Connectivity Architecture for Highly Autonomous Vehicles

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Autonomous Systems Challenges

- Manage complex data flow and state
- Ease system integration
- Ensure reliable data availability
- Guarantee real-time response
- Allow any network
- Build in security from the start
- Make deployment flexible
- Ease safety certification
- Adapt Intelligence
- Connect Vehicle/Cloud Systems
• State-of-the-art isn’t good enough (functional)
  – Innovation arms race

• Still can’t forget the “-ilities” (non-functional):
  – Reliability, Durability, Manufacturability, Serviceability, Maintainability, Flexibility, Scalability, Extensibility, Portability, Security, Reusability, Compatibility, Interoperability, …

**AUTONOMOUS SYSTEMS MUST HANDLE BOTH**
Typical CAN Bus, Signal-Based Communications

Signals connected over the CAN bus

... and the system evolves
The Network is the Car

AUTONOMY
PERFORMANCE
SECURITY
SAFETY
Evolving Architectures
Why a Common Framework

• Manage uncertainty
• Reuse IP investment
• Keep pace with innovation
• Scalability
• Plug-n-play function
• Lower costs
• Future-proof

Either build for a platform, or build the platform
A Software Databus Creates This...

What happens to the system when your needs evolve
Autonomous Vehicles

Vehicle

- Maintenance
- Availability
- Fleet Management Databus
- V2X Databus
- HMI
- GATEWAY
- Traffic Management
- Road Management
- Municipal Cloud Databus
- Telematics
- Sensors
- Situation Awareness
- Planning
- Vehicle Control (Safety Critical)
- GPS
- Camera
- LiDAR
- Sensor Fusion
- Data Recording
- CAN
- AUTOSAR

National Operations Center of Excellence

Fleet Management Weekly

Traffic Management

Road Management

Municipal Cloud Databus

Telematics

Sensors

Situation Awareness

Planning

Vehicle Control (Safety Critical)

GPS

Camera

LiDAR

Sensor Fusion

Data Recording

CAN

AUTOSAR
What Framework Should I Choose?
200+ RTI Autonomous Vehicle Programs!

• 40+ commercial systems
  – 8+ 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

• 100+ defense systems (land, sea, air)

• 75+ research programs (companies, universities, etc.)
DDS on the IIoT Stack

Information
- Distributed Data Interoperability and Management
- Information (Data in Context)

Connectivity
- Network
- Transport
- Framework
- Data (State, Events, Streams)
- Messages
- Packets
- Frames
- Link
- Physical
- Bits

Networking
- Participant Y
- Distributed Data Interoperability and Management

DDS

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RTI Connext DDS Suite

Visualization & Debug Tools
Recording & Playback Services
Application Prototyper
Data Modeling Tools
Connectivity SDKs (C, C++, Java, .NET, Javascript, Python ...)

API
Publish-Subscribe
Request-Reply
Discovery
Exception Handling

Data Resource Model
ID and Addressing
Data Type System
Lifecycle (CRUD)
State Management

DDS-RTPS Messaging Protocol
Connectivity Gateway
Database Integration Service
Persistence Service

Tools & SDKs
Databus
Connectivity Services

Quality of Service
Governance
Security

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DDS: A “Plug-n-Play” Databus for Integrating Software Modules
## Shared Global Dataspace

### Source (Key) Data

<table>
<thead>
<tr>
<th>Source (Key)</th>
<th>Speed</th>
<th>Power</th>
<th>Phase</th>
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### Diagram Elements

- **DATABUS**
- **Persistence Service**
- **Recording Service**
DDS in Adaptive AUTOSAR

Adaptive Application

- ara::com Communication Mgmt.
- ara::rest RESTful
- ara::time Time Synchronization
- ara::per Persistency
- ara::phm Platform Health Mgmt.
- ara::exec Execution Mgmt.
- ara::iam Identity Access Mgmt.

POSIX PSE51 / C++ STL Operating System

- ara::crypto Cryptography
- ara::log Logging & Tracing
- ara::am Servant Type
- ara::ucm service Update and Configuration Management

Legend

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

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DDS in ROS2

User Code  Tools  Capabilities  Ecosystem

C++ Client Library  C Client Library  Python Client Library

ROS Client Library (rcl)
ROS Abstract Middleware Layer (RMW) (C API)

CONNEXT DATABUS

OS
Linux  OS X  Windows  Your OS Here
Take it to Massive Scale

• Each level of the hierarchy has:
  – Data model
  – Discovery
  – Security domain

• System-of-systems require:
  – Subsystem export control
  – Data model translation
  – Discovery control
What about Safety and Security?
Secure the Data, Not the Pipe

DDS Domain

<table>
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<th>Line</th>
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<tr>
<td>7654</td>
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<td>432</td>
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</table>

Squawk | Long | Lat  | Alt |
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<tr>
<td>7654</td>
<td>40.7</td>
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<td>250.0</td>
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Fine-Grained, DDS Security

Data Flow Security, by Topic

- Authentication
- Access Control
- Encryption
- Data Tagging
- Logging

RTI Core Library

Any Transport (e.g., TCP, UDP, multicast, shared memory,)

DDS = Data Distribution Service

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Providing a Pathway to Safety Certification

• Meets the demands of highly autonomous systems, with a roadmap to ISO 26262 ASIL-D certification
Safety-Certifiable Connectivity Platform

- Provides non-stop availability
  - Decentralized architecture
  - No single point of failure
  - Support for redundant networks
  - Automatic failover between redundant publishers
  - Dynamic upgrades
    - No central server or services
    - Version-independent interoperability protocol

- Supports subsystem isolation and incremental certification
- Controls real-time Quality of Service (QoS)
- Makes missed deadlines and presence visible
- Proven in thousands of mission-critical systems
And the Performance?
Large Data Streaming Use Cases

Autonomous Driving

**LIDAR UNIT**
Constantly spinning, it uses laser beams to generate a 360-degree image of the car’s surroundings

**RADAR SENSORS**
Measure the distance from the car to obstacles

**ADDITIONAL LIDAR UNIT**

**CAMERAS**
Uses parallax from multiple images to find the distance to various objects. Cameras also detect traffic lights and signs, and help recognize moving objects

By Guilbert Gates | Source: Google

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Operational latency introduced by the middleware to provide functionality that otherwise would have to be provided by the application.

Latency introduced by copying the sample content. This includes, among other copies the serialization (marshaling) and deserialization (unmarshalling) copies.

Latency introduced by the underlying transport and networking infrastructure.

Small Sample Latency
- Middleware
- Copy
- Transport

Large Sample Latency
- Middleware
- Copy
- Transport
Scale in Time and Space

Applications

Research

Production

Maintenance

Teams

Networks

Systems

Devices

Platform & Transport Abstraction

Distributed & Evolves with Development

DDS X-Type — Config Evolution

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Thank you

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