Your systems.
Working as one.

Trends and Technical Direction

Gerardo Pardo-Castellote, Ph.D.
Chief Technology Officer, RTI

The IIoT Disruption

The IIoT lives at the intersection of functional artificial intelligence and pervasive networking

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

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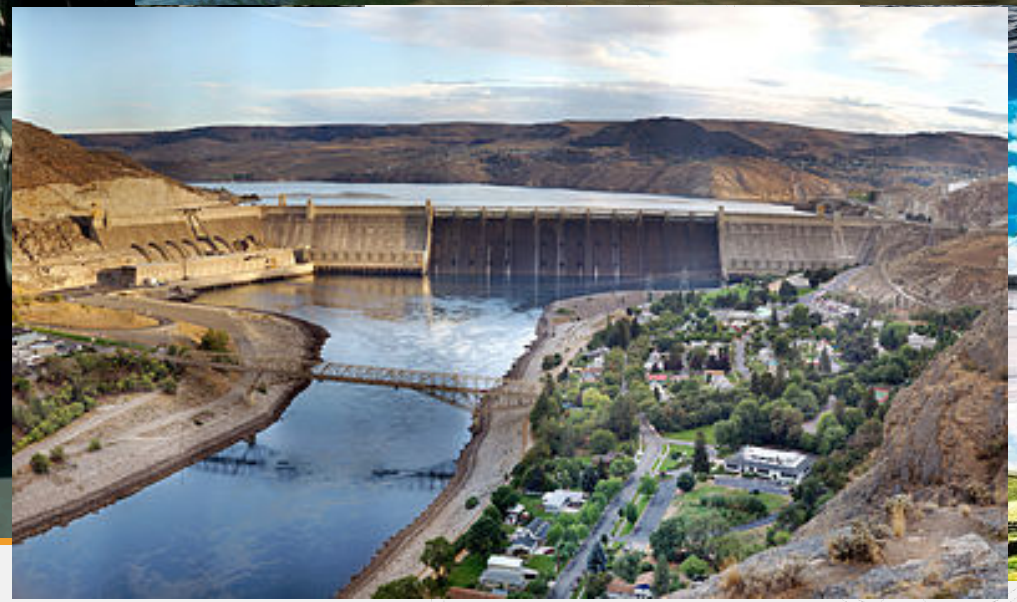
Help customers build amazing & challenging applications
Solve the problems that matter the most



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Outline

- IIC Connectivity Reference Architecture
- Standards Update
- Trends
- Product Update
- Focus

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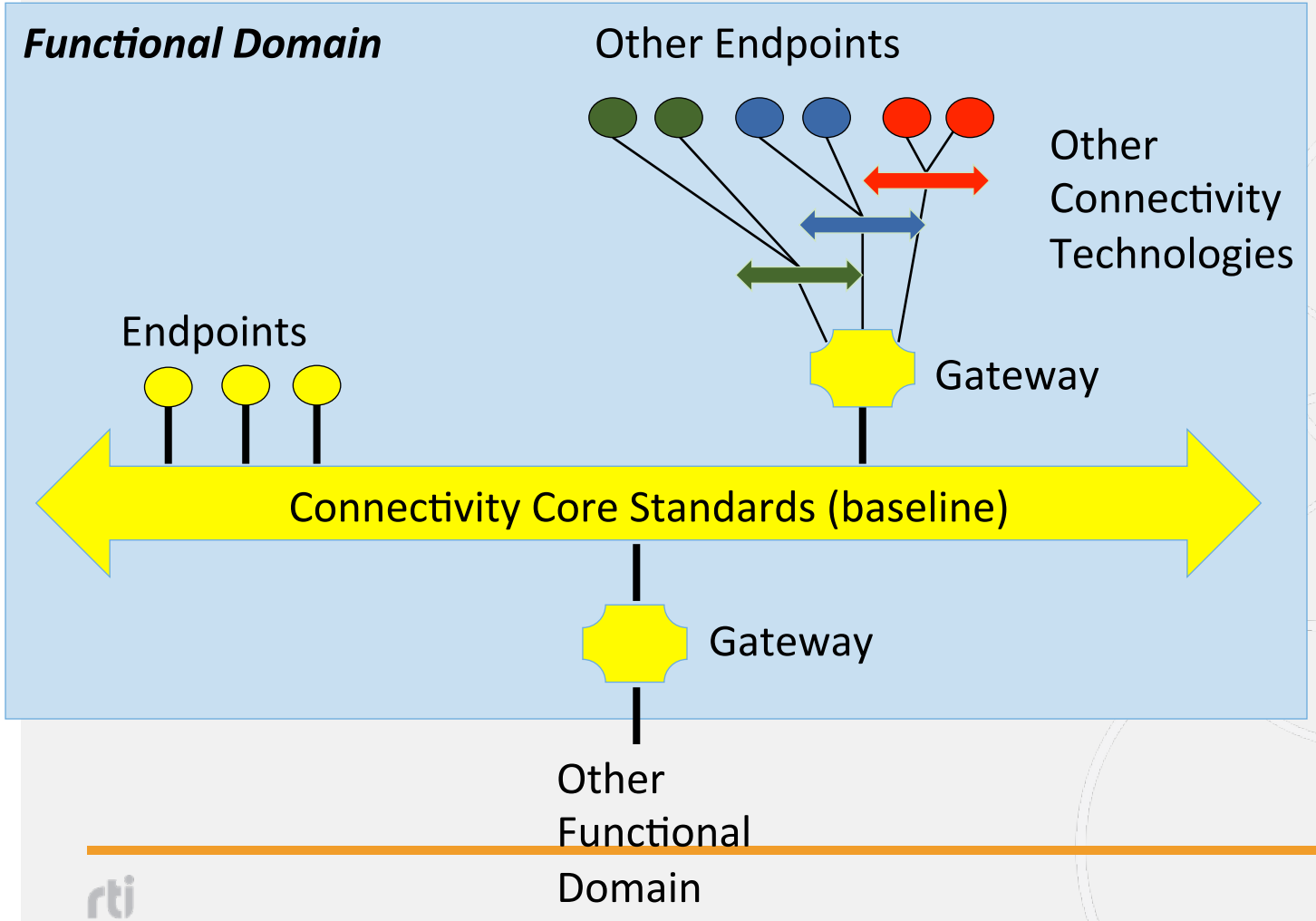
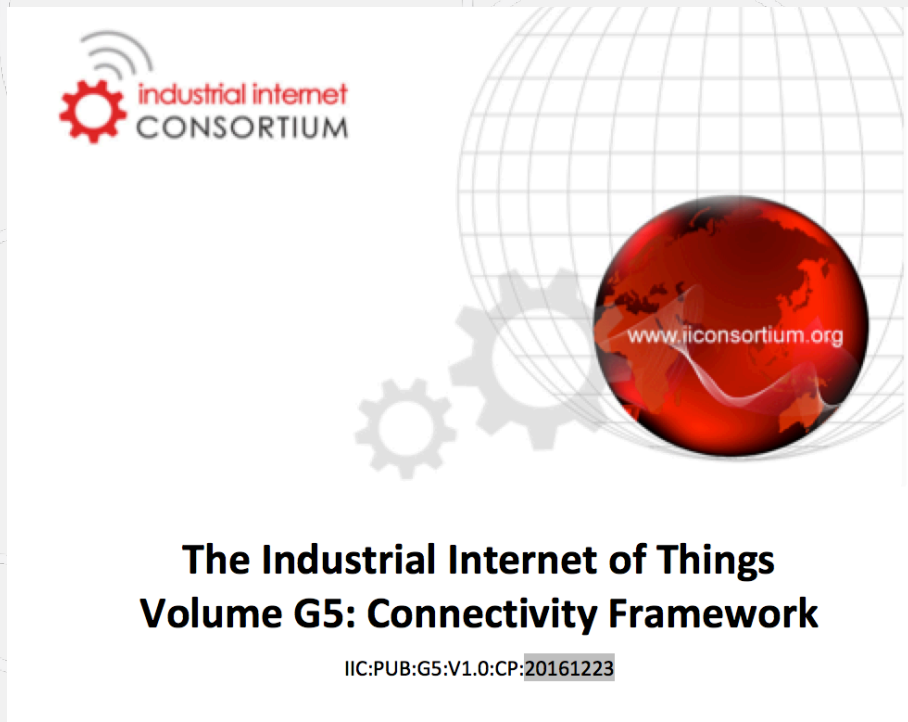
IICF

Industrial Internet Connectivity Framework

https://www.iiconsortium.org/IICF.htm

IIC releases Connectivity Reference Architecture





DDS anointed the

Core connectivity Databus

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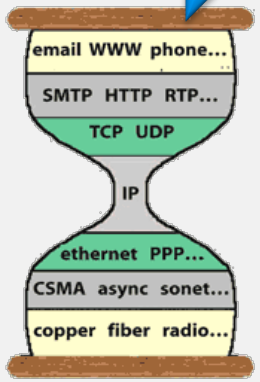
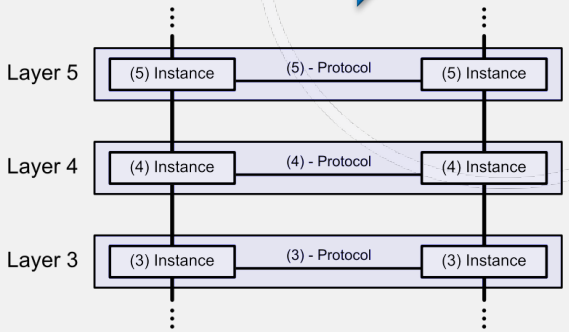
Evolution of the IIoT Connectivity Stack

4-Layer Internet Stack Model (1989)

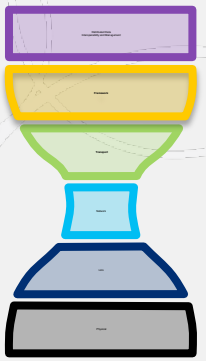


7-Layer OSI Stack Model (1994)

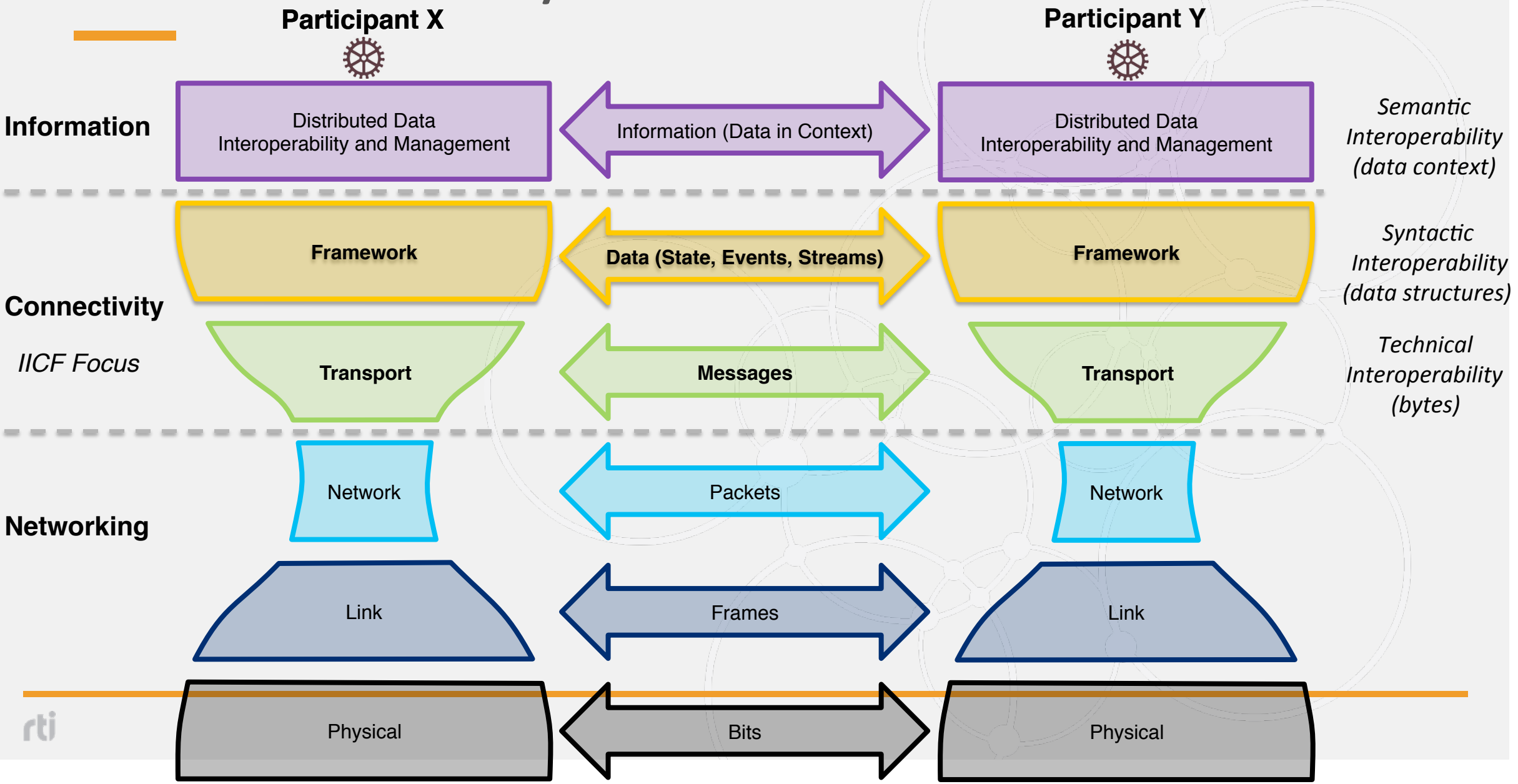


Industrial IoT (2014)

