ROS 2 Network Monitoring

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Agenda

01 Motivation
- Introduction to the statistics toolkit
- Available data in the statistics toolkit

02 Fast DDS Statistics Module
- Introduction to the Statistics Module
- How to enable Fast DDS Statistics on ROS 2

03 Fast DDS Statistics Backend
- Library overview
- Demo: Exporting statistics data to Prometheus and visualizing with Grafana

04 ROS 2 Monitor
- GUI overview
- Demo: Visualize demo_nodes_cpp statistics
- Demo: Network bandwidth at discovery phase
Motivation

Use cases of the Fast DDS statistics toolkit

Real-time network status monitoring
Show the data supplied by a network monitor.

Measure endpoints discovery time
Compute globally the total time of the discovery phase per each pair of endpoints.
Motivation

**ROS 2 user action items**

- **Minimize communications latency**
  The network monitor will report the communications latency.

- **Maximize publication's throughput**
  Monitor the throughput so that the rate of packets/bytes sent per second can be maximized.

- **Minimize packet loss**
  Monitor packet loss to reduce the number of lost/dropped packets by adjusting the publication settings.
## Reported data

**Available statistics data in the Fast DDS Statistics toolkit**

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<thead>
<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Fast DDS Latency</td>
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<td>2</td>
<td>Throughput</td>
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<td></td>
<td>- Subscription’s throughput</td>
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<td>- Publication’s throughput</td>
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<td>3</td>
<td>Re-sent DATA packets</td>
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<td>Discovery time</td>
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<td>5</td>
<td><strong>Sub-messages</strong> sent by each DDS entity and used in the communication:</td>
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<td></td>
<td>- <a href="#">HEARTBEAT</a> (DataWriter)</td>
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<td>- <a href="#">ACK</a> (DataReader)</td>
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<td>- <a href="#">NACK</a> (DataReader)</td>
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<td>- <a href="#">GAP</a> (DataWriter)</td>
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<td>- <a href="#">DATA</a> (DataWriter)</td>
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<td>6</td>
<td>Meta-traffic packets transmitted by each DDS entity:</td>
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<td></td>
<td>- Discovery meta-traffic</td>
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<td>- <a href="#">PDP packets</a></td>
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<td>- Reliability meta-traffic</td>
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<td>- <a href="#">HEARBEATs</a></td>
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<td>- <a href="#">ACKNACKs</a></td>
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Fast DDS Statistics Toolkit

Fast DDS statistics toolkit components within the ROS 2 stack
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Fast DDS statistics toolkit components within the ROS 2 stack

1. Statistics Module
   - FAST DDS

2. Statistics Backend
   - rclcpp
   - rclpy
   - rcljava
   - rmw
   - rmw_fastrtps

3. Monitor
   - Custom User App
Fast DDS Statistics Module

A Fast DDS extension that enables the recollection of data concerning the DDS communication.
Fast DDS Statistics Toolkit

Fast DDS statistics toolkit components within the ROS 2 stack
Fast DDS Statistics Module

Key concepts and operation of Fast DDS Statistics Module

- Extension of DDS Layer
- Fast DDS collects the data describing its operation
- Internal DomainParticipant (ROS 2 context)
- One builtin Publisher for each data type (latency, throughput, data lost, etc.)
- One can subscribe to this topics directly to retrieve the raw data

_ fastdds_statistics_history2history_latency  
_ fastdds_statistics_subscription_throughput  
_ fastdds_statistics_heartbeat_count  
_ fastdds_statistics_gap_count  
_ fastdds_statistics_sample_data  
_ fastdds_statistics_discovered_entity  
_ fastdds_statistics_network_latency  
_ fastdds_statistics_rtps_sent  
_ fastdds_statistics_acknack_count  
_ fastdds_statistics_data_count  
_ fastdds_statistics_pdp_packets  
_ fastdds_statistics_physical_data  
_ fastdds_statistics_rtps_lost  
_ fastdds_statistics_nackfrag_count  
_ fastdds_statistics_resent_data  
_ fastdds_statistics_edp_packets  

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Fast DDS Statistics Module

Main concerns about Fast DDS Statistics Module in ROS 2

- Available in:
  - ROS 2 Humble (Fast DDS v2.6.2)
  - ROS 2 Galactic (Fast DDS v2.3.5)
- Disabled by default
- Enabled at compilation
How to enable Statistics

