

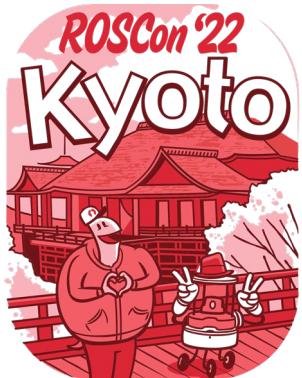


ROS 2 Network Monitoring

ROSCon 2022

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Agenda



01

Motivation



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

03

Fast DDS Statistics Backend



- Library overview
- Demo: Exporting statistics data to Prometheus and visualizing with Grafana

02

Fast DDS Statistics Module



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

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



1 Fast DDS Latency

2 Throughput

- Subscription's throughput
- Publication's throughput

3 Re-sent DATA packets

4 Discovery time

5

Sub-messages sent by each DDS entity and used in the communication:

- HEARTBEAT (DataWriter)
- ACK (DataReader)
- NACK (DataReader)
- GAP (DataWriter)
- DATA (DataWriter)

6

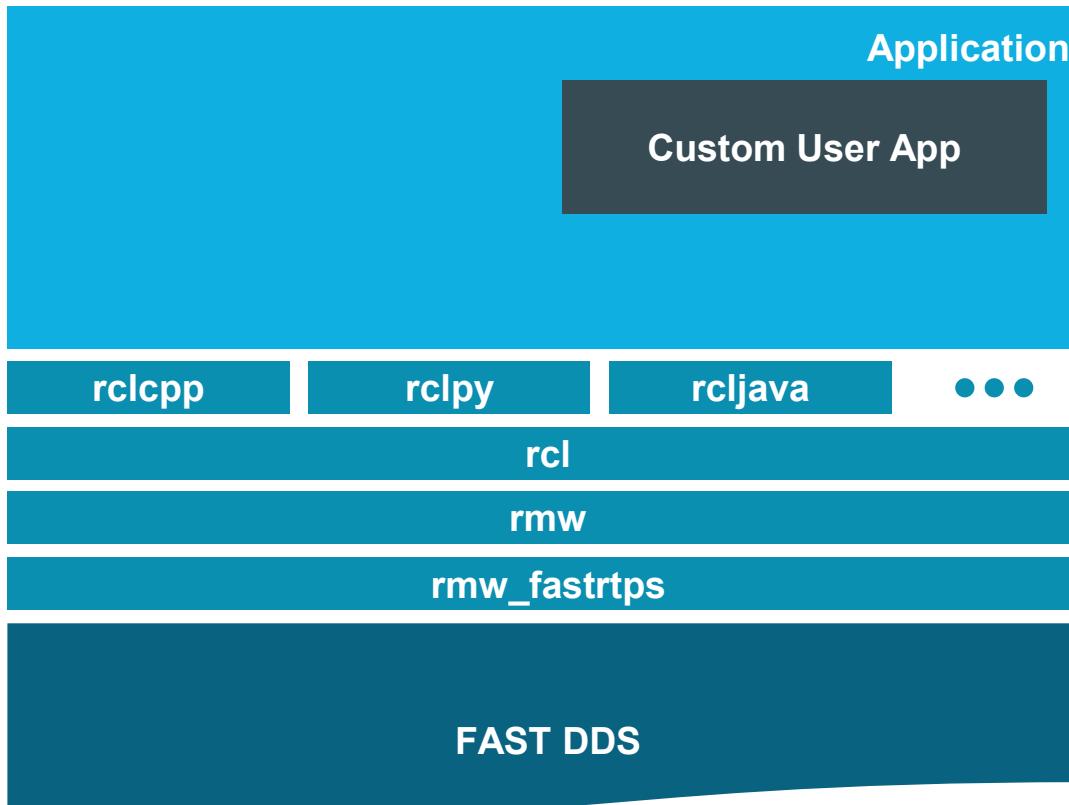
Meta-traffic packets transmitted by each DDS entity:

- Discovery meta-traffic
 - PDP packets
 - EDP packets
- Reliability meta-traffic
 - HEARBEATs
 - ACKNACKs

Fast DDS Statistics Toolkit



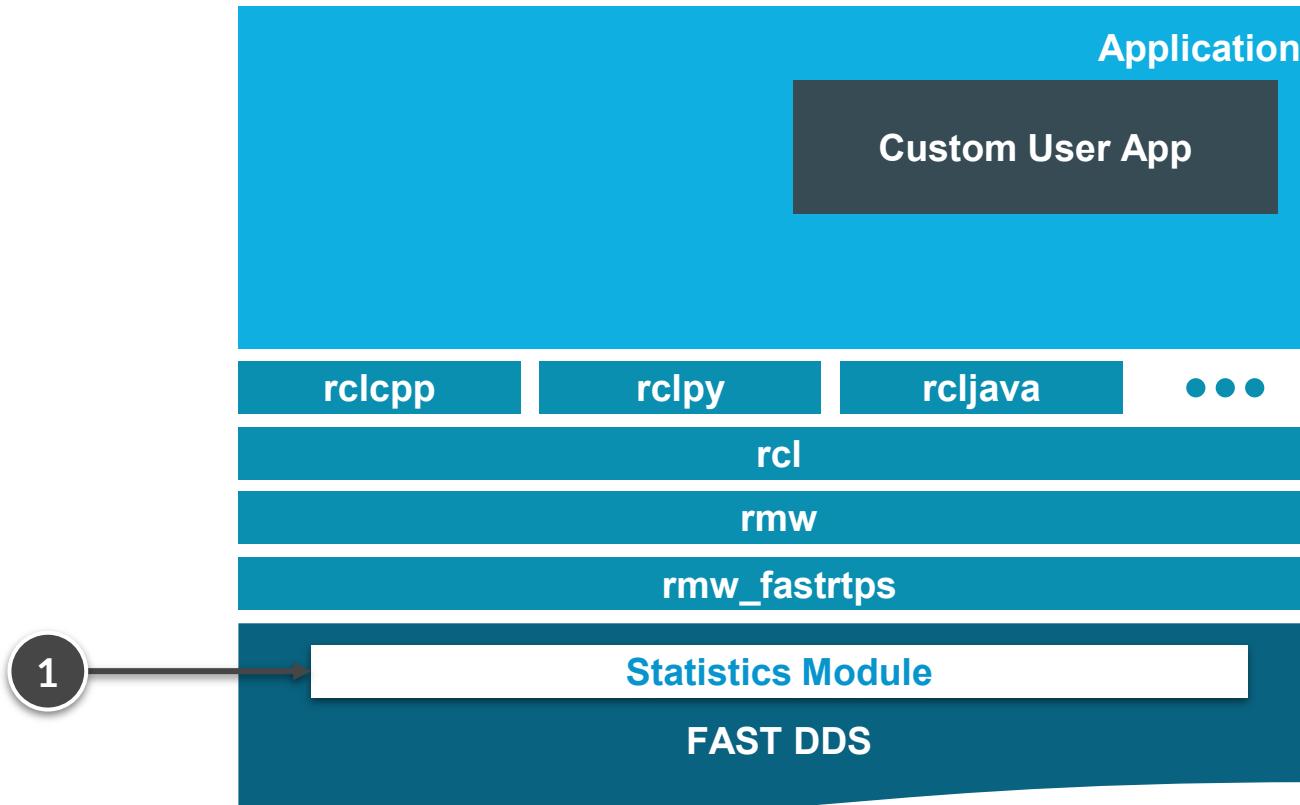
Fast DDS statistics toolkit components within the ROS 2 stack