IIoT Connectivity Stack Model (2017)



IIoT Connectivity Stack Model



Considerations

System Architecture

- Peer to Peer vs Broker
- Data-Centric vs App Centric
- Explicit/Implicit Governance
  - Types
  - Data flows
  - Qos
  - Security

Data selection

- Content-Based selection
- Time-Based selection

Performance

- Real-time
- Latency, Jitter, Throughput

Scalability

- Large number of data-objects
- Large number of applications

Availability

- Redundancy
- Recovery

Deployment

- Platform constraints
- Incremental upgrades

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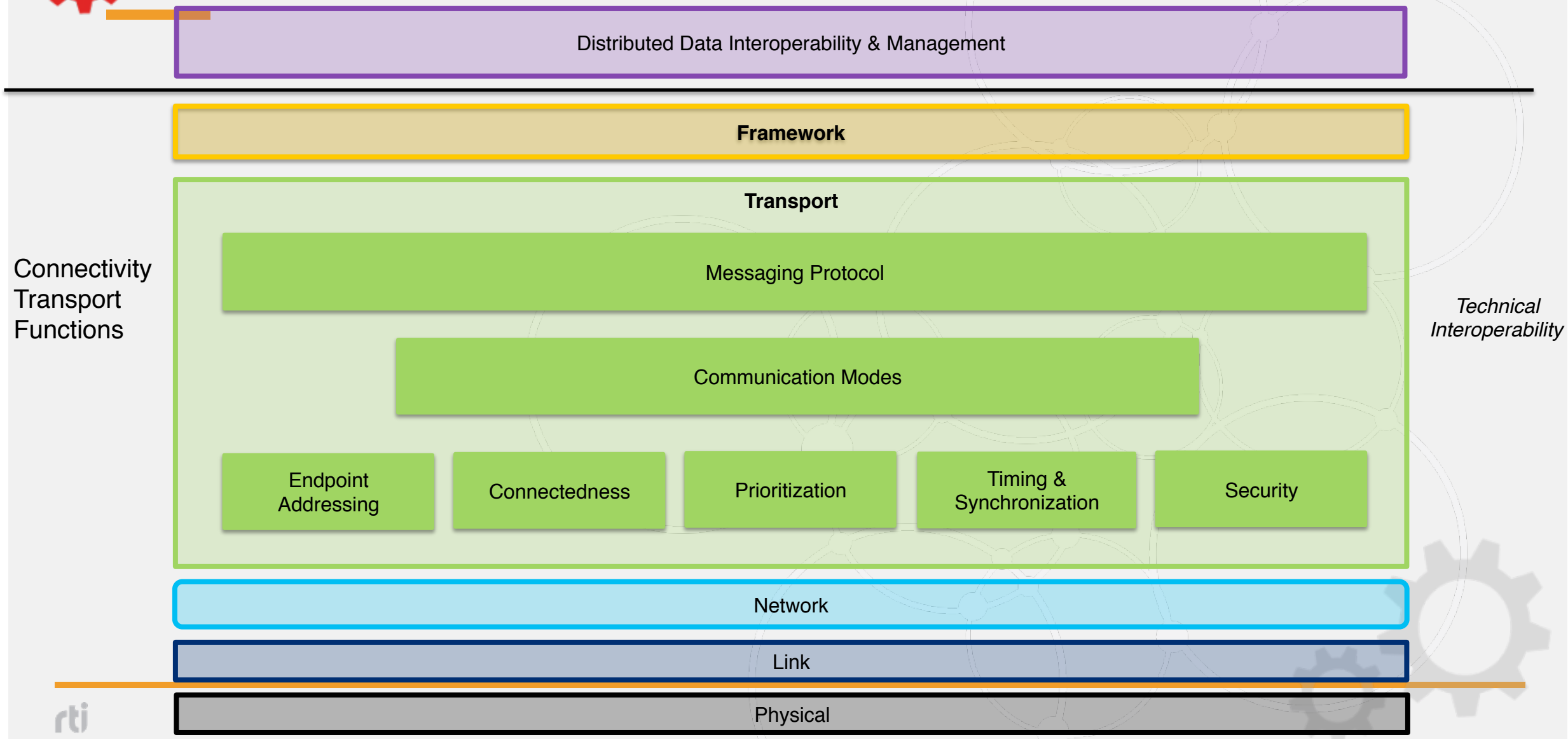
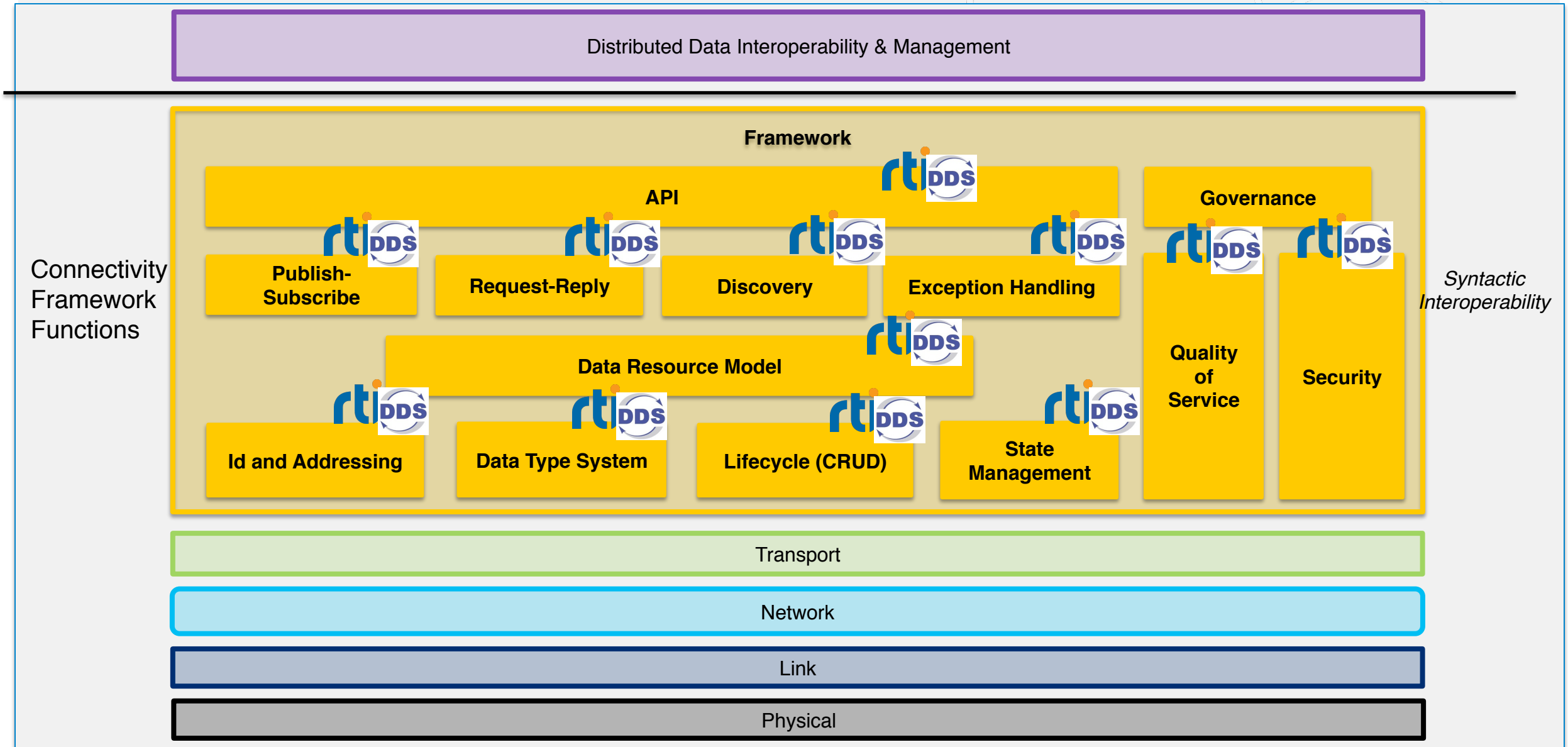
Connectivity Transport Layer



Connectivity Framework: Core Functions



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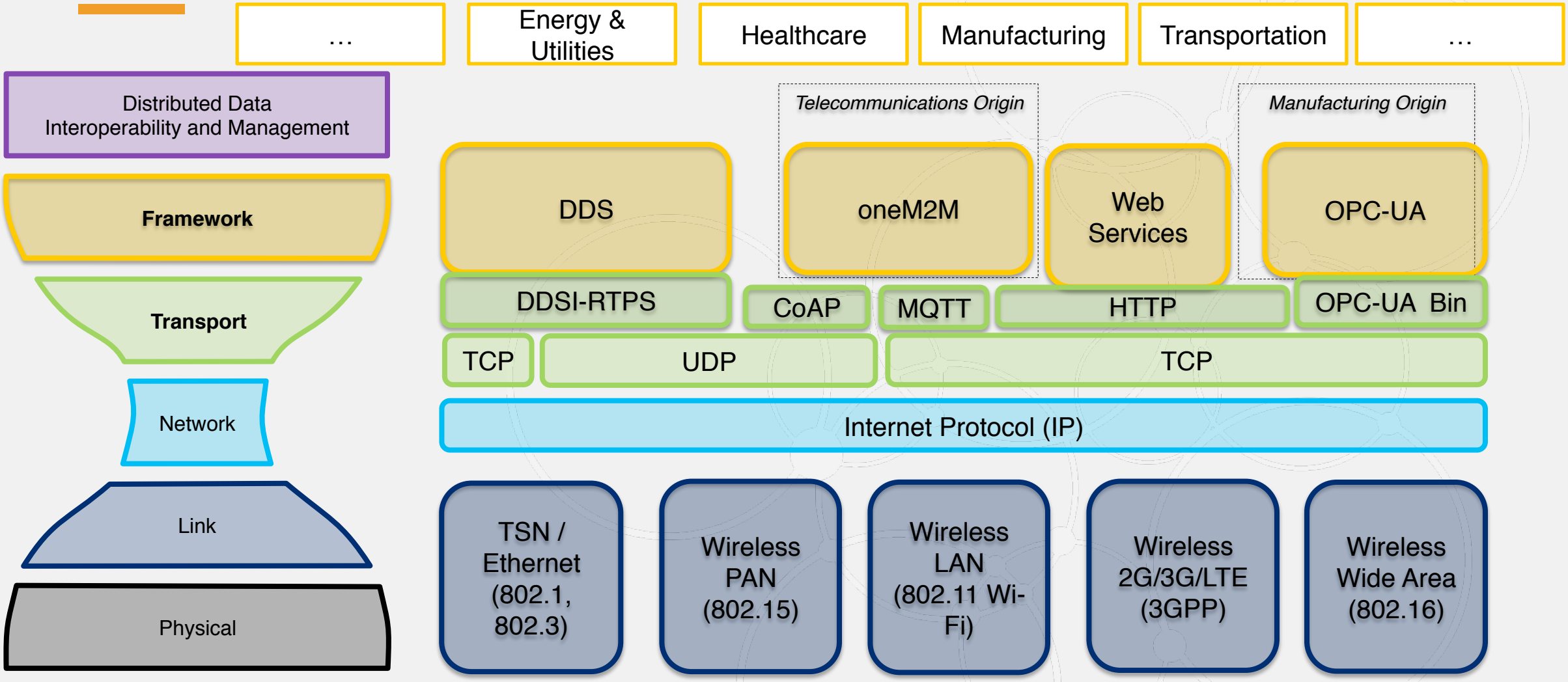
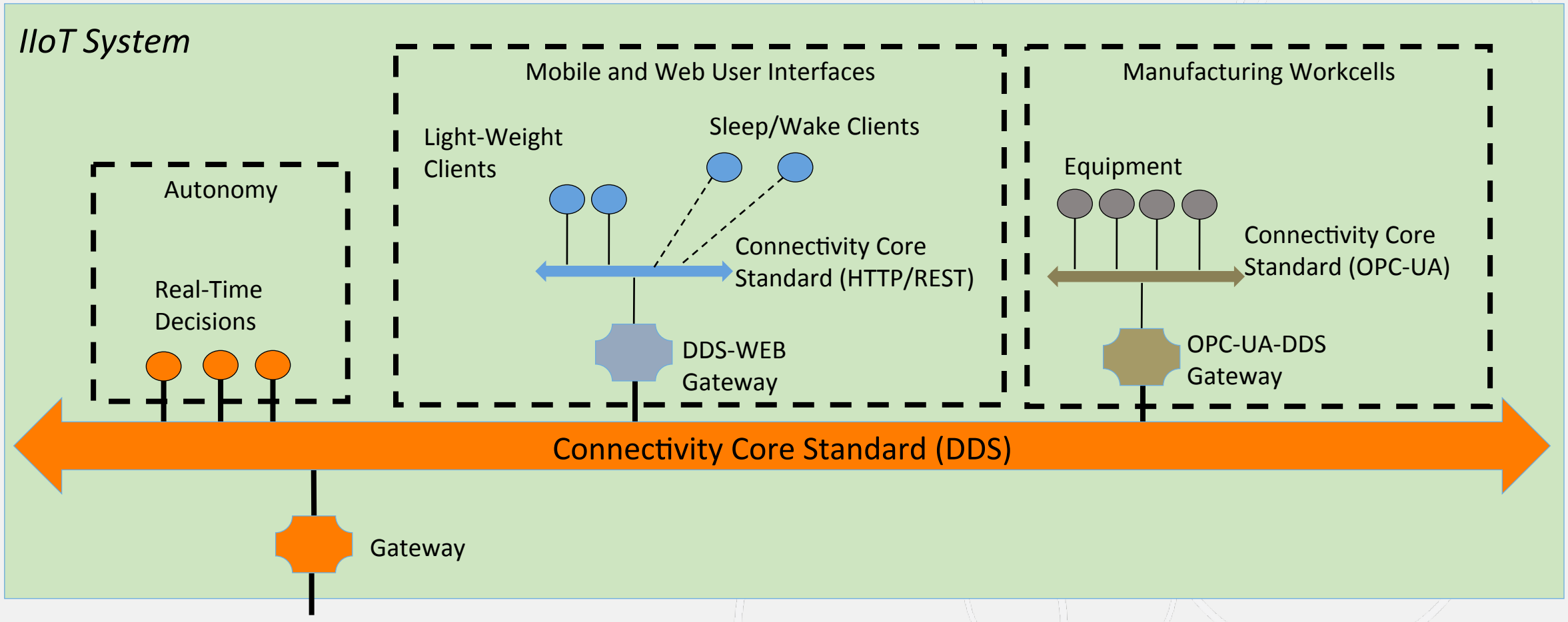
Connectivity Standards



