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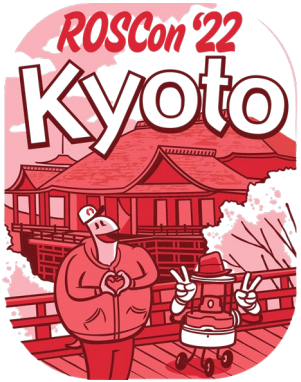
The Middleware Experts



ROS 2 Network Monitoring

ROSCon 2022

Speaker:

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Agenda

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- 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

Computate 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**

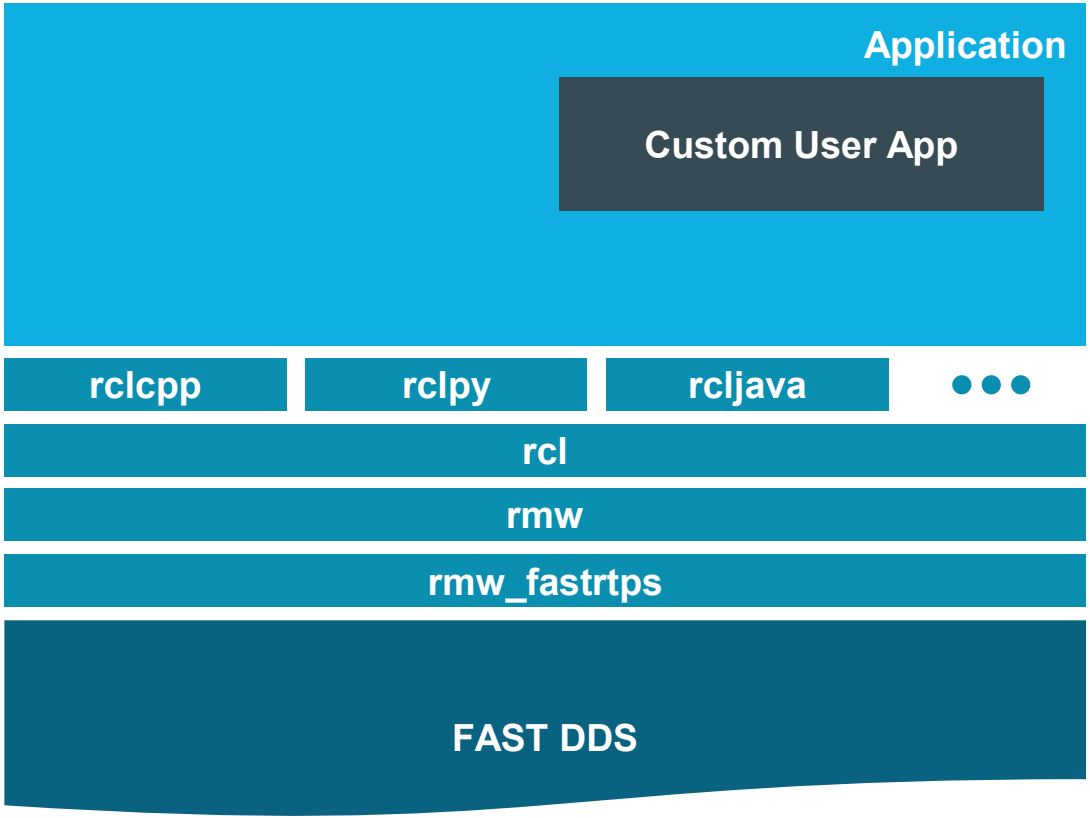
4. **Discovery time**

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

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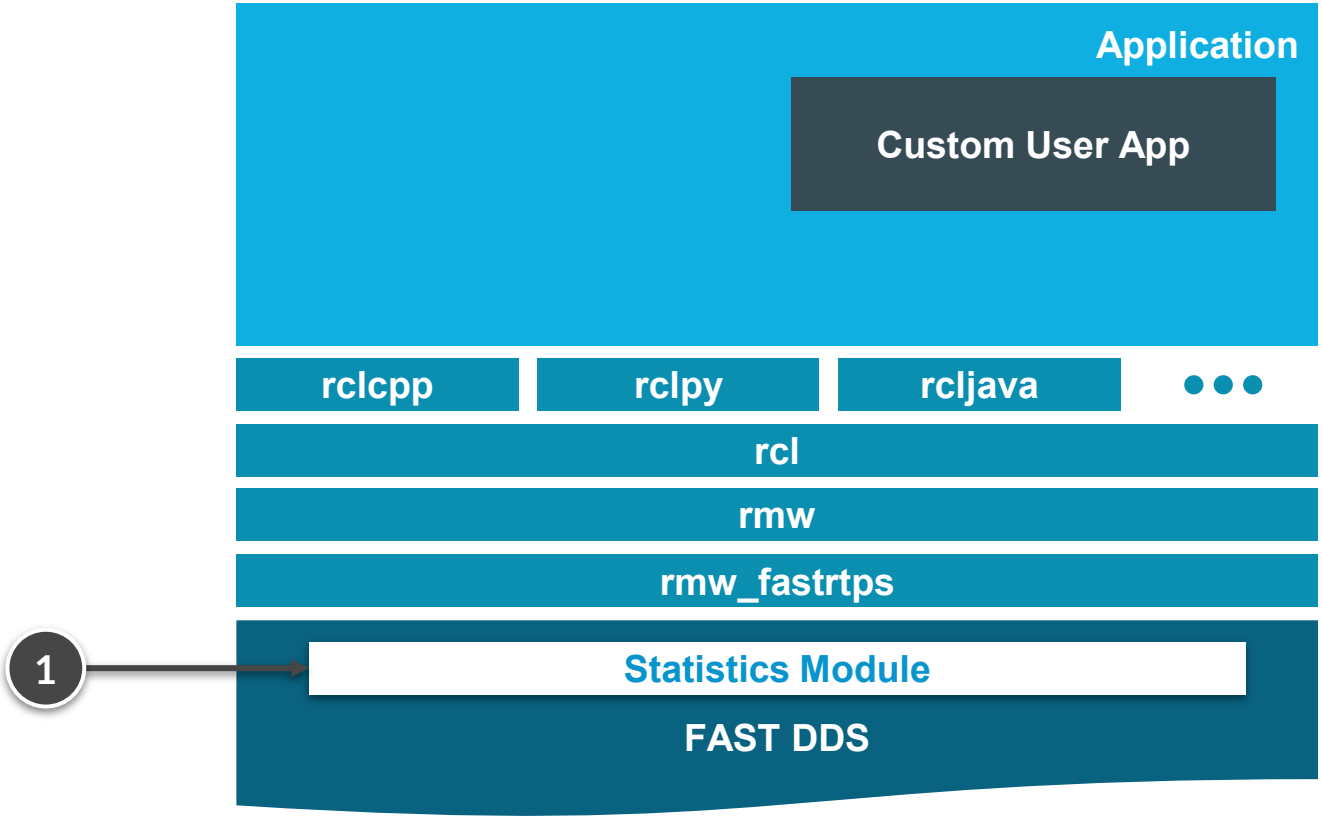

Fast DDS Statistics Toolkit

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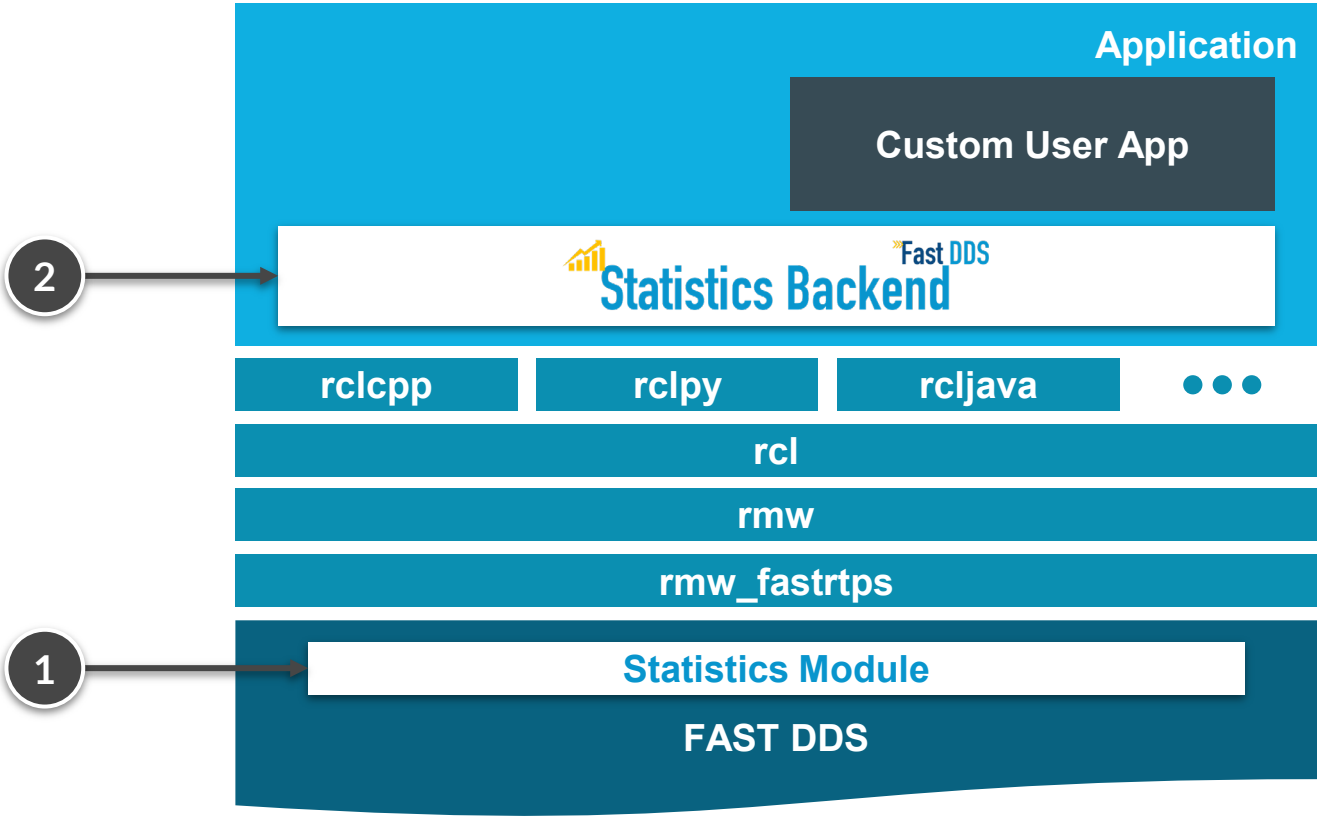

