RTI Connext

Core Libraries and Utilities

Latency Performance Test Example Using C++

Instructions

Version 5.1.0

Your systems. Working as one.

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Contents

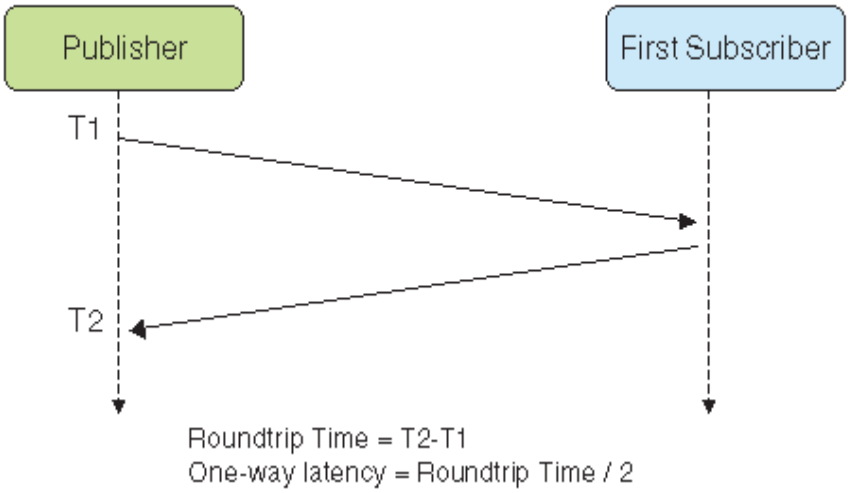
Latency Test Example Using C++

This document provides instructions on using the *RTI® Connext* (formerly *RTI Data Distribution Service)* latency test example, which is provided in source code.

1 Introduction

For a one-to-one test, one-way latency is estimated as half of the round-trip time of a message, as seen in Figure 1.

Figure 1 **One-to-One Publish-Subscribe Latency Measurement**



For a one-to-many test, one-way latency to the last subscriber is estimated by subtracting the one-way latency (as determined from a one-to-one case) from the roundtrip time to the last subscriber. Figure 2 and Figure 3 depict unicast and multicast scenarios, respectively.

Note: because of the testing methodology, for the results to be valid, the publisher and subscriber machines must be identical with respect to hardware and software setups.

Both the publisher and subscriber applications will need to be able to write and receive data. The publisher needs to be able to receive the returned data; the subscriber needs to be able to send the returned data. The publisher is the application that initiates the data stream.