	Core Standard Criterion	DDS	Web Services	OPC-UA	oneM2M
1	Provide **syntactic interoperability**	✔	**Need XML or JSON**	✔	✔
2	Open standard with strong **independent, international** governance	✔	✔	✔	✔
3	**Horizontal** and neutral in its applicability across industries	✔	✔	✔	✔
4	**Stable** and **proven** across multiple vertical industries	**Software Integration & Autonomy**	✔	**Manufacturing**	**Home Automation**
5	Have **standards-defined *Core Gateways*** to *all* other core connectivity standards	Web Services, OPC-UA*, oneM2M*	DDS, OPC-UA, oneM2M	Web Services, DDS*, oneM2M*	Web Services, DDS*
6	Meet the connectivity framework **functional** requirements	✔		**Pub-Sub in Development**	✔
7	Meet **non-functional** requirements of performance, scalability, reliability, resilience	✔		**Real-Time in development**	**Reports not yet documented or public**
8	Meet **security** and safety requirements	✔	✔	✔	✔
9	Not require any single component from any single vendor	✔	✔	✔	✔
		✔			

***** = work in progress **blank** = No P = **open source** GREEN = Gating Criteria

RTI Integrated Vision



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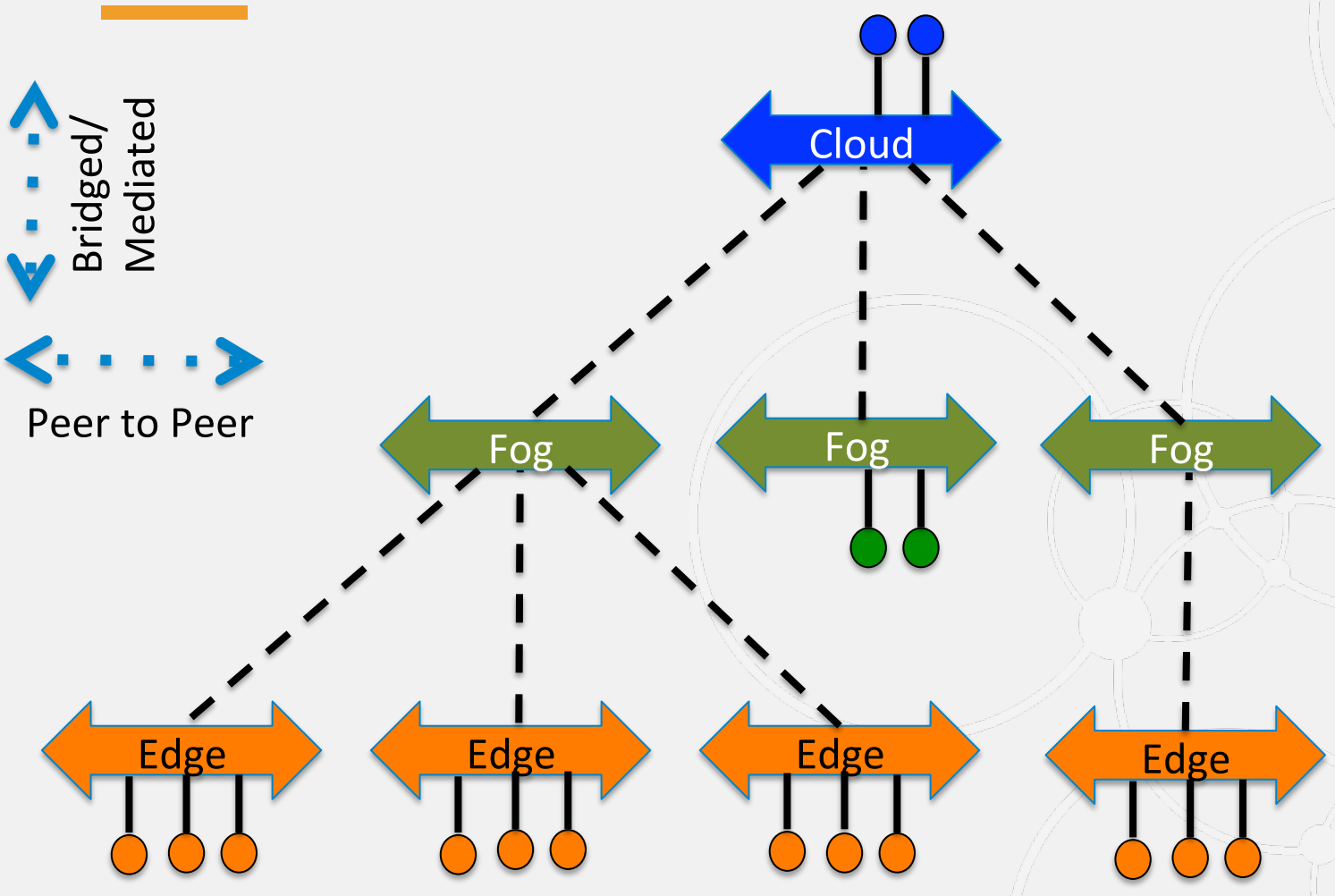
Layered Databus



- Cloud:
  - Datacenter
  - Elasticity, Provisioning, Management, Analytics
- Fog:
  - Distributed computing
  - Processing “close to the edge”
  - Latency, Robustness, availability
- Edge:
  - Locality
  - Information Scoping

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Example: Grand Coulee Dam

Interested in many quantities

Control Room

Displays

Logging

Alarming Monitor

Migratio n Server

Existing SCADA (to be replaced)

Control Room Bus

Redundant Routing

TCP (WAN)

VPN/Firewall

VPN/Firewall

VPN/Firewall

Local quantity interest

Segment Bus

IPC

Segment Bus

IPC

Segment Bus

IPC

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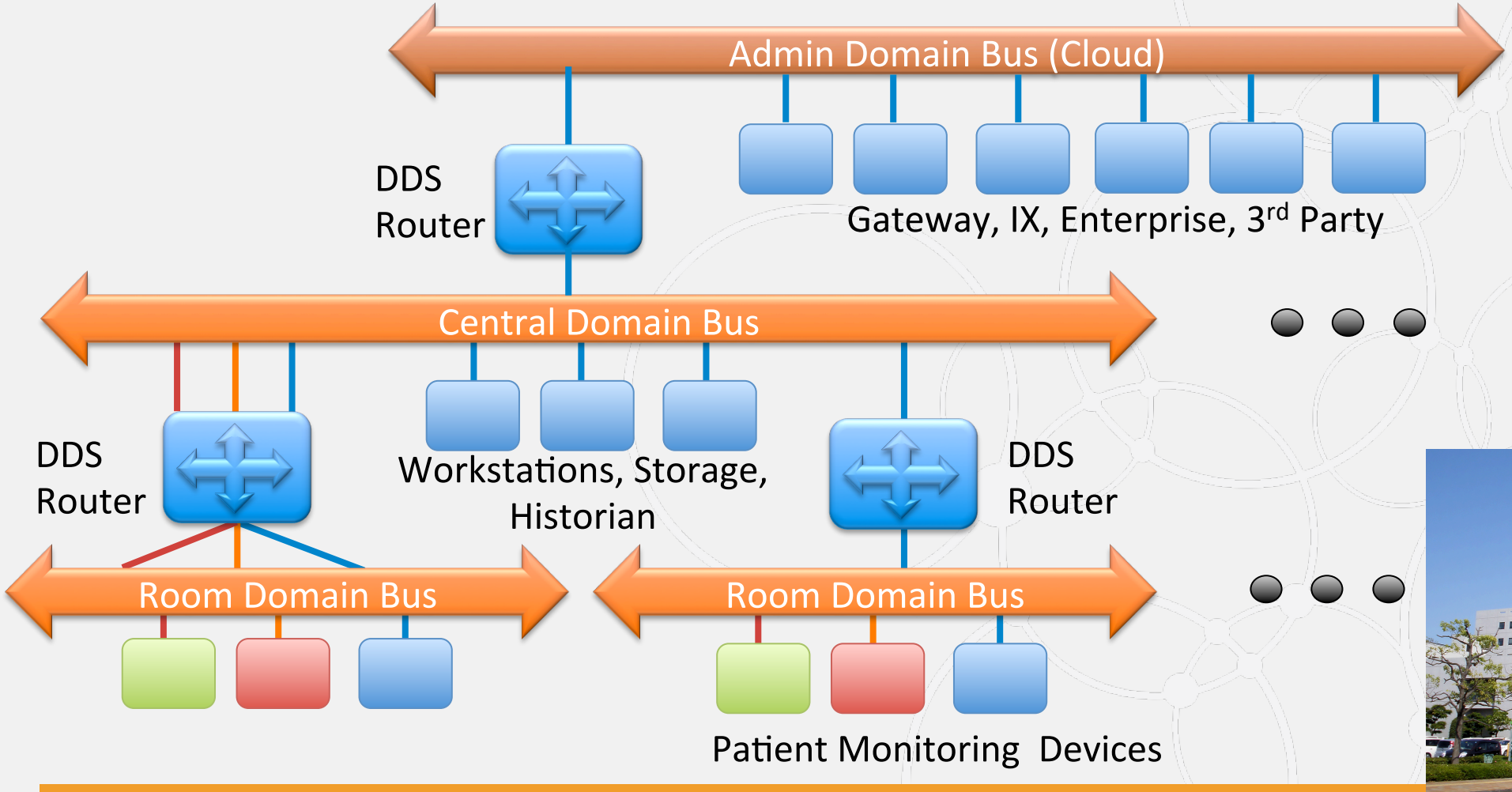
Example: Clinical Decision System Architecture



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Standards Update

Key standards we are focusing on

High Priority:

DDS-Security	1.1	9/2017
DDS-XTYPES	1.2	3/2017
IDL	4.1	12/2016
DDS-XML	Beta	6/2017
DDS-OPCUA	Beta	9/2017
DDS-XRCE	Beta	9/2017

Slower burner:

DDS-RTPS	2.3	03/2018
DDS	1.5	06/2018
DDS-PSM-TCP	Beta	2018
C++ PSM	1.1	2018
Java5 PSM	1.1	2018
DDS-RPC	1.1	2018
IDL to C#	Beta	TBD
IDL to Java	Beta	TBD

DDS-Security 1.1

- Updates required for vendor interoperability
- More efficient cryptography
- Enhanced authentication and key derivation
- Strengthen some edge cases:
  - Mobility, Changes in Qos, Timing/Race conditions
- Basis for Interoperability Tests:
  - https://github.com/omg-dds/dds-security

Most all being included in Connext 5.3

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IDL 4.1 + XTYPES 1.2

- IDL as data & interface modeling language
  - DDS data-modeling extensions (keys, optional members, extensibility)
  - Support for DDS-RPC
  - General annotation support for extensibility
- Enable definition of “platform-independent” information model
  - Lingua franca for IIOT data models
    - vs. XSD, JSON, YAML, ProtoBufs, ROS-IDL, Ad-hoc …
  - 3rd party tooling support - UML, Matlab, LabView, …
- Enhance serialization and dynamic data performance
- We have started to incorporate these into RTI Code Generator in 5.3

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DDS-XML

- Normalize representation of DDS systems
- Includes features already available in Connext DDS
  - XML definition of Qos Profiles
  - XML definition of Data-Types
  - XML Application Creation
    - Also RTI Web-Integration Svc, Prototyper, Connector
- “tool interchange format” -> foster ecosystem
  - SysML, Simulink, TSN tools can all use it
  - RTI System Designer

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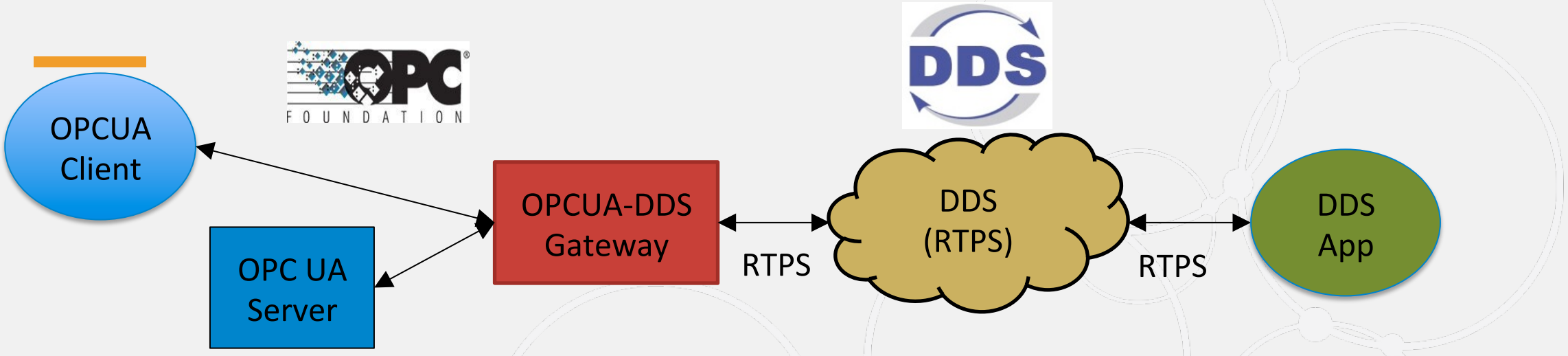
DDS to OPCUA Bridge



- Existing: OPC UA Server on controller
- Existing: OPC UA Client applications
- Existing: DDS App
- New: OPCUA-DDS Gateway– Maps "operations" on OPCUA to DDS

NOTE: OPC foundation also working on a "Pub-Sub" mechanism for OPCUA.
Plan is to make "DDS" one of the 3 supported "communication" models for pub-sub.

