The Rise of the Robot Overlords: Clarifying the Industrial IoT
Part 3: Software and Device Integration: Deep dive into DDS and OPC UA

Speaker:

Stan Schneider, Ph.D.
CEO,
Real-Time Innovations, Inc. (RTI)

Moderator:

Curt Schwaderer, OpenSystems Media

Agenda

- Housekeeping
- Presentation
- Questions and Answers
- Wrap-up

The Rise of the Robot Overlords

Clarifying the Industrial IoT

Part 3: Software and Device Integration: Theory and Practice

How to compare, contrast, and integrate DDS and OPC UA.

Stan Schneider, PhD
RTI CEO
IIC Vice Chair

The Big Picture

NGC3370

Education
- Colleges & Universities
- Conferences & Workshops
- Laboritories
- Publication
- Schools
- Trade Schools

Aerospace & Defense
- Air Force
- Arrmy
- Aviation
- Home Land Security
- Military
- Navy
- Space Flight

Environment
- Air Pollution Control
- Biodiversity
- Eco-construction
- Environmental Monitoring & Instrumentation
- Environmental Research & Development
- Heat & Energy Saving and Management
- Metrology
- Nature Protection
- Noise & Vibration Control
- Oceanography
- Recycled Materials
- Remediation & Clean Up of Soil & Groundwater
- Renewable Energy Production
- Waste Management & Recycling
- Waste Water Treatment
- Water Supply

Buildings & Facilities
- Apartments
- Building & Construction
- Building Maintenance
- Building Security
- Commercial Buildings
- Construction
- Engineering
- Home
- Housing Authorities
- HVAC
- Office
- Real Estate

Media & Communication
- Cable Providers
- Computers
- Entertainment
- Global Media
- Phones
- Satellite TV
- Telecommunications Carriers
- Televisions
- Video Recorders
- Wireless Services

Energy & Utilities
- Chemicals
- Electric
- Mining
- Oil & Gas
- Petro-Chemicals
- Power
- Renewable
- Sewer
- Water

Consumer & Home
- Automotive
- Commercial Cooking
- Consumer Products
- Day Care
- Elder Ca
- Entert
- Food a
- Food T
- Groce
- Home
- Hospit
- Pet Ca
- Pharm
- Photogra
- Recreation Services
- Restaurants
- Sporting Events
- Street Vendors
- Tourism
- Travel

Finance & Banking
- Accounting Systems
- ATM Systems
- Credit Card Systems
- Point of Sales
- Retail Banking

Transportation
- Aeronautics
- Airport
- Cargo Handling
- Cruise Industry
- Fleet Management
- Freight Management
- Logistics
- Mobility
- Pipelines
- Postal & Delivery Services
- Public Transportation
- Rail
- Roads
- Shipping

The IIoT will have a multi-trillion-dollar impact across all industries

There are many, many use cases in the IIoT

- Disaster Prevention
- Education
- Emergency & Crisis Response
- Environment
- Fire
- Law Enforcement & Police
- Municipalities & Counties
- Public Safety
- Public Security
- Surveillance
- Transportation
- Waste Management
- Water

Manufacturing
- Apparel
- Beverage & Tobacco Product
- Chemicals
- Computer & Electronic Products
- Electrical Equipment & Components
- Fabricated Metal Products
- Factory
- Food
- Furniture & Related Products
- Industrial Automation
- Leather & Allied Products
- Machinery
- Nonmetallic Mineral Products
- Paper
- Petroleum & Coal
- oducts
- facturing
- pport Activities
- pment

hcare
- Clinical Trials
- Connected Medical Devices
- Continuous Patient Monitoring
- Dentistry
- Disease Diagnosis
- Home Healthcare
- Hospitals
- Life Sciences
- Medical Offices
- Medical Therapy
- Pharma
- Pharmacies

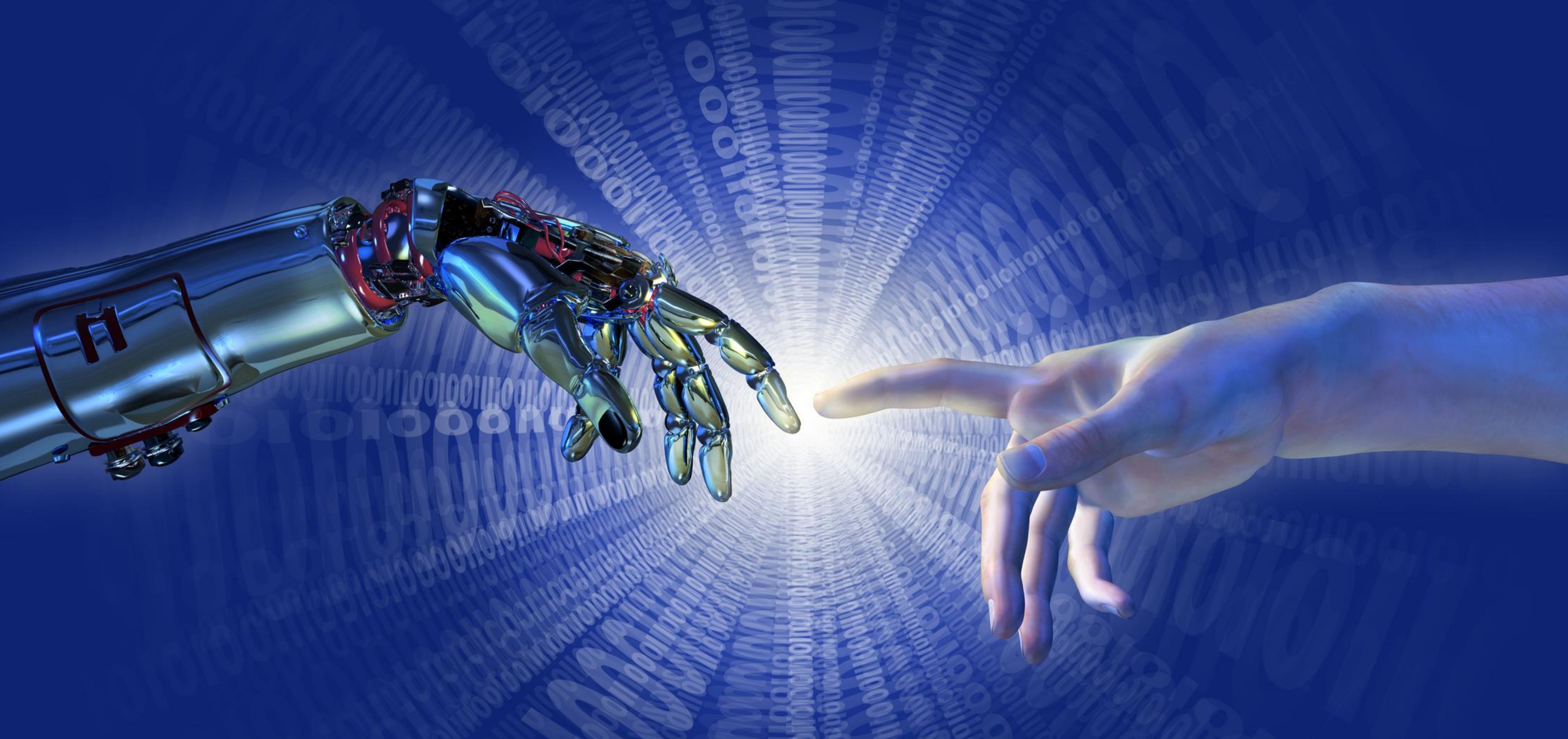
Near Space & New Space
- Closed Loop Ecological Systems
- Closed Loop Living Systems
- Constellation Controllers
- Consumer Traffic Analytics
- Ecological Planning
- Environmental Monitoring
- Hyper-Local Agriculture
- Hyper-Local Construction
- Hyper-Spectral Imaging
- In-Flight Satelite Servicing
- On-Site Materials Analytics and Inventory
- On-Site Materials Optimization
- Parametric City Planning
- Parametric Construction Planning
- Remote Maintenance and Diagnostics
- Space Based Planning
- Weather Pattern Analytics

Agriculture
- Farming
- Fishing
- Forestry
- Hydrology
- Life Sciences
- Ranching
- Weather

Mining & Metals
- Aluminum
- Coal
- Diamonds & Gemstones
- General Mining
- Gold
- Iron & Steel
- Nonferrous Metals
- Platinum & Precious Metals

Retail
- Apparel Retailers
- Broadline Retailers
- Drug Retailers
- Food Retailers & Wholesalers
- Home Improvement Retailers
- Specialized Consumer Services
- Specialty Retailers

rti



The smart machine era will be the most disruptive in the history of IT

-- Gartner

A *Better* Smart Machine World

You don't compete against competitors.
You compete against market transitions.
– John Chambers

The real value is a common architecture that connects sensor to cloud, interoperates between vendors, and spans industries

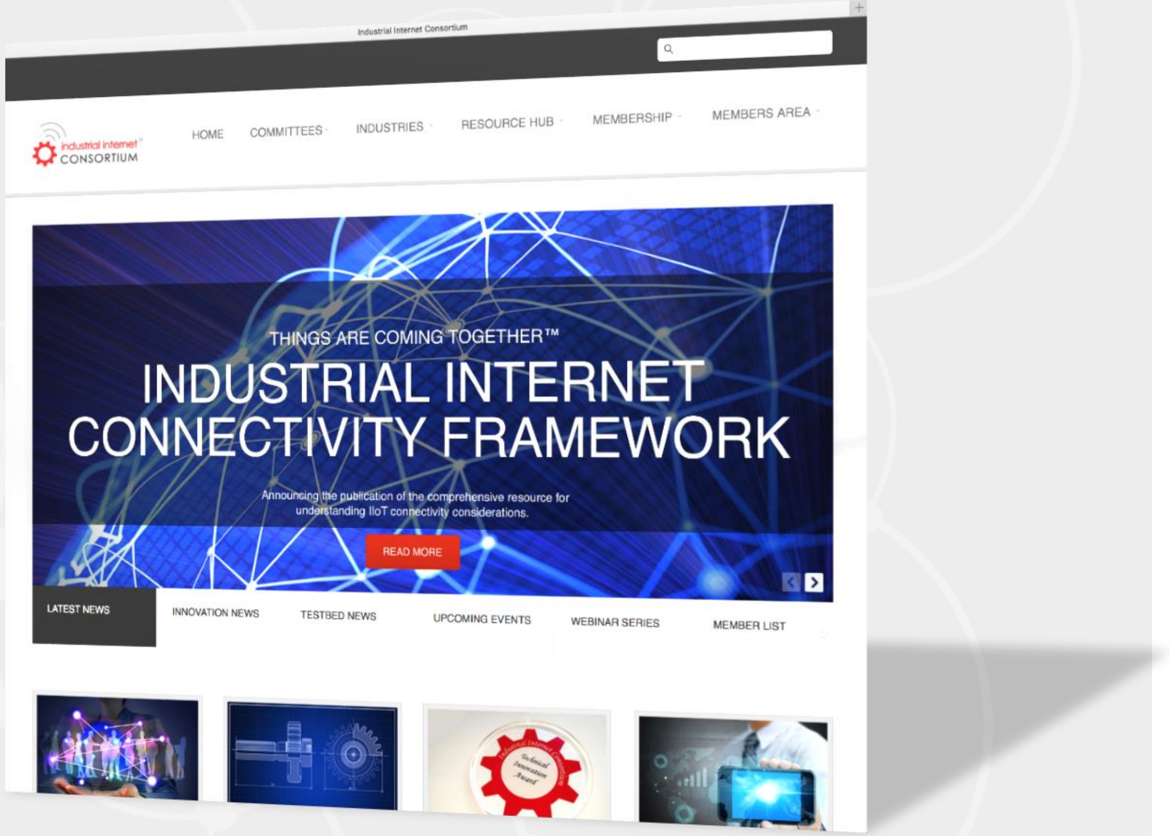
Rise of the Robot Overlords Webinar Series

- Part 1: What is the IoT, Anyway?
- Part 2: A Practical Guide to IIoT Connectivity
  - How to choose between DDS, OPC UA, MQTT, RESTful HTTP, OneM2M and CoAP
- Part 3: Data-Centric vs Device-Centric Integration: Theory and Practice
  - How to compare, contrast, and integrate DDS and OPC UA.
- Part 4: Why a Databus is so Unique
- Part 5: The IIoT Security Challenge
- Part 6: A deeper IIoT example: Autonomous Vehicles (Carbots)
- Part 7: The Age of the Robot Overlords

