Your systems.
Working as one.

DDS Introduction

Neil Puthuff <neil@rti.com>
Software Integration Engineer, RTI

June 11, 2020

1

Agenda

- Networking & Vehicle Evolution
- What is DDS?
- ROS 2 and DDS
- Getting Started with DDS

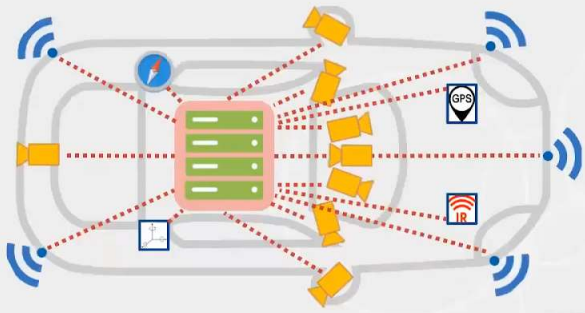
2

Autonomous Vehicle Evolution

Control	Use Case	Autonomy Level	Processor	Sensors	Communication
Human	Manual Drive	0	none	n/a	n/a
	+ Cruise Control, ABS	1	Small MCU	+ Speedometer	Point-to-point
	+ Traction Control		+ MCU	+ Wheel spin	
	+ Adaptive Cruise Control	2	++	+ GPS, Compass	shared memory
	+ Parking Assist		++	+ Accelerometer	
	+ Lane-Keeping	3	++	+ Gyroscope	Network
	+ ADAS		+ GPU	+ Ultrasound	
	+ Semi-Autonomous	4	++	+ Cameras	...
	+ Fully-Autonomous	5	++	+ LiDAR, RADAR	
System	+ Cooperative Autonomy		...	+ V2X(V,I,P,G)	??

3

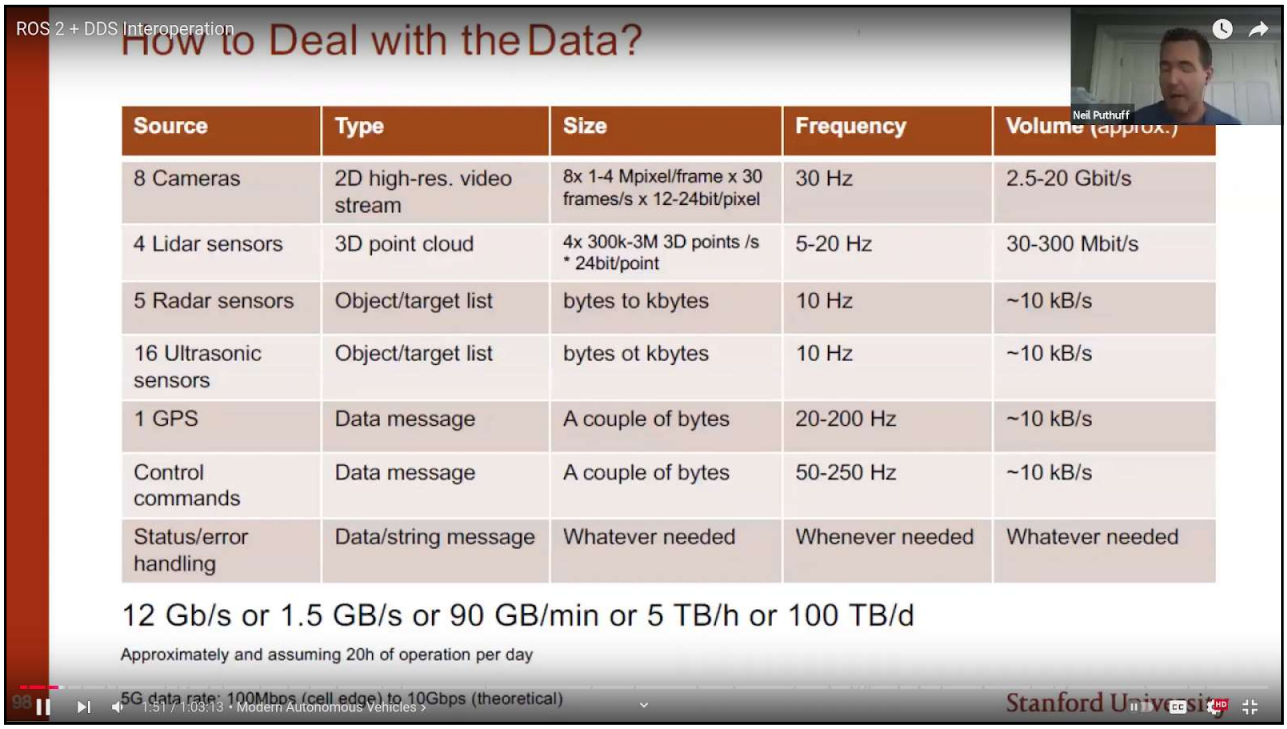
Modern Autonomous Vehicles



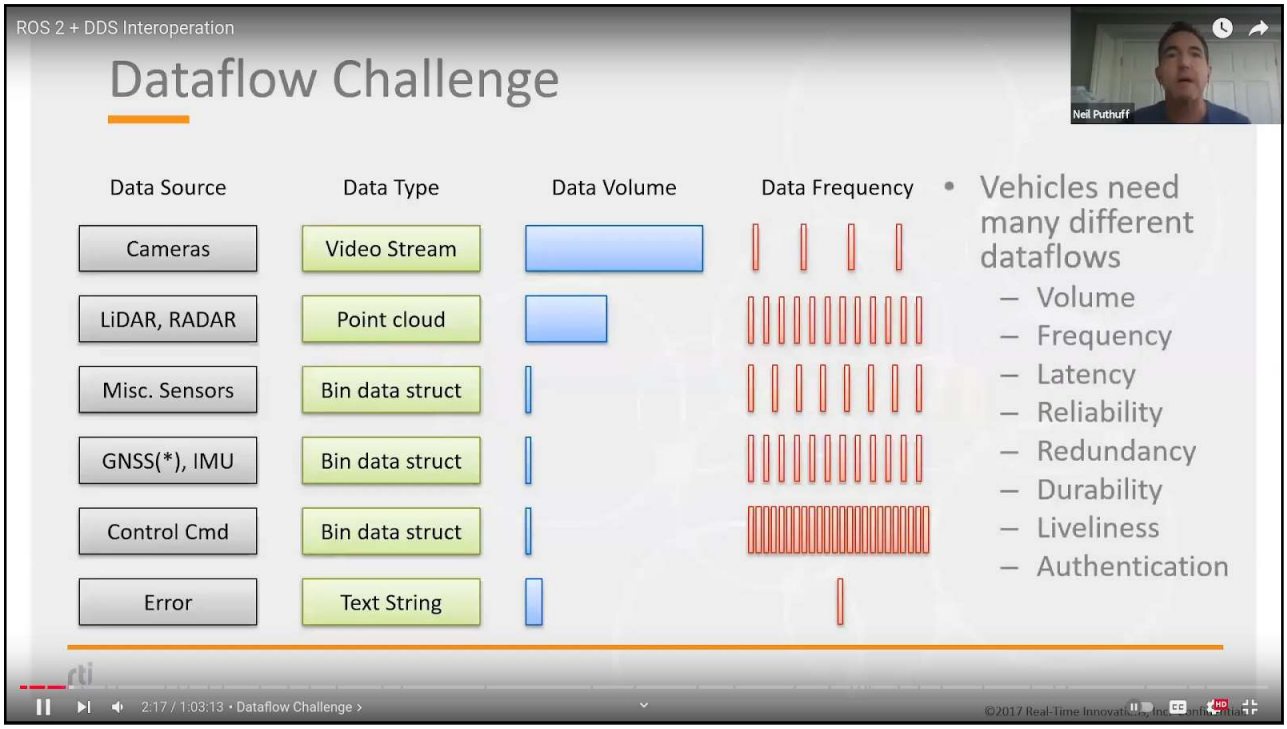
- Cameras
- LiDAR
- RADAR
- Compass
- Accelerometer
- Gyroscope
- Environmental
- Ultrasonic Range
- Road Ice
- Wheel Sensors
- Location (GPS, GNSS)
- Driver Controls
- Driver Monitoring

Low Latency High throughput Safety Critical

4


ROS 2 + DDS Interoperation
How to Deal with the Data?
Neil Puthuff
Source | Type | Size | Frequency | Volume (approx.)
8 Cameras | 2D high-res. video stream | 8x 1-4 Mpixel/frame x 30 frames/s x 12-24bit/pixel | 30 Hz | 2.5-20 Gbit/s
4 Lidar sensors | 3D point cloud | 4x 300k-3M 3D points /s * 24bit/point | 5-20 Hz | 30-300 Mbit/s
5 Radar sensors | Object/target list | bytes to kbytes | 10 Hz | ~10 kB/s
16 Ultrasonic sensors | Object/target list | bytes ot kbytes | 10 Hz | ~10 kB/s
1 GPS | Data message | A couple of bytes | 20-200 Hz | ~10 kB/s
Control commands | Data message | A couple of bytes | 50-250 Hz | ~10 kB/s
Status/error handling | Data/string message | Whatever needed | Whenever needed | Whatever needed
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)
1:51 / 1:03:13 • Modern Autonomous Vehicles >

5


ROS 2 + DDS Interoperation
Dataflow Challenge
Neil Puthuff
Data Source
Data Type
Data Volume
Data Frequency
Cameras
Video Stream
LiDAR, RADAR
Point cloud
Misc. Sensors
Bin data struct
GNSS(*), IMU
Bin data struct
Control Cmd
Bin data struct
Error
Text String
• Vehicles need many different dataflows
– Volume
– Frequency
– Latency
– Reliability
– Redundancy
– Durability
– Liveliness
– Authentication
2:17 / 1:03:13 • Dataflow Challenge >

6

Dataflow Challenge

Data Source	Data Type	Data Volume	Data Frequency
Cameras	Video Stream		
LiDAR, RADAR			
Misc. Sensors			
GNSS(*), IMU			
Control Cmd			
Error	Text String		

A single technology that can handle this entire range of Dataflow & QoS

- Vehicles need many different dataflows
  - Volume
  - Frequency
  - Latency
  - Reliability
  - Redundancy
  - Durability
  - Liveliness
  - Authentication

= Wide-range QoS

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Evolution of Networking

Point-to-Point	Client/Server	Publish/Subscribe	Queuing
			
			
TCP Sockets	MQTT XMPP OPC CORBA	CAN Bus SOME/IP ZeroMQ JMS	NATS.io AMQP Active MQ

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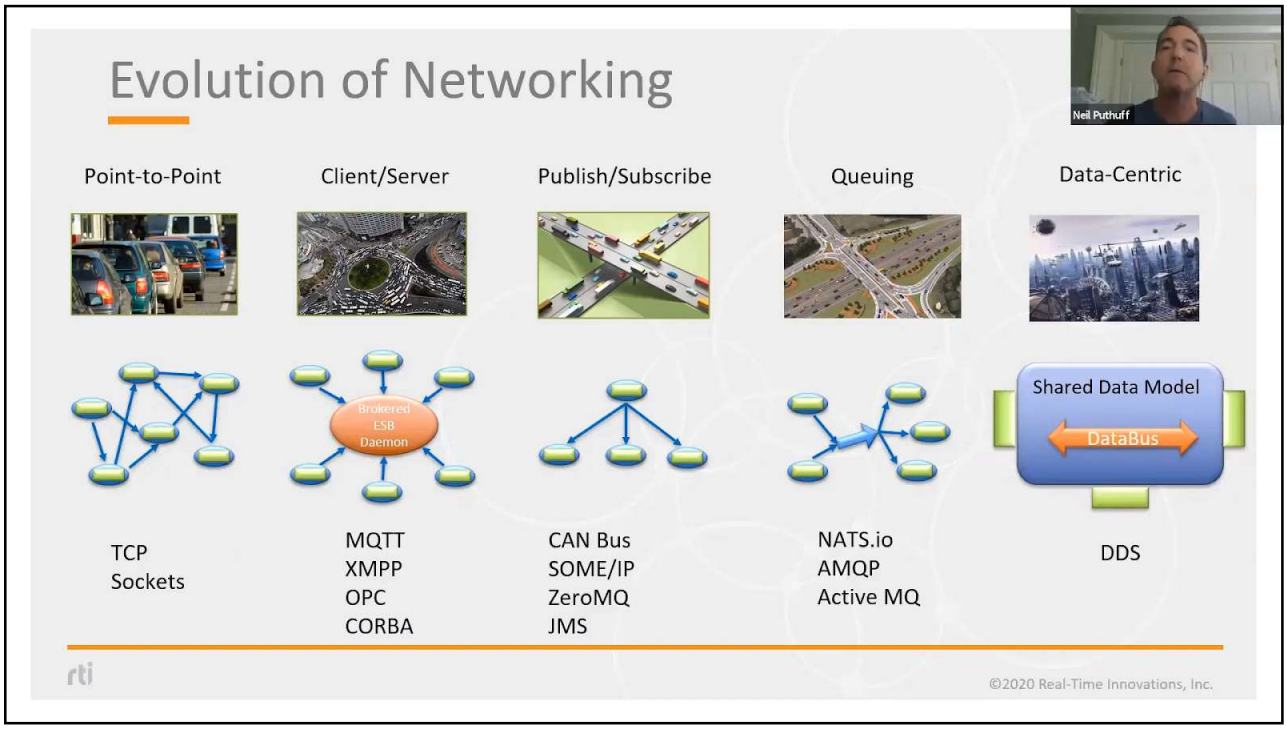
Evolution of Networking
Neil Puthuff
Point-to-Point
Client/Server
Publish/Subscribe
Queuing
Data-Centric
Brokered
ESB
Daemon
Shared Data Model
DataBus
TCP
Sockets
MQTT
XMPP
OPC
CORBA
CAN Bus
SOME/IP
ZeroMQ
JMS
NATS.io
AMQP
Active MQ
DDS
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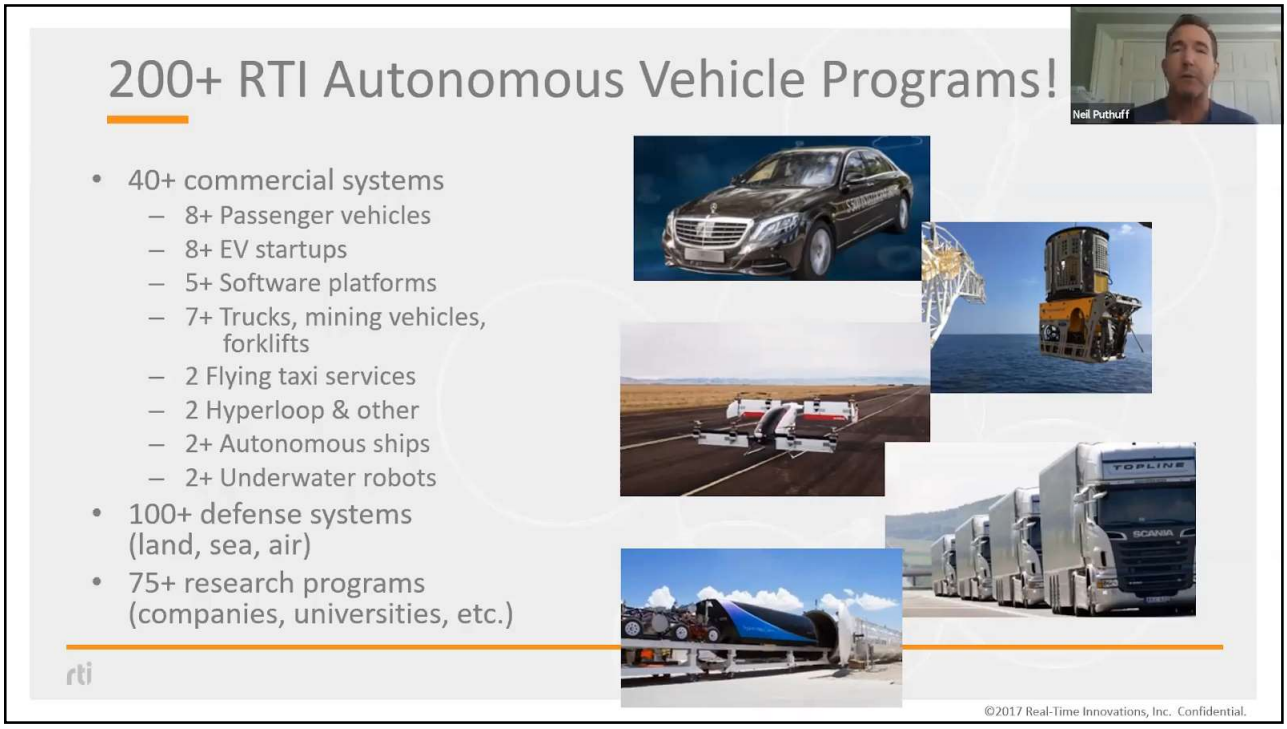
200+ RTI Autonomous Vehicle Programs!
Neil Puthuff
40+ commercial systems
8+ Passenger vehicles
8+ EV startups
5+ Software platforms
7+ Trucks, mining vehicles, forklifts
2 Flying taxi services
2 Hyperloop & other
2+ Autonomous ships
2+ Underwater robots
100+ defense systems (land, sea, air)
75+ research programs (companies, universities, etc.)
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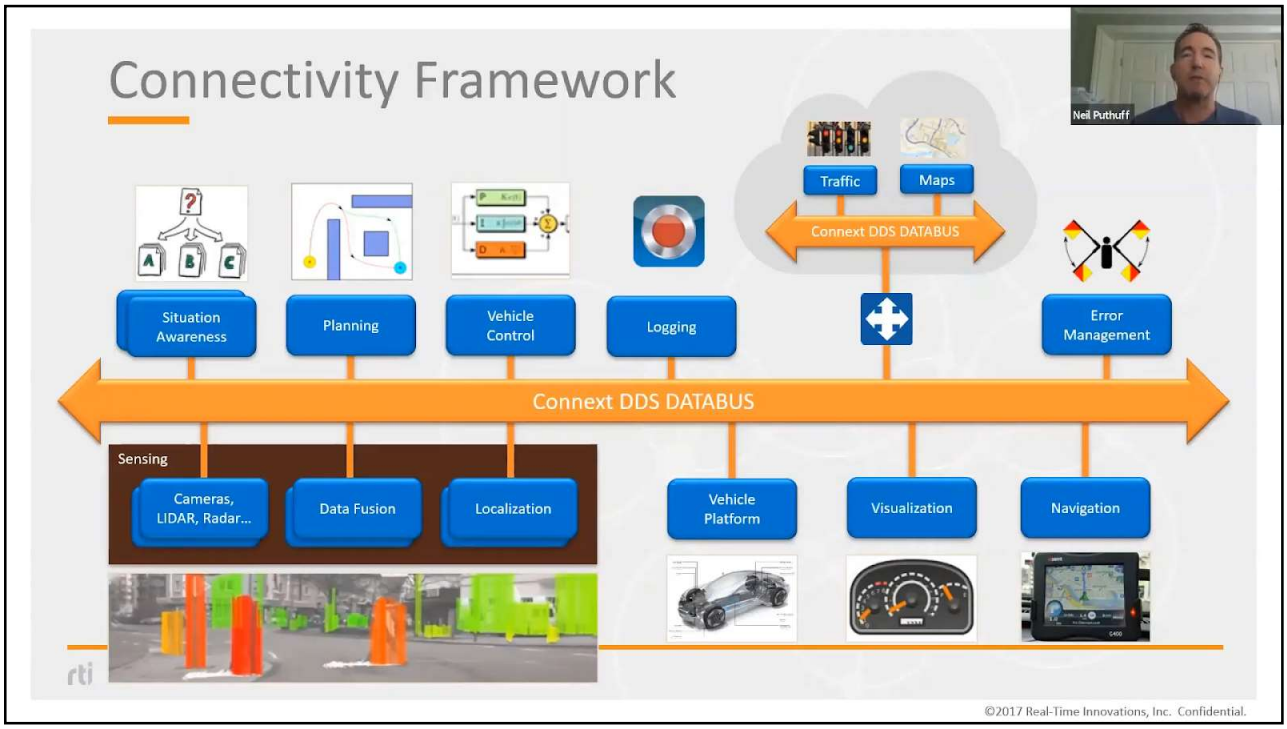
Connectivity Framework
Neil Puthuff
Traffic
Maps
Connext DDS DATABUS
Situation Awareness
Planning
Vehicle Control
Logging
Error Management
Connext DDS DATABUS
Sensing
Cameras, LIDAR, Radar...
Data Fusion
Localization
Vehicle Platform
Visualization
Navigation
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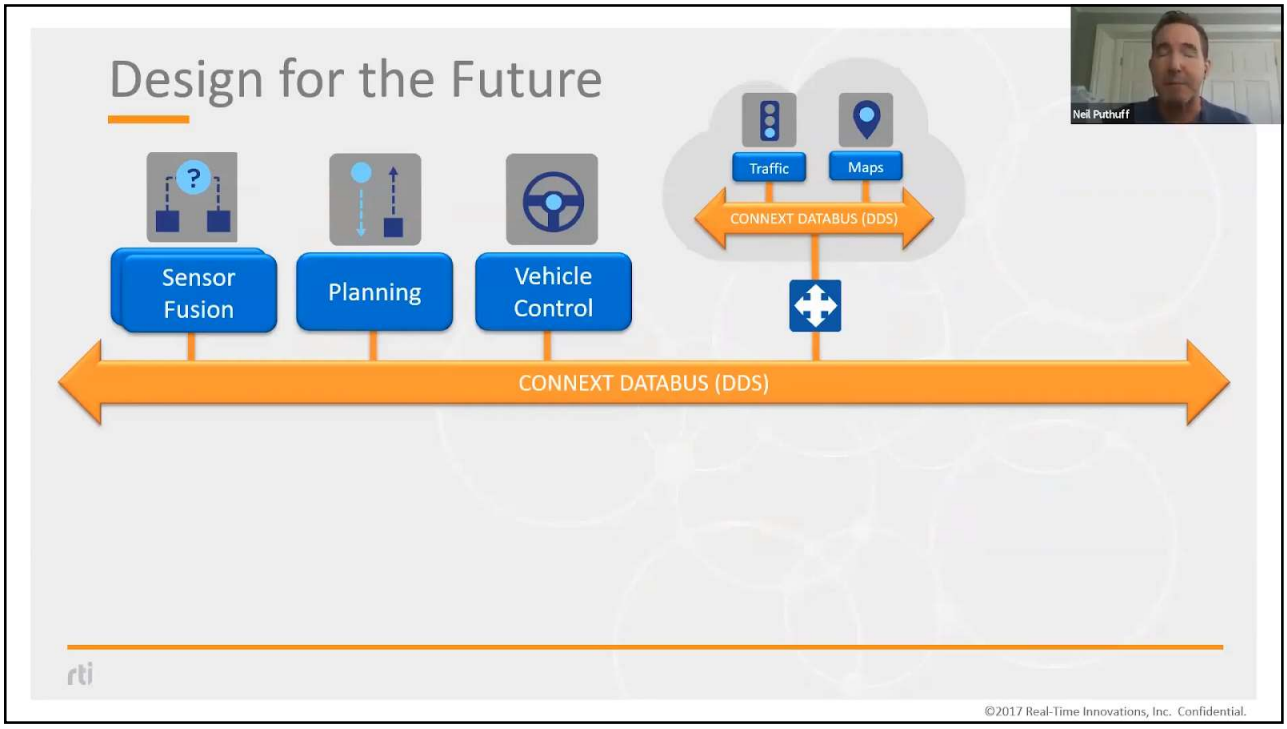
Design for the Future
Neil Puthuff
Traffic
Maps
CONNEXT DATABUS (DDS)
Sensor Fusion
Planning
Vehicle Control
CONNEXT DATABUS (DDS)
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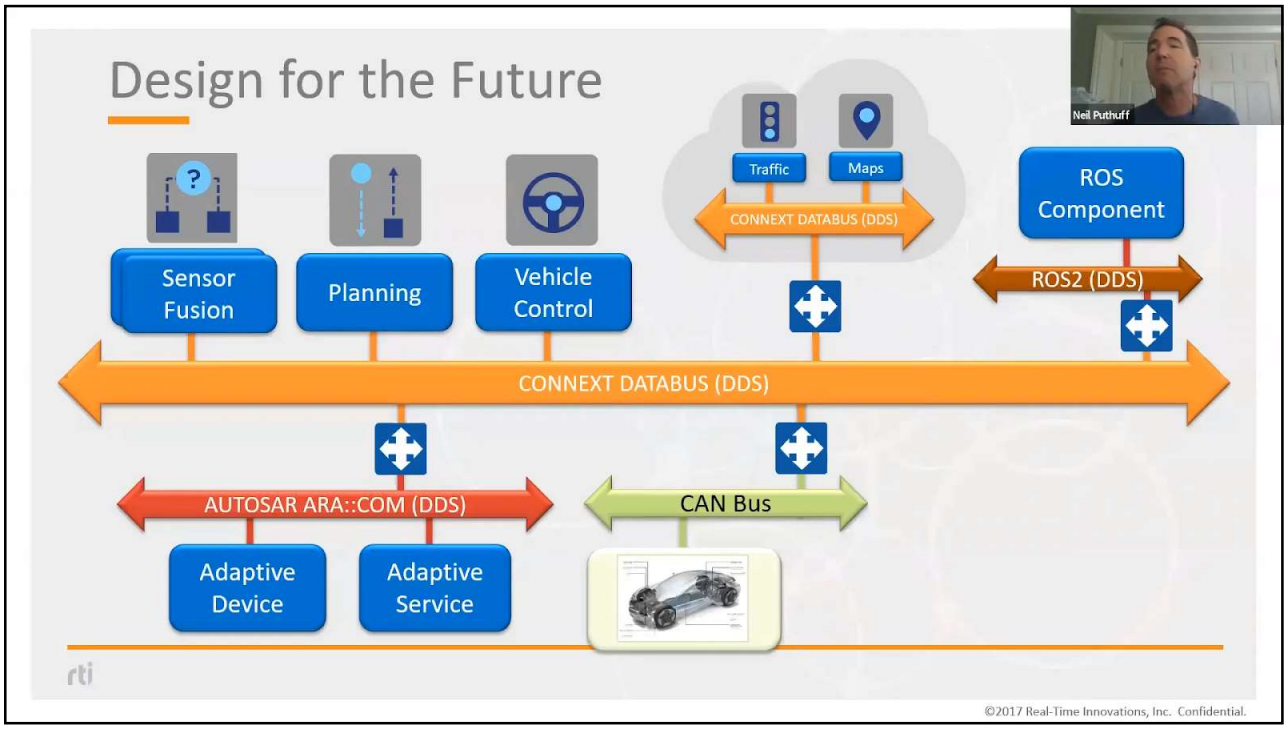
Design for the Future
Neil Puthuff
Traffic
Maps
CONNEXT DATABUS (DDS)
ROS Component
ROS2 (DDS)
Sensor Fusion
Planning
Vehicle Control
CONNEXT DATABUS (DDS)
AUTOSAR ARA::COM (DDS)
CAN Bus
Adaptive Device
Adaptive Service
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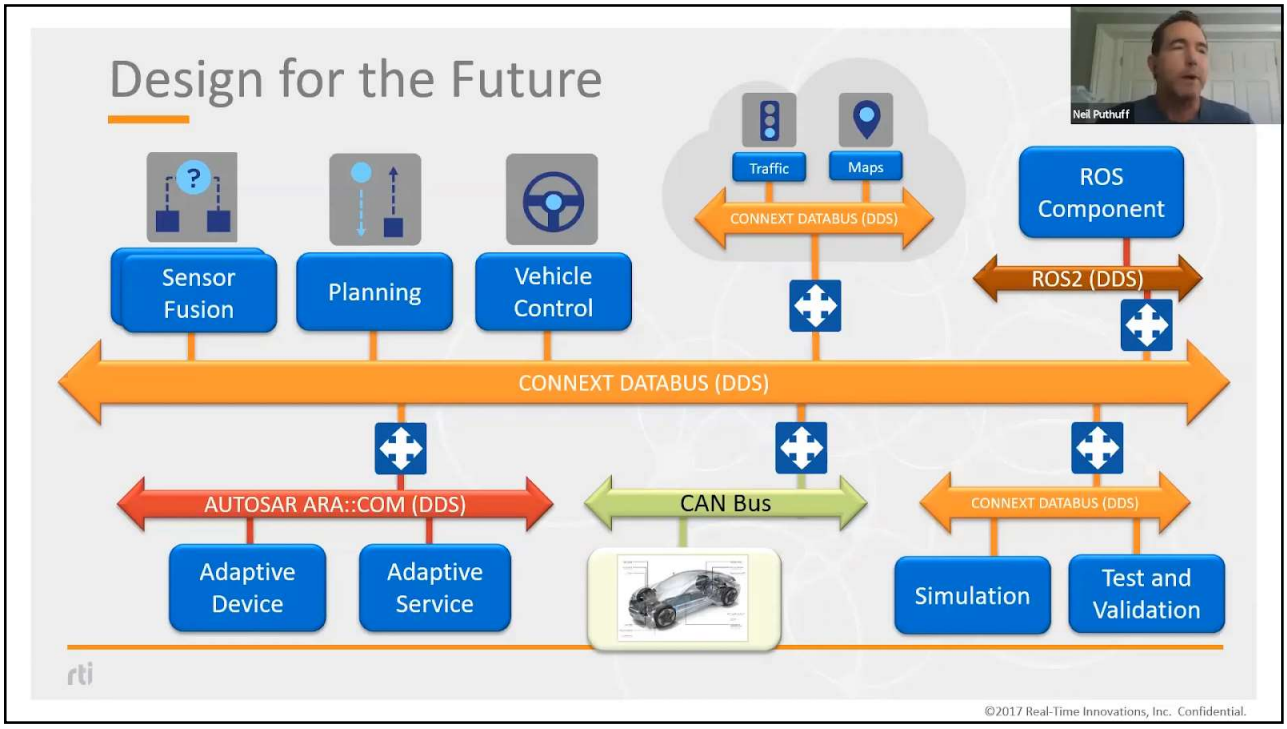
Design for the Future
Neil Puthuff
Traffic
Maps
CONNEXT DATABUS (DDS)
ROS Component
ROS2 (DDS)
Sensor Fusion
Planning
Vehicle Control
CONNEXT DATABUS (DDS)
AUTOSAR ARA::COM (DDS)
CAN Bus
CONNEXT DATABUS (DDS)
Adaptive Device
Adaptive Service
Simulation
Test and Validation
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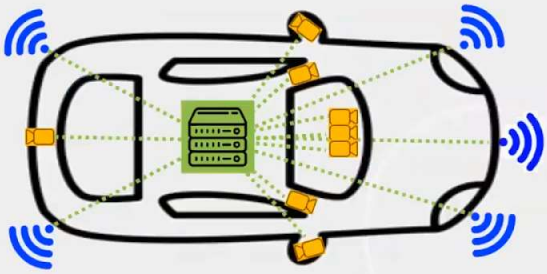
Distributed Architectures for Higher Autor

Central Fusion or "Late" Fusion



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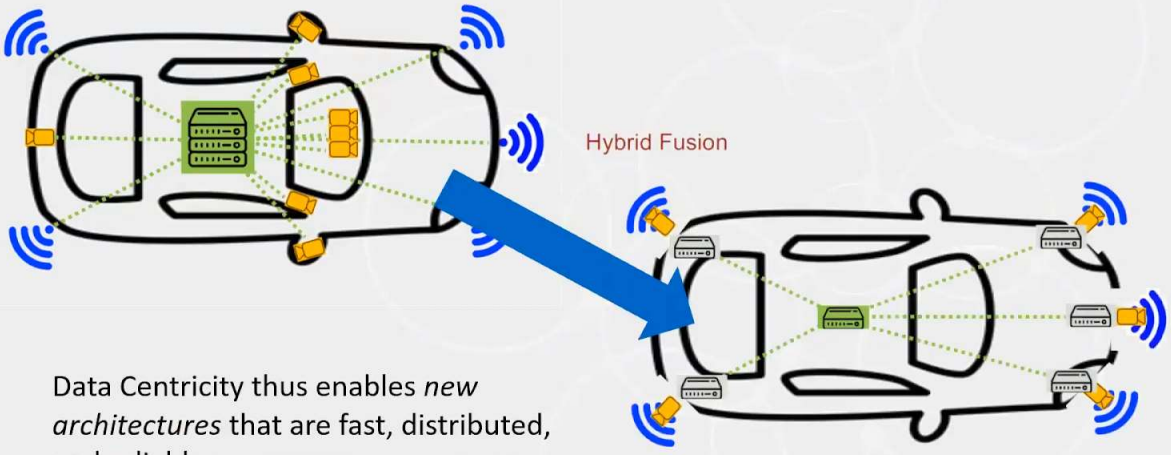
Distributed Architectures for Higher Autor

Central Fusion or "Late" Fusion



Data Centricity thus enables *new architectures* that are fast, distributed, and reliable.