DDS-XRCE – Extremely Resource-Constrained Environments

DDS-XRCE

XRCE Agent

PROCESSING

ANALYTICS

DDS

Global Data Space

ARCHIVAL

DDS/ RTPS

XRCE Clients

Scope is wire protocol between XRCE Client and XRCE Agent

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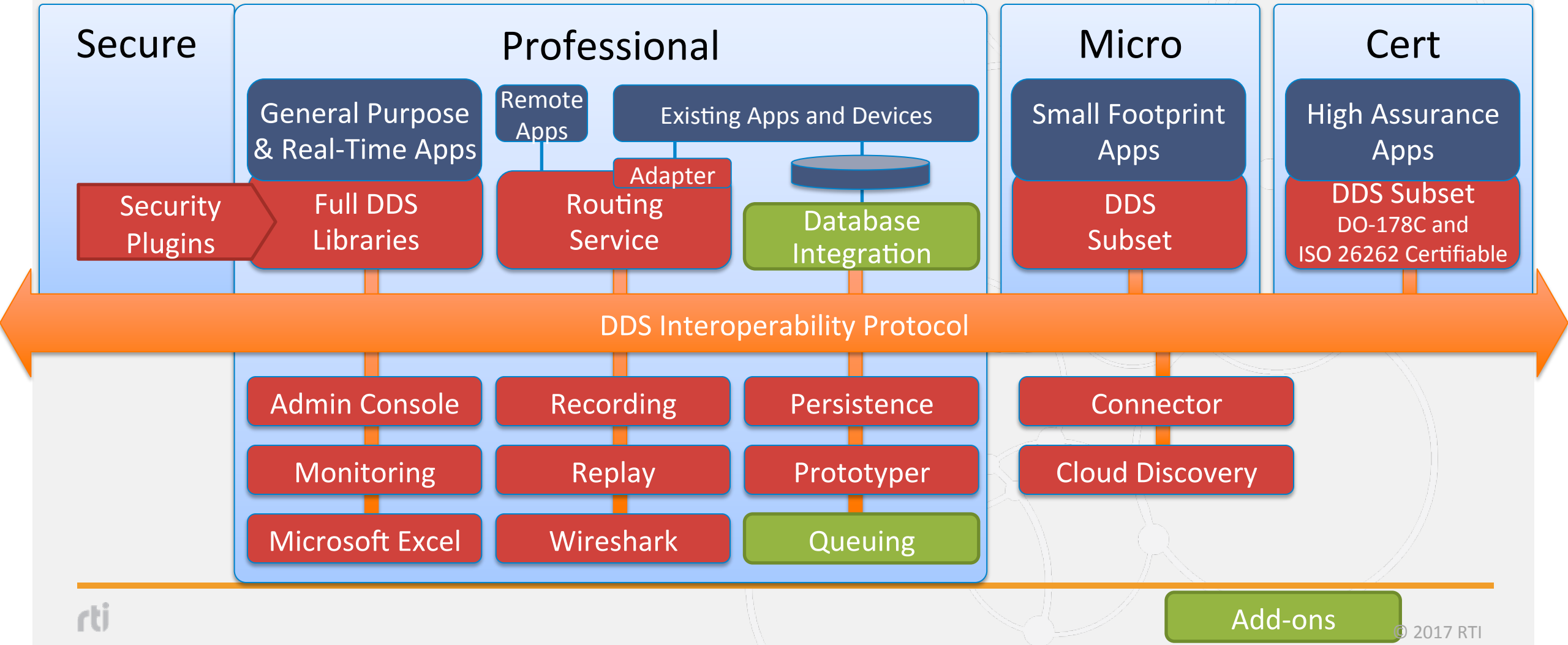
Product Update

Three pillars

- Features
- Usability
- Robustness, Scalability & Performance

RTI Connext DDS Product Family



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RTI Web Integration Service(*)

Operational Data

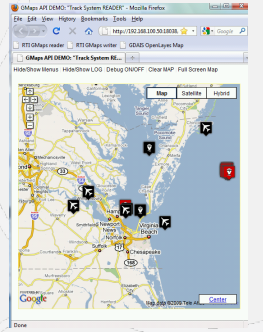
DDS

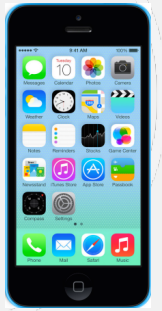
DDS/ RTPS

Connectivity Core Standards

DDS-WEB Service

HTTP/ HTTPS





GUARD

(*) Also an OMG standard (DDS-WEB 1.0)

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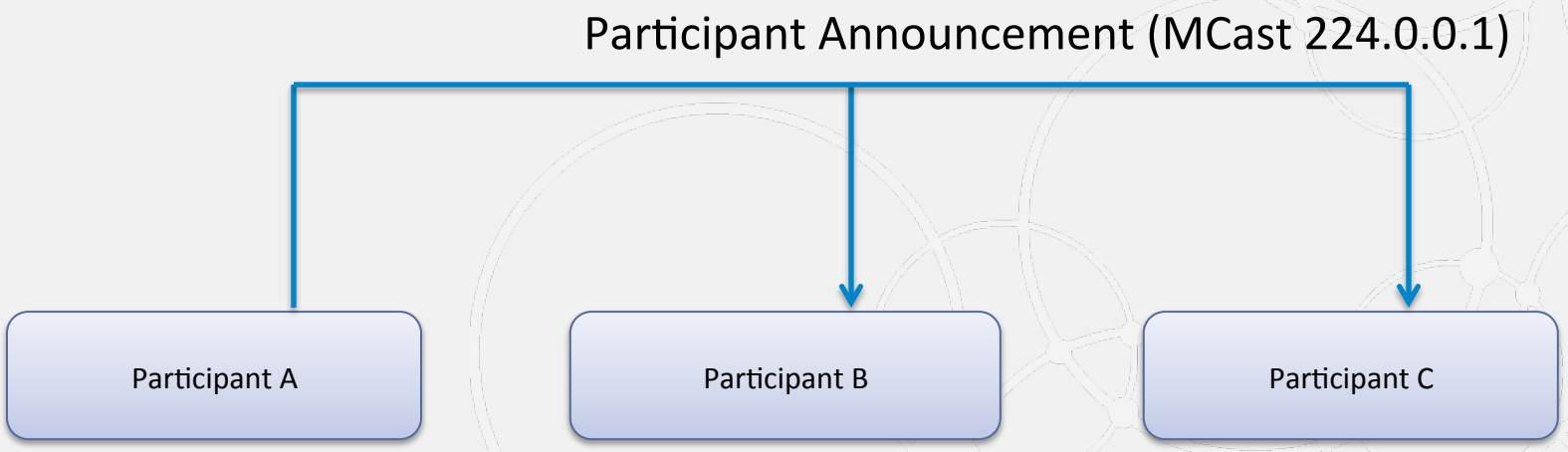
Without Cloud Discovery Service (1)



DDS discovery is bootstrapped using multicast

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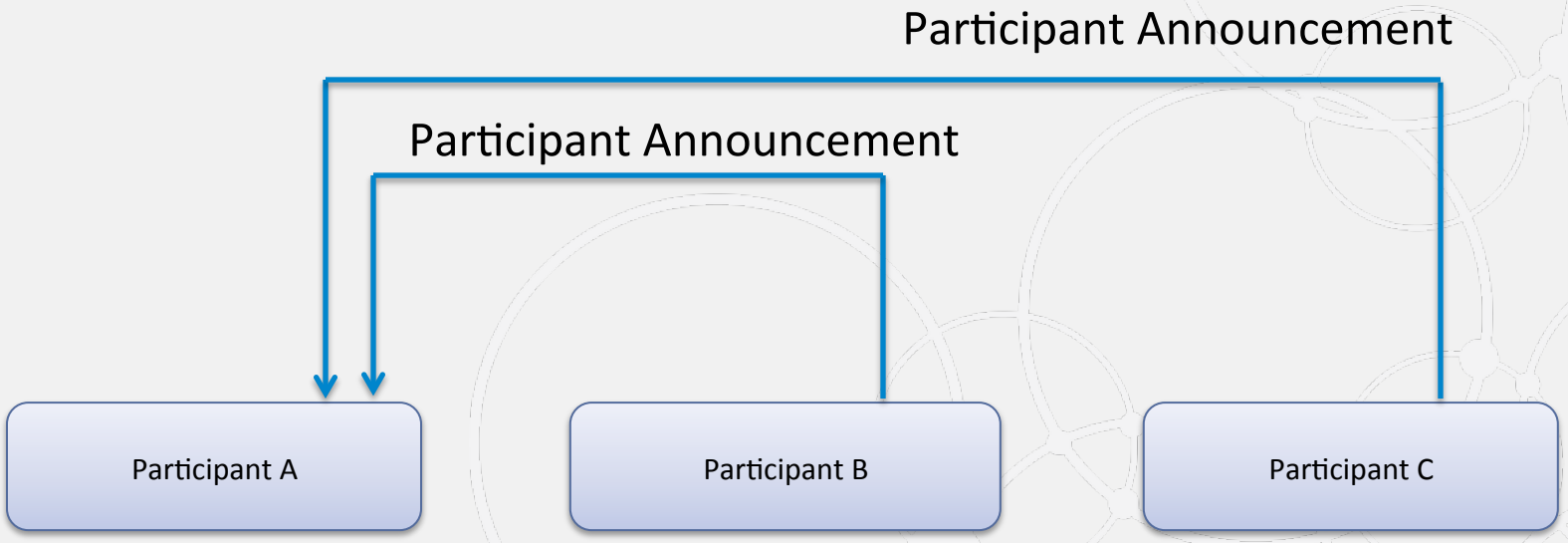
Without Cloud Discovery Service (2)



Once detected Participant information is exchanged

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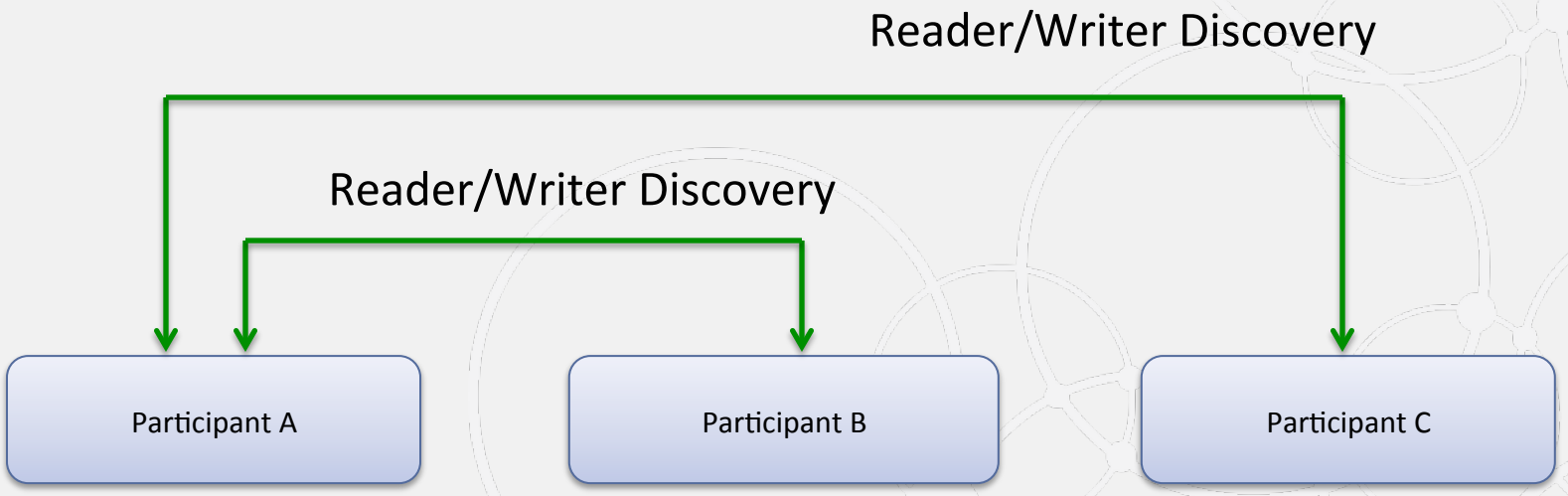
Without Cloud Discovery Service (2)



