Your systems.
Working as one.

Robotics and Autonomy in Manufacturing

Stan Schneider, PhD

RTI CEO

IIC Steering Committee Vice Chair

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

The *Industrial* IoT Disruption Across Industries

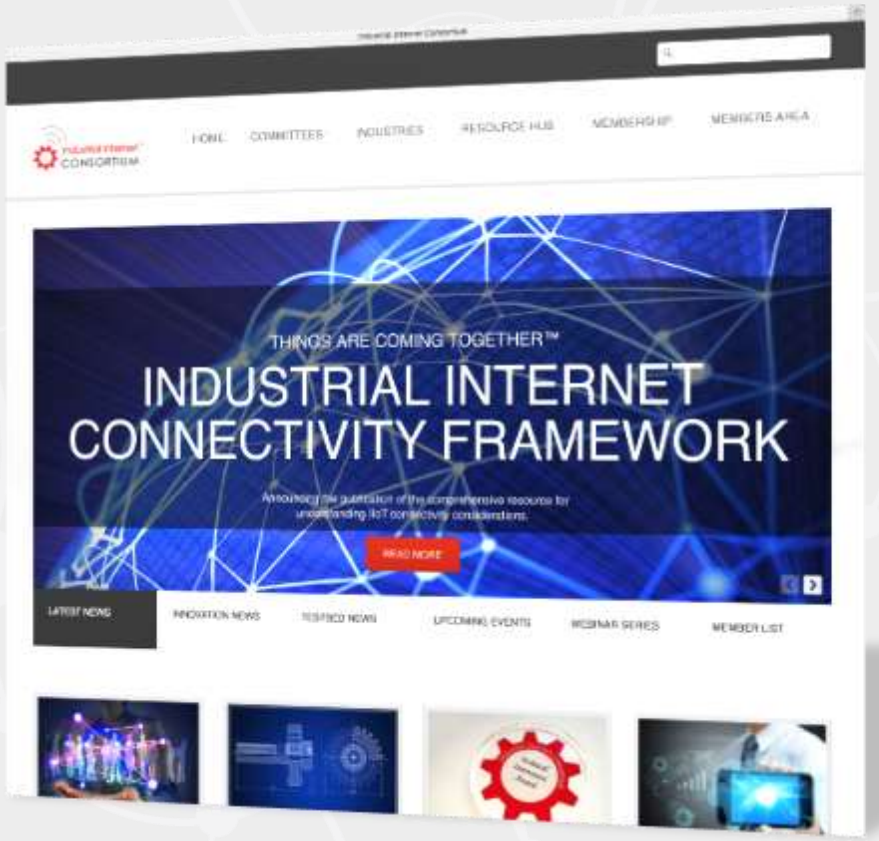
You don't compete against competitors.
You compete against market transitions.
– John Chambers

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

Connectivity Technologies

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



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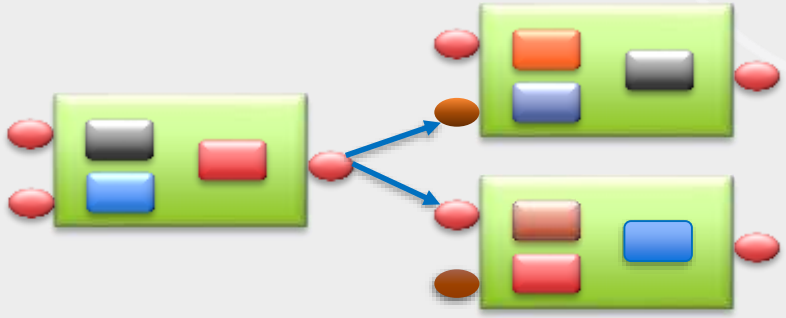
Connectivity Technologies Don't Overlap!

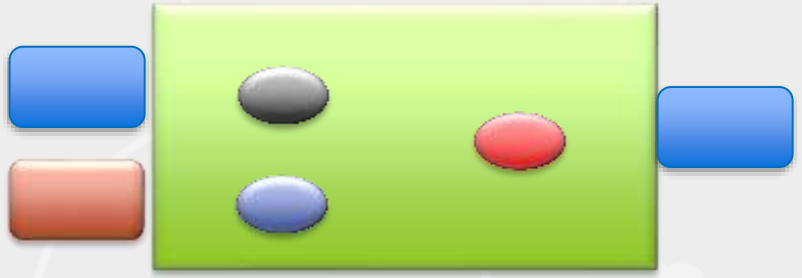
System Aspect	Example User	Approach	Standard
Software Integration & Autonomy	Software Architect integrating components	Data-centric	DDS
Device interchangeability	Device manufacturer selling devices to technicians	Device-centric	OPC-UA
Web & Mobile User I/F	App builder supporting back-end services	RESTful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

Data Centric is the Opposite of OO

Object Oriented

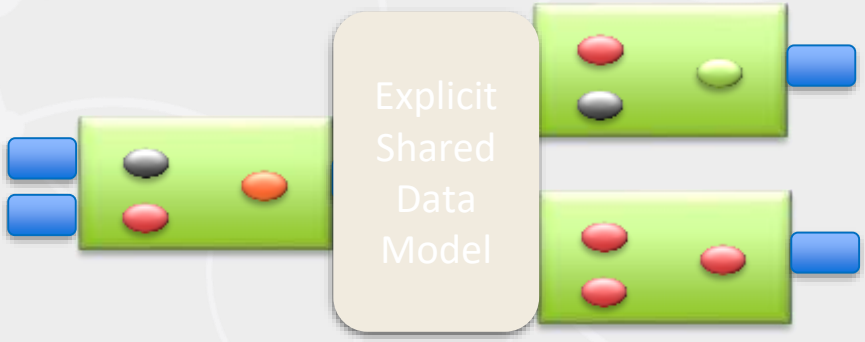
- Encapsulate data
- Expose methods
- Sequential execution





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

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

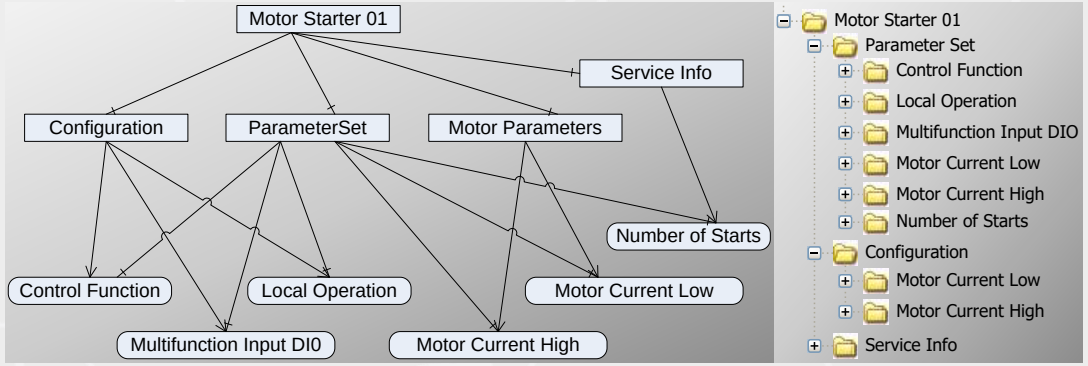
OPC UA

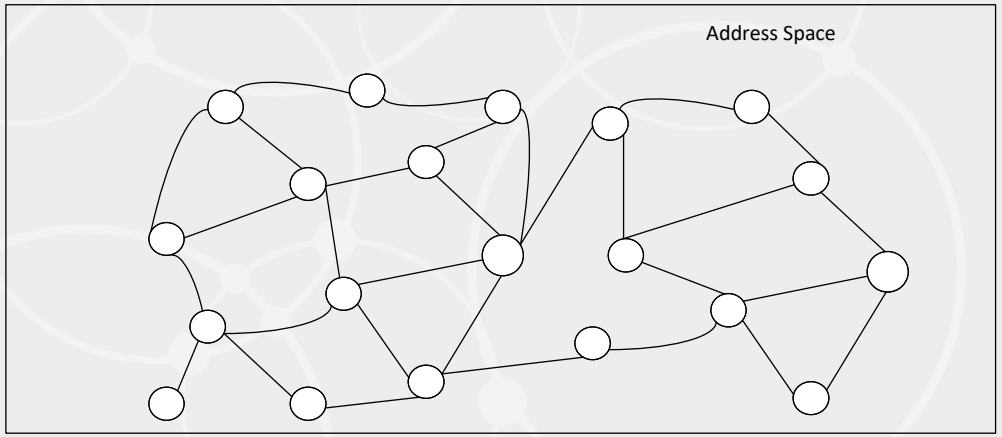
Device Integration for Vendor Interoperability