Steps to enable Fast DDS Statistics Module on ROS 2 Humble

1. Install ROS 2 Humble
2. Build Fast DDS from sources with FASTDDS_STATISTICS=ON
   
   $ colcon build --cmake-args -DFASTDDS_STATISTICS=ON
3. Source the ROS 2 Humble environment
   
   $ source /opt/ros/humble/setup.bash
4. Source the built Fast DDS environment (overlay)
   
   $ source <path/to/fastdds_ws>/install/setup.bash

At this point the Statistics Module is **compiled but not enabled**!

5. Enable by XML configuration file or setting an environment variable
   
   $ export FASTDDS_STATISTICS="HISTORY_LATENCY_TOPIC;NETWORK_LATENCY_TOPIC;PUBLICATION_THROUGHPUT_TOPIC;
   SUBSCRIPTION_THROUGHPUT_TOPIC;RTPS_SENT_TOPIC;RTPS_LOST_TOPIC;HEARTBEAT_COUNT_TOPIC;
   ACKNACK_COUNT_TOPIC;NACKFRAG_COUNT_TOPIC;GAP_COUNT_TOPIC;DATA_COUNT_TOPIC;RESENT_DATAS_TOPIC;
   SAMPLE_DATAS_TOPIC;PDP_PACKETS_TOPIC;EDP_PACKETS_TOPIC;DISCOVERY_TOPIC;PHYSICAL_DATA_TOPIC"
Fast DDS Statistics Backend

C++ library to collect data from the Fast DDS Statistics Module, and generate statistical information to be used by applications.
Fast DDS Statistics Toolkit

**Fast DDS statistics toolkit components within the ROS 2 stack**
Main features

**Main features of the Fast DDS Statistics Backend**

- **In-memory database**
- **C++ library** to access entities discovered and its statistics issued by Fast DDS
- Deploy **DataReaders subscribed to statistics topics** (Statistics Module)
- **Records the DDS entities** (DomainParticipant, DataReader / DataWriter, Locator, Domain and Topic) and **Physical entities** (Host, User, Process) discovered in a Domain
- **Compute the statistics** (mean, std. dev, median, max, min, sum) on the stored data
- **Full documentation and examples available on ReadTheDocs.**
Exporting statistics from ROS 2 using the Fast DDS Statistics Backend to Prometheus and visualizing with Grafana
Statistics, Prometheus & Grafana

Exporting statistics from ROS 2 using the Fast DDS Statistics Backend to Prometheus and visualizing with Grafana
ROS 2
Monitor

Graphical User Interface to monitor a ROS 2 network in real-time, with introspection methods and statistical data measure capabilities.
Fast DDS Statistics Toolkit

Fast DDS statistics toolkit components within the ROS 2 stack

Application

Custom User App

Monitor

Statistics Backend

rclcpp
rclpy
rcljava

rcl
rmw
rmw_fastrtps

Statistics Module

FAST DDS
ROS 2 Monitor

Overview of ROS 2 Monitor graphical user interface
Normal operation

Normal operation of ROS 2 Monitor
Main features

Listing DDS and physical entities

1. List of all DDS and physical entities discovered
Main features

Initializing a monitor

2. Initialize a monitor in a DDS Domain or in a Discovery Server network
Main features
Compatible with ROS 2 Discovery Server networks

Initialize Monitor in a Discovery Server network
Main features

Real-time statistics visualization

Visualize in real-time the main statistics of each entity
Main features

Live configurable charts for every reported data

Create interactive real-time charts
Main features

Exporting recorded data in CSV format

Export all recorded data in CSV format
Custom features for ROS 2

Monitoring meta-traffic ROS 2 nodes and topics
Custom features for ROS 2

Hiding meta-traffic ROS 2 nodes and topics
Custom features for ROS 2

Monitoring actual user data ROS 2 nodes and topics
Talker & Listener network statistics

Visualize talker & listener demo_nodes_cpp network statistics with Fast DDS Monitor
Discovery traffic analysis

Network traffic comparative between default ROS 2 nodes discovery and ROS 2 Discovery Server