Fast DDS Statistics Toolkit



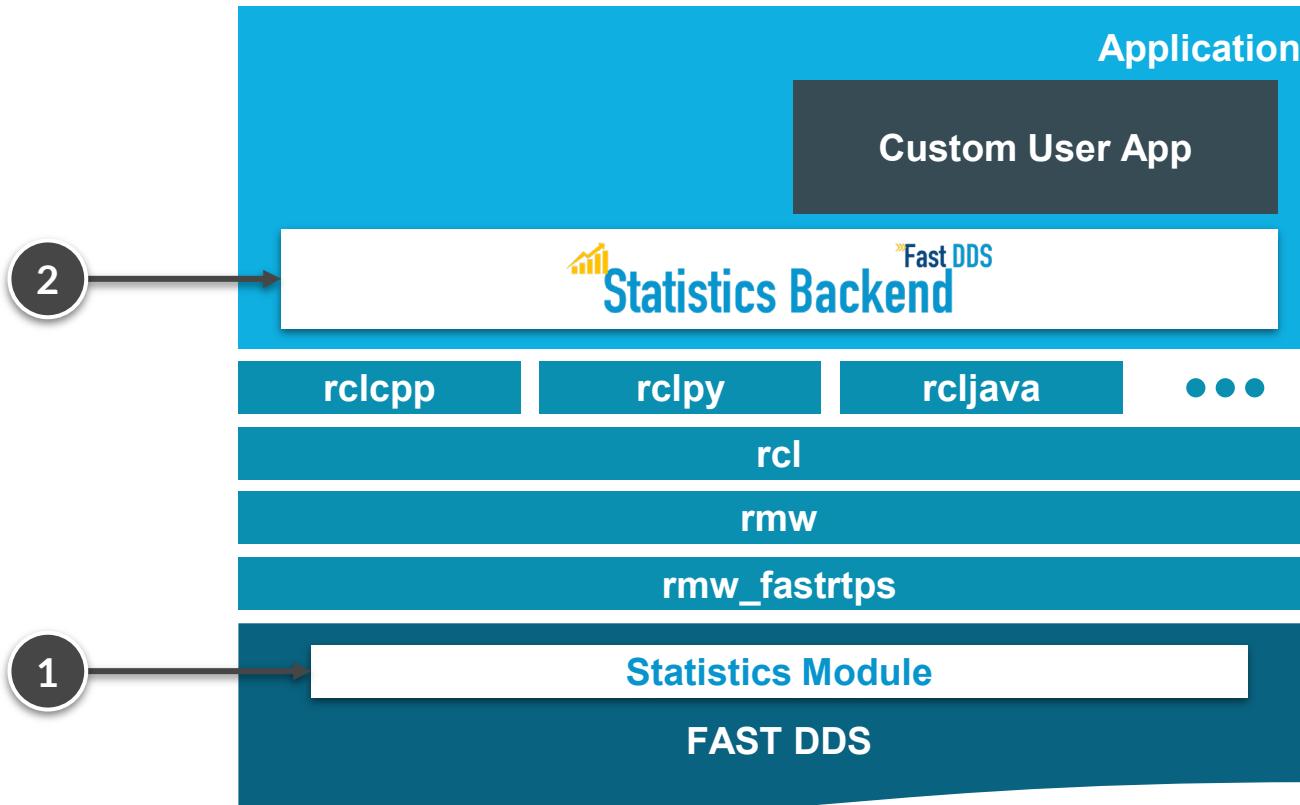
Fast DDS statistics toolkit components within the ROS 2 stack



Fast DDS Statistics Toolkit



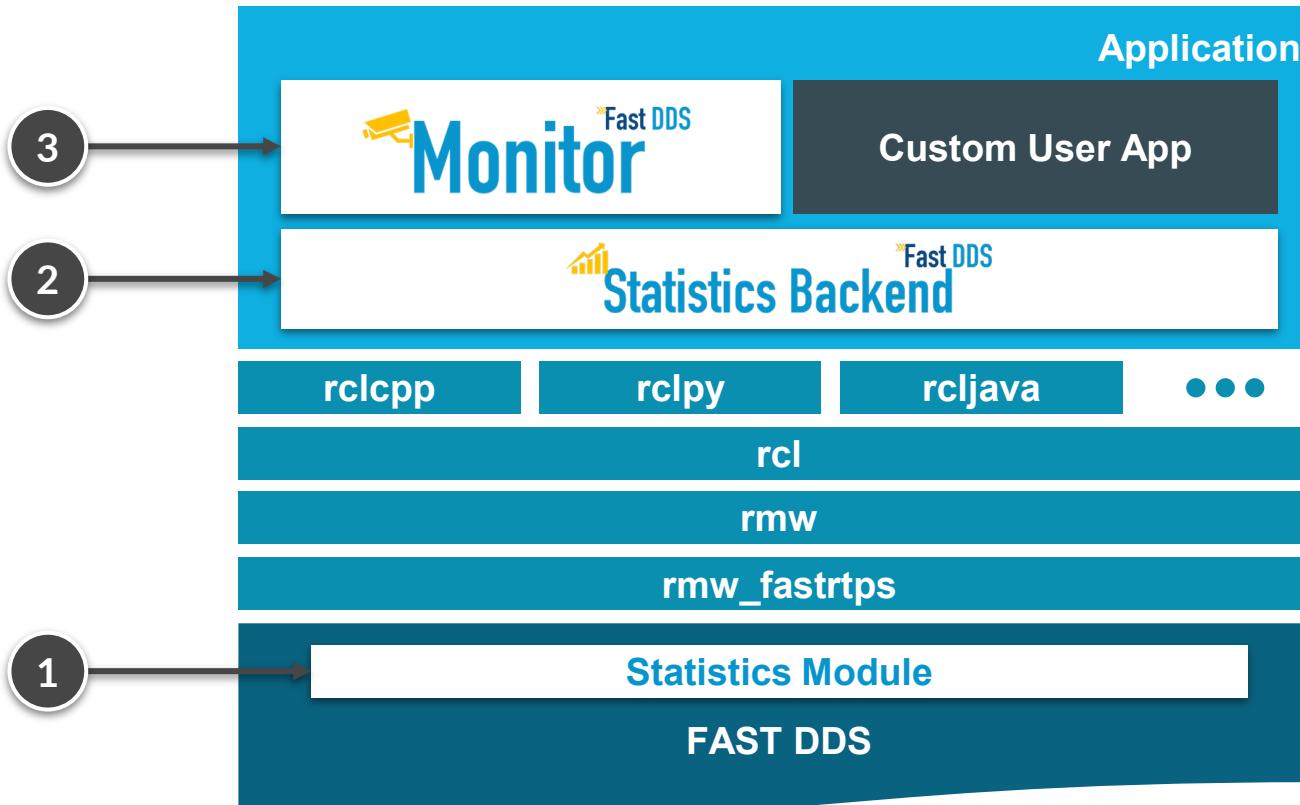
Fast DDS statistics toolkit components within the ROS 2 stack