OPC UA Devices Provide Vendor Interoperability

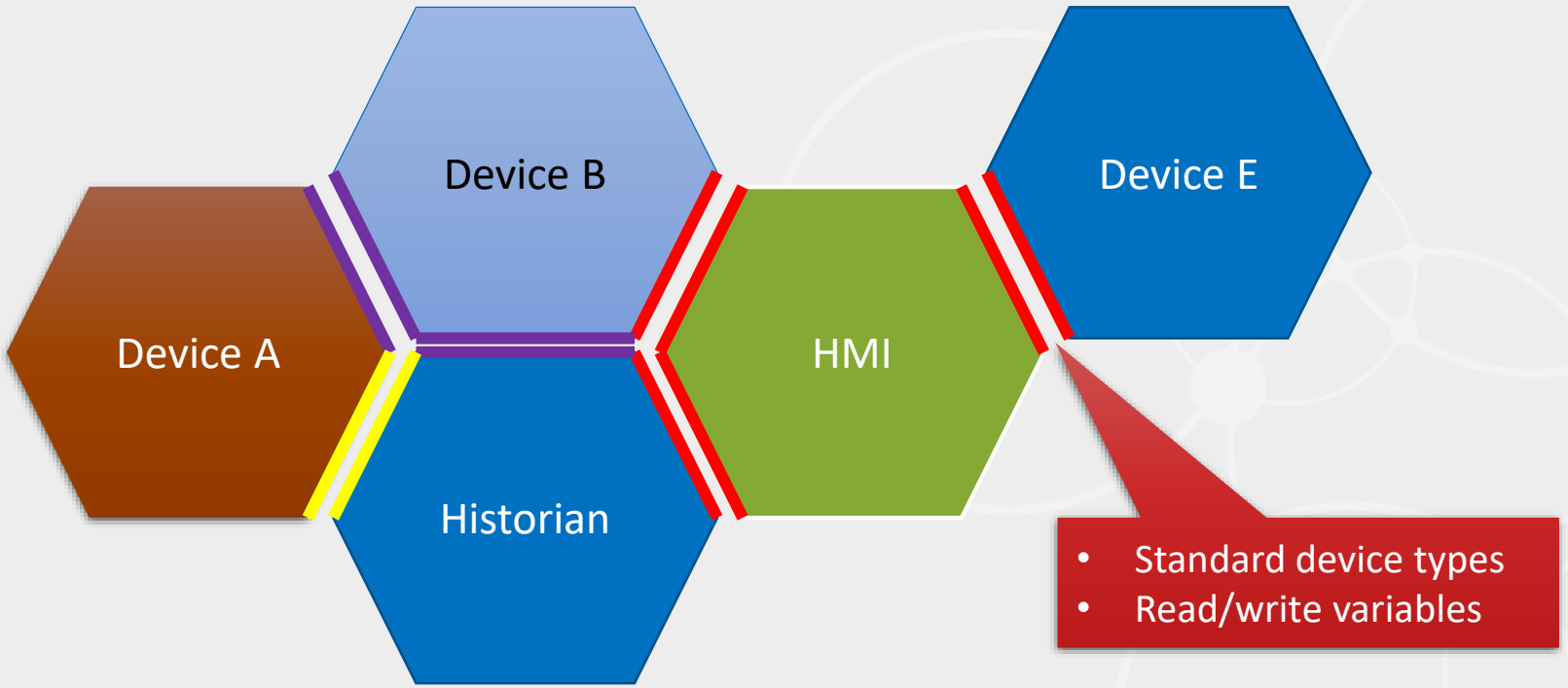
OPC UA

- 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





Device Integration

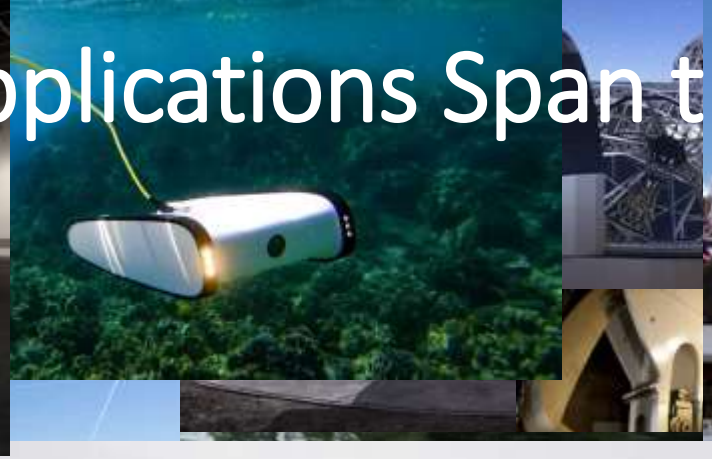


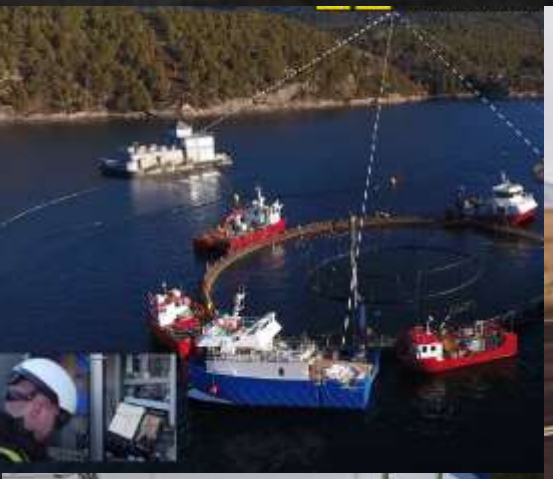
- Challenges
  - Interoperate between vendors
  - Assembled by engineers or technicians
- Components
  - Devices
  - Reusable software products (e.g. HMI)
- Interfaces
  - Standard device models
  - Dynamic address space rollup
  - Read/write variables

