DDS in Robotic Systems: Advancements in Technologies and Ecosystem Collaboration

30 November 2023

Zhi Kai Lim
Senior Field Application Engineer
RTI
Requirements for Advanced Robotics

Technical Requirements:

• Low Latency
• Reliability
• Scalability
• Interoperability
• Security
• Quality of Service (QoS)
• Redundancy and Failover
• Standards Compliance
**Robot Operating System (ROS)**

- Open-source middleware framework for robotic applications
  - Component-oriented
  - Topic-based pub/sub with typed messages
  - Remote method invocation
  - ROS Client API language bindings: C++, Python, Java

- Version 2 adopted DDS as its default communication layer
  - Abstracted by a "middleware layer" to support alternative communication technologies
DDS Standard Family - 15 specifications (and growing)

Technical Benefits

- Data-Centric
- Open Standard
- High Performance & Efficient
- Automated Discovery
- Transport-independent
- Secure Protocol
- Type Extensibility
- Redundancy/Failover
- Platform Support (>100)
- Language Support
- Safety-Cert
- Quality of Service (QoS)
OMG® DDS - Data Distribution Service (DDS)
  – DDS Foundation
OMG Standard defines
  – Interoperability – RTPS Wire Protocol
  – Portability - DDS Language API
  – Security - Plug-in Security Architecture
Multi-platform support
  – Windows, Linux, RTOS, iOS, Android

DDS excels at mission critical, real-world data communications

Cross-vendor portability

Cross-vendor interoperability
DDS Quality of Service

- Deadline
- Time Based Filter
- Partition
- Resource Limits
- Batching
- Reliability
- Content Filtering
- Presentation
- Latency Budget
- Transports
- Destination Order
- Durability
- Lifespan
- User, Group, Topic Data
- Flow Control
- Liveliness
- Ownership
- History
- Async Publisher
- Multi-Channel

Unique to RTI Connext®
Leveraging DDS for Robotics
DDS is the Connectivity Backbone for ROS 2

- ROS2 is built on the DDS framework
- All ROS2 applications are DDS applications
- DDS applications can freely interoperate with ROS2 applications
- ROS 2 uses a subset of the DDS standard
DDS + ROS 2 Synergies

- ROS 2 and DDS are data-centric technologies
- ROS 2 is built on the DDS framework
- ROS 2 applications are DDS applications
- ROS 2 is part of the DDS ecosystem
- ROS 2 and DDS offer standards-based interoperability
- **ROS 2 utilizes a subset of OMG DDS**
  - Limits QoS
  - Limits API/Patterns
ROS2 Quality of Service

- Deadline
- Time Based Filter
- Partition
- Resource Limits
- Batching

- Reliability
- Content Filtering
- Presentation
- Latency Budget
- Transports

- Destination Order
- Durability
- Lifespan
- Flow Control
- Multi-Channel

- Liveliness
- Ownership
- History
- User, Group, Topic Data
- Async Publisher

©2023 Real-Time Innovations, Inc.
What if ROS 2 relied more on DDS Features?

Disadvantages:
- Almost none
- Retains full interoperability with existing DDS/ROS 2 systems
- Slightly more complex API because of additional features and configuration options

Advantages:
- QoS Capabilities
- Performance
- Scalability
- Design Patterns
- Improved interoperability with (non-ROS) DDS systems
Using DDS instead of ROS 2 for Component Development

**Disadvantages:**
- Loss of some higher-level abstractions provided by ROS 2 (e.g. actions)
- Unfamiliar API for ROS 2 users
- No dependency management and packaging system
- No predefined message types

**Advantages:**
- QoS capabilities
- Performance
- Scalability
- Reduced executable size
- Safety certifiable
- Platform support
- Alternative build systems
- Design patterns
- Full interoperability with any DDS system
- Richer type system
- Deployment-grade architecture
Use Case: AGVs / AMRs
AGV/AMR - Data-Centric Edge-to-Cloud Solution

