Using DDS with TSN and Adaptive AUTOSAR

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Agenda

- Intro to Data Distribution Service (DDS)
- Use Cases for DDS in Automotive
- AUTOSAR and other platforms
- DDS and TSN
Intro to DDS
DDS and the Industrial Internet of Things

Deployed in 1000s of Systems

Industrial IoT Systems

- Reliability: Severe consequences if offline for 5ms (or 5 min)
- Real-time: measure in ms or µs
- Interface scale: 10+ applications/teams
- Dataflow complexity: data has many destinations
- Architecture: Next generation IIoT

INDUSTRIES
Energy, Industrial Control, Transportation, Healthcare, Defense
RTI Connext DDS in Autonomous Vehicles

- Commercial systems
  - 7+ Passenger vehicles
  - 8+ EV startups
  - 5+ Software platforms
  - 7+ Trucks, mining vehicles, forklifts
  - 2 Flying taxi services
  - 2 Hyperloop & other
  - 2+ Autonomous ships
  - 2+ Underwater robots
- Many defense systems (land, sea, air)
- Many research programs (companies, universities, etc.)
The DDS Standard

- DDS is the Proven Data Connectivity Standard for the IoT
- OMG: world’s largest systems software standards org
  - UML, DDS, Industrial Internet Consortium
- DDS: open and cross-vendor
  - Open Standard and Open Source
  - 12+ implementations
DDS Wire Protocol (RTPS)

- Peer to peer
- Transport-independent QoS-aware and Reliable Communication
  - Including multicast, for 1-many reliable communication
- Any data size over any transport.
- Automatic Discovery and Presence Plug and Play
- Decoupled
  - Start applications in any order
- Support for Redundancy
  - Multiple data sources
  - Multiple network paths
- High performance native “wire” speeds
What most systems of systems look like

How the system is initially designed

What happens to the system when your needs evolve
DDS Creates This...

What happens to the system when your needs evolve
Use Cases
## How to Deal with the Data?

<table>
<thead>
<tr>
<th>Source</th>
<th>Type</th>
<th>Size</th>
<th>Frequency</th>
<th>Volume (approx.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Cameras</td>
<td>2D high-res. video stream</td>
<td>8x 1-4 Mpixel/frame x 30 frames/s x 12-24bit/pixel</td>
<td>30 Hz</td>
<td>2.5-20 Gbit/s</td>
</tr>
<tr>
<td>4 Lidar sensors</td>
<td>3D point cloud</td>
<td>4x 300k-3M 3D points /s * 24bit/poin</td>
<td>5-20 Hz</td>
<td>30-300 Mbit/s</td>
</tr>
<tr>
<td>5 Radar sensors</td>
<td>Object/target list</td>
<td>bytes to kbytes</td>
<td>1-5 Hz</td>
<td>~10 kB/s</td>
</tr>
<tr>
<td>16 Ultrasonic sensors</td>
<td>Object/target list</td>
<td>bytes to kbytes</td>
<td>10 Hz</td>
<td>~10 kB/s</td>
</tr>
<tr>
<td>1 GPS</td>
<td>Data message</td>
<td>A couple of bytes</td>
<td>20-200 Hz</td>
<td>~10 kB/s</td>
</tr>
<tr>
<td>Control commands</td>
<td>Message</td>
<td>A couple of bytes</td>
<td>50-250 Hz</td>
<td>~10 kB/s</td>
</tr>
<tr>
<td>Status/error handling</td>
<td>Data/string message</td>
<td>Whatever needed</td>
<td>Whenever needed</td>
<td>Whatever needed</td>
</tr>
</tbody>
</table>

12 Gb/s or 1.5 GB/s or 90 GB/min or 5 TB/h or 100 TB/d

Approximately and assuming 20h of operation per day

5G data rate: 100Mbps (cell edge) to 10Gbps (theoretical)
Dataflow Challenge

- Carbots need many different dataflows:
  - Volume
  - Frequency
  - Latency
  - Reliability
  - Destination

- A single databus that can handle all greatly simplifies the system

<table>
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<th>Data Type</th>
<th>Data Volume</th>
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</tr>
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<tr>
<td>Cameras</td>
<td>Video Stream</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lidar</td>
<td>Data List</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radar</td>
<td>Point cloud</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPS</td>
<td>Bin data struct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Cmd</td>
<td>Bin data struct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>Text String</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

QoS
Quality of Service Capabilities

<table>
<thead>
<tr>
<th>QoS Policy</th>
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</tr>
</thead>
<tbody>
<tr>
<td>DURABILITY</td>
<td>USER DATA</td>
</tr>
<tr>
<td>HISTORY</td>
<td>TOPIC DATA</td>
</tr>
<tr>
<td>LIFESPAN</td>
<td>GROUP DATA</td>
</tr>
<tr>
<td>WRITER DATA LIFECYCLE</td>
<td>PARTITION</td>
</tr>
<tr>
<td>READER DATA LIFECYCLE</td>
<td>PRESENTATION</td>
</tr>
<tr>
<td>ENTITY FACTORY</td>
<td>DESTINATION ORDER</td>
</tr>
<tr>
<td>RESOURCE LIMITS</td>
<td>OWNERSHIP</td>
</tr>
<tr>
<td>RELIABILITY</td>
<td>OWNERSHIP STRENGTH</td>
</tr>
<tr>
<td>TIME BASED FILTER</td>
<td>LIVELINESS</td>
</tr>
<tr>
<td>DEADLINE</td>
<td>LATENCY BUDGET</td>
</tr>
<tr>
<td>CONTENT FILTERS</td>
<td>TRANSPORT PRIORITY</td>
</tr>
</tbody>
</table>

Use TSN?  