The DDS Databus

Software Integration for Autonomous Control

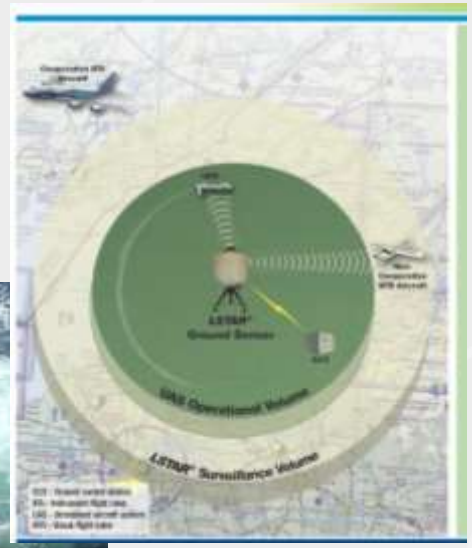
DDS Autonomy Applications Span the IIoT





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

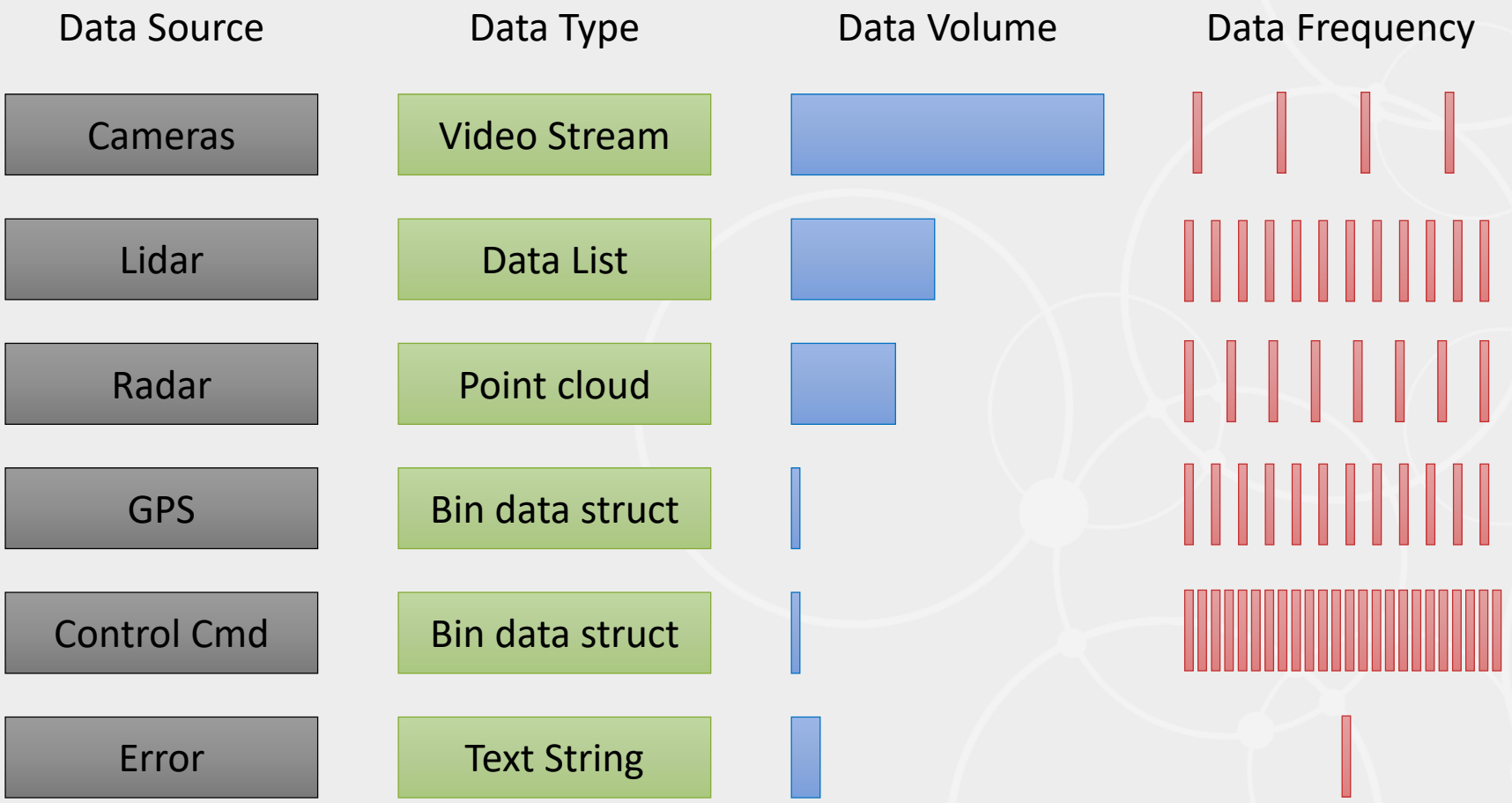
Autonomous Systems Generate Massive Data Flow

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)

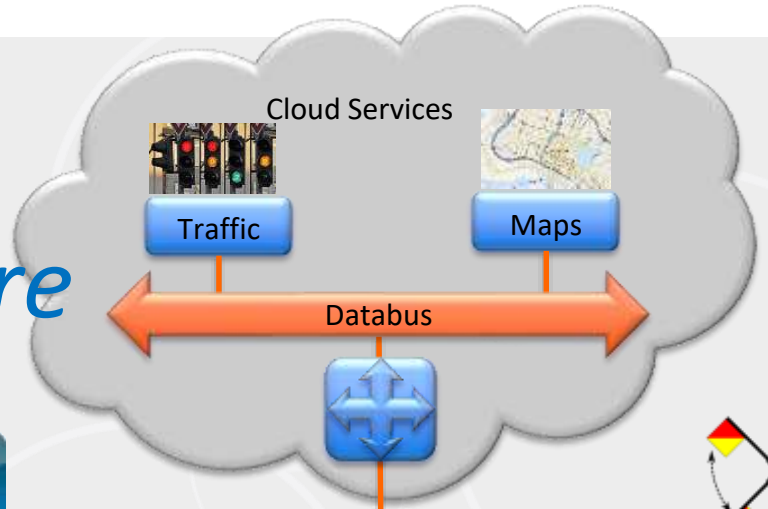
Autonomy Dataflow Challenge



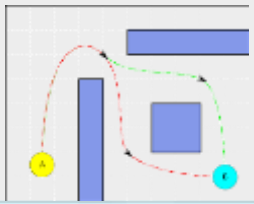
- Autonomy combines:
  - Volume
  - Frequency
  - Latency
  - Reliability
  - Destination
- A single abstraction that can handle all greatly simplifies the system