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15+ Standards and Consortia Efforts
Neil Puthuff
DDS
OMG
OBJECT MANAGEMENT GROUP
AUTOSAR
industrial internet CONSORTIUM
ROS
OpenFog
FACE
Future Airborne Capability Environment
Smart Electric Power Alliance
MD PnP
Getting connected for patient safety
ICE Alliance
Integrating Clinical Environments
AVNU
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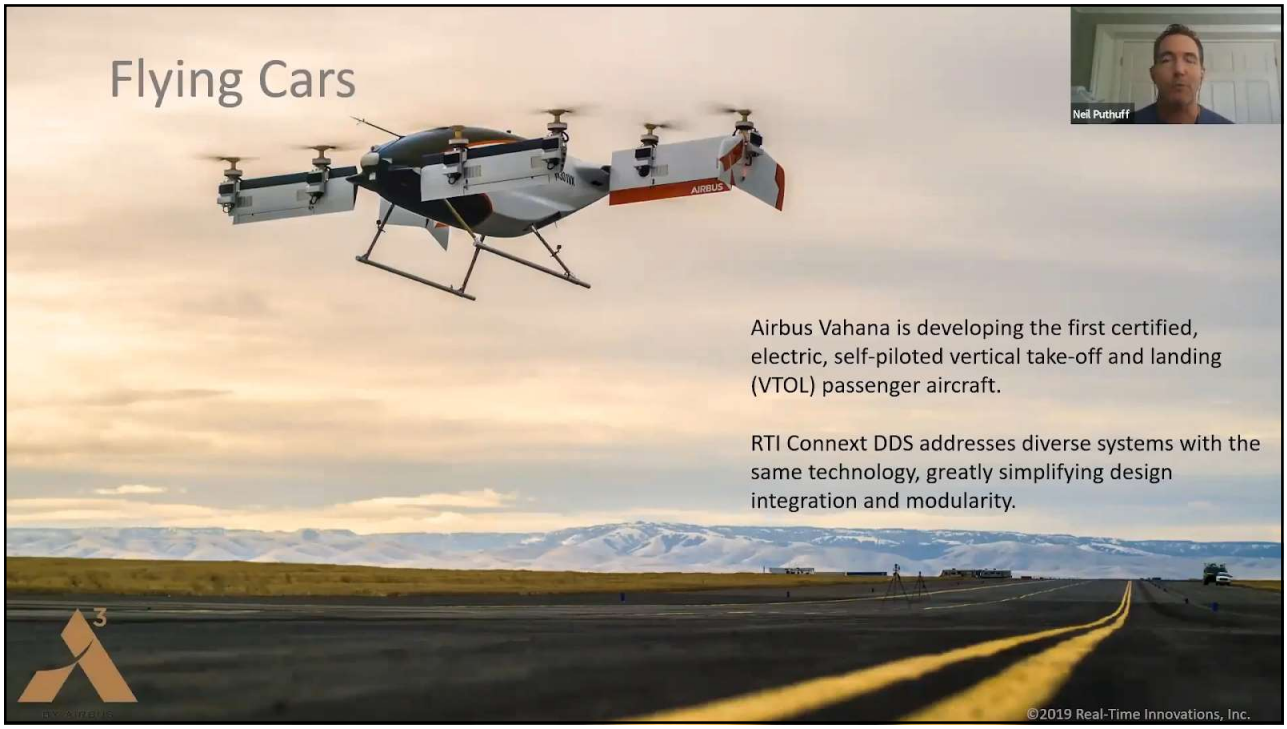
Flying Cars
Neil Puthuff
AIRBUS
Airbus Vahana is developing the first certified, electric, self-piloted vertical take-off and landing (VTOL) passenger aircraft.
RTI Connext DDS addresses diverse systems with the same technology, greatly simplifying design integration and modularity.
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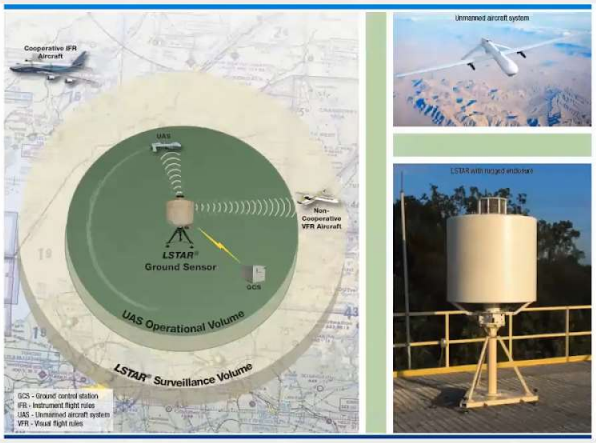
Enable UAS Flight in National Air Space

- The Ground Based Sense and Avoid system allows autonomous planes in US National Air Space
  - Repositioning
  - Training & testing
  - Disaster relief
  - Forest monitoring and fire suppression
- DO178C safety certified
- Operational with RTI Connext DDS in 2016



Management: US Army UAS Project Office
System integrator: SRC, Inc.

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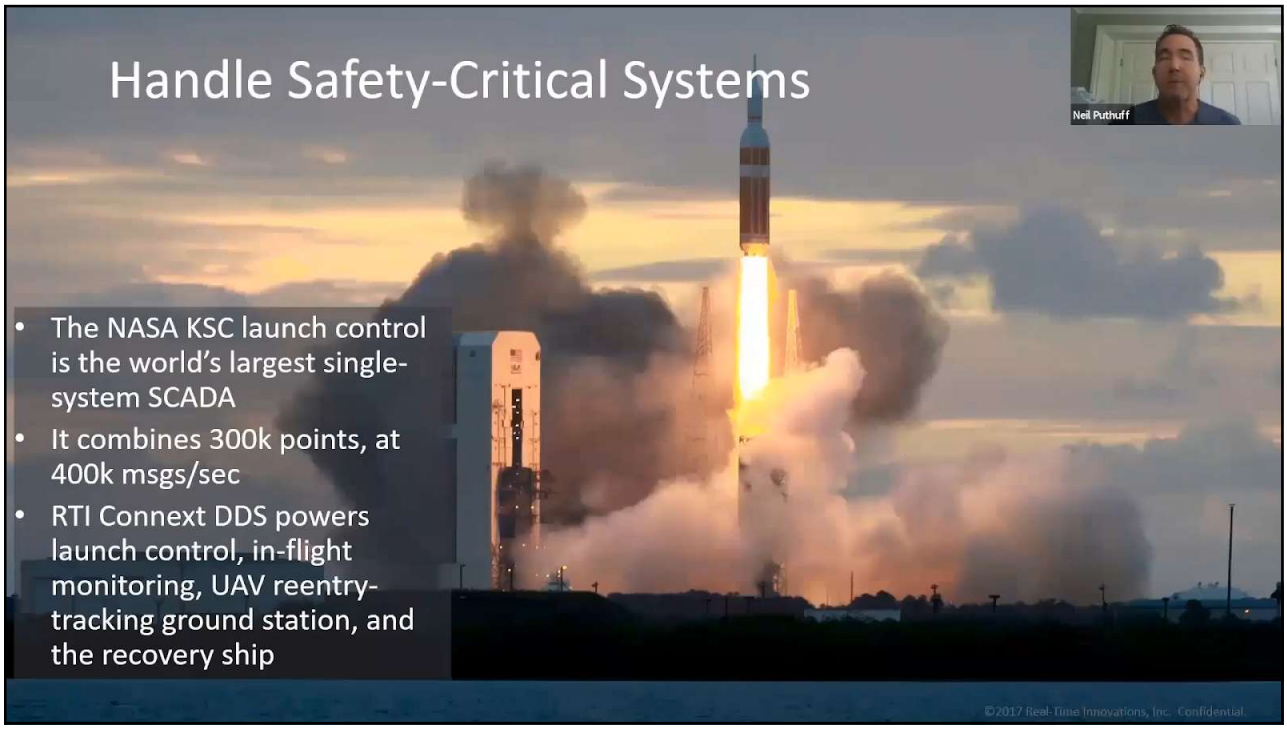
Autonomy in Deep Water

- Provides service telepresence at depths to 4000M
- Autonomous compensation for ocean current, ship, and target motion

TechnipFMC

20


Handle Safety-Critical Systems
Neil Puthuff
• The NASA KSC launch control is the world's largest single-system SCADA
• It combines 300k points, at 400k msgs/sec
• RTI Connext DDS powers launch control, in-flight monitoring, UAV reentry-tracking ground station, and the recovery ship
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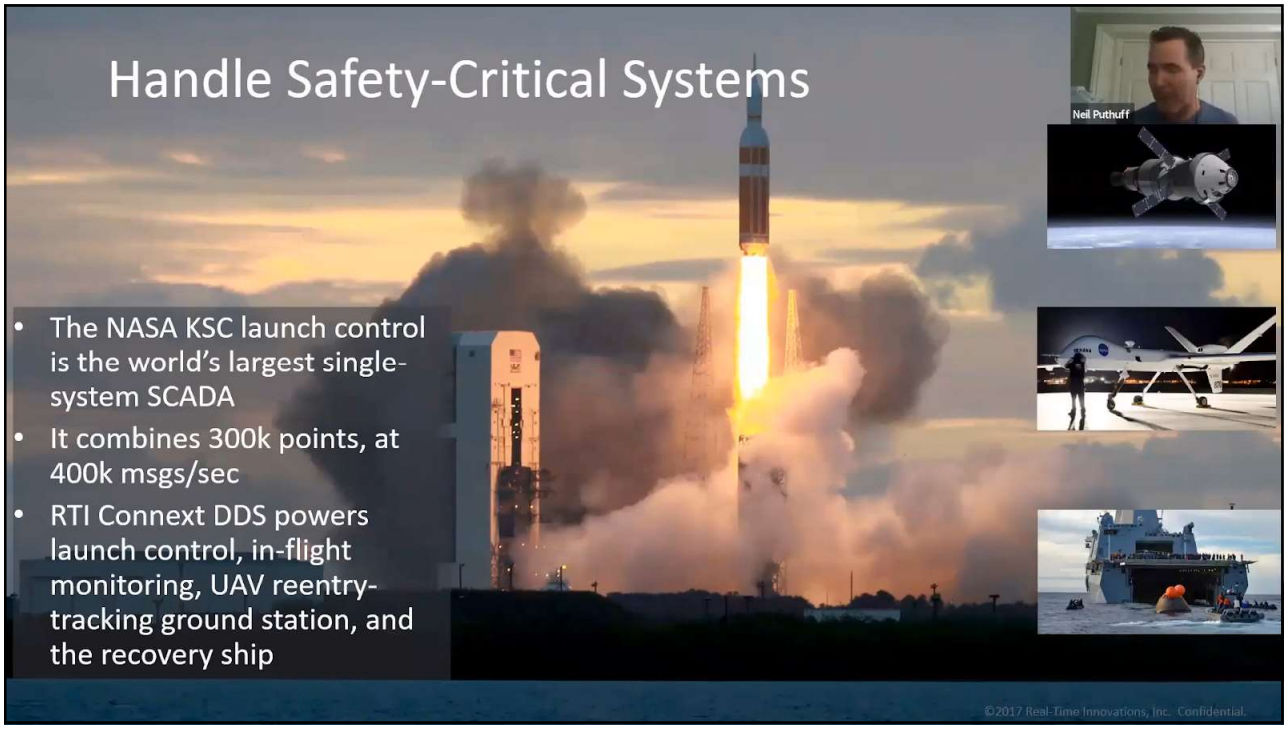
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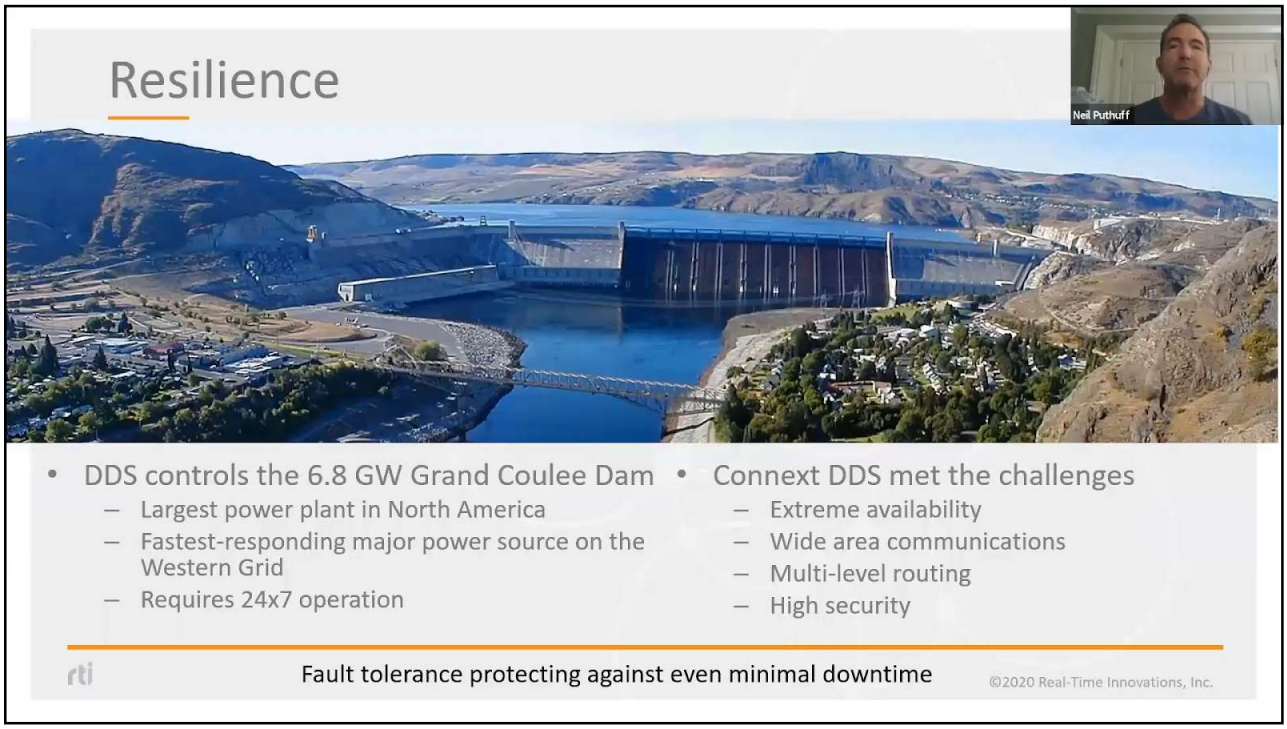
Resilience
Neil Puthuff
• DDS controls the 6.8 GW Grand Coulee Dam
– Largest power plant in North America
– Fastest-responding major power source on the Western Grid
– Requires 24x7 operation
• Connext DDS met the challenges
– Extreme availability
– Wide area communications
– Multi-level routing
– High security
Fault tolerance protecting against even minimal downtime
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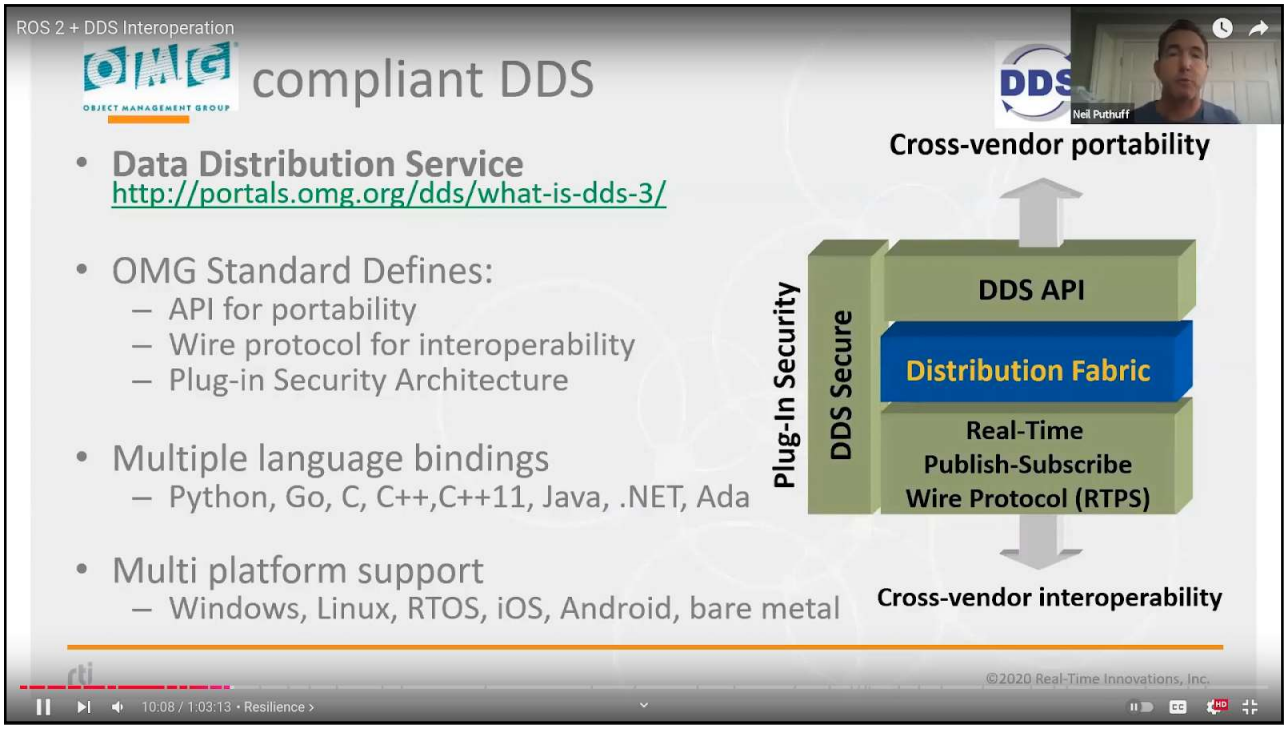
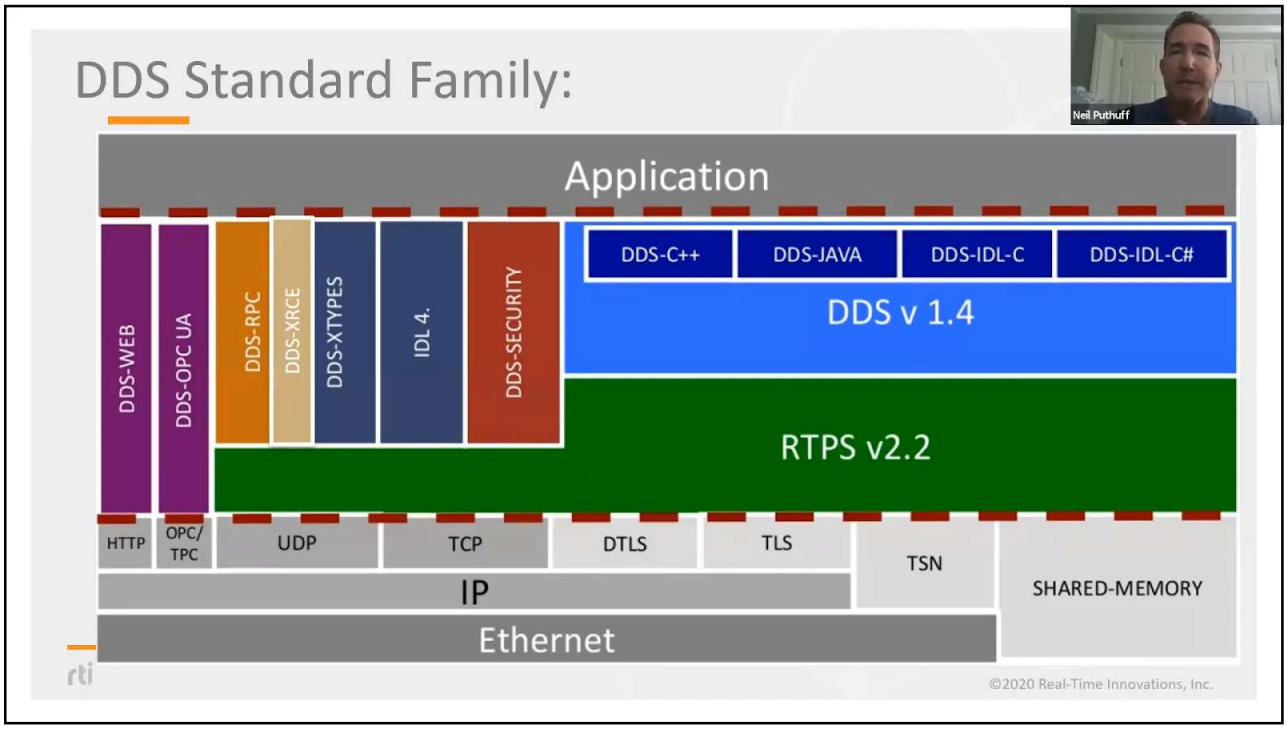

ROS 2 + DDS Interoperation
compliant DDS
Neil Puthuff
• Data Distribution Service
http://portals.omg.org/dds/what-is-dds-3/
• OMG Standard Defines:
– API for portability
– Wire protocol for interoperability
– Plug-in Security Architecture
• Multiple language bindings
– Python, Go, C, C++,C++11, Java, .NET, Ada
• Multi platform support
– Windows, Linux, RTOS, iOS, Android, bare metal
Cross-vendor portability
DDS API
Distribution Fabric
Real-Time Publish-Subscribe Wire Protocol (RTPS)
DDS Secure
Plug-In Security
Cross-vendor interoperability
©2020 Real-Time Innovations, Inc.
10:08 / 1:03:13 • Resilience ›

24


DDS Standard Family:
Neil Puthuff
Application
DDS-WEB
DDS-OPC UA
DDS-RPC
DDS-XRCE
DDS-XTYPES
IDL 4.
DDS-SECURITY
DDS-C++
DDS-JAVA
DDS-IDL-C
DDS-IDL-C#
DDS v 1.4
RTPS v2.2
HTTP
OPC/ TPC
UDP
TCP
DTLS
TLS
TSN
SHARED-MEMORY
IP
Ethernet
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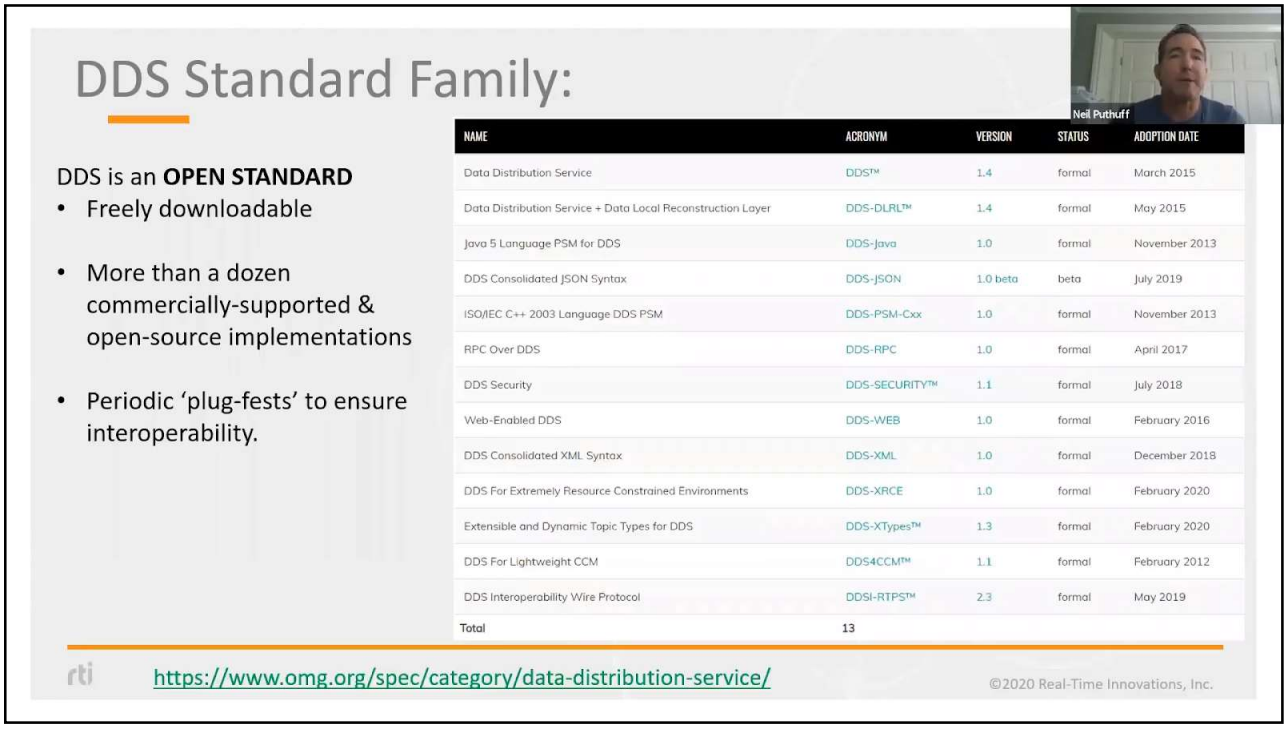
DDS Standard Family:
Neil Puthuff
DDS is an **OPEN STANDARD**
• Freely downloadable
• More than a dozen commercially-supported & open-source implementations
• Periodic 'plug-fests' to ensure interoperability.
NAME | ACRONYM | VERSION | STATUS | ADOPTION DATE
Data Distribution Service | DDS™ | 1.4 | formal | March 2015
Data Distribution Service + Data Local Reconstruction Layer | DDS-DLRL™ | 1.4 | formal | May 2015
Java 5 Language PSM for DDS | DDS-Java | 1.0 | formal | November 2013
DDS Consolidated JSON Syntax | DDS-JSON | 1.0 beta | beta | July 2019
ISO/IEC C++ 2003 Language DDS PSM | DDS-PSM-Cxx | 1.0 | formal | November 2013
RPC Over DDS | DDS-RPC | 1.0 | formal | April 2017
DDS Security | DDS-SECURITY™ | 1.1 | formal | July 2018
Web-Enabled DDS | DDS-WEB | 1.0 | formal | February 2016
DDS Consolidated XML Syntax | DDS-XML | 1.0 | formal | December 2018
DDS For Extremely Resource Constrained Environments | DDS-XRCE | 1.0 | formal | February 2020
Extensible and Dynamic Topic Types for DDS | DDS-XTypes™ | 1.3 | formal | February 2020
DDS For Lightweight CCM | DDS4CCM™ | 1.1 | formal | February 2012
DDS Interoperability Wire Protocol | DDSI-RTPS™ | 2.3 | formal | May 2019
Total | 13
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https://www.omg.org/spec/category/data-distribution-service/
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DDS Highlights

- Data-Centric
- *High Performance & Efficiency*
- Automated Discovery
- Transport-independent
- Rich set of QoS options

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DDS 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