Fast DDS Statistics Toolkit



Fast DDS statistics toolkit components within the ROS 2 stack





Fast DDS Statistics Module

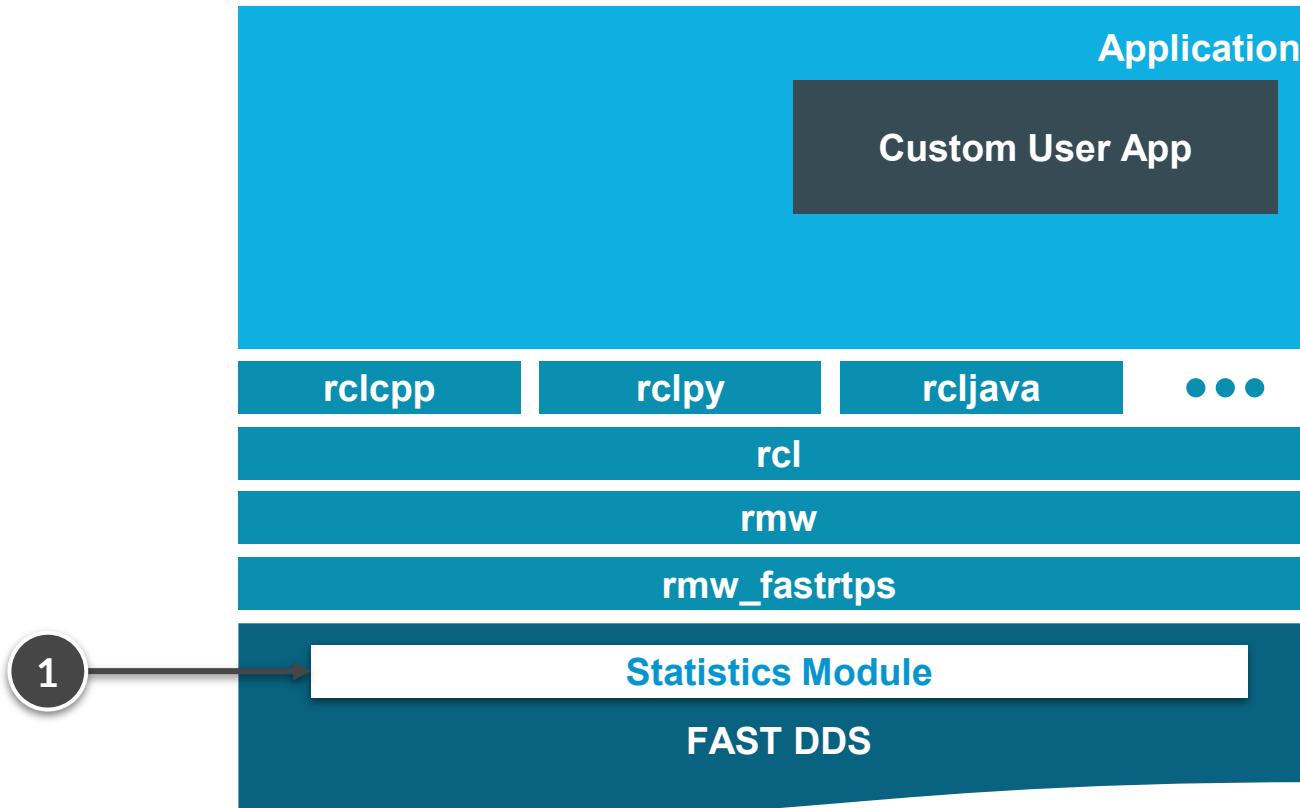
A Fast DDS extension that enables the recollection of data concerning the DDS communication.



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_datas
_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_publication_throughput
_fastdds_statistics_rtps_lost
_fastdds_statistics_nackfrag_count
_fastdds_statistics_resent_datas
_fastdds_statistics_edp_packets

