows 32 bit. If not specified, x64 is implied.
- re - Release build. If not specified, Debug is implied.
- clangX/gccY - compiler used to build OpenDDS. If not specified, the default system compiler is used. Windows Server 2019 uses Visual Studio 2019 Windows Server 2022 uses Visual Studio 2022

Build Type

- stat - Static build
- bsafe/esafe - Base Safety/Extended Safety build
- sec - Security build
- asan/tsan - Address/Thread Sanitizer build

Build Options

- o1 - enables `--optimize`
- d0 - enables `--no-debug`
- i0 - enables `--no-inline`
- p1 - enables `--ipv6`
- w1 - enables wide characters
- v1 - enables versioned namespace
- cpp03 - `--std=c++03`
- j/j<N> - Java version default/N
- ace7 - uses ace7tao3 rather than ace6tao2
- xer0 - disables xerces
- qt - enables `--qt`
- ws - enables `--wireshark`
- js0 - enables `--no-rapidjson`
- a1 - enables TAO's Anys using `--features=dds_suppress_anys=0`

Feature Mask

This is a mask in an attempt to keep names shorter.

- FM-08
  - `--no-built-in-topics`
  - `--no-content-subscription`
  - `--no-ownership-profile`
  - `--no-object-model-profile`
  - `--no-persistence-profile`

- FM-1f
  - `--no-built-in-topics`
- FM-2c
  - `--no-content-subscription`
  - `--no-object-model-profile`
  - `--no-persistence-profile`
- FM-2f
  - `--no-content-subscription`
- FM-37
  - `--no-content-filtered-topics`

3.4.3 build_and_test.yml Workflow

Our main workflow which dictates our GitHub Actions run is `.github/workflows/build_and_test.yml`. It defines jobs, which are the tasks that are run by the CI.

Triggering the Build And Test Workflow

There are a couple ways in which a run of build and test workflow can be started.

Any pull request targeting master will automatically run the OpenDDS workflows. This form of workflow run will simulate a merge between the branch and master.

Push events on branches prefixed `gh_wf_` will trigger workflow runs on the fork in which the branch resides. These fork runs of GitHub Actions can be viewed in the "Actions" tab. Runs of the workflow on forks will not simulate a merge between the branch and master.

Job Types

There are a number of job types that are contained in the file build_and_test.yml. Where possible, a configuration will contain 3 jobs. The first job that is run is *ACE_TAO_*. This will create an artifact which is used later by the OpenDDS build. The second job is *build_*, which uses the previous *ACE_TAO_* job to configure and build OpenDDS. This job will then export an artifact to be used in the third step. The third step is the *test_* job, which runs the appropriate tests for the associated OpenDDS configuration.

Certain builds do not follow this 3 step model. Static and Release builds have a large footprint and therefore cannot fit the entire test suite onto a GitHub Actions runner. As a result, they only build and run a subset of the tests in their final jobs, but then have multiple final jobs to increase test coverage. These jobs are prefixed by:

- *compiler_* (and for some build configurations, *compiler2_*) which runs the `tests/DCPS/Compiler` tests.
- *unit_* which runs the unit tests located in `tests/unit-tests`.
- *messenger_* which runs the tests in `tests/DCPS/Messenger` and `tests/DCPS/C++11/Messenger`.

To shorten the runtime of the continuous integration, some other builds will not run the test suite.

All builds with safety profile disabled and ownership profile enabled, will run the `tests/cmake` tests. Test runs which only contain CMake tests are prefixed by `cmake_`.

.lst Files

.lst files contain a list of tests with configuration options that will turn tests on or off. The *test_* jobs pass in `tests/dcps_tests.lst`. MacOS, Windows 22, Static, and Release builds instead use `tests/core_ci_tests.lst`. The Thread Sanatizer build uses `tests/tsan_tests.lst`. This separation of .lst files is due to how excluding all but a few tests in the `dcps_tests.lst` would require adding a new config option to every test we didn't want to run. There is a separate security test list, `tests/security/security_tests.lst`, which governs the security tests which are run when `--security` is passed to `auto_run_tests.pl`. The last list file used by `build_and_test.yml` is `tools/modeling/tests/modeling_tests.lst`, which is included by passing `--modeling` to `auto_run_tests.pl`.

To disable a test in GitHub Actions, `!GH_ACTIONS` must be added next to the test in the .lst file. There are similar test blockers which only block for specific GitHub Actions configurations from running marked tests:

- `!GH_ACTIONS_OPENDDS_SAFETY_PROFILE` blocks Safety Profile builds
- `!GH_ACTIONS_M10` blocks the MacOS10 runners

This option currently does nothing because GitHub sees MacOS runners as unresponsive when they attempt to run some of the more intensive tests in dcps_tests.lst.

- `!GH_ACTIONS_ASAN` blocks the Address Sanitizer builds
- `!GH_ACTIONS_W22` blocks the Windows Server 2022 runner

These blocks are necessary because certain tests cannot properly run on GitHub Actions due to how the runners are configured. `-Config GH_ACTIONS` is assumed by `auto_run_tests.pl` when running on GitHub Actions, but the other test configurations must be passed using `-Config`.

See also:

Running Tests
: For how `auto_run_tests.pl` and the lst files work in general.

Workflow Checks

The `.github/workflows/lint.yml` workflow runs `.github/workflows/lint_build_and_test.pl`, which checks that the `.github/workflows/build_and_test.yml` workflow has gcc-problem-matcher and msvc-problem-matcher in the correct places.

Running this script requires the YAML CPAN module. As a safety measure, it has some picky rules about how steps are named and ordered. In simplified terms, these rules include:

- If used, the problem matcher must be appropriate for the platform the job is running on.
- The problem matcher must not be declared before steps that are named "setup gtest" or named like "build ACE/TAO". This should reduce any warnings from Google Test or ACE/TAO.
- A problem matcher should be declared before steps that start with "build" or contain "make". These steps should also contain `cmake --build`, `make`, or `msbuild` in their `run` string.

Blocked Tests

Certain tests are blocked from GitHub actions because their failures are either unfixable, or are not represented on the scoreboard. If this is the case, we have to assume that the failure is due to some sort of limitation caused by the GitHub Actions runners.

Only Failing on CI

- tests/DCPS/SharedTransport/run_test.pl multicast
  - Multicast times out waiting for remote peer. Fails on `test_u20_p1_j8_FM-1f` and `test_u20_p1_sec`.
- tests/DCPS/Thrasher/run_test.pl high/aggressive/medium XXXX XXXX
  - The more intense thrasher tests cause consistent failures due to the increased load from ASAN. GitHub Actions fails these tests very consistently compared to the scoreboard which is more intermittent. Fails on `test_u20_p1_asan_sec`.

Failing Both CI and scoreboard

These tests fail on the CI as well as the scoreboard, but will remain blocked on the CI until fixed. Each test has a list of the builds it was failing on before being blocked.

- tests/DCPS/BuiltInTopicTest/run_test.pl
  - `test_u18_esafe_js0`
- tests/DCPS/CompatibilityTest/run_test.pl rtps_disc
  - `test_m10_o1d0_sec`
- tests/DCPS/Federation/run_test.pl
  - `test_u18_w1_sec`
  - `test_u18_j_cft0_FM-37`
  - `test_u18_w1_j_FM-2f`
  - `test_u20_ace7_j_qt_ws_sec`
  - `test_u20_p1_asan_sec`
  - `test_u20_p1_asan_sec`
- tests/DCPS/MultiDPTest/run_test.pl
  - `test_u18_bsafe_js0_FM-1f`
  - `test_u18_esafe_js0`
- tests/DCPS/NotifyTest/run_test.pl
  - `test_u18_esafe_js0`
- tests/DCPS/Reconnect/run_test.pl restart_pub
  - `test_w22_x86_i0_sec`
- tests/DCPS/Reconnect/run_test.pl restart_sub
  - `test_w22_x86_i0_sec`
- tests/DCPS/TimeBasedFilter/run_test.pl -reliable

- `test_u18_bsafe_js0_FM-1f`
- `test_u18_esafe_js0`

Test Results

The tests are run using autobuild which creates a number of output files that are turned into a GitHub artifact. This artifact is processed by the "check results" step which uses the script `tools/scripts/autobuild_brief_html_to_text.pl` to catch failures and print them in an organized manner. Due to this being a part of the "test" jobs, the results of each run will appear as soon as the job is finished.

Artifacts

Artifacts from the continuous integration run can be downloaded by clicking details on one of the Build & Test runs. Once all jobs are completed, a dropdown will appear on the bar next to "Re-run jobs", called "Artifacts" which lists each artifact that can be downloaded.

Alternatively, clicking the "Summary" button at the top of the list of jobs will list all the available artifacts at the bottom of the page.

Using Artifacts to Replicate Builds

You can download the `ACE_TAO_` and `build_` artifacts then use them for a local build, so long as your operating system is the same as the one on the runner.

1. `git clone` the ACE_TAO branch which is targeted by the build. This is usually going to be `ace6tao2`.
2. `git clone --recursive` the OpenDDS branch on which the CI was run.
3. Merge OpenDDS master into your cloned branch.
4. run `tar xvfJ` from inside the cloned ACE_TAO, targeting the `ACE_TAO_*.tar.xz` file.
5. run `tar xvfJ` from inside the cloned OpenDDS, targeting the `build_*.tar.xz` file.
6. Adjust the setenv.sh located inside OpenDDS to match the new locations for your ACE_TAO, and OpenDDS. The word "runner" should not appear within the setenv.sh once you are finished.

You should now have a working duplicate of the build that was run on GitHub Actions. This can be used for debugging as a way to quickly set up a problematic build.

Using Artifacts to View More Test Information

Tests failures which are recorded on GitHub only contain a brief capture of output surrounding a failure. This is useful for some tests, but it can often be helpful to view more of a test run. This can be done by downloading the artifact for a test step you are viewing. This test step artifact contains a number of files including `output.log_Full.html`. This is the full log of all output from all test runs done for the corresponding job. It should be opened in either a text editor or Firefox, as Chrome will have issues due to the length of the file.

Caching

The OpenDDS workflows create .tar.xz archives of certain build artifacts which can then be up uploaded and shared between jobs (and the user) as part of GitHub Actions' "artifact" API. A cache key comparison made using the relevant git commit SHA will determine whether to rebuild the artifact, or to use the cached artifact.

3.5 Running Tests

3.5.1 Main Test Suite

Building

Tests are not built by default, `--tests` must be passed to the `configure` script. This will build all the tests. There are a few ways to only have specific tests built:

- If using Make, specify the targets instead of leaving it default to the `all` target.
- Run MPC on the test directory and build separately. Make sure to also build the test's dependencies.
- Create a custom workspace with the tests and pass it to the `configure` script using the `--workspace` option. Also make sure to include the test's dependencies.

Running

Note: Make sure *ACE_ROOT* and *DDS_ROOT* are set, which can be done by running `source setenv.sh` on Linux and macOS or `call setenv.cmd` on Windows.

OpenDDS' main suite of tests is ran by the `tests/auto_run_tests.pl` Perl script that reads lists of tests from files and selectively runs based on how the script has been configured.

For Unixes (Linux, macOS, BSDs, etc)

Run this in *DDS_ROOT*:

```
bin/auto_run_tests.pl
```

For Windows

Run this in *DDS_ROOT*:

```
bin\auto_run_tests.pl
```

If OpenDDS was built in Release mode add `-ExeSubDir Release`. If it was built as static libraries add `-ExeSubDir Static_Debug` or `-ExeSubDir Static_Release`.

Manual Configuration

Manual configuration is done by passing `-Config`, `-Exclude`, and test list files arguments to the script.

To manually configure what tests to run:

- See the `--list-all-configs` or `--show-all-configs` options to see the existing configurations used by all test list files.
- See the `--list-configs` or `--show-configs` options to see the existing configurations used by specific test list files.
- See the test list files for the tests themselves:
  - `tests/dcps_tests.lst`
    - This is included by default. Use `--no-dcps` to exclude this list.
    - If `--no-auto-config` was passed, then `--dcps` will have to be passed to include this.
  - `tests/security/security_tests.lst`
    - Use `--security` to include this list.
  - `java/tests/dcps_java_tests.lst`
    - Use `--java` to include this list.
  - `tools/modeling/tests/modeling_tests.lst`
    - Use `--modeling` to include this list.
- In a test list file each of the-space delimited words after the colon determines when the test is ran.
- Passing `-Config RTPS` will run tests that have `RTPS` and leave out tests with `!RTPS`.
- Passing `-Exclude RTPS` will exclude all tests that have `RTPS` in the entry. This option matches using RegEx, so a test with `SUPER_DUPER_RTPS` will also be excluded. It also ignores inverse entries, so it will not exclude a test with `!SUPER_DUPER_RTPS`.
- There are `-Config` options that are added automatically if `--no-auto-config` wasn't passed:
  - `-Config RTPS`
  - `-Config GH_ACTIONS` if running on *GitHub Actions*
  - These are based on the OS `auto_run_tests.pl` is running under:
    - `-Config Win32`
    - `-Config macOS`
    - `-Config Linux`
- Assuming they were built, CMake tests are ran if `--cmake` is passed. This uses CTest, which is a system that is separate from the one previously described.
- See `--help` for all the available options.