Figure 2 **One-to-Two Unicast Publish -Subscribe Latency Measurement**

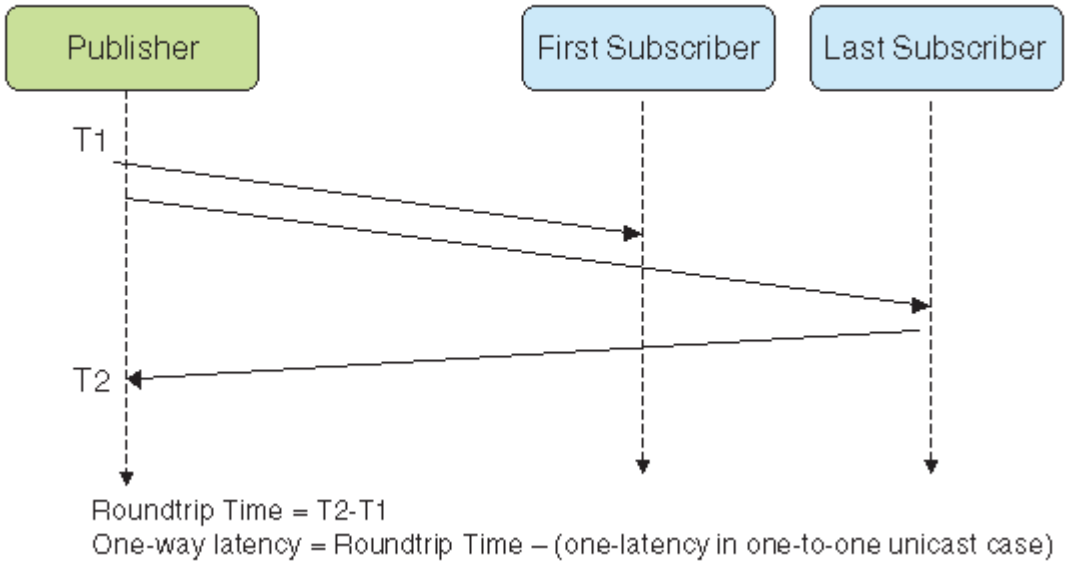
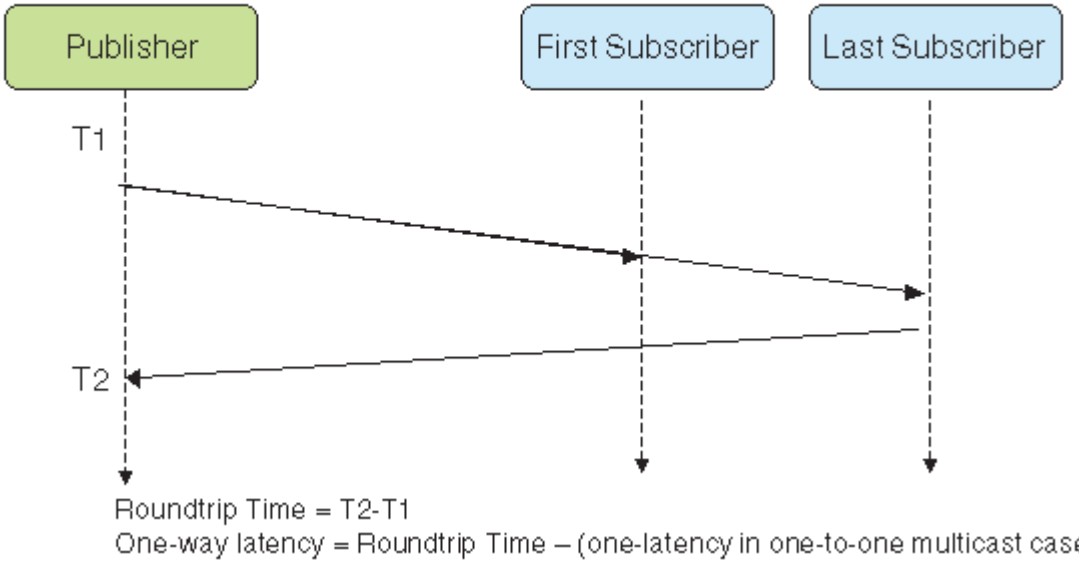


Figure 3 **One-to-Two Multicast Publish-Subscribe Latency Measurement**



By default, the message size ranges from 16 bytes to 8K, where the maximum size is indicated in the IDL file. To ensure a controlled environment for the performance test, discovery is done over unicast, not multicast.

2 Test Operation

The test code contains two applications: one for the publishing node, one for the subscribing node(s).

1. You will start the applications from the command line. For internal algorithmic reasons, the publisher must be started first, followed by each subscriber in the order of their **-cookie** (command-line option) values.
2. The publication application waits for the subscribing applications to announce their participation.
3. Once the publishing application recognizes that the specified numbers of subscribers are 'on-line,' the publisher starts publishing data.
4. After the required number of samples has been sent and the same number of replies received, the publisher signals the end of the test to all the subscribers.
5. The subscribers terminate.
6. The publisher reports the achieved latency.

3 Building the Test Applications

The example source code is found in **example/CPP/performance/latency**. For Solaris and Windows users, an example makefile and workspace is offered. The data type for the test is in **Latency.idl**.

The source files are:

- **Communicator.hxx, NddsCommunicator.cxx**: Abstract *Connext* communication endpoints
- **DataProcessor.hxx, DataProcessor.cxx**: Measured data processing
- **Latency_publisher.cxx**: Publisher application
- **Latency_subscriber.cxx**: Subscriber application
- **LatencyGlobalSettings.hxx**: test parameters

Regardless of the platform, this test requires the following preprocessor defines, in addition to the platform-specific defines described in the *RTI Core Libraries and Utilities Platform Notes*:

- **RTI_SHARED_MEMORY**: Do not define if your platform does not support shared memory.
- **RTI_IPV6**: Do not define if your platform does not support the IPv6 transport. (Please see the Known Issues section of the *RTI Core Libraries and Utilities Release Notes* for information on using IPv6.)