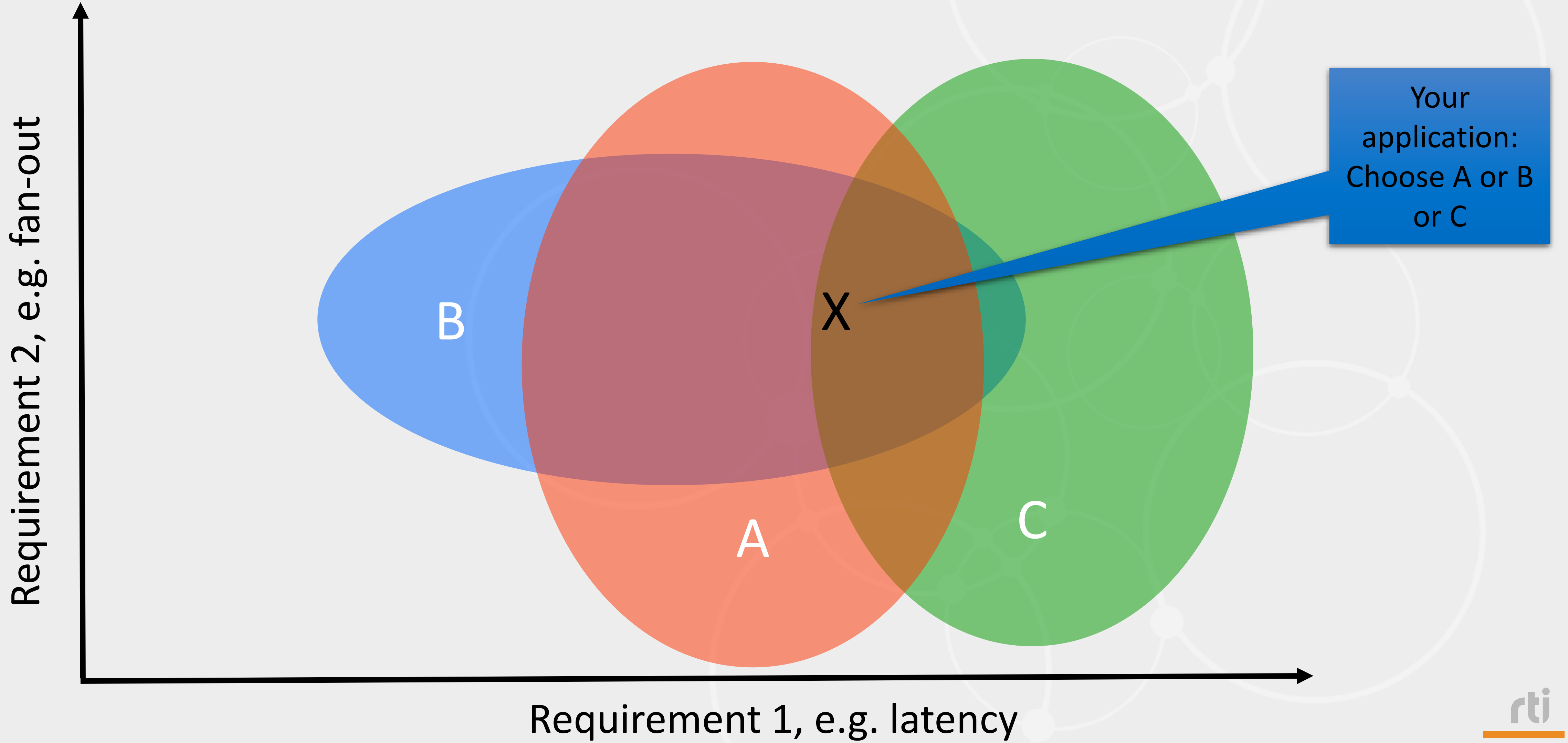
Choosing a Connectivity Standard

The Industrial Internet Connectivity Framework

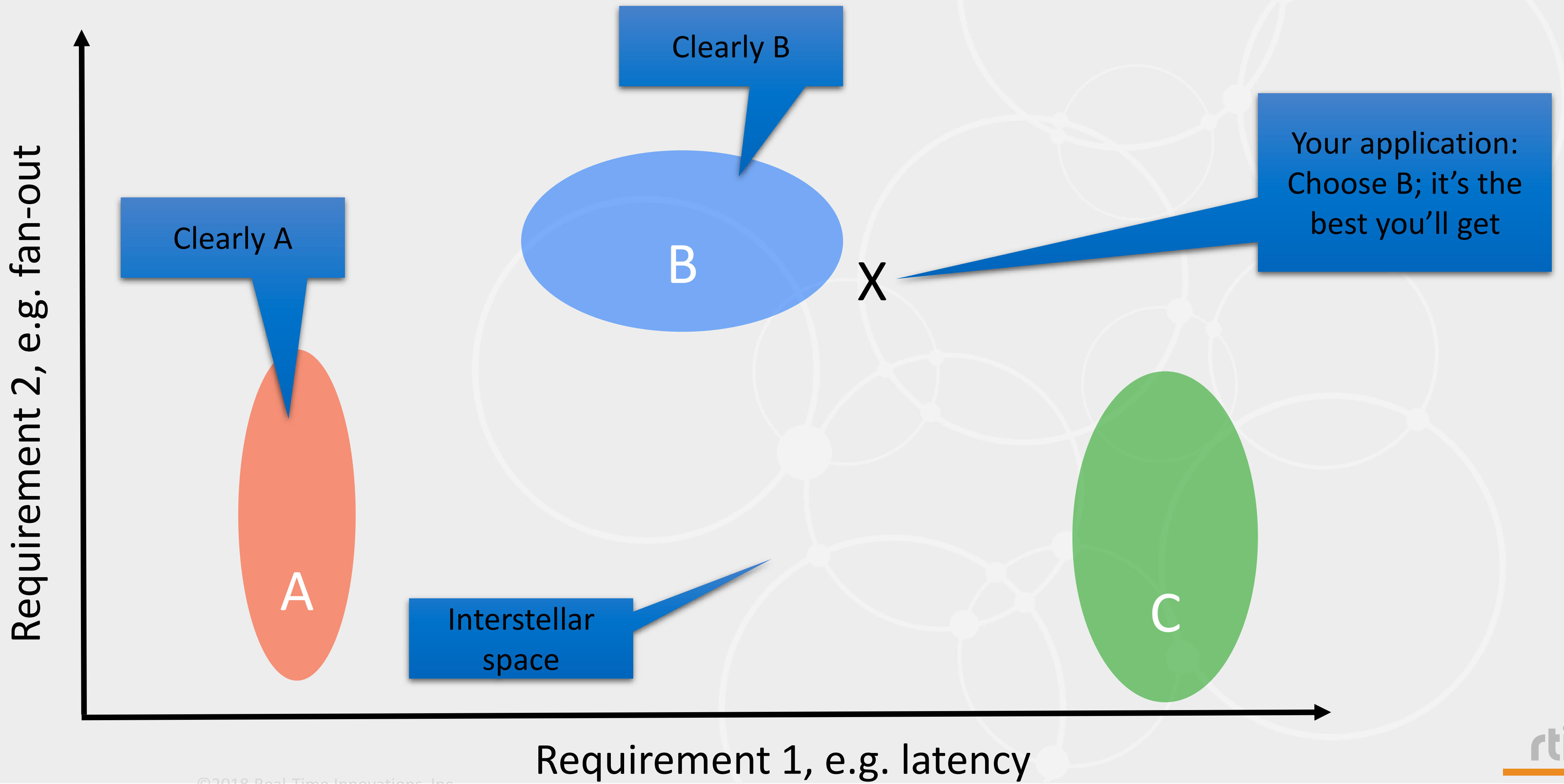
- The industry's only detailed analysis of IIoT Connectivity Technologies
- Architecture
- Assessment
- Standards
  - DDS
  - OPC UA
  - OneM2M
  - HTTP
  - MQTT
  - CoAP
- Examples & selection guidance
- Years of work by many architects across industries, standards, & technologies



IIoT Connectivity Perception



IIoT Connectivity Reality

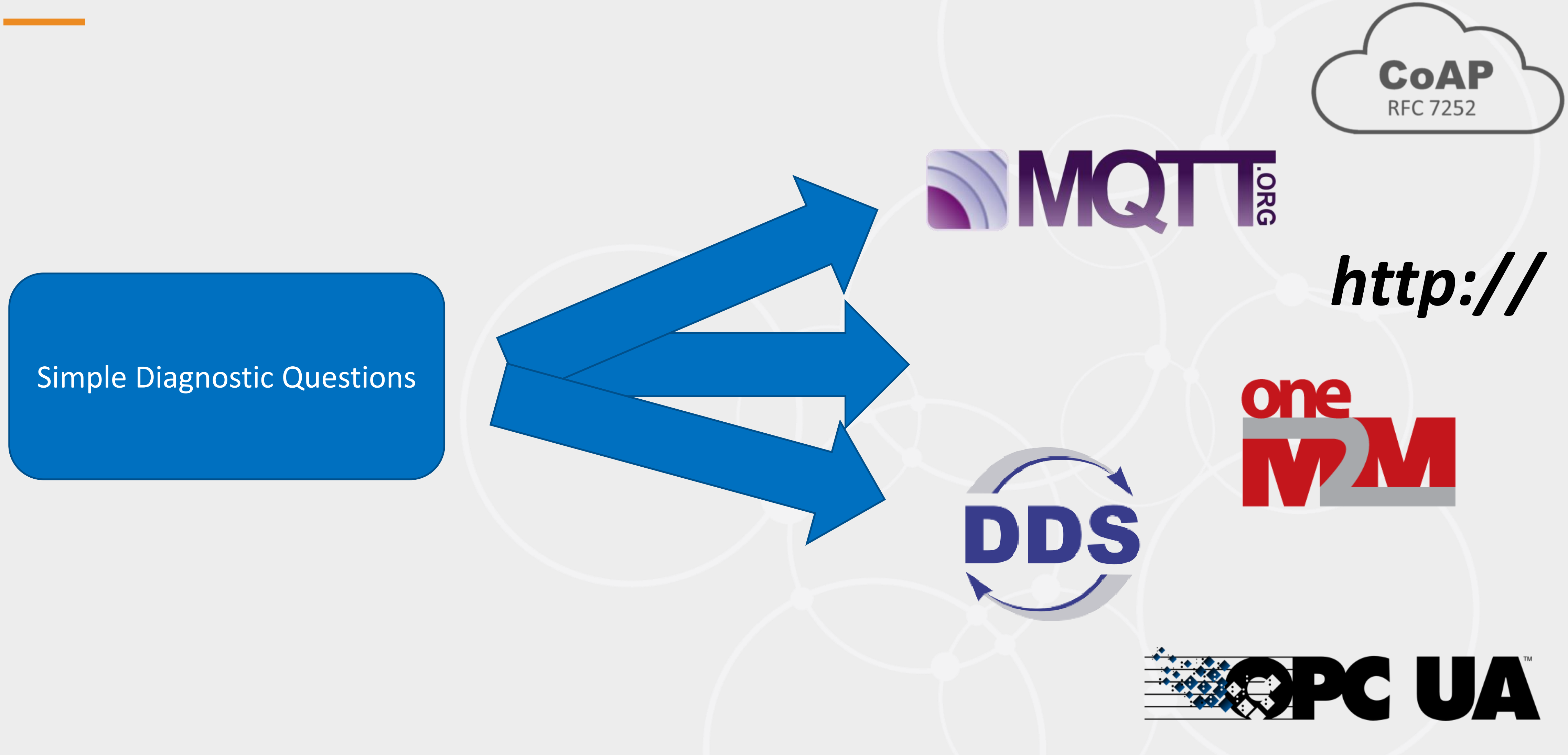


rti

How to Choose?

System Aspect	Example User	Approach	Standard
Software Integration & Autonomy	Software Architect integrating components	Data-centric	DDS
Device interchangeability	Device manufacturer selling devices to technicians	Device-centric	OPC-UA
Web & Mobile User I/F	App builder supporting back-end services	RESTful	Web services/HTTP
ICT integration	Wide-area wireless telecom integrator	Common services layer	oneM2M

Selection Guide



Choose DDS?

- Are there severe consequences of short-time failure (min/sec)?
- Have you said “millisecond” in the last 2 weeks?
- Do you have more than 10 software engineers?
- Does your data have many destinations?
- Are you building a next-generation IIoT design?

3+ Yes?

DDS

Choose OPC UA?

- Are you in in discrete manufacturing?
- Are you associated with the German Plattform Industrie 4.0?
- Are you building a device that will be integrated by industrial or control engineers and technicians, rather than software engineers?
- Will your product be used in different applications in different systems, as opposed to a single (type of) system where you control the architecture?
- Have you said the word “workcell” in the last two weeks?

3+ Yes?

Why?

Why do these questions diagnose your choice for OPC UA vs DDS?

Some Background…

Architecture == Abstraction

- A “software architecture” is an abstraction, or model, that makes it possible to understand and process data. It determines:
  - Types of entities & components
  - How components find, use, store, and update information
  - Where state lives
- A connectivity technology implements an abstraction to integrate components into a system. It determines:
  - What types of components are integrated
  - Interfaces between components
  - Types of users who effect integration

The Architectural Challenge

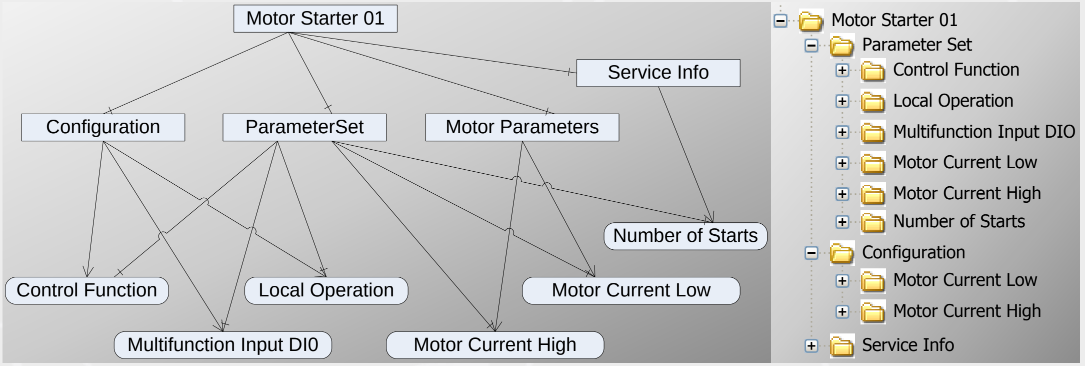
Create a powerful abstraction to effect integration with minimal extraneous coupling

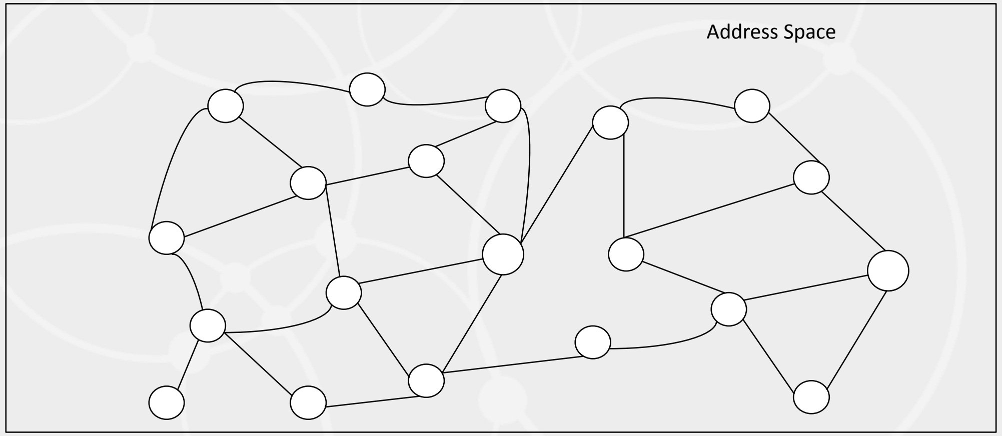
OPC UA

Device Integration for Vendor Interoperability

OPC UA

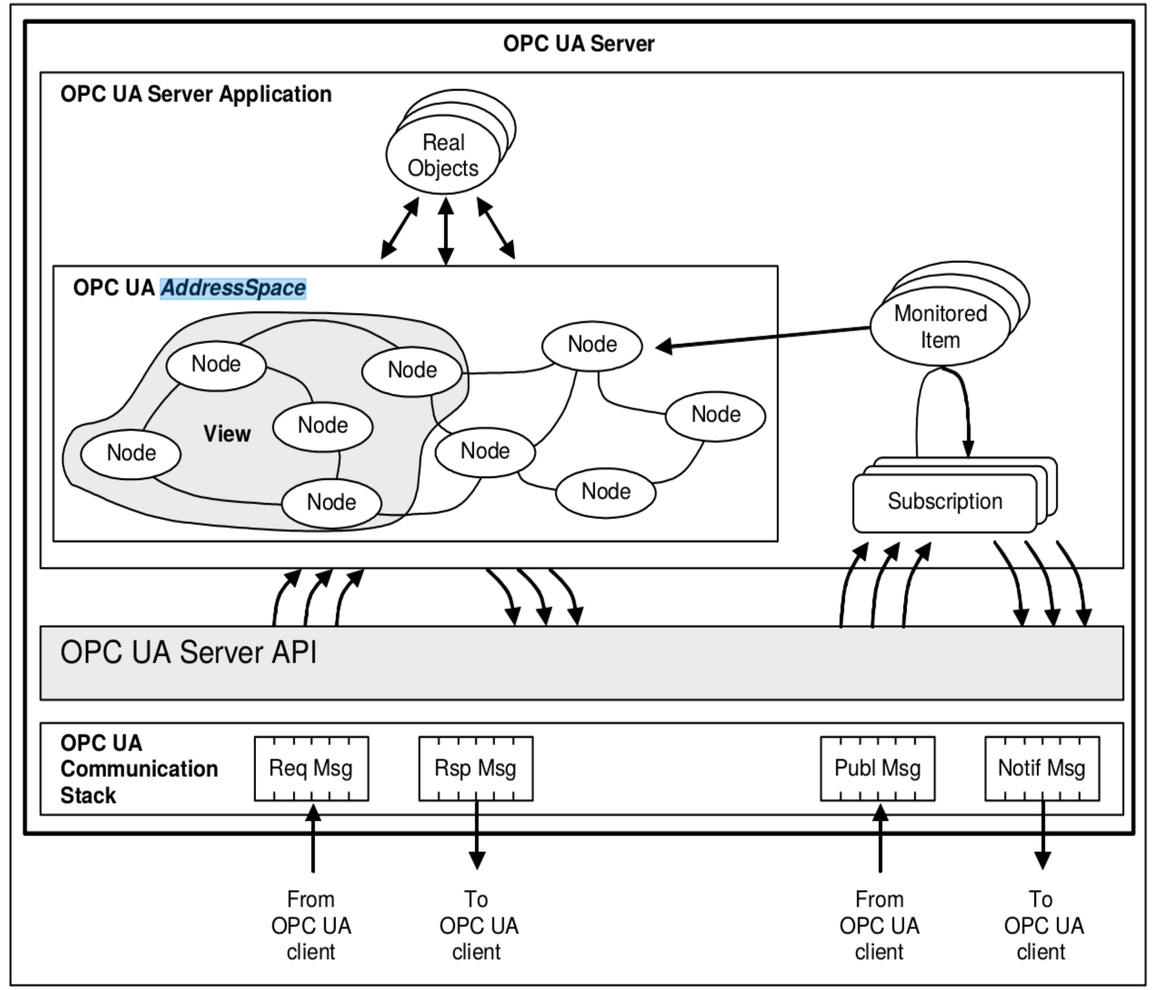
- Device-Centric Object-Oriented Framework
  - Device models for common devices
  - Integrate devices into workcells
  - Client-server architecture
  - Browsable address space
  - New simple UDP pub-sub





