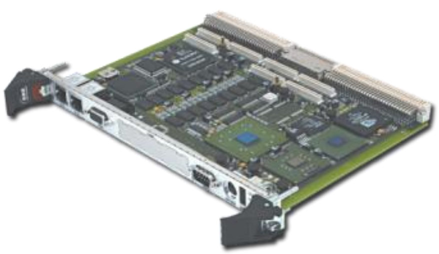
TWINOAKS COMPUTING INC.
PRACTICAL MIDDLEWARE EXPERTISE

Twin Oaks Computing, Inc.

How to Connect the Diverse Platforms of the IIoT

June 2015

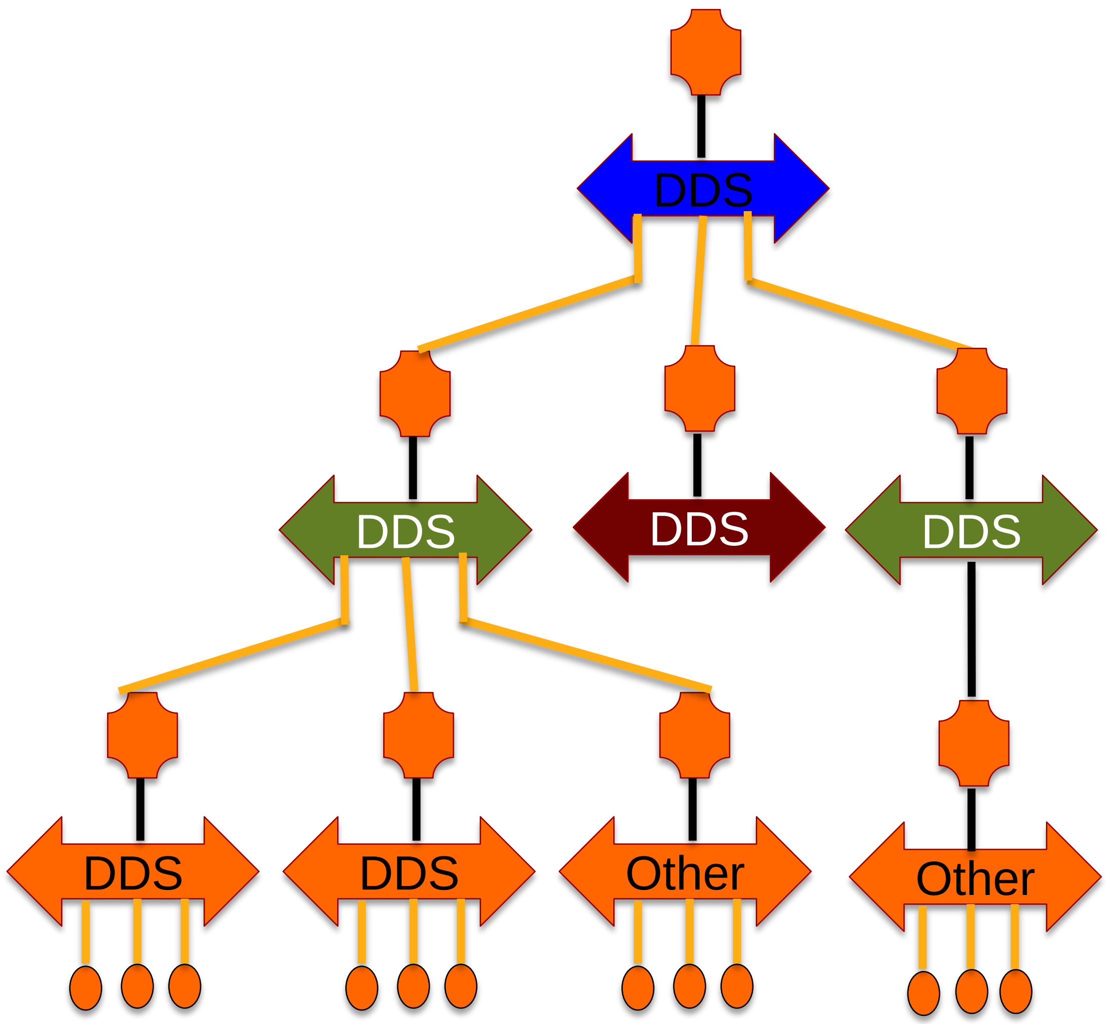


CoreDX™ DDS

Introduction & Agenda

- Nina Tucker, VP Twin Oaks Computing, Inc.
- DDS Platform Support, Interoperability
- DDS Protocol, Features
- DDS Performance, Scalability
- DDS and other IoT middleware technologies