Note: For those editing and creating test list files: The `ConfigList` code in ACE can't properly handle mutiple test list entries with the same command. It will run all those entries if the last one will run, even if based on the configs only one entry should run. `auto_run_tests.pl` will warn about this if it's using a test list file that has this problem.

3.6 Bench Performance & Scalability Test Framework

3.6.1 Motivation

The Bench framework (version 2) grew out of a desire to be able to test the performance and scalability of OpenDDS in large and heterogeneous deployments, along with the ability to quickly develop and deploy new test scenarios across a potentially-unspecified number of machines.

3.6.2 Overview

The resulting design of the Bench framework depends on three primary test applications: worker processes, one or more node controllers, and a test controller.

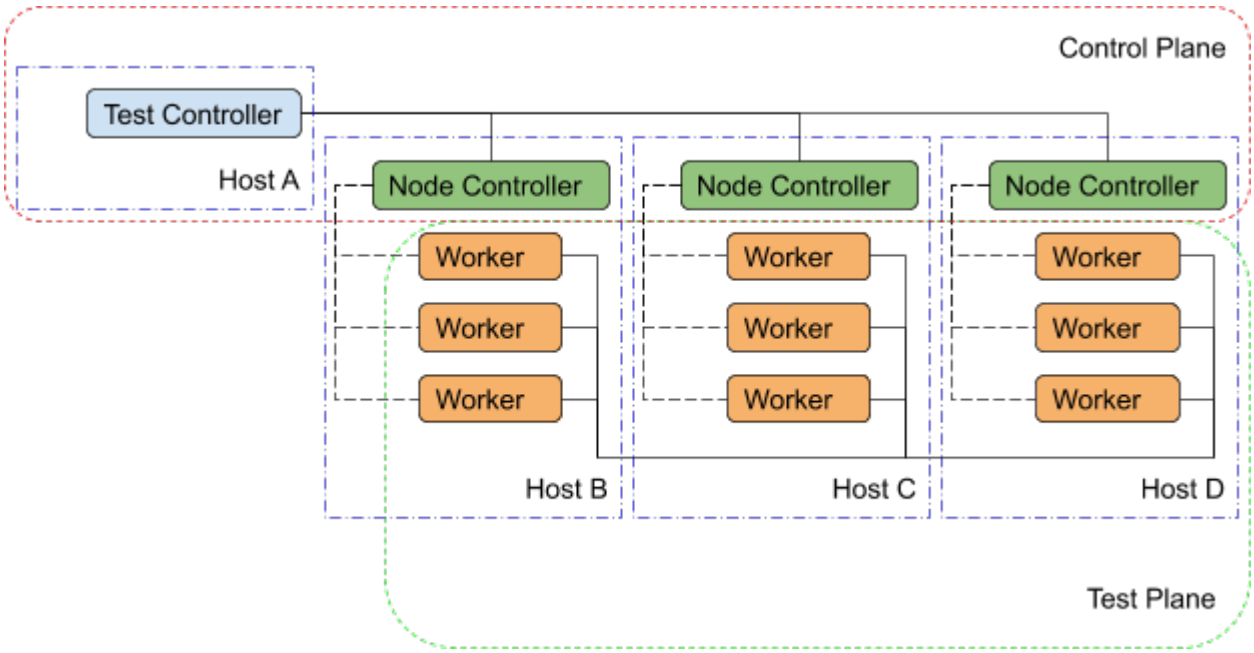


Fig. 1: Bench Overview

Worker

The `worker` application, true to its name, performs most of the work associated with any given test scenario. It creates and exercises the DDS entities specified in its configuration file and gathers performance statistics related to discovery, data integrity, and performance. The worker's configuration file contains regions that may be used to represent OpenDDS's configuration sections as well as individual DDS entities and the QoS policies to be for their creation. In addition, the worker configuration contains test timing values and descriptions of test `actions` to be taken (e.g. publishing and forwarding data read from subscriptions). Upon test completion, the worker can write out a report file containing the performance statistics gathered during its run.

Node Controller

Each machine in the test environment will run (at least) one `node_controller` application which acts as a daemon and, upon request from a `test_controller`, will spawn one or more worker processes. Each request will contain the configuration to use for the spawned workers and, upon successful exit, the workers' report files will be read and sent back to the `test_controller` which requested it. Failed workers processes (aborts, crashes) will be noted and have their output logs sent back to the requesting `test_controller`. In addition to collecting worker reports, the node controller also gathers general system resource statistics during test execution (CPU and memory utilization) to be returned to the test controller at the end of the test.

Test Controller

Each execution of the test framework will use a `test_controller` to read in a scenario configuration file (an annotated collection of worker configuration file names) before listening for available `node_controller`'s and parceling out the scenario's worker configurations to the individual `node_controller`'s. The `test_controller` may also optionally adjust certain worker configuration values for the sake of the test (assigning a unique DDS partition to avoid collisions, coordinating worker test times, etc.). After sending the allocated scenario to each of the available node controllers, the test controller waits to receive reports from each of the node controllers. After receiving all the reports, the `test_controller` coalesces the performance statistics from each of the workers and presents the final results to the user (both on screen & in a results file).

3.6.3 Building Bench

Required Features

The primary requirements for building OpenDDS such that Bench also gets built:

- C++11 Support, either with a compiler that defaults to C++11 (or later) support or by manually specifying a compatible standard (e.g. `--std=c++11`)
- RapidJSON present and enabled (`--rapidjson`)
- Tests are being built (`--tests`)

Required Targets

If these elements are present, you can either build the entire test suite (slow) or use these 3 targets (faster), which also cover all the required libraries:

- `Bench_Worker`
- `Bench_node_controller`
- `Bench_test_controller`

3.6.4 Running Bench

Environment Variables

To run Bench executables with dynamically linked or shared libraries, you'll want to make sure the Bench libraries are in your library path.

Linux/Unix

Add `${DDS_ROOT}/performance-tests/bench/lib` to your `LD_LIBRARY_PATH`

Windows

Add `%DDS_ROOT%\performance-tests\bench\lib` to your `PATH`

Assuming *DDS_ROOT* is already set on your system (from the `configure` script or from sourcing `setenv.sh`), there are convenience scripts to do this for you in the `performance-tests/bench` directory (`set_bench_env[.sh/.cmd]`)

Running a Bench CI Test

In the event that you're debugging a failing Bench CI test, you can use `performance-tests/bench/run_test.pl` to execute the full scenario without first setting the environment as listed above. This is because the perl script sets the appropriate environment variables automatically before launching its processes (a single `node_controller` in the background, as well as the test controller with the requested scenario). The perl script can be inspected in order to determine which scenarios have been made available in this way. The script can be modified to easily run other available scenarios (see `performance-tests/bench/example/config/scenario`) against a single node controller with relative ease.

Running Scenarios Manually

Assuming you already have scenario and worker configuration files defined, the general approach to running a scenario is to start one or more `node_controller`s (across one or more hosts) and then execute the test_controller with the desired scenario configuration.

3.6.5 Configuration Files

As a general rule, Bench uses JSON configuration files that directly map onto the C++ Platform Specific Model (PSM) of the IDL found in `performance-tests/bench/idl` and the IDL used in the *Data Distribution Service (DDS) for Real-Time Systems*. This allows the test applications to easily convert between configuration files and the C++ structures used for the configuration of DDS entities.

Scenario Configuration Files

Scenario configuration files are used by the test controller to determine the number and type (configuration) of worker processes required for a particular test scenario. In addition, the scenario file may specify certain sets of workers to be run on the same node by placing them together in a node "prototype" (see below).

IDL Definition

```
struct WorkerPrototype {
  // Filename of the JSON Serialized Bench::WorkerConfig
  string config;
  // Number of workers to spawn using this prototype (Must be >=1)
  unsigned long count;
};

typedef sequence<WorkerPrototype> WorkerPrototypes;

struct NodePrototype {
  // Assign to a node controller with a name that matches this wildcard
  string name_wildcard;
  WorkerPrototypes workers;
  // Number of Nodes to spawn using this prototype (Must be >=1)
  unsigned long count;
  // This NodePrototype must have a Node to itself
  boolean exclusive;
};

typedef sequence<NodePrototype> NodePrototypes;

// This is the root type of the scenario configuration file
struct ScenarioPrototype {
  string name;
  string desc;
  // Workers that must be deployed in sets
  NodePrototypes nodes;
  // Workers that can be assigned to any node
  WorkerPrototypes any_node;
  /*
   * Number of seconds to wait for the scenario to end.
   * 0 means never timeout.
   */
  unsigned long timeout;
};
```

Annotated Example

```
{
  "name": "An Example",
  "desc": "This shows the structure of the scenario configuration",
  "nodes": [
    {
      "name_wildcard": "example_nc_*",
      "workers": [
        {
          "config": "daemon.json",
          "count": 1
        },
        {
          "config": "spawn.json",
          "count": 1
        }
      ],
      "count": 2,
      "exclusive": false
    }
  ],
  "any_node": [
    {
      "config": "master.json",
      "count": 1
    }
  ],
  "timeout": 120
}
```

This scenario configuration will launch 5 worker processes. It will launch 2 pairs of "daemon" / "spawn" processes, with each member of each pair being kept together on the same node (i.e. same `node_controller`). The pairs themselves may be split across nodes, but each "daemon" will be with at least one "spawn" and vice-versa. They may also wind up all together on the same node, depending on the number of available nodes. And finally, one "master" process will be started wherever there is room available.

The "name_wildcard" field is used to filter the `node_controller` instances that can be used to host the nodes in the current node config - only the `node_controller` instances with names matching the wildcard can be used. If the "name_wildcard" is omitted or its value is empty, any `node_controller` can be used. If node "prototypes" are marked exclusive, the test controller will attempt to allocate them exclusively to their own node controllers. If not enough node controllers exist to honor all the exclusive nodes, the test controller will fail with an error message.

Worker Configuration Files

QoS Masking

In a typical DDS application, default QoS objects are often supplied by the entity factory so that the application developer can make required changes locally and not impact larger system configuration choices. As such, the QoS objects found within the JSON configuration file should be treated as a "delta" from the default configuration object of a parent factory class. So while the JSON "qos" element names will directly match the relevant IDL element names, there will also be an additional "qos_mask" element that lives alongside the "qos" element in order to specify which elements apply. For each QoS attribute "attribute" within the "qos" object, there will also be a boolean "has_attribute" within

the "qos_mask" which informs the builder library that this attribute should indeed be applied against the default QoS object supplied by the parent factory class before the entity is created.

IDL Definition

```
struct TimeStamp {
  long sec;
  unsigned long nsec;
};

typedef sequence<string> StringSeq;
typedef sequence<double> DoubleSeq;

enum PropertyValueKind { PVK_TIME, PVK_STRING, PVK_STRING_SEQ, PVK_STRING_SEQ_SEQ, PVK_
↪DOUBLE, PVK_DOUBLE_SEQ, PVK_ULL };
union PropertyValue switch (PropertyValueKind) {
  case PVK_TIME:
    TimeStamp time_prop;
  case PVK_STRING:
    string string_prop;
  case PVK_STRING_SEQ:
    StringSeq string_seq_prop;
  case PVK_STRING_SEQ_SEQ:
    StringSeqSeq string_seq_seq_prop;
  case PVK_DOUBLE:
    double double_prop;
  case PVK_DOUBLE_SEQ:
     DoubleSeq double_seq_prop;
  case PVK_ULL:
    unsigned long long ull_prop;
};

struct Property {
  string name;
  PropertyValue value;
};
typedef sequence<Property> PropertySeq;

struct ConfigProperty {
  string name;
  string value;
};
typedef sequence<ConfigProperty> ConfigPropertySeq;

// ConfigSection

struct ConfigSection {
  string name;
  ConfigPropertySeq properties;
};
typedef sequence<ConfigSection> ConfigSectionSeq;

// Writer
```

(continues on next page)

(continued from previous page)

```
struct DataWriterConfig {
  string name;
  string topic_name;
  string listener_type_name;
  unsigned long listener_status_mask;
  string transport_config_name;
  DDS::DataWriterQos qos;
  DataWriterQosMask qos_mask;
};
typedef sequence<DataWriterConfig> DataWriterConfigSeq;

// Reader

struct DataReaderConfig {
  string name;
  string topic_name;
  string listener_type_name;
  unsigned long listener_status_mask;
  PropertySeq listener_properties;
  string transport_config_name;
  DDS::DataReaderQos qos;
  DataReaderQosMask qos_mask;
  StringSeq tags;
};
typedef sequence<DataReaderConfig> DataReaderConfigSeq;

// Publisher

struct PublisherConfig {
  string name;
  string listener_type_name;
  unsigned long listener_status_mask;
  string transport_config_name;
  DDS::PublisherQos qos;
  PublisherQosMask qos_mask;
  DataWriterConfigSeq datawriters;
};
typedef sequence<PublisherConfig> PublisherConfigSeq;

// Subscription

struct SubscriberConfig {
  string name;
  string listener_type_name;
  unsigned long listener_status_mask;
  string transport_config_name;
  DDS::SubscriberQos qos;
  SubscriberQosMask qos_mask;
  DataReaderConfigSeq datareaders;
};
typedef sequence<SubscriberConfig> SubscriberConfigSeq;
```