Section 3.1 and Section 3.2 provide information on specifying these defines.

3.1 Building the Test using the Makefile

1. A sample makefile is shipped with the latency example. To generate a makefile specific to your platform, use *rtiddsgen* with the **-example** flag, as follows:

   ```
   rtiddsgen -example <your arch> -notypecode Latency.idl
   ```

   You may get messages saying that some files already exist and will not be replaced. You can safely ignore these messages, since all the source files for this example are already provided in the same directory.

2. Remove the newly generated **USER_QOS_PROFILES.xml** file (its default profiles are not consistent with the QoS used by the test).
3. In the generated makefile, add the preprocessor defines for shared memory and IPv6 to the **DEFINES_ARCH_SPECIFIC** variable, if your platform supports those features:

```
DEFINES_ARCH_SPECIFIC = -DRTI_UNIX -DRTI_SHARED_MEMORY -DRTI_IPV6
```

4. Add the additional source files (**NddsCommunicator.cxx**, **DataProcessor.cxx**) to the **COMMMONSOURCES** variable in the generated makefile:

```
COMMONSOURCES = Latency.cxx LatencyPlugin.cxx \
LatencySupport.cxx DataProcessor.cxx NddsCommunicator.cxx
```

   Refer to the provided makefile as an example.
5. Set the **NDDSHOME** environment variable (for more information, see the *RTI Core Libraries and Utilities Getting Started Guide*).
6. Run this command to build:

```
gmake -f makefile_Latency_<your arch>
```

3.2 Building the Test on Windows using a Workspace

1. Use *rtiddsgen* to generate a workspace and a project file for the example:

```
rtiddsgen -example <your arch> -notypecode Latency.idl
```

   Since all the source files for this example are already present in the directory, *rtiddsgen* may print messages saying that some files already exist and will not be replaced. You can safely ignore these messages.
2. Remove the newly generated **USER_QOS_PROFILES.xml** file (its default profiles are not consistent with the QoS used by the test).
3. Add **NddsCommunicator.cxx**, **DataProcessor.cxx** to the publisher and subscriber projects.
   - Select the files, and drag and drop them into the **Source files** folder in the **latency_publisher** and **latency_subscriber** projects.
   - Alternatively in Visual Studio:
     - Right-click the **Source Files** folder under the project.
     - Select **Add**, **Add Existing Item**.
     - Select the desired files.
4. Add the preprocessor definitions **RTI_IPV6** and **RTI_SHARED_MEMORY**, if appropriate to your platform.

   In Visual Studio:
   - Right-click the project and select **Properties**.
   - In the Properties window, select the **C/C++**, **Preprocessor**.
   - Add the definitions to the Preprocessor definitions box (which should already have some defines, such as RTI_WIN32).
5. Set the **NDDSHOME** environment variable (for more information, see the *RTI Core Libraries and Utilities Getting Started Guide*).
6. Build your project.

3.3 Special Note for VxWorks Users using Kernel Mode

If you will be running the test on a VxWorks system in kernel mode, please read the following:

Since the test runs in the same process as the kernel, there is no "main" function in the publisher or subscriber. In addition, a VxWorks system has a limit of 10 command-line options, which precludes you from running the entry point subscriber or publisher function directly.

To run the test in VxWorks kernel mode, hard-code the configuration parameters in the source file prior to compiling the test.

If you plan to run both the Latency publisher and subscriber as Kernel tasks on the same VxWorks target to test loopback or shared memory, you should use dynamic linking to avoid symbol conflicts. More generally, dynamic linking should be used every time you run 2 or more *Connext* applications as Kernel tasks of the same VxWorks target.

3.4 Special Note for VxWorks Users using RTP Mode

If you will be running in RTP mode, the test runs in a separate process from the kernel and thus has a regular "main" function. None of the above limitations exist for RTP mode processes.

There is no high-resolution clock available for VxWorks in RTP mode, so do not try running a Latency Publisher in RTP mode because it would not be able to measure delays with the required accuracy. Be advised that while RTPs provide the advantage of being separated from the kernel, they have a latency much greater than kernel tasks, because RTPs still have to rely on the kernel.