OPC UA Basics

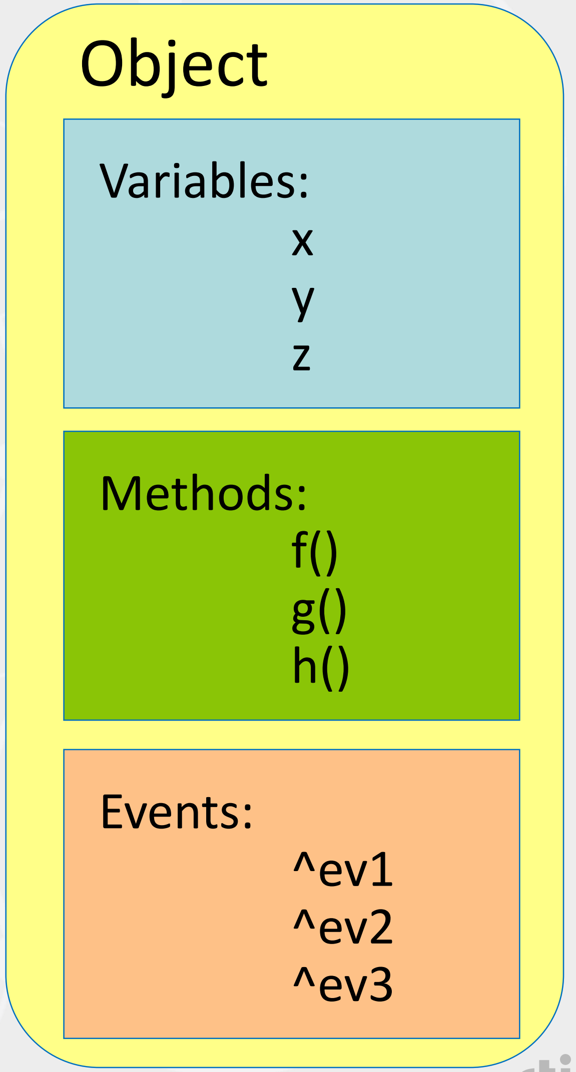
- Client/Server Model
  - Servers expose Address Space
  - Clients access information using services
- Object-oriented meta-model
  - Used for sensors, actuators…
  - Information as nodes in Address Space
  - Nodes are organized hierarchically
- OPC UA Services:
  - Connection management
  - Node management
  - View, Query
  - Attribute, Method
  - Subscription, Monitor items



©2018 Real-Time Innovations, Inc.

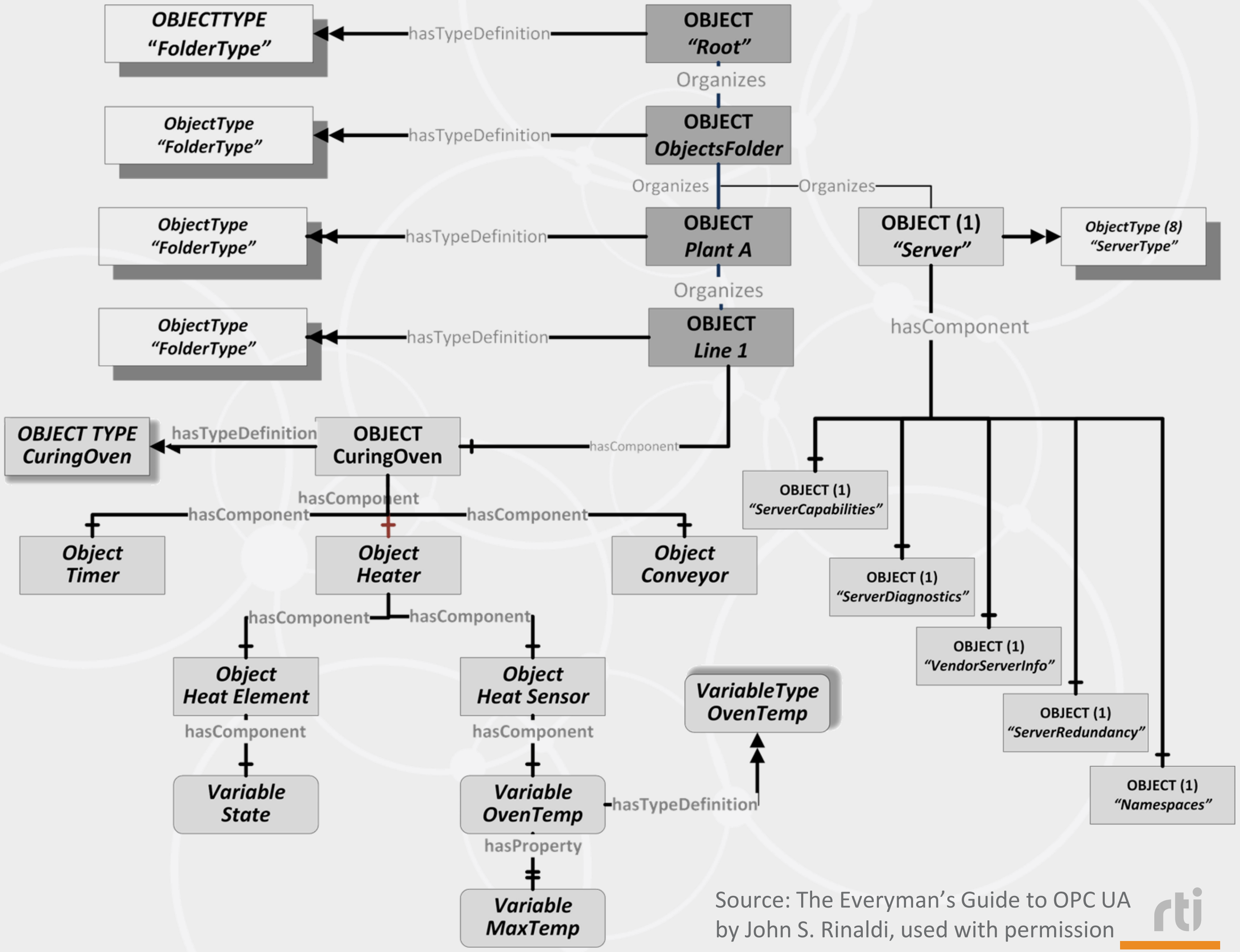
OPC UA Object model

- Nodes and References between nodes
  - Nodes have: ***NodeId***, ***NodeClass***, ***BrowseName***, ***DisplayName***, ***Description***, ***WriteMask***, ***UserWriteMask***
  - References – relations between nodes
- Types of Nodes:
  - Object – Used to structure the address space. They group other Nodes. E.g. Variables and Methods always exists within the concept of an Object
  - Variable – represent a value that an be read, written, subscribed by a client
  - Method – Operations that may be called by a client, have arguments (input, output) and a result
  - Events – Notifications that may be subscribed by the client
  - Other: ReferenceType, VariableType, DataType, ObjectType, ...



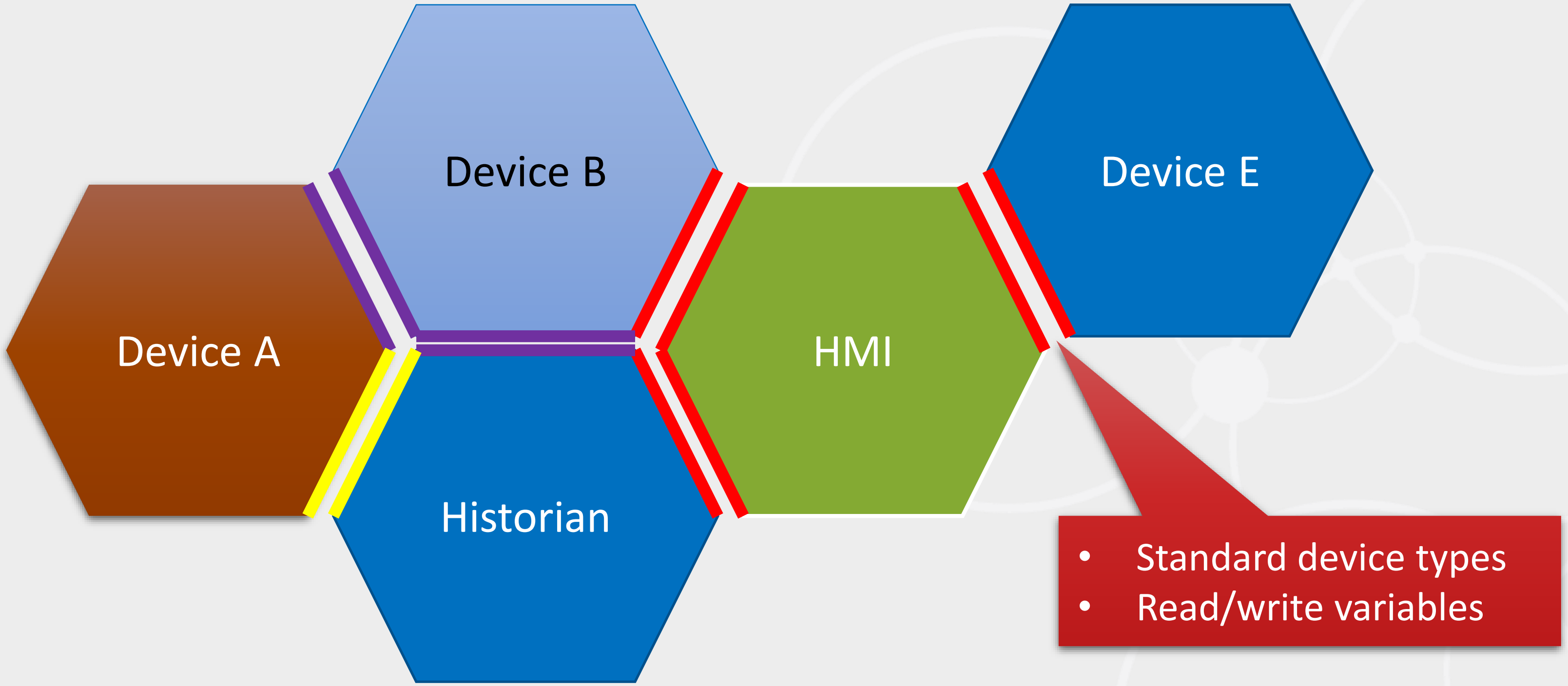
OPC UA Object-Oriented Abstraction

- Entities
  - Objects with methods (execution) and state (data)
- Entity Interaction
  - Get data by calling methods, or “subscribing” to methods
  - Update by calling methods
- State lives in objects
  - Operational data
  - “Meta data”, e.g. units, part numbers
- Browsable information model “rolls up” the system from sub-parts hierarchically



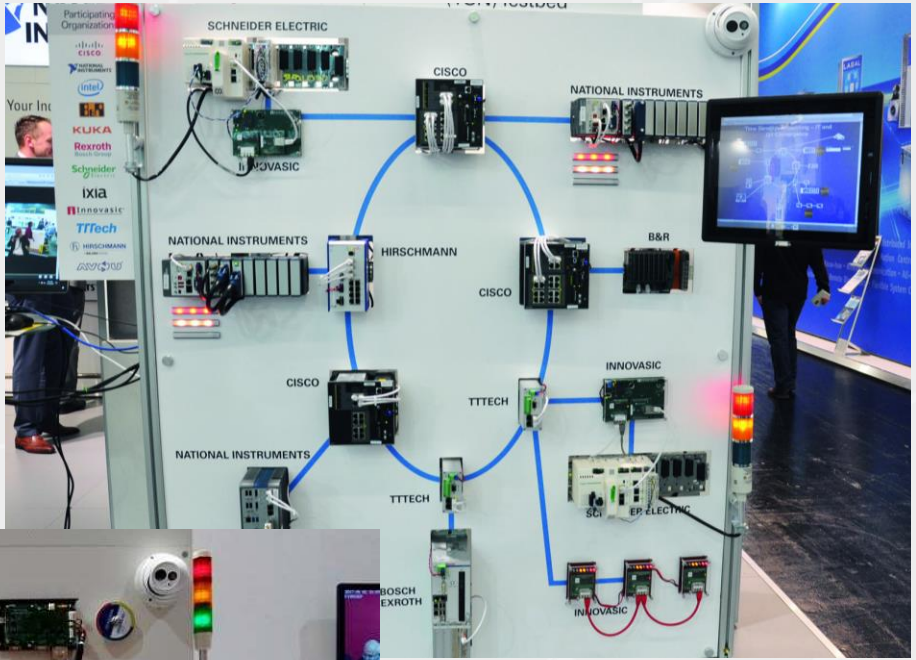
Source: The Everyman’s Guide to OPC UA by John S. Rinaldi, used with permission

Device Integration



- Challenges
  - Interoperate between vendors
  - Assembled by engineers or technicians
- Components
  - Devices
  - Reusable software products (e.g. HMI)
- Interfaces
  - Standard device models
  - Dynamic address space rollup
  - Read/write variables

OPC UA Interoperability Decouples Vendors



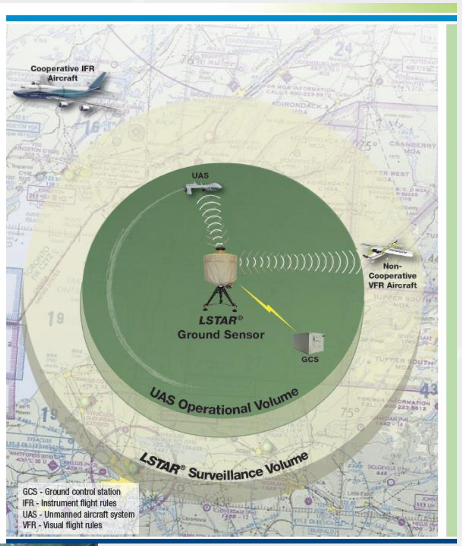
- Crisp protocol definition
- Companion specs define device & component models
- Formal conformance testing

The DDS Databus

Software Integration for Autonomous Systems

Autonomous Systems Challenges

RTI founded from Stanford Aerospace Robotics Lab



- 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 with Cloud Systems

Integrate Complex Software for Real-Time Distributed Control

How to Deal with the Data?