(continues on next page)

(continued from previous page)

```
// Topic

struct ContentFilteredTopic {
  string cft_name;
  string cft_expression;
  DDS::StringSeq cft_parameters;
};

typedef sequence<ContentFilteredTopic> ContentFilteredTopicSeq;

struct TopicConfig {
  string name;
  string type_name;
  DDS::TopicQos qos;
  TopicQosMask qos_mask;
  string listener_type_name;
  unsigned long listener_status_mask;
  string transport_config_name;
  ContentFilteredTopicSeq content_filtered_topics;
};
typedef sequence<TopicConfig> TopicConfigSeq;

// Participant

struct ParticipantConfig {
  string name;
  unsigned short domain;
  DDS::DomainParticipantQos qos;
  DomainParticipantQosMask qos_mask;
  string listener_type_name;
  unsigned long listener_status_mask;
  string transport_config_name;
  StringSeq type_names;
  TopicConfigSeq topics;
  PublisherConfigSeq publishers;
  SubscriberConfigSeq subscribers;
};
typedef sequence<ParticipantConfig> ParticipantConfigSeq;

// TransportInstance

struct TransportInstanceConfig {
  string name;
  string type;
  unsigned short domain;
};
typedef sequence<TransportInstanceConfig> TransportInstanceConfigSeq;

// Discovery

struct DiscoveryConfig {
  string name;
```

(continues on next page)

(continued from previous page)

```
  string type; // "rtps" or "repo"
  string ior; // "repo" URI (e.g. "file://repo.ior")
  unsigned short domain;
};
typedef sequence<DiscoveryConfig> DiscoveryConfigSeq;

// Process

struct ProcessConfig {
  ConfigSectionSeq config_sections;
  DiscoveryConfigSeq discoveries;
  TransportInstanceConfigSeq instances;
  ParticipantConfigSeq participants;
};

// Worker

// This is the root structure of the worker configuration
// For the sake of readability, module names have been omitted
// All structures other than this one belong to the Builder module
struct WorkerConfig {
  TimeStamp create_time;
  TimeStamp enable_time;
  TimeStamp start_time;
  TimeStamp stop_time;
  TimeStamp destruction_time;
  PropertySeq properties;
  ProcessConfig process;
  ActionConfigSeq actions;
  ActionReportSeq action_reports;
};
```

Annotated Example

```
{
  "create_time": { "sec": -1, "nsec": 0 },
```

Since the timestamp is negative, this treats the time as relative and waits one second.

```
"enable_time": { "sec": -1, "nsec": 0 },
"start_time": { "sec": 0, "nsec": 0 },
```

Since the time is zero and thus neither absolute nor relative, this treats the time as indefinite and waits for keyboard input from the user.

```
"stop_time": { "sec": -10, "nsec": 0 },
```

Again, a relative timestamp. This time, it waits for 10 seconds for the test actions to run before stopping the test.

```
"destruction_time": { "sec": -1, "nsec": 0 },
```

(continues on next page)

(continued from previous page)

```
"process": {
```

This is the primary section where all the DDS entities are described, along with configuration of OpenDDS.

```
"config_sections": [
```

The elements of this section are functionally identical to the *Run-time Configuration* sections of an OpenDDS `.ini` file with the same name. Each config section is created programmatically within the worker process using the name provided and made available to the OpenDDS `ServiceParticipant` during entity creation. The example here sets the value of both the *`[common] DCPSSecurity`* and *`[common] DCPSDebugLevel`* keys to `0`.

```
  { "name": "common",
    "properties": [
      { "name": "DCPSDefaultDiscovery",
        "value":"rtps_disc"
      },
      { "name": "DCPSGlobalTransportConfig",
        "value":"$file"
      },
      { "name": "DCPSDebugLevel",
        "value": "0"
      },
      { "name": "DCPSPendingTimeout",
        "value": "3"
      }
    ]
  },
  { "name": "rtps_discovery/rtps_disc",
    "properties": [
      { "name": "ResendPeriod",
        "value": "5"
      }
    ]
  },
  { "name": "transport/rtps_transport",
    "properties": [
      { "name": "transport_type",
        "value": "rtps_udp"
      }
    ]
  }
],
"participants": [
```

The list of participants to create.

```
{ "name": "participant_01",
  "domain": 7,
  "transport_config_name": "rtps_instance_01",
```

The transport config that gets bound to this participant

```
"qos": { "entity_factory": { "autoenable_created_entities": false } },
"qos_mask": { "entity_factory": { "has_autoenable_created_entities": false } },
```

An example of QoS masking. Note that in this example, the boolean flag is `false`, so the QoS mask is not actually applied. In this case, both lines here were added to make switching back and forth between `autoenable_created_entities` easier (simply change the value of the bottom element `"has_autoenable_created_entities"` to `"true"`).

```
"topics": [
```

List of topics to register for this participant

```
{ "name": "topic_01",
  "type_name": "Bench::Data"
```

Note the type name. `"Bench::Data"` is currently the only topic type supported by the Bench framework. That said, it contains a variably sized array of octets, allowing a configurable range of data payload sizes (see write_action below).

```
"content_filtered_topics": [
  {
    "cft_name": "cft_1",
    "cft_expression": "filter_class > %0",
    "cft_parameters": ["2"]
  }
]
```

List of content filtered topics. Note `"cft_name"`. Its value can be used in DataReader `"topic_name"` to use the content filter.

```
   }
 ],
"subscribers": [
```

List of subscribers

```
{ "name": "subscriber_01",
  "datareaders": [
```

List of DataReaders

```
{ "name": "datareader_01",
  "topic_name": "topic_01",
  "listener_type_name": "bench_drl",
  "listener_status_mask": 4294967295,
```

Note the listener type and status mask. `"bench_drl"` is a listener type registered by the Bench Worker application that does most of the heavy lifting in terms of stats calculation and reporting. The mask is a fully-enabled bitmask for all listener events (i.e. `2^32 - 1`).

```
"qos": { "reliability": { "kind": "RELIABLE_RELIABILITY_QOS" } },
"qos_mask": { "reliability": { "has_kind": true } },
```

DataReaders default to best effort QoS, so here we are setting the reader to reliable QoS and flagging the `qos_mask` appropriately in order to get a reliable datareader.

```
"tags": [ "my_topic", "reliable_transport" ]
```

The config can specify a list of tags associated with each data reader. The statistics for each tag is computed in addition to the overall statistics and can be printed out at the end of the run by the `test_controller`.

```
      }
    ]
  }
],
"publishers": [
```

List of publishers within this participant

```
{ "name": "publisher_01",
  "datawriters": [
```

List of DataWriters within this publisher

```
{ "name": "datawriter_01",
```

Note that each DDS entity is given a process-entity-unique name, which can be used below to locate / identify this entity.

```
              "topic_name": "topic_01",
              "listener_type_name": "bench_dwl",
              "listener_status_mask": 4294967295
            }
          ]
        }
      ]
    }
  ]
},
"actions": [
```

A list of worker 'actions' to start once the test 'start' period begins.

```
{
  "name": "write_action_01",
  "type": "write",
```

Current valid types are `"write"`, `"forward"`, and `"set_cft_parameters"`.

```
"writers": [ "datawriter_01" ],
```

Note the datawriter name defined above is passed into the action's writer list. This is used to locate the writer within the process.

```
"params": [
  { "name": "data_buffer_bytes",
```

The size of the octet array within the `Bench::Data` message. Note, actual messages will be slightly larger than this value.

```
  "value": { "$discriminator": "PVK_ULL", "ull_prop": 512 }
},
{ "name": "write_frequency",
```

The frequency with which the write action attempts to write a message. In this case, twice a second.

```
  "value": { "$discriminator": "PVK_DOUBLE", "double_prop": 2.0 }
},
```

```
{ "name": "filter_class_start_value",
  "value": { "$discriminator": "PVK_ULL", "ull_prop": 0 }
},
{ "name": "filter_class_stop_value",
  "value": { "$discriminator": "PVK_ULL", "ull_prop": 0 }
},
{ "name": "filter_class_increment",
  "value": { "$discriminator": "PVK_ULL", "ull_prop": 0 }
}
```

Value range and increment for "`filter_class`" data variable, used when writing data. This variable is an unsigned integer intended to be used for content filtered topics "set_cft_parameters" actions.

```
  ]
},

{ "name": "cft_action_01",
  "type": "set_cft_parameters",
  "params": [
    { "name": "content_filtered_topic_name",
      "value": { "$discriminator": "PVK_STRING", "string_prop": "cft_1" }
    },
    { "name": "max_count",
      "value": { "$discriminator": "PVK_ULL", "ull_prop": 3 }
    },
```

Maximum count of "Set" actions to be taken.

```
{ "name": "param_count",
  "value": { "$discriminator": "PVK_ULL", "ull_prop": 1 }
},
```

Number of parameters to be set

```
{ "name": "set_frequency",
  "value": { "$discriminator": "PVK_DOUBLE", "double_prop": 2.0 }
},
```

The frequency for set action, per second

```
{ "name": "acceptable_param_values",
  "value": { "$discriminator": "PVK_STRING_SEQ_SEQ", "string_seq_seq_prop": [ ["1", "2",
↪"3"] ] }
},
```

Lists of allowed values to set to, for each parameter. Worker will iterate thought the list sequentially unless "random_order" flag (below) is specified

```
        { "name": "random_order",
          "value": { "$discriminator": "PVK_ULL", "ull_prop": 1 }
        }
      ]
  }

  ]
}
```

3.6.6 Detailed Application Descriptions

test_controller

As mentioned above, the `test_controller` application is the application responsible for running test scenarios and, as such, will probably wind up being the application most frequently run directly by testers. The `test_controller` needs network visibility to at least one `node_controller` configured to run on the same domain. It expects, as arguments, the path to a directory containing config files (both scenario & worker) and the name of a scenario configuration file to run (without the `.json` extension). For historical reasons, the config directory is often simply called `example`. The `test_controller` application also supports a number of optional configuration parameters, some of which are described in the section below.

Usage

`test_controller CONFIG_PATH SCENARIO_NAME [OPTIONS]`

`test_controller --help|-h`

This is a subset of the options. Use `--help` option to see all the options.

CONFIG_PATH

Path to the directory of the test configurations and artifacts

SCENARIO_NAME

Name of the scenario file in the test context without the *.json* extension.

--domain N

The DDS Domain to use. The default is 89.

--wait-for-nodes N

The number of seconds to wait for nodes before broadcasting the scenario to them. The default is 10 seconds.

--timeout N

The number of seconds to wait for a scenario to complete. Overrides the value defined in the scenario. If N is 0, there is no timeout.

--override-create-time N

Overwrite individual worker configs to create their DDS entities N seconds from now (absolute time reference)

--override-start-time N

Overwrite individual worker configs to start their test actions (writes & forwards) N seconds from now (absolute time reference)

`--tag` TAG

Specify a tag for which the performance statistics will be printed out (and saved to a results file). Multiple instances of this option can be specified, each for a single tag.

`--json-result-id` ID

Specify a name to store the raw JSON report under. By default, this not enabled. These results will contain the full raw `Bench::TestController` report, including all node controller and worker reports (and DDS entity reports)

node_controller

The node controller application is best thought of as a daemon, though the application can be run both in a long-running `daemon` mode and also a `one-shot` mode more appropriate for testing. The `daemon-exit-on-error` mode additionally has the ability to exit the process every time an error is encountered, which is useful for restarting the application when errors are detected, if run as a part of an OS system environment (systemd, supervisord, etc).

Usage

`node_controller [OPTIONS] one-shot|daemon|daemon-exit-on-error`

one-shot

Run a single batch of worker requests (configs > processes > reports) and report the results before exiting. Useful for one-off and local testing.

daemon

Act as a long-running process that continually runs batches of worker requests, reporting the results. Attempts to recover from errors.

daemon-exit-on-error

Act as a long-running process that continually runs batches of worker requests, reporting the results. Does not attempt to recover from errors.

`--domain` N

The DDS Domain to use. The default is 89.

`--name` STRING

Human friendly name for the node. Will be used by the test controller for referring to the node. During allocation of node controllers, the name is used to match against the "name_wildcard" fields of the node configs. Only node controllers whose names match the "name_wildcard" of a given node config can be allocated to that node config. Multiple nodes could have the same name.

worker

The worker application is meant to mimic the behavior of a single arbitrary OpenDDS test application. It uses the Bench builder library along with its JSON configuration file to first configure OpenDDS (including discovery & transports) and then create all required DDS entities using any desired DDS QoS attributes. Additionally, it allows the user to configure several test phase timing parameters, using either absolute or relative times:

- DDS entity creation (`create_time`)
- DDS entity "enabling" (`enable_time`) (only relevant if `autoenable_created_entities` QoS setting is false)
- test actions start time (`start_time`)
- test actions stop time (`stop_time`)

- DDS entity destruction (`destruction_time`)

Finally, it also allows for the configuration and execution of test "actions" which take place between the "start" and "stop" times indicated in configuration.These may make use of the created DDS entities in order to simulate application behavior. At the time of this writing, the three actions are **"write"**, which will write to a datawriter using data of a configurable size and frequency (and maximum count), **"forward"**, which will pass along the data read from one datareader to a datawriter, allowing for more complex test behaviors (including round-trip latency & jitter calculations), and "set_cft_parameters", which will change the content filtered topic parameter values dynamically. In addition to reading a JSON configuration file, the worker is capable of writing a JSON report file that contains various test statistics gathered from listeners attached to the created DDS entities. This report is read by the `node_controller` after the worker process ends and is then sent back to the waiting `test_controller`.