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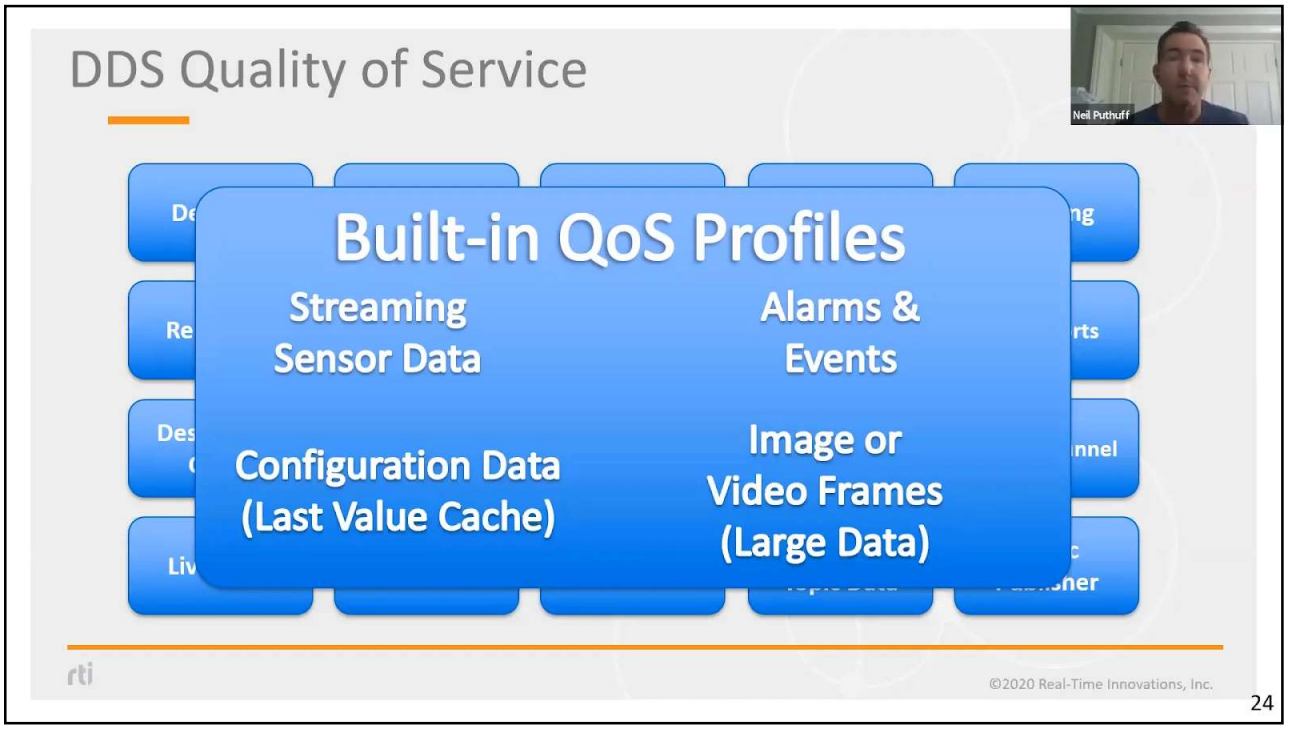
DDS Quality of Service
Built-in QoS Profiles
Streaming Sensor Data
Alarms & Events
Configuration Data (Last Value Cache)
Image or Video Frames (Large Data)
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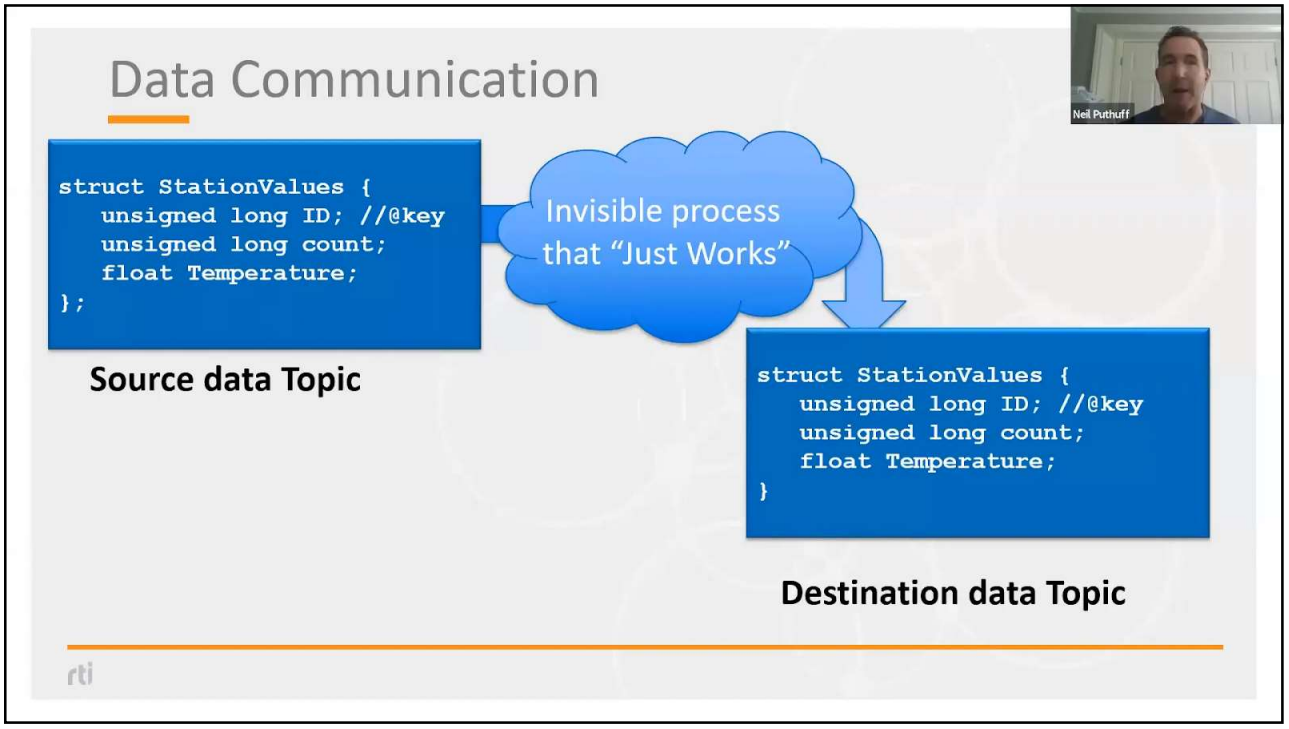
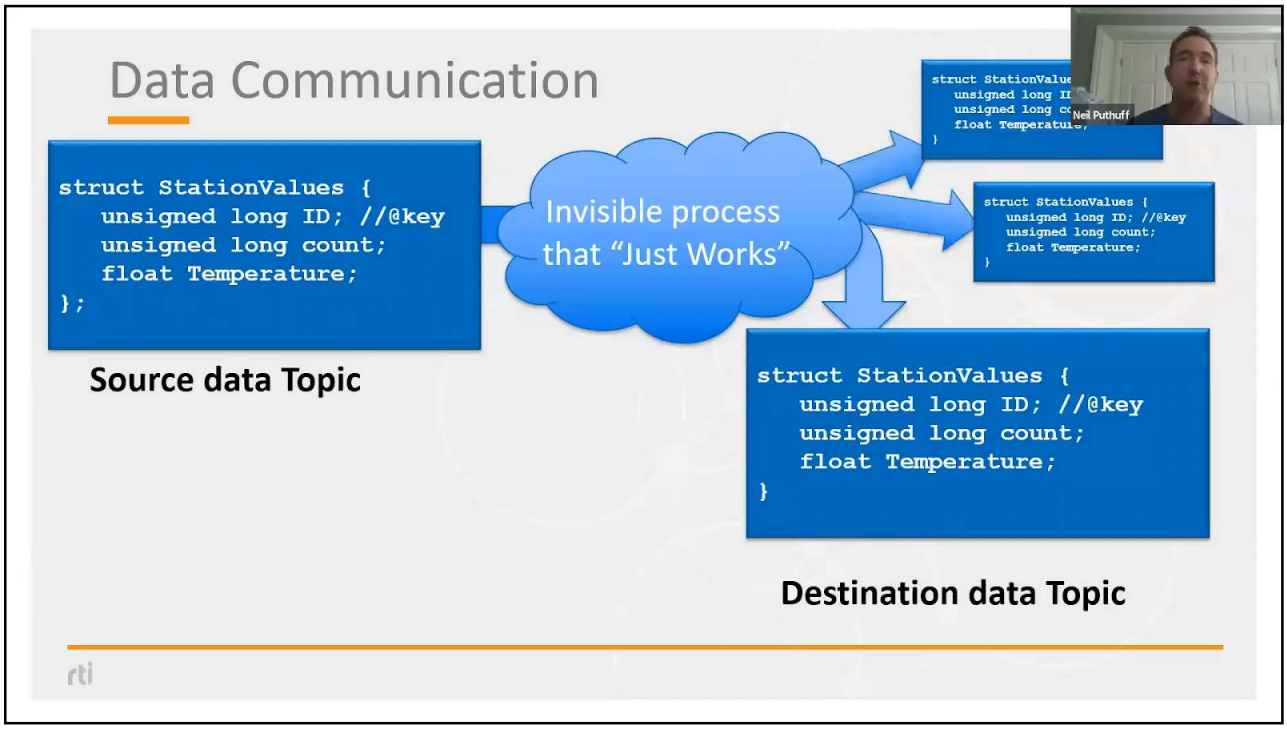

Data Communication
struct StationValues {
unsigned long ID; //@key
unsigned long count;
float Temperature;
};
Invisible process that "Just Works"
Source data Topic
struct StationValues {
unsigned long ID; //@key
unsigned long count;
float Temperature;
}
Destination data Topic
rti

30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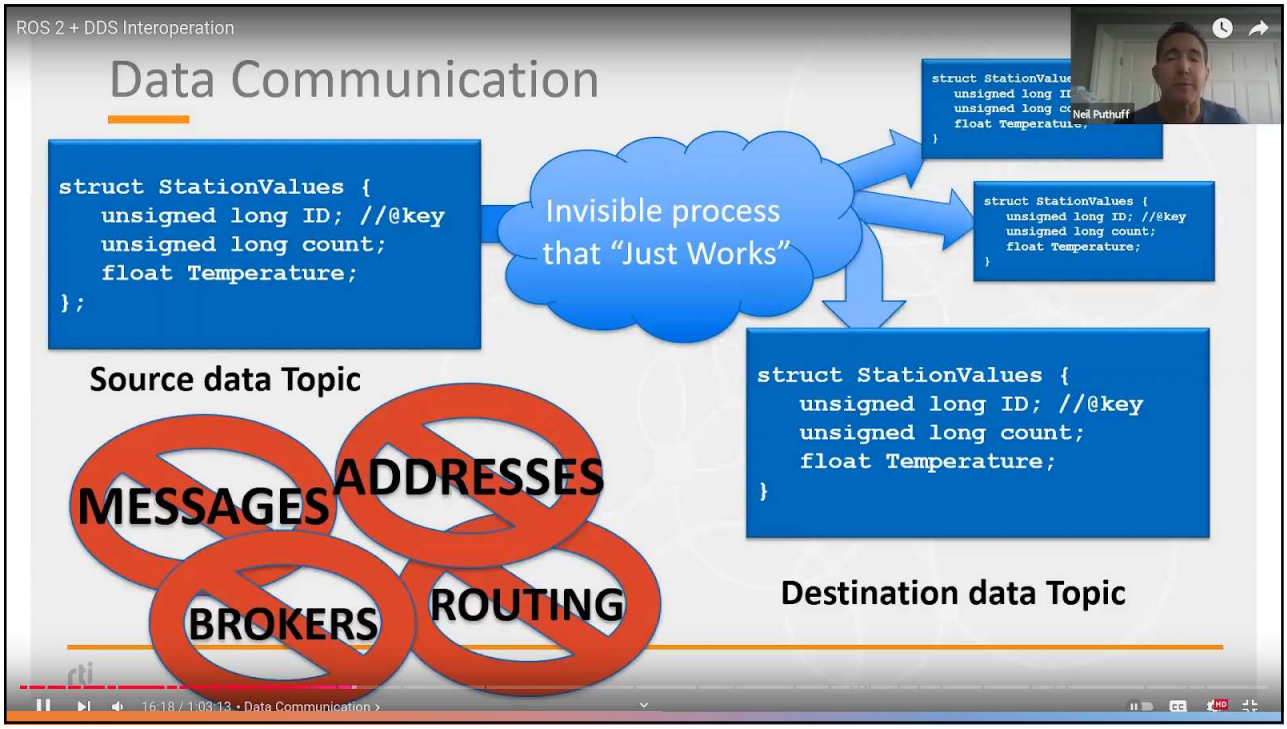
Destination data Topic
Neil Puthuff

31


ROS 2 + DDS Interoperation
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Source data Topic
Invisible process that "Just Works"
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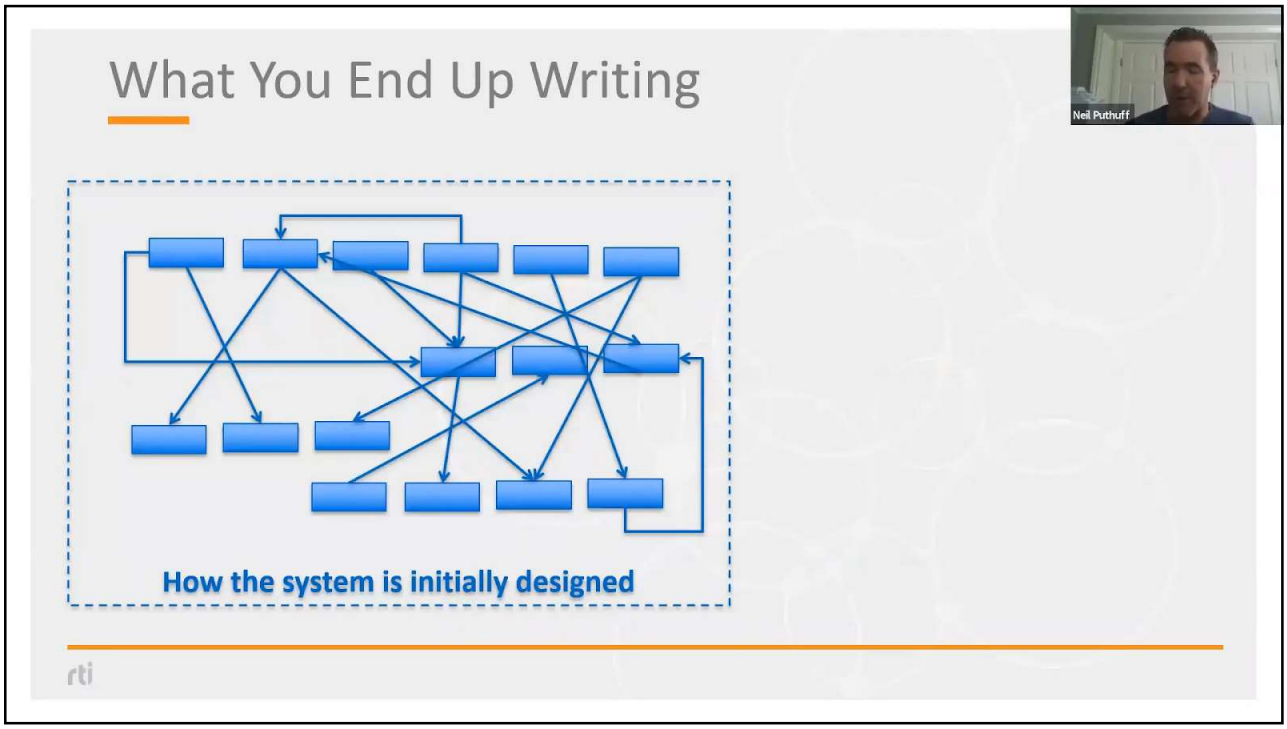
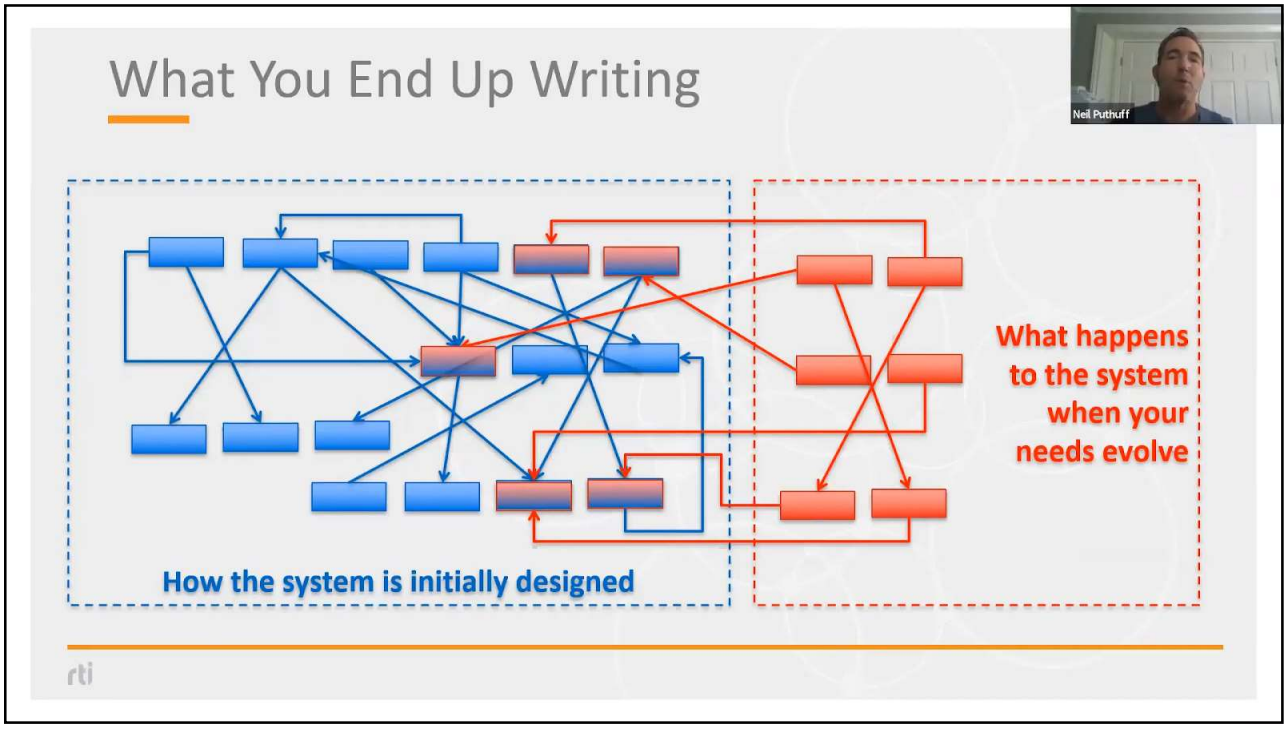
float Temperature;
}
Destination data Topic
MESSAGES
ADDRESSES
BROKERS
ROUTING
Neil Puthuff

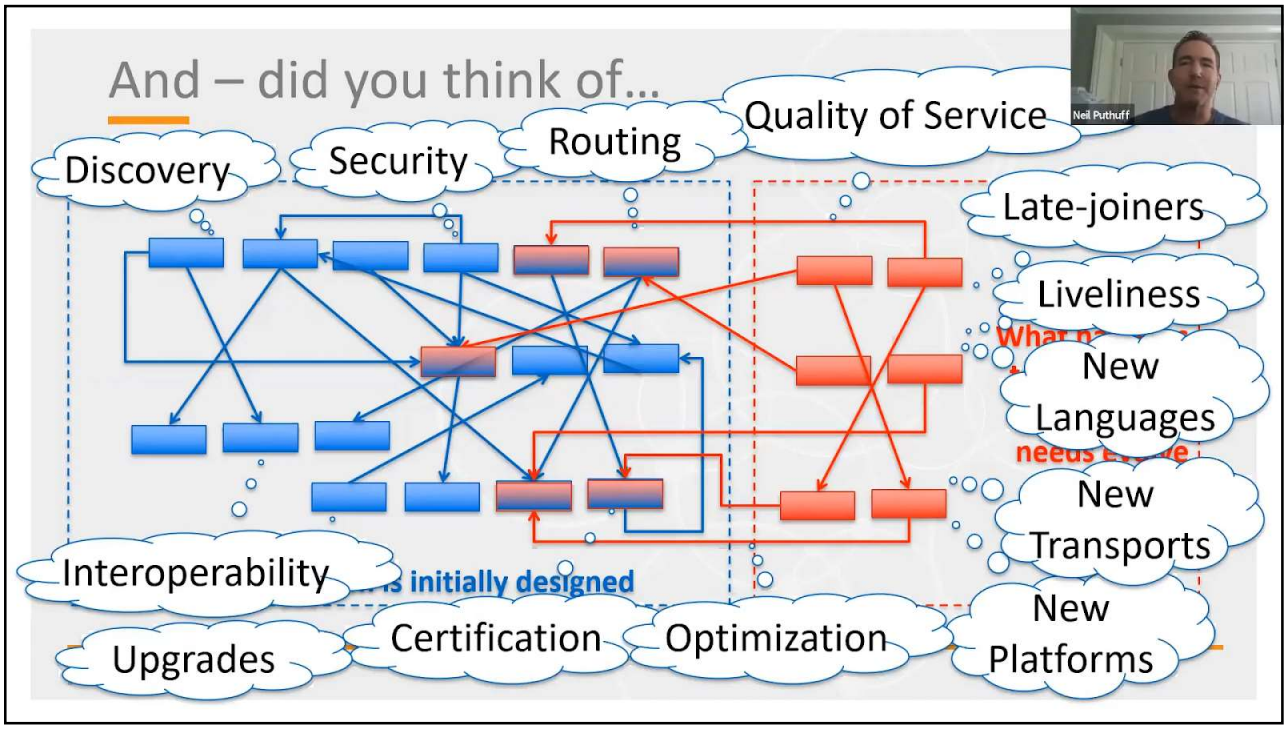
32


What You End Up Writing
Neil Puthuff
How the system is initially designed
rti

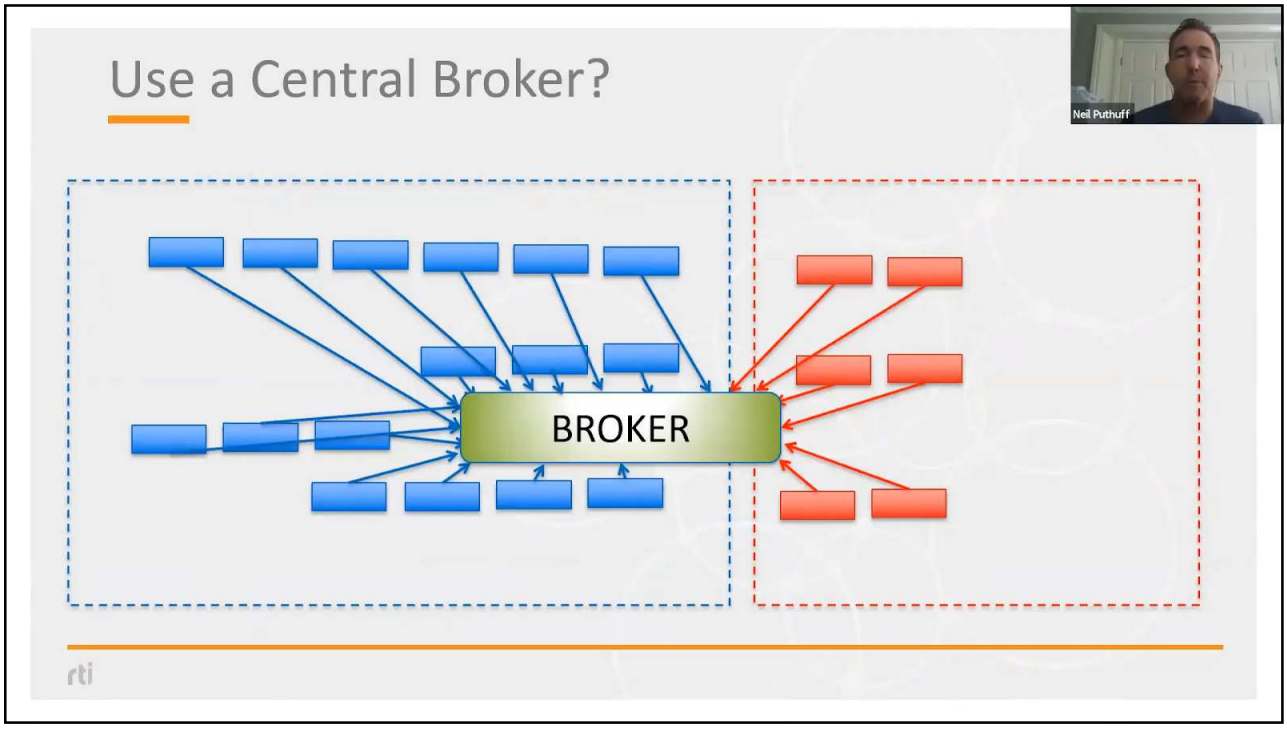
33


What You End Up Writing
Neil Puthuff
What happens to the system when your needs evolve
How the system is initially designed
rti

34


And – did you think of…
Discovery
Security
Routing
Quality of Service
Late-joiners
Liveliness
New Languages
New Transports
New Platforms
Interoperability
Certification
Optimization
Upgrades

35


Use a Central Broker?
BROKER
rti

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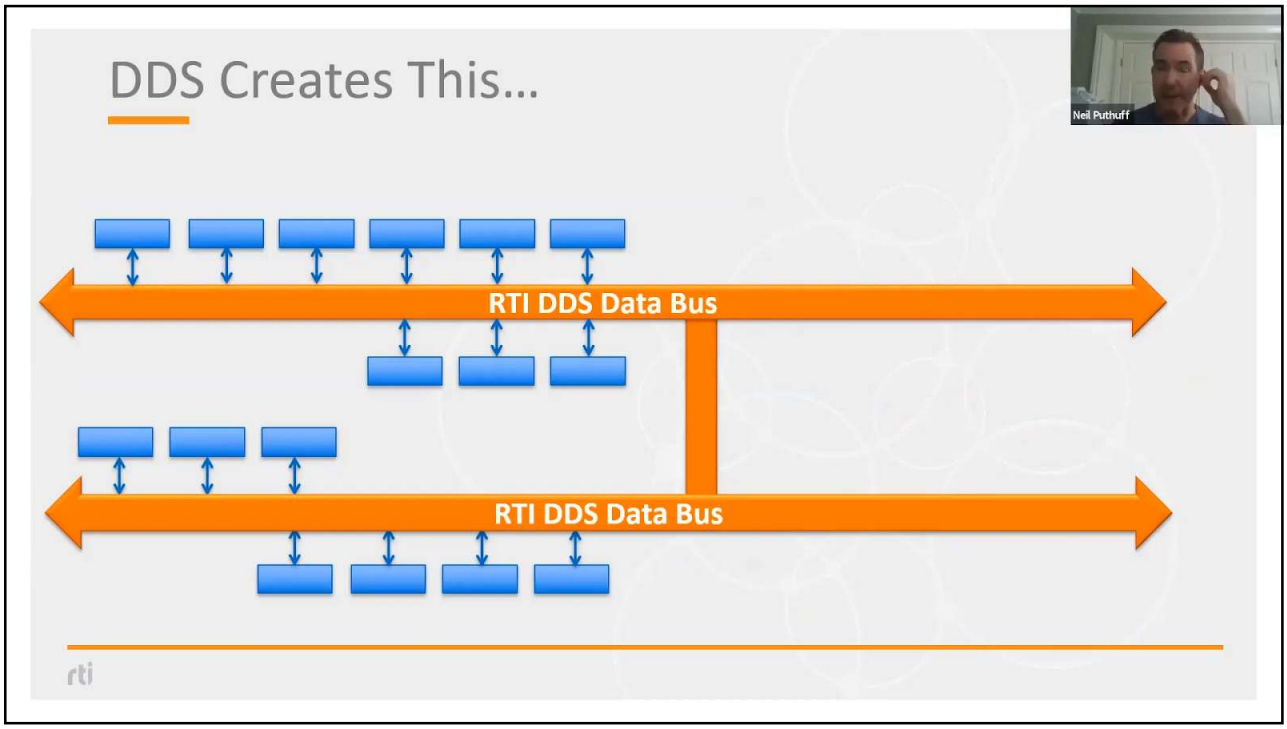
DDS Creates This…
Neil Puthuff
RTI DDS Data Bus
RTI DDS Data Bus
rti

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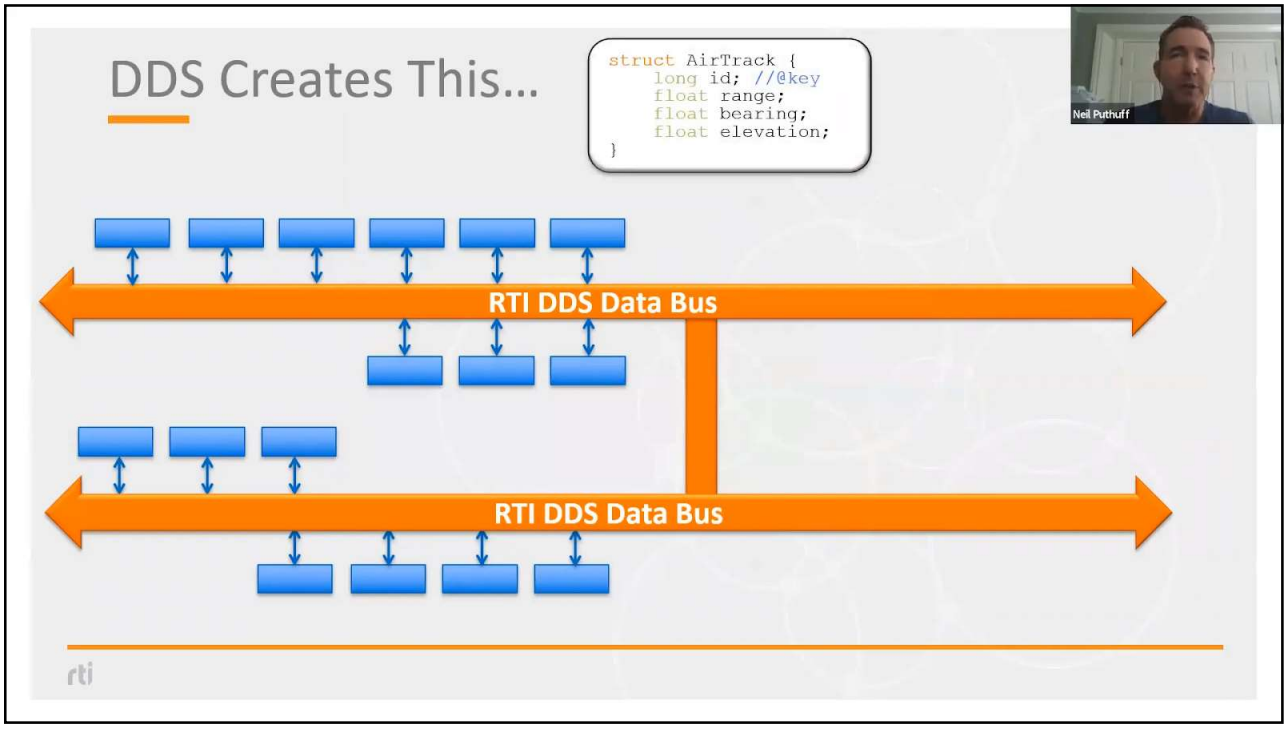
DDS Creates This…
struct AirTrack {
long id; //@key
float range;
float bearing;
float elevation;
}
Neil Puthuff
RTI DDS Data Bus
RTI DDS Data Bus
rti