3.5 Special Note for QNX Users

The reading of high-resolution timestamps on QNX systems is not implemented in the RTI libraries. Therefore, do not run a Latency Publisher on a QNX target, because it will not be able to measure delays with the required accuracy.

4 Command-Line Options

As you will see in Table 4.1, all options are preceded by a minus sign (-). Some options take additional information where required. Test output can be captured using redirection on the command line.

All parameters are optional; the defaults can be found in the main function (vx_publisher_main and vx_subscriber_main for VxWorks Kernel Mode).

For examples, please see Example Command-Line Options (Section 5).

5 Example Command-Line Options

In the following tests, start the publisher first, so that it can wait for subscribers to come online.

In Table 5.1, pub_IP, sub1_IP, sub2_IP, sub3_IP, sub4_IP represent the IP addresses of the publisher, subscriber 1, subscriber 2, subscriber 3, and subscriber 4, respectively. All IP addresses must belong to the same network. In the Scenario column, BE means Best Effort reliability, SR means Strict Reliability; 1-4 means 1 publisher to 4 subscribers.

Table 4.1 **Command-Line Options**

Option	Publishing Application	Subscribing Application
`-domainId #`	Sets the domain ID. This test can be run at the same time as other *Connext* applications, provided that the domain ID is unique.	
`-cookie #`	N/A	Sets the 'ID' of the subscriber, starting from 1. This value helps to distinguish the subscribers from each other and to the publisher. It should be unique among the subscribers and not exceed the total number of expected subscribers on the publisher side (set with `-subscribers`). The subscribers should be started in increasing order of their `-cookie` numbers. If you have two or more subscribers, this option is required, combined with `-noecho`.
`-nic <IP>`	Restricts *Connext* to sending output through this interface. This can be the IP address of any available network interface on the machine. By default, *Connext* will attempt to contact all possible subscribing nodes on all available network interfaces. While this may be interesting for some users, we are focusing on a simple case. Even on a multi-NIC machine, the performance over one NIC vs. another may be different (e.g., Gbit vs. 100 Mbit), so choosing the correct NIC is critical for a proper test.	
`-noecho`	N/A	Tells the subscribing application not to echo back received data. In all test arrangements, there needs to be one and only one subscribing application that will echo back data. If there are multiple subscribing applications, all subscribing applications need to specify this argument—except the subscribing application with the highest `-cookie` number. If there is only one subscribing application, this option should *not* be used.
`-transport #`	Determines which transport to use for the test: 1 = UDP over IPv4 2 = Shared Memory 8 = UDP over IPv6 (Please see the Known Issues section of the *RTI Core Libraries and Utilities Release Notes* for information on using IPv6.)	
`-peer <peer>`	Specifies each peer taking part in the test. For the publishing application, specify as many peers as there are subscriber hosts. For example: `-peer shmem://`, `-peer sub_IP`, `-peer sub_HostName` For the subscribing application, you only need to specify the publisher's peer. You can specify up to 32 peers; to change this limit, modify the #definition for LATENCY_MAX_SUBSCRIPTIONS in LatencyGlobalSettings.hxx.	

Table 4.1 **Command-Line Options**

Option	Publishing Application	Subscribing Application
-reliable	Tells the test to use reliable communication. By default, the test uses best-effort communication.	
-mcast_recv_addr <IP>	Specifies the multicast address to use for receiving data.	
-multicast_ttl #	Indicates the number of Time-To-Live (TTL) hops for the multicast packet. This argument must be used for a multicast test.	
-subscribers #	Sets the number of subscribing applications participating in the test. Note that there may be more than one subscribing application (participant) on each node. This should match the largest *-cookie* number of the subscribers.	N/A
-numIter #	Sets the number of data samples to send (no limit).	
-minSize #	Sets the minimum size of the data packet to send. The packet size plus the additional bytes form the *Connext* packet that is sent over the network using the RTPS on-wire protocol. It is the complete packet size, excluding the protocol overhead used in the latency calculation.	
-maxSize #	Sets the maximum size of the data packet to send. By default, the test will send data of up to 8K. The maximum size here must be smaller than the maximum specified by the IDL file.	N/A