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 [illegible]	30-300 Mbit/s
5 Radar sensors	Object/target list	bytes to kbytes	[illegible]z	~10 kB/s
16 Ultrasonic sensors	Object/target list	byte[illegible]	10 Hz	~10 kB/s
1 GPS	Data messag[illegible]	[illegible]ouple of bytes	20-200 Hz	~10 kB/s
Control commands	Da[illegible]	A couple of bytes	50-250 Hz	~10 kB/s
Status/error handling	[illegible]ata/string message	Whatever needed	Whenever needed	Whatever needed

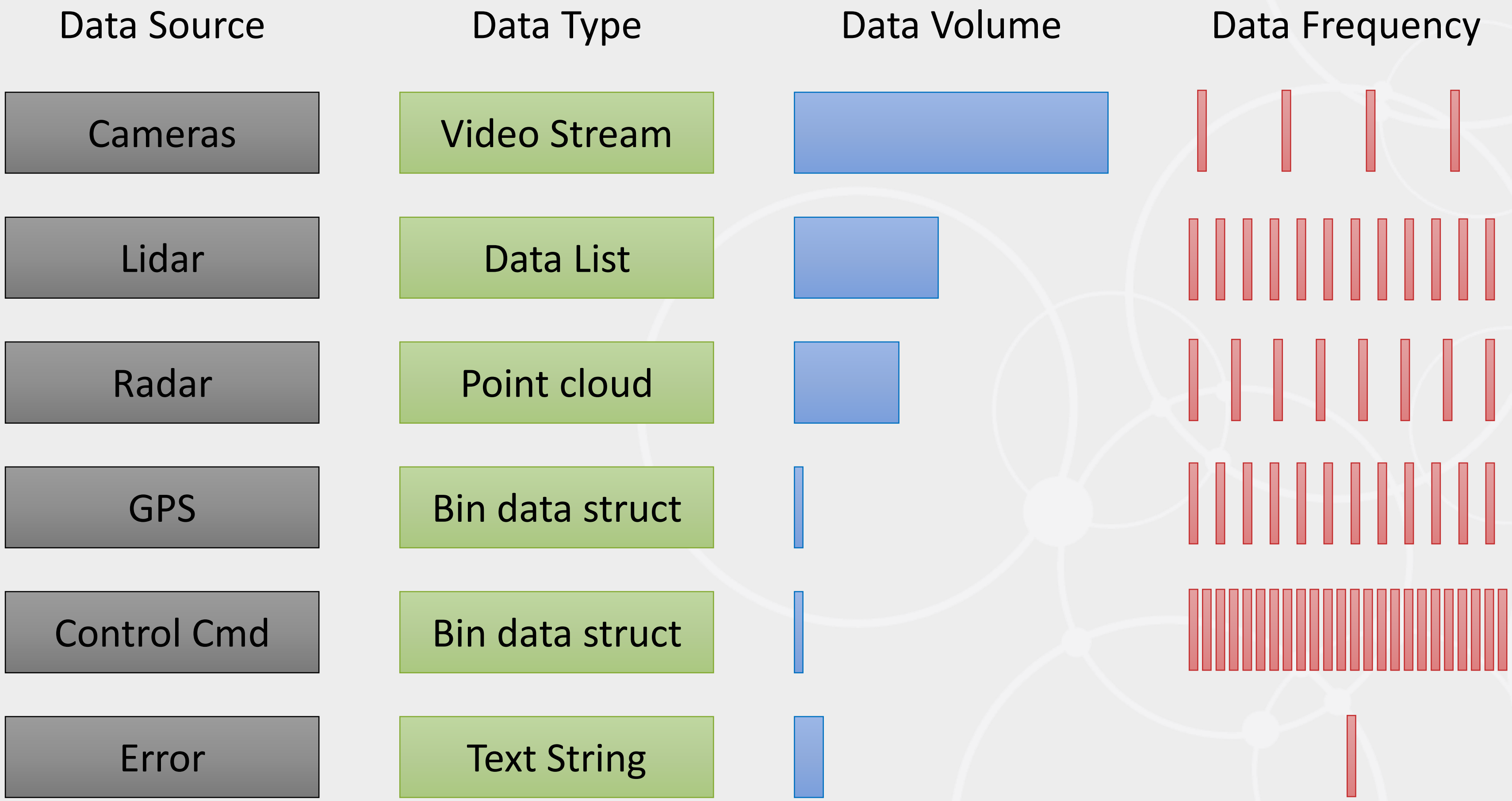
Autonomous Systems Generate Massive Data Flow

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)

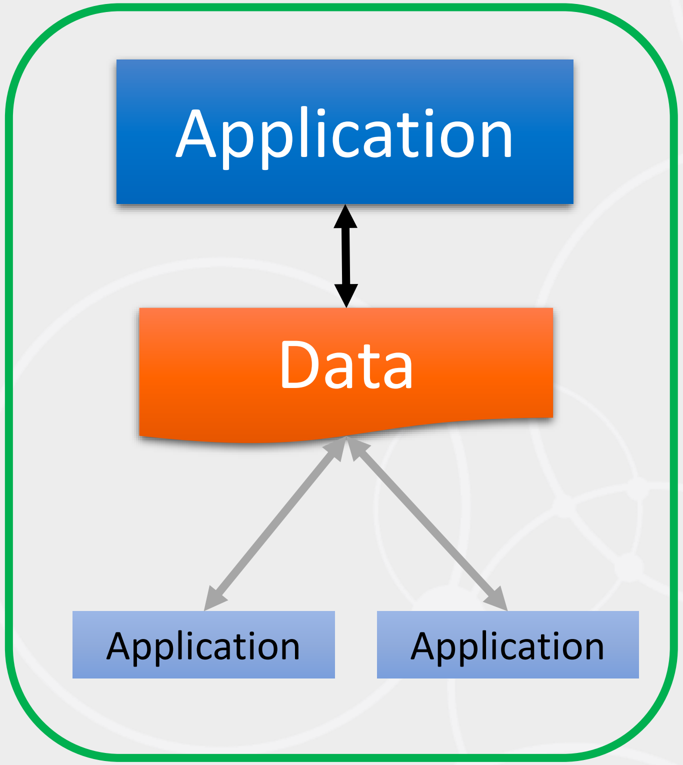
Autonomy Dataflow Challenge



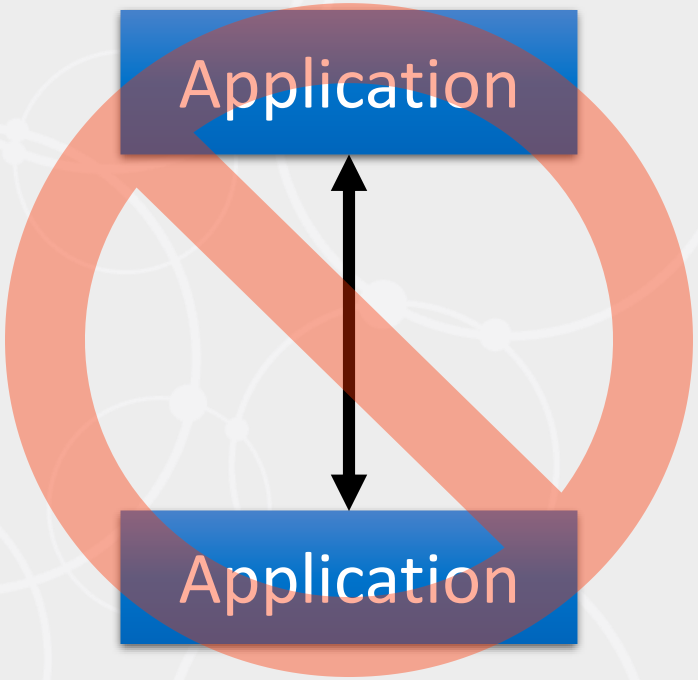
- Autonomy combines:
  - Volume
  - Frequency
  - Latency
  - Reliability
  - Destination
- A single abstraction that can handle all greatly simplifies the system

The DDS *Databus*

DDS is the standard that defines a databus



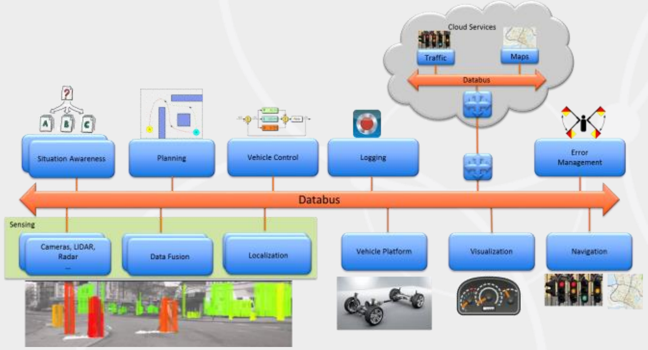
Data-centric technology connects applications to the data, not to each other



Message centric
Client/Server
Remote Objects
Publish-subscribe
SOA

Database and Databus are *Data Centric*

Database



Databus

DDS

Stores & searches old data

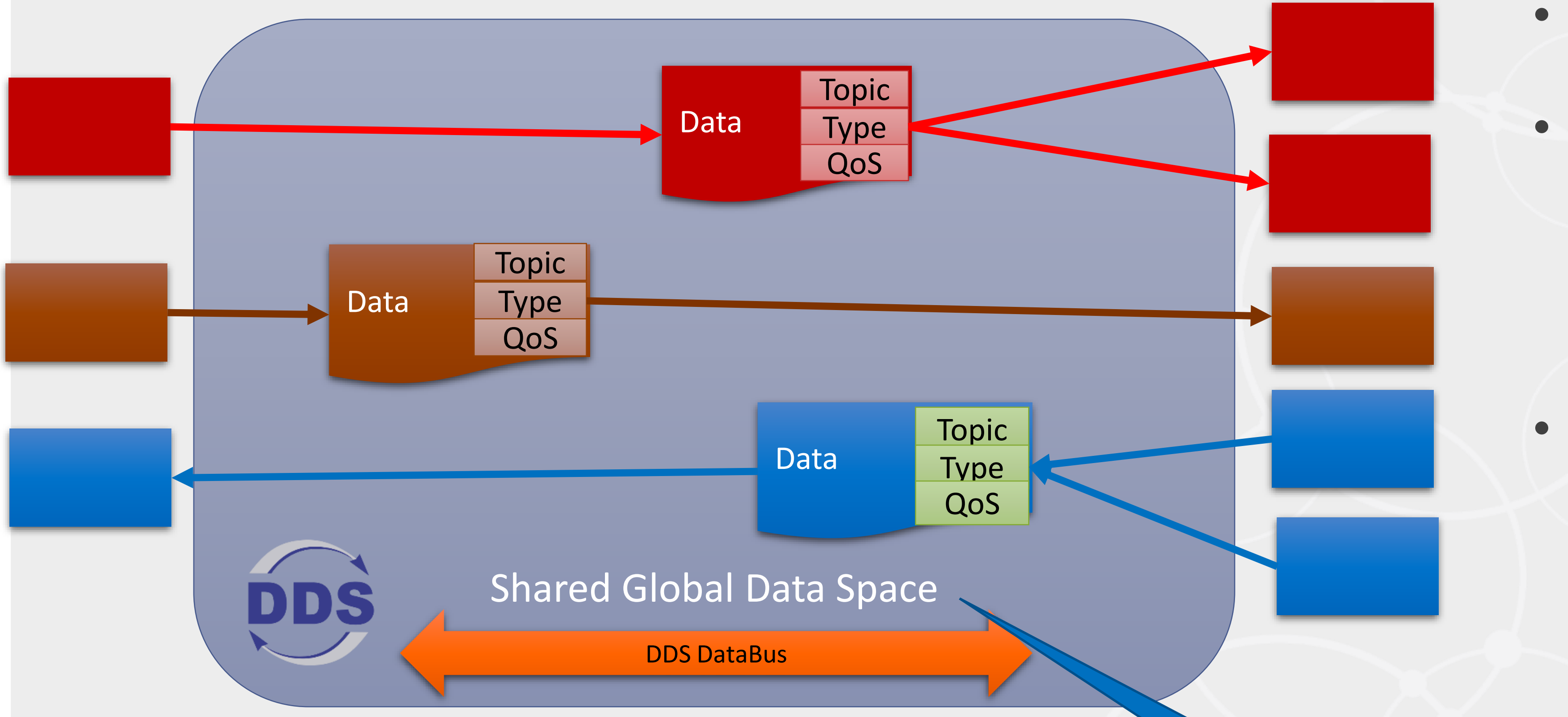
Seeks & filters future data

Why Data Centricity?