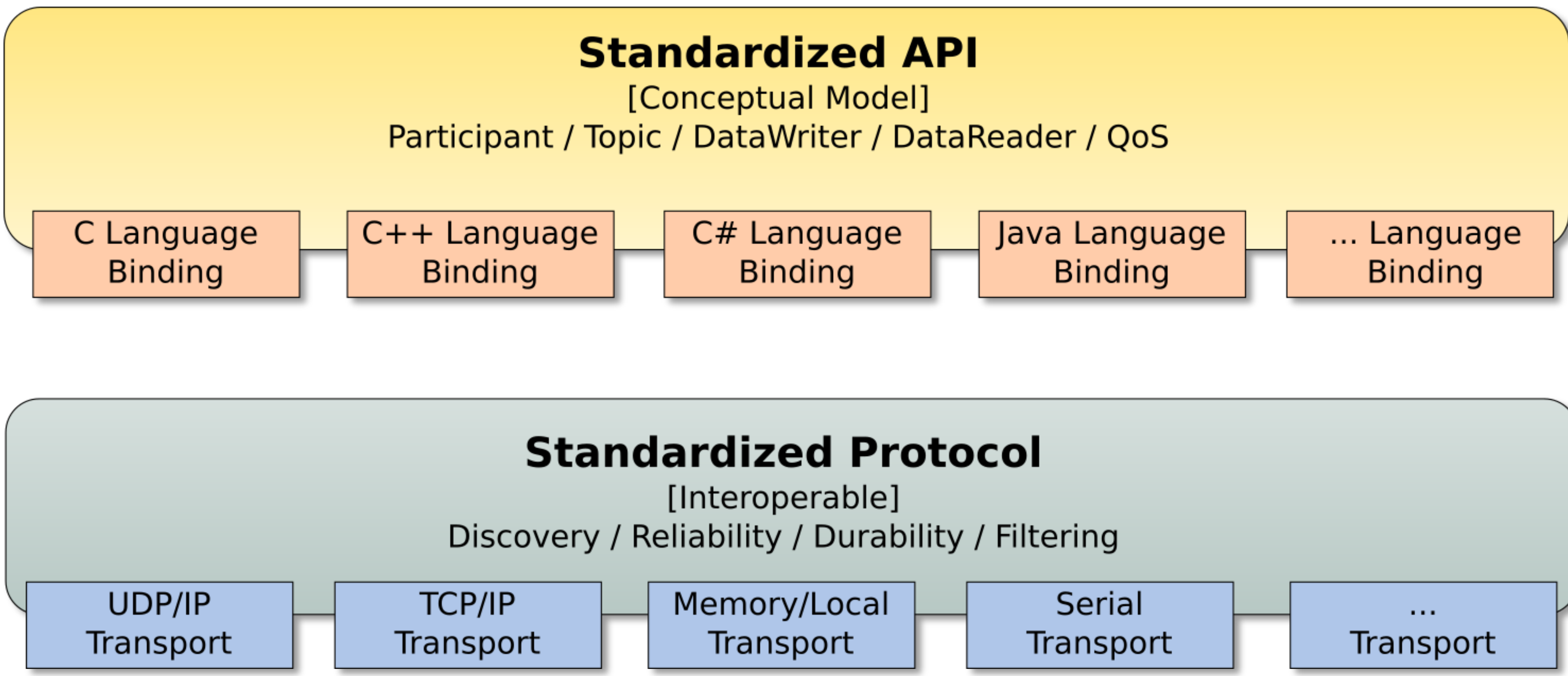
Typical IIoT Architecture



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

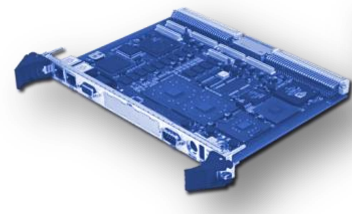
DDS Platform Support and Interoperability