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
- 4 Source the built Fast DDS environment (overlay)

```
$ source /opt/ros/humble/setup.bash
```

```
$ 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

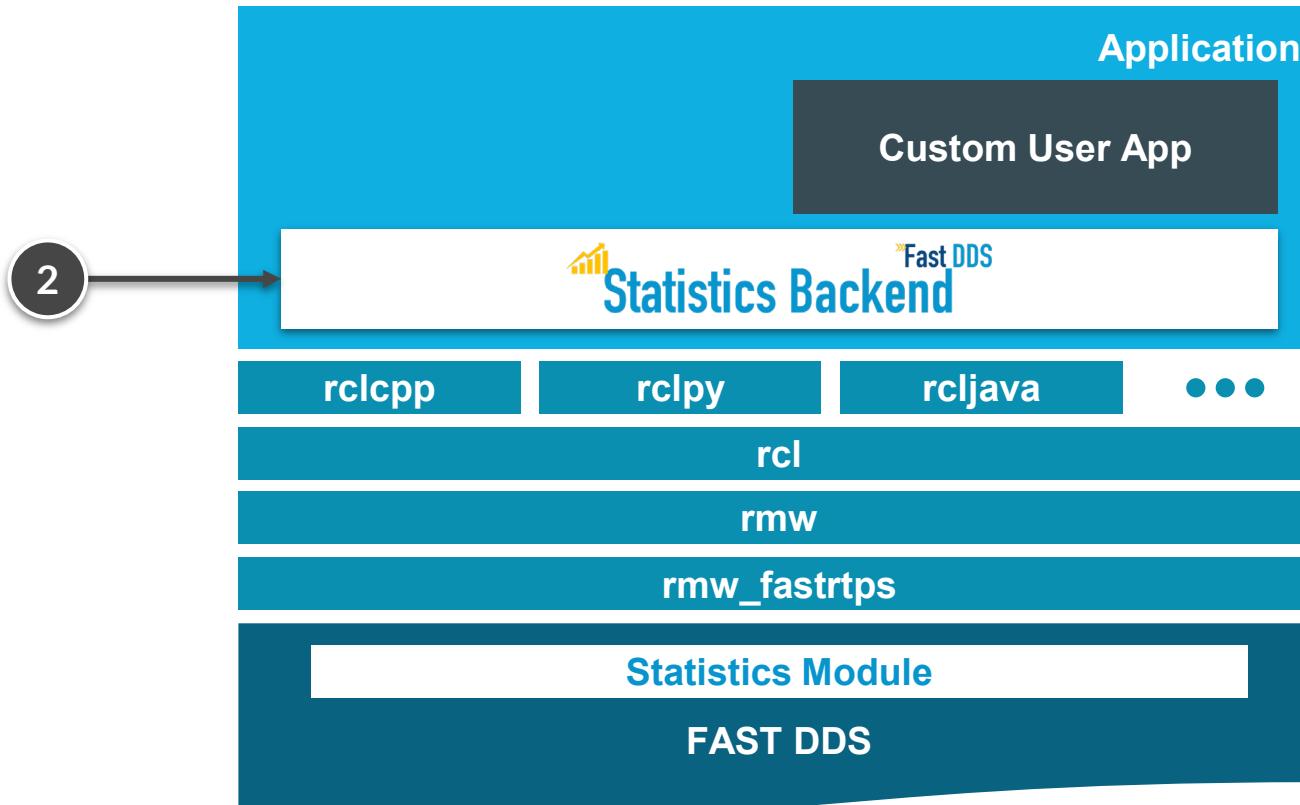
C++ library to collect data from the Fast DDS Statistics Module, and generate statistical information to be used by applications.



Fast DDS Statistics Toolkit



Fast DDS statistics toolkit components within the ROS 2 stack



Main features

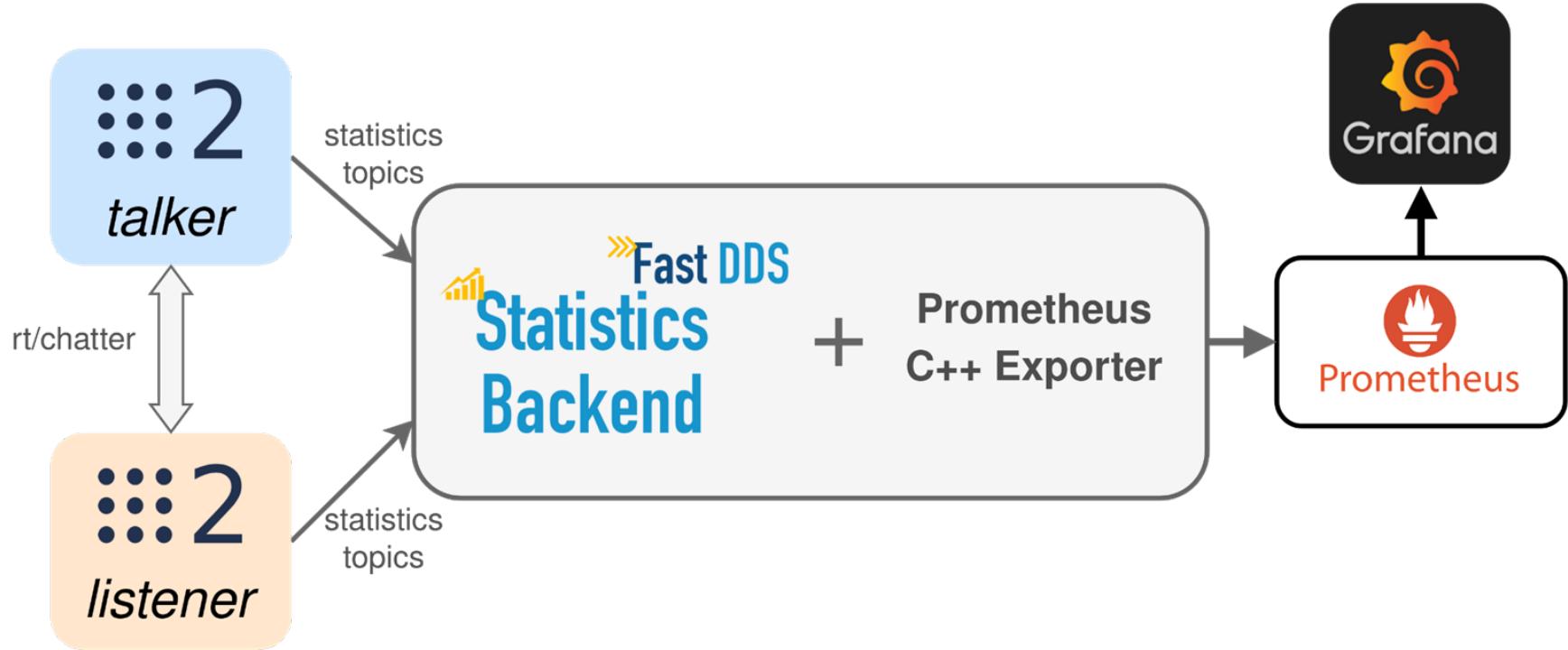
Main features of the Fast DDS Statistics Backend



Statistics, Prometheus & Grafana



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





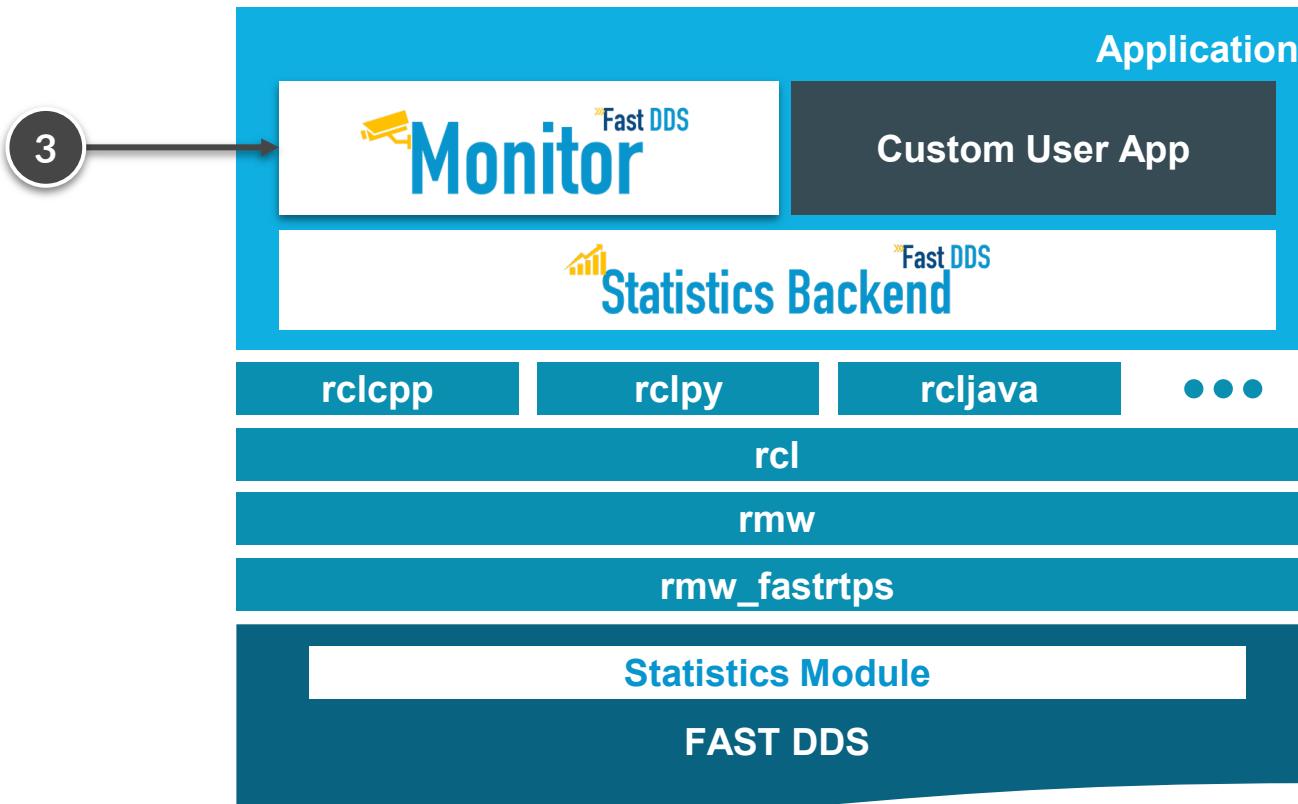
ROS 2 Monitor

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



ROS 2 Monitor

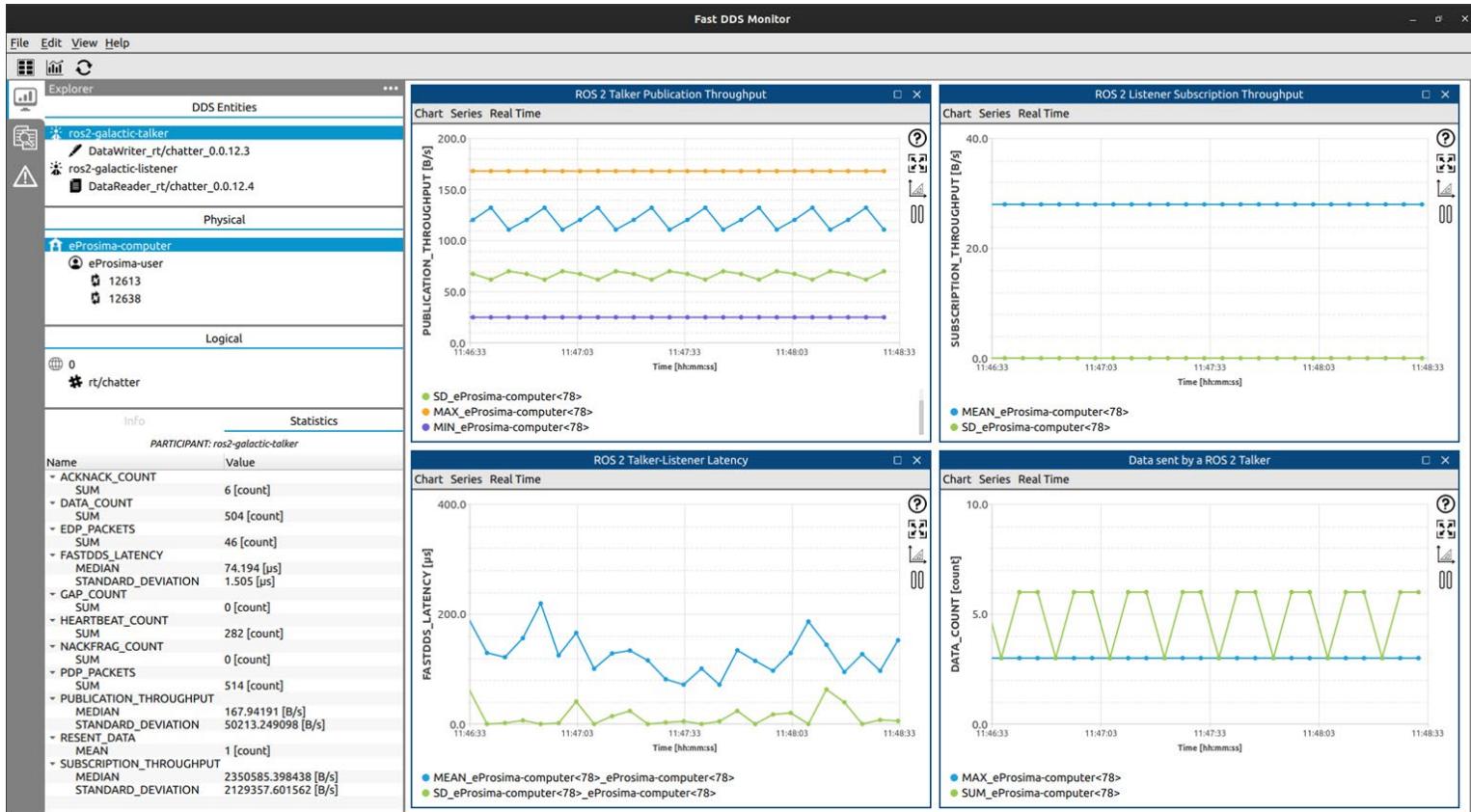
Overview of ROS 2 Monitor graphical user interface