Enable Autonomy

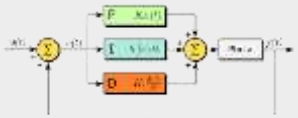
Cars Now Compete on *Software*



Situation Awareness



Planning



Vehicle Control

Logging

Error Management

Databus

Sensing

Cameras, LIDAR, Radar …

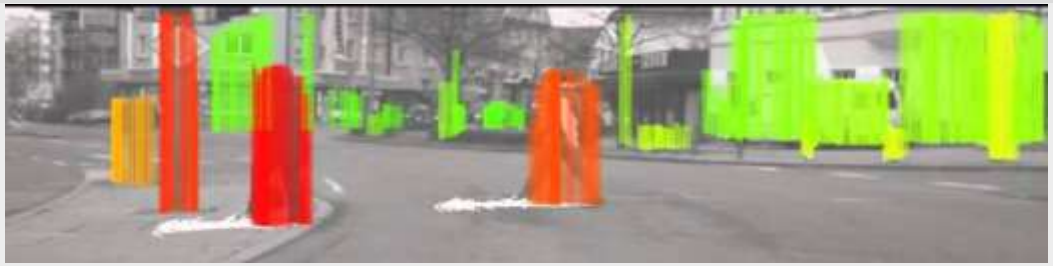
Data Fusion

Localization

Vehicle Platform

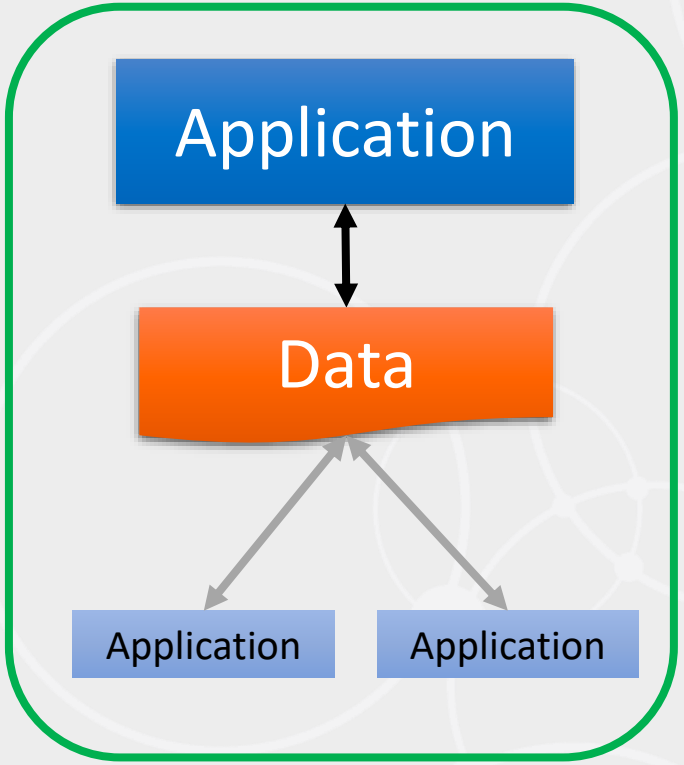
Visualization

Navigation

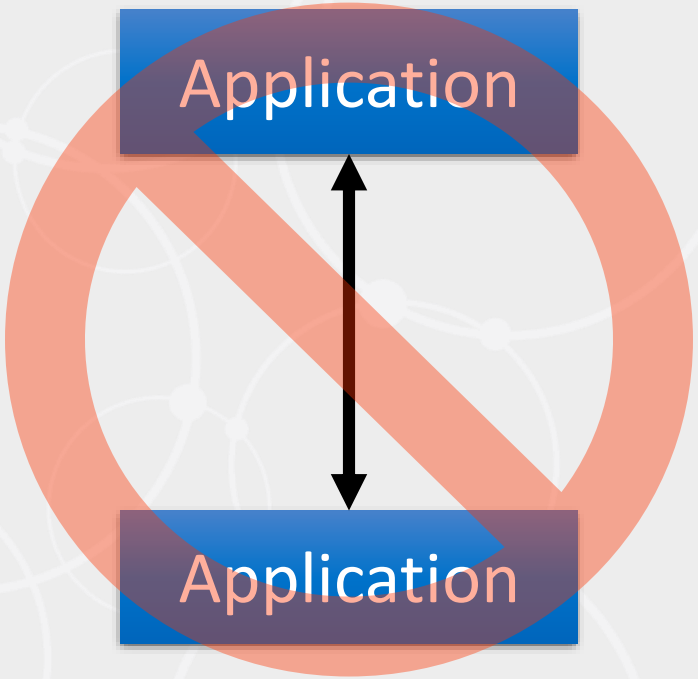


The DDS *Databus*

DDS is the standard that defines a databus

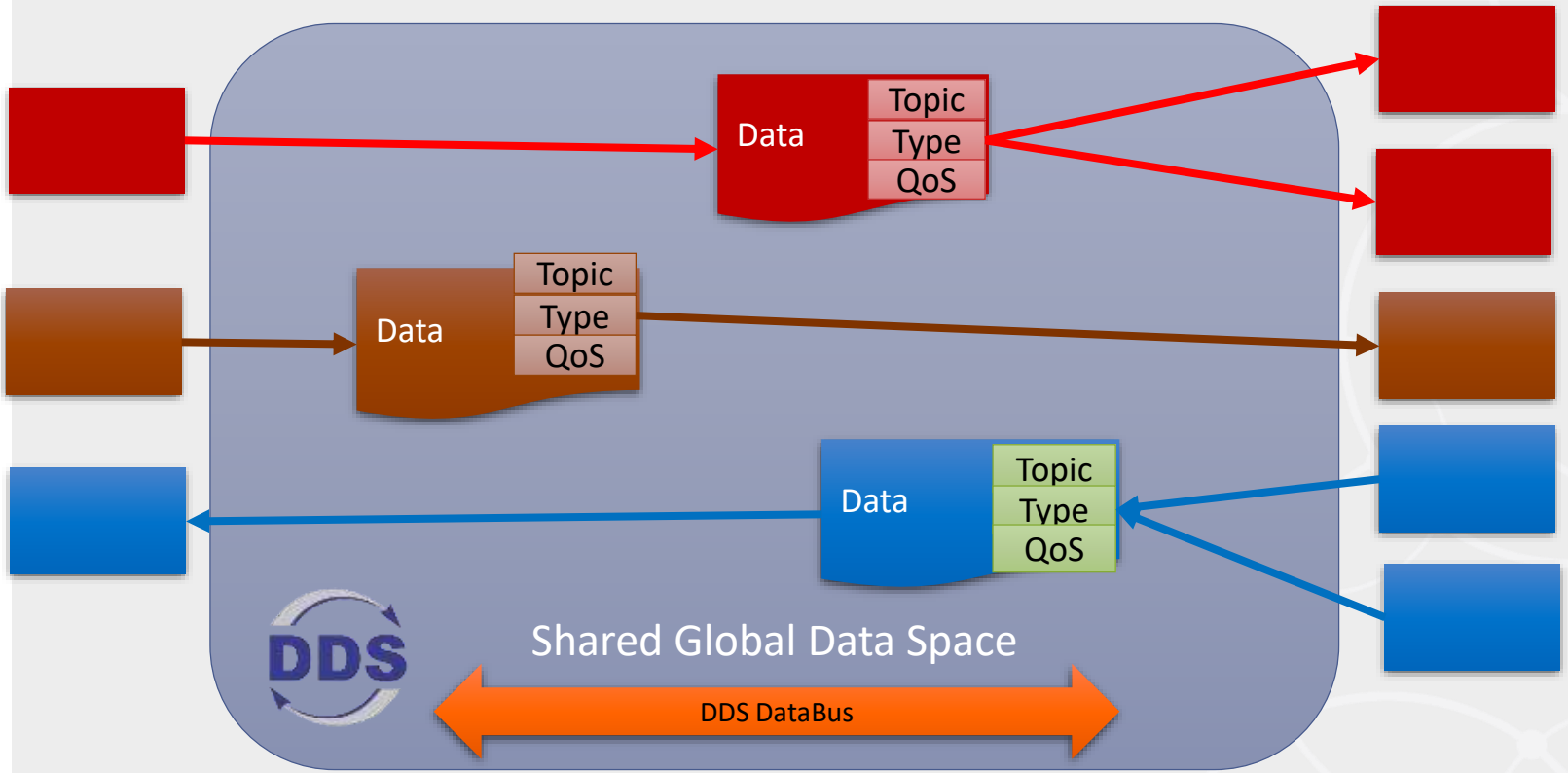


Data-centric technology connects applications to the data, not to each other



Message centric
Client/Server
Remote Objects
Publish-subscribe
SOA

DDS “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
- No servers
- Fast, reliable, scalable

Naturally parallel virtual shared memory

Why a Databus? Software Decoupling.

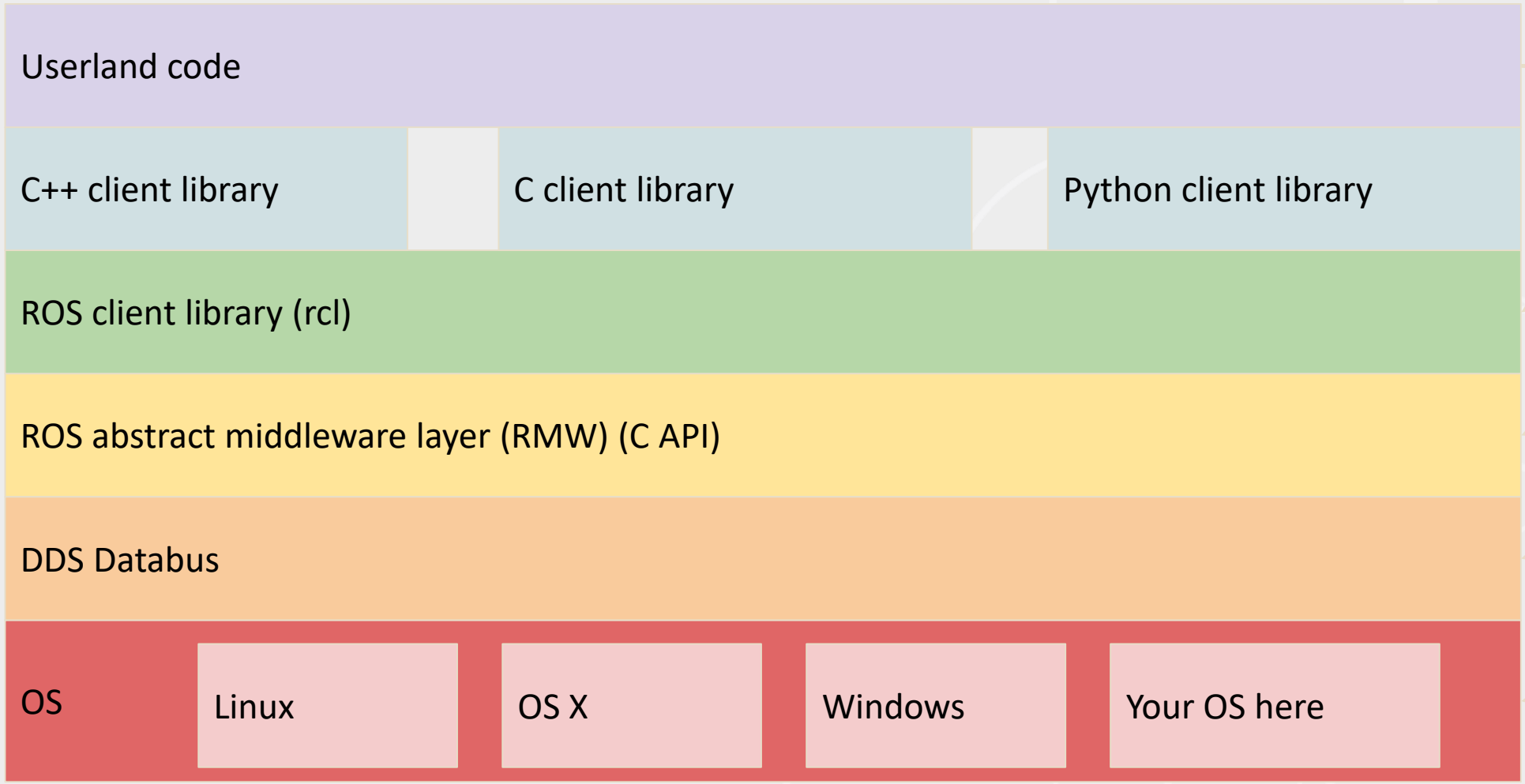
- Flow: discovery, rates, reliability uncoupled
  - Any network, any transport
  - Full QoS control for every flow
- Space: services live anywhere
  - Cloud, fog, devices
  - Move them transparently
  - Controlled, natural redundancy
- Time: robust system operations
  - No dependency on startup sequence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