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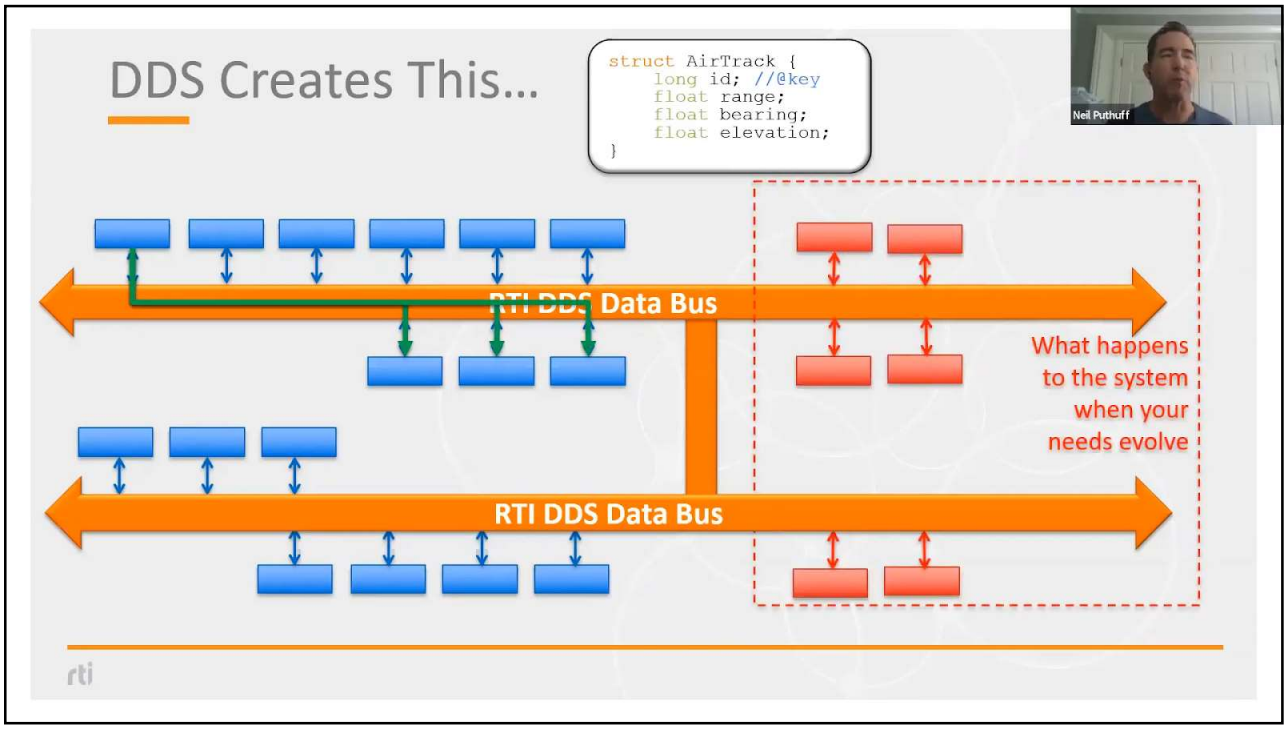
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RTI DDS Data Bus
What happens to the system when your needs evolve
RTI DDS Data Bus
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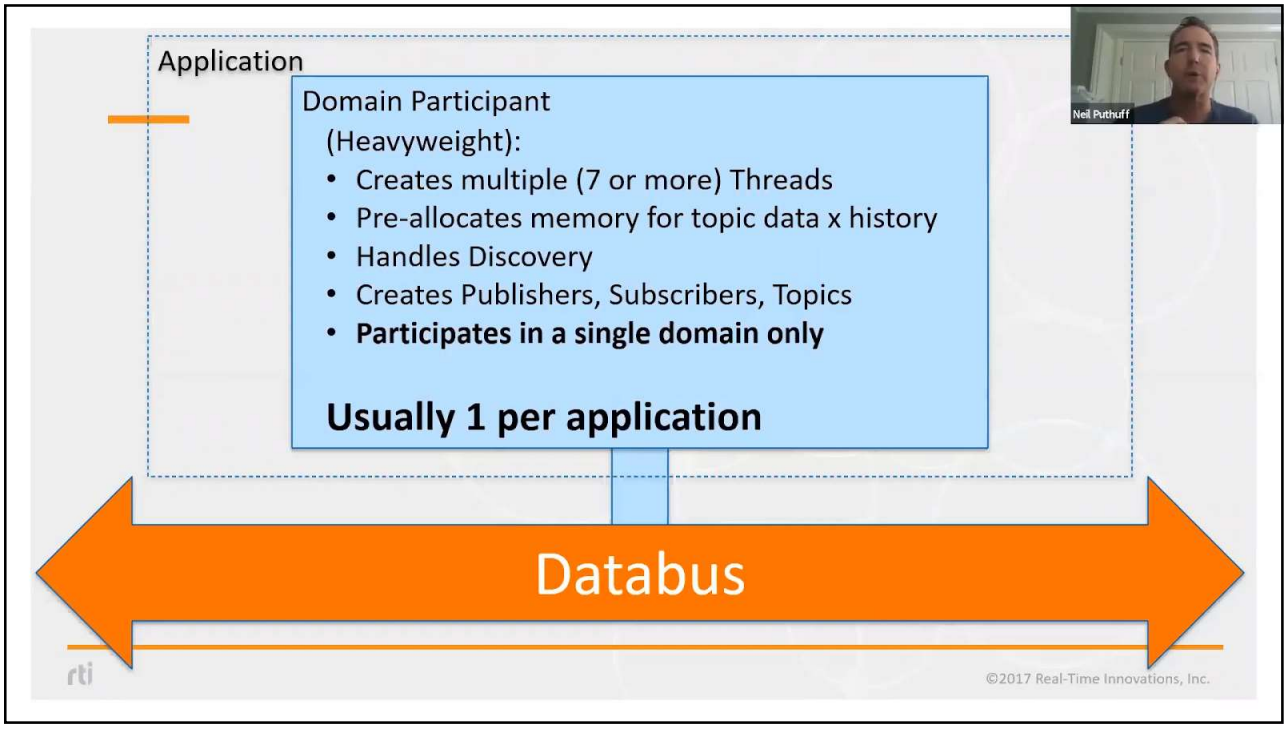
Application
Domain Participant
(Heavyweight):
• Creates multiple (7 or more) Threads
• Pre-allocates memory for topic data x history
• Handles Discovery
• Creates Publishers, Subscribers, Topics
• Participates in a single domain only
Usually 1 per application
Databus
rti
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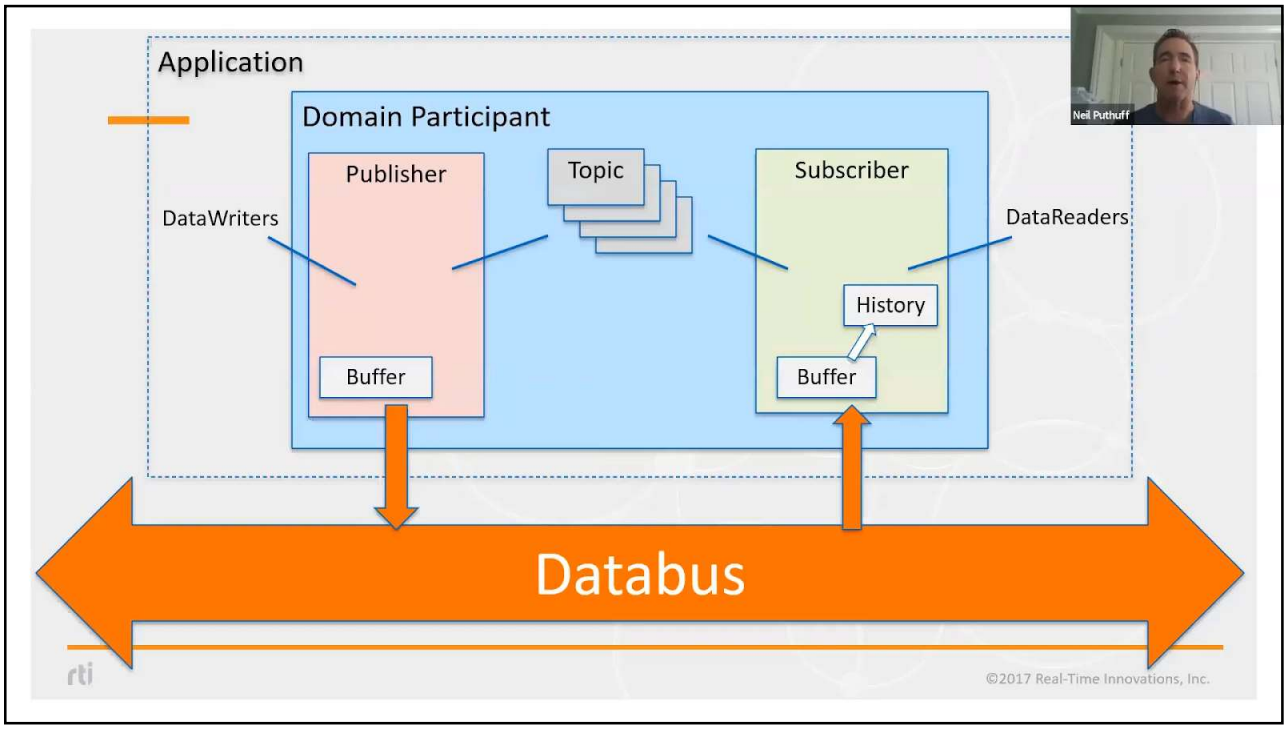
Application
Domain Participant
Publisher
Topic
Subscriber
DataWriters
DataReaders
History
Buffer
Buffer
Databus
rti
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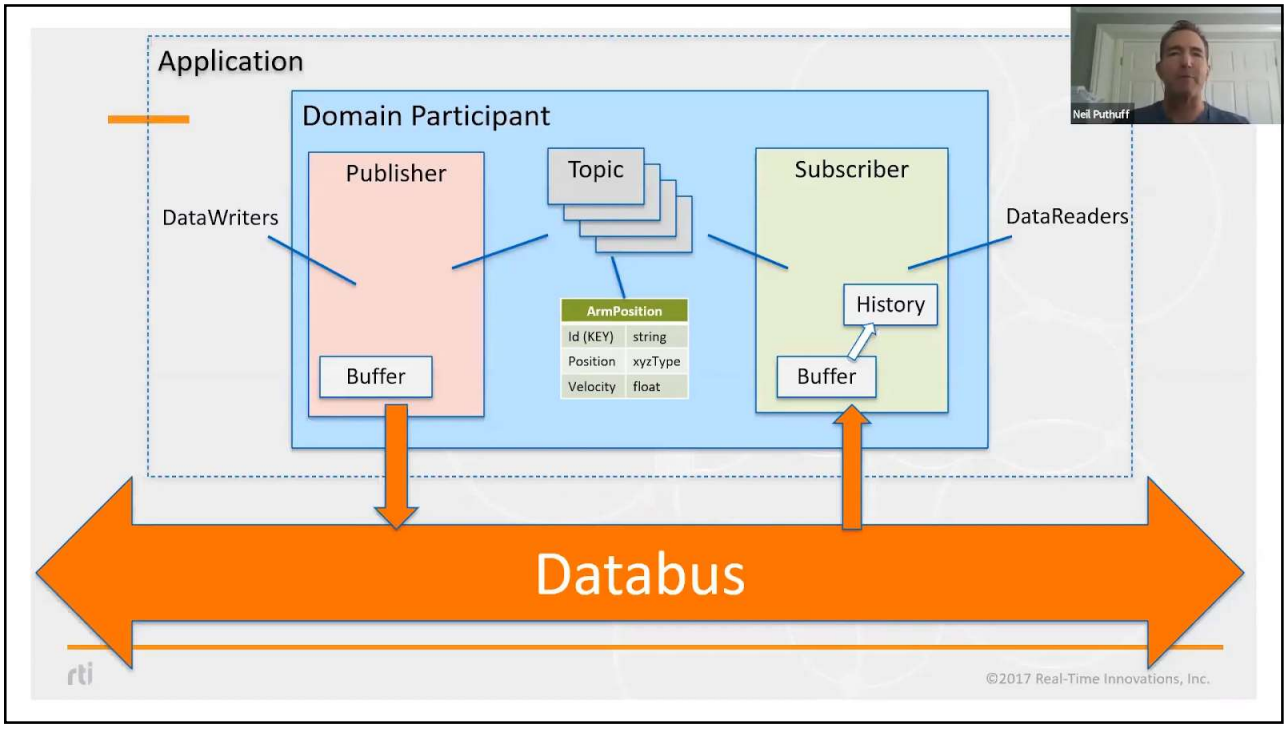
41


Application
Domain Participant
Publisher
Topic
Subscriber
DataWriters
DataReaders
ArmPosition
Id (KEY) string
Position xyzType
Velocity float
History
Buffer
Buffer
Databus
rti
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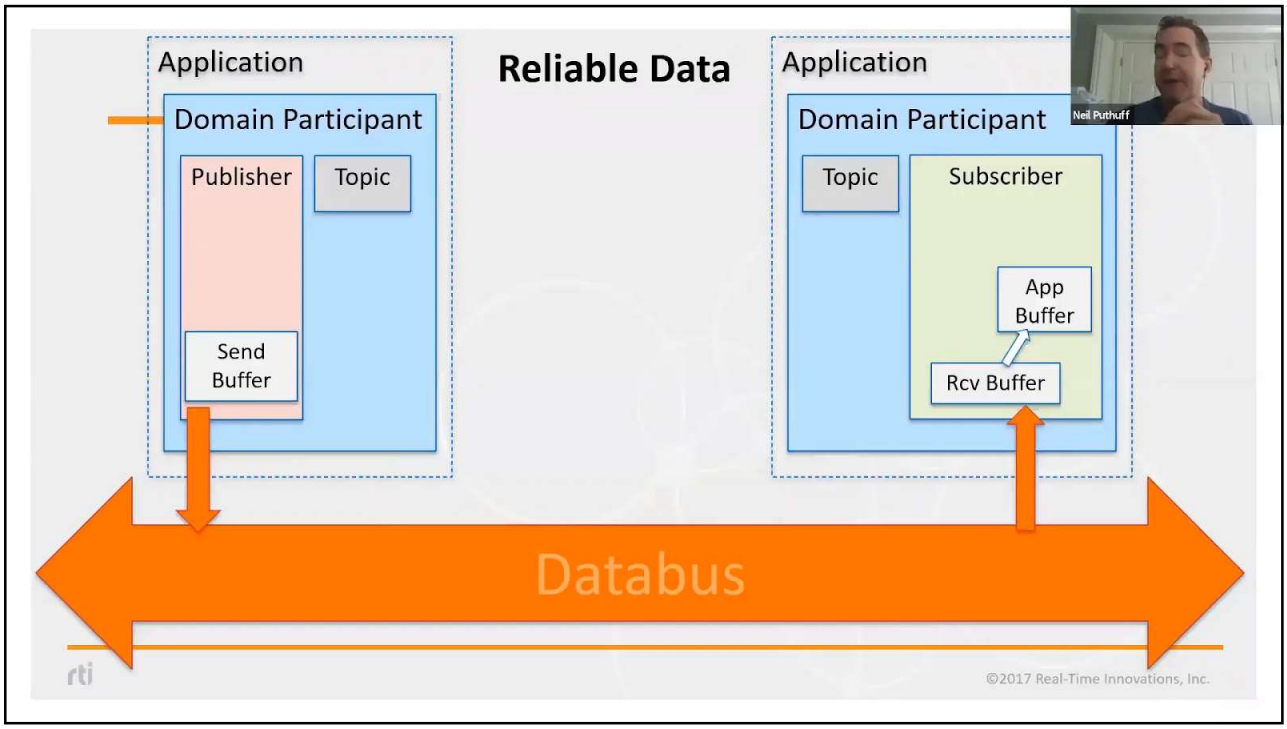
Application
Reliable Data
Application
Domain Participant
Domain Participant
Publisher
Topic
Topic
Subscriber
App Buffer
Send Buffer
Rcv Buffer
Databus
rti
©2017 Real-Time Innovations, Inc.

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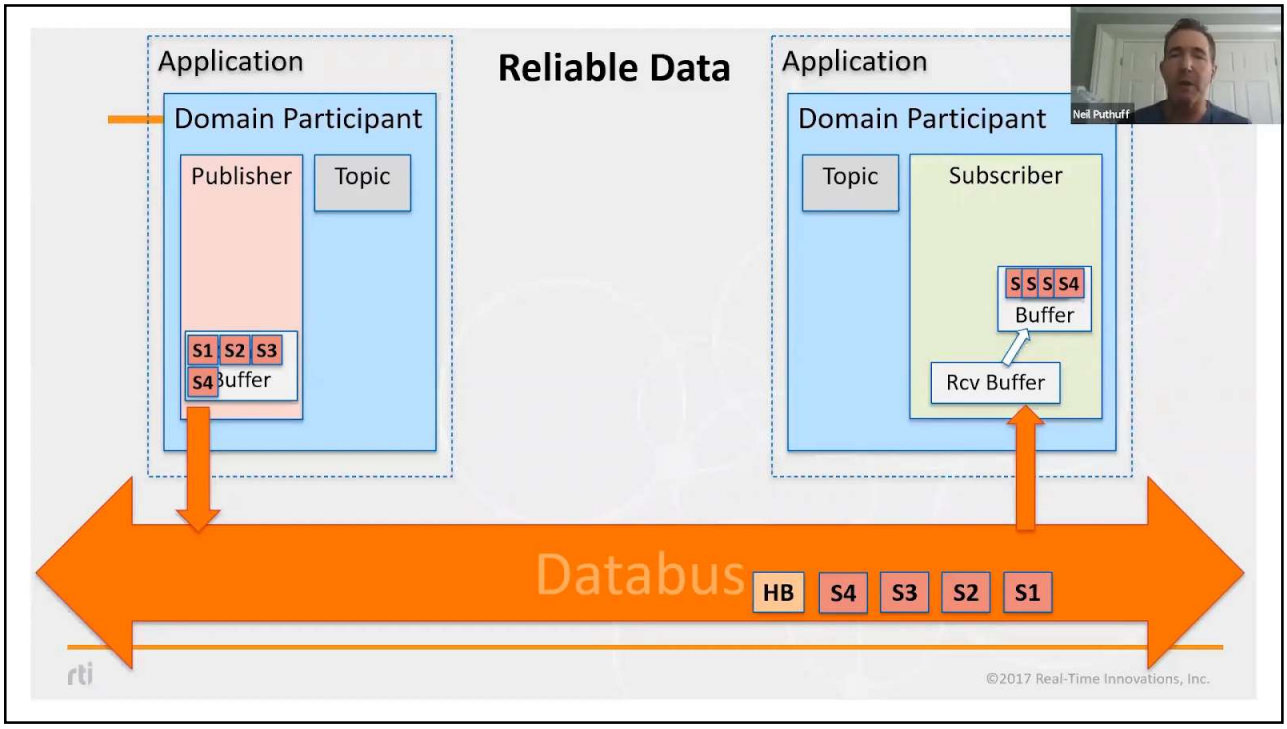
Application
Reliable Data
Application
Domain Participant
Domain Participant
Publisher
Topic
Topic
Subscriber
S S S S4
Buffer
S1 S2 S3
S4 Buffer
Rcv Buffer
Databus
HB
S4
S3
S2
S1
rti
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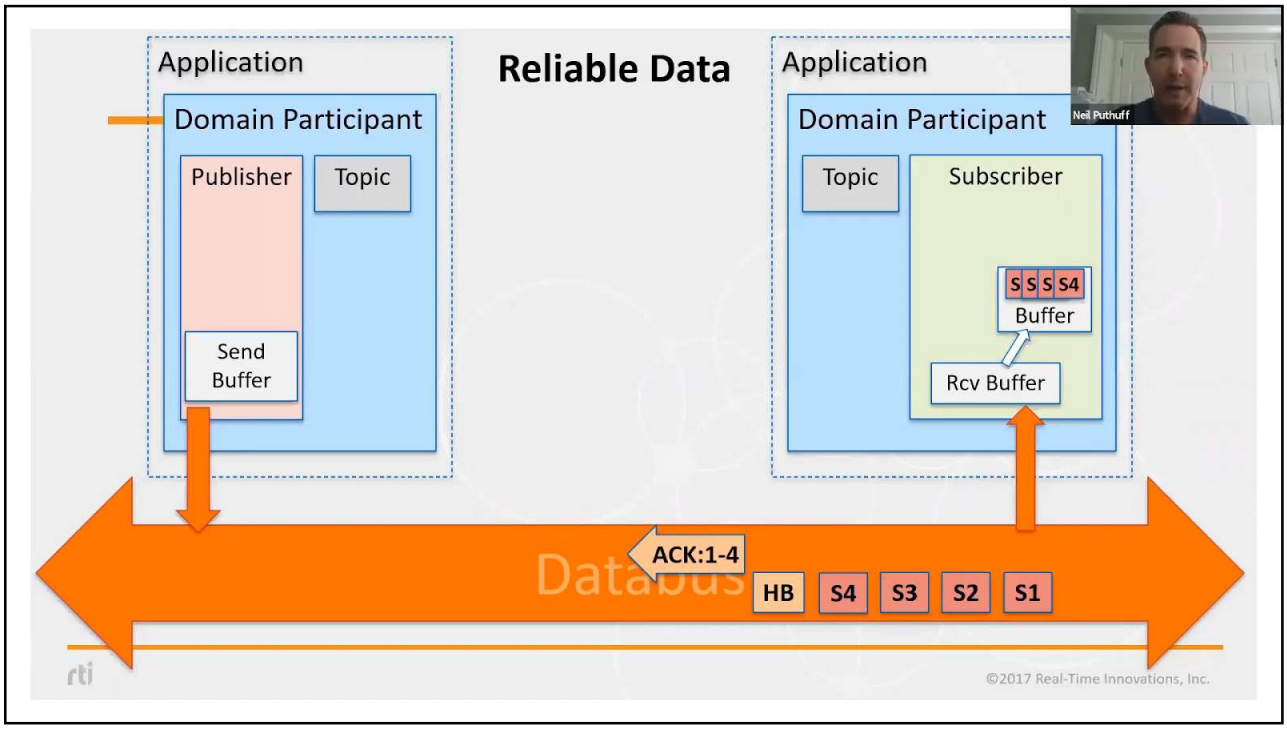
Application
Reliable Data
Application
Domain Participant
Domain Participant
Publisher
Topic
Topic
Subscriber
Send Buffer
S S S S4
Buffer
Rcv Buffer
ACK:1-4
HB
S4
S3
S2
S1
rti
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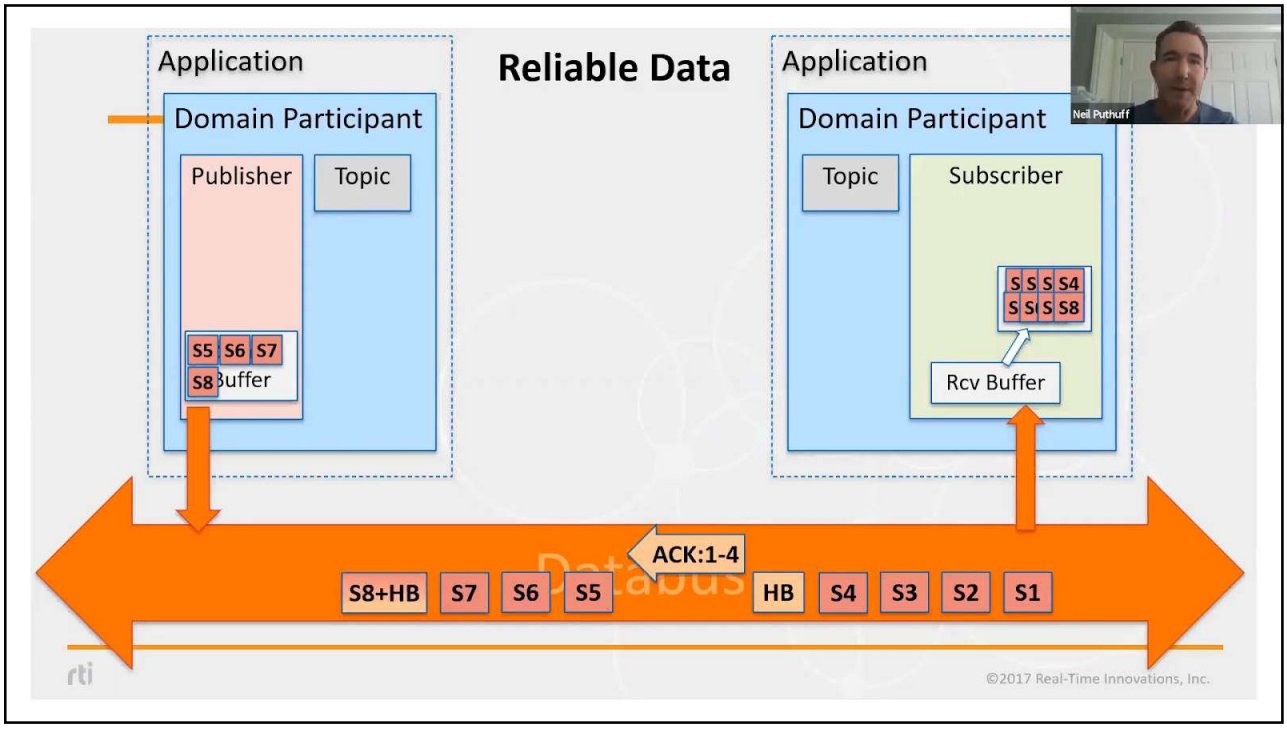
45