Table 5.1 **Example Command-Line Options**

Scenario	Command-Lines Options

1-1 BE over shmem	**Publisher:**
	`-domainId 88 -nic pub_IP -transport 2 -peer shmem:// -subscribers 1 \`
	`-numIter 100000`
	
	Subscriber:
	`-domainId 88 -cookie 1 -nic sub1_IP -transport 2 -peer shmem://`

1-4 BE over shmem	**Publisher:**
	`-domainId 88 -nic pub_IP -transport 2 -peer shmem:// -subscribers 4 \`
	`-numIter 100000`
	
	1st Subscriber:
	`-domainId 88 -cookie 1 -nic sub1_IP -noecho -transport 2 -peer shmem://`
	
	2nd Subscriber:
	`-domainId 88 -cookie 2 -nic sub2_IP -noecho -transport 2 -peer shmem://`
	
	3rd Subscriber:
	`-domainId 88 -cookie 3 -nic sub3_IP -noecho -transport 2 -peer shmem://`
	
	4th Subscriber:
	`-domainId 88 -cookie 4 -nic sub4_IP -transport 2 -peer shmem://`

1-1 SR over shmem	**Publisher:**
	`-domainId 88 -nic pub_IP -transport 2 -peer shmem:// -subscribers 1 \`
	`-numIter 100000 -reliable`
	
	Subscriber:
	`-domainId 88 -cookie 1 -nic sub1_IP -transport 2 -peer shmem:// -reliable`

1-4 SR over shmem	**Publisher:**
	`-domainId 88 -nic pub_IP -transport 2 -peer shmem:// -subscribers 4 \`
	`-numIter 100000 -reliable`
	
	1st Subscriber:
	`-domainId 88 -cookie 1 -nic sub1_IP -noecho -transport 2 \`
	`-peer shmem:// -reliable`
	
	2nd Subscriber:
	`-domainId 88 -cookie 2 -nic sub2_IP -noecho -transport 2 \`
	`-peer shmem:// -reliable`
	
	3rd Subscriber:
	`-domainId 88 -cookie 3 -nic sub3_IP -noecho -transport 2 \`
	`-peer shmem:// -reliable`
	
	4th Subscriber:
	`-domainId 88 -cookie 4 -nic sub4_IP -transport 2 -peer shmem:// -reliable`

Table 5.1 **Example Command-Line Options**

Scenario	Command-Lines Options

1-1 BE over UDP unicast	**Publisher:**
	`-domainId 88 -nic pub_IP -transport 1 -peer sub1_IP -subscribers 1 \`
	`-numIter 100000`
	
	Subscriber:
	`-domainId 88 -cookie 1 -nic sub1_IP -transport 1 -peer pub_IP`

1-4 BE over UDP unicast	**Publisher:**
	`-domainId 88 -nic pub_IP -transport 1 -peer sub1_IP -peer sub2_IP \`
	`-peer sub3_IP -peer sub4_IP -subscribers 4 -numIter 100000`
	
	1st Subscriber:
	`-domainId 88 -cookie 1 -nic sub1_IP -noecho -transport 1 -peer pub_IP`
	
	2nd Subscriber:
	`-domainId 88 -cookie 2 -nic sub2_IP -noecho -transport 1 -peer pub_IP`
	
	3rd Subscriber:
	`-domainId 88 -cookie 3 -nic sub3_IP -noecho -transport 1 -peer pub_IP`
	
	4th Subscriber:
	`-domainId 88 -cookie 4 -nic sub4_IP -transport 1 -peer pub_IP`

1-4 BE over UDP multicast	**Publisher:**
	`-domainId 88 -nic pub_IP -transport 1 -peer sub1_IP -peer sub2_IP \`
	`-peer sub3_IP -peer sub4_IP -subscribers 4 -numIter 100000 \`
	`-mcast_recv_addr 225.1.2.3 -multicast_ttl 1`
	
	1st Subscriber:
	`-domainId 88 -cookie 1 -nic sub1_IP -noecho -transport 1 -peer pub_IP \`
	`-mcast_recv_addr 225.3.2.1 -multicast_ttl 1`
	
	2nd Subscriber:
	`-domainId 88 -cookie 2 -nic sub2_IP -noecho -transport 1 -peer pub_IP \`
	`-mcast_recv_addr 225.3.2.1 -multicast_ttl 1`
	