The screenshot displays the ROS 2 Monitor graphical user interface, specifically the Fast DDS Monitor window. The main window features a large "Start monitoring!" button at the bottom left. On the left, the "DDS Entities" section of the "Explorer" panel shows a tree structure with nodes: "Participant_pub" (with two entries), "Participant_sub" (with one entry), and "DataReader_HelloWorldTopic_0.0.1.4". The right side of the window contains a "Fast DDS Monitor" interface with tabs for "File", "Edit", "View", and "Help". The "File" tab includes options like "Init new monitor", "Display historical data", "Display real-time data", and "Refresh". A central pane shows "DOS Entities" with an "Info" tab displaying "No entity selected" and "Statistics" tab showing "No monitors active.". A modal dialog titled "Init Monitor" is open, showing "Simple Discovery" selected under "Discovery Server" and a "DDS domain:" field set to 0. Below the monitor interface is a chart titled "Chart Series Real Time" showing "FASTDDS_LATENCY [Dynamic]". The chart displays three data series: "Real-Time Fast DDS Latency [Standard Deviation]" (red line), "Real-Time Fast DDS Latency [Min]" (blue line), and "Real-Time Fast DDS Latency [Mean]" (green line). The x-axis represents time from 10:00:00 to 10:00:20, and the y-axis represents latency in microseconds from 0.0 to 200.0.

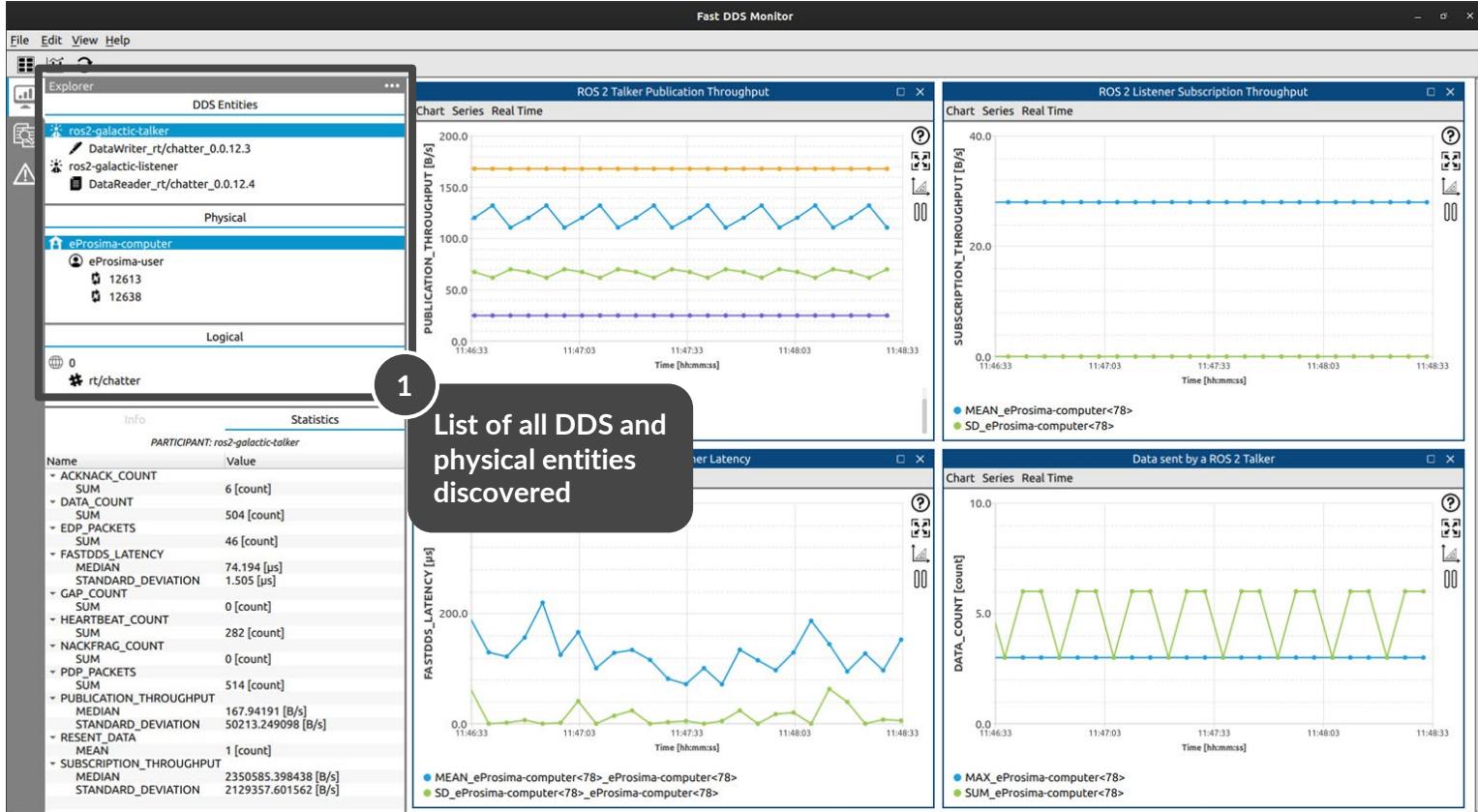
Normal operation

Normal operation of ROS 2 Monitor



Main features

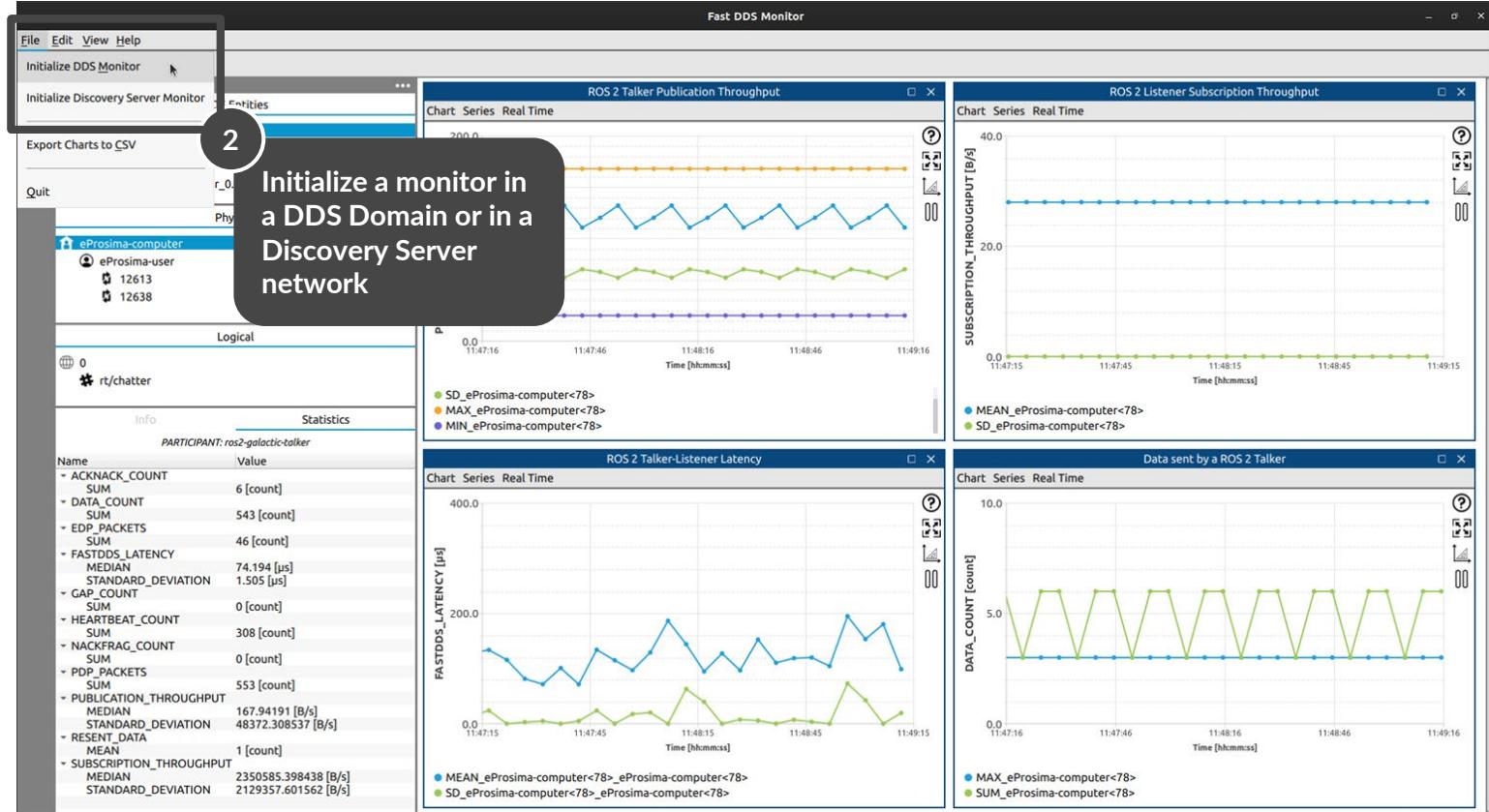
Listing DDS and physical entities



Main features



Initializing a monitor



Main features

Compatible with ROS 2 Discovery Server networks



Fast DDS Monitor

File Edit View Help

Explorer

DDS Entities

- ros2-galactic-talker
 - DataWriter_rt/chatter_0.0.12.3
 - DataReader_rt/chatter_0.0.12.4
- Physical
- eProsimacomputer
 - eProsimacomputer
 - 12613
 - 12638
- Logical