Application
Reliable Data
Application
Domain Participant
Domain Participant
Publisher
Topic
Topic
Subscriber
S5 S6 S7
S8 Buffer
S S S S4
S S S S8
Rcv Buffer
ACK:1-4
S8+HB
S7
S6
S5
HB
S4
S3
S2
S1
rti
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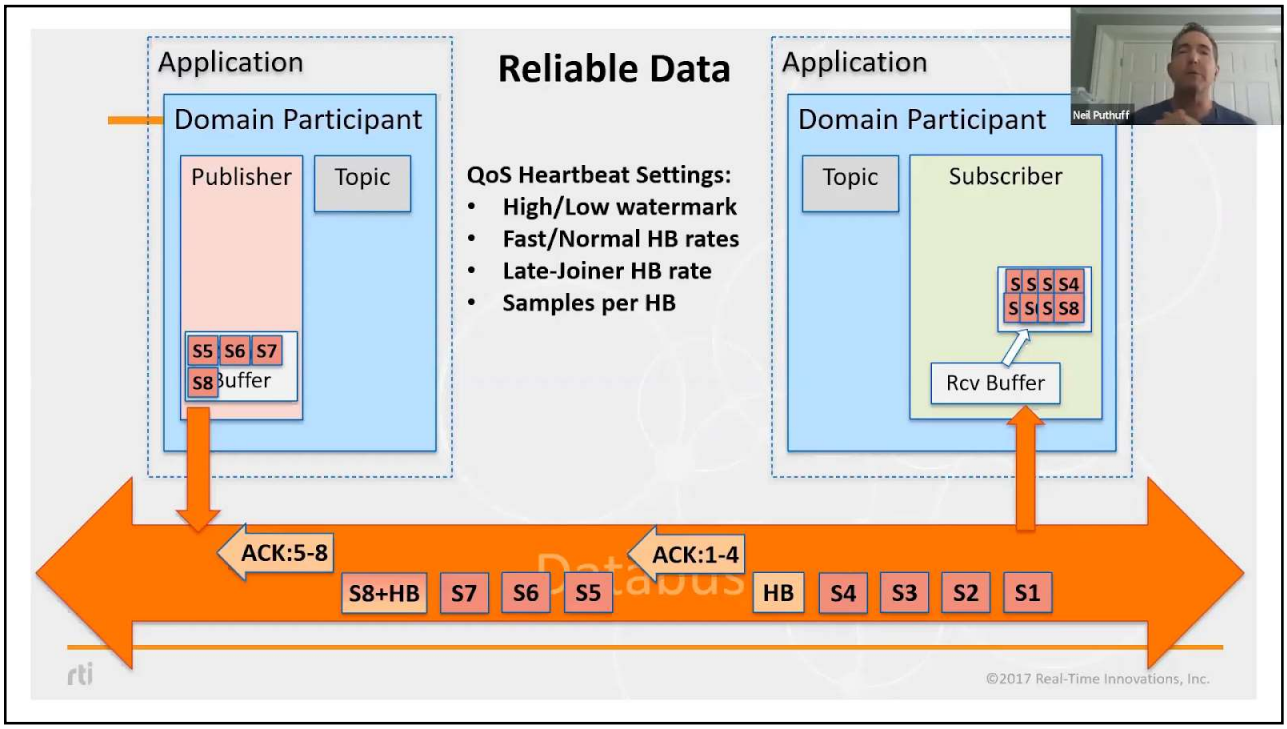
Application
Domain Participant
Publisher
Topic
S5 S6 S7
S8 uffer
Reliable Data
QoS Heartbeat Settings:
• High/Low watermark
• Fast/Normal HB rates
• Late-Joiner HB rate
• Samples per HB
Application
Domain Participant
Topic
Subscriber
S S S S4
S S S S8
Rcv Buffer
ACK:5-8
ACK:1-4
S8+HB
S7
S6
S5
HB
S4
S3
S2
S1
rti
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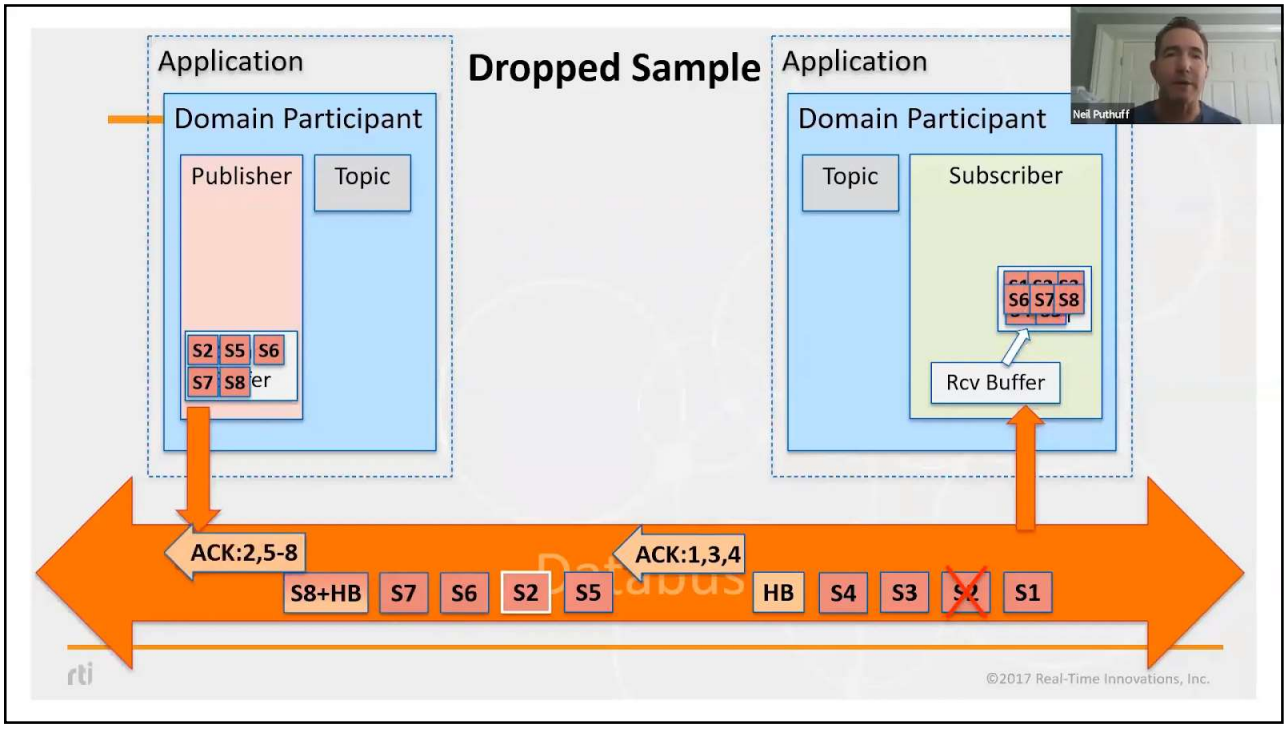
47


Application
Domain Participant
Publisher
Topic
S2 S5 S6
S7 S8 er
Dropped Sample
Application
Domain Participant
Topic
Subscriber
S6 S7 S8
Rcv Buffer
ACK:2,5-8
ACK:1,3,4
S8+HB
S7
S6
S2
S5
HB
S4
S3
S1
rti
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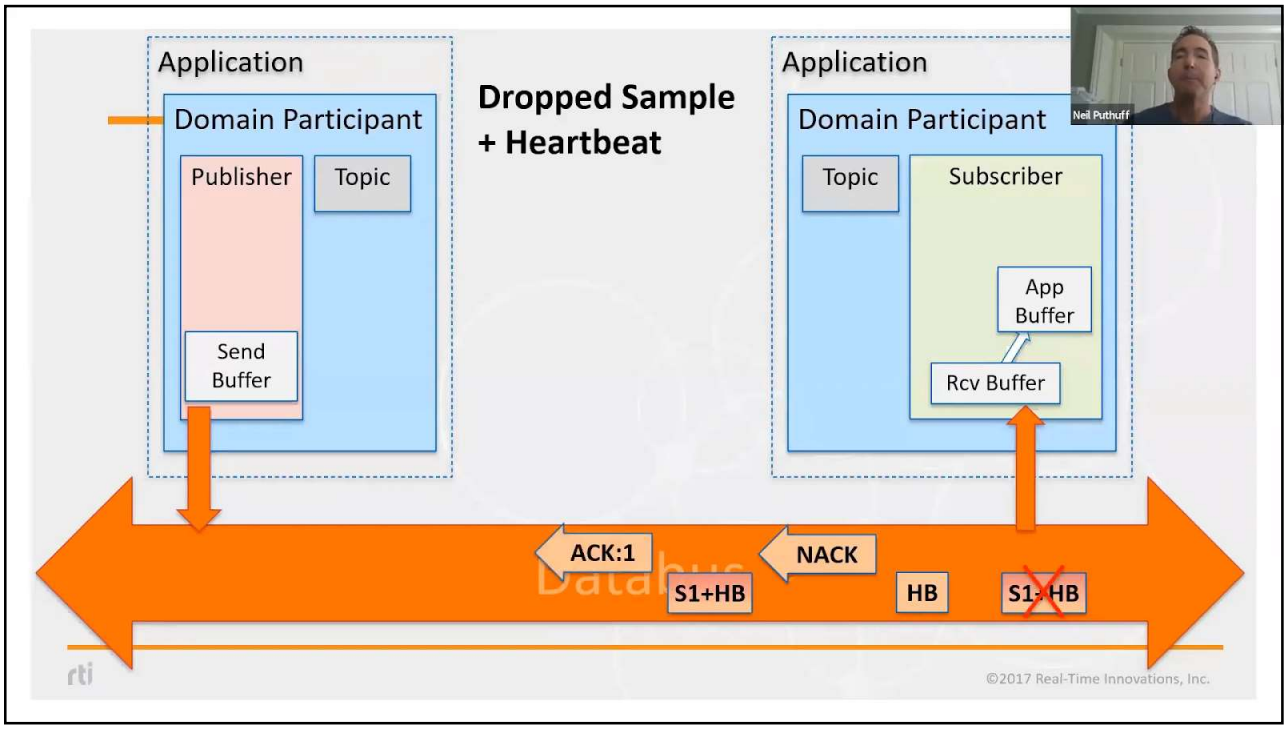
Application
Domain Participant
Publisher
Topic
Send Buffer
Dropped Sample + Heartbeat
Application
Domain Participant
Topic
Subscriber
App Buffer
Rcv Buffer
ACK:1
NACK
S1+HB
HB
S1+HB
Databus
rti
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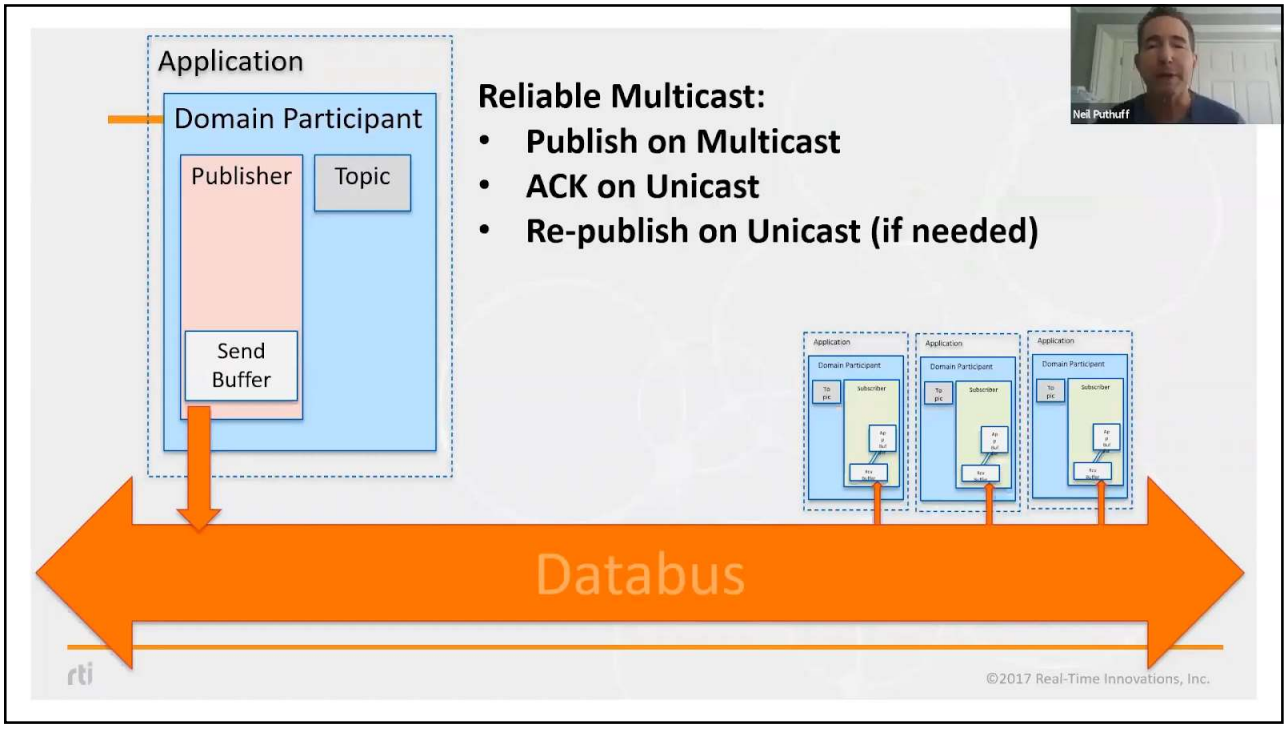
Application
Domain Participant
Publisher
Topic
Send Buffer
Reliable Multicast:
• Publish on Multicast
• ACK on Unicast
• Re-publish on Unicast (if needed)
Databus
rti
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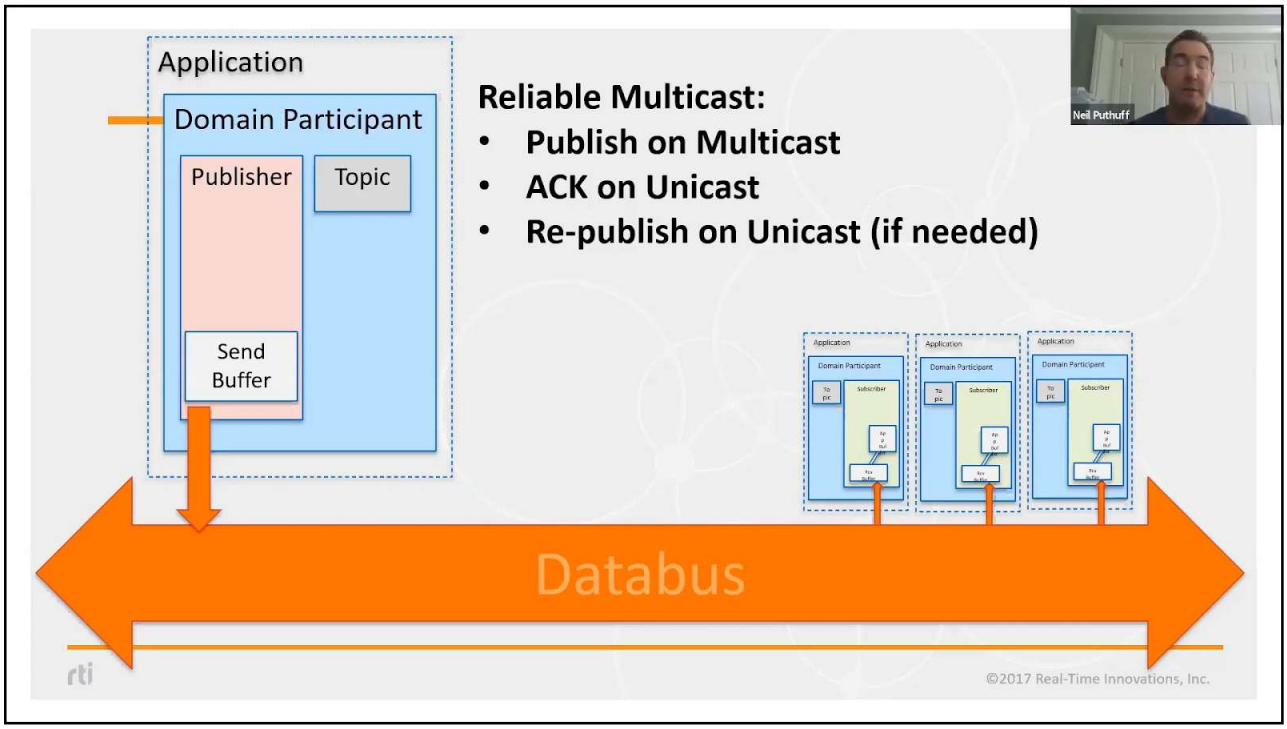
Application
Domain Participant
Publisher
Topic
Send Buffer
Reliable Multicast:
• Publish on Multicast
• ACK on Unicast
• Re-publish on Unicast (if needed)
Databus
rti
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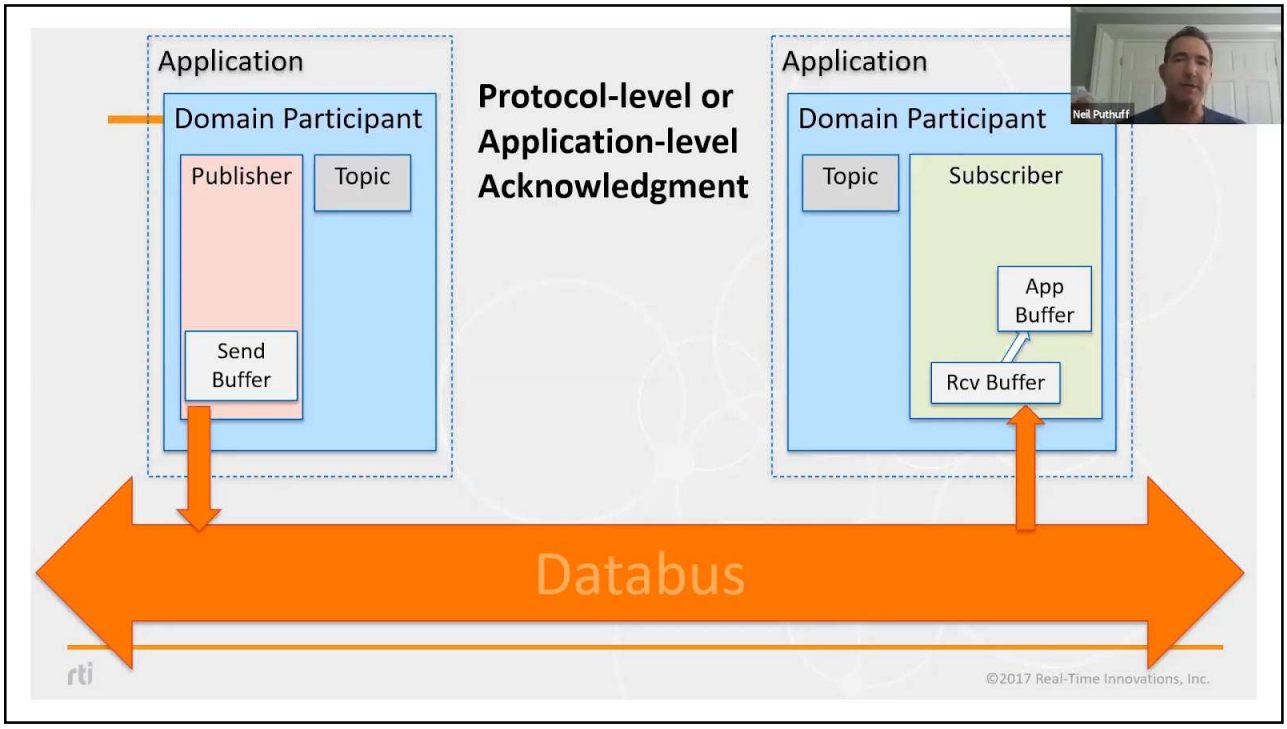
Application
Domain Participant
Publisher
Topic
Send Buffer
Protocol-level or Application-level Acknowledgment
Application
Domain Participant
Topic
Subscriber
App Buffer
Rcv Buffer
Databus
rti
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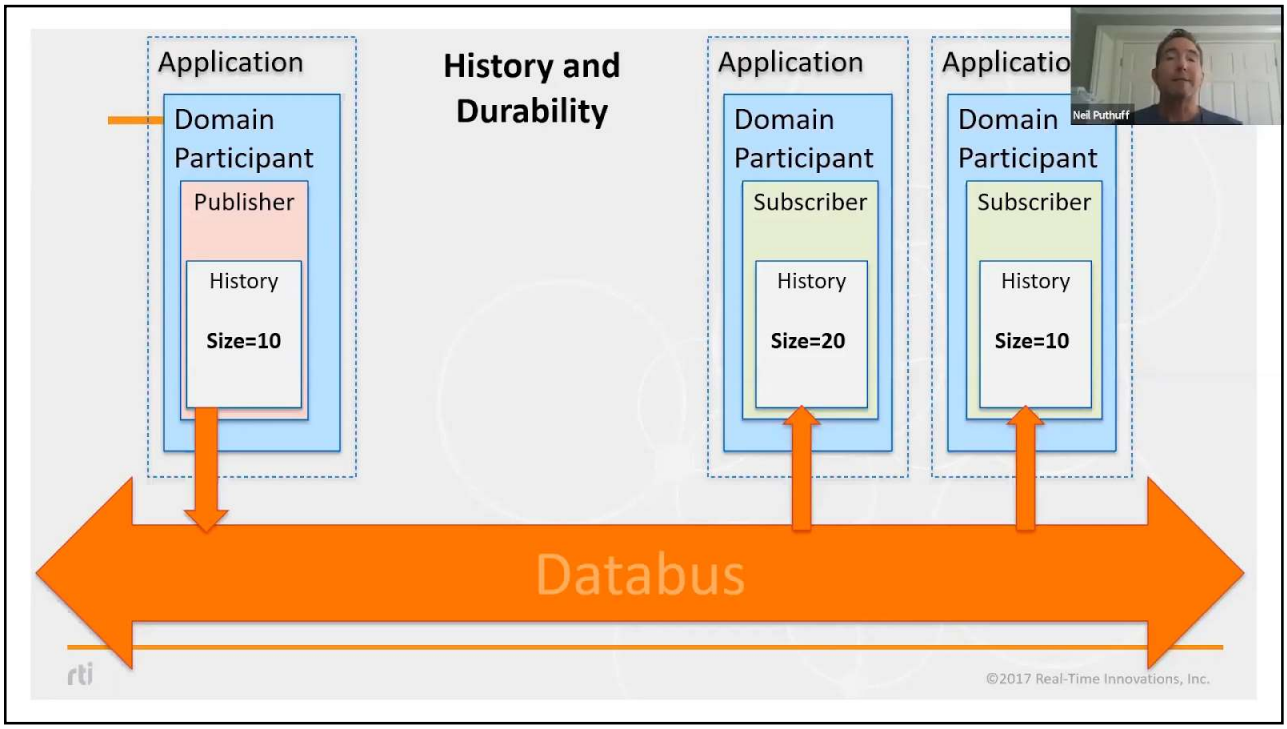
Application
Domain Participant
Publisher
History
Size=10
History and Durability
Application
Domain Participant
Subscriber
History
Size=20
Applicatio
Domain Participant
Subscriber
History
Size=10
Databus
rti
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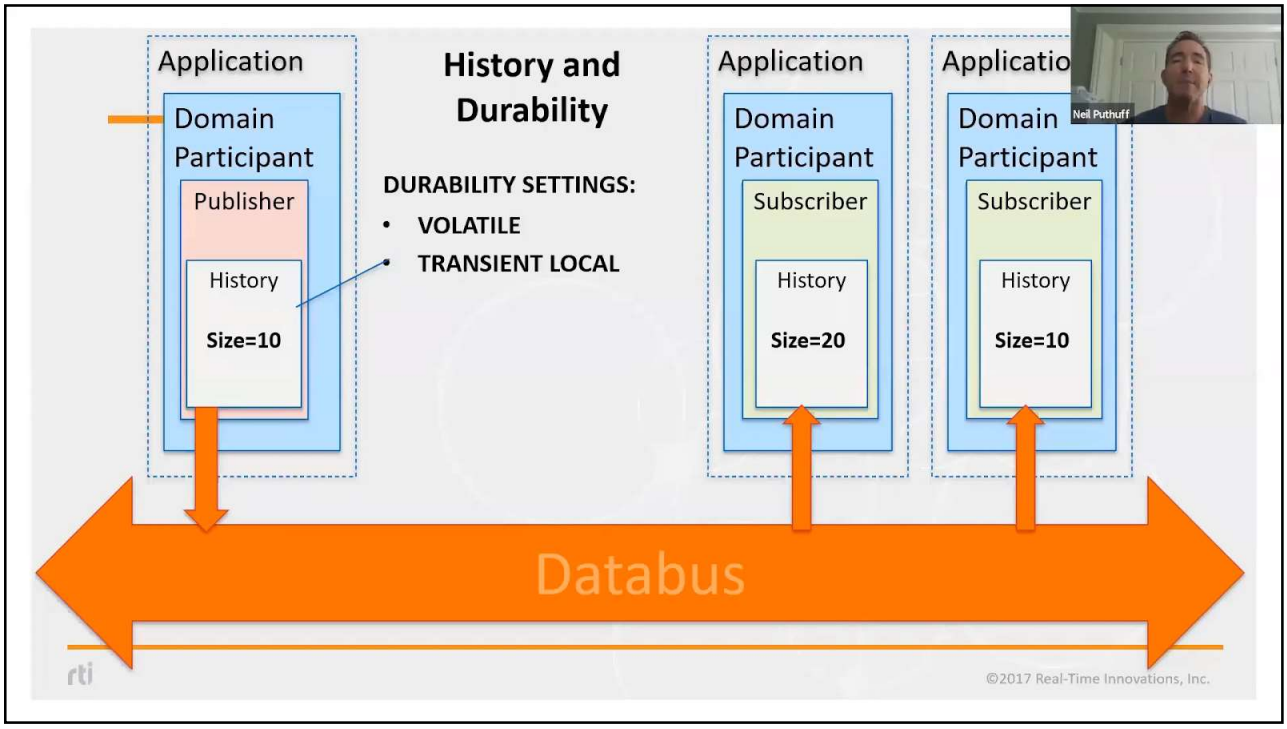
Application
Domain Participant
Publisher
History
Size=10
History and Durability
DURABILITY SETTINGS:
• VOLATILE
• TRANSIENT LOCAL
Application
Domain Participant
Subscriber
History
Size=20
Applicatio
Domain Participant
Subscriber
History
Size=10
Databus
rti
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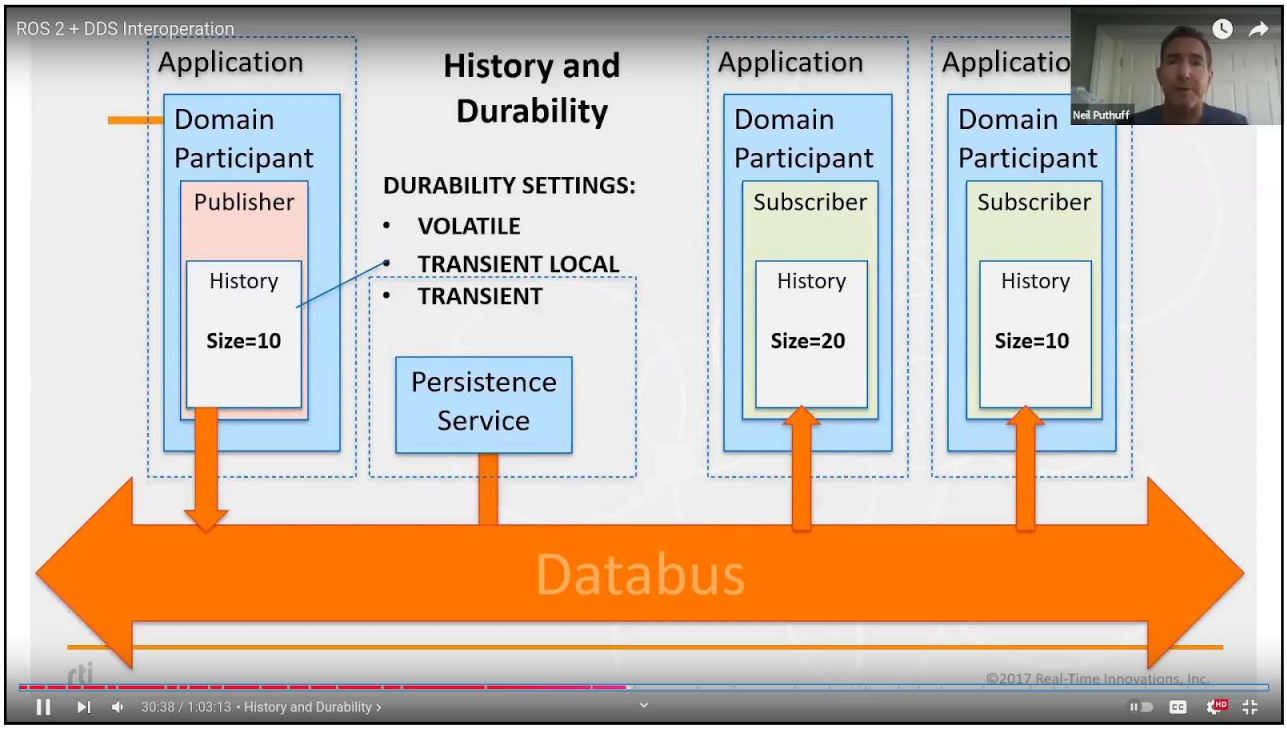
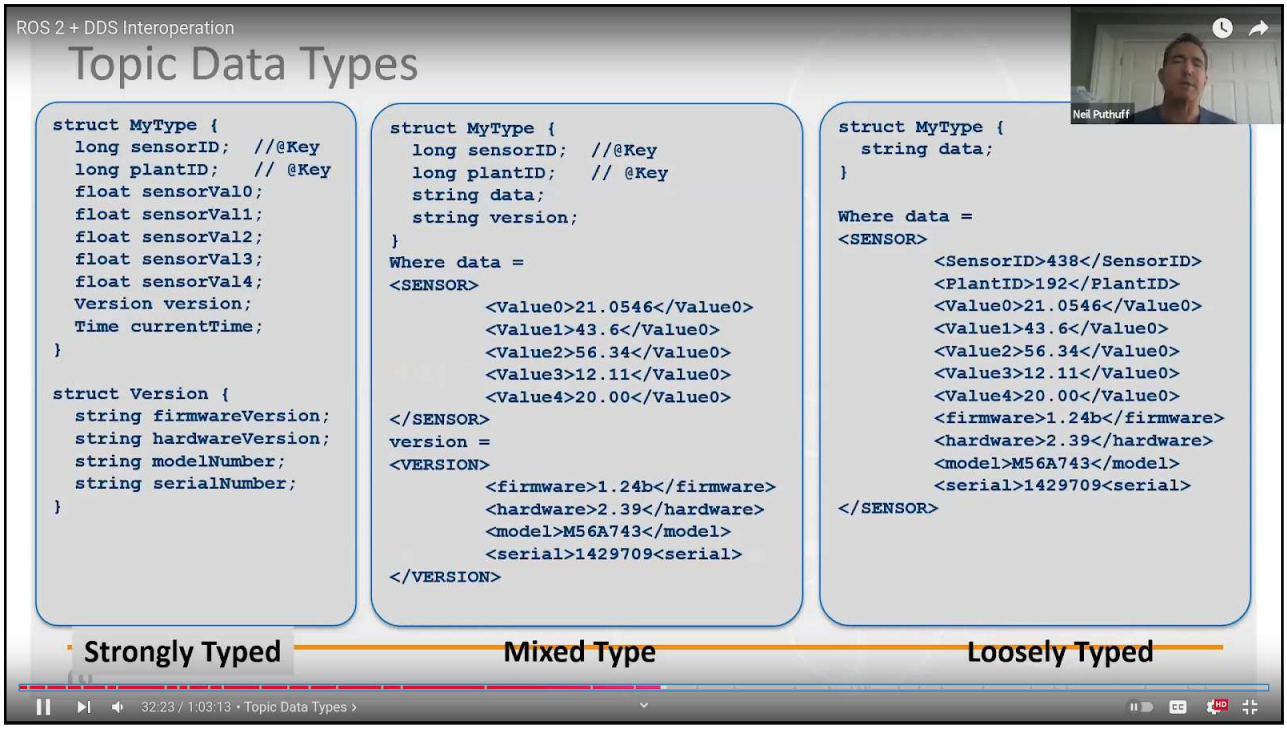