Unified Data Model

Warehouse Management System Databus (DDS)
- Track Inventory
- Layout Planning
- Order Processing
- Analytics

Fleet Management Databus (DDS)
- Scheduling
- Collaboration
- Real-Time Monitoring

Cloud
- GATEWAY to Cloud
- GATEWAY to WMS Databus
- GATEWAY to Fleet Management Databus

AGV/AMR
- VDA 5050 (DDS)
- Trajectory Planner
- Sensor Fusion
- SLAM
- Speed Planner

ROS 2 RMW Layer
- GPS
- Camera
- LiDAR
- RADAR
- Drives
- Batteries

©2023 Real-Time Innovations, Inc.
RTI Connext RMW
RTI Connext support for ROS 2

- Connext is integrated with ROS 2 via `rmw_connextdds`
  - New RMW implementation (since ROS 2 Galactic)
  - Created and maintained by RTI, in collaboration with OSRF
- Improved performance and vendor interoperability
- Advanced QoS configuration via XML configuration files
- Easier integration with Connext tools and applications
  - Automatic propagation of topic types
- Support for any version of Connext DDS
  - 5.3.1 or newer
Connext offers a roadmap for better synergy between DDS and ROS

- Improved use of DDS in the RMW layer
  - Piggyback ROS metadata over DDS built-in discovery topics
- Extended DDS support in the ROS Client API
  - Support *keyed* data types and topic *instances*
  - Direct access to the RMW's underlying DDS middleware
  - Easier configuration of advanced QoS settings
- Simplified integration between DDS and ROS components
  - Automatic "(de)mangling" of topic and type names
  - Automatic mediation between *keyed* and *unkeyed* versions of the same topic
  - DDS/ROS data binding interoperability
DDS Node API

- Extends the ROS Node API to facilitate use of DDS from ROS applications:
  - Access the DDS DomainParticipant created by the RMW layer
  - Create DDS DataWriters and DataReaders with a ROS-like API
- Focused on ease of use by ROS 2 developers:
  - Drop-in replacement superclass (rclcpp::Node\rightarrow rclcpp_dds::DDSNode)
  - Automatic creation of other DDS entities (Topic, Publisher, Subscriber)
  - Automatic "mangling" of ROS topic and type names
    - my_topic\rightarrow rt/my_topic
    - my_package::msg::MyType\rightarrow my_package::msg::dds_::MyType_
  - Callback-based interface to consume incoming data one at a time
- Based on the DDS C++11 API
- Experimental prototype available on GitHub
Gateway Adapters
Connext Gateway

- Enables users to easily integrate various communication protocols into a DDS databus
- Built-in adaptors for several common protocols, including: MQTT, Apache Kafka, Modbus, OPC UA
- Open framework based on the RTI Routing Service SDK for easy add-on of new adaptors, processors and transformations

Unreal Engine Plugin for RTI Connext
Simplified Real-Time Data Sharing with Unreal Engine

- Fast, secure and interoperable data communications infrastructure
- Distributes real-time data:
  - Between Unreal Engine projects
  - Between Unreal Engine projects and other applications (C, C++, C#, Java)
- Reliably scales systems to hundreds or even thousands of applications distributed across local and wide area networks

Download it on the Unreal Engine Marketplace

Summary
Summary

- DDS and ROS 2 are closely related ecosystems, with mutually beneficial technologies and increasingly overlapping user bases.
  - They must continue to complement and support each other for the ultimate success of their users.
- Full, optimal integration between DDS and ROS 2 is critical.
  - Efficient use of DDS by the RMW layer.
  - Support for all DDS features in the ROS API.
  - Direct access to the DDS databus.
- Feedback is important
  - What does the community want?
  - Let us know! community.rti.com or via email at robotics@rti.com
Questions?

Thank you!
Try a full version of Connext for 30 days

TRY CONNEXT AT RTI.COM/DOWNLOADS

Includes resources to get you up and running fast