- 0 rt/chatter

Info Statistics

PARTICIPANT: ros2-galactic-talker

Name	Value
ACKNACK_COUNT	6 [count]
DATA_COUNT	582 [count]
EDP_PACKETS	46 [count]
FASTDDS_LATENCY	74.194 [μs] MEDIAN STANDARD_DEVIATION 1.505 [μs]
GAP_COUNT	0 [count]
HEARTBEAT_COUNT	334 [count]
NACKFRAG_COUNT	0 [count]
PDP_PACKETS	592 [count]
PUBLICATION_THROUGHPUT	MEDIAN 167.94191 [B/s] STANDARD_DEVIATION 46720.050143 [B/s]
RESENT_DATA	1 [count]
SUBSCRIPTION_THROUGHPUT	MEDIAN 2350585.398438 [B/s] STANDARD_DEVIATION 2129357.601562 [B/s]

ROS 2 Talker Publication Throughput

Chart Series Real Time

PUBLICATION_THROUGHPUT [B/s]

ROS 2 Listener Subscription Throughput

Chart Series Real Time

OPTION_THROUGHPUT [B/s]

Initialize Discovery Server Monitor

Set the GUID and the network addresses (locators) of a Discovery Server.

Discovery Server GUID:
44.53.00.5f45.50.52.4f.53.49.4d.41

Discovery Server locator(s):
Idx Transport Protocol IP Port

1. UDPv4 127.0.0.1 11811