Fast DDS Statistics Toolkit

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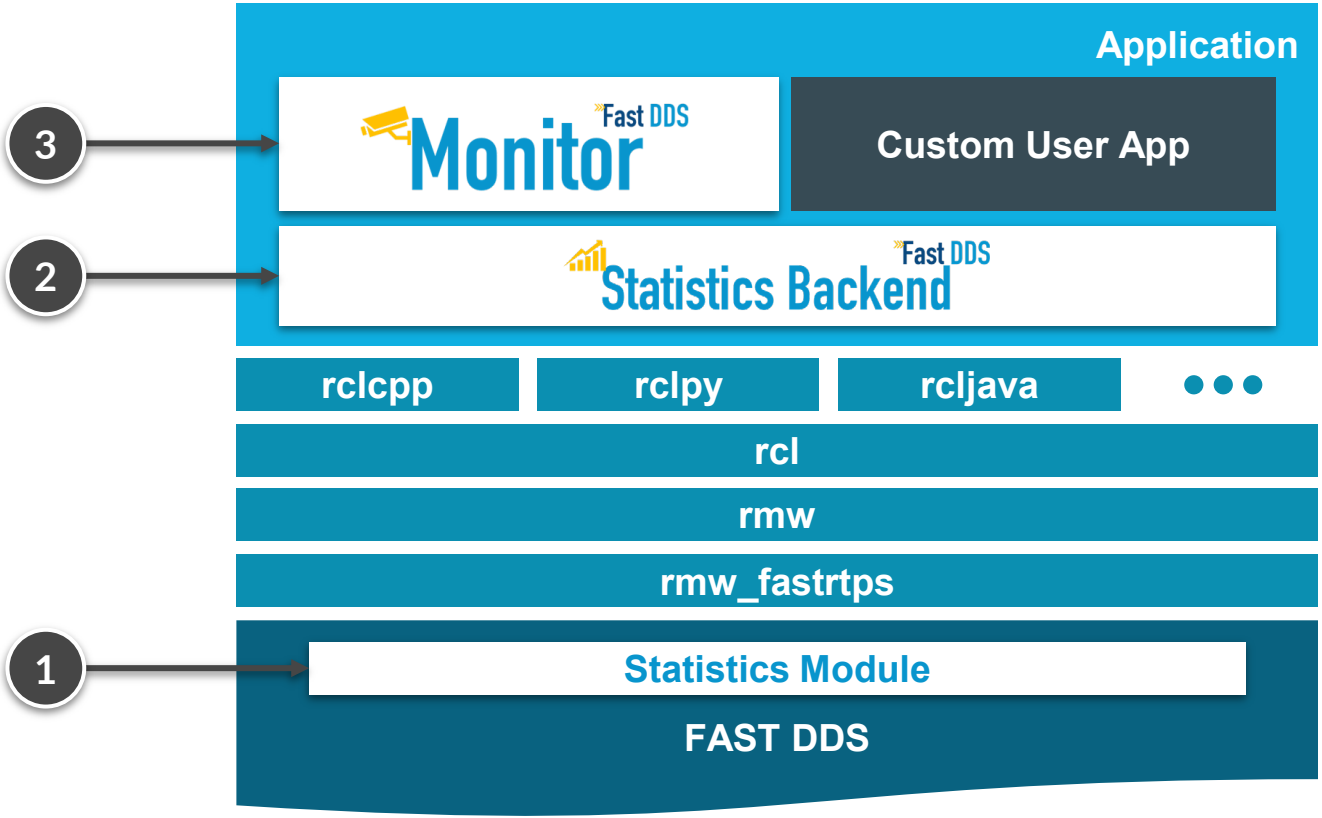
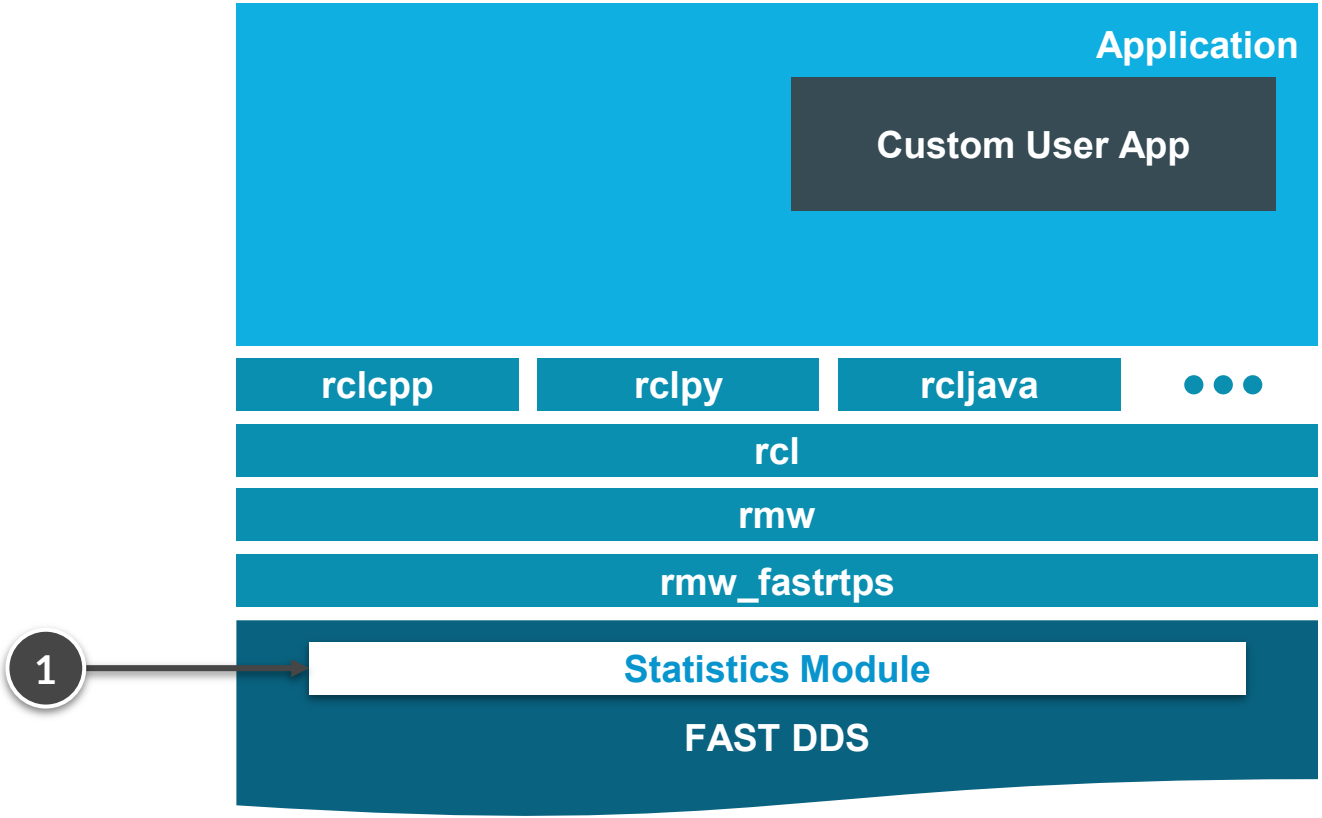