Usage

```
worker [OPTIONS] CONFIG_FILE
```

--log LOG_FILE
: The log file path. Will log to `stdout` if not passed.

--report REPORT_FILE
: The report file path.

3.7 Release Process

The page provides the steps needed to make and publish a release of OpenDDS.

3.7.1 Notes About OpenDDS Releases

Temporary Notes

List of current problems with the release process and their workarounds. If there's nothing to note then the list should just consist of `- N/A`.

Attention:

- N/A

File Updates

This guide will document what should be updated manually. Almost all manual updates should be done before the release and are documented in *Update Files in the Repo as Needed*.

All authoritative references to OpenDDS versions in the source code (like `VERSION.txt` or `dds/Version.h`) will be automatically updated by the release script, so normally there's no need to do it manually. Other files such as `NEWS.md` and `README.md` shouldn't be updated manually specifically for a release.

References to ACE/TAO versions are handled using `acetao.ini`, which is automatically updated by `.github/workflows/update-ace-tao.yml`.

Versioning

Micro release (a.k.a. patch release)
Releases with `X.Y.Z` versions. They should only contain fixes. They should avoid additional functionality and breaking changes if possible. Some parts of the release process are different for micro releases. See *Micro Releases* for more information.

Minor release
Releases with `X.Y.0` versions. They should only contain fixes and additional functionality. They should avoid breaking changes if possible.

Major release
Releases with `X.0.0` versions. They are generally the only time breaking changes can be made.

Version metadata
Text that follows the version in most circumstances. Currently there's only two uses for this:

- The default state of the repo is for the metadata to be `dev` (e.g. `4.0.0-dev`). The release script will remove the metadata before a release and restore it afterwards.
- A preview release/prerelease/release candidate can be indicated by `pre.N` where `N` starts at 1 (e.g. `4.0.0-pre.2`). Currently this isn't supported by the release script, so it would have to be manually created.

Latest release
The release that has the highest version number. Some parts of the release process are only done for the latest release.

3.7.2 Prior to the Release

Address Automated Code Analysis Results

- Address any serious compiler warnings seen on the CI
- Address any serious diagnostic messages generated by Coverity at https://scan.coverity.com/projects/opendds?tab=overview

Update Files in the Repo as Needed

These are files or the parts of the files that the release script won't be able to automatically update or should be checked beforehand to make sure they are correct.

- Check *Release Notes* to make sure the release notes for the next release look correct. If they need changes, then the news fragments should be changed before release.

  See also:

  News documents how news fragments works.

- The `AUTHORS` file should also be checked. This file is automatically generated from git history by the release script during the release. It can also be generated ahead of time to get a preview:
  - Fetch the latest `master` branch and run `tools/scripts/gitrelease.pl --update-authors` to see what the file will look like after release. This doesn't require any other arguments like the release script normally does.
  - If the file changed, but something is wrong, then it might be good to correct it before the release. For example a contributor might have used a Git client that is inserting an name/email that might not be what they want in the file or including a name/email might be in addition to their existing name/email combo. Corrections will have to be inserted into `.mailmap` using the format described in the git documentation listed

in the file. In addition to that there are general rules in the release script such as ignoring bots, preferring `objectcomputing.com` email addresses to `ociweb.com` ones, and dealing with GitHub-specific issues.

  - Run `tools/scripts/gitrelease.pl --update-authors` again to make sure the changes worked.

- Update `README.md` and *Dependencies* for any platform or dependency changes.
- Document changes to building OpenDDS, at least in *Building and Installing*, but possibly also in `java/README` and `java/INSTALL`.

Update the Modeling SDK version numbers and release notes

Our convention recently has been to only update these if changes have been made to the Modeling SDK plugins in the current release cycle. Notes are in `tools/modeling/plugins/org.opendds.modeling.help/html/gettingstarted/maintopic.html` (View as HTML). Version numbers are updated by running `tools/modeling/update_version.pl`.

Generate the Modeling SDK Eclipse update site

Our convention recently has been to only update these if changes have been made to the Modeling SDK plugins in the current release cycle.

Follow all the steps in `tools/modeling/features/org.opendds.modeling.site/README.txt` The step dealing with version numbers is already taken care of by the above section "Update the Modeling SDK version numbers and release notes". The result of this process is adding the update site contents to the repository for http://www.opendds.org (which will be synced to the live site in the steps below).

Update the opendds.org Website

The www.opendds.org website is hosted by GitHub as special branch named `gh-pages` in the OpenDDS repository. The website is updated when changes are pushed to that branch. To do this follow these steps:

- Clone the OpenDDS repository and checkout the branch named `website-next-release` to make changes to website source files This branch is used instead of `gh-pages` to hold changes that shouldn't be public until the release is made. When the release script runs it has a step for merging `website-next-release` into `gh-pages`.

```
git clone -b gh-pages git@github.com:OpenDDS/OpenDDS.git website
cd website
git checkout -B website-next-release
```

- To have Jekyll generate and serve `gh-pages` website locally in order to validate website changes:
  - You will need to have Ruby and bundler installed.
  - Run the commands:

```
bundle install
bundle exec jekyll serve
```

  - This will generate the website from the Jekyll source files and serve the generated website on localhost port TCP/4000

See also:

The gh-pages README
Detailed instructions

Testing your GitHub Pages site locally with Jekyll
Official GitHub tutorial

- Update the website source files and commit local changes to the `website-next-release` branch.
- Push local `website-next-release` branch changes to the central repository or your forked repository
- If using a forked repo, generate a pull request for the `website-next-release` branch to get the changes in to the central OpenDDS/OpenDDS repository.

The release script will merge `website-next-release` into `gh-pages` on the `OpenDDS/OpenDDS` repository during the release process.

Check if GHA Workflows need Updating

Note: This should only be done for the *latest release*.

For non-micro releases, if the release workflows haven't been updated in a while, manually trigger them to make sure they work. If any don't, then make changes as necessary.

For micro releases check to see if the workflows have been updated on master and backport those changes to the release series branch. Then manually trigger them to make sure they work.

The workflows are:

- *Shapes Demo*: (file), (runs),
- OMG RTPS interoperability test: (file), (runs),

These will be triggered by the release script, then must be *uploaded after release*.

3.7.3 Making a Release

The release script (`tools/scripts/gitrelease.pl`) performs or validates the release steps. All the steps can be listed using the `--list-all` option. The steps that would be ran with the full set arguments can be listed with the `--list` options. By default it will try to run all the steps it can or you can run an arbitrary subset of the steps using the `--steps` option. Some manual steps are required. It will make modifications to the repository of the current working directory while using a directory of your choosing for intermediate and release files.

Before Running the Release Script

- Release Script Prerequisites:
  - Commands available:
    * `md5sum` and `sha256sum`
    * `zip`, `unzip`, and `zipinfo`
    * Git version 2.5 or later
    * *Python 3 for News Generation*
  - Your GitHub account meets the following requirements:
    * It has been added as a member of the OpenDDS organization with the appropriate permissions.
    * It has permissions to update the release artifacts for the OMG RTPS Interop repo for *Upload Artifacts from Release Workflows*.

    * You have uploaded your SSH public key to your GitHub account
    * You have created a Personal Access Token for your GitHub account
  - You are a maintainer on the OpenDDS Read the Docs project.
    * Maintainers can add new maintainers here.
    * You will need a API token.
  - The following Perl CPAN modules are required (Perl core modules should not be listed here):
    * Pithub
    * Net::SFTP::Foreign
    * Time::Piece
    * LWP::UserAgent
    * LWP::Protocol::https

    To install them run:

```
cpan -T -i Pithub Net::SFTP::Foreign Time::Piece LWP::UserAgent␣
↪LWP::Protocol::https
```

- Choose a directory for the `WORKSPACE` argument. It doesn't have to exist but the release script must be able to create it if it doesn't. It should not contain files created by previous release (mocked or otherwise).
- You should start a new clone of the OpenDDS repository for just for this release. That clone shouldn't be inside the directory being passed as `WORKSPACE`.

```
git clone git@github.com:OpenDDS/OpenDDS.git
```

  For micro releases, check out the relevant branch that the release will come from and pass `--branch=BRANCH` along with the `--micro` argument.

- Set tokens the release script needs to interact with web services by exporting them as environment variables. These are `GITHUB_TOKEN` for your GitHub Personal Access Token and `READ_THE_DOCS_TOKEN` for your Read the Docs API token as shown below:

```
export GITHUB_TOKEN=ff00ff00ff00ff00ff00ff00ff00ff00ff00ff00
export READ_THE_DOCS_TOKEN=ff00ff00ff00ff00ff00ff00ff00ff00ff00ff00
```

Running the Release Script

The release script is located at `tools/scripts/gitrelease.pl` and should be ran from the root of the repo. (See above note in mock releases for the exception) There are two required arguments, the `WORKSPACE` and `VERSION` arguments:

- `WORKSPACE` is the directory where the script will place all intermediate files. If it doesn't exist the script will try to create it for you. This should be different for different releases of OpenDDS.
- `VERSION` is the version to release.

Run the script with just the required arguments to validate each step of the process. It will stop at the first error and give you instructions of what to do. In most cases `--remedy` should be used to continue.

When the script wants to commit something, it will show you the `git diff`. Press `q` and it will ask you for confirmation that it's okay to commit it.

The most important options are:

- `--list`, which lists the steps with their number and description
- `--remedy`, which tells the release script to attempt to resolve issues with the release
- `--steps`, which will specify the steps to run If one of the steps isn't verifying correctly, but you already manually fixed it, you can skip the step by passing `--step ^STEP` where `STEP` is the step you want to skip. You can also skip whole ranges of the steps. See `--help` for the notation it accepts.
- `--micro`, which excludes the steps that probably are not desired when doing a micro release and requires `--branch`.

Run `perl tools/scripts/gitrelease.pl --help` to see the full help.

Here is an example of what to run for a version 1.0.0 release command assuming that the release script can take care of everything for us:

```
tools/scripts/gitrelease.pl ../1.0.0-release-workspace 1.0.0 --remedy
```

Micro Releases

The release script has a `--micro` option which skips steps that probably are not relevant to *micro releases*. You must pass the `--branch` argument as you should be on the release branch for the minor release. As of writing these steps skipped are:

- Merging `website-next-release` with `gh-pages`

Some other notes about using `--micro`:

- The notation of the version argument has no effect on if the script is doing a micro release.
- Steps are skipped if they are one of the ones listed above, even if that step number is the only one explicitly passed in.

Otherwise the script should behave the same way.

Here is an example of what to run for a version 1.0.1 release assuming that the release script can take care of everything for us:

```
git checkout branch-DDS-1.0
tools/scripts/gitrelease.pl ../1.0.1-release-workspace 1.0.1 --micro --branch=branch-DDS-
↪1.0 --remedy
```

Doing Mock Releases with the Release Script

It is possible to do a mock release where basically everything is tested, but the script will make sure it's not making any real changes to the real thing. To set this up, you must do the following:

- Fork OpenDDS on GitHub.
  - To avoid conflicts with regular work on a fork you might already have, it's recommended to create a new organization for this purpose and create a token for the repository just like for an actual release. Pass the organization name using `--github-user`.
  - This can be skipped if code involving GitHub doesn't need to be tested and `--skip-github` is passed.
- Pass `--mock`. This actually isn't absolutely necessary, but it is useful as it does some basic checks to make sure the mock release won't interfere with the actual releases.

It's possible to use and edit `gitrelease.pl` without having to commit changes to it for a mock release if you use two repos. One repo, lets call it `$MOCK_ROOT`, is the one cloned from the mock organization mentioned in the previous instructions and is where the release is going to happen. The other, `$WORKING_ROOT`, is a normal repo where you can edit `gitrelease.pl` and other files and push changes to your normal GitHub fork. Running `$WORKING_ROOT/tools/scripts/gitrelease.pl` from `$MOCK_ROOT` will work because `gitrelease.pl` does everything relative to the current working directory. This also might be possible with `git worktree` instead of fully separate repos but this hasn't been tested.

After Running the Release Script

Test the release package

A simple test of Messenger will do. The git tag is already cloned for you as part of the release process.

Update News on Master

Note: This should only be done for the *latest release* that's also a *:ref: `micro release <release-micro-release>*.

The news on the master branch has to be updated to account for the micro release. Updating the news consists of:

- Copy the micro release entry in `NEWS.md`.
- Copy the micro release file in `docs/news.d/_releases`.
- Remove the *news fragments* in `docs/news.d` for the PRs that were backported.

Upload Artifacts from Release Workflows

Note: This should only be done for the *latest release*.