- Common “truth” for integration
- Natural redundancy
- Right data, right time, right place
- Complexity in infrastructure, not code
- No startup dependencies
- Generic tools and analyzers

rti

DDS Databus "Data Everywhere" Abstraction

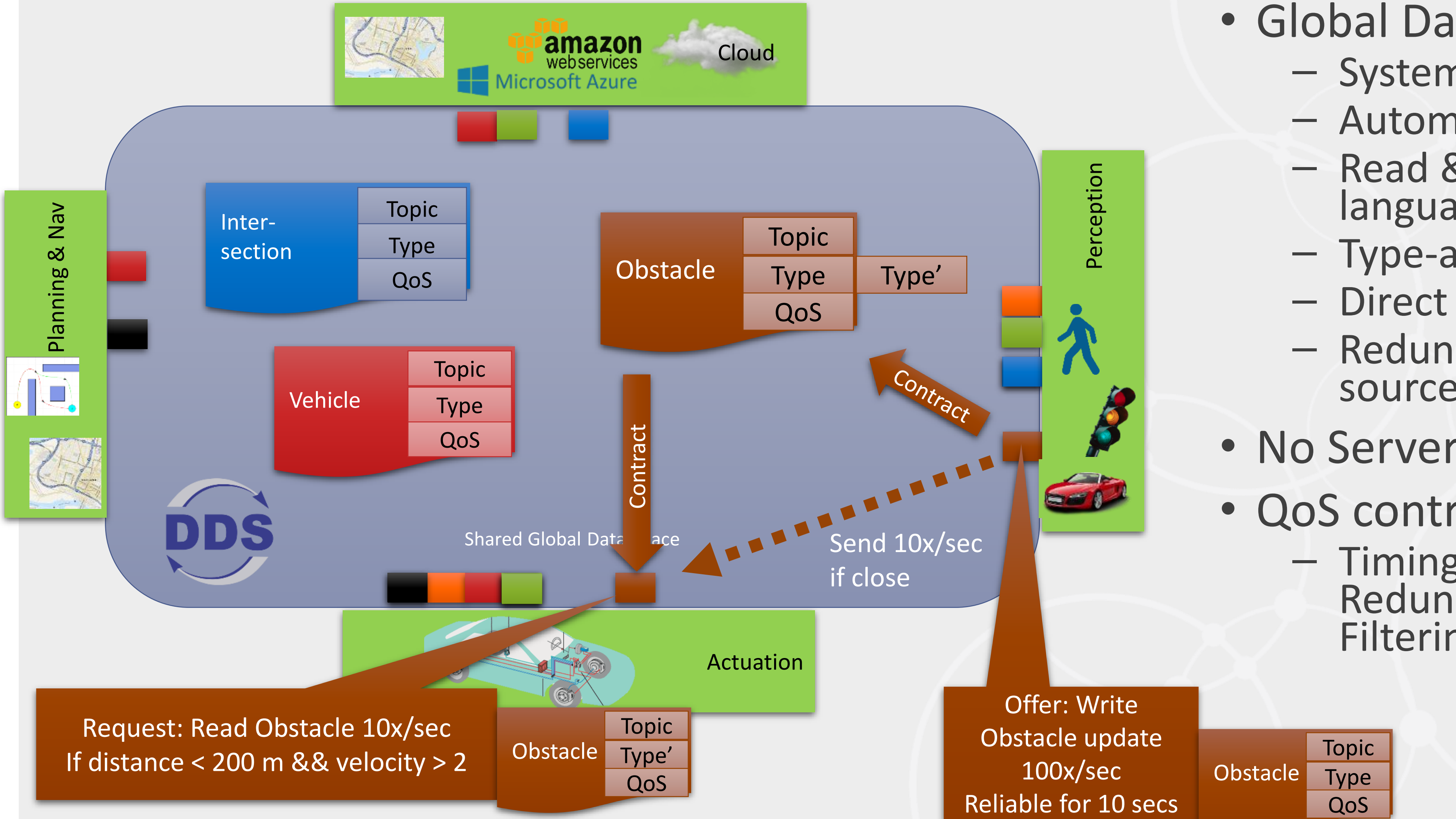


- Doesn't actually send all data…
- Every application gets everything it needs, when it needs it
  - Applications declare needs and capabilities
  - Databus delivers data
- Applications interface only to data
  - Every app speaks its own language
  - Databus maps language, CPU, OS, transport
- Fast, reliable, scalable

Naturally, massively parallel

Data Centricity

The Databus Integrates Software Applications



- Global Data Space
  - System data model
  - Automatic discovery
  - Read & write data in any OS, language, transport
  - Type-aware matching
  - Direct peer-to-peer comms
  - Redundant sources/sinks/nets
- No Servers!
- QoS control
  - Timing, Reliability, Liveliness, Redundancy, Ordering, Filtering, Security

Take it to Massive Scale

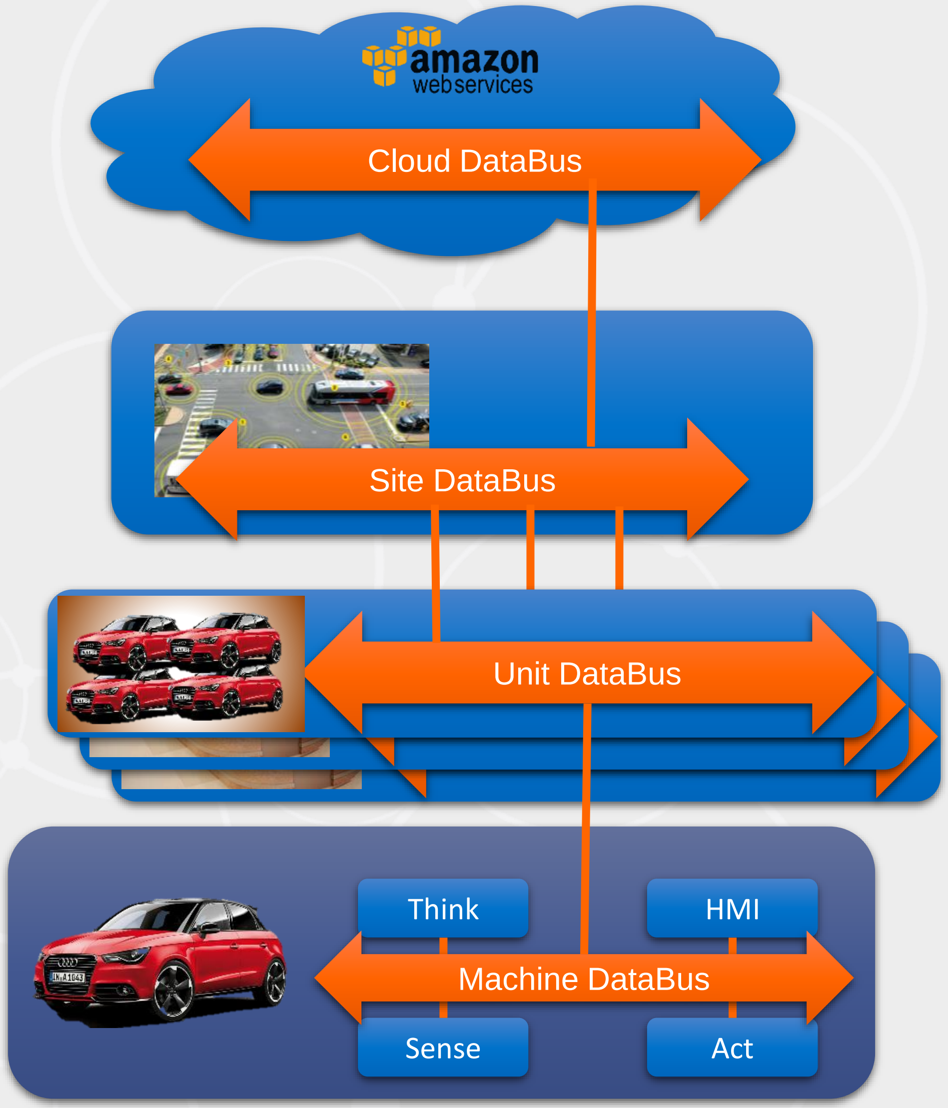
- Each level of the hierarchy has
  - Data model
  - Discovery
  - Security domain
- System-of-systems require
  - Subsystem export control
  - Data model translation
  - Discovery control

Intelligent Industrial Internet

Intelligent System of Systems

Intelligent Systems

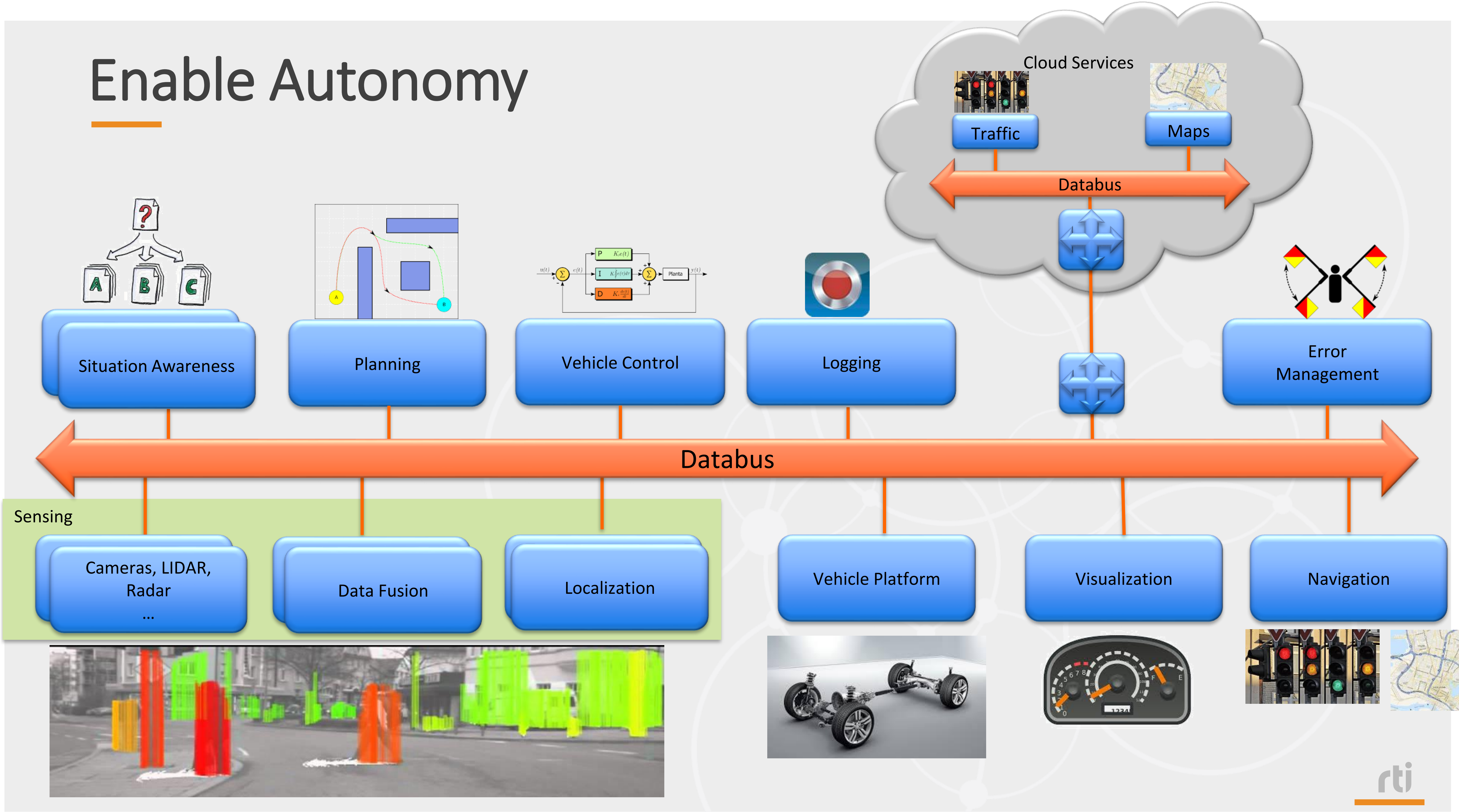
Intelligent Machines



DDS Abstraction

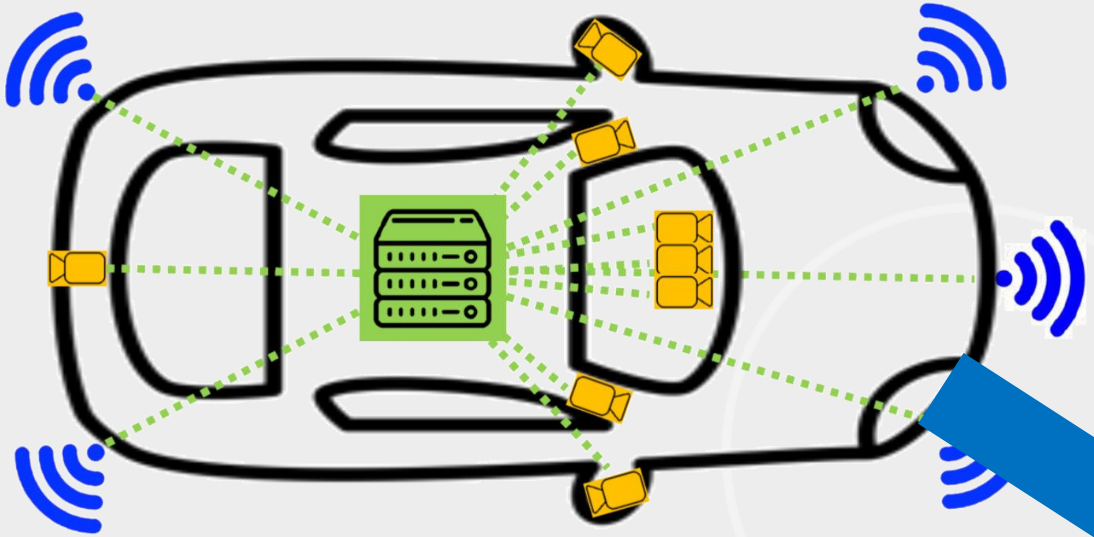
- Entities
  - Participants (software modules)
- Entity Interaction
  - Local read/write of managed objects with a CRUD interface
  - Relational model "finds" data for any participant
- State lives in a virtual "global address space"
  - Not coupled to participants (although cached in participants)
- Automatic discovery across the system

Enable Autonomy

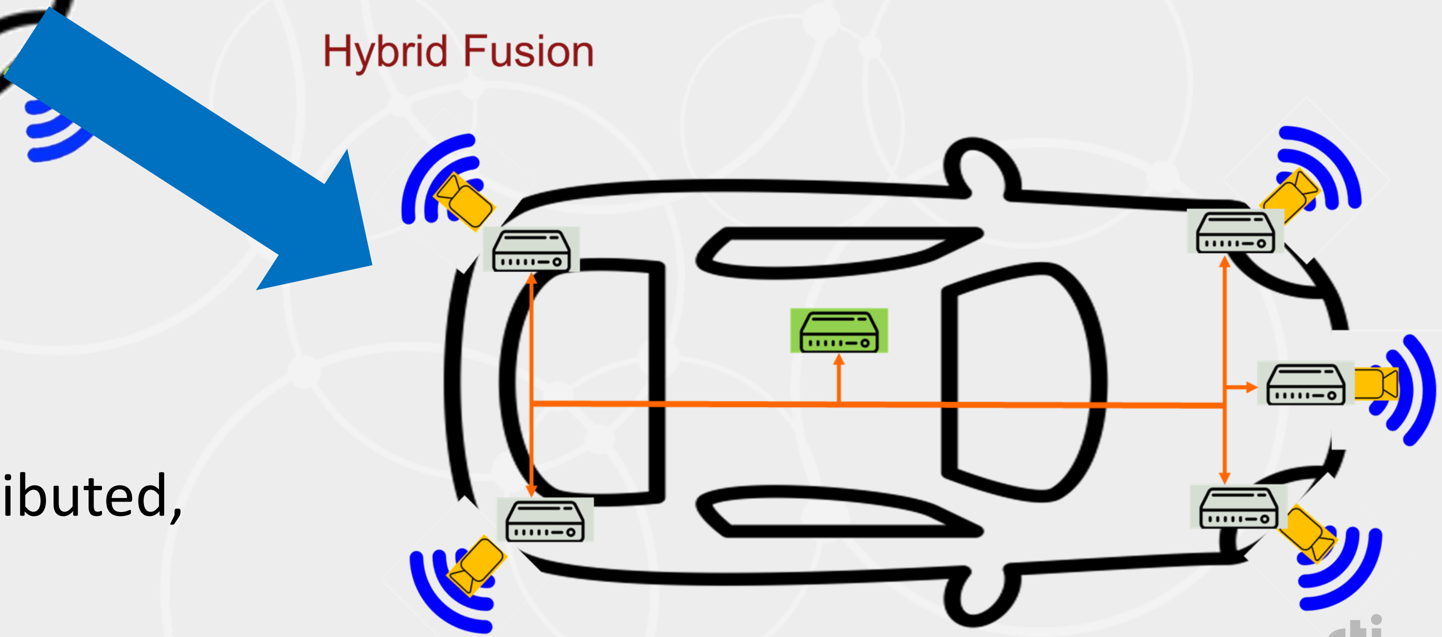


Data Centricity Supports Higher Autonomy

Central Fusion or “Late” Fusion



Hybrid Fusion



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

Why a Databus? Software Decoupling.