Fast DDS Statistics Module

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

```
$ 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

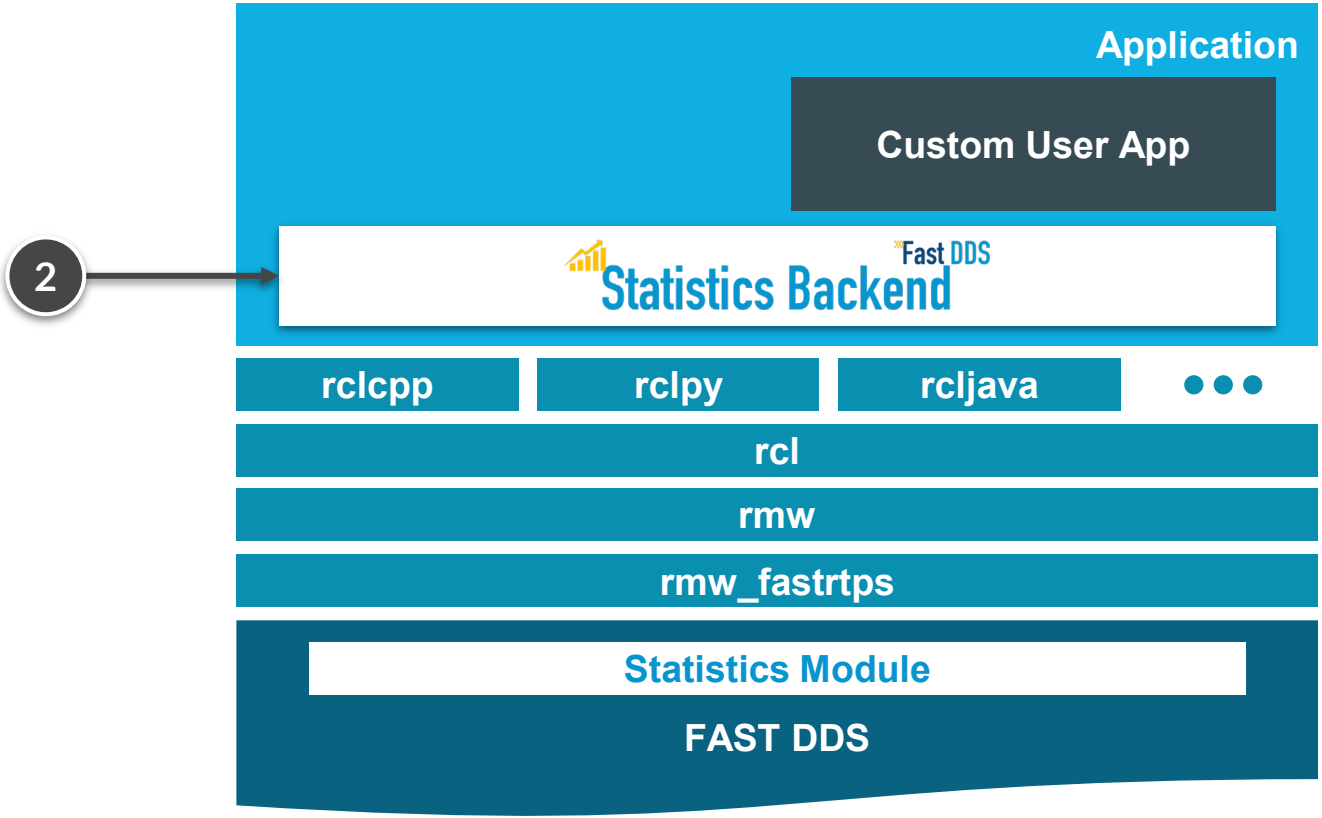
```
$ export FASTDDS_STATISTICS="HISTORY_LATENCY_TOPIC;NETWORK_LATENCY_TOPIC;PUBLICATION_THROUGHPUT_TOPIC;
                             SUBSCRIPTION_THROUGHPUT_TOPIC;RTPS_SENT_TOPIC;RTPS_LOST_TOPIC;HEARTBEAT_COUNT_TOPIC;
                             ACKNACK_COUNT_TOPIC;NACKFRAG_COUNT_TOPIC;GAP_COUNT_TOPIC;DATA_COUNT_TOPIC;RESENT_DATAS_TOPIC;
                             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



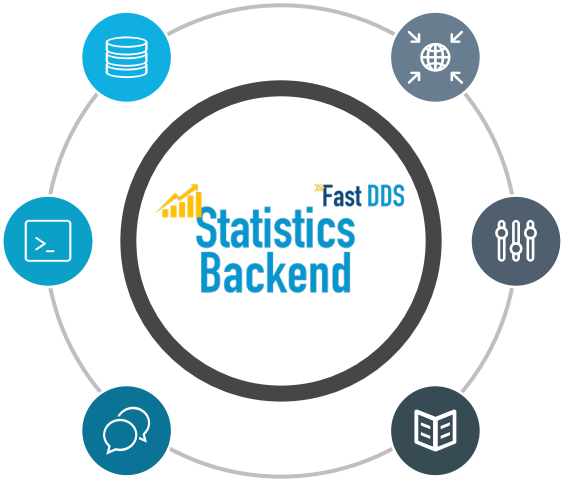
Main features

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)



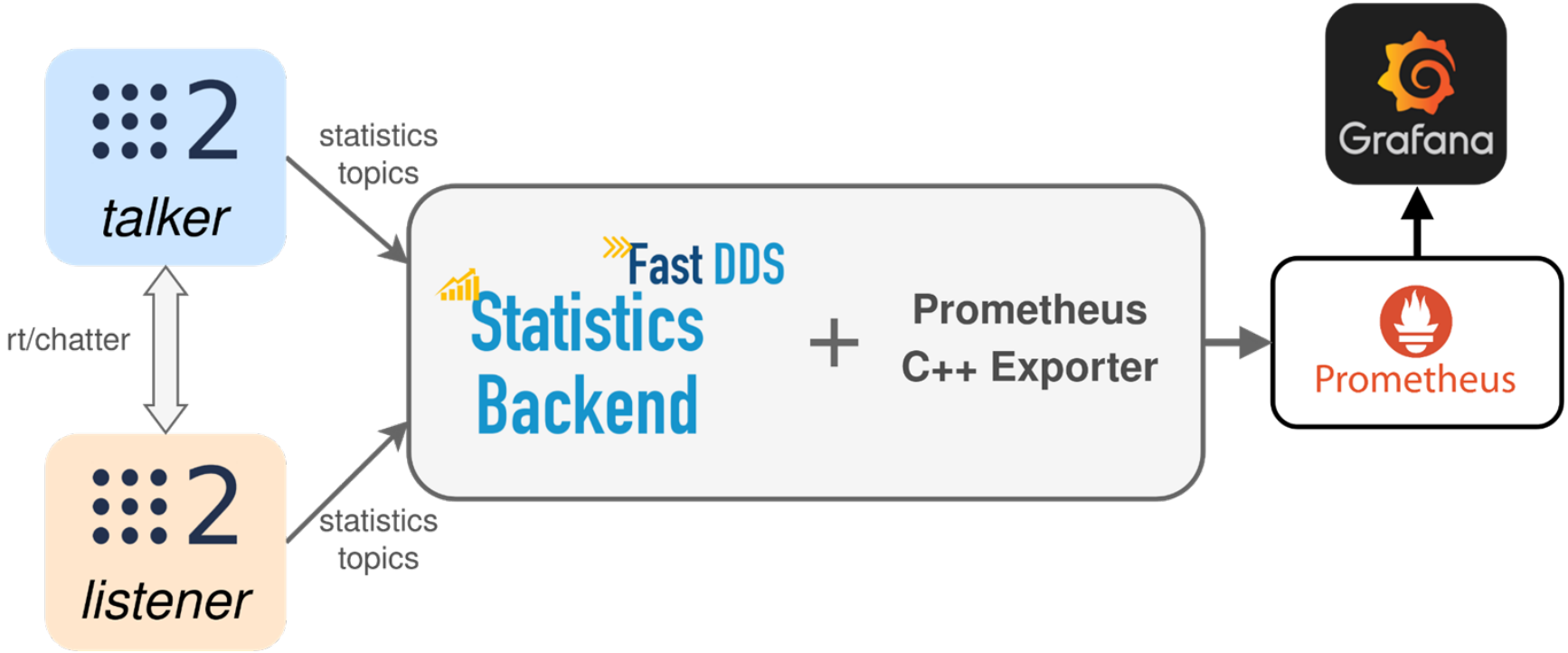
Records the DDS entities (DomainParticipant, DataReader / DataWriter, Locator, Domain and Topic) **and Physical entities** (Host, User, Process) **discovered in a Domain**

Compute the statistics (mean, std. dev, median, max, min, sum) on the stored data

Full documentation and examples available on ReadTheDocs.