The release script has steps that trigger *release workflows* on GitHub Actions and print out links to the runs. After they have finished successfully, run the release script with the version and workspace arguments and the `--upload-artifacts` option. If the workflows are still in progress it will say so and give the links again. If the workflows were successful, it will download the artifacts, package them, and upload them to GitHub.

Remove Files Used for Release

Once everything is been finished, the repo and workspace directory used for release can usually be safely deleted. Erring on the side of caution though, they could be kept around for at least a few days after the release to help rerun steps if necessary or inspecting contents of the workspace directory for debugging purposes.

CHAPTER

FOUR

GLOSSARY

4.1 Common Terms

Adaptive Communication Environment
ACE
: ACE is an open source C++ framework that is maintained alongside *TAO* and is extensively used by OpenDDS. It provides a platform abstraction layer and various utilities such as reactors for event handing.

  See *ACE* for more information.

Built-in Topics
BITs
: Built-in Topics are *topics* that contain meta-information about local and remote *DDS entites* and the operational status of OpenDDS.

  See *Built-in Topics* for more information.

Common Data Representation
CDR
Extended Common Data Representation
XCDR
: CDR is a family of binary encoding formats used by OpenDDS to serialize and deserialize *samples*. XCDR is an extended form of CDR defined by the *XTypes* specification.

  See *Data Representation* for more information.

Common Object Request Broker Architecture
CORBA
: CORBA, put simply, is a set of specifications that allows a client to perform remote procedure calls on objects held in a server. It is separate from *DDS*, but both are published by the *OMG* and make use of *IDL* and *CDR*. *TAO* is a CORBA implementation that OpenDDS uses for InfoRepo discovery.

  See https://www.corba.org/ for more information.

Condition
: Conditions are a method of being notified of events from *entities*, such a new *sample* being available from a *DataReader*, via a status that can be checked synchronously.

  See *Conditions and Listeners* for more information.

Data Distribution Service
DDS
: DDS is a specification for exchanging strongly-typed data across a distributed system. It is essentially synonymous with *DCPS*, but can specifically refer to the main DDS specification.

  See *Data Distribution Service (DDS) for Real-Time Systems* for more information.

Data-Centric Publish-Subscribe
DCPS
: DCPS is essentially synonymous with *DDS*, but can specifically refer to the API described in the main DDS specification.

`DataReader`
: A `DataReader` is an *Entity* that is used to read *samples* from a *topic*. `DataReader`s are created and managed by *Subscribers*.

`DataWriter`
: A `DataWriter` is an *Entity* that is used to write *samples* to a *topic*. `DataWriter`s are created and managed by *Publishers*.

Discovery
: Discovery is the configurable method that *DomainParticipant*s use to find one another.

  See *Discovery, Matching, and Association* for more information.

Dispose
: When an *instance* is disposed by a *DataWriter*, it means keeping the cached data related to it is no longer necessary. This is done automatically if the instance is *unregister*ed and `autodispose_unregistered_instances` of *Writer Data Lifecycle QoS* is set to `true`. This can also be done manually using `dispose` method on `DataWriter`.

Domain
: Domains are sets of *DomainParticipant* that can interact with one another. To interact they must share the same domain identifier and must have compatible *discovery* and *transport*.

`DomainParticipant`
: `DomainParticipant` is an *Entity* that is used to create and manage *Publishers* and *Subscribers*.

`Entity`
: `Entity` is the abstract base class for the main classes in the *DDS*/*DCPS* API, including *DataReader* and *DataWriter*. All entities have *QoS* and can accept *Listener*s and *Condition*s.

Instance
: In the specific context of *DDS* and *sample*s, instances refer to a set of samples that share a common key value. Many parts of the DDS API involve instances, including the *dispose* and *unregister* operations.

  See *Keys* for more information.

Interface Definition Language
IDL
: IDL, specifically *OMG* IDL, is a C-like language for describing data-structures and interfaces. In OpenDDS *opendds_idl* and *tao_idl* are used to generate code from IDL.

Listener
: Listeners are a method of being notified of events from *entities*, such a new *sample* being available from a *DataReader*, via asynchronous callbacks.

  See *Conditions and Listeners* for more information.

Makefile, Project, and Workspace Creator
MPC
`mwc.pl`
`mpc.pl`
: A build-system that generates GNU Makefiles, Visual Studio projects, and other such files. It serves the same role that CMake, Meson, and Automake do in other projects.

  See *MPC* for more information.

Object Management Group
OMG
: A standards organization which publishes *DDS and the other specifications used by OpenDDS*.

  See https://www.omg.org/ for more information.

`opendds_idl`
: A program that generates C++ code from *IDL* for use in OpenDDS.

`Publisher`
: `Publisher` is an *Entity* that is used to create and manage *DataWriters*.

Quality of Service
QoS
: QoS is a set of requested policies for how *entities* should behave.

  See *Quality of Service* for more information.

Real-time Publish-Subscribe
RTPS
: RTPS, sometimes also called *DDSI-RTPS*, is a specification that defines how different DDS implementations can interact with one another.

  See *Real-time Publish-Subscribe (RTPS)* for more information.

Sample
: Samples are the messages sent from *DataWriter*s and received by *DataReader*s.

`Subscriber`
: `Subscriber` is an *Entity* that is used to create and manage *DataReaders*.

`tao_idl`
: A program that is part of *TAO* that generates C++ code from *IDL* for use in TAO and OpenDDS.

The ACE ORB
TAO
: TAO is a *CORBA* implementation that is maintained alongside *ACE*. OpenDDS uses it for InfoRepo discovery and *tao_idl*.

  See *TAO* for more information.

`Topic`
: A `Topic` is an *Entity* with a name and a *type* that the system uses to figure out which *DataReader*s get a *sample* from a *DataWriter*.

Topic type
: A topic type, sometimes also called a *data type*, is the *IDL* type of a *topic* and also type of the *samples* of the *DataWriter*s and *DataReader*s that use that topic.

Transport
: Transports are the configurable methods that *DataWriter*s and *DataReader*s use to communicate.

Unregister
: When an *instance* is unregistered by a *DataWriter*, it means the writer "no longer has 'anything to say' about the instance", as phrased by the DDS specification. This is similar, but separate from *disposing* an instance. They are usually done at the same time, but this can be changed using *Writer Data Lifecycle QoS* and the `unregister_instance` method of `DataWriter` to make what unregister means application-defined.

XTypes
Extensible and Dynamic Topic Types for DDS
: XTypes is an *OMG* specification that defines how DDS systems can have *topic type*s that can evolve over time and be used without defining IDL.

See *Extensible and Dynamic Topic Types for DDS (XTypes)* and *XTypes* for more information.

4.2 Environment Variables

ACE_ROOT

The path of the *ACE* source tree or installation prefix being used.

DDS_ROOT

The path of the OpenDDS source tree or installation prefix being used.

TAO_ROOT

The path of the *TAO* source tree or installation prefix being used.

OPENDDS_CONFIG_DIR

Makes `-DCPSConfigFile` paths relative to the path in the environment variable.

See *here* for more information.

Welcome to the documentation for OpenDDS 3.28.0!

OpenDDS is an open-source C++ framework for exchanging data in distributed systems. See *What is OpenDDS?* for more information.

OpenDDS 3.28.0 is available for download on GitHub.

Looking for the documentation for another version of OpenDDS? The documentation for version 3.24.0 onwards is hosted on Read the Docs. The Developer's Guide PDFs for versions before 3.24.0 are available on GitHub. They are attached to their corresponding releases as `OpenDDS-VERSION.pdf`.

CHAPTER

FIVE

USING OPENDDS

Quick Start Guides
: Download and compile OpenDDS and then run an example application

Introduction to DDS
: A conceptual overview of the Data Distribution Service

What is OpenDDS?
: OpenDDS is an open-source DDS

Building and Installing
: How to build and install OpenDDS

Getting Started
: A tutorial on making basic OpenDDS applications

Much more information can be found in the *Developer's Guide*

CHAPTER

SIX

OTHER DOCUMENTATION

Release Notes
: What are the latest changes in OpenDDS?

Internal Documentation
: Documentation for OpenDDS contributors

Glossary
: A dictionary of common terms

genindex

INDEX

Symbols

:default: (*directive option*)
    cfg:prop (*directive*), 335
:required: (*directive option*)
    cfg:prop (*directive*), 335
-AllowEmptyPartition
    RtpsRelay command line option, 284
-ApplicationDomain
    RtpsRelay command line option, 284
-BufferSize
    RtpsRelay command line option, 284
-Dname
    opendds_idl command line option, 230
-Gequality
    opendds_idl command line option, 231
-GfaceTS
    opendds_idl command line option, 231
-Gitl
    opendds_idl command line option, 231
-Governance
    RtpsRelay command line option, 284
-Gv8
    opendds_idl command line option, 231
-Gxtypes-complete
    opendds_idl command line option, 231
-HorizontalAddres
    RtpsRelay command line option, 283
-Id
    RtpsRelay command line option, 283
-IdentityCA
    RtpsRelay command line option, 284
-IdentityCertificate
    RtpsRelay command line option, 284
-IdentityKey
    RtpsRelay command line option, 284
-Idir
    opendds_idl command line option, 231
-InactivePeriod
    RtpsRelay command line option, 284
-Lc++11
    opendds_idl command line option, 231
-Lface
    opendds_idl command line option, 231
-Lifespan
    RtpsRelay command line option, 284
-LogActivity
    RtpsRelay command line option, 284
-LogDiscovery
    RtpsRelay command line option, 284
-LogHandlerStatistics
    RtpsRelay command line option, 285
-LogParticipantStatistics
    RtpsRelay command line option, 285
-LogRelayStatistics
    RtpsRelay command line option, 284
-LogThreadStatus
    RtpsRelay command line option, 285
-LogWarnings
    RtpsRelay command line option, 284
-Lspcpp
    opendds_idl command line option, 231
-MaxIpsPerClient
    RtpsRelay command line option, 285
-MetaDiscoveryAddress
    RtpsRelay command line option, 285
-MetaDiscoveryContent
    RtpsRelay command line option, 285
-MetaDiscoveryContentPath
    RtpsRelay command line option, 285
-MetaDiscoveryContentType
    RtpsRelay command line option, 285
-Permissions
    RtpsRelay command line option, 284
-PermissionsCA
    RtpsRelay command line option, 284
-PublishHandlerStatistics
    RtpsRelay command line option, 285
-PublishParticipantStatistics
    RtpsRelay command line option, 285
-PublishRelayStatistics
    RtpsRelay command line option, 285
-PublishRelayStatus
    RtpsRelay command line option, 285
-PublishRelayStatusLiveliness

RtpsRelay command line option, 285
-RejectedAddressDuration
RtpsRelay command line option, 285
-RelayDomain
RtpsRelay command line option, 284
-RestartDetection
RtpsRelay command line option, 284
-St
opendds_idl command line option, 231
-ThreadStatusSafetyFactor
RtpsRelay command line option, 285
-UserData
RtpsRelay command line option, 284
-UtilizationLimit
RtpsRelay command line option, 285
-V
opendds_idl command line option, 230
-VerticalAddress
RtpsRelay command line option, 283
-Wb,export_include
opendds_idl command line option, 230
-Wb,export_macro
opendds_idl command line option, 230
-Wb,java
opendds_idl command line option, 231
-Wb,pch_include
opendds_idl command line option, 230
-Wb,tao_include_prefix
opendds_idl command line option, 231
--default-autoid
opendds_idl command line option, 232
--default-enum-extensibility-zero
opendds_idl command line option, 232
--default-extensibility
opendds_idl command line option, 232
--default-try-construct
opendds_idl command line option, 232
--domain
node_controller command line option, 366
test_controller command line option, 365
--help
opendds_idl command line option, 230
--idl-version
opendds_idl command line option, 230
--json-result-id
test_controller command line option, 366
--list-idl-versions
opendds_idl command line option, 230
--log
worker command line option, 367
--name
node_controller command line option, 366
--no-dcps-data-type-warnings
opendds_idl command line option, 231
--old-typeobject-encoding
opendds_idl command line option, 232
--old-typeobject-member-order
opendds_idl command line option, 232
--override-create-time
test_controller command line option, 365
--override-start-time
test_controller command line option, 365
--report
worker command line option, 367
--syntax-only
opendds_idl command line option, 230
--tag
test_controller command line option, 365
--timeout
test_controller command line option, 365
--unknown-annotations
opendds_idl command line option, 231
--version
opendds_idl command line option, 230
--wait-for-nodes
test_controller command line option, 365
--[no-]default-nested
opendds_idl command line option, 232
-h
opendds_idl command line option, 230
-o
opendds_idl command line option, 231
-v
opendds_idl command line option, 230

A

ACE, **375**
ACE::ACE (*CMake target*), 60
ACE::ace_gperf (*CMake target*), 60
ACE::XML_Utils (*CMake target*), 60
ACE_ROOT, 67, 87, 350
acetaorel (*role*), 330
active_conn_timeout_period (*config property*)
transport (*tcp config section*), 209
Adaptive Communication Environment, **375**
advertised_address (*config property*)
transport (*rtps_udp config section*), 217
ALWAYS_GENERATE_LIB_EXPORT_HEADER
opendds_target_sources, 61
ARG
opendds_cmake_function, 333
async_send (*config property*)
transport (*multicast config section*), 215
AuthResendPeriod (*config property*)
rtps_discovery (*config section*), 187
AUTO_LINK
opendds_target_sources, 62