- Flow: discovery, rates, reliability uncoupled
  - Any network, any transport
  - Full QoS control for every flow
- Space: services live anywhere
  - Cloud, fog, devices
  - Move them transparently
  - Controlled, natural redundancy
- Time: robust system operations
  - No dependency on startup sequence
  - Participants come & go at will
  - Matches evolving schema

Software Integration is All About The Data…

- Decoupled subsystems work independently
- Data-centric sharing lets them cooperate

Resulting in…

Your Systems. Working as One.

Software Integration

- Custom data model
- Dynamic types
- Dataflow control

- Challenges
  - Interface many software teams
  - Interoperate between software modules
  - Version matching
- Components
  - Custom software
  - AIs, libraries
- Interfaces
  - Global data abstraction
  - Dataflow control
  - Common system data model

DDS Applications Span the IIoT

RTI lives at the intersection of functional artificial intelligence and pervasive networking[SM]

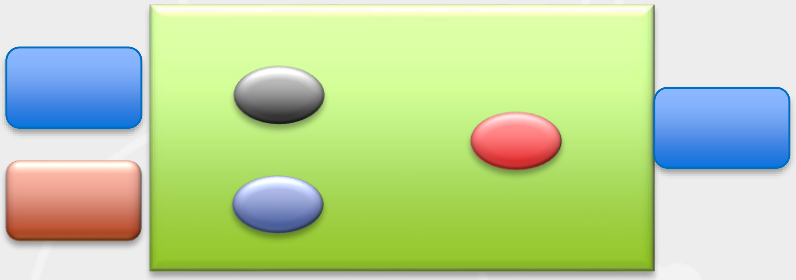
Are They That Different?

DDS & OPC UA in Depth

How to Choose?

System Aspect	Example User	Approach	Standard
Software Integration & Autonomy	Software Architect integrating components	Data-centric	DDS
Device interchangeability	Device manufacturer selling devices to technicians	Device-centric	OPC-UA
Web & Mobile User I/F	App builder supporting back-end services	RESTful	Web services/HTTP
ICT integration	Wide-area wireless telecom integrator	Common services layer	oneM2M

Data Centric is the Opposite of OO

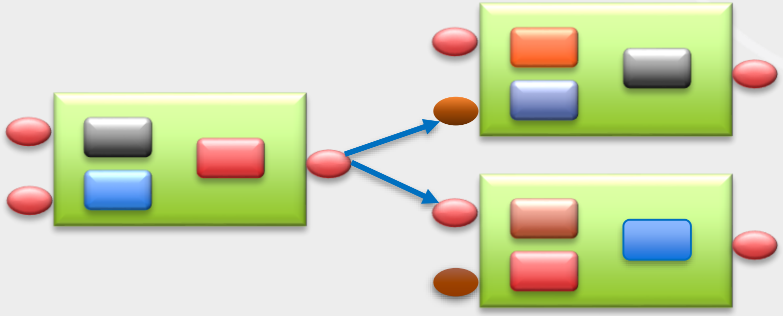


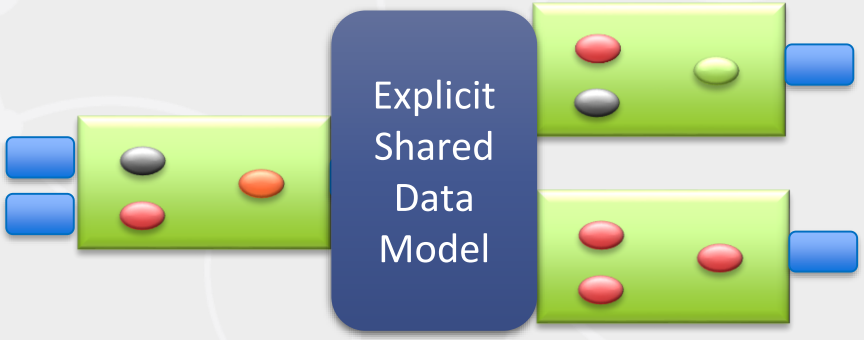
Object Oriented

- Encapsulate data
- Expose methods
- Sequential execution

Data Centric

- Encapsulate methods
- Expose *data*
- Parallel updates

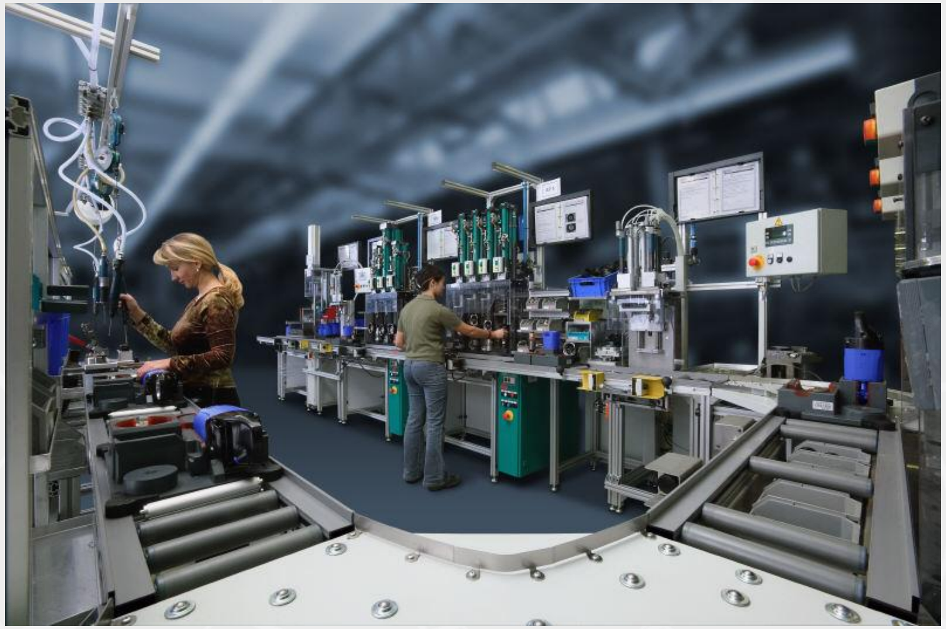




Users and Applications are Very Different!

- You are a software architect. You:
  - Manage & integrate software development teams
  - Design & control architecture & data model
  - Face challenges in defining software module interfaces, implementing redundancy, complex data flow

DDS



- You are a device manufacturer. You:
  - Build a device for many applications
  - Do not control the installation data architecture
  - Face challenges of device vendor interoperability, users who are not software experts

OPC FOUNDATION

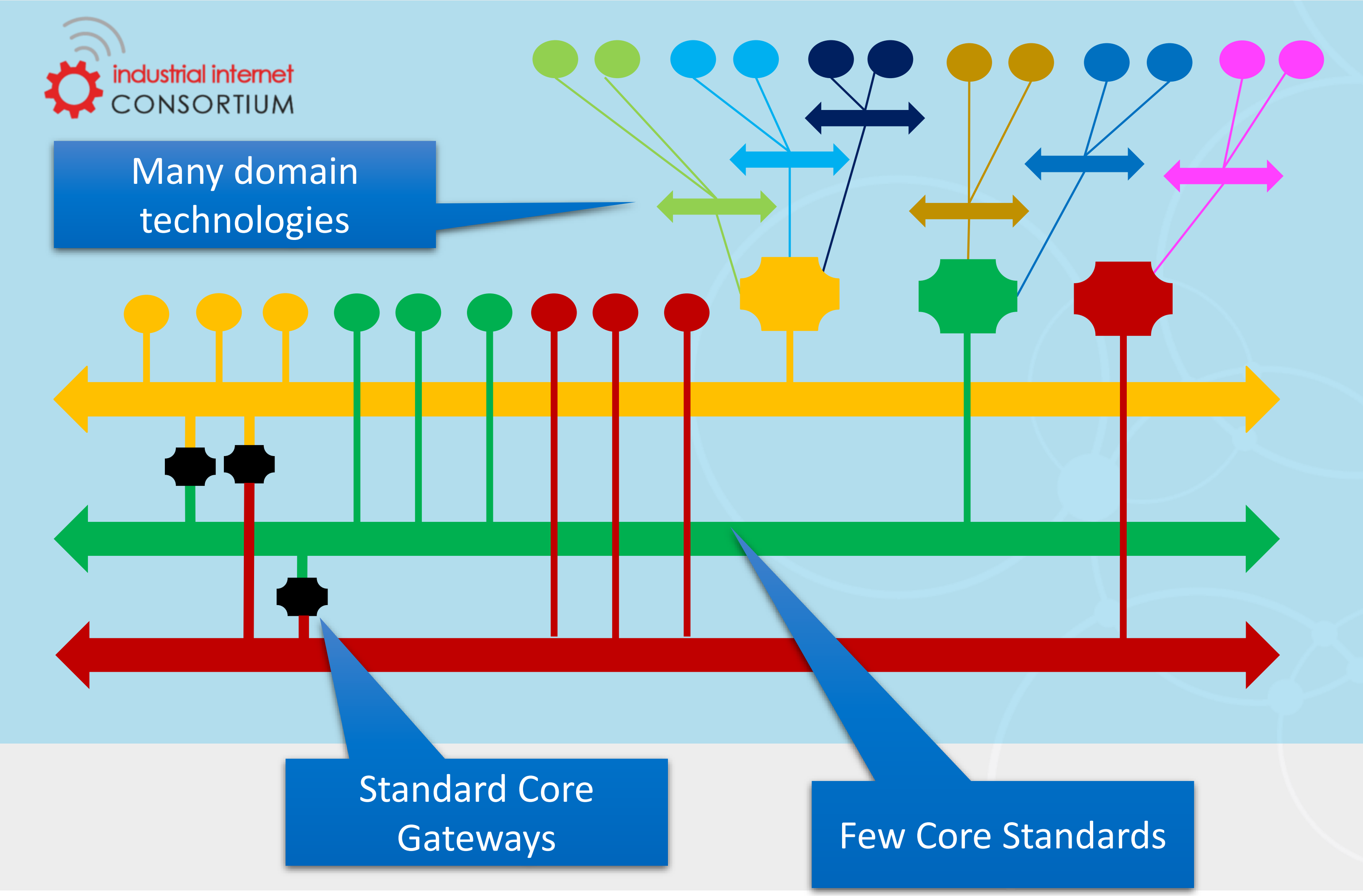
OPC UA and DDS Comparison

Aspect	OPC UA	DDS	
Integration Users	Engineers/technicians	Software teams	Opposite
Abstraction	Object Oriented	Data Centric	Opposite
Primary markets	Manufacturing	Transportation, medical, power, robotics, defense, etc… but *not* manufacturing	Opposite
System data model	Dynamically built at runtime	Fundamental integration point	Opposite
Product support	Extensive: hardware devices, software (HMI, historians)	None	Opposite
Data model	Hierarchical	Relational	Opposite
Data sharing model	Variables	CRUD managed types (with matching)	Opposite
Sends data	Yes	Yes	Similar

Can They Work Together?

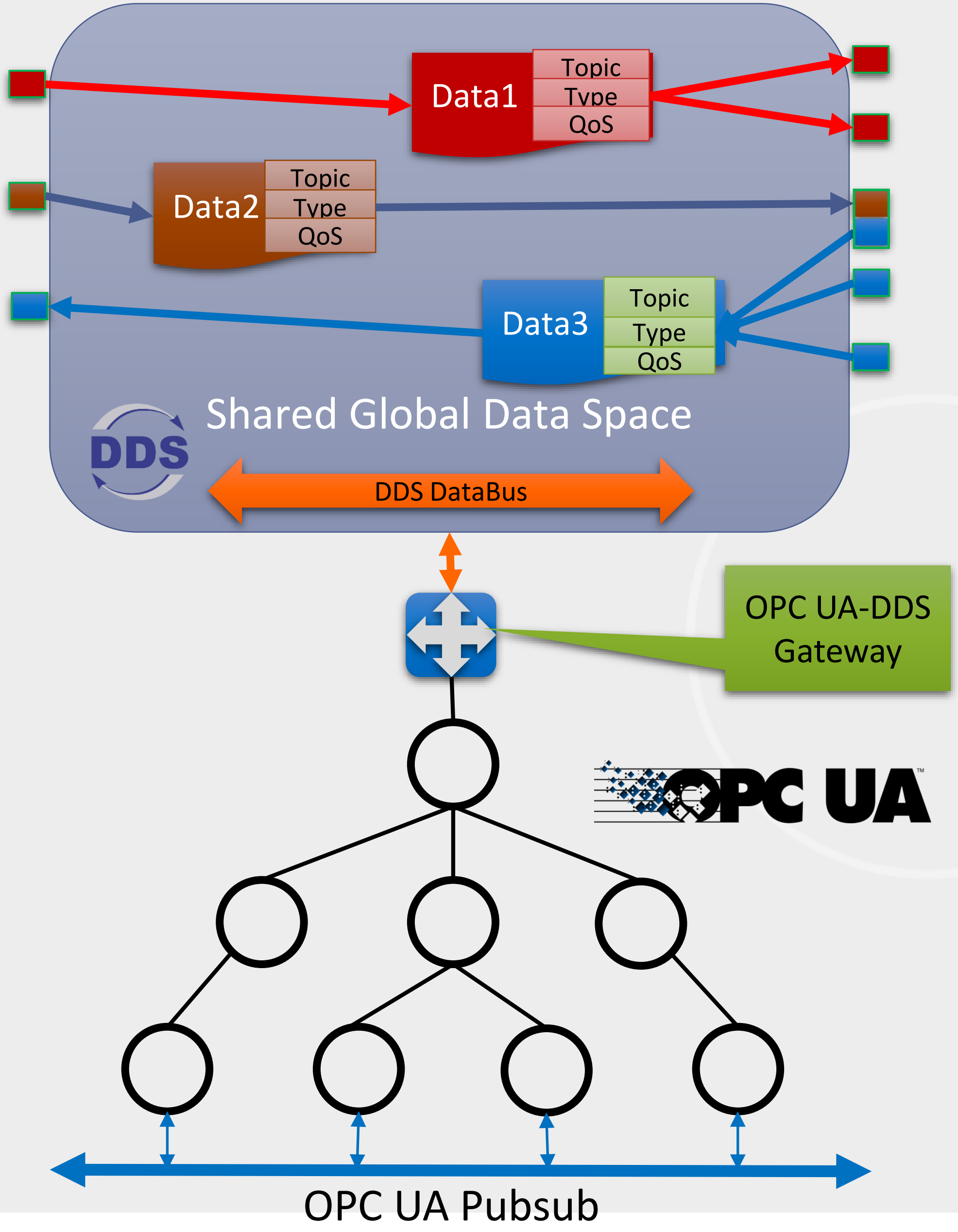
Integrating OPC UA and DDS combines benefits