Statistics, Prometheus & Grafana

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



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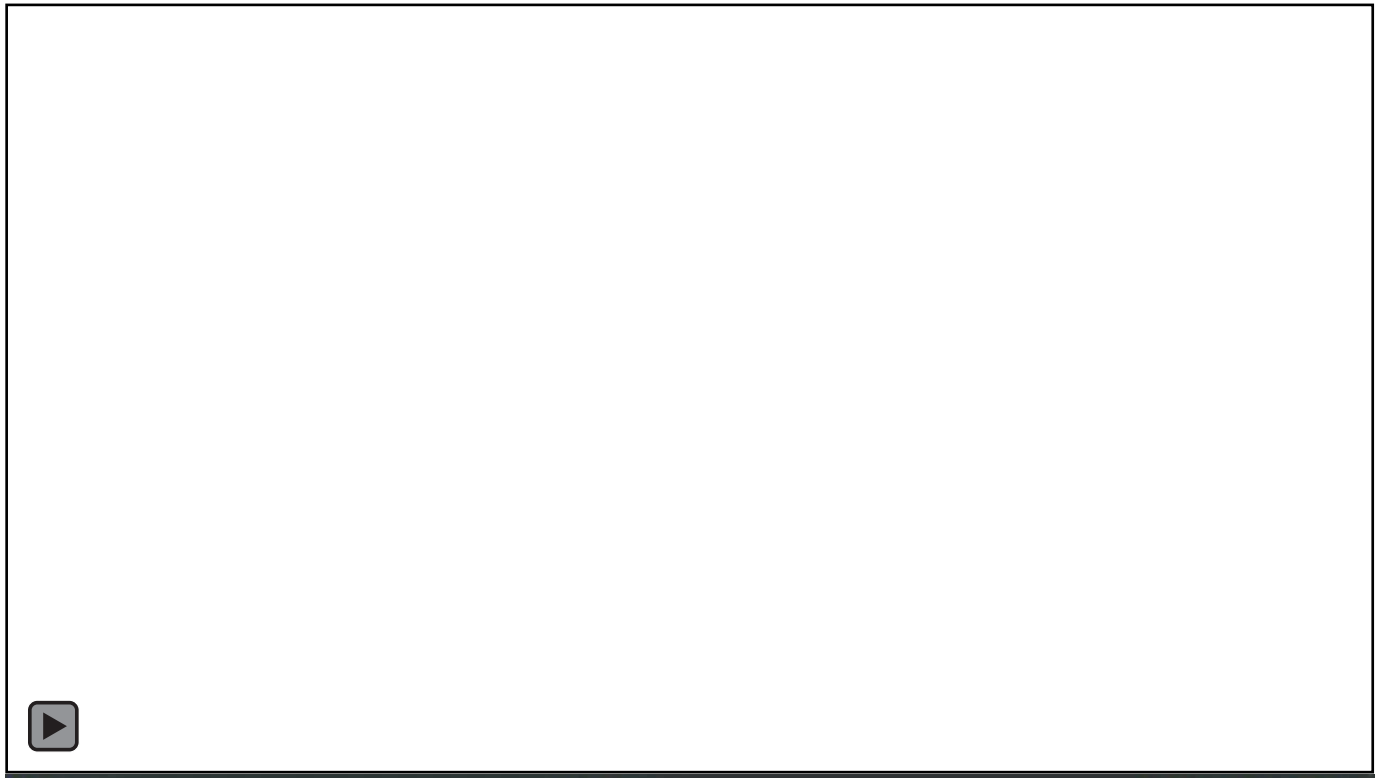
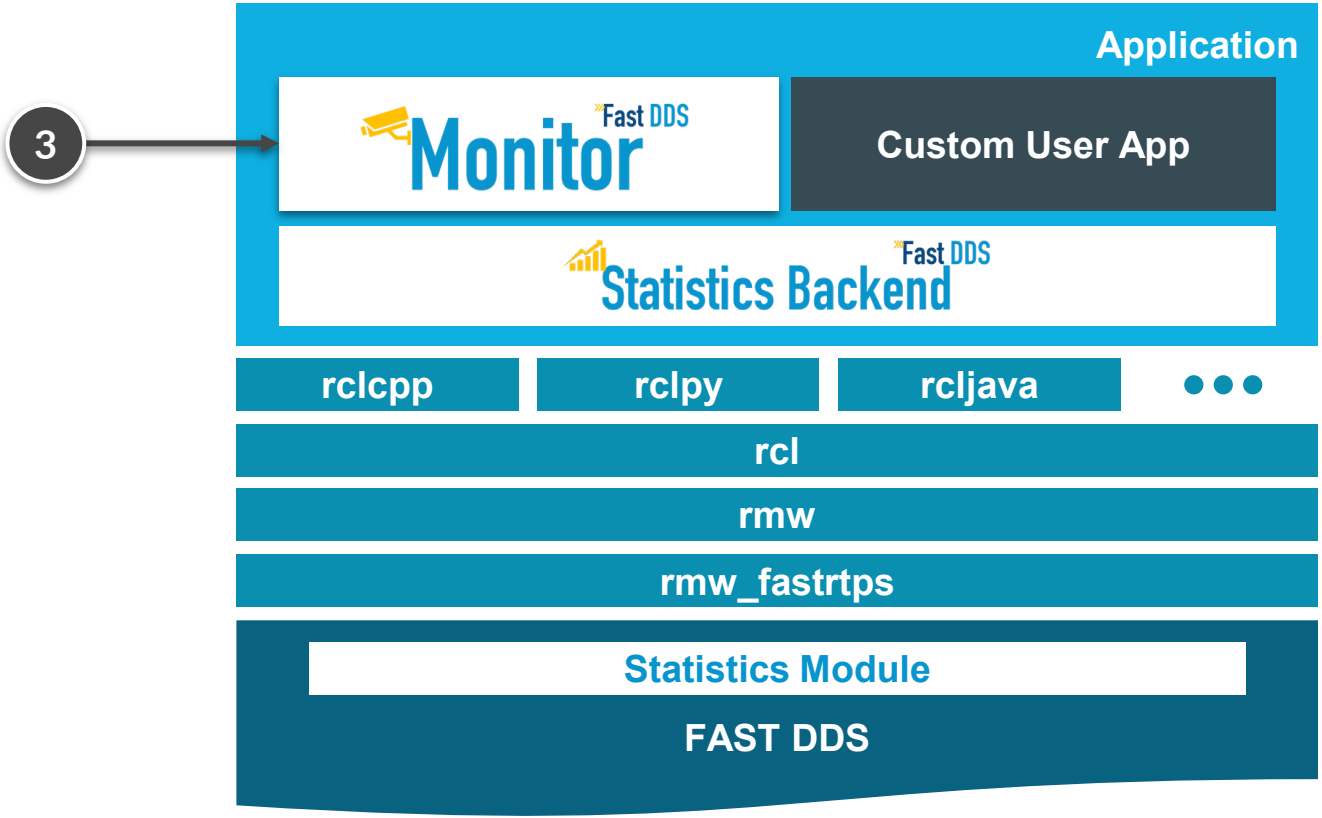