Delivery  

Resources Cache
Distributed Architectures for Higher Autonomy

Data Centricity thus enables new architectures that are fast, distributed, and reliable.
Connected & Secure

Traditional Method
• Secure the System
• Secure the Host
• Secure the Network

Security does not need to be black and white
Fine-Grained, DDS Security

Data Flow Security, by Topic

 DDS = Data Distribution Service
DDS Across Platforms, Industries, and Networks

• Integration in larger systems
Connext DDS as Core Connectivity Framework
Adaptive AUTOSAR and DDS
What is AUTOSAR?

• **AUTOSAR** (**AUT**omotive **Open** **System** **AR**chitecture) is a worldwide development partnership of vehicle manufacturers, suppliers, service providers and companies from the automotive electronics, semiconductor and software industry.

• > 270 partners including
  – Core Partners: BMW, Bosch, Continental, Daimler, Ford, GM, PSA, Toyota, and VW.
  – RTI joined as a Development Partner in 2017
Overview

• ara::com is the Communication Management API for the AUTOSAR Adaptive Platform.
  – EXP_AraComAPI.pdf provides an overview of the API.
  – SWS_CommunicationManagement.pdf provides the formal spec.
• Developed in 2014 in the context of Adaptive AUTOSAR FT-CM
  – Aims to be communication framework independent
  – Was initially built around SOME/IP and follows most of its principles
  – Based on a proxy/skeleton SOA architecture
  – Especially tailored for Modern C++ (C++11 in External APIs, C++14 in Internal APIs)
Adaptive AUTOSAR

User Applications

- ara::com Communication Mgmt.
- ara::rest RESTful
- ara::time Time Synchronization
- ara::per Persistency
- ara::phm Platform Health Mgmt.
- ara::iam Identity Access Mgmt.
- ara::exec Execution Mgmt.
- ara::log Logging & Tracing
- ara::crypto Cryptography
- ara::ucm service Update and Configuration Management

Legend

- SERVICE Non-PF Service
- SERVICE Func. Cluster
- API Func. Cluster

AUTOSAR Runtime for Adaptive Applications (ARA)

(Virtual) Machine / Container / Hardware
Network Stack

- DDS Application (Standard C++ API)
- DDS Application (Standard C API)
- AUTOSAR Application
- AUTOSAR (ara:com API)
- ROS2 Application
- DDS
- TSN / Ethernet (802.1, 802.3)
- UDP/IP Ethernet
- TCP/IP Ethernet
- Shared Memory
- [Secure] DDSI-RTPS
DDS can simplify wide deployment and use of TSN, across systems and platforms.
DDS   TSN

How do the two fit together?
How do DDS and TSN fit together

• Intuitively, DDS and TSN are a good fit
  – Fundamentally both are about predictable and fault tolerant one-to-many delivery with bound latencies
  – TSN could provide QoSes and mechanisms to DDS at a networking level
  – DDS could provide TSN mechanisms at higher level of abstraction
How do DDS and TSN fit together

• What does DDS provide to TSN?
  – Simplified usage by means of a higher level abstraction
    • TSN can be complicated to configure and use, compared to DDS
  – Best practices for real-time data distribution, which are designed into DDS
  – A standardized API for applications to use, in several languages
  – Adoption by industry frameworks that already have selected DDS (for example ROS2, AUTOSAR, …)
How do DDS and TSN fit together

What does TSN provide to DDS?
- Possibilities to truly implement certain DDS QoSes that live at the network level
- The concept of TSN data flows that naturally match DDS data flows, allowing for intuitive integration of the two all the way down to the network level
Problem statement

• DDS-TSN seems to have three different integration points. Looking at it from the DDS perspective, these are:
  1. Design-time system definition to include TSN-related properties
  2. Run-time DDS implementation to leverage TSN network
  3. Deployment-time actions to instruct TSN-enabled equipment
• All three need to be addressed by the OMG DDS-TSN standardisation
In order to allow DDS-TSN integration, DDS design-time system definitions need to be extended, for example with:
- DDS data flow properties such as “criticality” and “periodicity”
- DDS endpoint location information, in combination with the underlying network topology
Run-time DDS implementation

- DDS implementations should know how to interact with the TSN network and do it in a standardized way
  - For certain use cases, using the Level-3 (UDP/IP) stack in the right way is good enough
  - For other use cases, Level-2 (ETH) access is required and no standardized TSN APIs mechanisms seem to be available for that
  - Again, need to collaborate with TSN standardization body
DDS + TSN (Time Sensitive Networking)
OMG RFP

• OBJECT MANAGEMENT GROUP ISSUES DDS-TSN REQUEST FOR PROPOSALS
  ALLOWS DDS INFRASTRUCTURES BE DEPLOYED ON, AND LEVERAGE, TSN-ENABLED NETWORKS

Thank you

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IIC
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DDS portal
portals.omg.org/dds/