Since Software Integration is All About The Data…

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

Your Systems Work as One

DDS Underlies the ROS v2 Software Stack



Software Integration

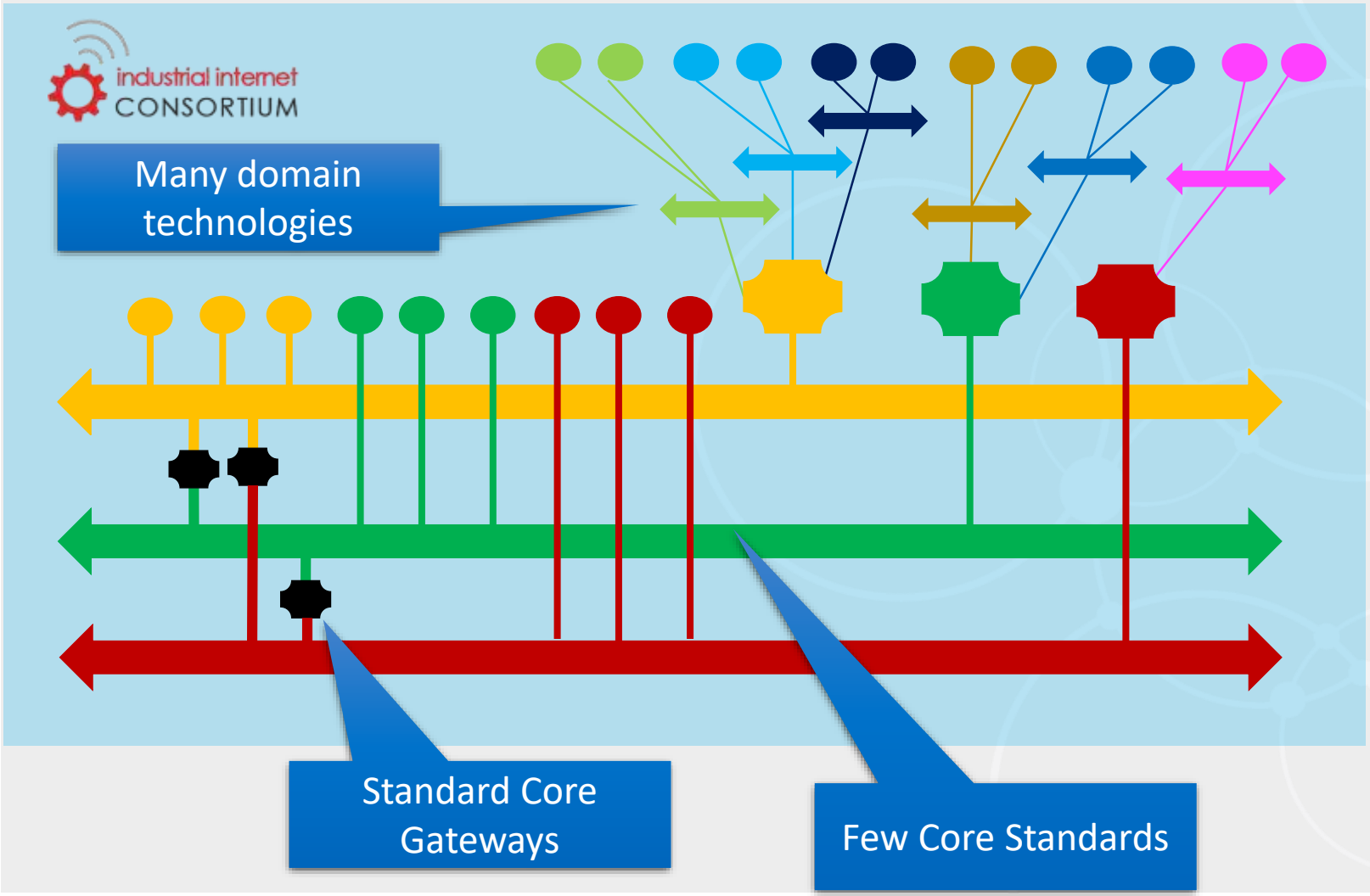
- Custom data model
- Dynamic types
- Dataflow control