ROS 2 Monitor

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

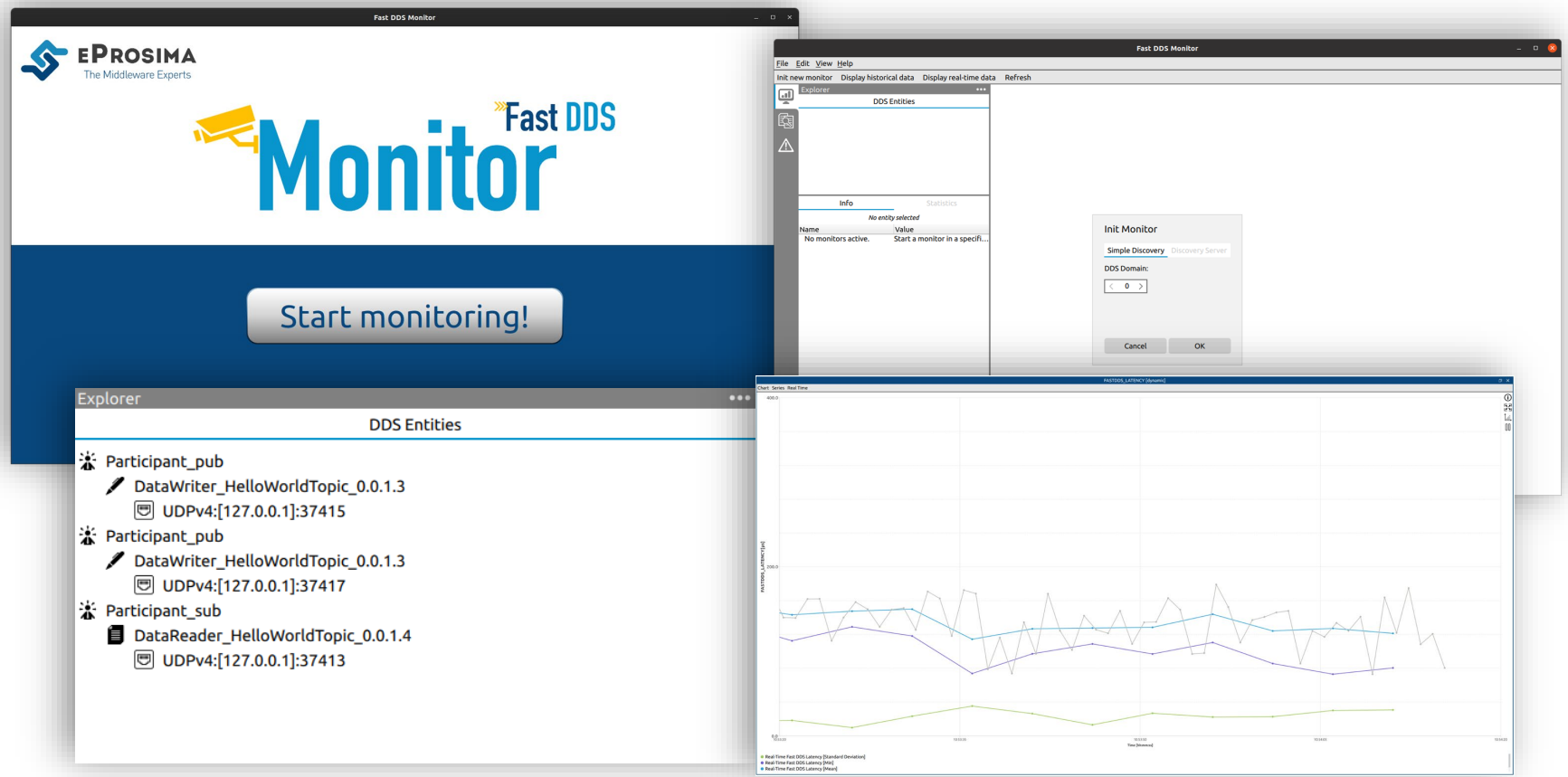
Fast DDS Statistics Toolkit

Fast DDS statistics toolkit components within the ROS 2 stack



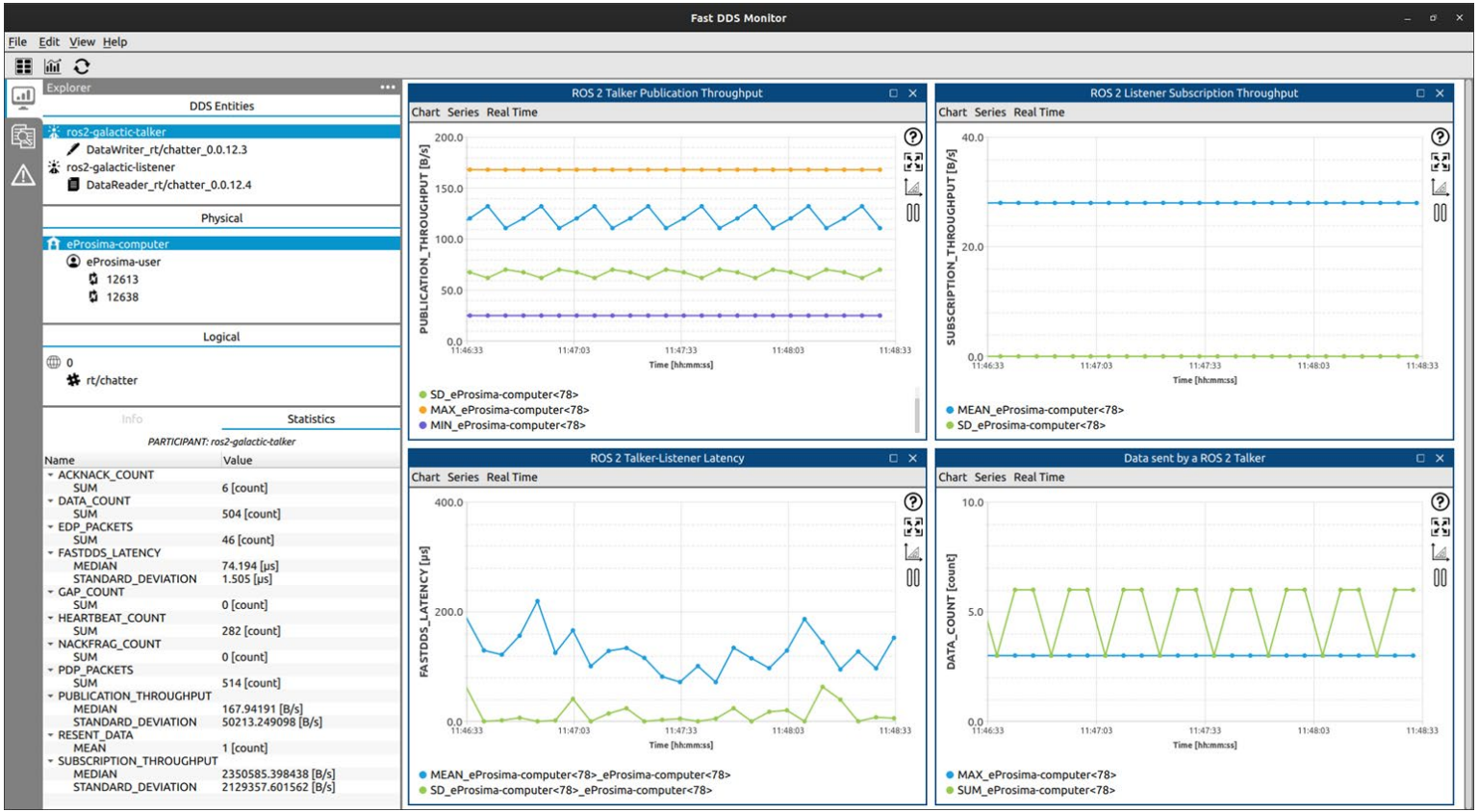
ROS 2 Monitor

Overview of ROS 2 Monitor graphical user interface



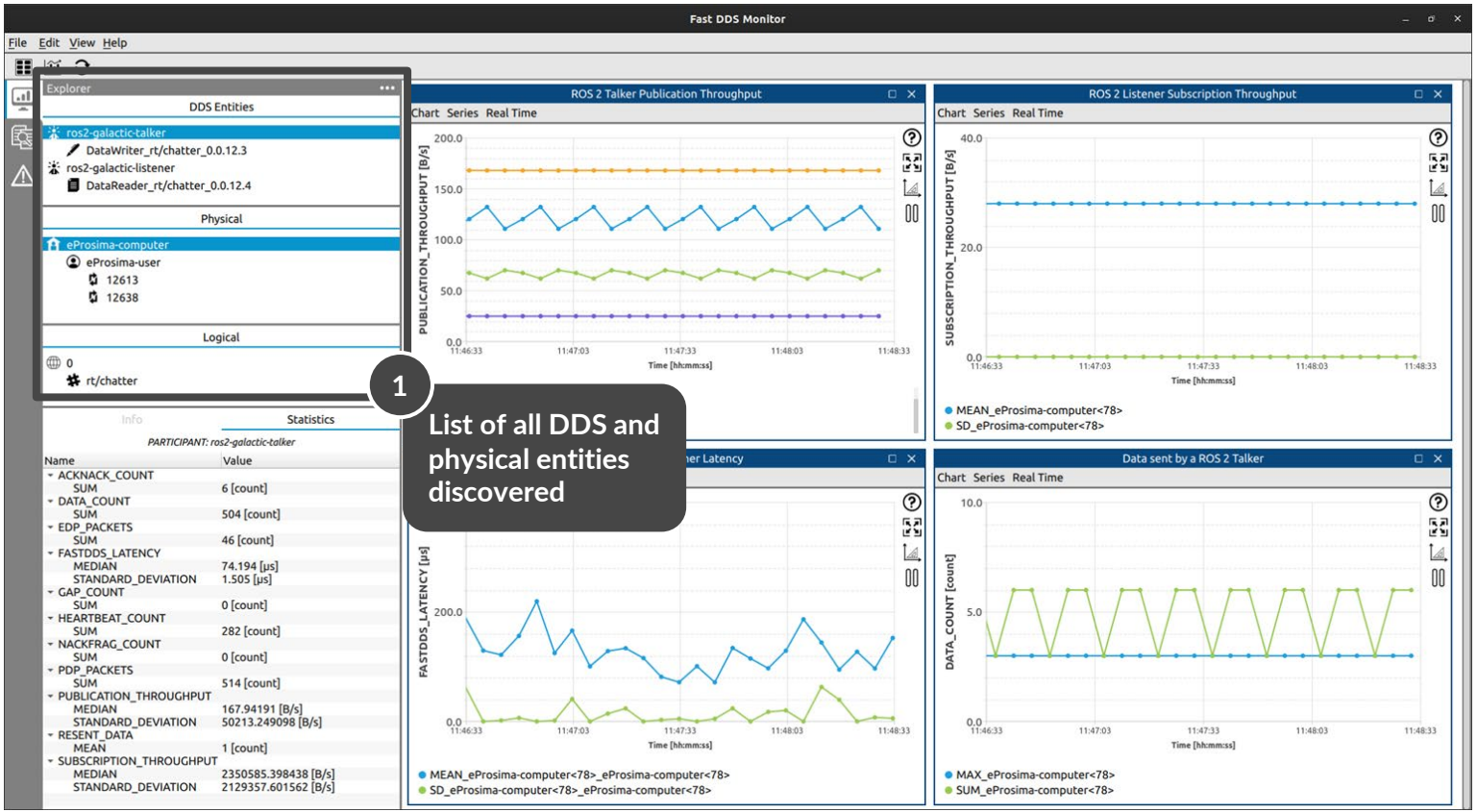