B

BITs, **375**
Built-in Topics, **375**

C

CDR, **375**
cfg:prop (*directive*), 334
    :default: (*directive option*), 335
    :required: (*directive option*), 335
cfg:prop (*role*), 335
cfg:sec (*directive*), 334
cfg:sec (*role*), 334
cfg:val (*directive*), 335
cfg:val (*role*), 335
ChangePasswordPeriod (*config property*)
    ice (*config section*), 223
ChecklistPeriod (*config property*)
    ice (*config section*), 222
CheckSourceIp (*config property*)
    rtps_discovery (*config section*), 189
cmake:func (*directive*), 332
cmake:func (*role*), 333
cmake:func:arg (*directive*), 333
cmake:prop (*directive*), 333
cmake:prop (*role*), 334
cmake:tgt (*directive*), 334
cmake:tgt (*role*), 334
cmake:var (*directive*), 333
cmake:var (*role*), 333
common (*config section*), 164
    DCPSBidirGIOP (*config property*), 164
    DCPSBit (*config property*), 164
    DCPSBitLookupDurationMsec (*config property*), 164
    DCPSBitTransportIPAddress (*config property*), 165
    DCPSBitTransportPort (*config property*), 165
    DCPSChunkAssociationMultiplier (*config property*), 165
    DCPSChunks (*config property*), 165
    DCPSDebugLevel (*config property*), 166
    DCPSDefaultAddress (*config property*), 166
    DCPSDefaultDiscovery (*config property*), 166
    DCPSGlobalTransportConfig (*config property*), 167
    DCPSInfoRepo (*config property*), 167
    DCPSLivelinessFactor (*config property*), 167
    DCPSLogLevel (*config property*), 167
    DCPSMonitor (*config property*), 168
    DCPSPendingTimeout (*config property*), 168
    DCPSPersistentDataDir (*config property*), 168
    DCPSPublisherContentFilter (*config property*), 169
    DCPSSecurity (*config property*), 169
    DCPSSecurityDebug (*config property*), 169
    DCPSSecurityDebugLevel (*config property*), 169
    DCPSSecurityFakeEncryption (*config property*), 169
    DCPSThreadStatusInterval (*config property*), 170
    DCPSTransportDebugLevel (*config property*), 170
    DCPSTypeObjectEncoding (*config property*), 170
    ORBLogFile (*config property*), 170
    ORBVerboseLogging (*config property*), 171
    pool_granularity (*config property*), 171
    pool_size (*config property*), 171
    Scheduler (*config property*), 171
    scheduler_slice (*config property*), 172
Common Data Representation, **375**
Common Object Request Broker Architecture, **375**
Condition, **375**
config (*config property*)
    endpoint (*config section*), 201
config (*config section*), 206
    passive_connect_duration (*config property*), 206
    swap_bytes (*config property*), 206
    transports (*config property*), 206
CONFIG_PATH
    test_controller command line option, 365
conn_retry_attempts (*config property*)
    transport (*tcp config section*), 209
conn_retry_backoff_multiplier (*config property*)
    transport (*tcp config section*), 210
conn_retry_initial_delay (*config property*)
    transport (*tcp config section*), 209
ConnectivityCheckTTL (*config property*)
    ice (*config section*), 222
CORBA, **375**
Customization (*config property*)
    DomainRange (*config section*), 224
    transport_template (*config section*), 224
Customization (*config section*), 225
    InteropMulticastOverride (*config property*), 225
    multicast_group_address (*config property*), 225

D

D0 (*config property*)
    rtps_discovery (*config section*), 182
D1 (*config property*)
    rtps_discovery (*config section*), 182
daemon
    node_controller command line option, 366
daemon-exit-on-error
    node_controller command line option, 366
Data Distribution Service, **375**

Data-Centric Publish-Subscribe, 376
datalink_control_chunks (*config property*)
transport (*config section*), 208
datalink_control_size (*config property*)
transport (*shmem config section*), 221
datalink_release_delay (*config property*)
transport (*config section*), 208
DataReader, 376
datareaderqos (*config property*)
endpoint (*config section*), 200
datareaderqos (*config section*), 195
deadline.period.nanosec (*config property*), 195
deadline.period.sec (*config property*), 195
destination_order.kind (*config property*), 196
durability.kind (*config property*), 195
history.depth (*config property*), 196
history.kind (*config property*), 196
latency_budget.duration.nanosec (*config property*), 195
latency_budget.duration.sec (*config property*), 195
liveliness.kind (*config property*), 195
liveliness.lease_duration.nanosec (*config property*), 196
liveliness.lease_duration.sec (*config property*), 195
reader_data_lifecycle.autopurge_dispose_samples_delay.nanosec (*config property*), 198
reader_data_lifecycle.autopurge_dispose_samples_delay.sec (*config property*), 198
reader_data_lifecycle.autopurge_nowriter_samples_delay.nanosec (*config property*), 198
reader_data_lifecycle.autopurge_nowriter_samples_delay.sec (*config property*), 197
reliability.kind (*config property*), 196
reliability.max_blocking_time.nanosec (*config property*), 196
reliability.max_blocking_time.sec (*config property*), 196
resource_limits.max_instances (*config property*), 197
resource_limits.max_samples (*config property*), 197
resource_limits.max_samples_per_instance (*config property*), 197
time_based_filter.minimum_separation.nanosec (*config property*), 197
time_based_filter.minimum_separation.sec (*config property*), 197
DataRtpsRelayAddress (*config property*)
transport (*rtps_udp config section*), 219
DataStunServerAddress (*config property*)
transport (*rtps_udp config section*), 219
DataWriter, 376
datawriterqos (*config property*)
endpoint (*config section*), 200
datawriterqos (*config section*), 191
deadline.period.nanosec (*config property*), 192
deadline.period.sec (*config property*), 192
destination_order.kind (*config property*), 193
durability.kind (*config property*), 191
history.depth (*config property*), 193
history.kind (*config property*), 193
latency_budget.duration.nanosec (*config property*), 192
latency_budget.duration.sec (*config property*), 192
lifespan.duration.nanosec (*config property*), 194
lifespan.duration.sec (*config property*), 194
liveliness.kind (*config property*), 192
liveliness.lease_duration.nanosec (*config property*), 192
liveliness.lease_duration.sec (*config property*), 192
ownership.kind (*config property*), 194
ownership_strength.value (*config property*), 194
reliability.kind (*config property*), 193
reliability.max_blocking_time.nanosec (*config property*), 193
reliability.max_blocking_time.sec (*config property*), 193
resource_limits.max_instances (*config property*), 194
resource_limits.max_samples (*config property*), 193
resource_limits.max_samples_per_instance (*config property*), 194
transport_priority.value (*config property*), 194
DCPS, 376
DCPSBidirGIOP (*config property*)
common (*config section*), 164
DCPSBit (*config property*)
common (*config section*), 164
DCPSBitLookupDurationMsec (*config property*)
common (*config section*), 164
DCPSBitTransportIPAddress (*config property*)
common (*config section*), 165
DCPSBitTransportPort (*config property*)
common (*config section*), 165
DCPSChunkAssociationMultiplier (*config property*)
common (*config section*), 165
DCPSChunks (*config property*)
common (*config section*), 165
DCPSDebugLevel (*config property*)
common (*config section*), 166

DCPSDefaultAddress (*config property*)
common (*config section*), 166
DCPSDefaultDiscovery (*config property*)
common (*config section*), 166
DCPSGlobalTransportConfig (*config property*)
common (*config section*), 167
DCPSInfoRepo (*config property*)
common (*config section*), 167
DCPSLivelinessFactor (*config property*)
common (*config section*), 167
DCPSLogLevel (*config property*)
common (*config section*), 167
DCPSMonitor (*config property*)
common (*config section*), 168
DCPSPendingTimeout (*config property*)
common (*config section*), 168
DCPSPersistentDataDir (*config property*)
common (*config section*), 168
DCPSPublisherContentFilter (*config property*)
common (*config section*), 169
DCPSSecurity (*config property*)
common (*config section*), 169
DCPSSecurityDebug (*config property*)
common (*config section*), 169
DCPSSecurityDebugLevel (*config property*)
common (*config section*), 169
DCPSSecurityFakeEncryption (*config property*)
common (*config section*), 169
DCPSThreadStatusInterval (*config property*)
common (*config section*), 170
DCPSTransportDebugLevel (*config property*)
common (*config section*), 170
DCPSTypeObjectEncoding (*config property*)
common (*config section*), 170
DDS, **375**
DDS_ROOT, 13, 44, 350, 354
deadline.period.nanosec (*config property*)
datareaderqos (*config section*), 195
datawriterqos (*config section*), 192
deadline.period.sec (*config property*)
datareaderqos (*config section*), 195
datawriterqos (*config section*), 192
default_to_ipv6 (*config property*)
transport (*multicast config section*), 212
DefaultTransportConfig (*config property*)
domain (*config section*), 174
DeferredTriggeredCheckTTL (*config property*)
ice (*config section*), 223
DEST
opendds_install_interface_files, 65
destination_order.kind (*config property*)
datareaderqos (*config section*), 196
datawriterqos (*config section*), 193
DG (*config property*)
rtps_discovery (*config section*), 181
DIR
opendds_export_header, 64
Discovery, **376**
DiscoveryConfig (*config property*)
domain (*config section*), 174
DiscoveryTemplate (*config property*)
DomainRange (*config section*), 223
Dispose, **376**
Domain, **376**
domain (*config property*)
endpoint (*config section*), 199
domain (*config section*), 174
DefaultTransportConfig (*config property*), 174
DiscoveryConfig (*config property*), 174
DomainId (*config property*), 174
DomainRepoKey (*config property*), 174
DomainId (*config property*)
domain (*config section*), 174
DomainParticipant, **376**
DomainRange (*config section*), 223
Customization (*config property*), 224
DiscoveryTemplate (*config property*), 223
DomainRepoKey (*config property*)
domain (*config section*), 174
durability.kind (*config property*)
datareaderqos (*config section*), 195
datawriterqos (*config section*), 191
DX (*config property*)
rtps_discovery (*config section*), 182

E

enable_nagle_algorithm (*config property*)
transport (*tcp config section*), 210
endpoint (*config section*), 199
config (*config property*), 201
datareaderqos (*config property*), 200
datawriterqos (*config property*), 200
domain (*config property*), 199
entity (*config property*), 200
participant (*config property*), 199
publisherqos (*config property*), 200
subscriberqos (*config property*), 201
topic (*config property*), 200
type (*config property*), 200
Entity, **376**
entity (*config property*)
endpoint (*config section*), 200
environment variable
ACE_ROOT, 67, 87, 350, 378
DDS_ROOT, 13, 44, 350, 354, 378
OPENDDS_CONFIG_DIR, 163, 378
TAO_ROOT, 67, 87, 378
EXPORT_HEADER_DIR

opendds_target_sources, 61
Extended Common Data Representation, **375**
Extensible and Dynamic Topic Types for DDS, **377**
EXTRA_GENERATED_FILES
opendds_install_interface_files, 65

G

GENERATE_SERVER_SKELETONS
opendds_target_sources, 62
ghfile (*role*), 329
ghissue (*role*), 329
ghpr (*role*), 330
ghrelease (*role*), 330
group_address (*config property*)
transport (*multicast config section*), 213
GuidInterface (*config property*)
rtps_discovery (*config section*), 185

H

heartbeat_period (*config property*)
transport (*rtps_udp config section*), 218
history.depth (*config property*)
datareaderqos (*config section*), 196
datawriterqos (*config section*), 193
history.kind (*config property*)
datareaderqos (*config section*), 196
datawriterqos (*config section*), 193
host_name (*config property*)
transport (*shmem config section*), 221

I

ice (*config section*), 221
ChangePasswordPeriod (*config property*), 223
ChecklistPeriod (*config property*), 222
ConnectivityCheckTTL (*config property*), 222
DeferredTriggeredCheckTTL (*config property*), 223
IndicationPeriod (*config property*), 222
NominatedTTL (*config property*), 222
ServerReflexiveAddressPeriod (*config property*), 222
ServerReflexiveIndicationCount (*config property*), 223
Ta (*config property*), 222
IDL, **376**
INCLUDE_BASE
opendds_install_interface_files, 65
opendds_target_sources, 62
IndicationPeriod (*config property*)
ice (*config section*), 222
Instance, **376**
instantiation_rule (*config property*)
transport_template (*config section*), 224
Interface Definition Language, **376**
InteropMulticastOverride (*config property*)
Customization (*config section*), 225
rtps_discovery (*config section*), 185
ipv6_advertised_address (*config property*)
transport (*rtps_udp config section*), 218
ipv6_local_address (*config property*)
transport (*rtps_udp config section*), 217
ipv6_multicast_group_address (*config property*)
transport (*rtps_udp config section*), 217