- 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

Putting Them Together

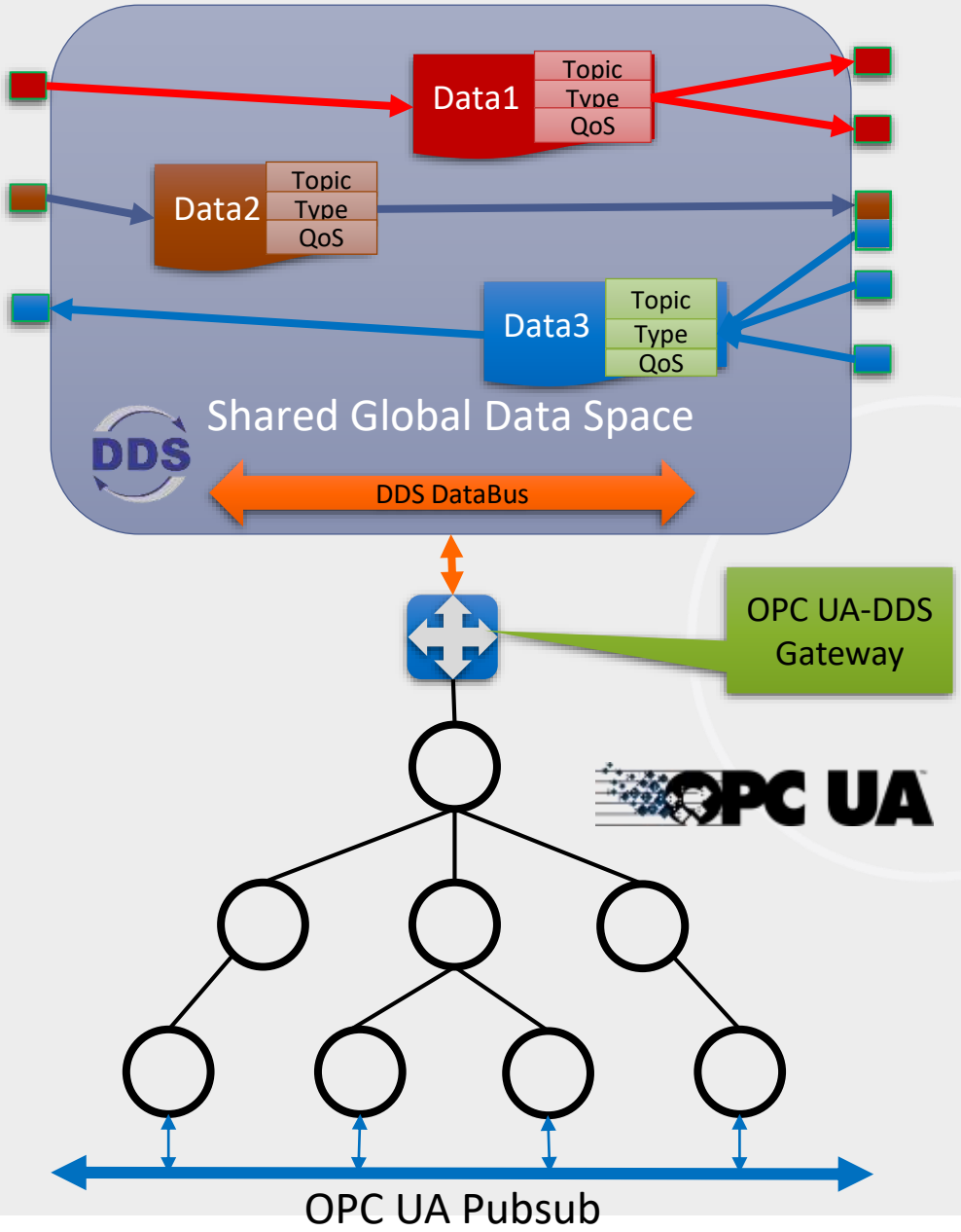
Integrating OPC UA and DDS

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

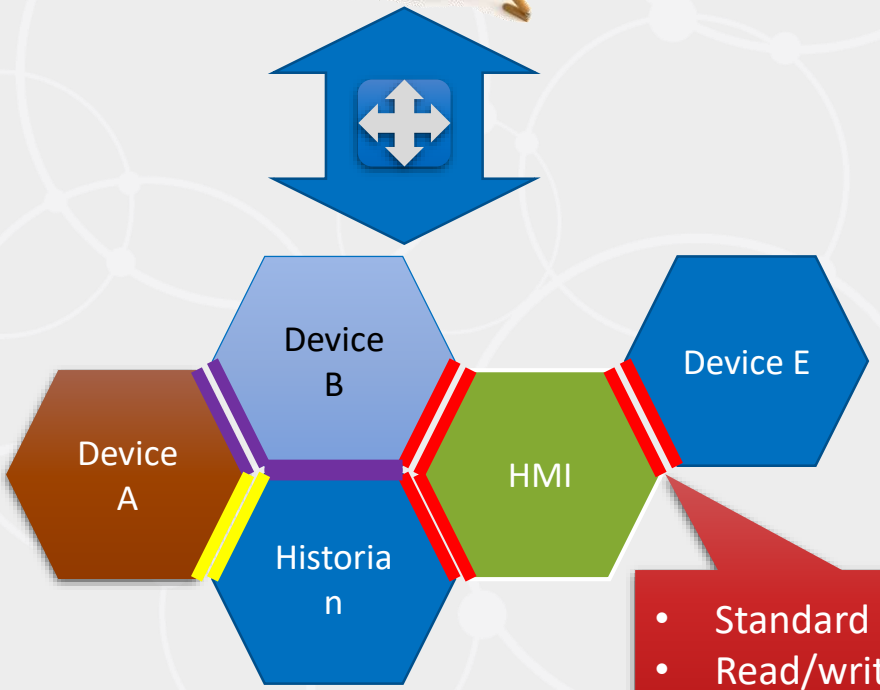
Conceptual Architecture



Integration Approach

- Custom data model
- Dynamic types
- Dataflow control

DDS **Software integration**

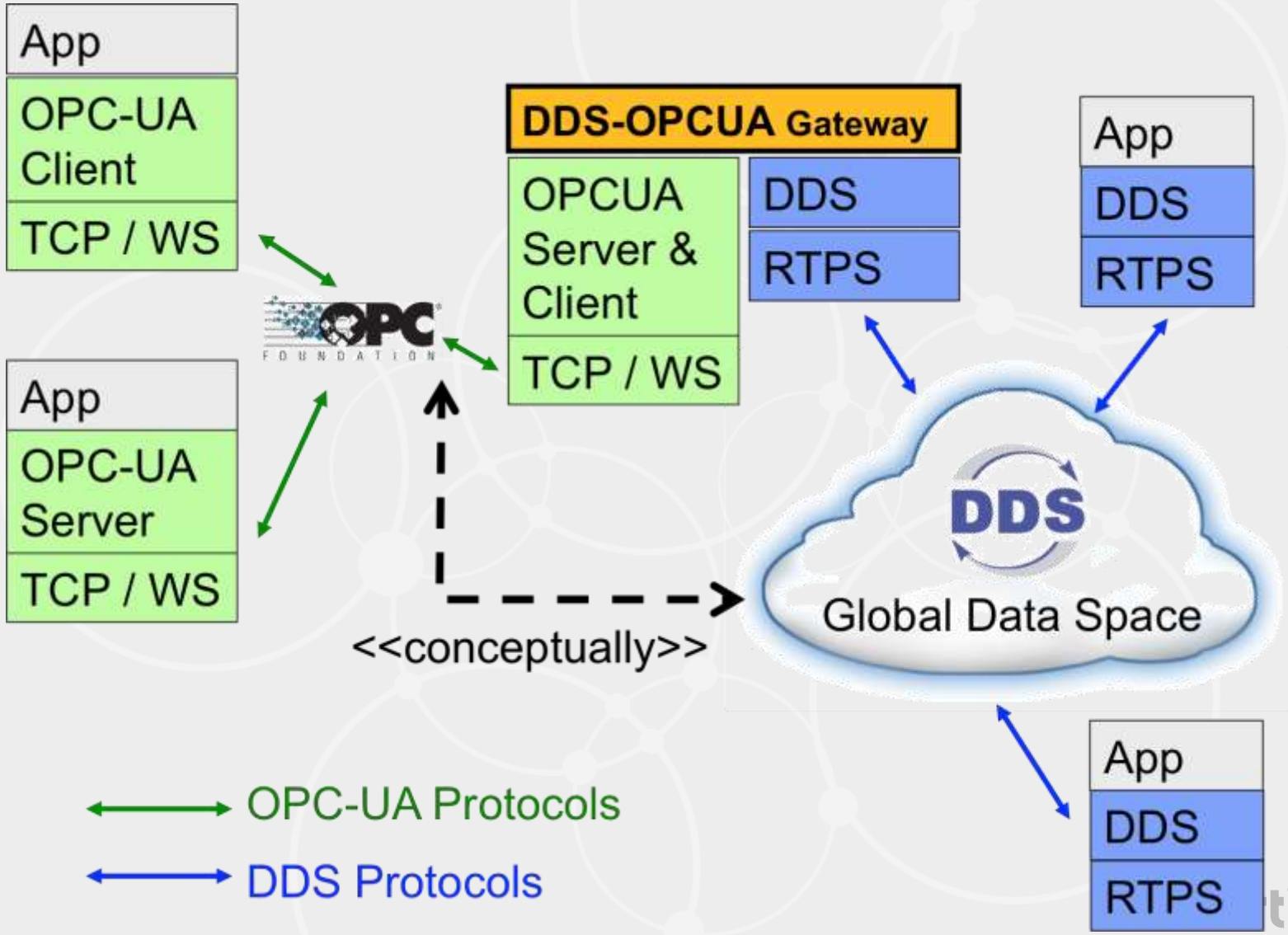


- Standard device types
- Read/write variables

OPC UA **Device Integration**

OPC-UA/DDS Gateway Standard

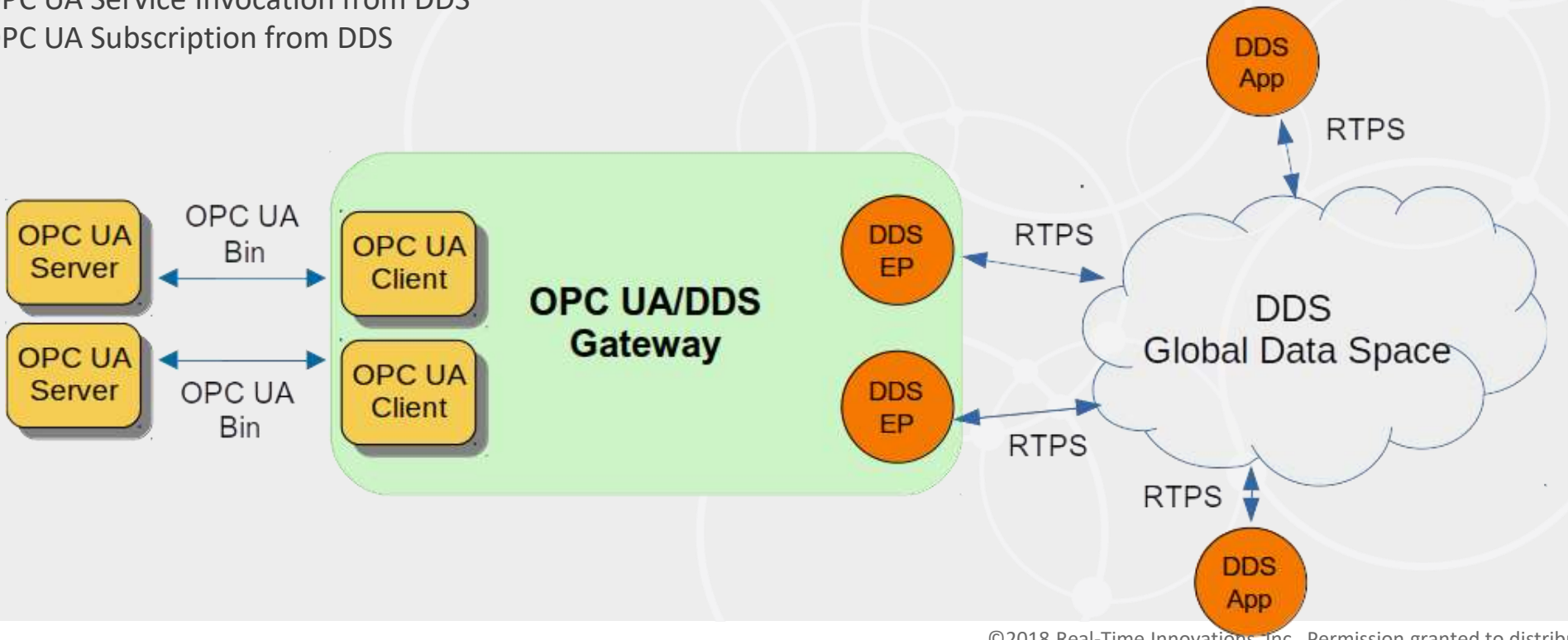
Provide transparent interoperability between *existing* DDS and OPC UA applications.