Normal operation

Normal operation of ROS 2 Monitor



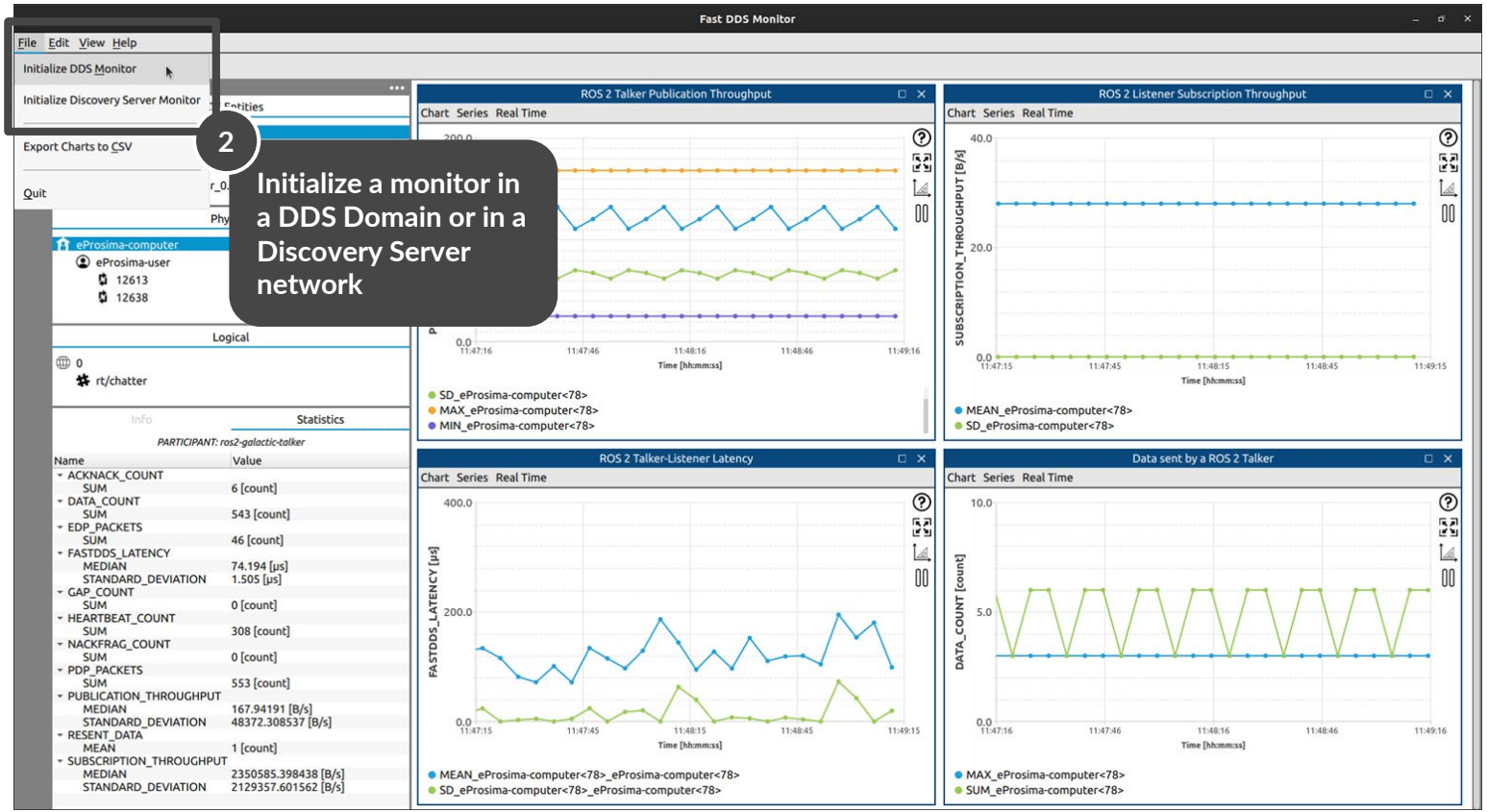
Main features

Listing DDS and physical entities



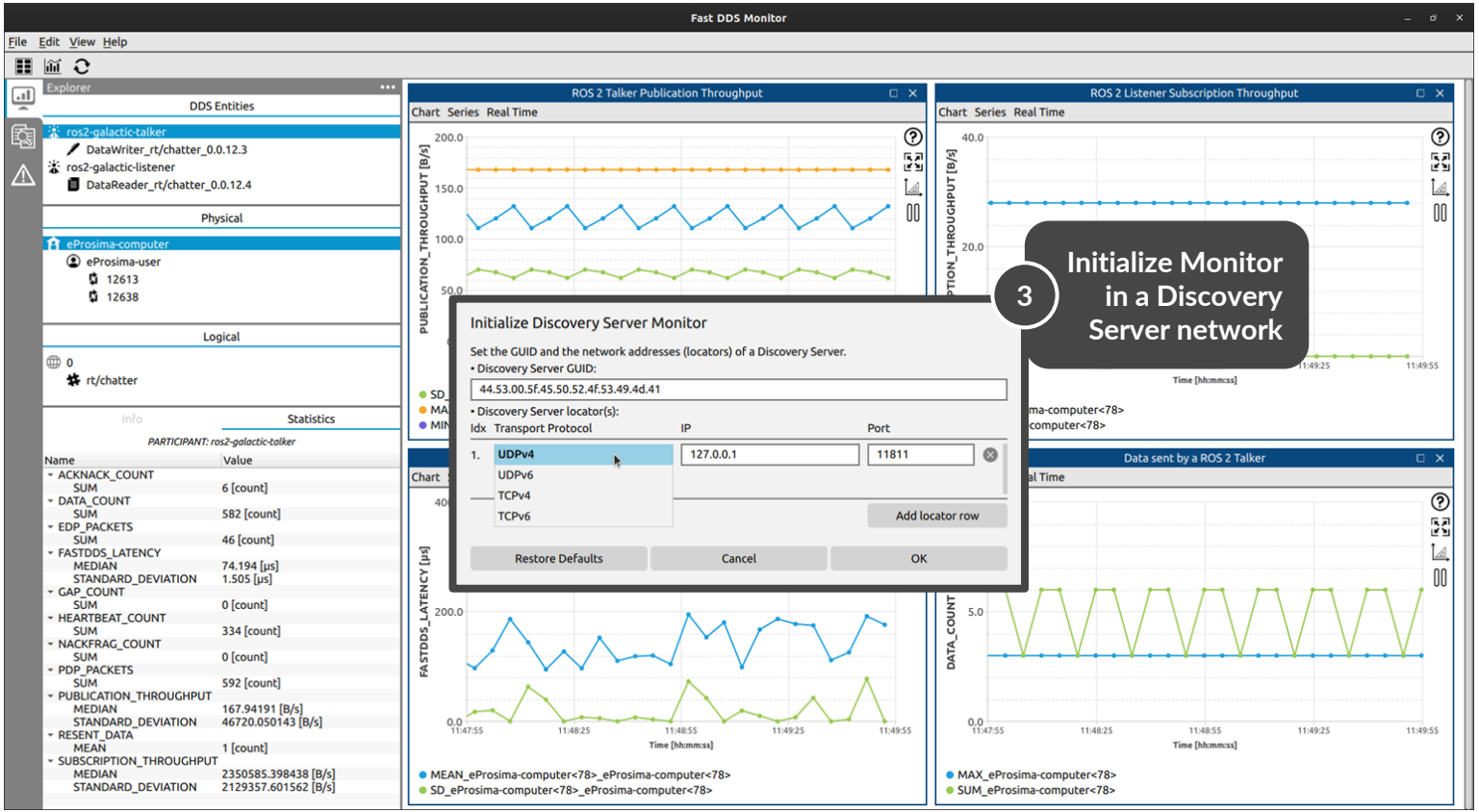
Main features

Initializing a monitor



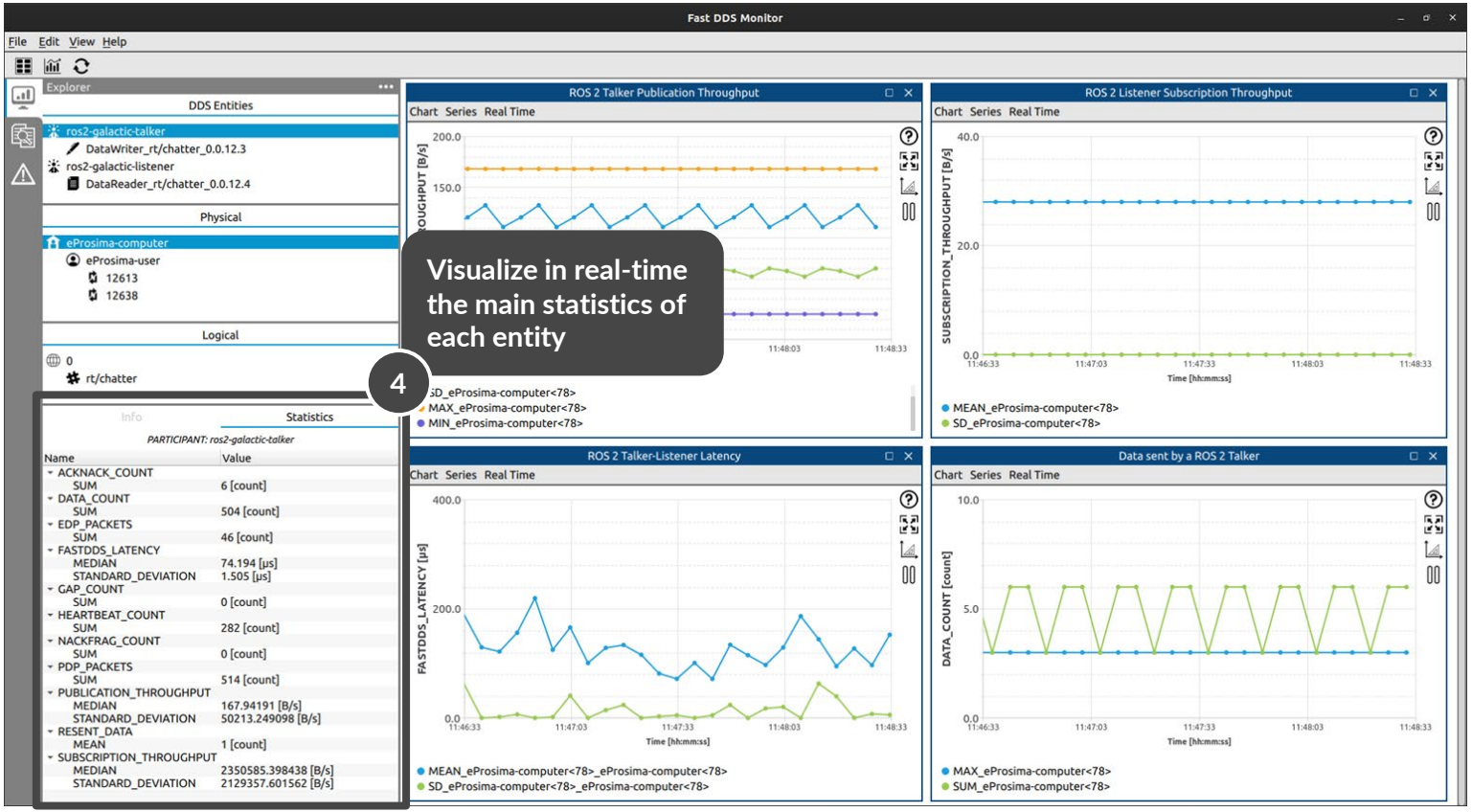
Main features

Compatible with ROS 2 Discovery Server networks