ROS 2 + DDS Interoperation
Application
Domain Participant
Publisher
History
Size=10
History and Durability
DURABILITY SETTINGS:
• VOLATILE
• TRANSIENT LOCAL
• TRANSIENT
Persistence Service
Application
Domain Participant
Subscriber
History
Size=20
Application
Domain Participant
Subscriber
History
Size=10
Databus
Neil Puthuff
©2017 Real-Time Innovations, Inc.
30:38 / 1:03:13 • History and Durability ›

55


ROS 2 + DDS Interoperation
Topic Data Types
struct MyType {
long sensorID; //@Key
long plantID; // @Key
float sensorVal0;
float sensorVal1;
float sensorVal2;
float sensorVal3;
float sensorVal4;
Version version;
Time currentTime;
}
struct Version {
string firmwareVersion;
string hardwareVersion;
string modelNumber;
string serialNumber;
}
struct MyType {
long sensorID; //@Key
long plantID; // @Key
string data;
string version;
}
Where data =
<SENSOR>
<Value0>21.0546</Value0>
<Value1>43.6</Value0>
<Value2>56.34</Value0>
<Value3>12.11</Value0>
<Value4>20.00</Value0>
</SENSOR>
version =
<VERSION>
<firmware>1.24b</firmware>
<hardware>2.39</hardware>
<model>M56A743</model>
<serial>1429709<serial>
</VERSION>
struct MyType {
string data;
}
Where data =
<SENSOR>
<SensorID>438</SensorID>
<PlantID>192</PlantID>
<Value0>21.0546</Value0>
<Value1>43.6</Value0>
<Value2>56.34</Value0>
<Value3>12.11</Value0>
<Value4>20.00</Value0>
<firmware>1.24b</firmware>
<hardware>2.39</hardware>
<model>M56A743</model>
<serial>1429709<serial>
</SENSOR>
Strongly Typed
Mixed Type
Loosely Typed
Neil Puthuff
32:23 / 1:03:13 • Topic Data Types ›

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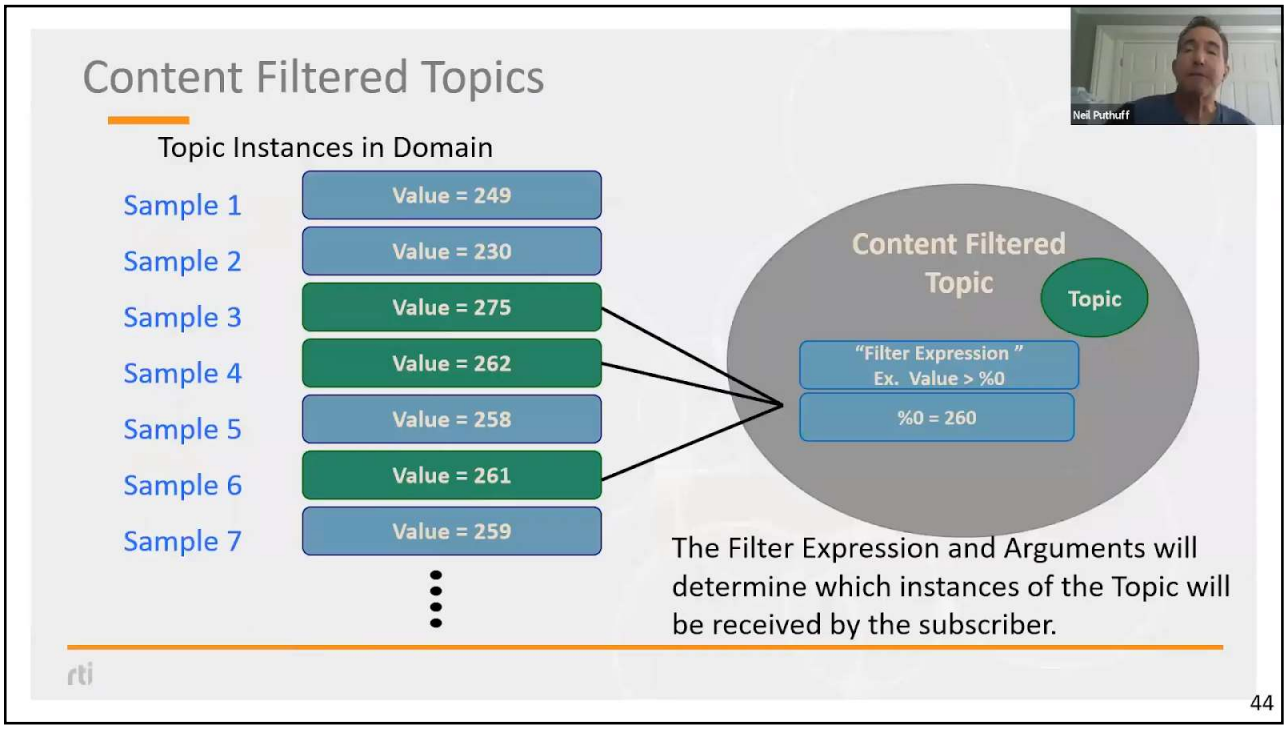
Content Filtered Topics
Topic Instances in Domain
Sample 1
Sample 2
Sample 3
Sample 4
Sample 5
Sample 6
Sample 7
Value = 249
Value = 230
Value = 275
Value = 262
Value = 258
Value = 261
Value = 259
Content Filtered Topic
Topic
"Filter Expression"
Ex. Value > %0
%0 = 260
The Filter Expression and Arguments will determine which instances of the Topic will be received by the subscriber.
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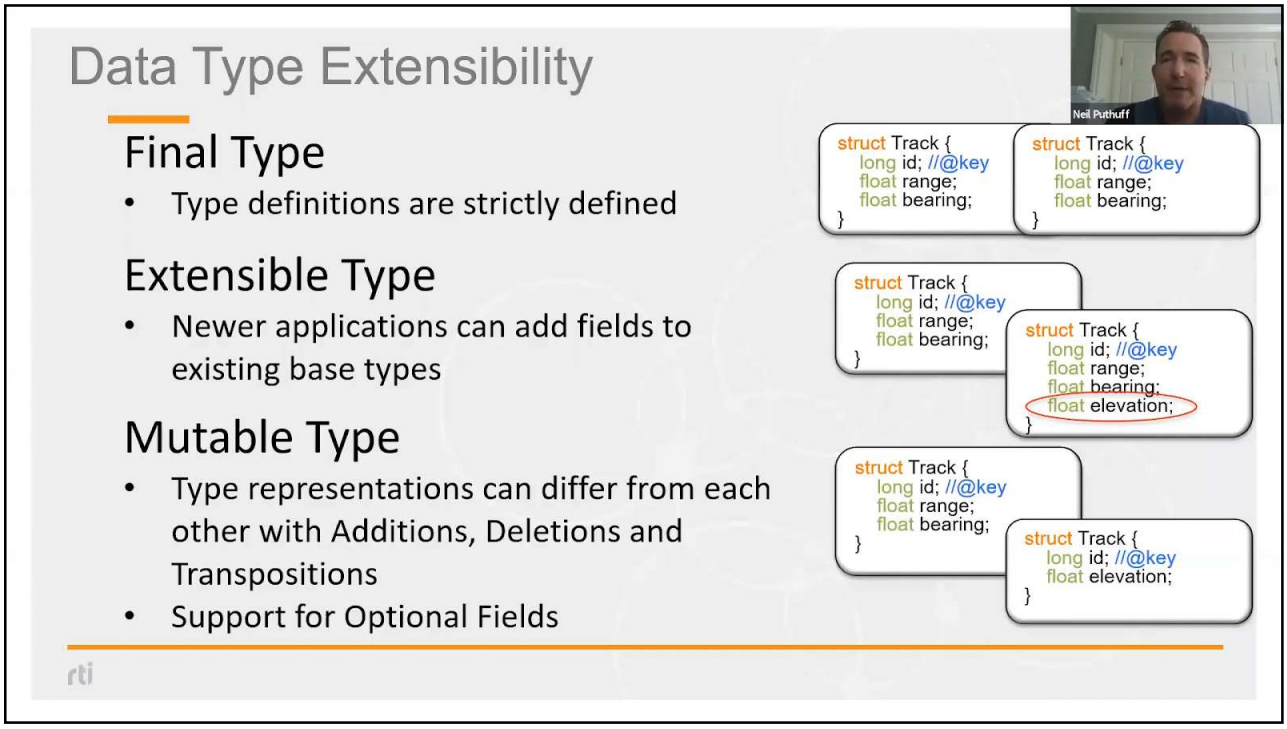
Data Type Extensibility
Final Type
• Type definitions are strictly defined
Extensible Type
• Newer applications can add fields to existing base types
Mutable Type
• Type representations can differ from each other with Additions, Deletions and Transpositions
• Support for Optional Fields
struct Track {
long id; //@key
float range;
float bearing;
}
struct Track {
long id; //@key
float range;
float bearing;
float elevation;
}
struct Track {
long id; //@key
float elevation;
}
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Topic Attributes

Sample Timestamps (@Pub & Sub)

- Time-based filtering
- Lifespan of Samples
- Pub-order reception from many publishers

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Topic Attributes

Sample Timestamps (@Pub & Sub)

- Time-based filtering
- Lifespan of Samples
- Pub-order reception from many publishers

Ownership & Strength

- Automatic fail-over
- System upgrades with zero downtime

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DDS Discovery
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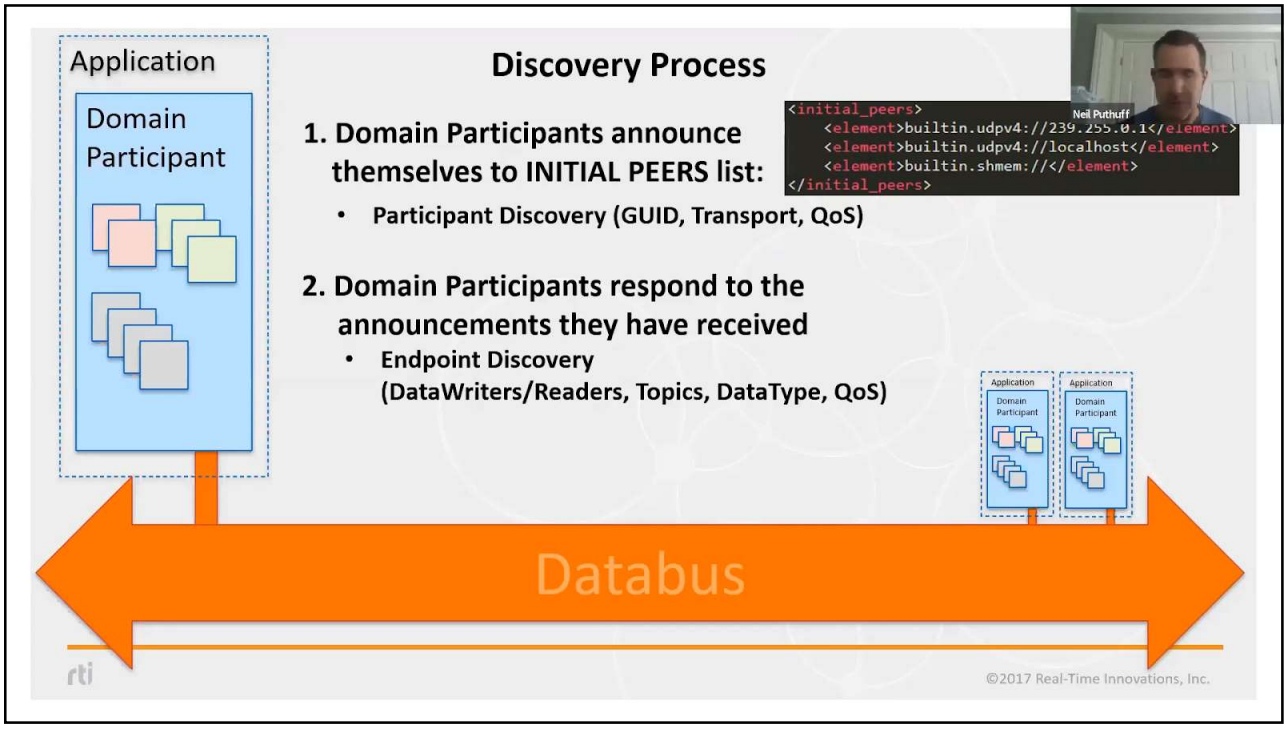
Neil Puthuff
Application
Domain Participant
Discovery Process
1. Domain Participants announce themselves to INITIAL PEERS list:
• Participant Discovery (GUID, Transport, QoS)
<initial_peers>
<element>builtin.udpv4://239.255.0.1</element>
<element>builtin.udpv4://localhost</element>
<element>builtin.shmem://</element>
</initial_peers>
2. Domain Participants respond to the announcements they have received
• Endpoint Discovery (DataWriters/Readers, Topics, DataType, QoS)
Application
Domain Participant
Application
Domain Participant
Databus
rti
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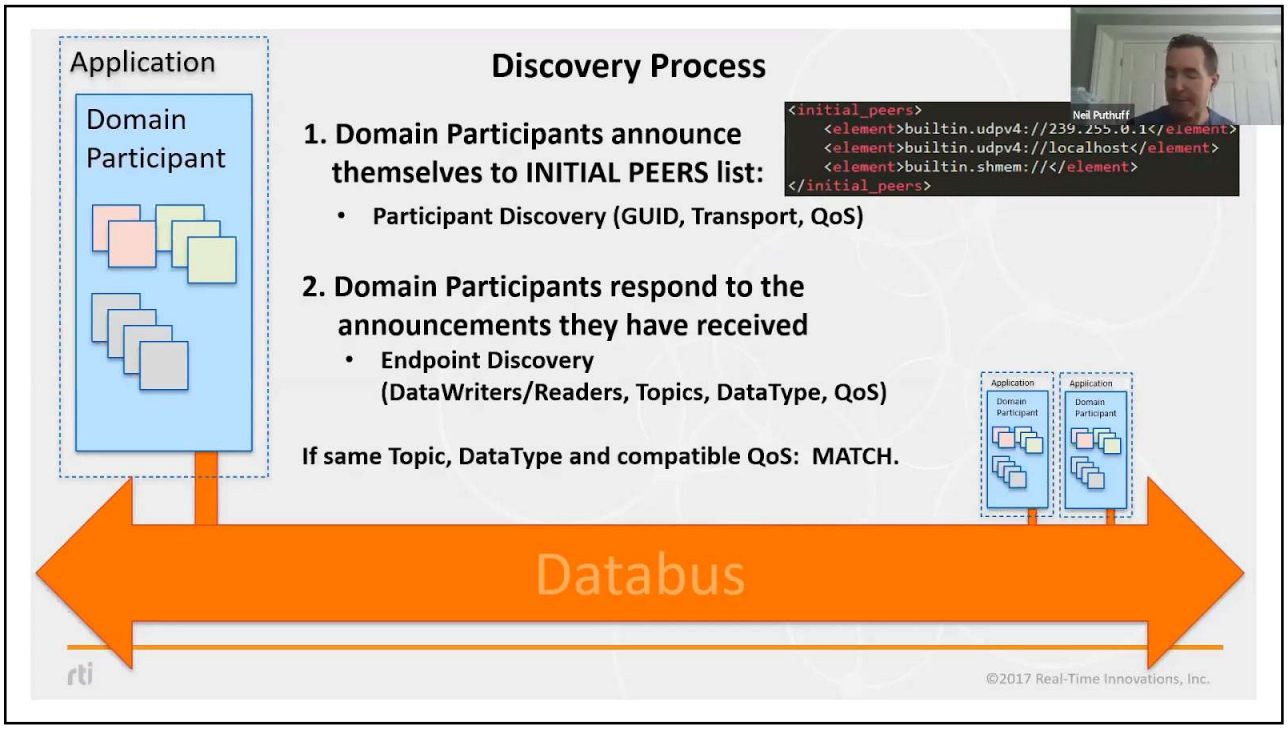
Application
Domain Participant
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<initial_peers>
<element>builtin.udpv4://239.255.0.1</element>
<element>builtin.udpv4://localhost</element>
<element>builtin.shmem://</element>
</initial_peers>
2. Domain Participants respond to the announcements they have received
• Endpoint Discovery (DataWriters/Readers, Topics, DataType, QoS)
If same Topic, DataType and compatible QoS: MATCH.
Application
Domain Participant
Application
Domain Participant
Databus
Neil Puthuff
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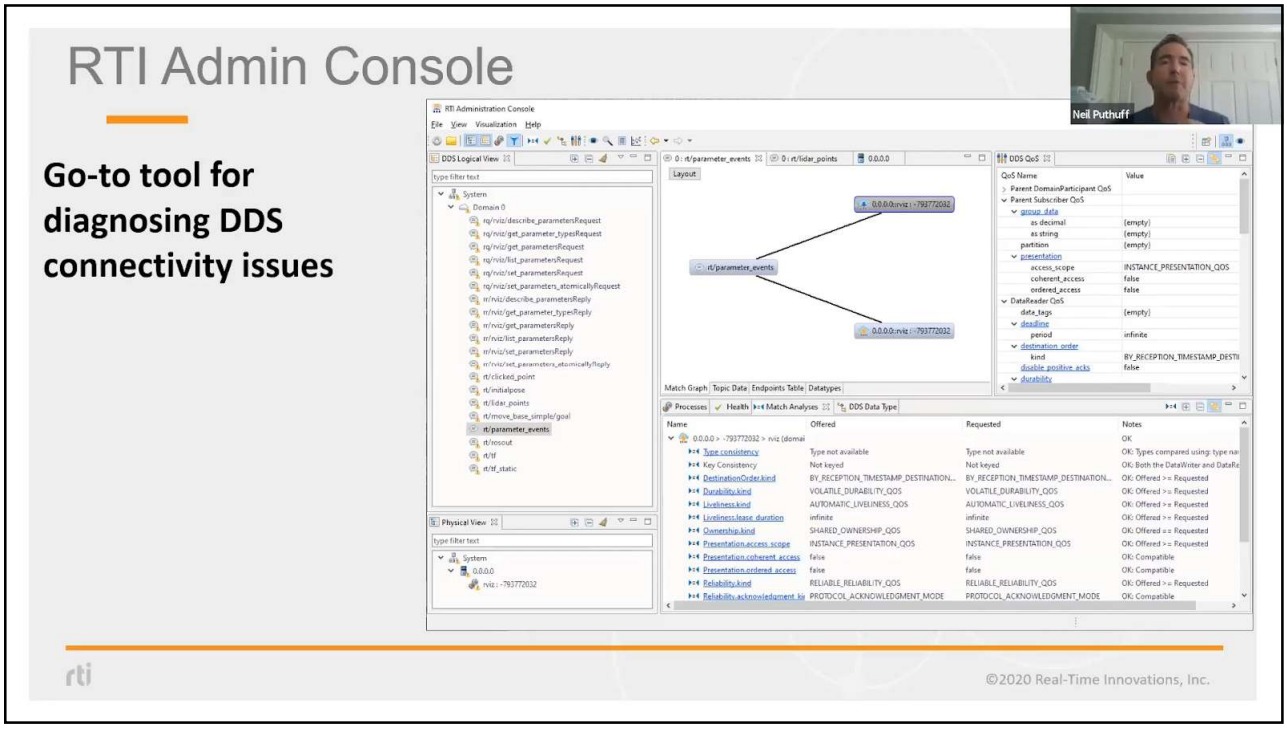
RTI Admin Console
Go-to tool for diagnosing DDS connectivity issues
Neil Puthuff
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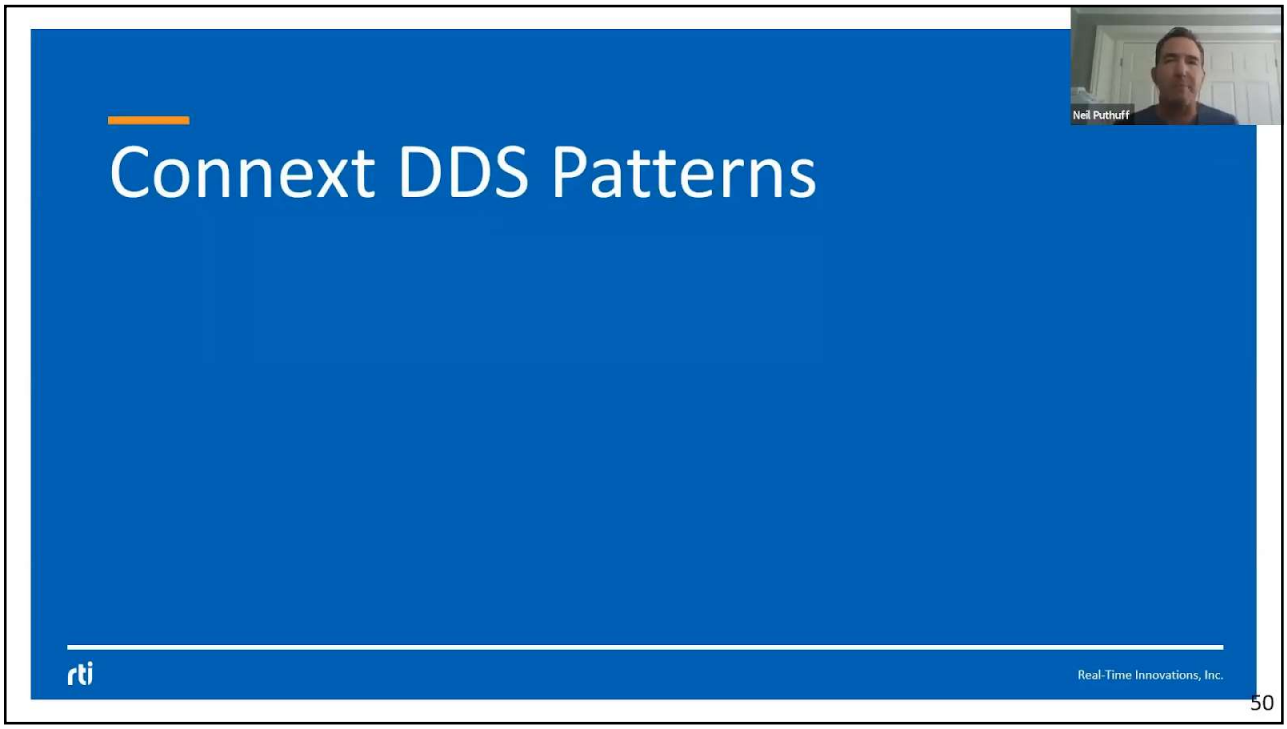
Neil Puthuff
Connext DDS Patterns
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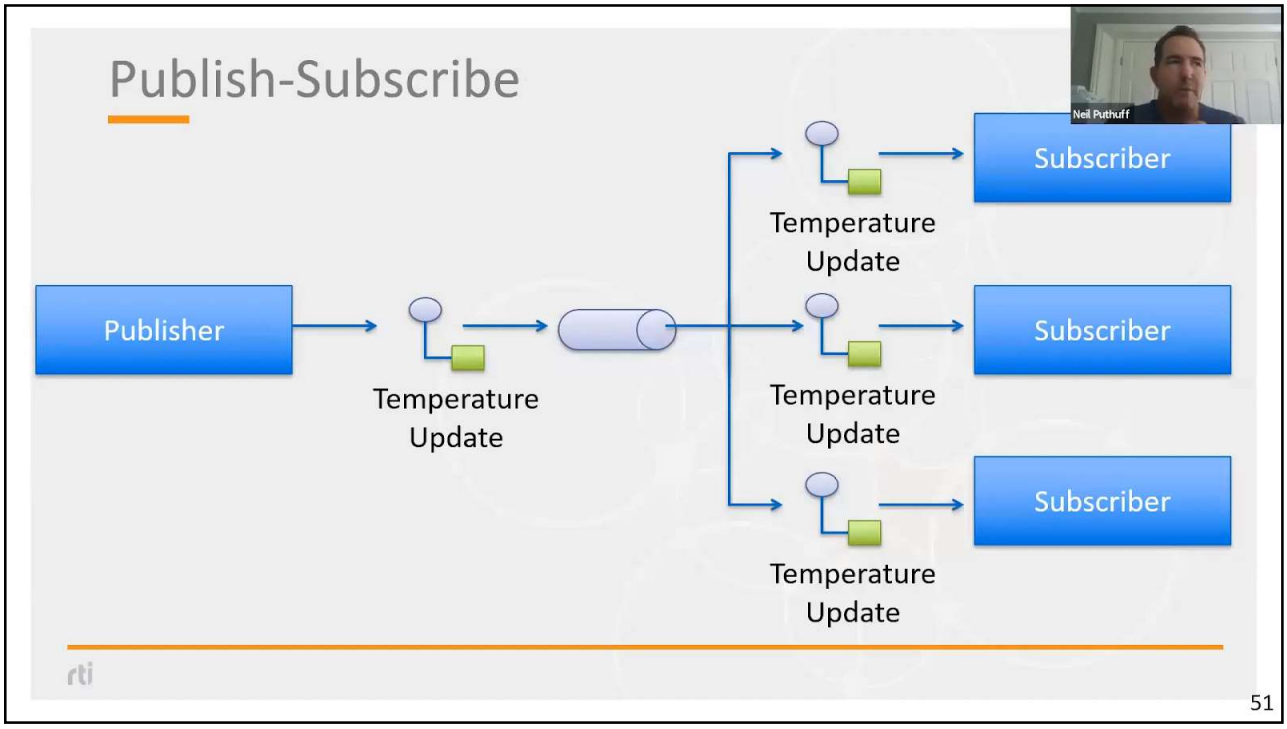
Neil Puthuff
Publish-Subscribe
Publisher
Temperature Update
Temperature Update
Subscriber
Temperature Update
Subscriber
Temperature Update
Subscriber
rti
51

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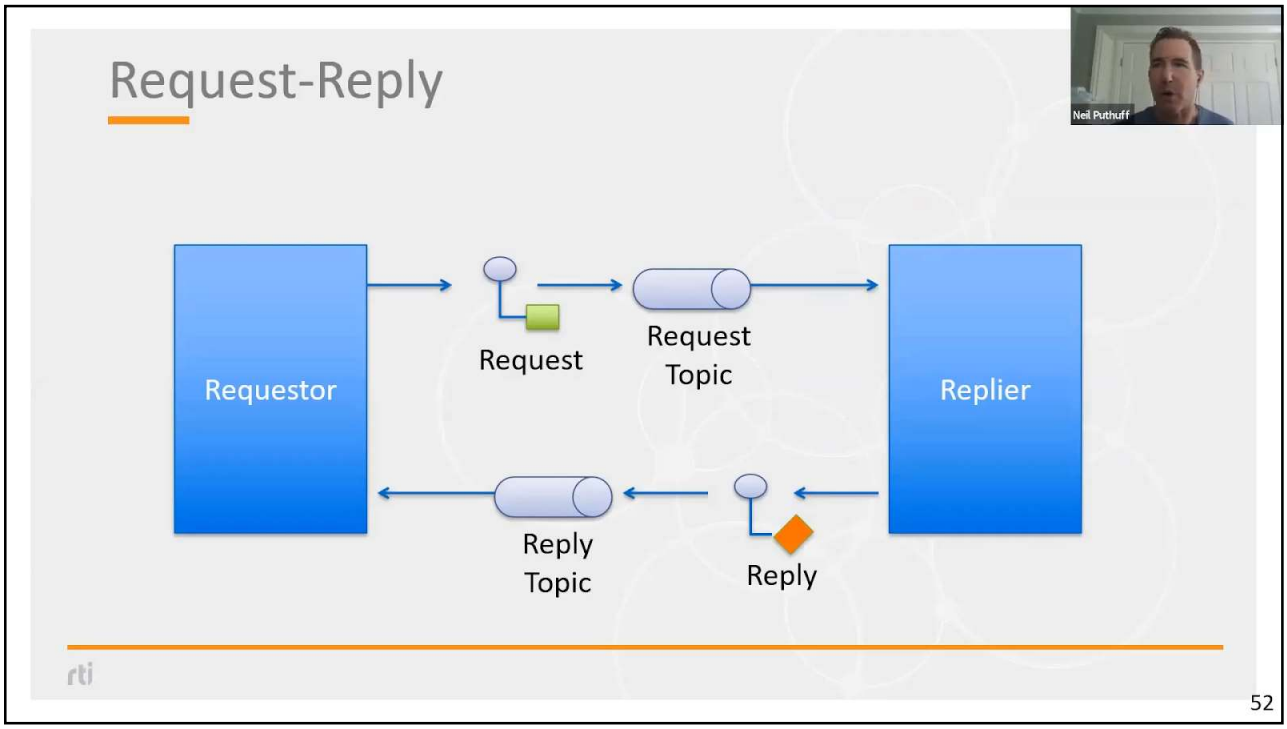
Request-Reply
Requestor
Request
Request Topic
Replier
Reply Topic
Reply
rti
52