IIC Connectivity Core Standards Architecture

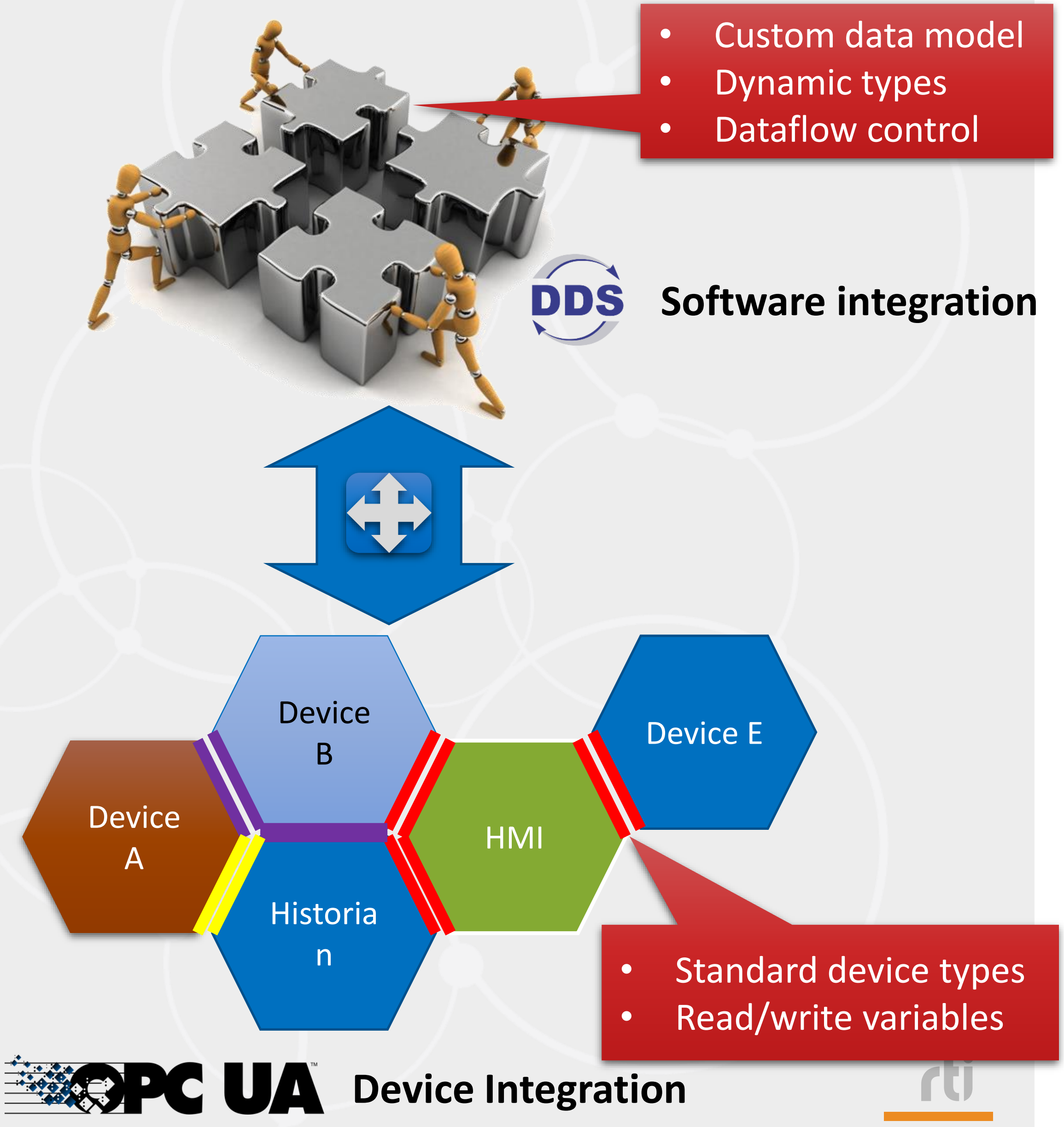


- Connectivity Core Standards
  - Provide syntactic interoperability
  - Stable, deployed, open standard
  - Standard *Core Gateways* to all other CCS
- Domain-Specific Connectivity Technologies
  - Connect via non-standard gateway to any connectivity core standard

Conceptual Architecture

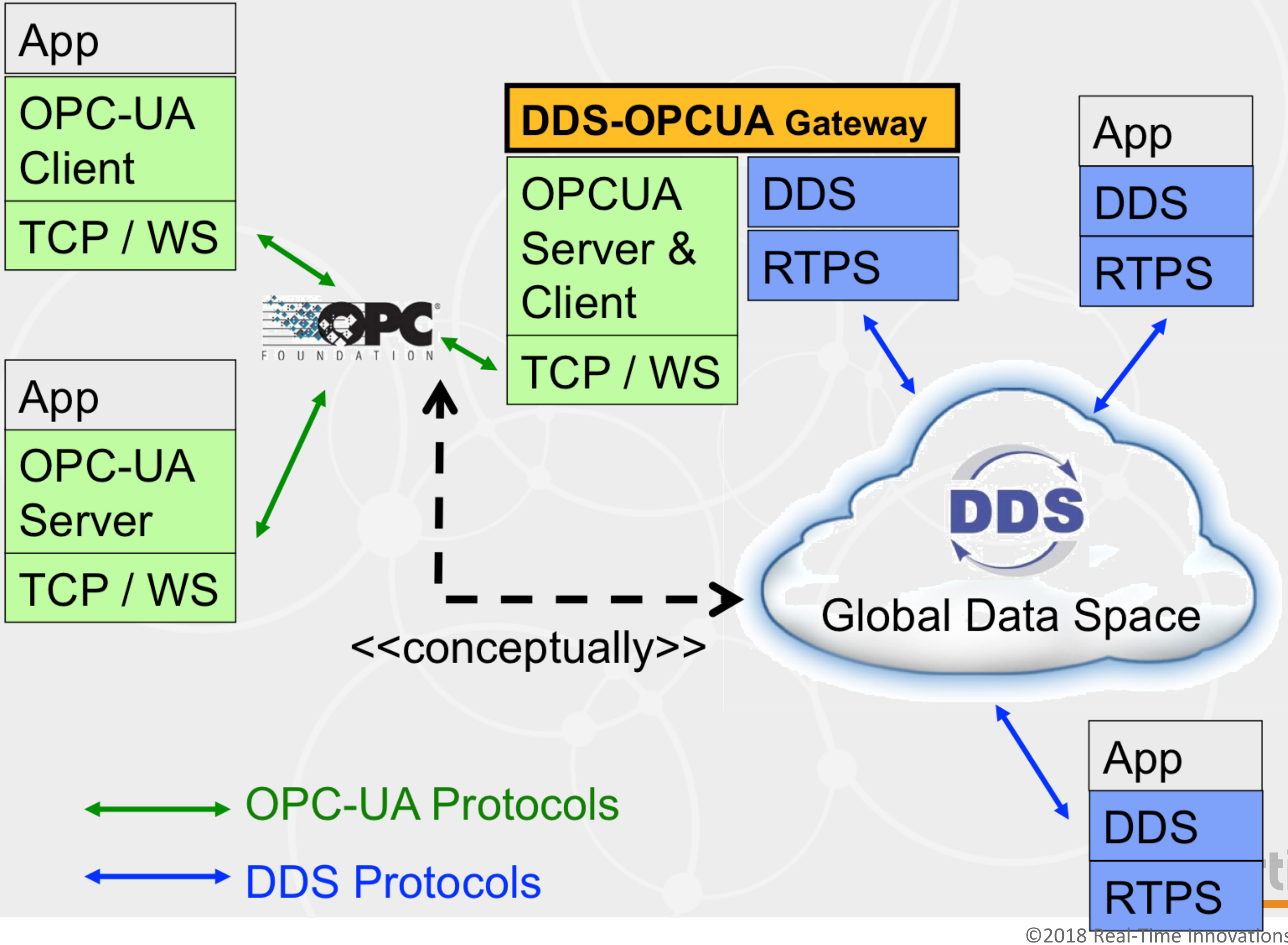


Integration Approach



OPC-UA/DDS Gateway Standard

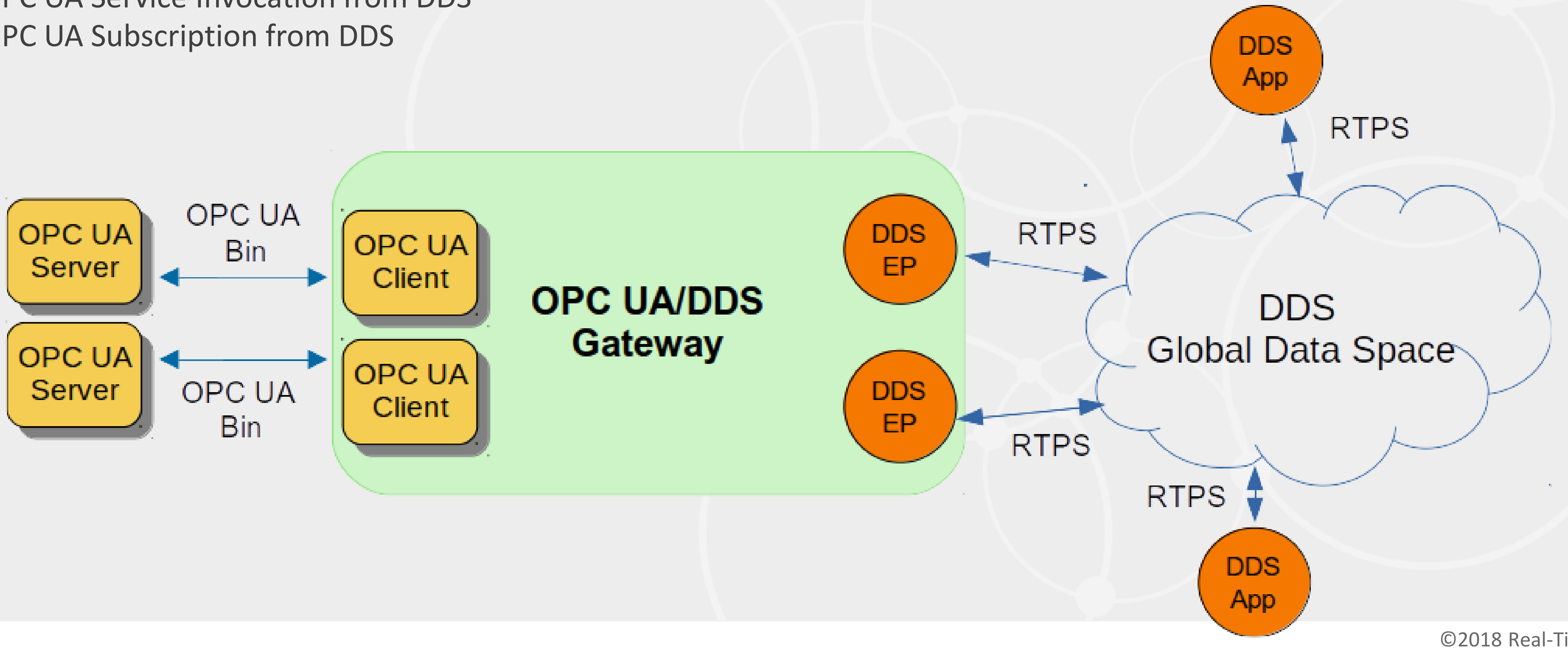
Provide transparent interoperability between *existing* DDS and OPC UA applications.



OMG mars/2018-02-01

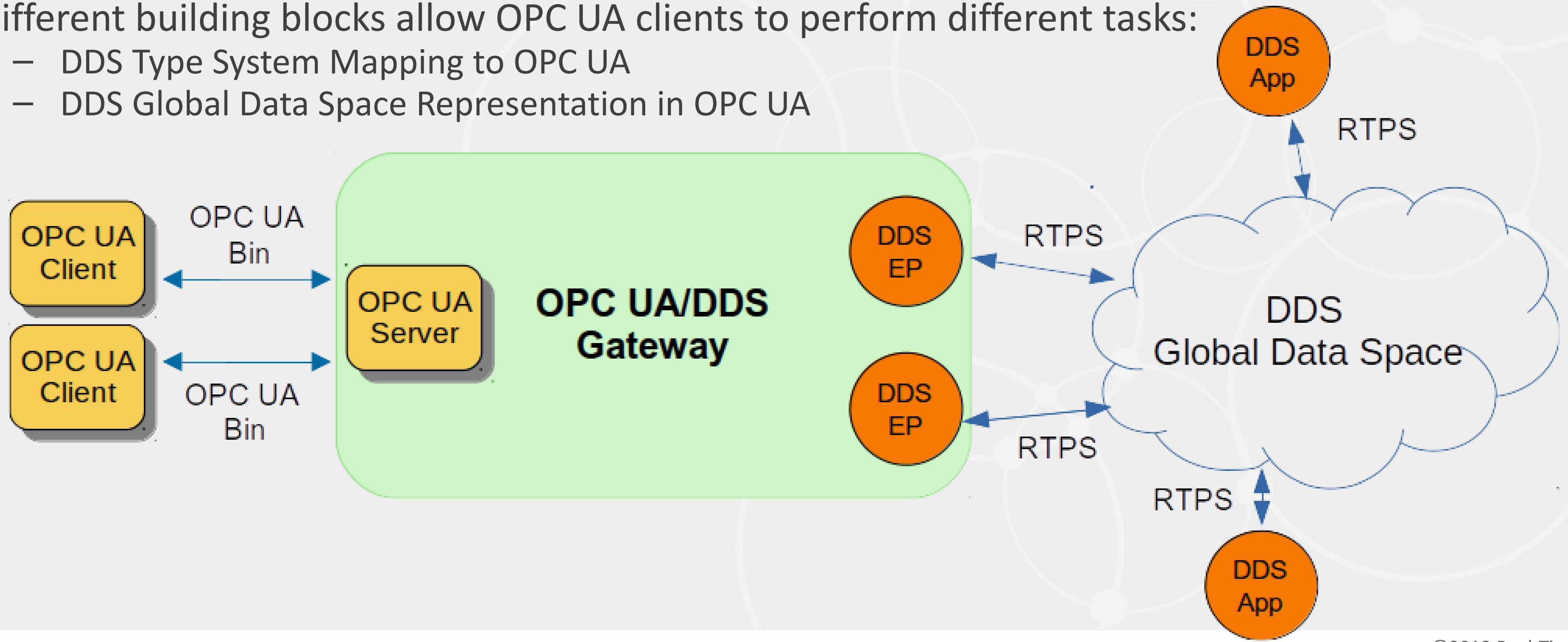
OPC UA → DDS

- To allow DDS applications to access, subscribe, read, and manage information from OPC UA, this side of the gateway has:
  - *DomainParticipants* and a set of endpoints (*DataReaders* and *DataWriters*) to interact with DDS applications.
  - An *OPC UA Client* (or a set of OPC UA Clients) to connect to OPC UA Servers that provide the information.
- Different building blocks allow DDS applications to perform different tasks:
  - OPC UA Type System Mapping to DDS
  - OPC UA Service Invocation from DDS
  - OPC UA Subscription from DDS