After participant discovery the endpoint information is exchanged

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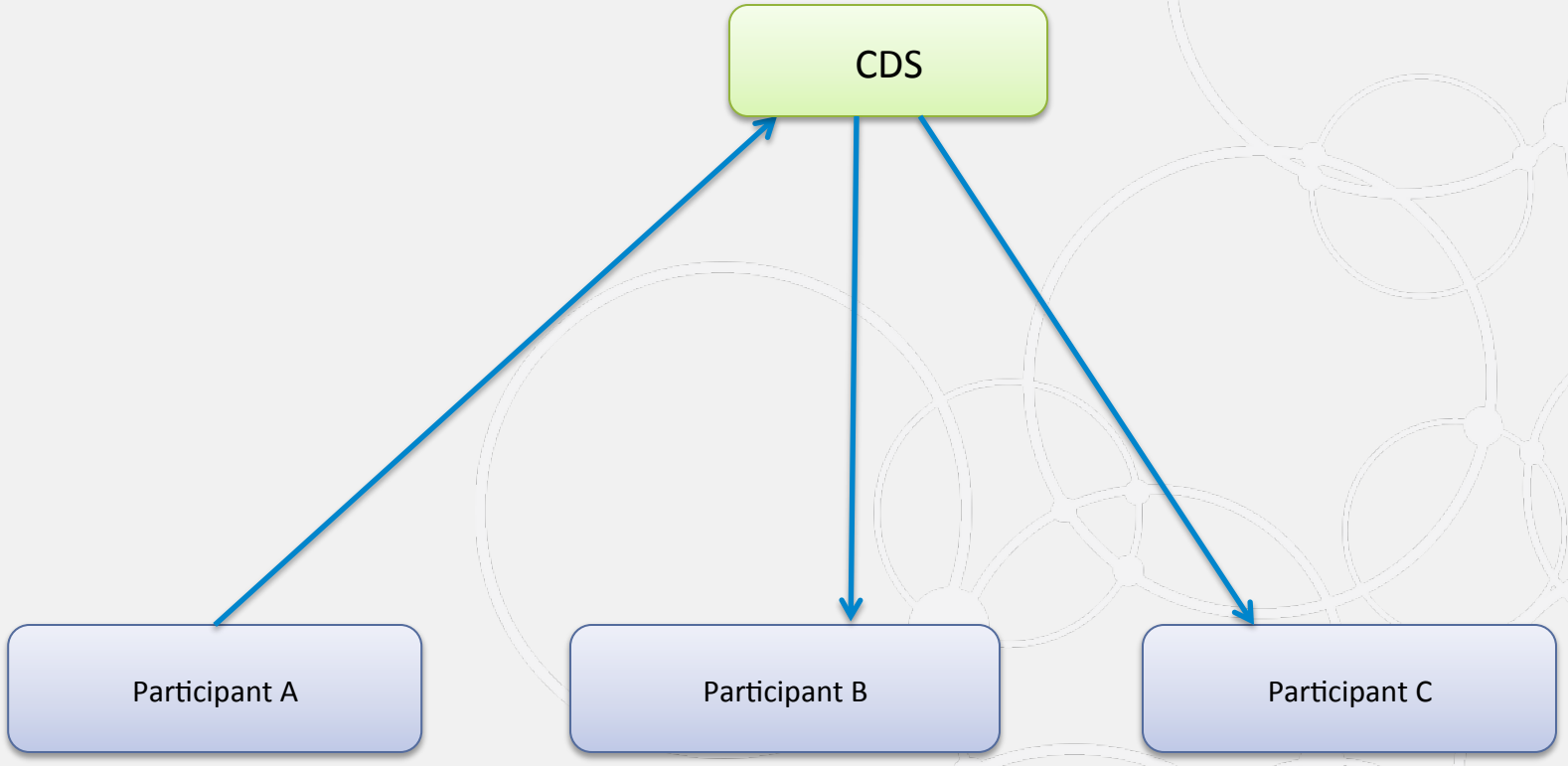
With Cloud Discovery Service (1)



DDS discovery is bootstrapped using CDS

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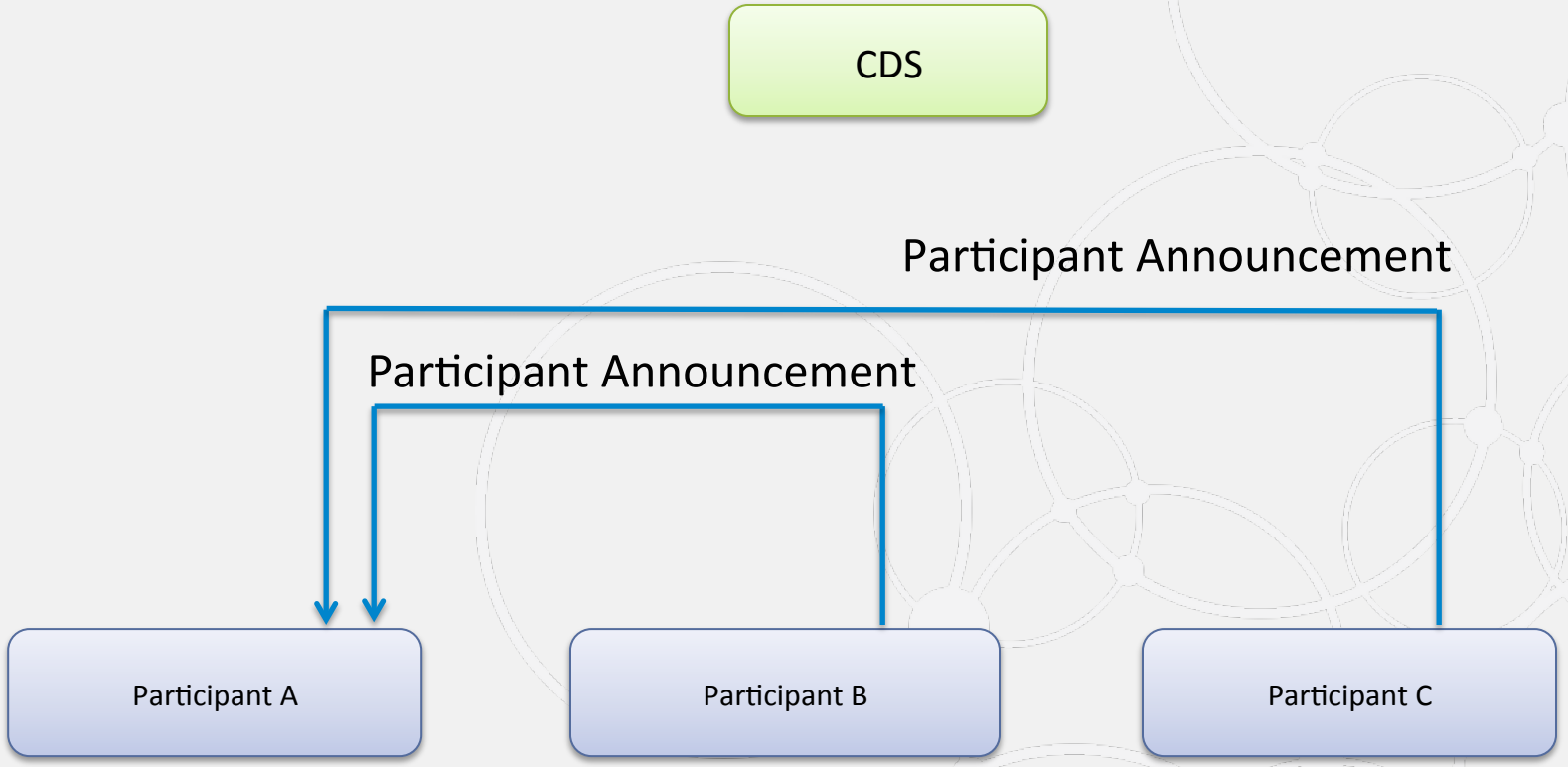
With Cloud Discovery Service (2)



Once detected via CDS, Participant information is exchanged directly. The same as without CDS.

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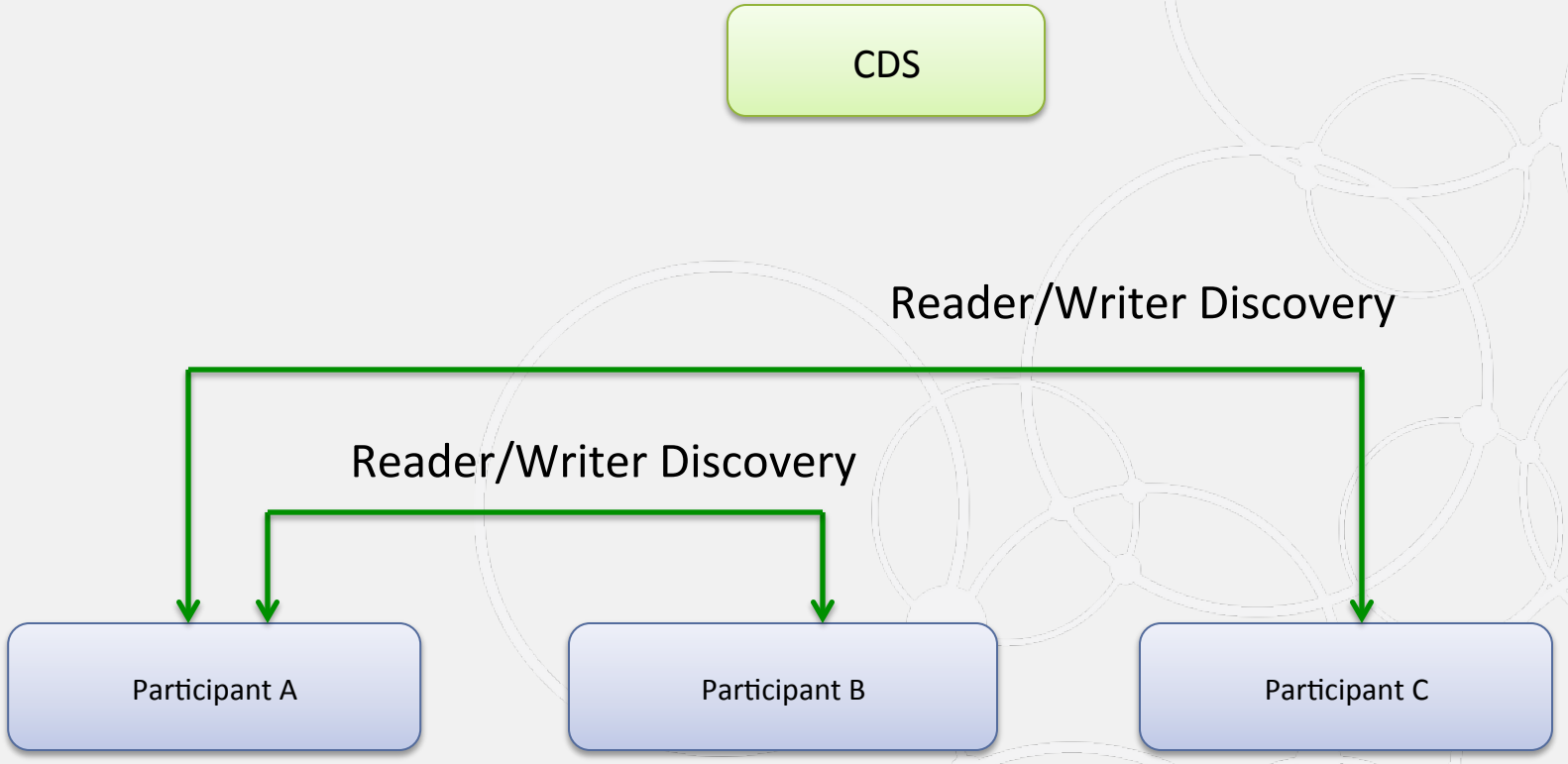
With Cloud Discovery Service (3)



After participant discovery the endpoint information is exchanged. The same as without CDS.