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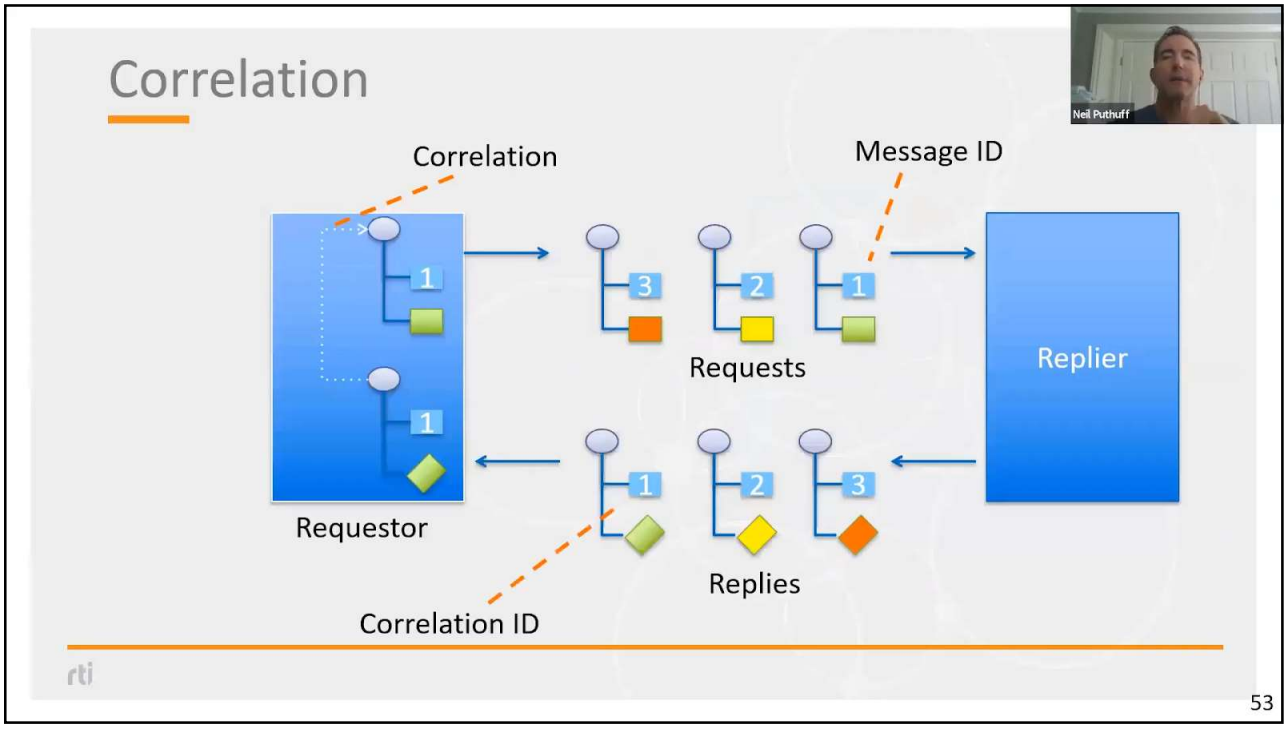
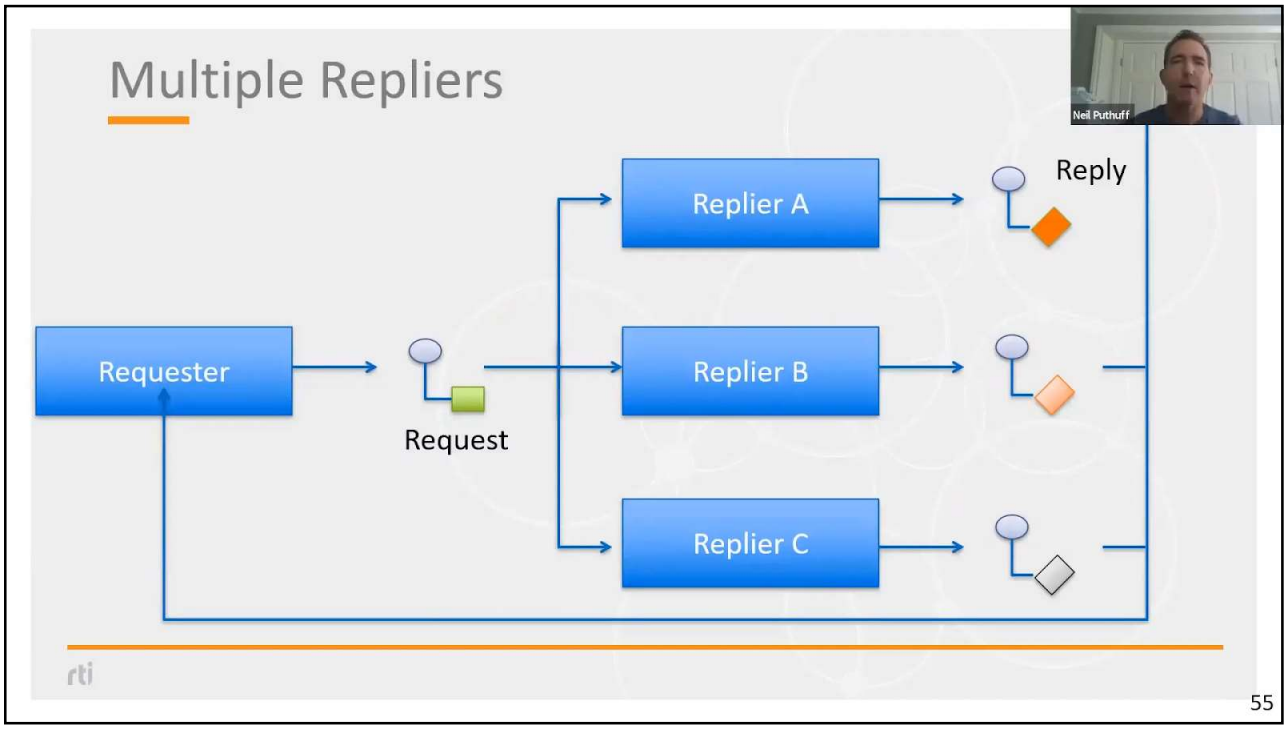

Correlation
Correlation
Message ID
1
1
3
2
1
Requests
Replier
Requestor
1
2
3
Replies
Correlation ID
rti
53

68


Multiple Repliers
Neil Puthuff
Reply
Replier A
Requester
Request
Replier B
Replier C
rti
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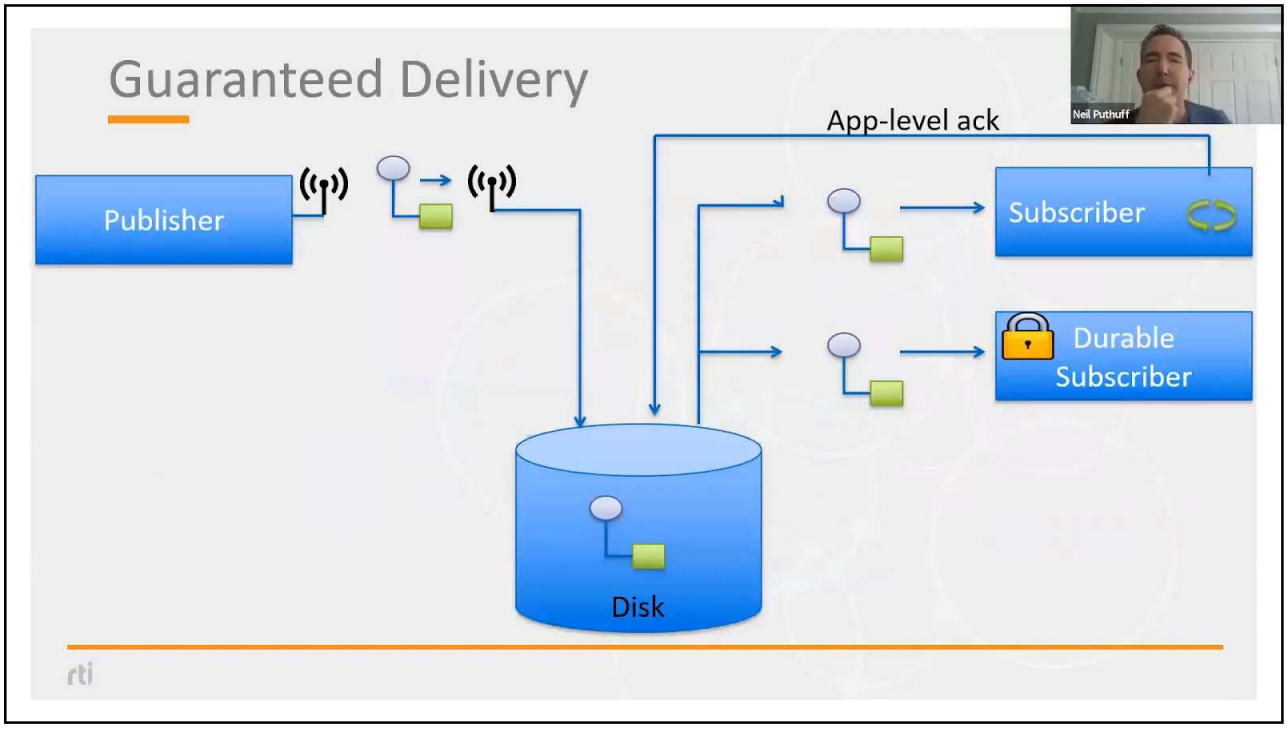
Guaranteed Delivery
Neil Puthuff
App-level ack
Publisher
Subscriber
Durable
Subscriber
Disk
rti

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ROS 2 & DDS
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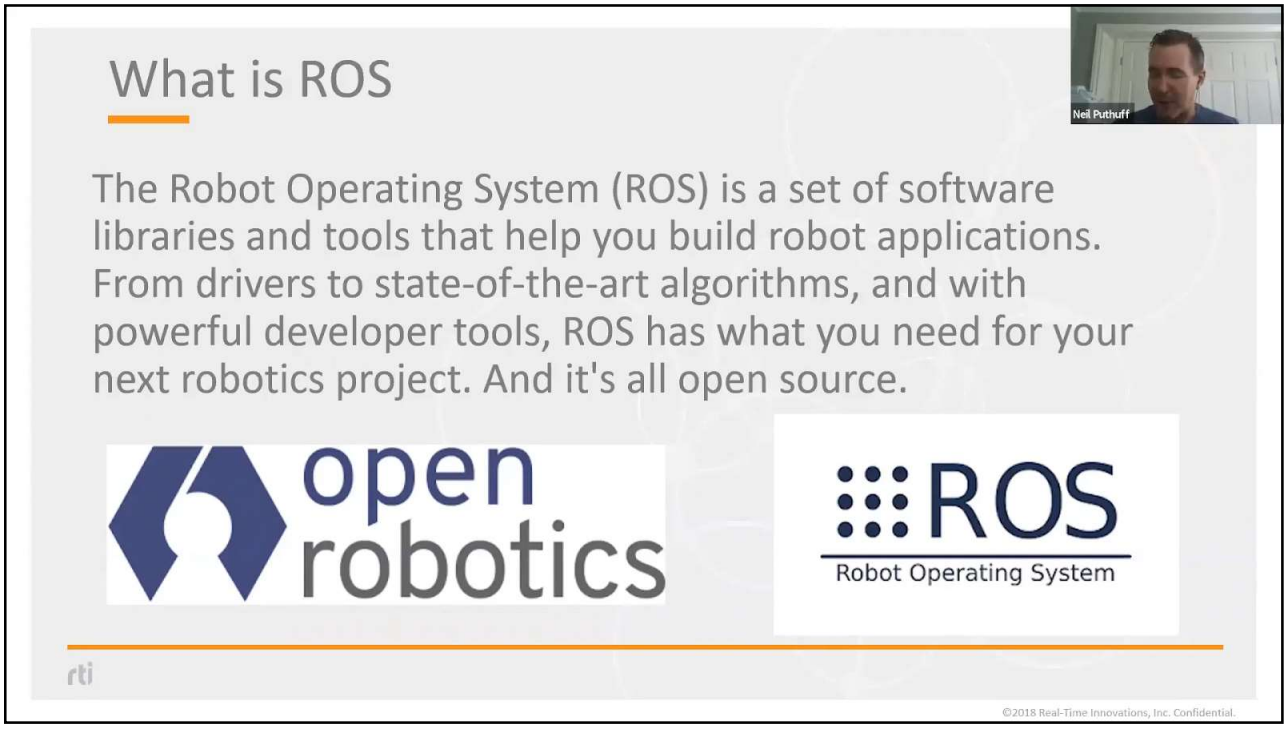
Neil Puthuff
What is ROS
The Robot Operating System (ROS) is a set of software libraries and tools that help you build robot applications. From drivers to state-of-the-art algorithms, and with powerful developer tools, ROS has what you need for your next robotics project. And it's all open source.
open robotics
ROS
Robot Operating System
rti
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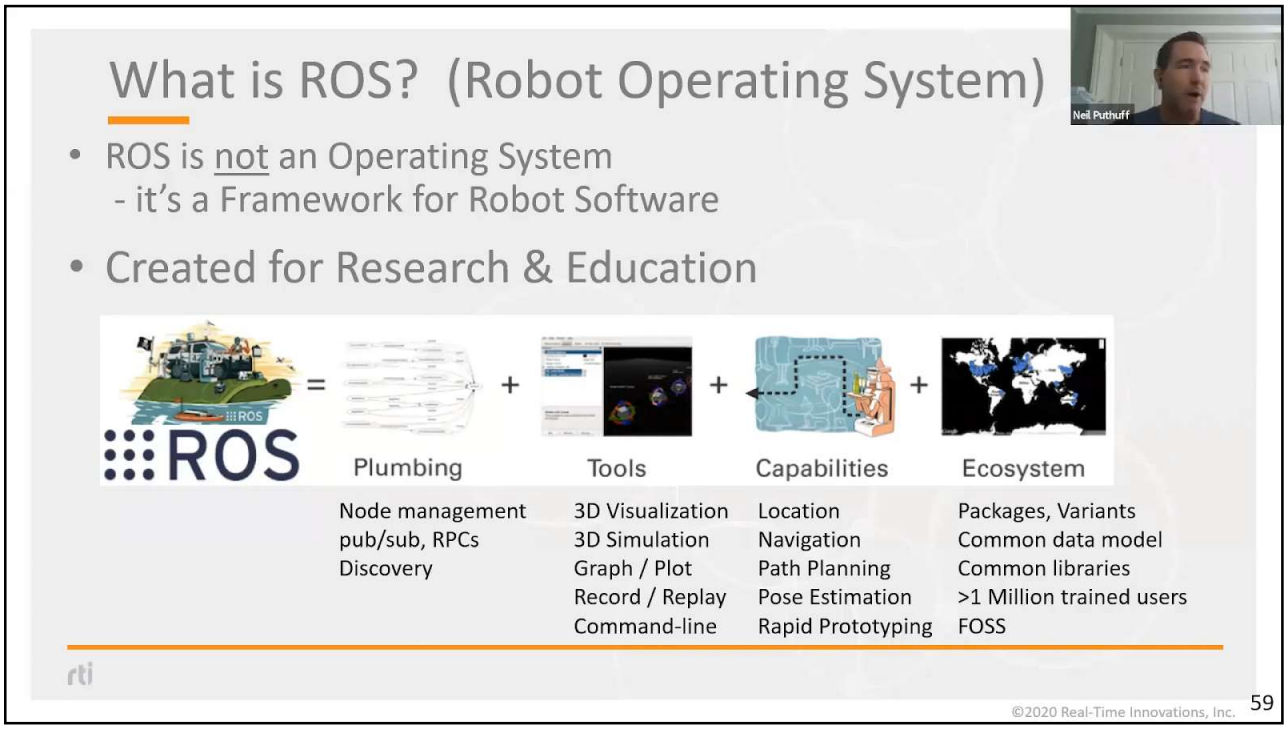
What is ROS? (Robot Operating System)
Neil Puthuff
• ROS is not an Operating System
- it's a Framework for Robot Software
• Created for Research & Education
ROS
Plumbing
Tools
Capabilities
Ecosystem
Node management
pub/sub, RPCs
Discovery
3D Visualization
3D Simulation
Graph / Plot
Record / Replay
Command-line
Location
Navigation
Path Planning
Pose Estimation
Rapid Prototyping
Packages, Variants
Common data model
Common libraries
>1 Million trained users
FOSS
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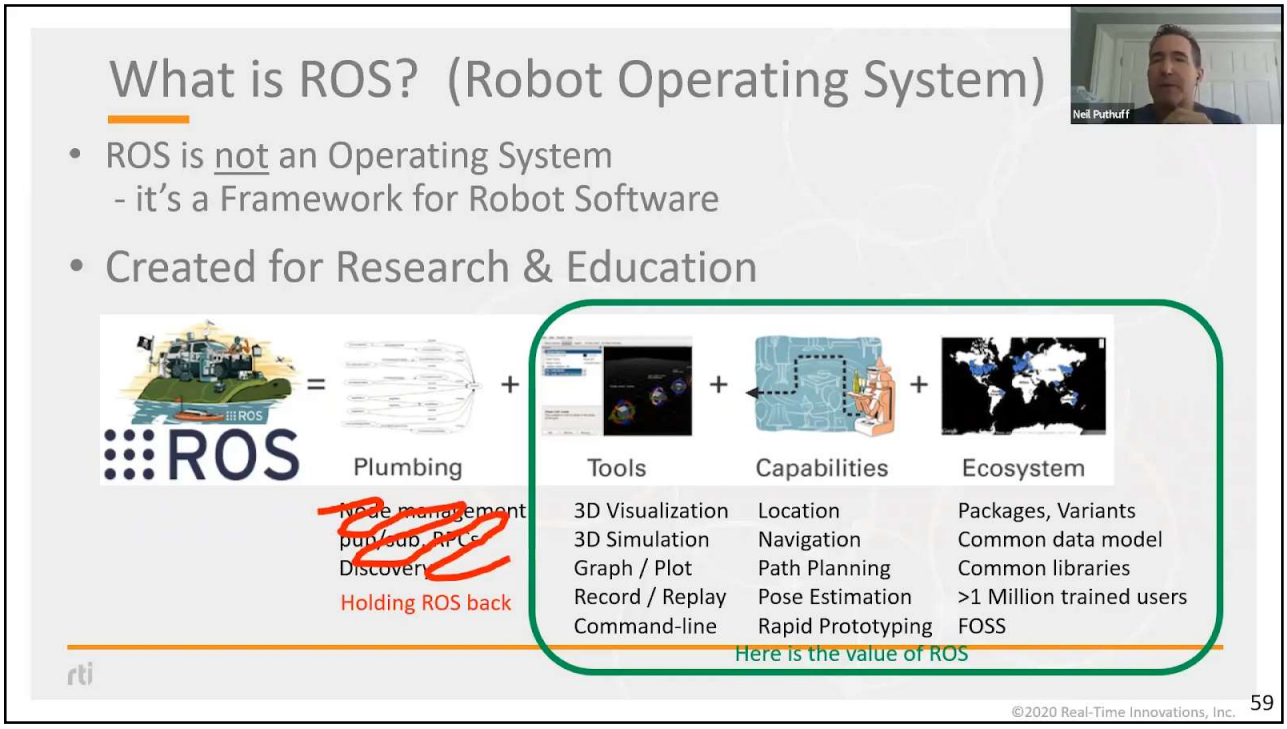
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ROS
Plumbing
Tools
Capabilities
Ecosystem
Holding ROS back
3D Visualization
3D Simulation
Graph / Plot
Record / Replay
Command-line
Location
Navigation
Path Planning
Pose Estimation
Rapid Prototyping
Packages, Variants
Common data model
Common libraries
>1 Million trained users
FOSS
Here is the value of ROS
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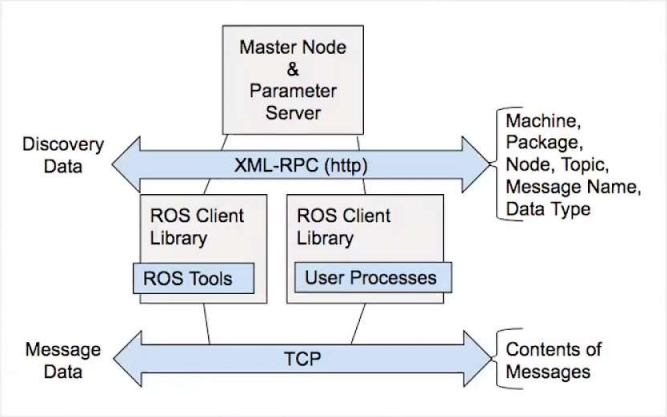
Original ROS Architecture

- Massive ecosystem build around open-source project
  - Popular Tools (Gazebo, RViz)
  - Sensor and device drivers
  - Applications
- Original ROS (ROS1) evolved to serve academia and research
- Not suitable for commercial or emerging applications:
  - Minimal security capabilities
  - Does not scale
  - Not deterministic
- ROS2 created for expanded use-cases



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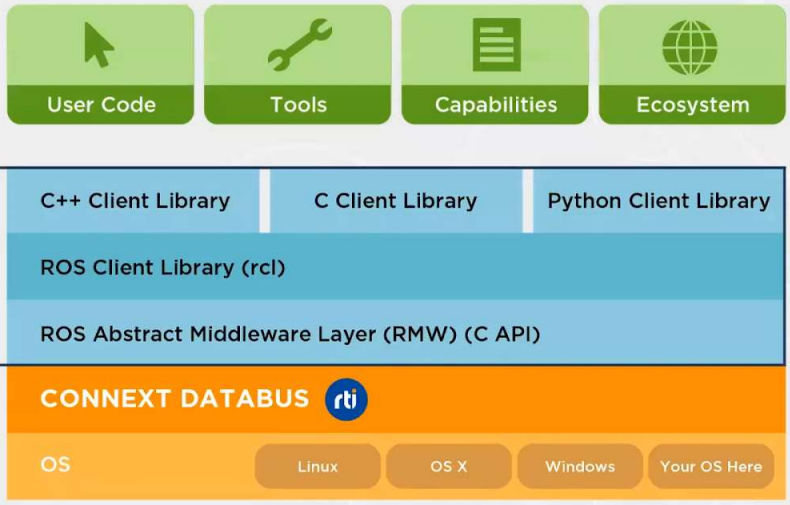
DDS in ROS2



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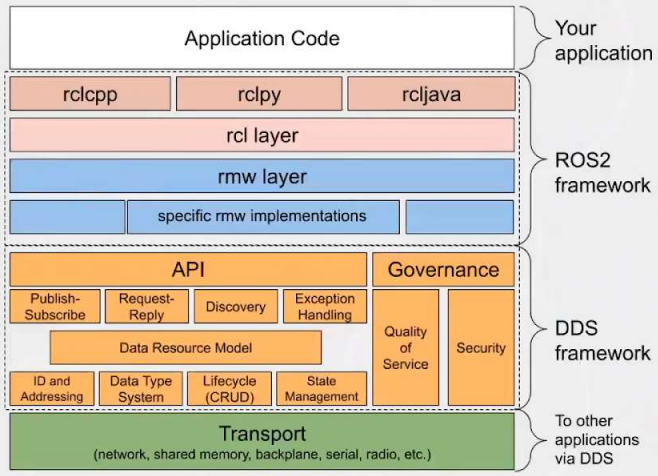
ROS2 is DDS

ROS2 is built on the DDS Framework

All ROS2 applications are actually DDS applications

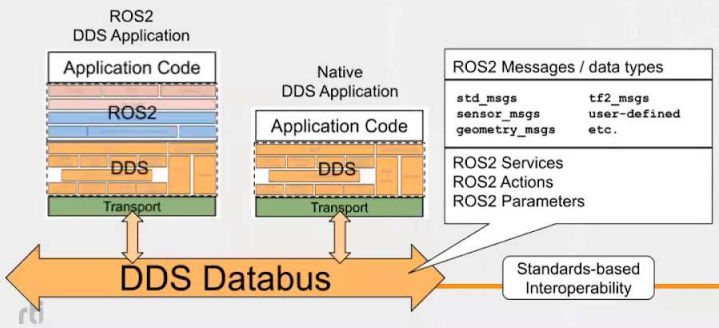


77

Standards-based Interoperability

Native DDS applications can freely interoperate with ROS2 DDS applications, given:

- Same data type, topic name, compatible QoS and security.



This enables optimized systems to be created today …

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Standards-based Interoperability

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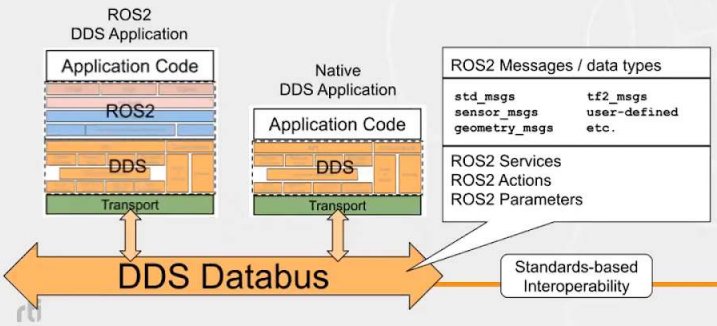

This enables optimized systems to be created today …

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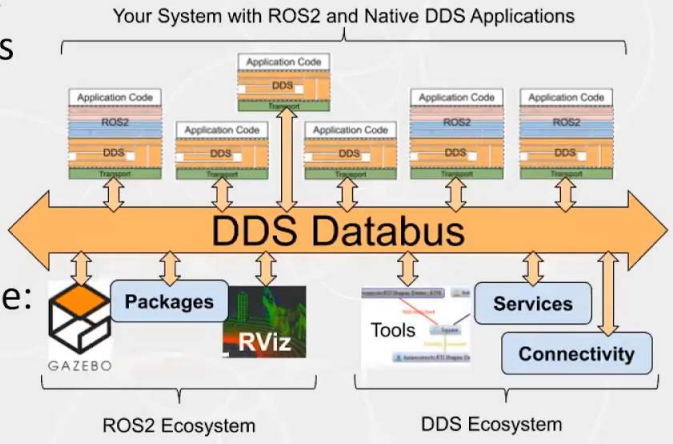
Optimized Systems, Merged Ecosystems

System Optimization Options:

- ROS2: pre-written packages
- DDS: safety certification, peak performance, difficult connectivity.

<u>BOTH</u> ecosystems are available:

- ROS2: packages, visualization tools
- DDS: layered services, connectivity, diagnostic tools



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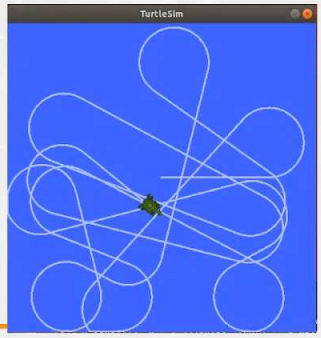
ROS 2 Interoperability: Data Model

- 350+ struct definitions
  - RTI Community GitHub (IDL & XML)
- Used in ROS 2 for 4 ways to communicate:
  - **Messages**: pub/sub data topics
  - **Services**: request/reply (using pairs of topics)
  - **Actions**: request/reply + feedback (similar to objective state)
  - **Parameters**: request/reply access to global data

TurtleSim: small demo program, uses all 4 →



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ROS 2 Interoperability: Topics

- Topic names are used as "keys"
  (topic keys are not used in ROS 2)
- Each application creates dozens of topics
  - This is from 1 instance of TurtleSim →
- Decoder ring:
  - rq/ = request
  - rr/ = response
  - rt/ = user topic (message)
  - */_action/* = action
  - */*_parameter* = parameters
  - */turtlesim/* = topics for the app
  - */turtle1/* = topics for a single turtle inst

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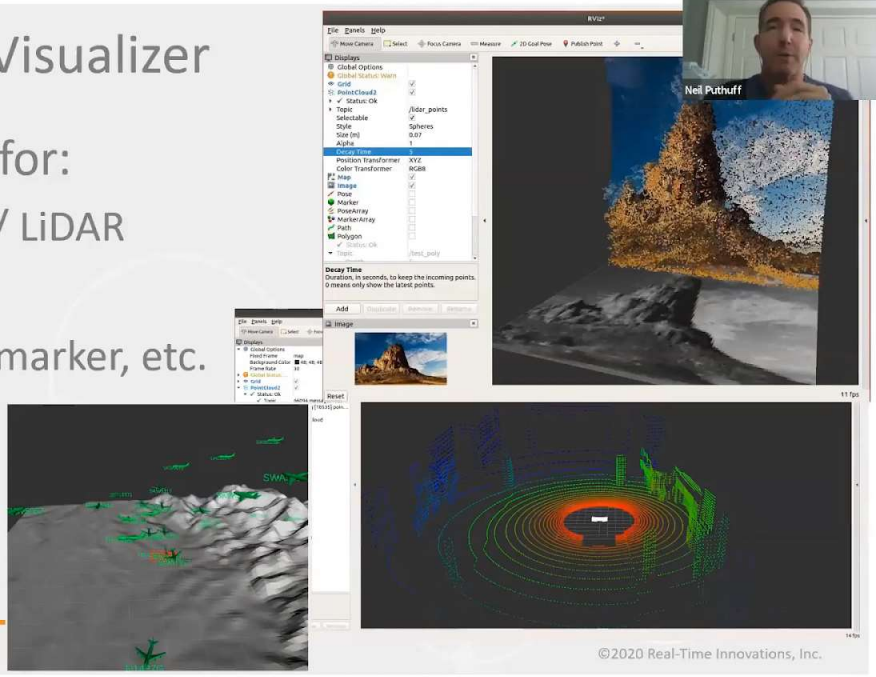
"RViz2" 3D Visualizer

- 3D visualizer for:
  - PointCloud / LiDAR
  - Camera
  - Path, pose, marker, etc.



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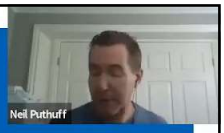
Getting Started



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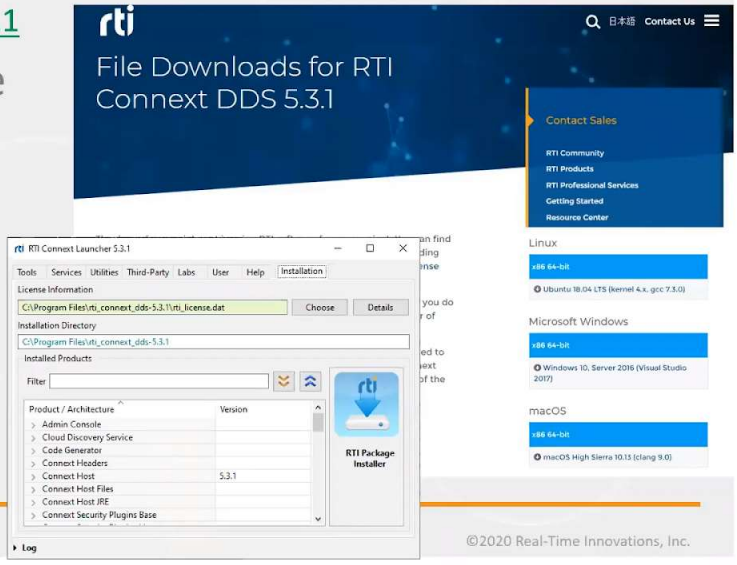
Download Connext Pro

- rti.com/free-trial/dds-files-5.3.1
- Download and run the windows installer
- Copy the license from the welcome email to your PC
- Locate the license file using RTI Connext Launcher.