OMG mars/2018-02-01

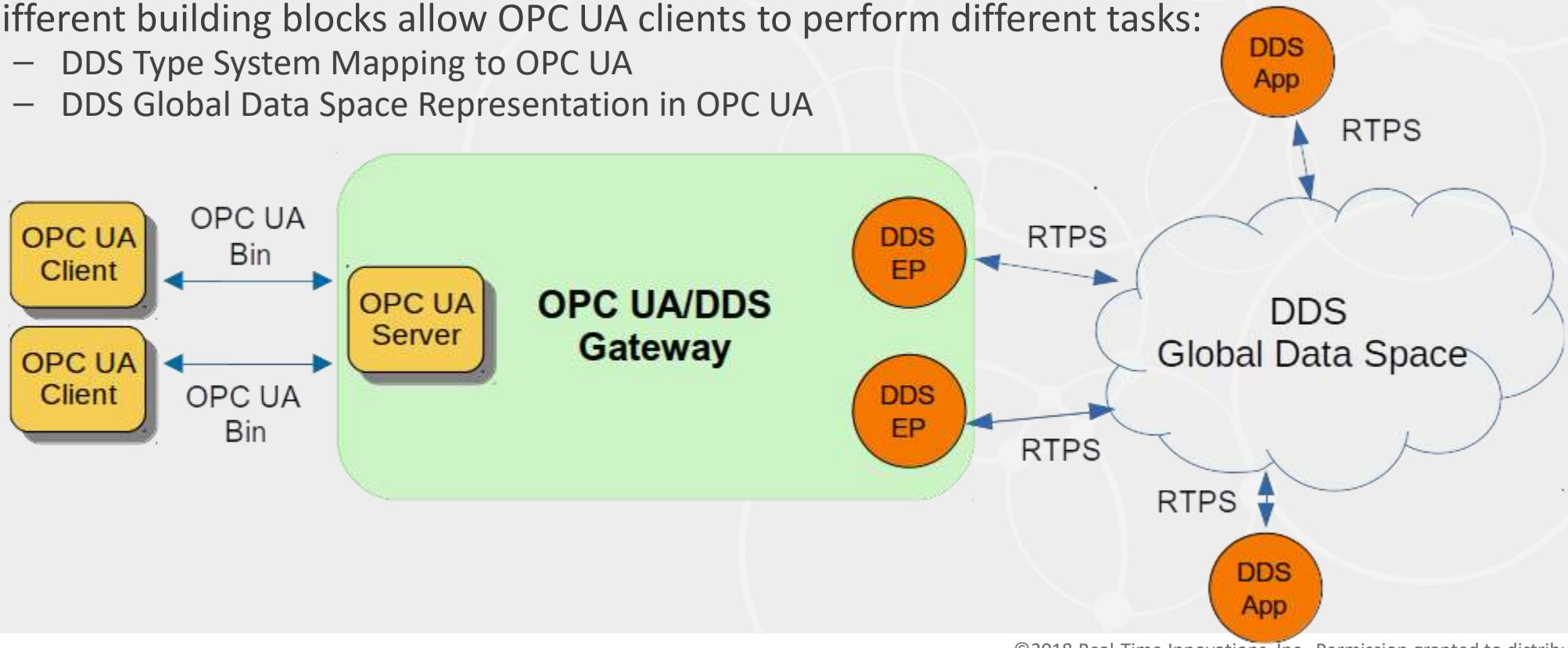
OPC UA → DDS

- 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

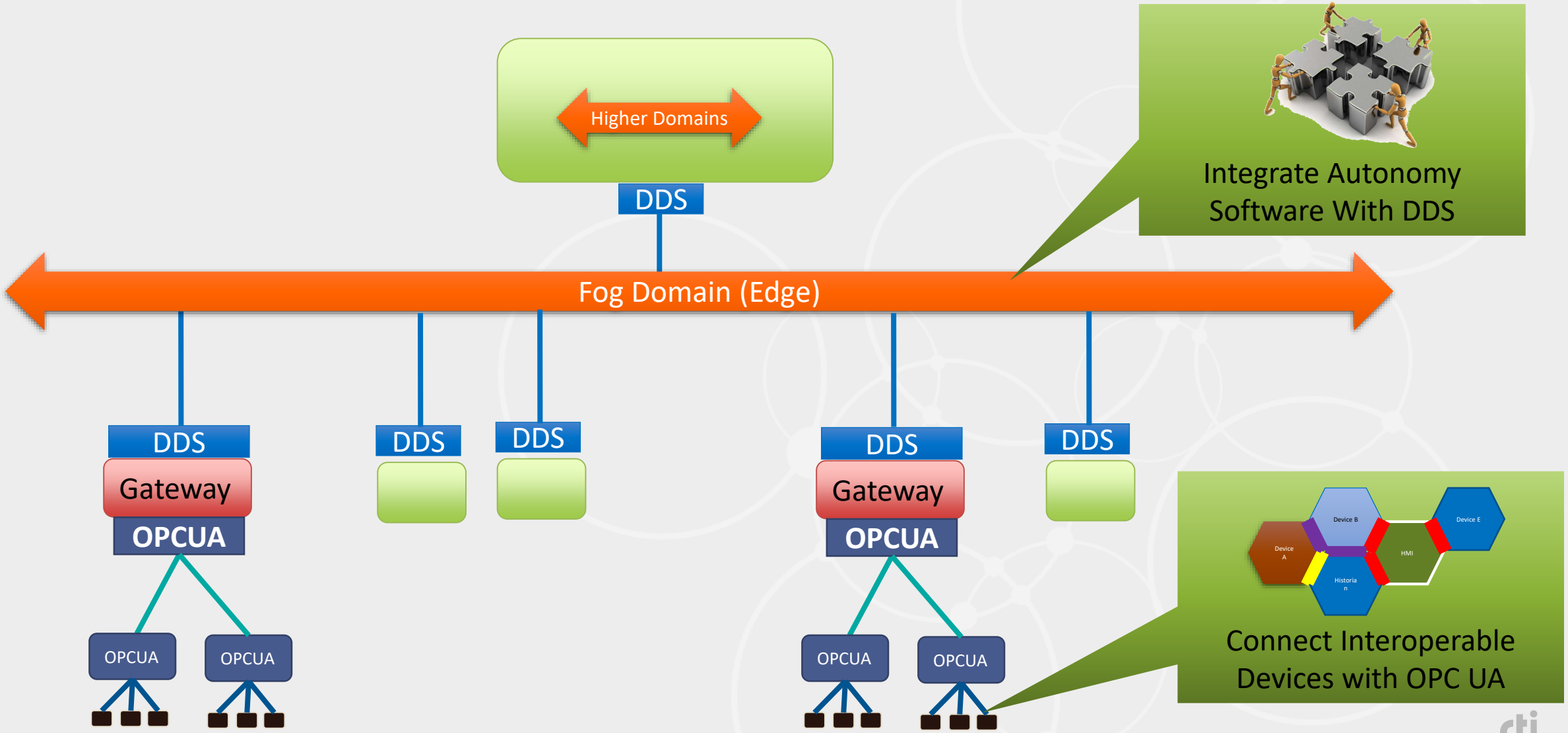


DDS → OPC UA

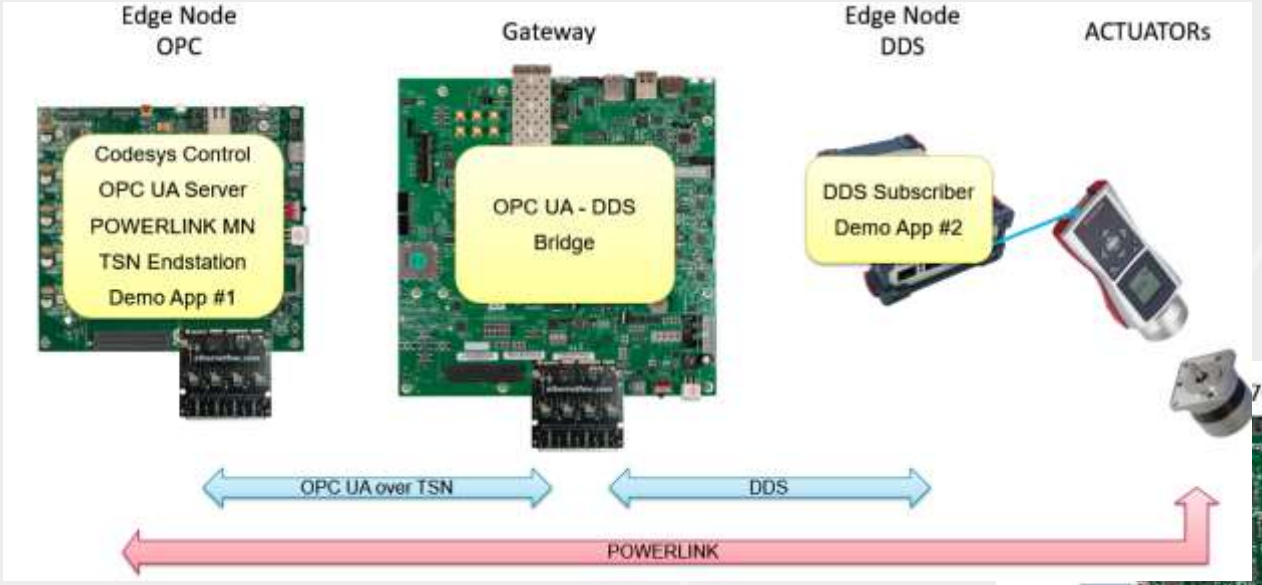
- To allow OPC UA clients to access, subscribe, read, and manage information from DDS, this side of the gateway has:
  - An *OPC UA Server* that exposes a portion of the information available in the DDS Global Data Space.
  - *DomainParticipants, Publishers, Subscribers, DataReaders, and DataWriters* 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