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Connector Concept

App Definition is Simple XML

XML DDS Application Description

Configure

Connect()

Join DDS
Create all Entities

Input1
Input2
Output1
Output2

DDS

Program API
Is simple reads/writes

```
getInput("Input1").read();
getOutput("Output1").write();
```

Use your favorite Language:

node.js

python

Lua

THE C PROGRAMMING LANGUAGE

- Fast "wrapper" API
- Supports Data-Centric programming
- Separates configuration & Logic

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Connector Example


```python
conn =
rti.Connector("MyParticipantLib::Zero",
              "./ShapeExample.xml");

o = conn.getOutput("Pub::SqWriter");


for i in range(1,500):
    o.instance.setNumber("x", i);
    o.instance.setNumber("y", i*2);
    o.instance.setNumber("shapesize", 30);
    o.instance.setString("color", "BLUE");
    o.write();
    time.sleep(2)
```


```javascript
var conn = new
rti.Connector("MyParticipantLib::Zero",
              "./ShapeExample.xml");

var o = conn.getOutput("Pub::SqWriter");

var i;
for (i=0; i<500; i++) {
  o.instance.setNumber("x",i);
  o.instance.setNumber("y",i*2);
  o.instance.setNumber("shapesize",30);
  o.instance.setString("color", "BLUE");
  o.write();
  sleep.usleep(1000);
}
```


```lua
conn =
rti.Connector("MyParticipantLib::Zero",
              "./ShapeExample.xml");

o = conn.getOutput("Pub::SqWriter");


for (i=0; i<500; i++) {
  o.instance.x = i;
  o.instance.y = i*2;
  o.instance.shapesize = 30;
  o.instance.color = "BLUE";
  o.write();
  sleep.usleep(1000);
}
```

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New Feature Highlights

- Mobility
  - Your data always finds you
- Topic Query
  - Past data as you want it, on demand
- Security
  - Fine grain protection for critical data…
- Tools
  - Admin Console, System Designer, …

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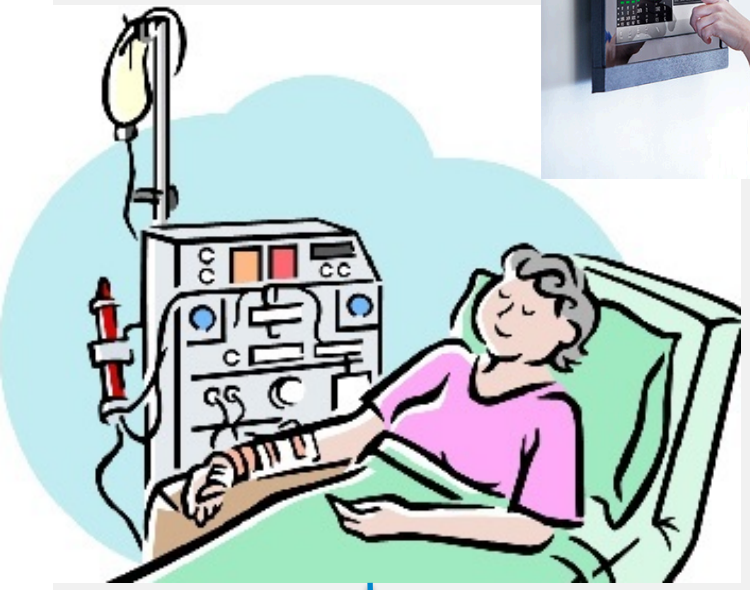
Topic Query



Last 4 Hours?

Mobility

Routing Service

Routing Service

Security

CONNEXT DDS SECURE

CONNEXT DDS SECURE

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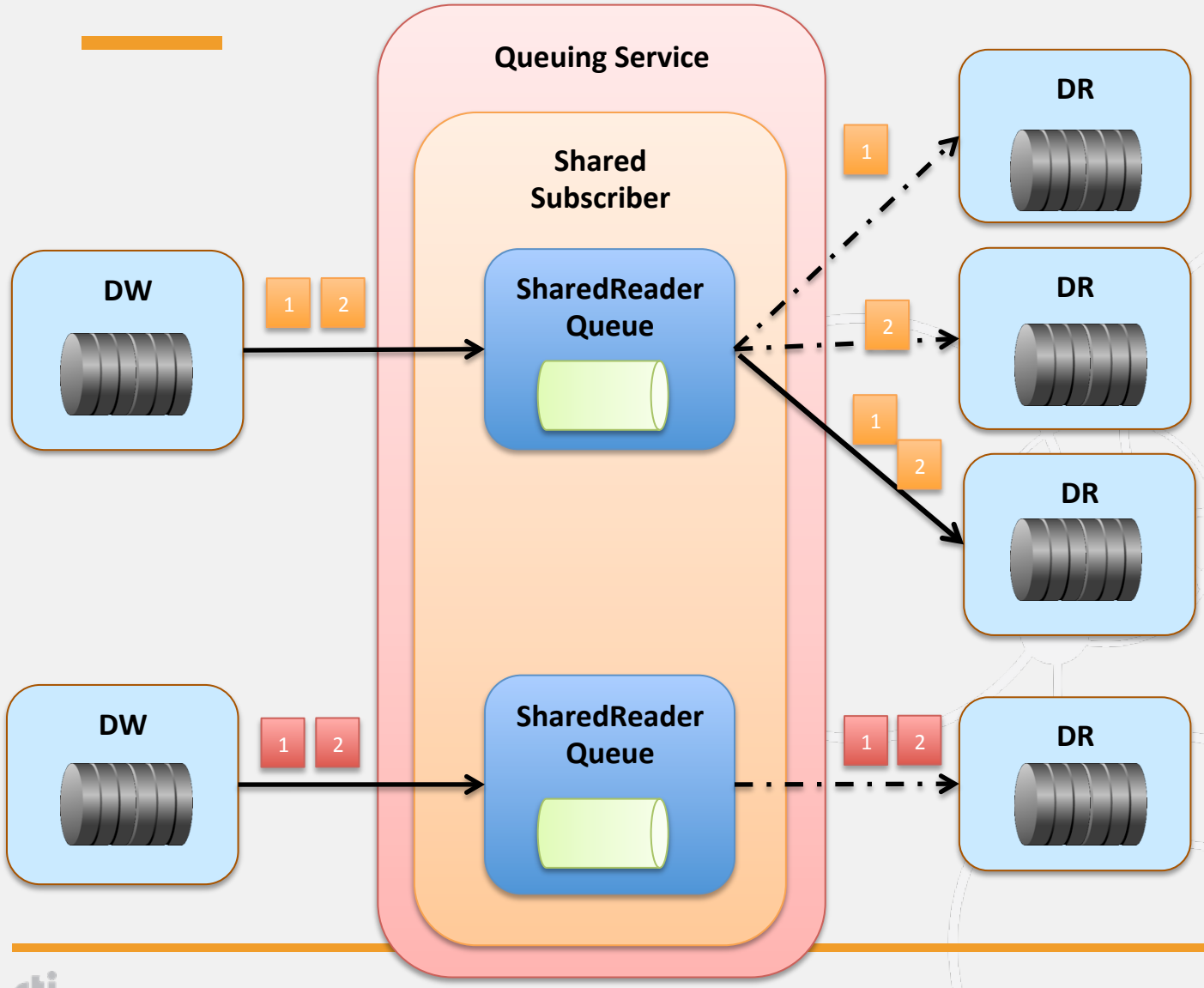
RTI Queuing Service



- Merges Queue and Pub-Sub
- Topic and Content-aware Queuing(*)
- Works natively with DDS APIs and Qos

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Connext DDS Micro roadmap

Connext DDS Micro Roadmap	
December 2016	• Maintenance Release 2.4.9 reliability, usability, and portability
Q3/Q4 2017	• Platform validation test suite for DIY ports • TBD: Modular UDP Registration to easily accommodate 3rd party transport plugins

Q1 2018
Early Access Release
	• Pluggable Interface for DDS Security plugins
	  • Based on OMG DDS Security specification
	  • Authentication, Access Control, Encryption, Logging

Mid 2018 General Access Release	• Connext DDS Micro release with small footprint security plugins. • Pursue wire interoperability with Connext DDS Pro & Connext DDS Secure • Support for X-Types (Extensible & Mutable Types, Optional Members)
Future Considerations	• Connext DDS Cert: ISO 26262 Functional Safety

Under Consideration	
Plugins	Tools
• Data Tagging	• XML Configuration

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Connext DDS Micro focus

- Robustness
- Galois formal verification
- Platforms (including ARINC 653)
- Performance & scalability lab

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More to come in 2017 and 2018

- Interoperable Security
  - 1.0 spec compliant
- Cloud/Fog Discovery Service
  - Run Connext DDS in cloud & containers
- System Designer
  - Web-based tool to design Connext DDS application
- OPCUA Gateway
  - Integrate Automation Systems
- New Tool Integrations
  - Matlab/Simulink, MagicDraw
- Recording Service 2.0
- Secure Micro

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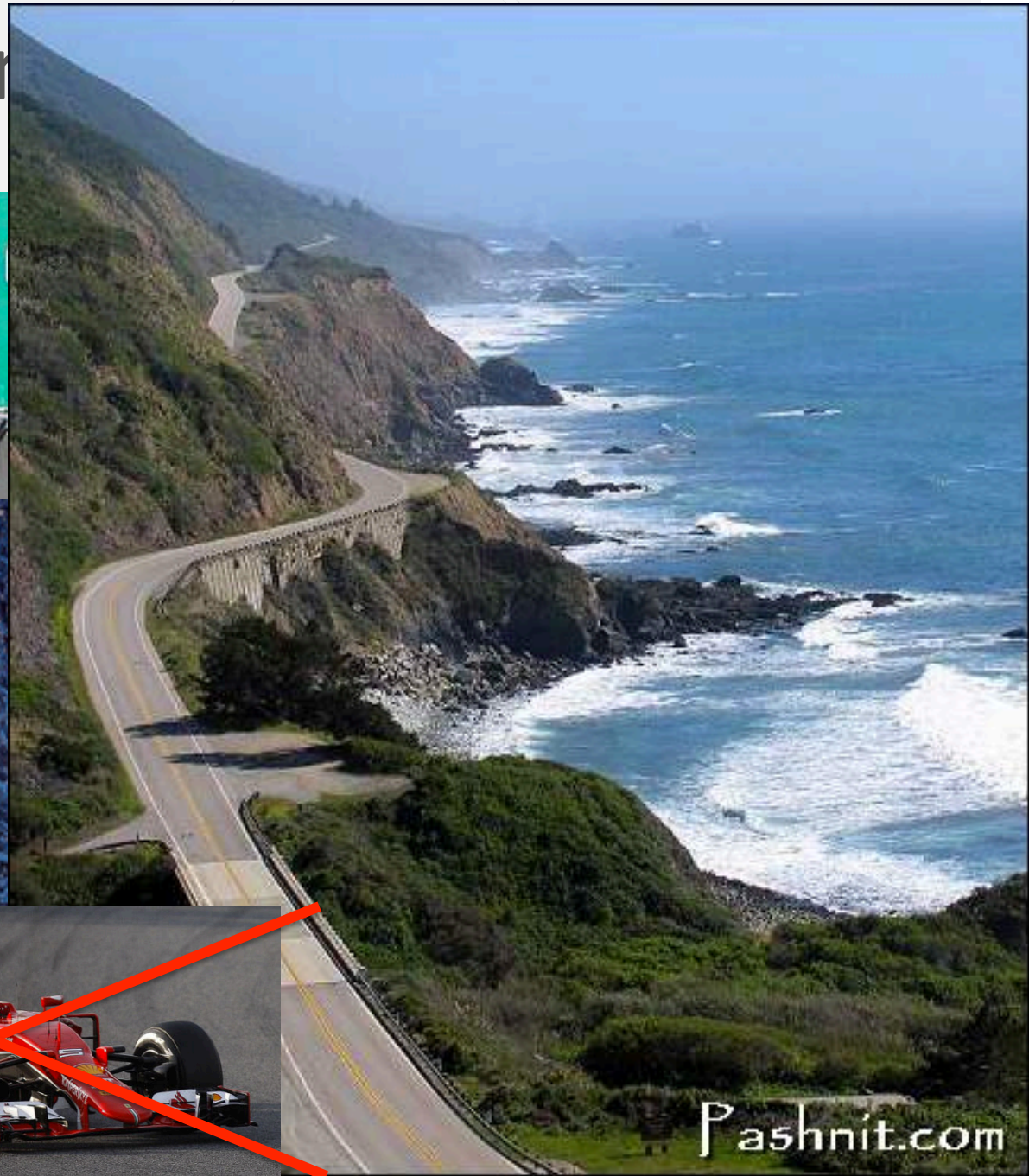
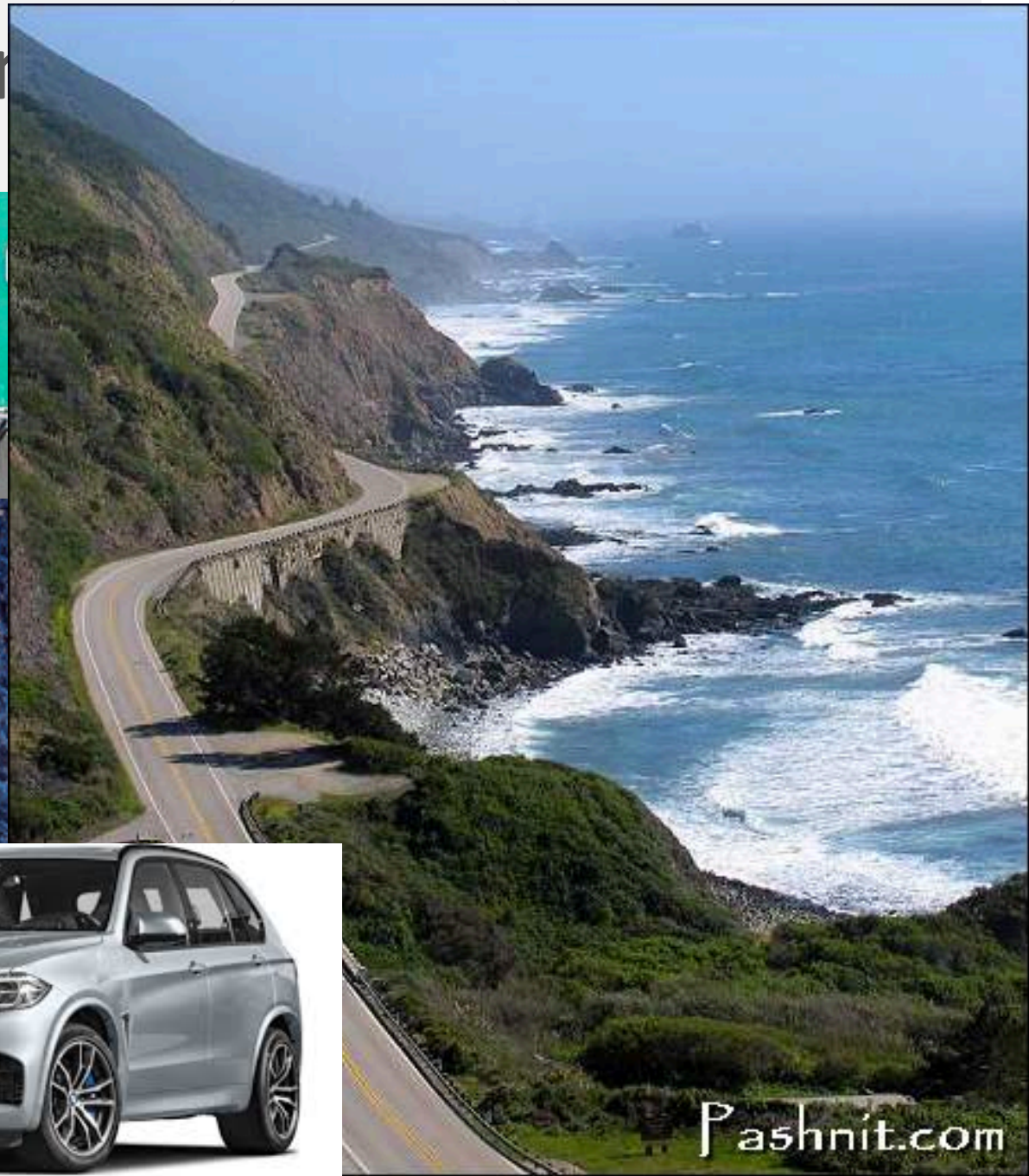
Robustness