L

latency_budget.duration.nanosec (*config property*)
datareaderqos (*config section*), 195
datawriterqos (*config section*), 192
latency_budget.duration.sec (*config property*)
datareaderqos (*config section*), 195
datawriterqos (*config section*), 192
LeaseDuration (*config property*)
rtps_discovery (*config section*), 181
LeaseExtension (*config property*)
rtps_discovery (*config section*), 181
lifespan.duration.nanosec (*config property*)
datawriterqos (*config section*), 194
lifespan.duration.sec (*config property*)
datawriterqos (*config section*), 194
Listener, **376**
liveliness.kind (*config property*)
datareaderqos (*config section*), 195
datawriterqos (*config section*), 192
liveliness.lease_duration.nanosec (*config property*)
datareaderqos (*config section*), 196
datawriterqos (*config section*), 192
liveliness.lease_duration.sec (*config property*)
datareaderqos (*config section*), 195
datawriterqos (*config section*), 192
local_address (*config property*)
transport (*multicast config section*), 213
transport (*rtps_udp config section*), 217
transport (*tcp config section*), 210
transport (*udp config section*), 212

M

Makefile, Project, and Workspace Creator, **376**
max_message_size (*config property*)
transport (*rtps_udp config section*), 219
max_output_pause_period (*config property*)
transport (*tcp config section*), 211
max_packet_size (*config property*)
transport (*config section*), 207
max_samples_per_packet (*config property*)
transport (*config section*), 207

MaxAuthTime (*config property*)
rtps_discovery (*config section*), 187
MaxParticipantsInAuthentication (*config property*)
rtps_discovery (*config section*), 188
MaxSpdpSequenceMsgResetChecks (*config property*)
rtps_discovery (*config section*), 184
MinResendDelay (*config property*)
rtps_discovery (*config section*), 180
MPC, **376**
mpc.pl, **376**
multicast_group_address (*config property*)
Customization (*config section*), 225
transport (*rtps_udp config section*), 217
multicast_interface (*config property*)
transport (*rtps_udp config section*), 217
MulticastInterface (*config property*)
rtps_discovery (*config section*), 185
mwc.pl, **376**

N

nak_delay_intervals (*config property*)
transport (*multicast config section*), 213
nak_depth (*config property*)
transport (*multicast config section*), 213
transport (*rtps_udp config section*), 218
nak_interval (*config property*)
transport (*multicast config section*), 213
nak_max (*config property*)
transport (*multicast config section*), 213
nak_response_delay (*config property*)
transport (*rtps_udp config section*), 218
nak_timeout (*config property*)
transport (*multicast config section*), 214
name (*config property*)
topic (*config section*), 191
node_controller command line option
--domain, 366
--name, 366
daemon, 366
daemon-exit-on-error, 366
one-shot, 366
NominatedTTL (*config property*)
ice (*config section*), 222

O

Object Management Group, **377**
OMG, **377**
omgissue (*role*), 330
omgspec (*role*), 331
one-shot
node_controller command line option, 366
OpenDDS::Dcps (*CMake target*), 59
OpenDDS::dcpsinfo_dump (*CMake target*), 60
OpenDDS::DCPSInfoRepo (*CMake target*), 60
OpenDDS::InfoRepoDiscovery (*CMake target*), 59
OpenDDS::inspect (*CMake target*), 60
OpenDDS::Multicast (*CMake target*), 59
OpenDDS::opendds_idl (*CMake target*), 60
OpenDDS::repoctl (*CMake target*), 61
OpenDDS::Rtps (*CMake target*), 59
OpenDDS::Rtps_Udp (*CMake target*), 59
OpenDDS::RtpsRelay (*CMake target*), 60
OpenDDS::RtpsRelayLib (*CMake target*), 59
OpenDDS::Security (*CMake target*), 59
OpenDDS::Shmem (*CMake target*), 59
OpenDDS::Tcp (*CMake target*), 59
OpenDDS::Udp (*CMake target*), 59
OPENDDS_ACE, 67
OPENDDS_ACE_TAO_GIT, 94
OPENDDS_ACE_TAO_GIT_REPO, 95
OPENDDS_ACE_TAO_GIT_TAG, 95
OPENDDS_ACE_TAO_HOST_TOOLS, 67
OPENDDS_ACE_TAO_KIND, 94
OPENDDS_ACE_TAO_SRC, 94
OPENDDS_ACE_VERSION, 67
OPENDDS_ALL_GENERATED_INTERFACE_FILES
opendds_target_sources, 63
OPENDDS_ALL_IDL_INTERFACE_FILES
opendds_target_sources, 63
OPENDDS_ALL_INTERFACE_FILES
opendds_target_sources, 64
OPENDDS_ALWAYS_GENERATE_LIB_EXPORT_HEADER, 66
OPENDDS_AUTO_LINK_DCPS, 66
OPENDDS_BOOTTIME_TIMERS, 95
OPENDDS_BUILD_EXAMPLES, 95
OPENDDS_BUILD_TESTS, 95
OPENDDS_BUILT_IN_TOPICS, 68
opendds_cmake_function
ARG, 333
target, 332
OPENDDS_CMAKE_VERBOSE, 65
OPENDDS_CONFIG_DIR, 163
OPENDDS_CONTENT_FILTERED_TOPIC, 69
OPENDDS_CONTENT_SUBSCRIPTION, 68
OPENDDS_CXX11, 68
OPENDDS_CXX_STD, 68
OPENDDS_DEBUG, 68
OPENDDS_DEFAULT_NESTED, 65
OPENDDS_DEFAULT_SCOPE, 66
opendds_export_header, 64
DIR, 64
USE_EXPORT_VAR, 64
OPENDDS_FILENAME_ONLY_INCLUDES, 65
OPENDDS_GENERATED_DIRECTORY
opendds_target_sources, 63
OPENDDS_GENERATED_HEADER_FILES
opendds_target_sources, 63

OPENDDS_GENERATED_IDL_INTERFACE_FILES
    opendds_target_sources, 63
opendds_get_library_dependencies, 64
OPENDDS_GTEST, 67
OPENDDS_HOST_TOOLS, 67
opendds_idl, 377
opendds_idl command line option
    -Dname, 230
    -Gequality, 231
    -GfaceTS, 231
    -Gitl, 231
    -Gv8, 231
    -Gxtypes-complete, 231
    -Idir, 231
    -Lc++11, 231
    -Lface, 231
    -Lspcpp, 231
    -St, 231
    -V, 230
    -Wb,export_include, 230
    -Wb,export_macro, 230
    -Wb,java, 231
    -Wb,pch_include, 230
    -Wb,tao_include_prefix, 231
    --default-autoid, 232
    --default-enum-extensibility-zero, 232
    --default-extensibility, 232
    --default-try-construct, 232
    --help, 230
    --idl-version, 230
    --list-idl-versions, 230
    --no-dcps-data-type-warnings, 231
    --old-typeobject-encoding, 232
    --old-typeobject-member-order, 232
    --syntax-only, 230
    --unknown-annotations, 231
    --version, 230
    --[no-]default-nested, 232
    -h, 230
    -o, 231
    -v, 230
OPENDDS_IDL_OPTIONS
    opendds_target_sources, 61
OPENDDS_INLINE, 68
opendds_install_interface_files, 64
    DEST, 65
    EXTRA_GENERATED_FILES, 65
    INCLUDE_BASE, 65
OPENDDS_JAVA, 67
OPENDDS_JUST_BUILD_HOST_TOOLS, 94
OPENDDS_LANGUAGE_MAPPINGS
    opendds_target_sources, 62
OPENDDS_MPC, 95
OPENDDS_MPC_GIT, 95
OPENDDS_MPC_GIT_REPO, 95
OPENDDS_MPC_GIT_TAG, 95
OPENDDS_MULTI_TOPIC, 69
OPENDDS_OBJECT_MODEL_PROFILE, 68
OPENDDS_OPENSSL, 67
OPENDDS_OPTIMIZE, 68
OPENDDS_OWNERSHIP_KIND_EXCLUSIVE, 68
OPENDDS_OWNERSHIP_PROFILE, 68
OPENDDS_PASSED_IDL_INTERFACE_FILES
    opendds_target_sources, 63
OPENDDS_PERSISTENCE_PROFILE, 68
OPENDDS_QT, 67
OPENDDS_QUERY_CONDITION, 69
OPENDDS_RAPIDJSON, 67
OPENDDS_SAFETY_PROFILE, 69
OPENDDS_SECURITY, 69
OPENDDS_STATIC, 68
OPENDDS_SUPPRESS_ANYS, 66
OPENDDS_TAO, 67
OPENDDS_TAO_IIOP, 68
OPENDDS_TAO_OPTIMIZE_COLLOCATED_INVOCATIONS, 68
OPENDDS_TAO_VERSION, 67
opendds_target_sources, 61
    ALWAYS_GENERATE_LIB_EXPORT_HEADER, 61
    AUTO_LINK, 62
    EXPORT_HEADER_DIR, 61
    GENERATE_SERVER_SKELETONS, 62
    INCLUDE_BASE, 62
    OPENDDS_ALL_GENERATED_INTERFACE_FILES, 63
    OPENDDS_ALL_IDL_INTERFACE_FILES, 63
    OPENDDS_ALL_INTERFACE_FILES, 64
    OPENDDS_GENERATED_DIRECTORY, 63
    OPENDDS_GENERATED_HEADER_FILES, 63
    OPENDDS_GENERATED_IDL_INTERFACE_FILES, 63
    OPENDDS_IDL_OPTIONS, 61
    OPENDDS_LANGUAGE_MAPPINGS, 62
    OPENDDS_PASSED_IDL_INTERFACE_FILES, 63
    SKIP_OPENDDS_IDL, 62
    SKIP_TAO_IDL, 62
    SUPPRESS_ANYS, 61
    TAO_IDL_OPTIONS, 61
    USE_EXPORT, 62
    USE_VERSIONED_NAMESPACE, 62
OPENDDS_USE_CORRECT_INCLUDE_SCOPE, 66
OPENDDS_VERSIONED_NAMESPACE, 68
OPENDDS_WCHAR, 68
OPENDDS_XERCES3, 67
optimum_packet_size (*config property*)
    transport (*config section*), 208
ORBLogFile (*config property*)
    common (*config section*), 170
ORBVerboseLogging (*config property*)
    common (*config section*), 171

ownership.kind (*config property*)
datawriterqos (*config section*), 194
ownership_strength.value (*config property*)
datawriterqos (*config section*), 194

P

participant (*config property*)
endpoint (*config section*), 199
partition.name (*config property*)
publisherqos (*config section*), 199
subscriberqos (*config section*), 199
passive_connect_duration (*config property*)
config (*config section*), 206
passive_reconnect_duration (*config property*)
transport (*tcp config section*), 211
PB (*config property*)
rtps_discovery (*config section*), 181
PeriodicDirectedSpdp (*config property*)
rtps_discovery (*config section*), 184
PG (*config property*)
rtps_discovery (*config section*), 181
pool_granularity (*config property*)
common (*config section*), 171
pool_size (*config property*)
common (*config section*), 171
transport (*shmem config section*), 221
port_offset (*config property*)
transport (*multicast config section*), 214
presentation.access_scope (*config property*)
publisherqos (*config section*), 198
subscriberqos (*config section*), 199
presentation.coherent_access (*config property*)
publisherqos (*config section*), 198
subscriberqos (*config section*), 199
presentation.ordered_access (*config property*)
publisherqos (*config section*), 198
subscriberqos (*config section*), 199
pub_address (*config property*)
transport (*tcp config section*), 211
Publisher, **377**
publisherqos (*config property*)
endpoint (*config section*), 200
publisherqos (*config section*), 198
partition.name (*config property*), 199
presentation.access_scope (*config property*), 198
presentation.coherent_access (*config property*), 198
presentation.ordered_access (*config property*), 198
Python Enhancement Proposals
PEP 8, 326

Q

QoS, **377**
Quality of Service, **377**
QuickResendRatio (*config property*)
rtps_discovery (*config section*), 180