Main features

Real-time statistics visualization

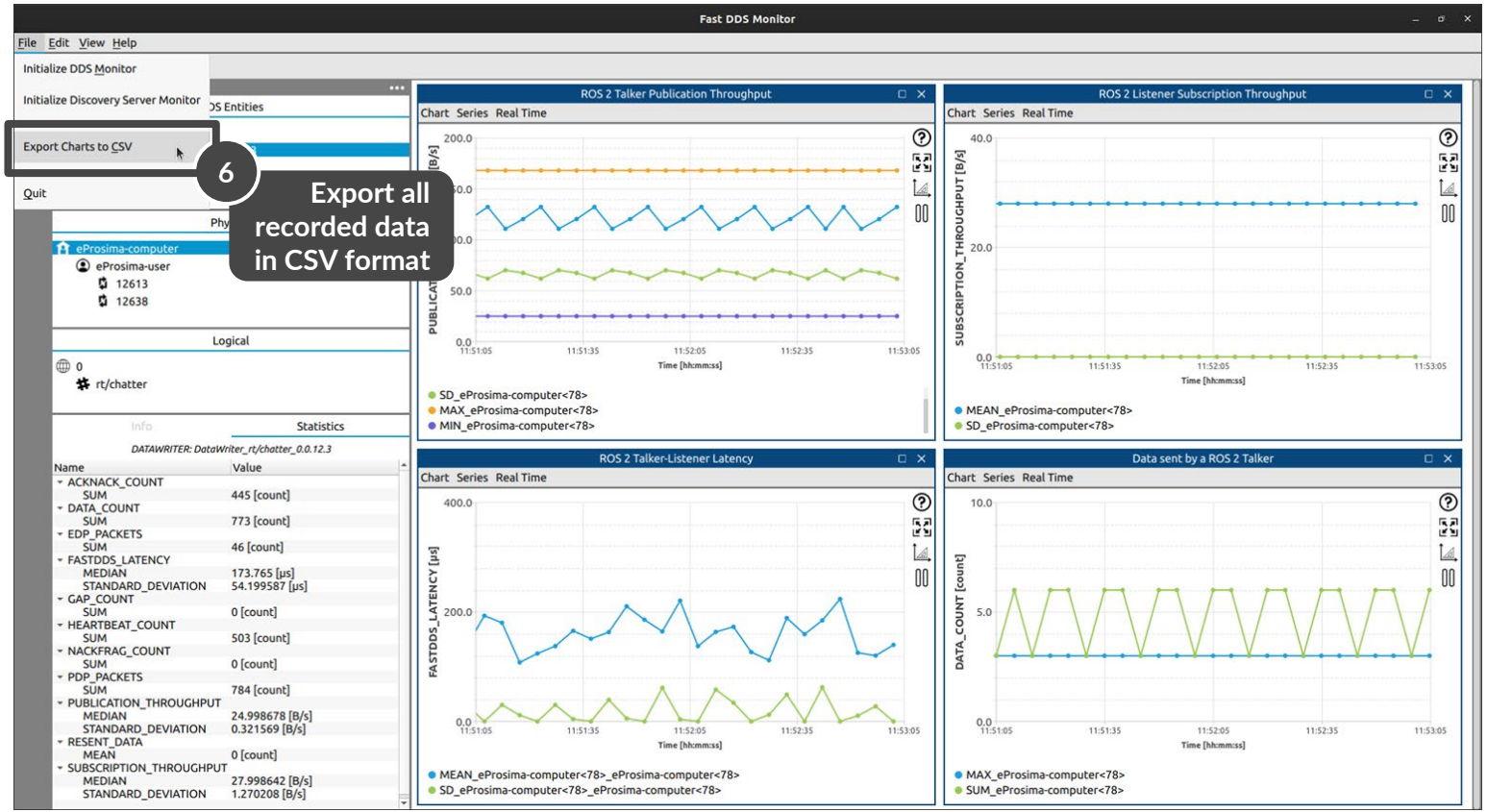


Main features

Live configurable charts for every reported data

Main features

Exporting recorded data in CSV format



Custom features for ROS 2

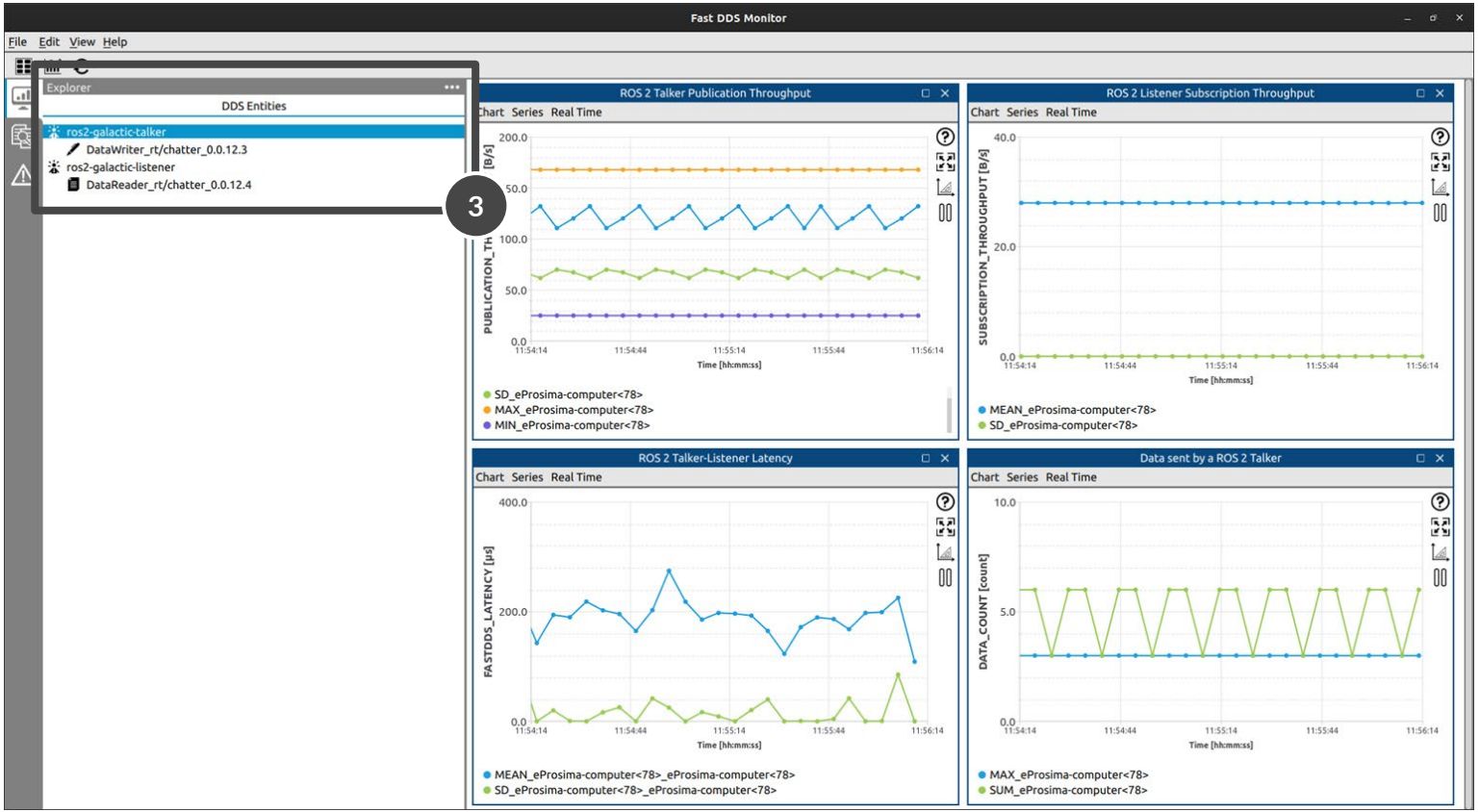
Monitoring meta-traffic ROS 2 nodes and topics