	3rd Subscriber:
	`-domainId 88 -cookie 3 -nic sub3_IP -noecho -transport 1 -peer pub_IP \`
	`-mcast_recv_addr 225.3.2.1 -multicast_ttl 1`
	
	4th Subscriber:
	`-domainId 88 -cookie 4 -nic sub4_IP -transport 1 -peer pub_IP \`
	`-mcast_recv_addr 225.3.2.1 -multicast_ttl 1`

6 Output Analysis

Typical Output from Publishing Application:

```
Connext Latency Test - Publisher
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Modifying RTI receive thread priorities from priority = -9999999 to -9999999
Modifying RTI database thread priorities from priority = -9999999 to -9999999
Modifying RTI event thread priorities from priority = -9999999 to -9999999
UDP enabled. Socket sendBuffer size = 8712, receiveBuffer size = 17424.
Successfully registered UDPv4 transport
Waiting for 2 receivers...[1]...[2]
Echoer restricted to the one in place #2, identified to have cookie 2.
Collecting statistics on 10000 samples per message size.
This is the roundtrip time, *not* the one-way-latency
bytes ,stdev us,ave us, min us, 50% us, 90% us, 99% us, 99.99%, max us
------,-------,-------,-------,-------,-------,-------,--------,-------
    16,   45.5,  114.0,   91.5,  104.0,  135.0,  210.0, 1790.0, 2078.5
    32,   81.1,  131.1,  101.5,  112.0,  178.0,  342.0, 1480.0, 6384.5
    64,   46.2,  118.6,  101.5,  111.0,  148.0,  206.0, 1430.0, 3006.5
   128,   46.2,  118.6,  100.5,  111.0,  134.0,  232.0, 2140.0, 2630.5
   256,   20.9,  114.4,  101.5,  111.0,  127.0,  180.0,  452.0, 1054.5
   512,   22.7,  117.4,  103.5,  113.0,  132.0,  192.0,  476.0,  511.5
  1024,   36.0,  123.5,  105.5,  114.0,  159.0,  240.0,  624.0, 1959.5
  2048,   52.8,  129.1,  108.5,  117.0,  161.0,  250.0, 2320.0, 2336.5
  4096,   32.5,  130.7,  110.5,  124.0,  132.0,  244.0, 1420.0, 1456.5
  8192,   67.1,  147.6,  126.5,  136.0,  196.0,  272.0, 2260.0, 4662.5
Test successful!
```

Typical Output from Subscribing Application:

```
Connext Latency Test - Subscriber
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Modifying RTI receive thread priorities from priority = -9999999 to -9999999
Modifying RTI database thread priorities from priority = -9999999 to -9999999
Modifying RTI event thread priorities from priority = -9999999 to -9999999
UDP enabled. Socket sendBuffer size = 8712, receiveBuffer size = 17424.
UDPv4 enabled
Test successful: 10011 messages received, 10011 replies sent.
```

Explanation of Results:

If you see the following output from the Publisher:

```
roundtrip time <= 0
```

This may be a symptom that the resolution of the Publisher's clock is not fine enough and thus is returning a round-trip time of zero. To correct this, ensure the clock has a high enough resolution, or lengthen the payload to add enough delay so that the round-trip time is non-zero.

When we run a latency test, each sample varies slightly from either the average or the median. Thus, the determinism of the result can be measured by the width of the Poisson distribution. On a completely deterministic OS in an isolated network with no other network activity (which is hard to accomplish), the width should be infinitesimally small.

Details on each column of the results:

- Size is the size of the data packet in bytes.

- ❏ Minimum latency, which shows what the middleware is capable of doing in the best possible case. Since there is no guarantee that a run will actually hit this best case, the minimum may not increase as the payload grows. But as the sample size grows, the likelihood of such aberration decreases asymptotically.
- ❏ Latency at 50th percentile, also known as the median. Half of the samples had latency lower than this, and the other half had higher.
- ❏ Latency at 90th percentile
- ❏ Latency at 99th percentile
- ❏ Latency at 99.99th percentile, which means that only 0.01% of the samples (or 1 out of 10,000 samples) exhibited latency larger than this
- ❏ Maximum latency
- ❏ Standard deviation