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Connext Pro Launcher

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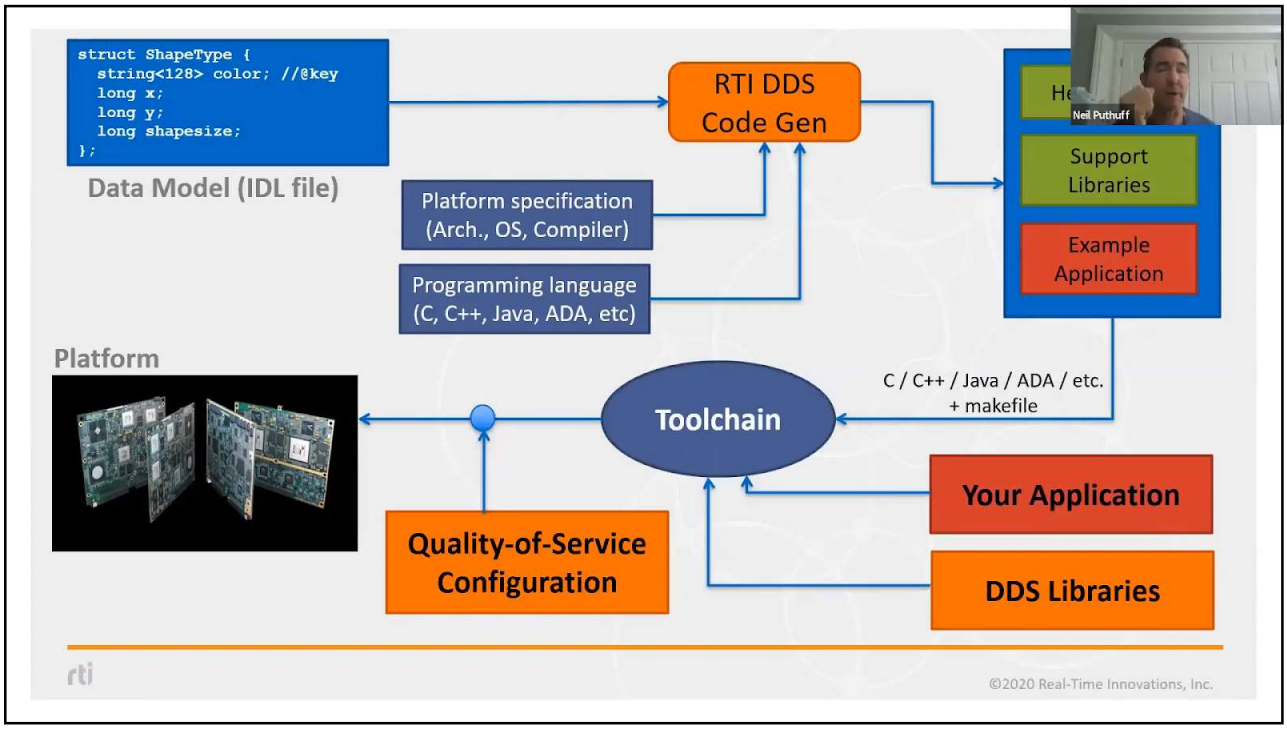
struct ShapeType {
string<128> color; //@key
long x;
long y;
long shapesize;
};
Data Model (IDL file)
RTI DDS Code Gen
Platform specification (Arch., OS, Compiler)
Programming language (C, C++, Java, ADA, etc)
Support Libraries
Example Application
Platform
Toolchain
C / C++ / Java / ADA / etc. + makefile
Your Application
DDS Libraries
Quality-of-Service Configuration
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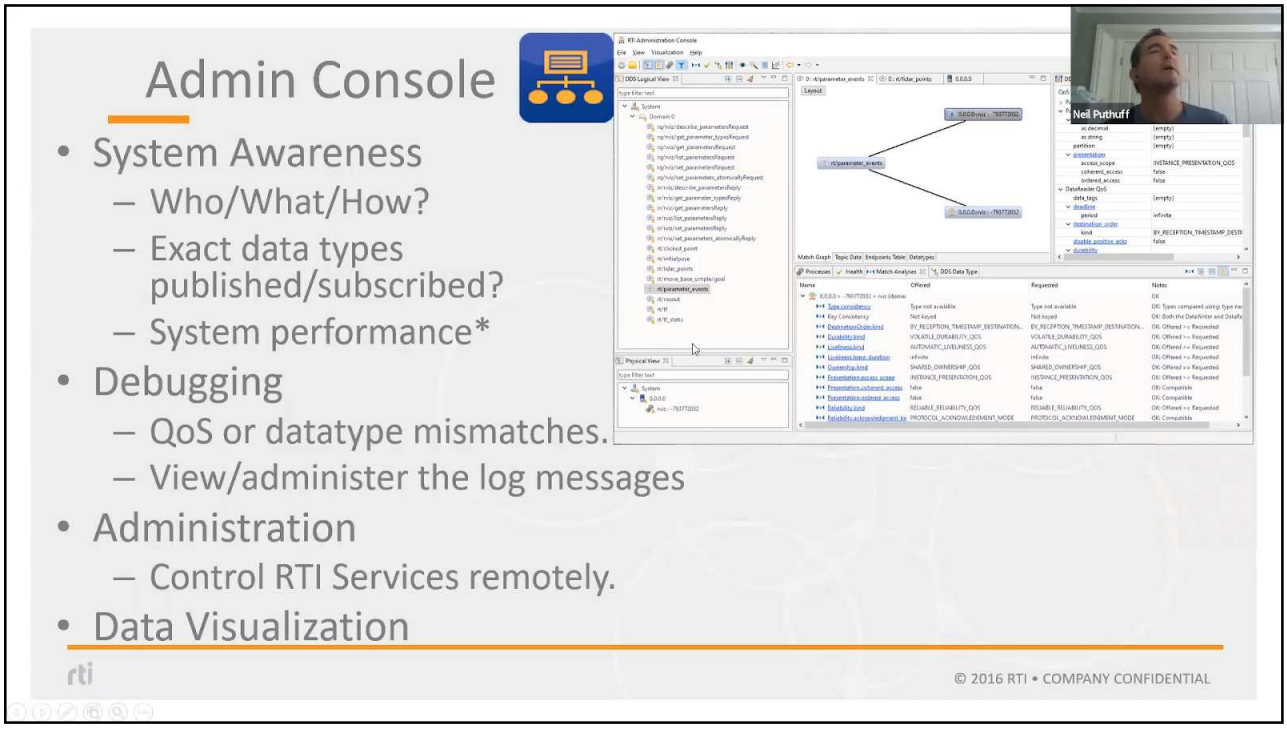
Admin Console
• System Awareness
– Who/What/How?
– Exact data types published/subscribed?
– System performance*
• Debugging
– QoS or datatype mismatches.
– View/administer the log messages
• Administration
– Control RTI Services remotely.
• Data Visualization
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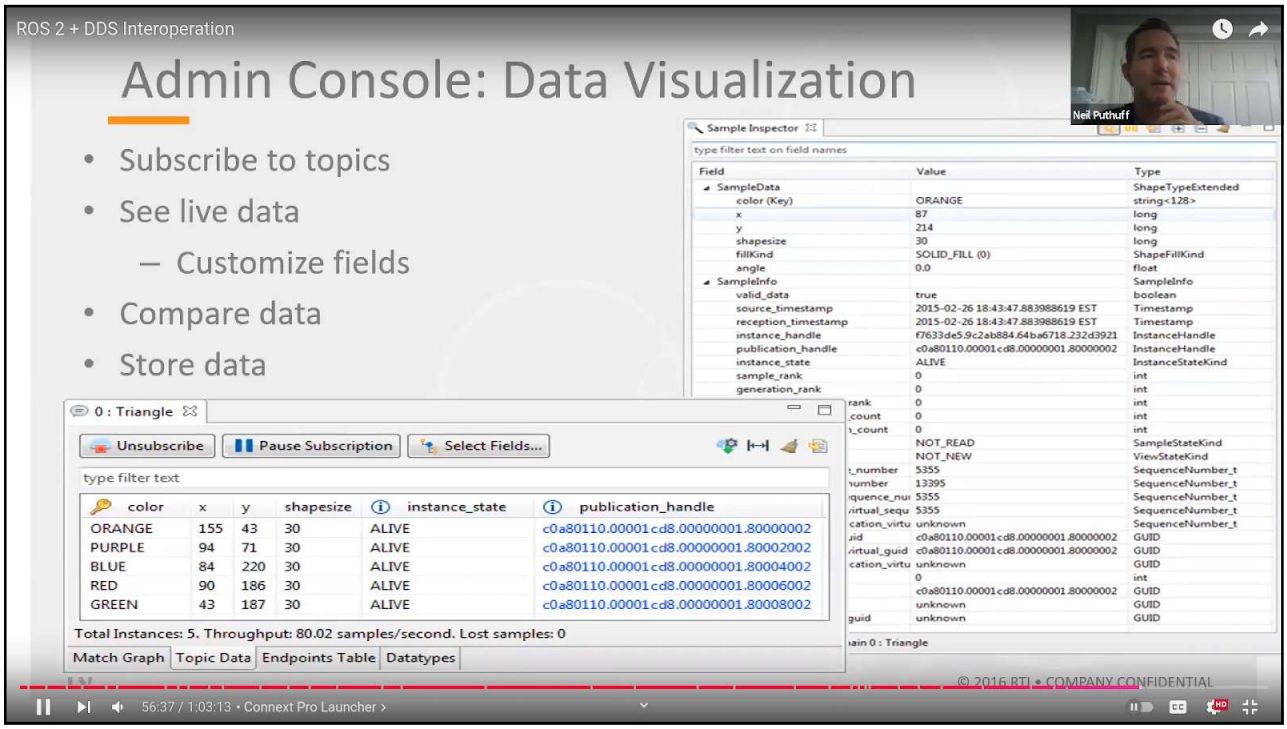
ROS 2 + DDS Interoperation
Admin Console: Data Visualization
Neil Puthuff
• Subscribe to topics
• See live data
– Customize fields
• Compare data
• Store data
Sample Inspector
type filter text on field names
Field
Value
Type
0 : Triangle
Unsubscribe
Pause Subscription
Select Fields...
type filter text
color
x
y
shapesize
instance_state
publication_handle
ORANGE 155 43 30 ALIVE c0a80110.00001cd8.00000001.80000002
PURPLE 94 71 30 ALIVE c0a80110.00001cd8.00000001.80002002
BLUE 84 220 30 ALIVE c0a80110.00001cd8.00000001.80004002
RED 90 186 30 ALIVE c0a80110.00001cd8.00000001.80006002
GREEN 43 187 30 ALIVE c0a80110.00001cd8.00000001.80008002
Total Instances: 5. Throughput: 80.02 samples/second. Lost samples: 0
Match Graph
Topic Data
Endpoints Table
Datatypes
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56:37 / 1:03:13 • Connext Pro Launcher ›

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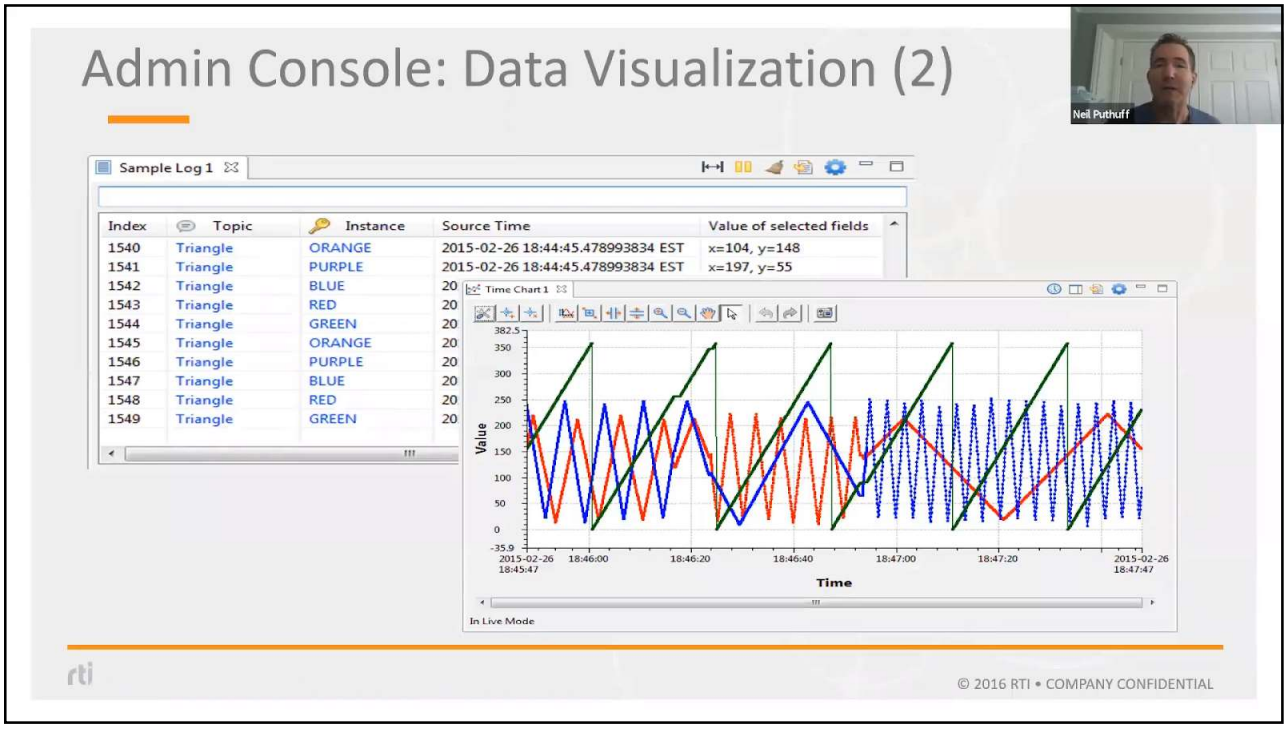
Admin Console: Data Visualization (2)
Neil Puthuff
Sample Log 1
Index
Topic
Instance
Source Time
Value of selected fields
1540 Triangle ORANGE 2015-02-26 18:44:45.478993834 EST x=104, y=148
1541 Triangle PURPLE 2015-02-26 18:44:45.478993834 EST x=197, y=55
1542 Triangle BLUE
1543 Triangle RED
1544 Triangle GREEN
1545 Triangle ORANGE
1546 Triangle PURPLE
1547 Triangle BLUE
1548 Triangle RED
1549 Triangle GREEN
Time Chart 1
Value
Time
In Live Mode
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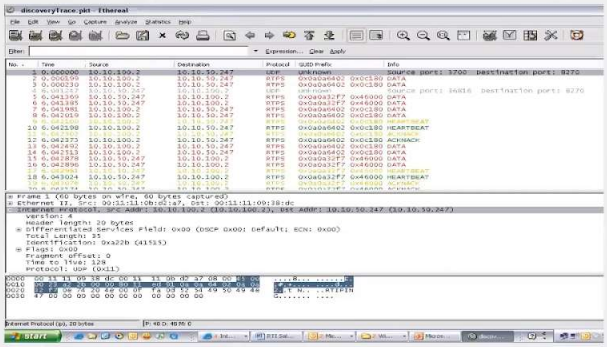
Wireshark Support

- RTPS dissector for Wireshark
  - Traps RTPS packets
  - Dissect discovery & user data
    - Heartbeats, acknowledgements,…
  - Destination & source check
- Totally non-invasive
  - No additional subscribers
- Customized filtering
- Debugging:
  - Capture & share your dissected traffic.
  - Including RTI TCP Control messages
- Support most platforms



Used to analyze wire traffic and adjust parameters for optimal performance

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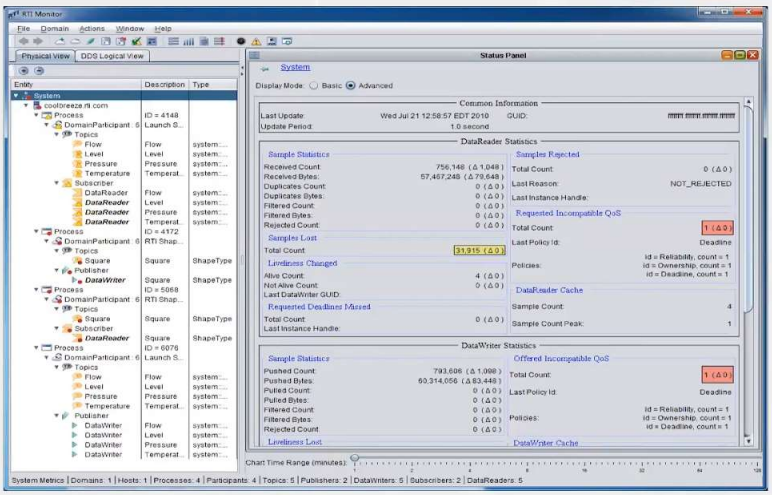
Application Monitoring

- Detailed statistics on traffic, errors, and resource usage
- Detailed system topology display
- Configurable alerts and thresholds
- Helps to Track and tune performance
- Helps in diagnosing unusual behavior



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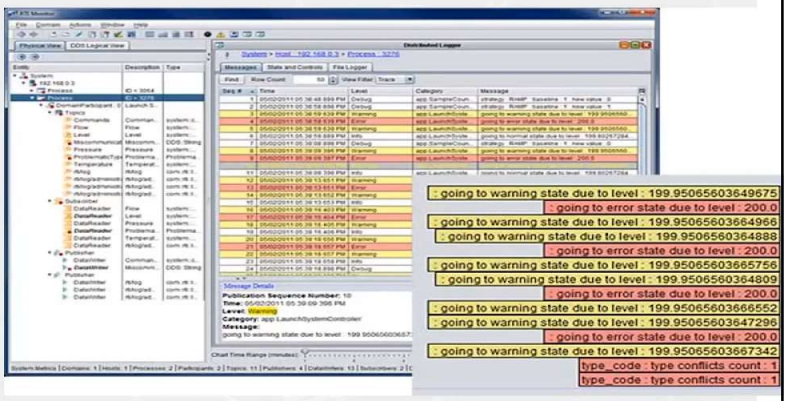
Distributed Logger

- Not exactly a tool
- Easy remote debugging from
  - Monitor
  - Admin Console
- Enabled in most RTI tools & services
- Customize your own messages



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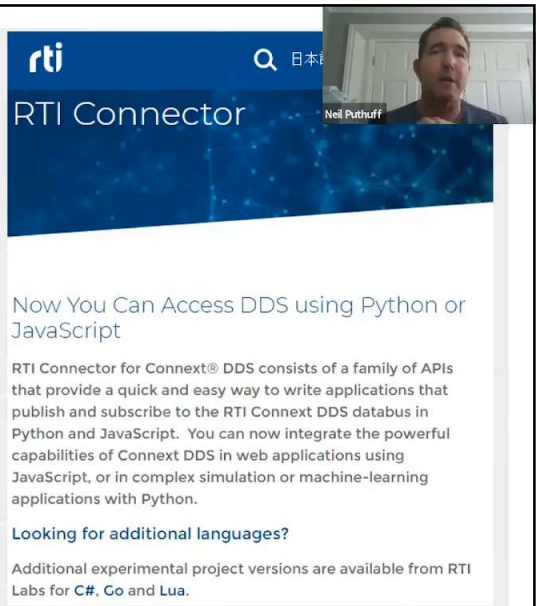
RTI Connector

Provides DDS access to Python, JavaScript, and other languages

https://www.rti.com/products/tools/connector

Available on GitHub, or installable via `pip` or `npm`



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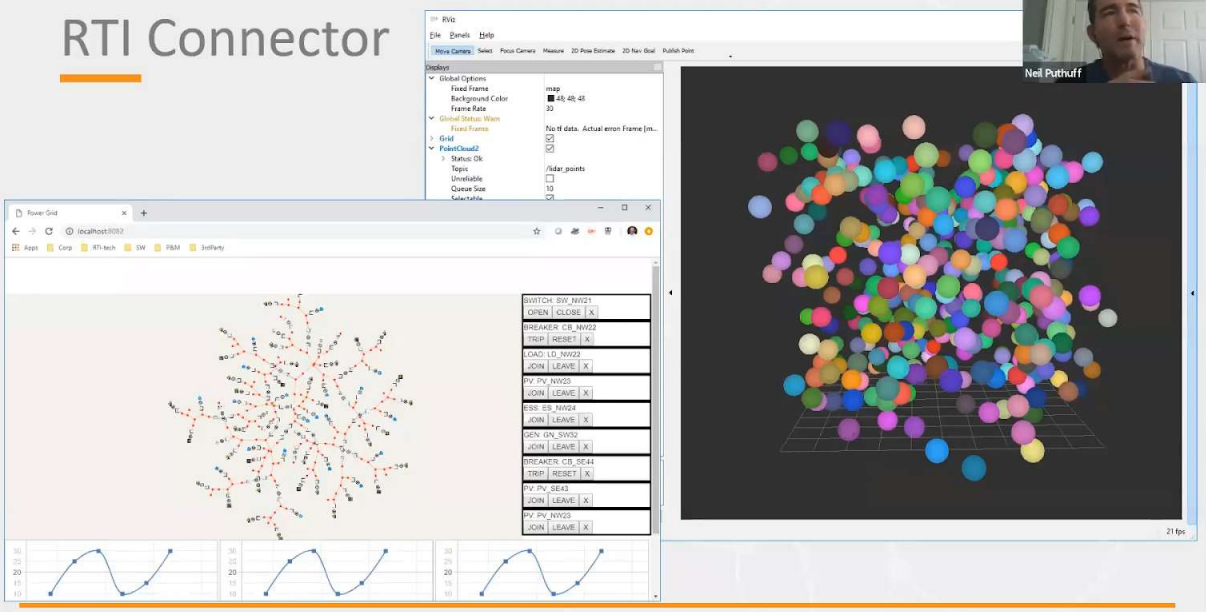
RTI Connector



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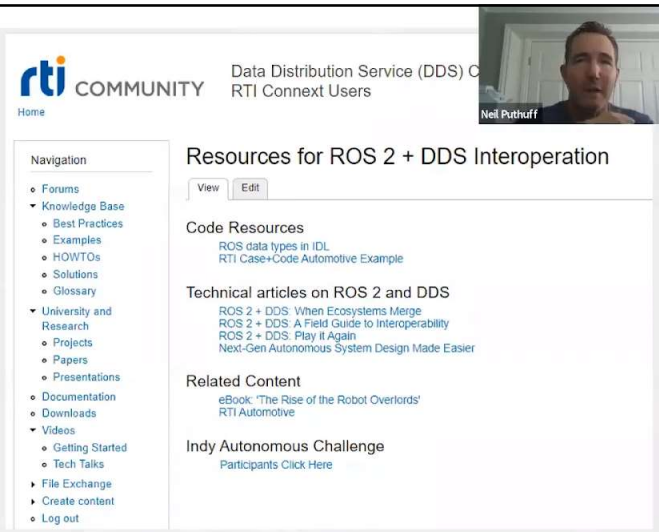
RTI Community

Resource for RTI / DDS

Forum for Q&A

Best practices, code examples, etc.



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Resources

- RTI Connext Pro v5.3.1:
  https://www.rti.com/free-trial/dds-files-5.3.1
- RTI Community
  https://community.rti.com/ros
- RTI Connector:
  https://www.rti.com/products/tools/connector
- White paper: ROS2 / DDS interop
  https://www.rti.com/hubfs/Collateral_2017/Whitepapers/rti-whitepaper-ros2-connext-dds.pdf
- Data types in IDL & XML:
  https://github.com/rticommunity/ros-data-types
  https://github.com/neil-rti/ros-data-types/blob/master/all_msgs/ros2interop/ros2-eloquent-all.idl
- Case + Code Automotive Example
  https://www.rti.com/developers/case-code/automotive

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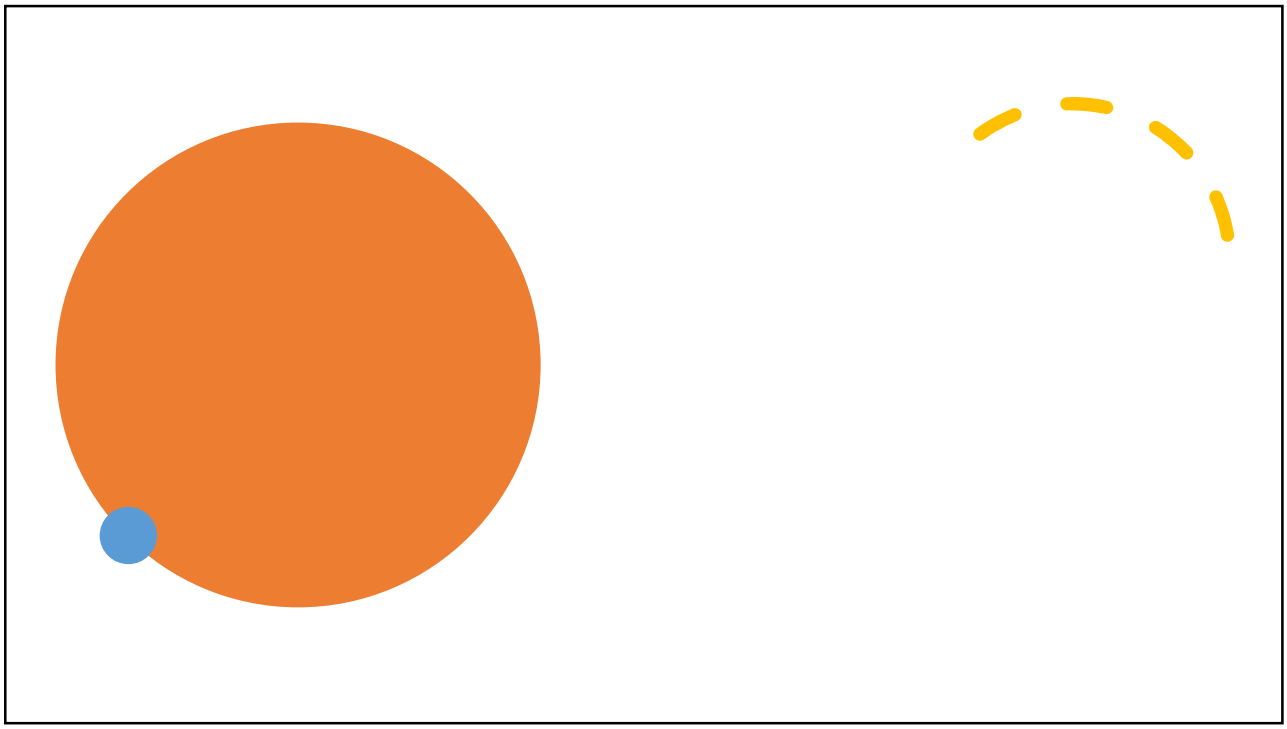
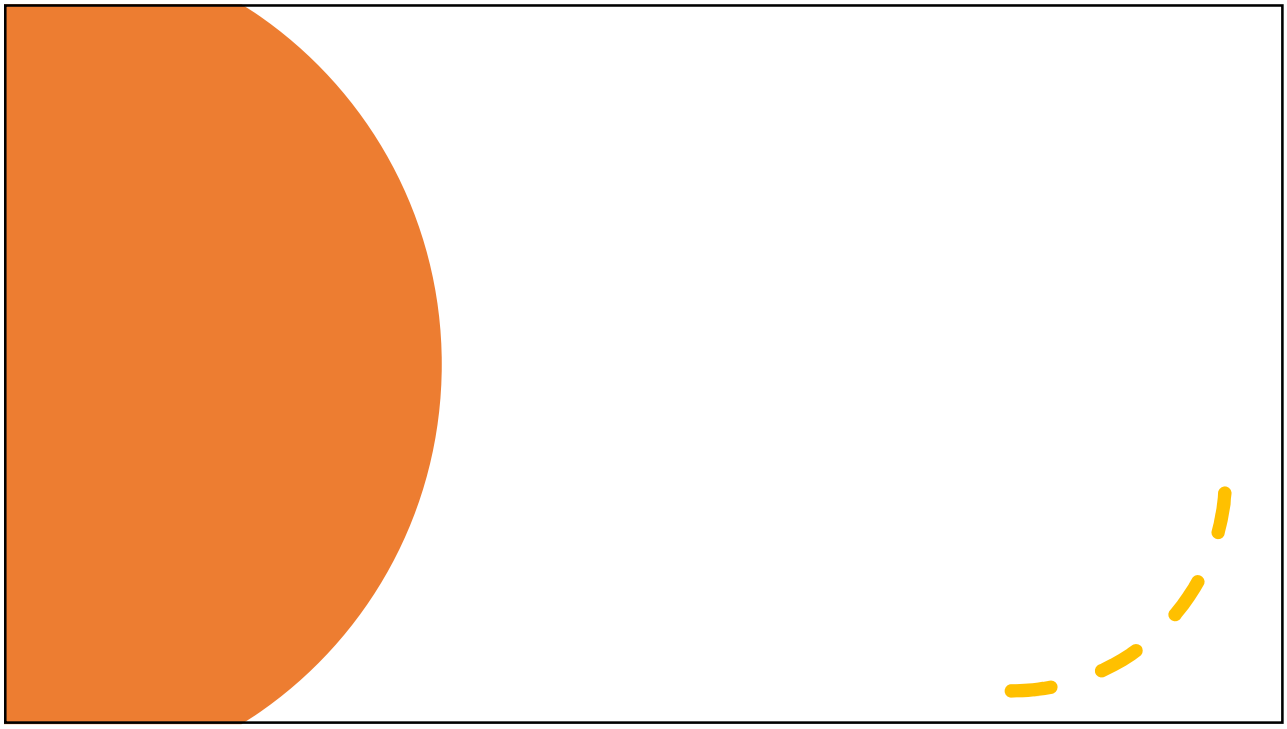


99



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