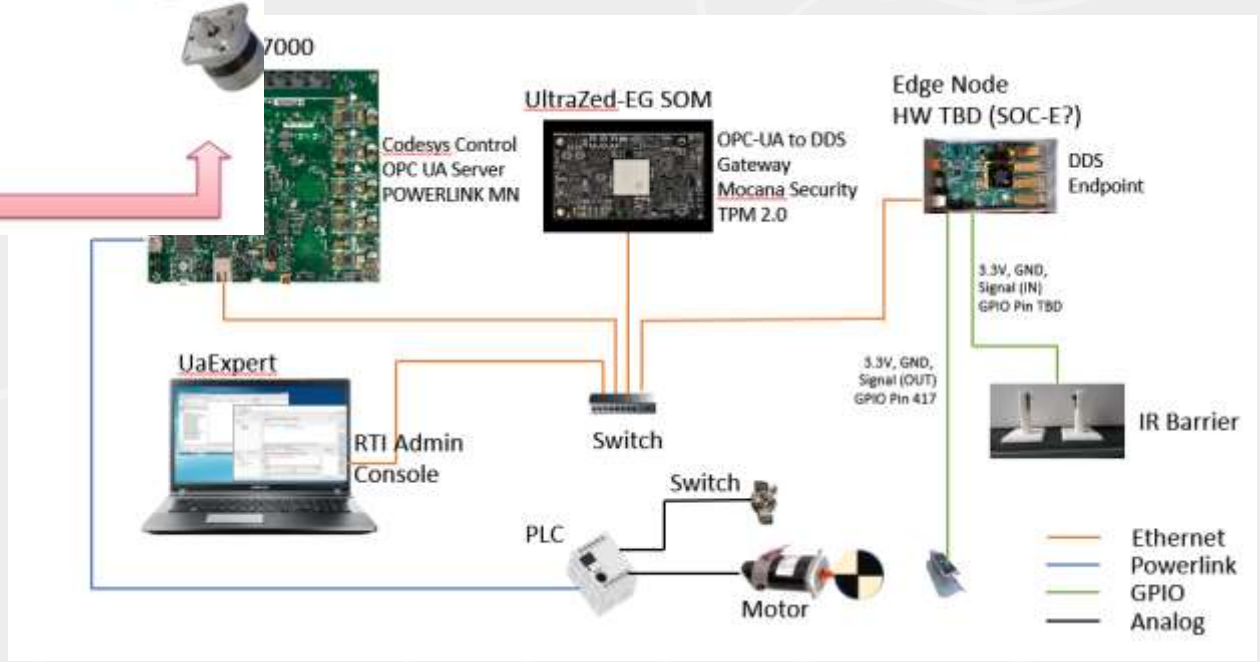


Combine Software and Device Integration



OPC UA/DDS Gateway Demo!

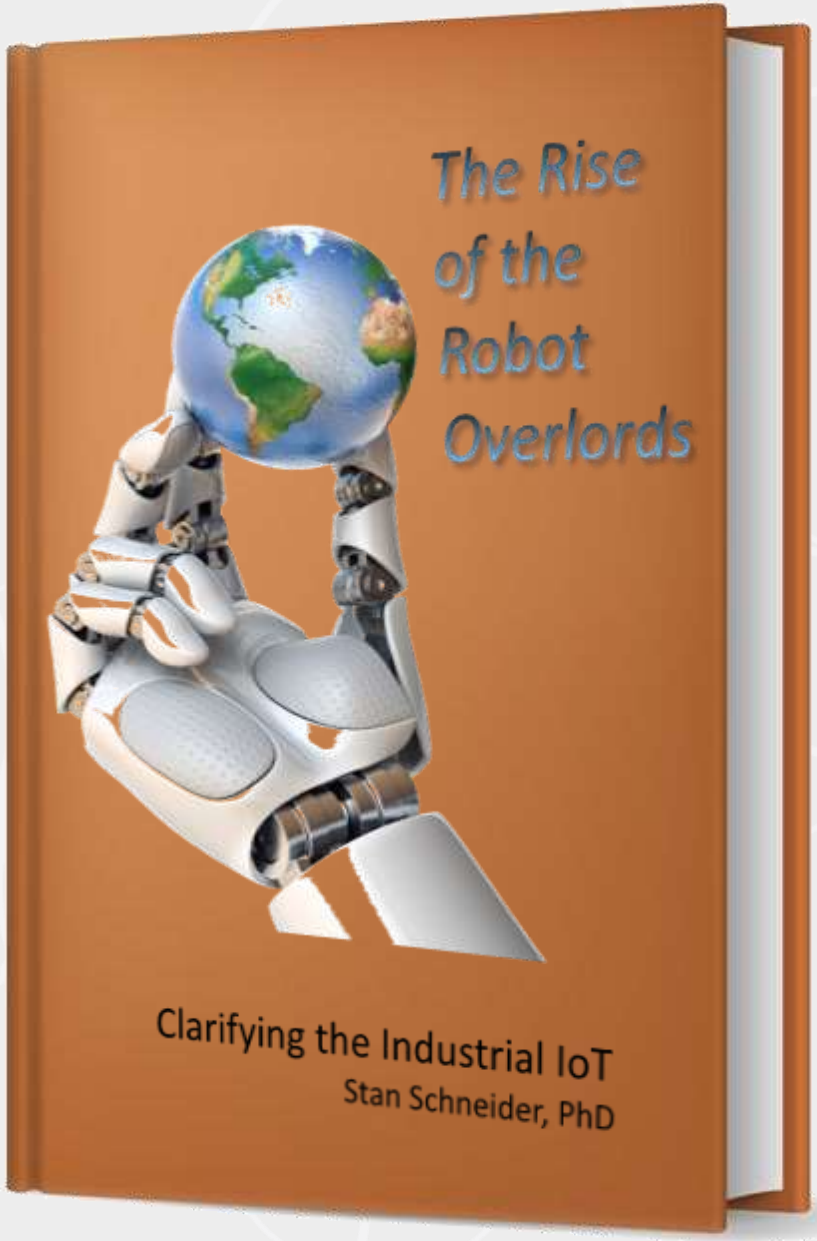




Further Information

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

- eBook coming in April; register for it online: www.rti.com/eBook



Connect!!

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    - Co-chair Ecosystem Task Group
  - Advisory Board, IoT SWC
  - Top-10 Global IIoT Influencer
  - PhD, EE/CS, Stanford