R

rcv_buffer_size (*config property*)
transport (*multicast config section*), 214
transport (*udp config section*), 212
reader_data_lifecycle.autopurge_dispose_samples_delay.nanc
(*config property*)
datareaderqos (*config section*), 198
reader_data_lifecycle.autopurge_dispose_samples_delay.sec
(*config property*)
datareaderqos (*config section*), 198
reader_data_lifecycle.autopurge_nowriter_samples_delay.nar
(*config property*)
datareaderqos (*config section*), 198
reader_data_lifecycle.autopurge_nowriter_samples_delay.sec
(*config property*)
datareaderqos (*config section*), 197
Real-time Publish-Subscribe, **377**
receive_preallocated_data_blocks (*config property*)
transport (*config section*), 209
receive_preallocated_message_blocks (*config property*)
transport (*config section*), 208
RecvBufferSize (*config property*)
rtps_discovery (*config section*), 188
reliability.kind (*config property*)
datareaderqos (*config section*), 196
datawriterqos (*config section*), 193
reliability.max_blocking_time.nanosec (*config property*)
datareaderqos (*config section*), 196
datawriterqos (*config section*), 193
reliability.max_blocking_time.sec (*config property*)
datareaderqos (*config section*), 196
datawriterqos (*config section*), 193
reliable (*config property*)
transport (*multicast config section*), 214
repository (*config section*), 178
RepositoryIor (*config property*), 178
RepositoryKey (*config property*), 179
RepositoryIor (*config property*)
repository (*config section*), 178
RepositoryKey (*config property*)
repository (*config section*), 179
ResendPeriod (*config property*)
rtps_discovery (*config section*), 180
resource_limits.max_instances (*config property*)

datareaderqos (*config section*), 197
datawriterqos (*config section*), 194
resource_limits.max_samples (*config property*)
datareaderqos (*config section*), 197
datawriterqos (*config section*), 193
resource_limits.max_samples_per_instance (*config property*)
datareaderqos (*config section*), 197
datawriterqos (*config section*), 194
ResponsiveMode (*config property*)
transport (*rtps_udp config section*), 218
RFC
RFC 1149, 334, 340
RFC 2560, 281
RFC 5280, 281
RFC 5389, 286
RFC 8445, 286
RTPS, **377**
rtps_discovery (*config section*), 180
AuthResendPeriod (*config property*), 187
CheckSourceIp (*config property*), 189
D0 (*config property*), 182
D1 (*config property*), 182
DG (*config property*), 181
DX (*config property*), 182
GuidInterface (*config property*), 185
InteropMulticastOverride (*config property*), 185
LeaseDuration (*config property*), 181
LeaseExtension (*config property*), 181
MaxAuthTime (*config property*), 187
MaxParticipantsInAuthentication (*config property*), 188
MaxSpdpSequenceMsgResetChecks (*config property*), 184
MinResendDelay (*config property*), 180
MulticastInterface (*config property*), 185
PB (*config property*), 181
PeriodicDirectedSpdp (*config property*), 184
PG (*config property*), 181
QuickResendRatio (*config property*), 180
RecvBufferSize (*config property*), 188
ResendPeriod (*config property*), 180
RtpsRelayOnly (*config property*), 186
SecureParticipantUserData (*config property*), 187
SedpAdvertisedLocalAddress (*config property*), 183
SedpHeartbeatPeriod (*config property*), 184
SedpLocalAddress (*config property*), 183
SedpMaxMessageSize (*config property*), 182
SedpMulticast (*config property*), 183
SedpNakResponseDelay (*config property*), 184
SedpPassiveConnectDuration (*config property*), 188
SedpReceivePreallocatedDataBlocks (*config property*), 189
SedpReceivePreallocatedMessageBlocks (*config property*), 189
SedpResponsiveMode (*config property*), 188
SedpRtpsRelayAddress (*config property*), 186
SedpSendDelay (*config property*), 183
SedpStunServerAddress (*config property*), 186
SendBufferSize (*config property*), 188
SpdpLocalAddress (*config property*), 183
SpdpRequestRandomPort (*config property*), 182
SpdpRtpsRelayAddress (*config property*), 185
SpdpRtpsRelaySendPeriod (*config property*), 185
SpdpSendAddrs (*config property*), 184
SpdpStunServerAddress (*config property*), 186
SpdpUserTag (*config property*), 189
TTL (*config property*), 185
TypeLookupServiceReplyTimeout (*config property*), 187
UndirectedSpdp (*config property*), 184
UseIce (*config property*), 186
UseRtpsRelay (*config property*), 186
UseXTypes (*config property*), 187
RtpsRelay command line option
-AllowEmptyPartition, 284
-ApplicationDomain, 284
-BufferSize, 284
-Governance, 284
-HorizontalAddres, 283
-Id, 283
-IdentityCA, 284
-IdentityCertificate, 284
-IdentityKey, 284
-InactivePeriod, 284
-Lifespan, 284
-LogActivity, 284
-LogDiscovery, 284
-LogHandlerStatistics, 285
-LogParticipantStatistics, 285
-LogRelayStatistics, 284
-LogThreadStatus, 285
-LogWarnings, 284
-MaxIpsPerClient, 285
-MetaDiscoveryAddress, 285
-MetaDiscoveryContent, 285
-MetaDiscoveryContentPath, 285
-MetaDiscoveryContentType, 285
-Permissions, 284
-PermissionsCA, 284
-PublishHandlerStatistics, 285
-PublishParticipantStatistics, 285
-PublishRelayStatistics, 285

-PublishRelayStatus, 285
-PublishRelayStatusLiveliness, 285
-RejectedAddressDuration, 285
-RelayDomain, 284
-RestartDetection, 284
-ThreadStatusSafetyFactor, 285
-UserData, 284
-UtilizationLimit, 285
-VerticalAddress, 283
RtpsRelayOnly (*config property*)
rtps_discovery (*config section*), 186
transport (*rtps_udp config section*), 219

S

Sample, **377**
SCENARIO_NAME
test_controller command line option, 365
Scheduler (*config property*)
common (*config section*), 171
scheduler_slice (*config property*)
common (*config section*), 172
SecureParticipantUserData (*config property*)
rtps_discovery (*config section*), 187
SedpAdvertisedLocalAddress (*config property*)
rtps_discovery (*config section*), 183
SedpHeartbeatPeriod (*config property*)
rtps_discovery (*config section*), 184
SedpLocalAddress (*config property*)
rtps_discovery (*config section*), 183
SedpMaxMessageSize (*config property*)
rtps_discovery (*config section*), 182
SedpMulticast (*config property*)
rtps_discovery (*config section*), 183
SedpNakResponseDelay (*config property*)
rtps_discovery (*config section*), 184
SedpPassiveConnectDuration (*config property*)
rtps_discovery (*config section*), 188
SedpReceivePreallocatedDataBlocks (*config property*)
rtps_discovery (*config section*), 189
SedpReceivePreallocatedMessageBlocks (*config property*)
rtps_discovery (*config section*), 189
SedpResponsiveMode (*config property*)
rtps_discovery (*config section*), 188
SedpRtpsRelayAddress (*config property*)
rtps_discovery (*config section*), 186
SedpSendDelay (*config property*)
rtps_discovery (*config section*), 183
SedpStunServerAddress (*config property*)
rtps_discovery (*config section*), 186
send_buffer_size (*config property*)
transport (*udp config section*), 212
send_delay (*config property*)
transport (*rtps_udp config section*), 218
SendBufferSize (*config property*)
rtps_discovery (*config section*), 188
ServerReflexiveAddressPeriod (*config property*)
ice (*config section*), 222
ServerReflexiveIndicationCount (*config property*)
ice (*config section*), 223
SKIP_OPENDDS_IDL
opendds_target_sources, 62
SKIP_TAO_IDL
opendds_target_sources, 62
SpdpLocalAddress (*config property*)
rtps_discovery (*config section*), 183
SpdpRequestRandomPort (*config property*)
rtps_discovery (*config section*), 182
SpdpRtpsRelayAddress (*config property*)
rtps_discovery (*config section*), 185
SpdpRtpsRelaySendPeriod (*config property*)
rtps_discovery (*config section*), 185
SpdpSendAddrs (*config property*)
rtps_discovery (*config section*), 184
SpdpStunServerAddress (*config property*)
rtps_discovery (*config section*), 186
SpdpUserTag (*config property*)
rtps_discovery (*config section*), 189
Subscriber, **377**
subscriberqos (*config property*)
endpoint (*config section*), 201
subscriberqos (*config section*), 199
partition.name (*config property*), 199
presentation.access_scope (*config property*), 199
presentation.coherent_access (*config property*), 199
presentation.ordered_access (*config property*), 199
SUPPRESS_ANYS
opendds_target_sources, 61
swap_bytes (*config property*)
config (*config section*), 206
syn_backoff (*config property*)
transport (*multicast config section*), 214
syn_interval (*config property*)
transport (*multicast config section*), 215
syn_timeout (*config property*)
transport (*multicast config section*), 215

T

Ta (*config property*)
ice (*config section*), 222
TAO, **377**
TAO::AnyTypeCode (*CMake target*), 60
TAO::BiDirGIOP (*CMake target*), 60
TAO::CodecFactory (*CMake target*), 60

TAO::IDL_FE (*CMake target*), 60
TAO::ImR_Client (*CMake target*), 60
TAO::IORManip (*CMake target*), 60
TAO::IORTable (*CMake target*), 60
TAO::PI (*CMake target*), 60
TAO::PortableServer (*CMake target*), 60
TAO::Svc_Utils (*CMake target*), 60
TAO::TAO (*CMake target*), 60
TAO::tao_idl (*CMake target*), 60
TAO::Valuetype (*CMake target*), 60
tao_idl, **377**
TAO_IDL_OPTIONS
    opendds_target_sources, 61
TAO_ROOT, 67, 87
target
    opendds_cmake_function, 332
test_controller command line option
    --domain, 365
    --json-result-id, 366
    --override-create-time, 365
    --override-start-time, 365
    --tag, 365
    --timeout, 365
    --wait-for-nodes, 365
    CONFIG_PATH, 365
    SCENARIO_NAME, 365
The ACE ORB, **377**
thread_per_connection (*config property*)
    transport (*config section*), 208
time_based_filter.minimum_separation.nanosec (*config property*)
    datareaderqos (*config section*), 197
time_based_filter.minimum_separation.sec (*config property*)
    datareaderqos (*config section*), 197
Topic, **377**
topic (*config property*)
    endpoint (*config section*), 200
topic (*config section*), 191
    name (*config property*), 191
    type_name (*config property*), 191
Topic type, **377**
Transport, **377**
transport (*config section*), 207
    datalink_control_chunks (*config property*), 208
    datalink_release_delay (*config property*), 208
    max_packet_size (*config property*), 207
    max_samples_per_packet (*config property*), 207
    optimum_packet_size (*config property*), 208
    receive_preallocated_data_blocks (*config property*), 209
    receive_preallocated_message_blocks (*config property*), 208
    thread_per_connection (*config property*), 208
    transport_type (*config property*), 207
transport (*multicast config section*), 212
    async_send (*config property*), 215
    default_to_ipv6 (*config property*), 212
    group_address (*config property*), 213
    local_address (*config property*), 213
    nak_delay_intervals (*config property*), 213
    nak_depth (*config property*), 213
    nak_interval (*config property*), 213
    nak_max (*config property*), 213
    nak_timeout (*config property*), 214
    port_offset (*config property*), 214
    rcv_buffer_size (*config property*), 214
    reliable (*config property*), 214
    syn_backoff (*config property*), 214
    syn_interval (*config property*), 215
    syn_timeout (*config property*), 215
    ttl (*config property*), 215
transport (*rtps_udp config section*), 216
    advertised_address (*config property*), 217
    DataRtpsRelayAddress (*config property*), 219
    DataStunServerAddress (*config property*), 219
    heartbeat_period (*config property*), 218
    ipv6_advertised_address (*config property*), 218
    ipv6_local_address (*config property*), 217
    ipv6_multicast_group_address (*config property*), 217
    local_address (*config property*), 217
    max_message_size (*config property*), 219
    multicast_group_address (*config property*), 217
    multicast_interface (*config property*), 217
    nak_depth (*config property*), 218
    nak_response_delay (*config property*), 218
    ResponsiveMode (*config property*), 218
    RtpsRelayOnly (*config property*), 219
    send_delay (*config property*), 218
    ttl (*config property*), 219
    use_multicast (*config property*), 216
    UseIce (*config property*), 220
    UseRtpsRelay (*config property*), 219
transport (*shmem config section*), 221
    datalink_control_size (*config property*), 221
    host_name (*config property*), 221
    pool_size (*config property*), 221
transport (*tcp config section*), 209
    active_conn_timeout_period (*config property*), 209
    conn_retry_attempts (*config property*), 209
    conn_retry_backoff_multiplier (*config property*), 210
    conn_retry_initial_delay (*config property*), 209
    enable_nagle_algorithm (*config property*), 210
    local_address (*config property*), 210

max_output_pause_period (*config property*), 211
passive_reconnect_duration (*config property*), 211
pub_address (*config property*), 211
transport (*udp config section*), 212
local_address (*config property*), 212
rcv_buffer_size (*config property*), 212
send_buffer_size (*config property*), 212
transport_priority.value (*config property*)
datawriterqos (*config section*), 194
transport_template (*config section*), 224
Customization (*config property*), 224
instantiation_rule (*config property*), 224
transport_type (*config property*)
transport (*config section*), 207
transports (*config property*)
config (*config section*), 206
TTL (*config property*)
rtps_discovery (*config section*), 185
ttl (*config property*)
transport (*multicast config section*), 215
transport (*rtps_udp config section*), 219
type (*config property*)
endpoint (*config section*), 200
type_name (*config property*)
topic (*config section*), 191
TypeLookupServiceReplyTimeout (*config property*)
rtps_discovery (*config section*), 187

U

UndirectedSpdp (*config property*)
rtps_discovery (*config section*), 184
Unregister, **377**
USE_EXPORT
opendds_target_sources, 62
USE_EXPORT_VAR
opendds_export_header, 64
use_multicast (*config property*)
transport (*rtps_udp config section*), 216
USE_VERSIONED_NAMESPACE
opendds_target_sources, 62
UseIce (*config property*)
rtps_discovery (*config section*), 186
transport (*rtps_udp config section*), 220
UseRtpsRelay (*config property*)
rtps_discovery (*config section*), 186
transport (*rtps_udp config section*), 219
UseXTypes (*config property*)
rtps_discovery (*config section*), 187

W

worker command line option
--log, 367
--report, 367

X

XCDR, **375**
XTypes, **377**