DDS → OPC UA

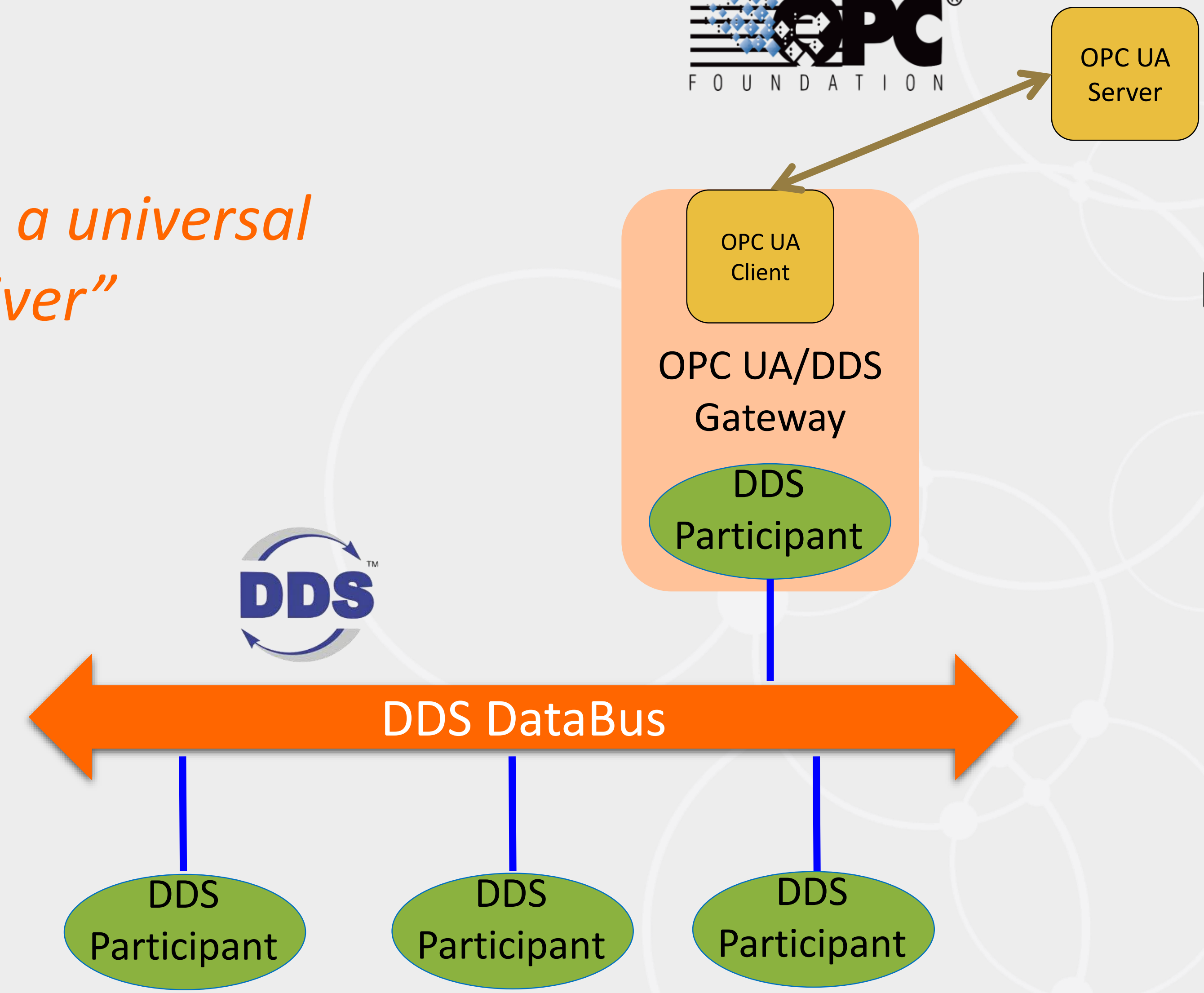
- To allow OPC UA clients to access, subscribe, read, and manage information from DDS, this side of the gateway has:
  - An *OPC UA Server* that exposes a portion of the information available in the DDS Global Data Space.
  - *DomainParticipants, Publishers, Subscribers, DataReaders, and DataWriters* endpoints to interact with DDS applications.
- Different building blocks allow OPC UA clients to perform different tasks:
  - DDS Type System Mapping to OPC UA
  - DDS Global Data Space Representation in OPC UA

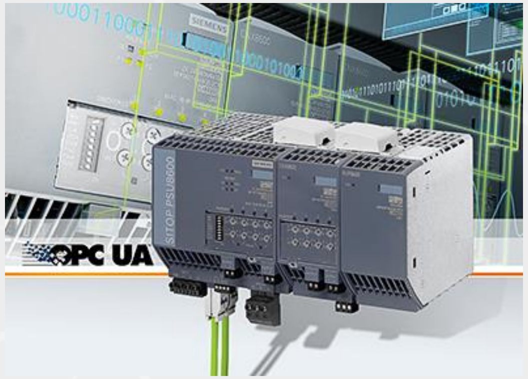


OPC UA & DDS Use Cases

Scale Access to OPC UA devices

OPC UA as a universal "device driver"



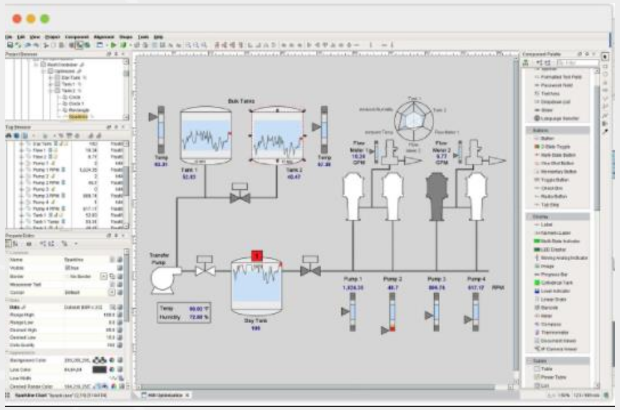


Device Supporting OPC UA

Use HMI Tools in DDS Systems

Many Industrial Automation Tools support a OPC UA Interface

OPC UA Client



SCADA tool supporting OPC UA

OPC UA Server

OPC UA/DDS Gateway

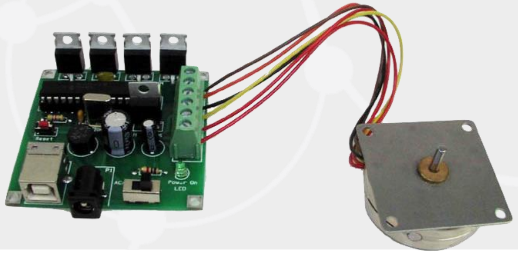
DDS Participant

DDS DataBus

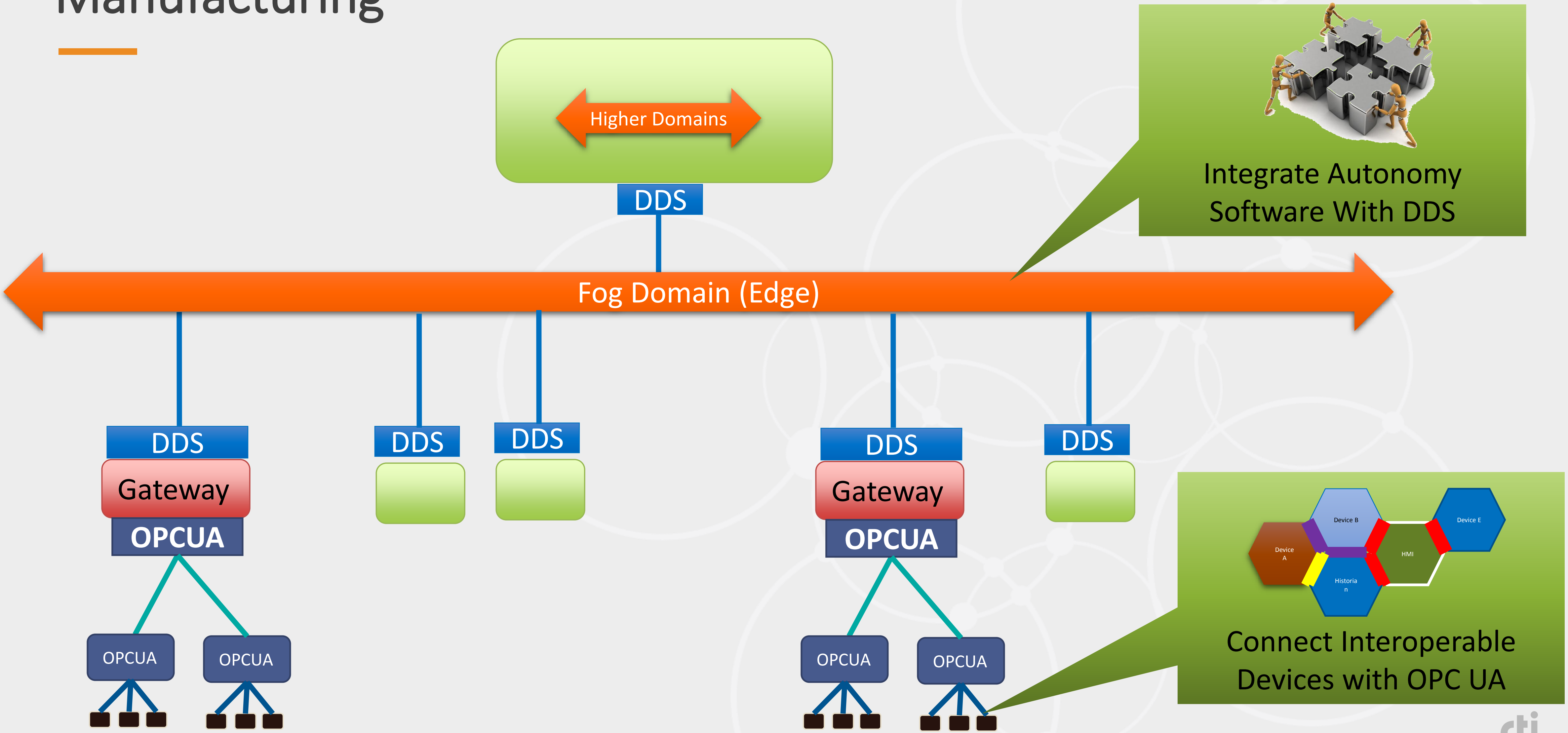
DDS Participant

DDS Participant

DDS Participant



Combine Software and Device Integration for Autonomous Manufacturing



Where Can I Learn More?

RTI & The Industrial IoT

- RTI is the largest embedded middleware vendor
- 1000+ designs, many real-world programs across industries
- Full DDS, tools, services, support, secure & certified versions





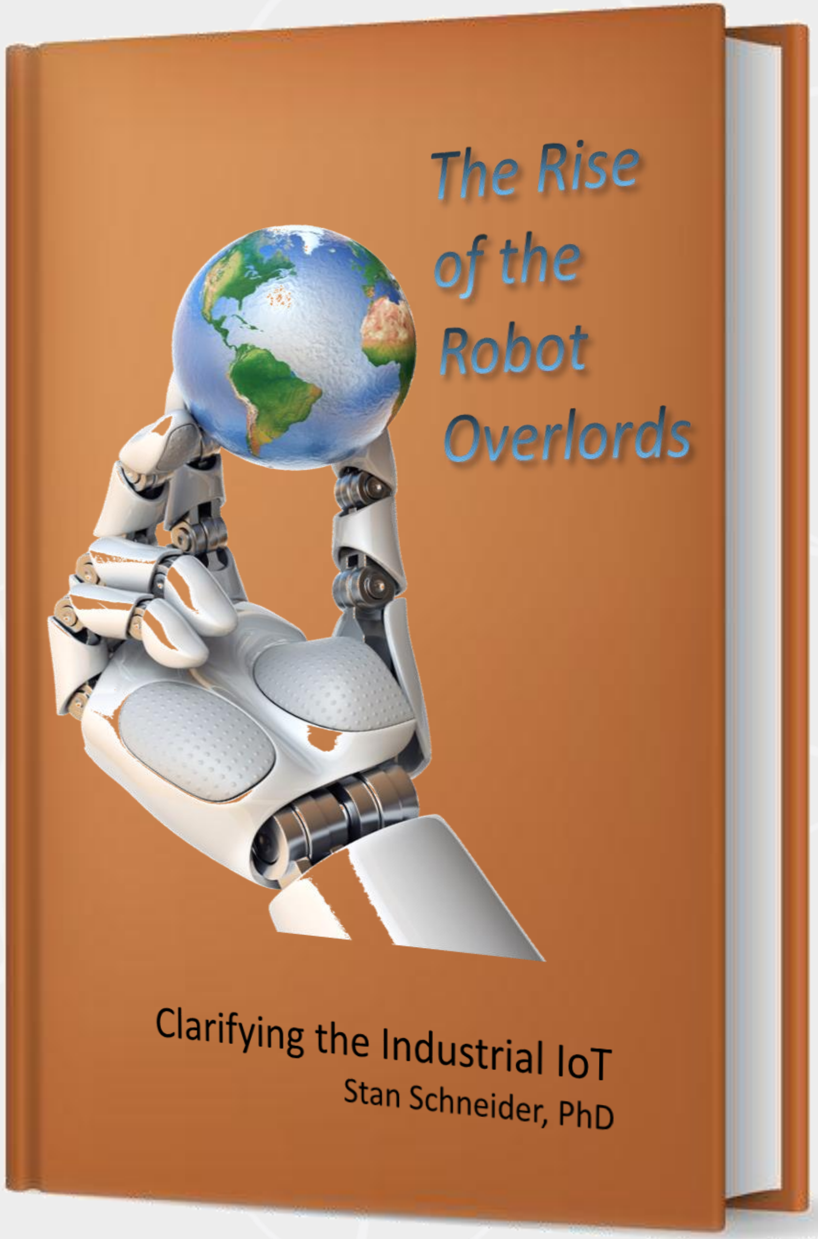




DDS
OSA
AUTOSAR
ROS
MD PnP™ Getting connected for patient safety
OpenFog™
industrial internet CONSORTIUM
OMG® OBJECT MANAGEMENT GROUP
FACE™ Future Airborne Capability Environment
THE OPEN GROUP OPEN PROCESS AUTOMATION™ FORUM
Smart Electric Power Alliance
ICE Alliance Integrating Clinical Environments
AVNU®

Further Information

- Industrial Internet Connectivity Framework (IICF): www.iiconsortium.org/IICF.htm
- Guide to IIoT Connectivity: http://www.iiconsortium.org/journal-of-innovation.htm
- eBook:
  - www.rti.com/resources /eBooks



Rise of the Robot Overlords Webinar Series

- Part 1: What is the IoT, Anyway?
- Part 2: A Practical Guide to IIoT Connectivity
  - How to choose between DDS, OPC UA, MQTT, RESTful HTTP, OneM2M and CoAP
- Part 3: Data-Centric vs Device-Centric Integration: Theory and Practice
  - How to compare, contrast, and integrate DDS and OPC UA.
- Part 4: Why a Databus is so Unique
- Part 5: The IIoT Security Challenge
- Part 6: A deeper IIoT example: Autonomous Vehicles (Carbots)
- Part 7: The Age of the Robot Overlords

rti

Connect!!

- Contact

  stan@rti.com

  @RTIStan

  LinkedIn: Stan Schneider
  https://www.linkedin.com/in/stan-schneider-102466/

- Bio
  - CEO Real-Time Innovations, Inc
  - IIC Steering Committee Vice Chair
    - Past Chair, Testbed Subcommittee
    - Co-chair Ecosystem Task Group
  - Advisory Board, IoT SWC
  - Top-10 Global IIoT Influencer
  - PhD, EE/CS, Stanford

Audience Q & A

Stan Schneider, Ph.D.
CEO,
Real-Time Innovations, Inc. (RTI)

Thanks for joining us

Event archive available at:

http://ecast.opensystemsmedia.com/

E-mail us at: jgilmore@opensystemsmedia.com