Building the best platfor



Building the best platfor



Building the best platform

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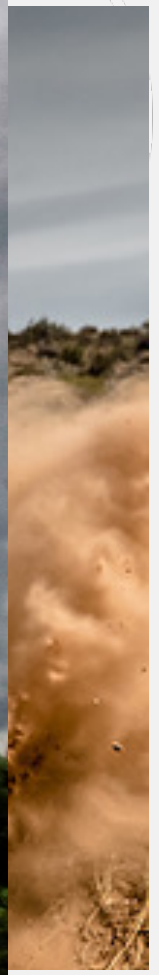
The kind of robustness our systems need



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Robustness

- Heap Monitoring
- Static Analysis
- Endurance Testing
- Continuous Benchmarking

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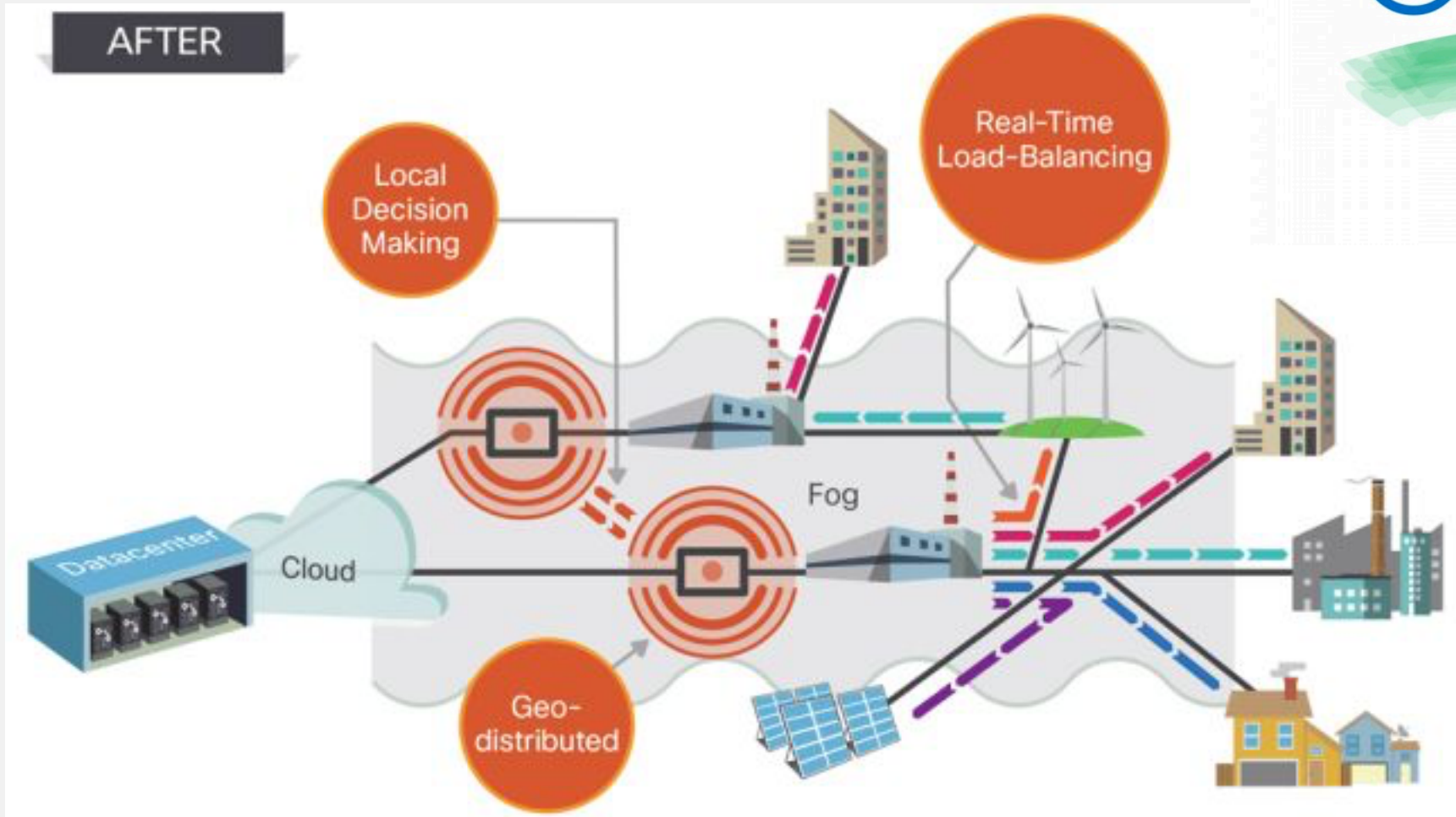
Trends

- Fog computing
- Containers
- TSN
- Integrated Tooling

Fog computing/deployments



OpenFog®

DELL

Microsoft

intel

CISCO

ARM®

PRINCETON UNIVERSITY

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Manage data close to the source

- Local Cloud
  - Performance/Scalability,
    - Leave it at the source as long as it is needed
    - Must combine with “push to central service”
  - Reliability/Availability, Policy
- Distributed caches
  - Ability to retained intermediate places
  - Enhancements to DDS Routing and Persistence

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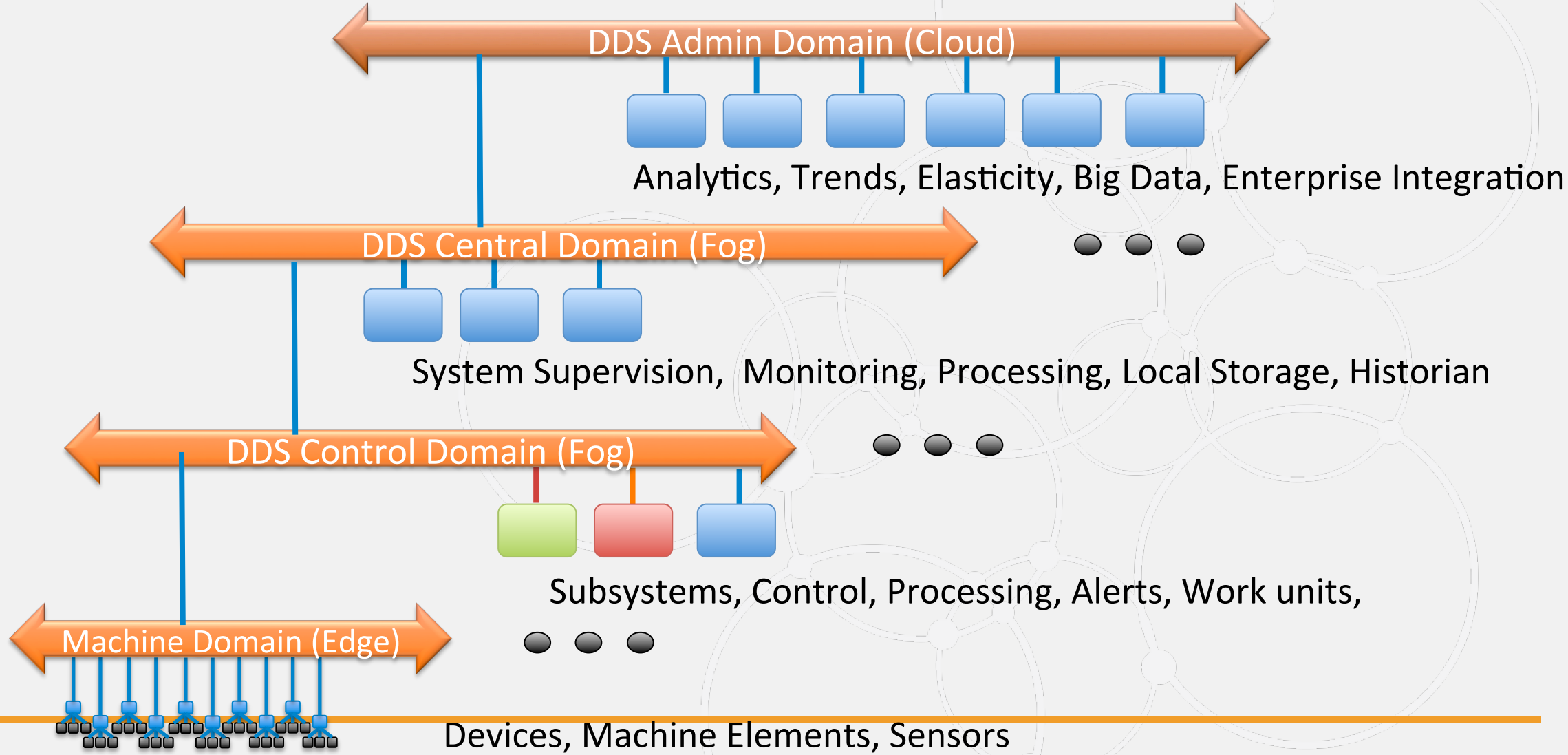
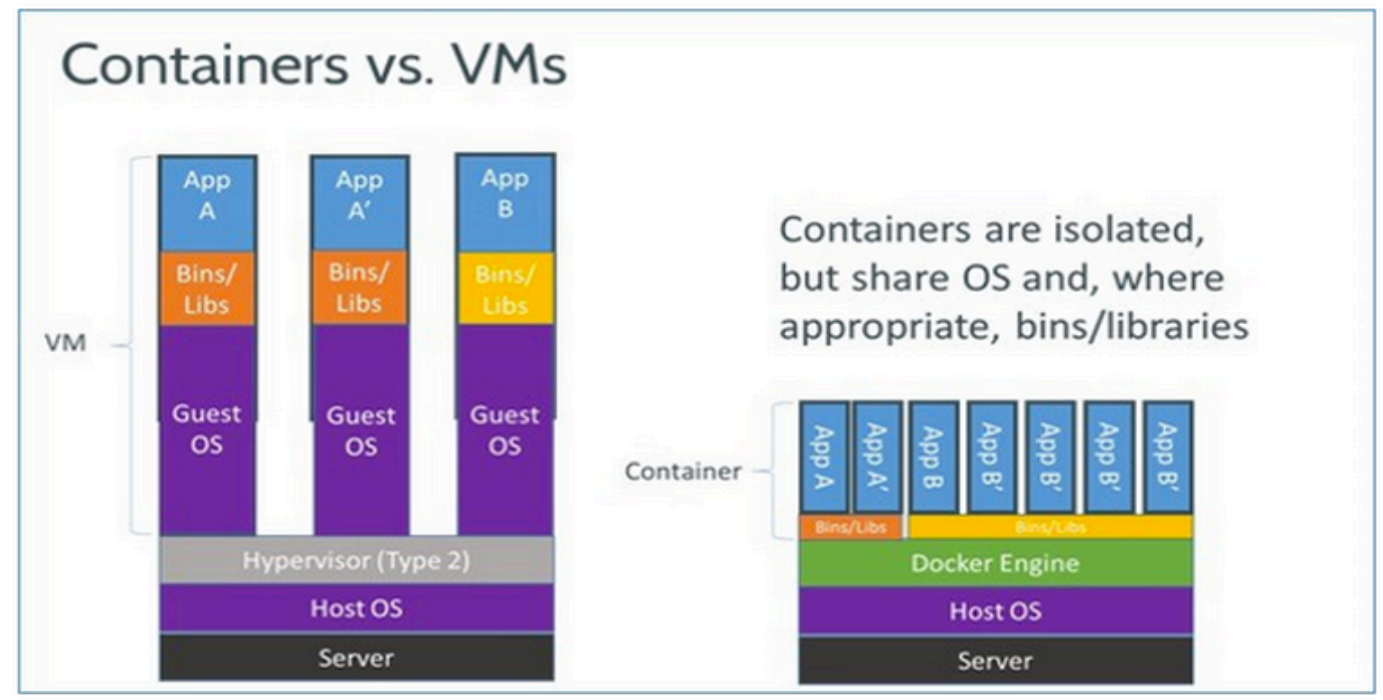
Layered Databus architecture required for Scalability