UDPv6
TCPv4
TCPv6

Add locator row

Restore Defaults Cancel OK

FASTDDS_LATENCY [μs]

Time [hh:mm:ss]

DATA_COUNT

Time [hh:mm:ss]

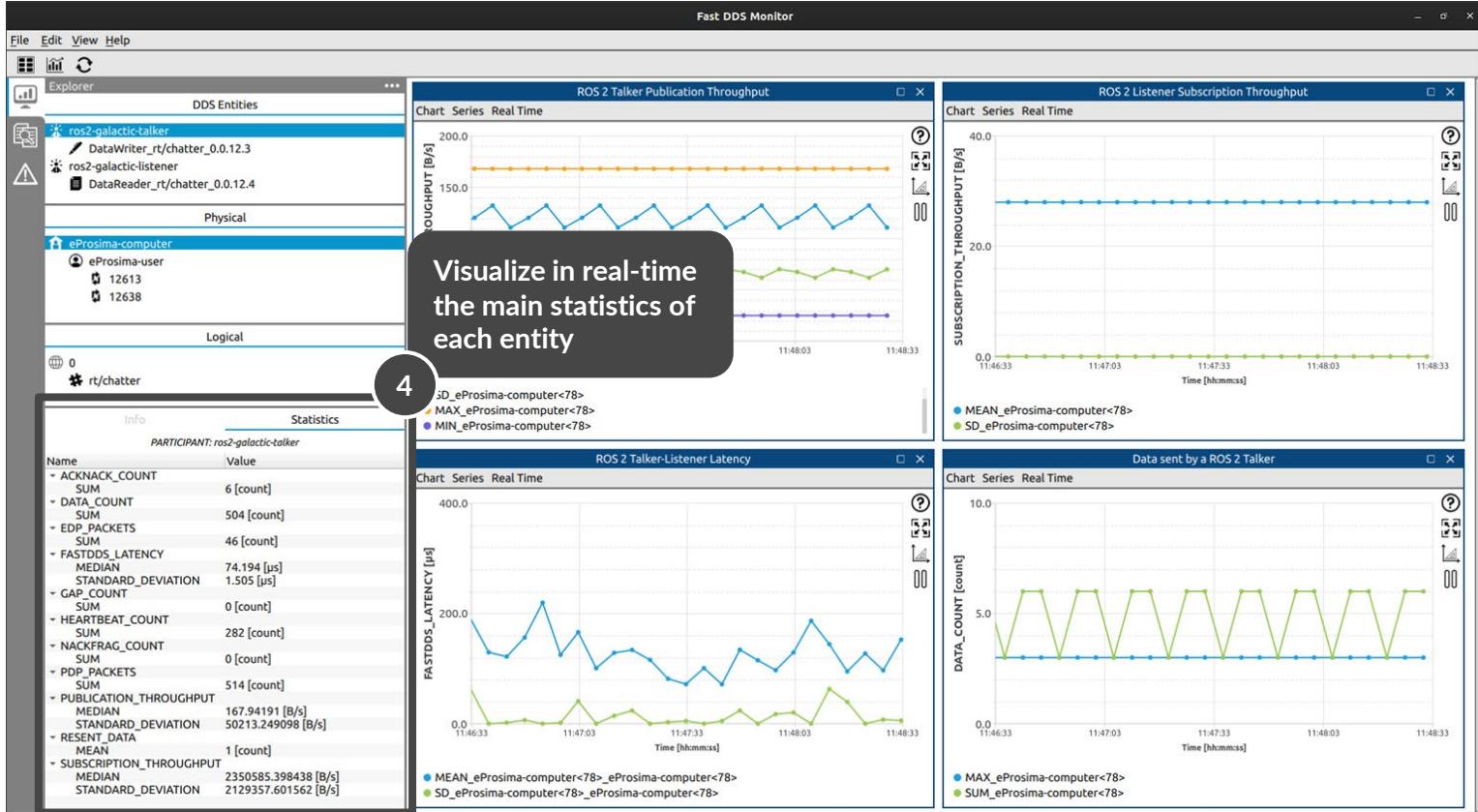
MEAN_eProsimacomputer<78>_eProsimacomputer<78>
SUM_eProsimacomputer<78>_eProsimacomputer<78>

3 Initialize Monitor in a Discovery Server network

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Main features

Real-time statistics visualization



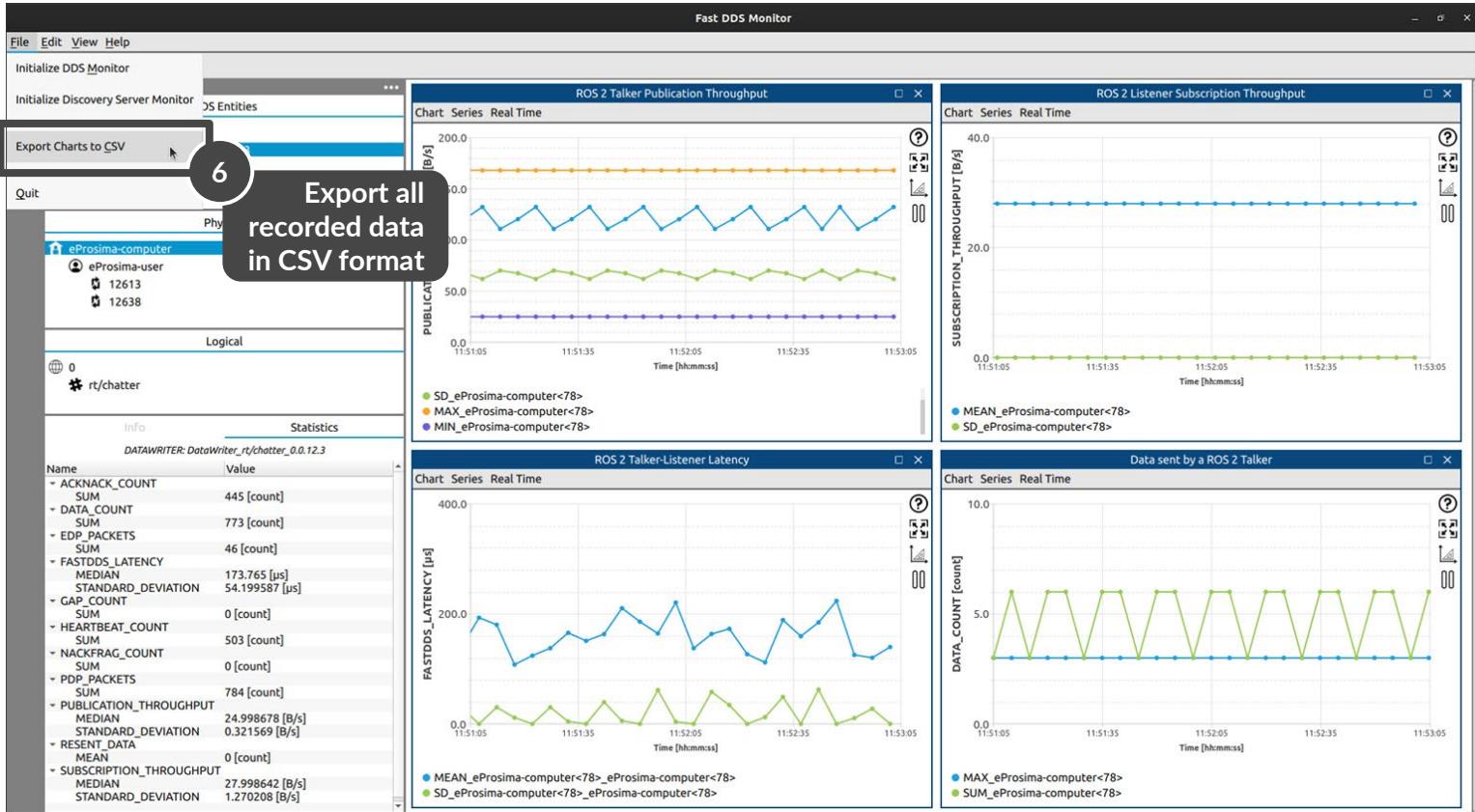
Main features

Live configurable charts for every reported data



Main features

Exporting recorded data in CSV format



Custom features for ROS 2

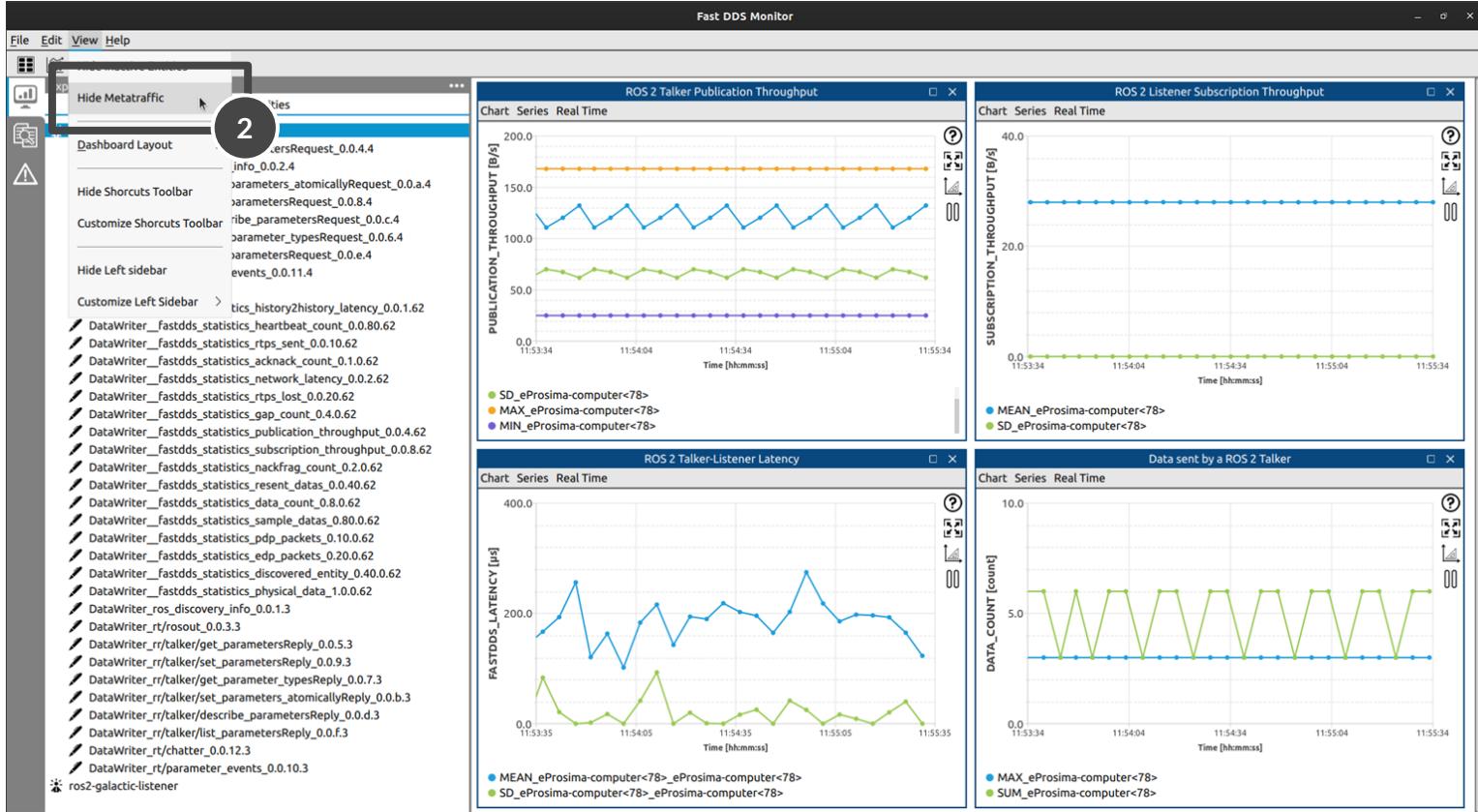
Monitoring meta-traffic ROS 2 nodes and topics



Custom features for ROS 2

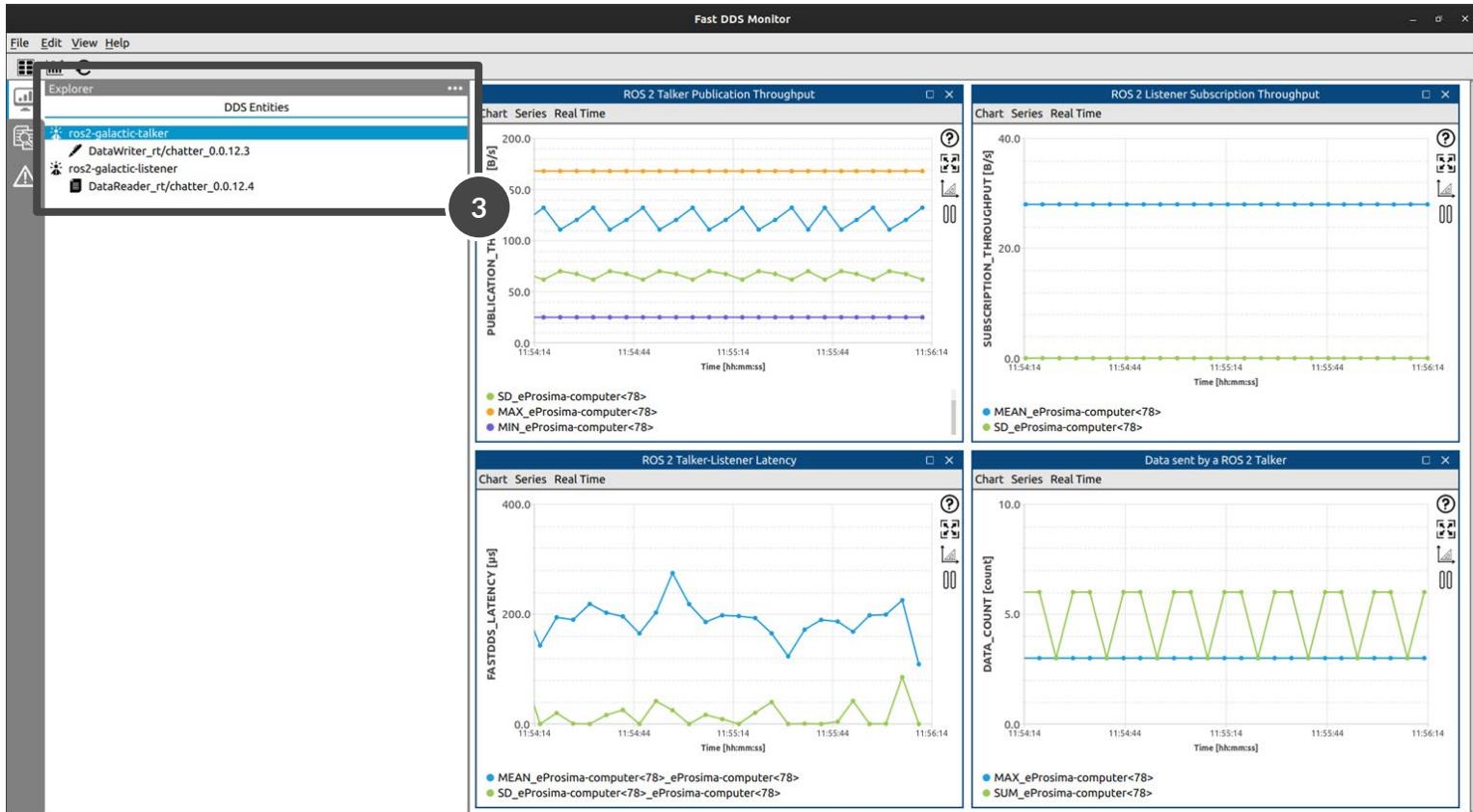


Hiding meta-traffic ROS 2 nodes and topics



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





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