Custom features for ROS 2

Hiding meta-traffic ROS 2 nodes and topics

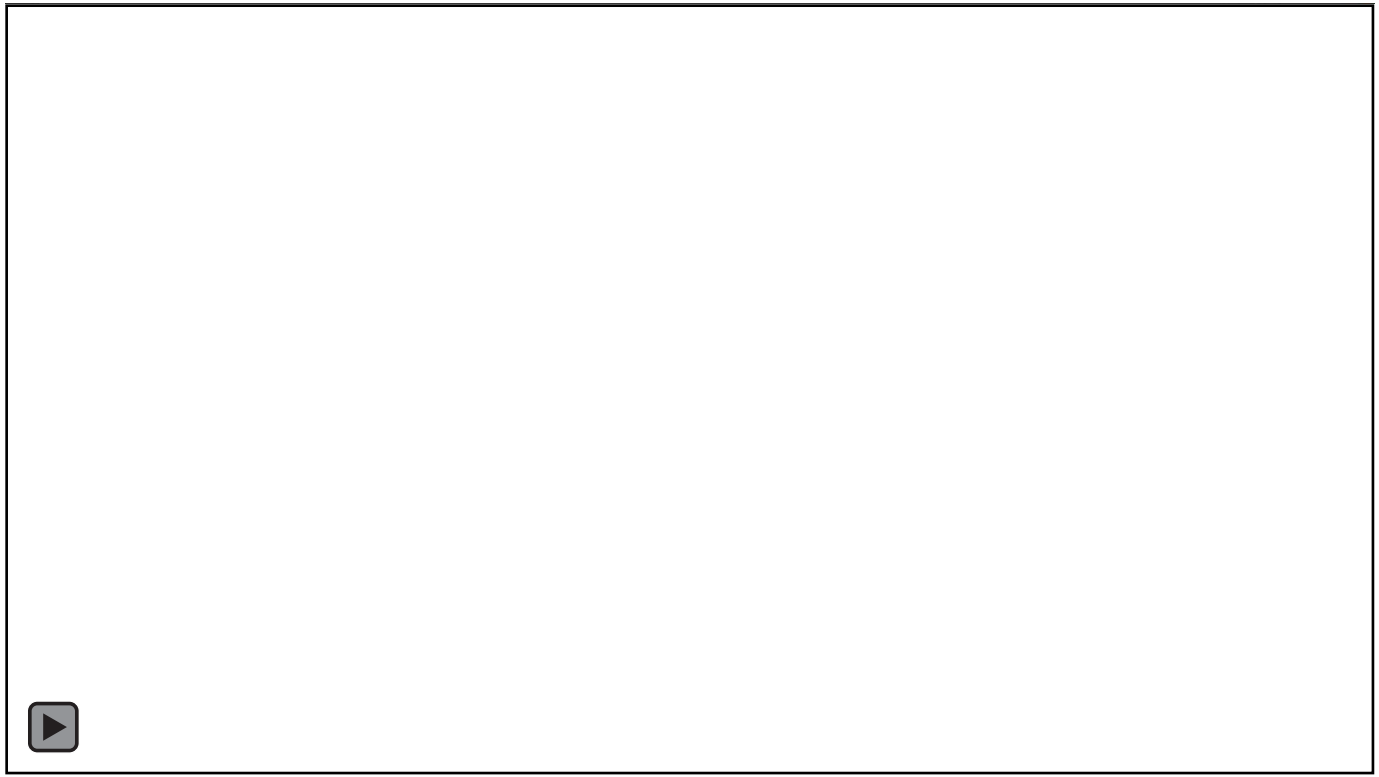
Custom features for ROS 2

Monitoring actual user data ROS 2 nodes and topics



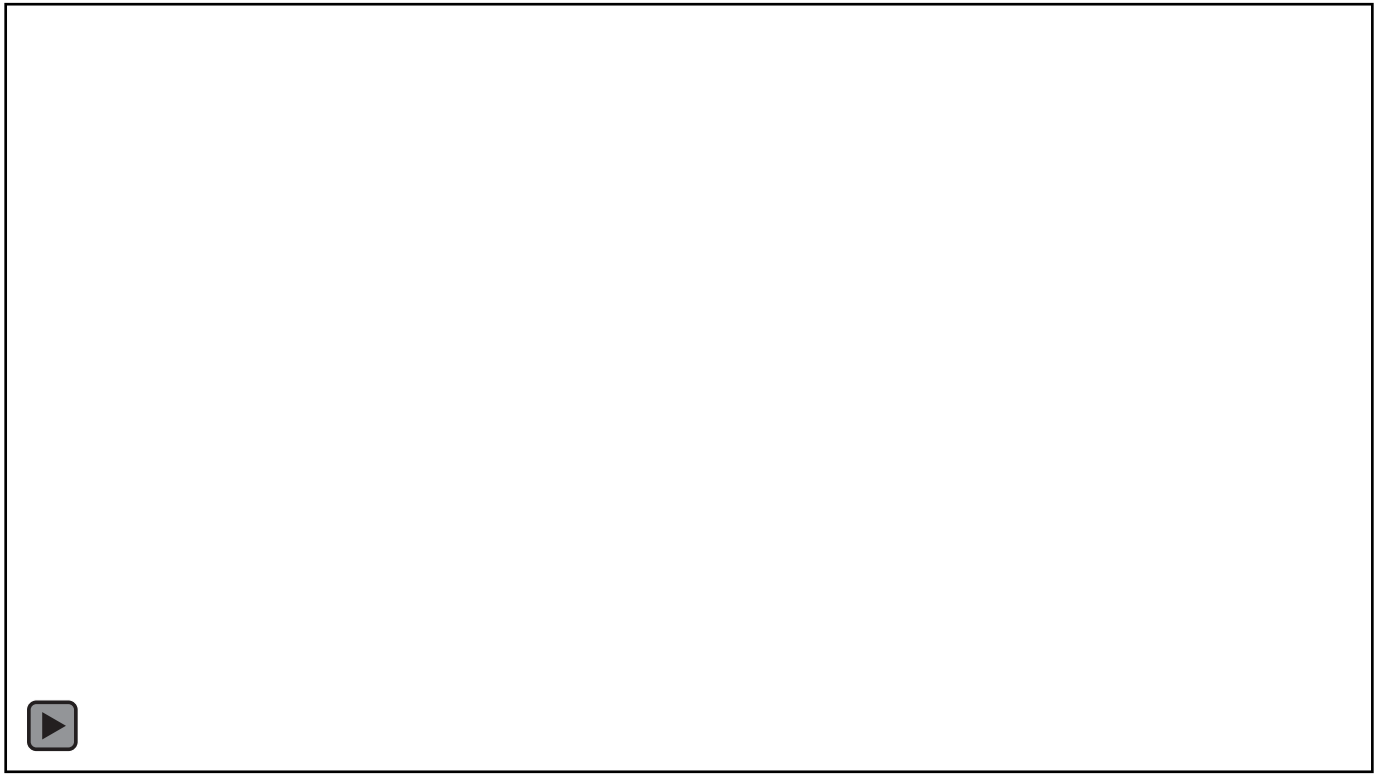
Talker & Listener network statistics

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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