Virtualization & Light-Weight Container deployments

- Modularization
- Packaged App deployment
- Optimal transport
  - e.g. shared memory within host



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Time Sensitive Networks (TSN) real-time

- TSN is a new set of IEEE standards aiming to provide deterministic packet delivery on Ethernet
- Supported by the main Ethernet chip and switch vendors.
  - HW support be “bundled” into all new Ethernet PHY and Switches
- Converged Network
  - Critical data streams co-exist with regular traffic
  - Avoid the need for separate networks to achieve determinism
- Big driver is home Audio/Video
  - Industrial application piggyback to this trend
- Seeing adoption in Automotive and Machine/Engine control

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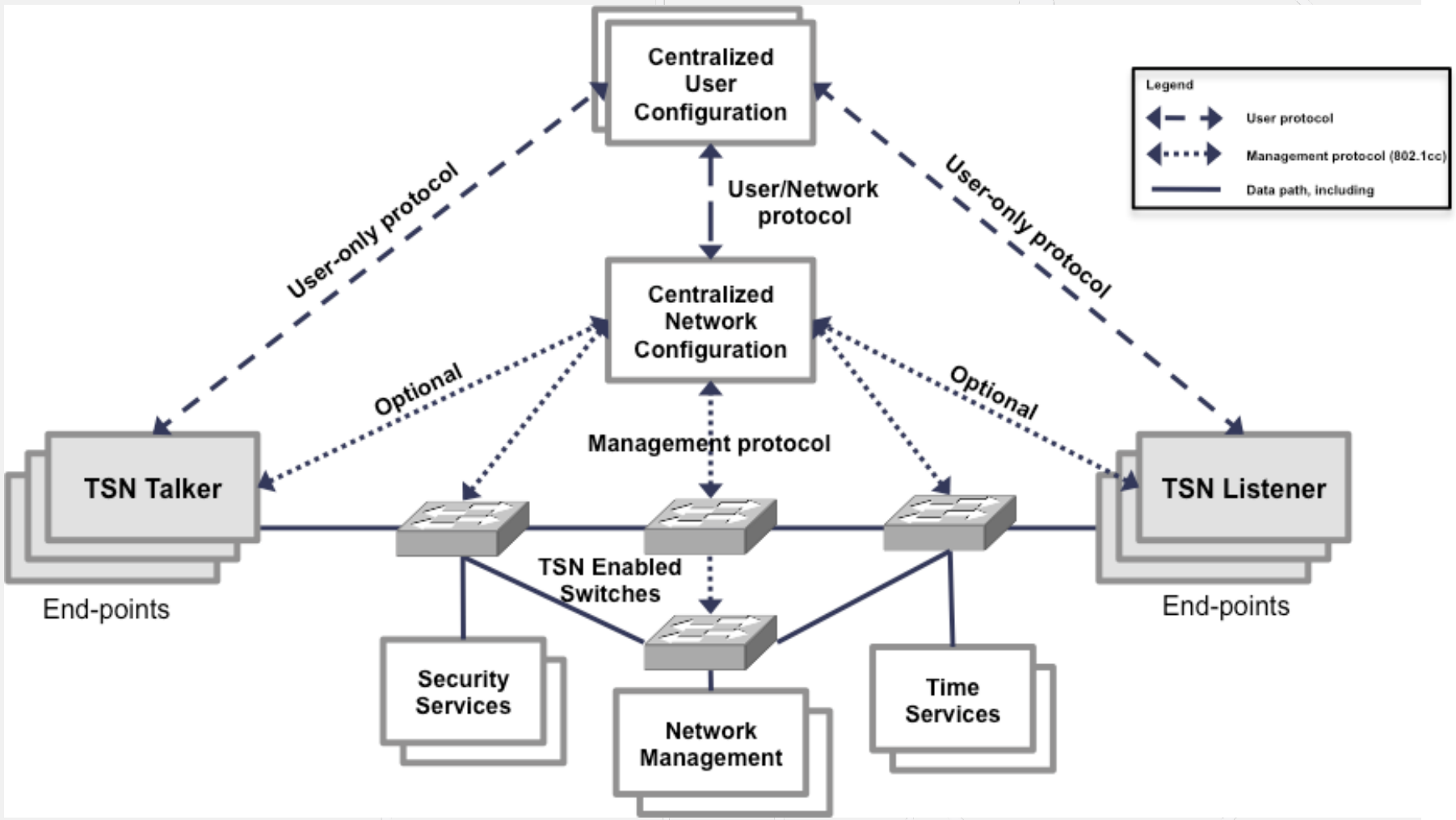
TSN Management/Control

- Configuration complexity
- Could be automated from DDS Qos



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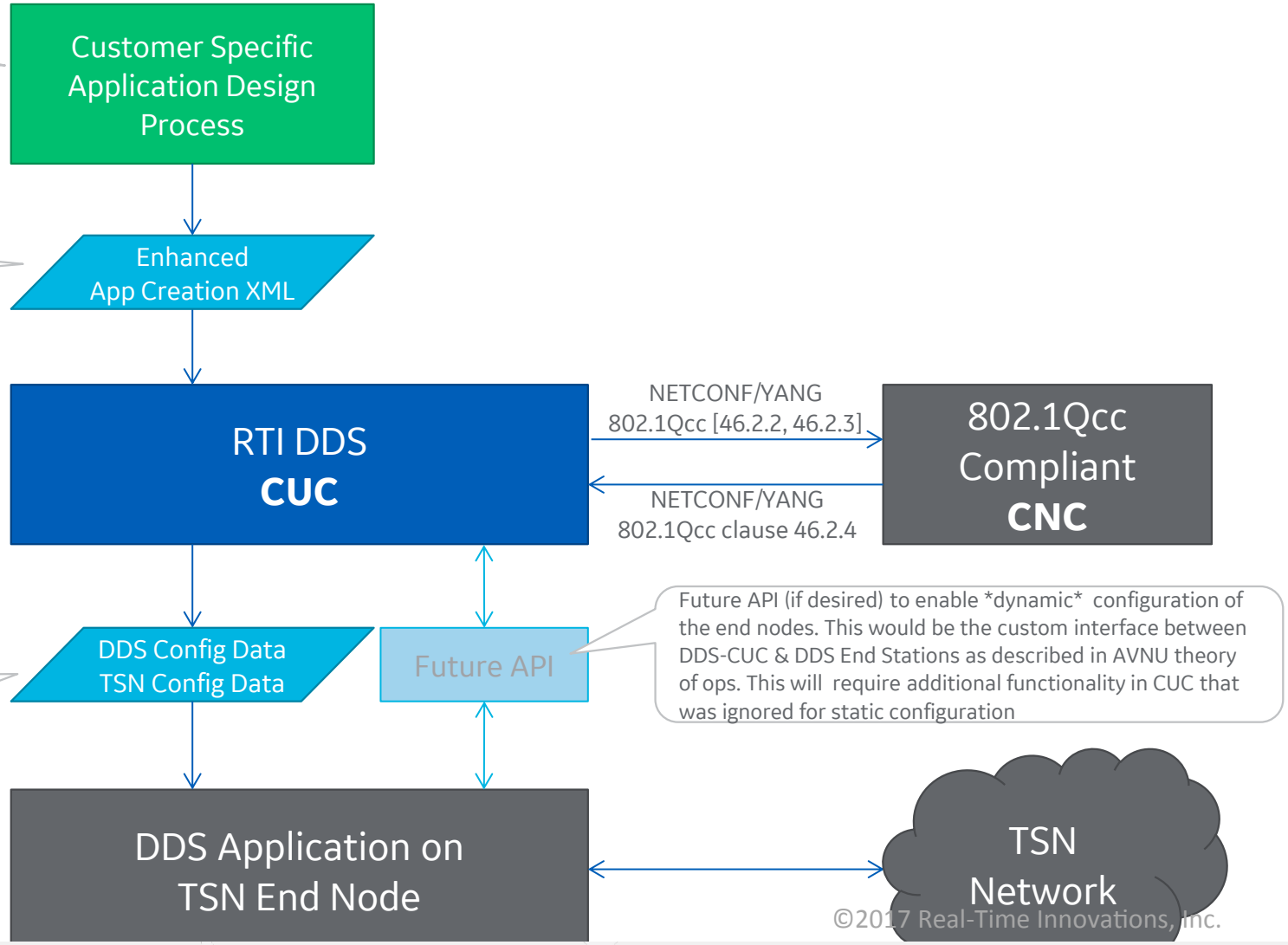
Approach

Customers may utilize RTI tools or some other proprietary design process to define topics, end points, QoS, etc. The end point identity could be based on some custom off-line topology model

In addition to DDS specific items(QoS, types, entities) this XML also specifies end point identity (e.g. MAC, IP address) and data characteristics (e.g. rate)

Proposed offline CUC: Based on the enhanced xml file, this block should be able to function as a standard CUC as defined in 802.1Qcc and further explained in AVNU theory of operations. Since it is an offline/static process, only key functionality (interactions with CNC as defined in 46.2.2, 46.2.3, 46.2.4) will be supported. Allows future upgrade for dynamic configuration

Static files to be loaded on the end node before run-time in an offline process
DDS Config Data: Represents the config needed for DDS application to adhere to design. This could simply be app creation xml from pervious step passed through with some modifications
TSN config data: Data Frame Specification and InterfaceConfiguration blocks received from CNC represented in YANG model with JSON/XML encoding



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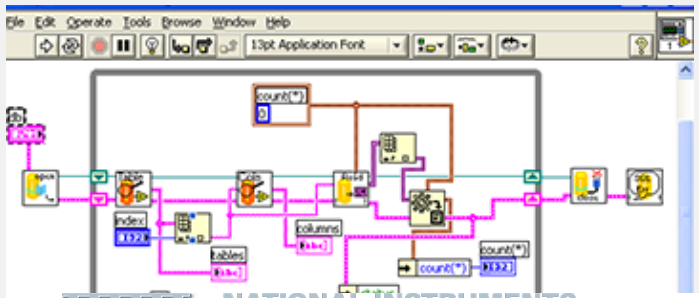
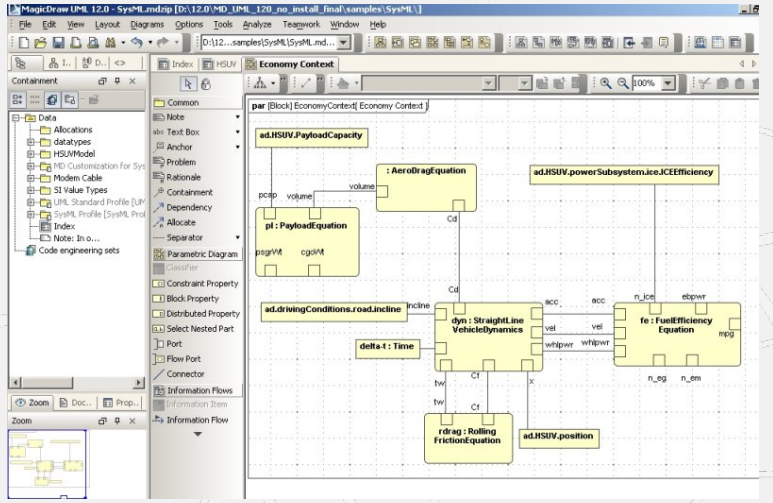
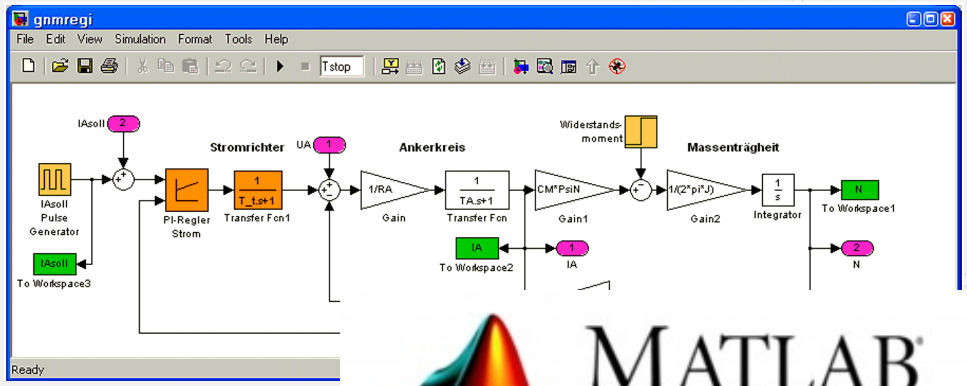
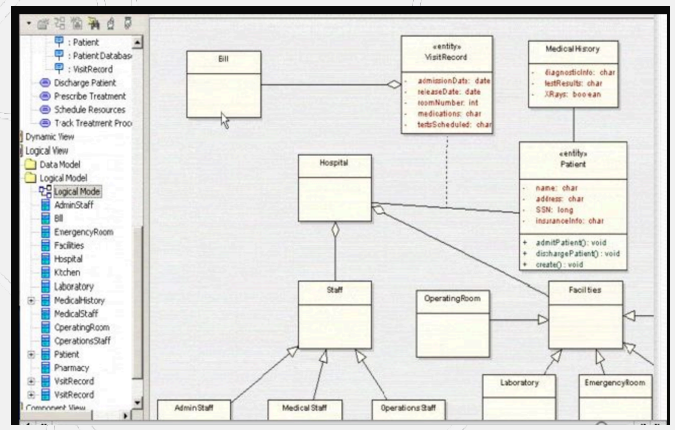
Integrating 3rd party tooling









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We are helping you meet the most critical application challenges

Thank You!