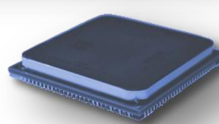
DDS Platform Support
Portable, Interoperable



DDS Platform Support:
Language, Platform, OS Support

- Languages:
  - C, C++, C#, Java, Ada, Perl, Scala
- Hardware Architectures:
  - x86 (32 & 64 bit), UltraSPARC, ARMv5, ARVMv7, PPC, MIPS, Microblaze, FPGAs, DSPs, PLCs
- Operating Systems:
  - Linux, Windows, Mac OSX, Solaris, QNX, VxWorks, NexusWare, LynxOS, INTEGRITY, Android, iOS, WinCE, Unison, ThreadX
- Transports:
  - UDP (Interoperable), TCP, Shared Memory, Local Machine, SSL, Serial, Zigbee, Backplane, RDMA





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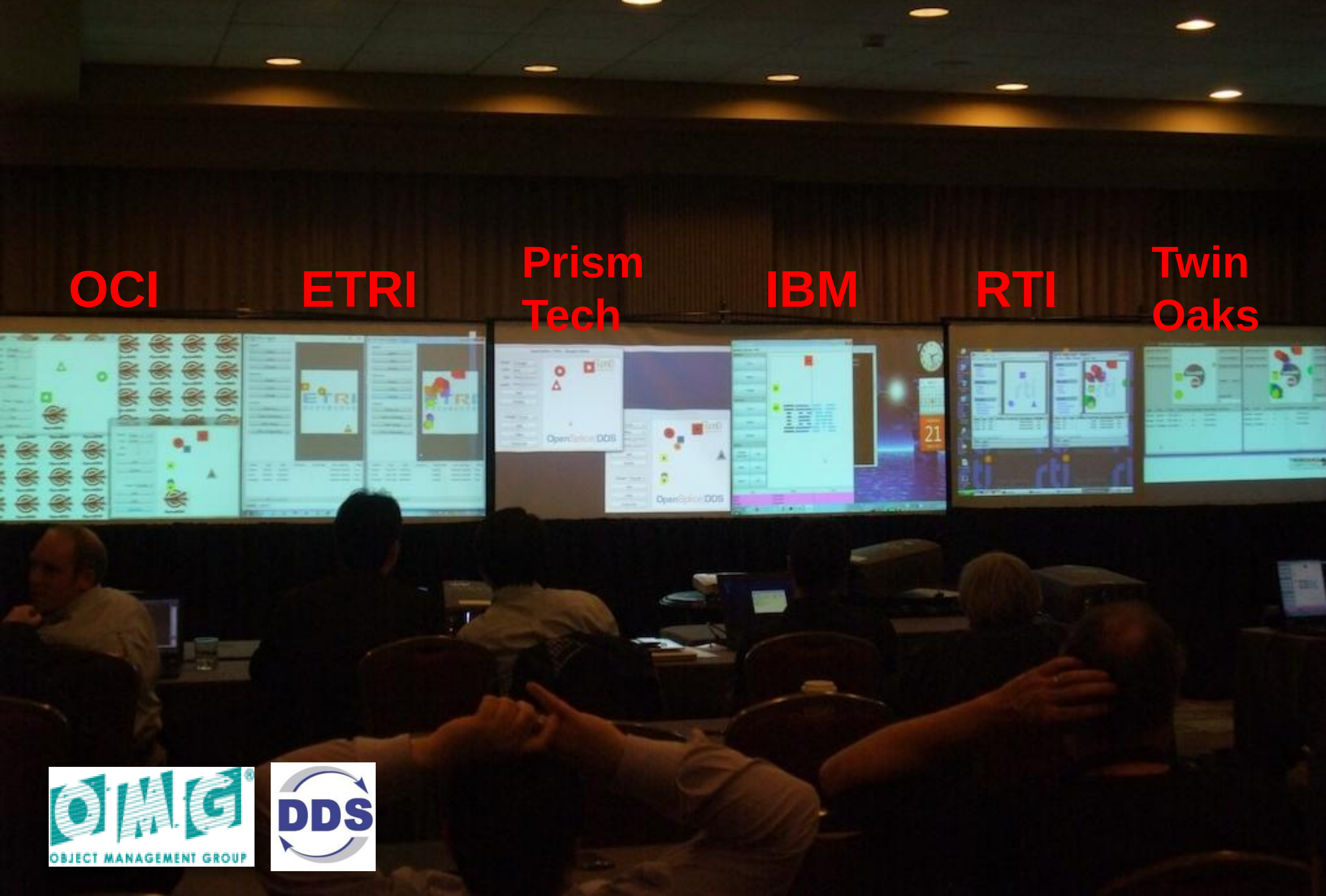
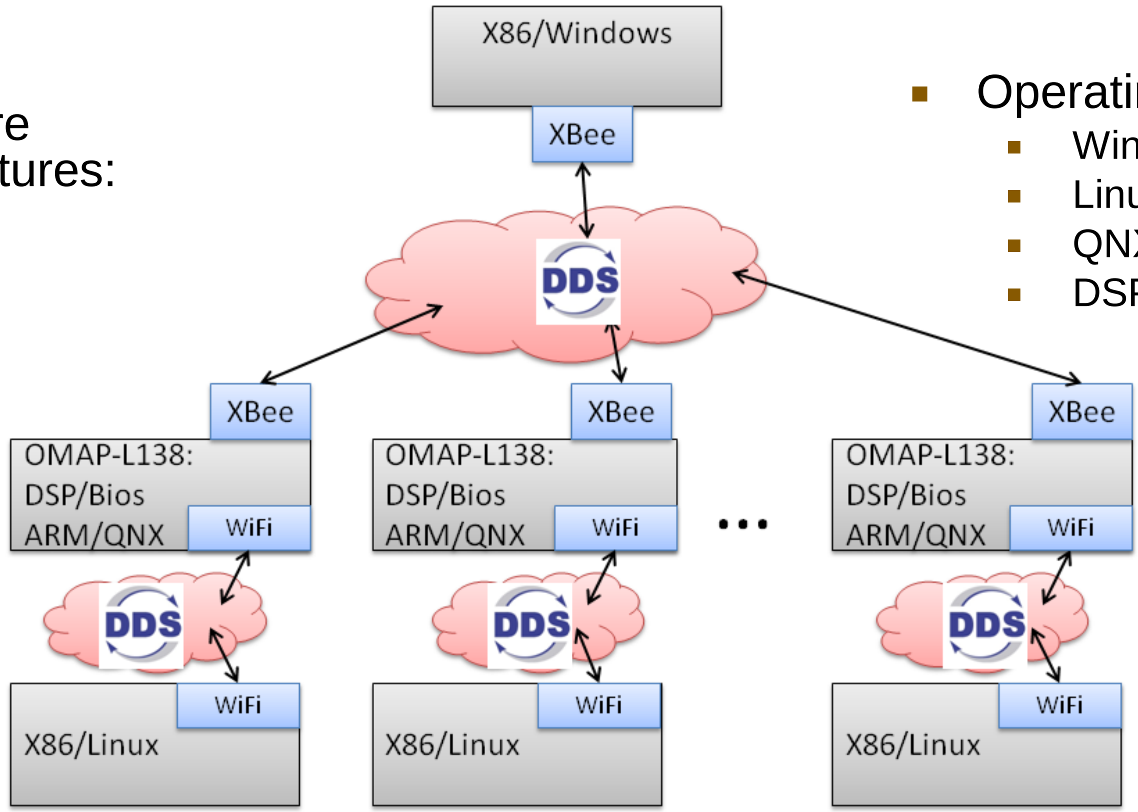
DDS Platform Support: Protocol Interoperability



Case Study:
Wearable Sensors & Mobile Relays

- Hardware Architectures:
  - x86
  - arm
  - DSP



- Operating Systems:
  - Windows
  - Linux
  - QNX
  - DSP Bios

- Transports:
  - UDP (Wifi, Wired)
  - Xbee

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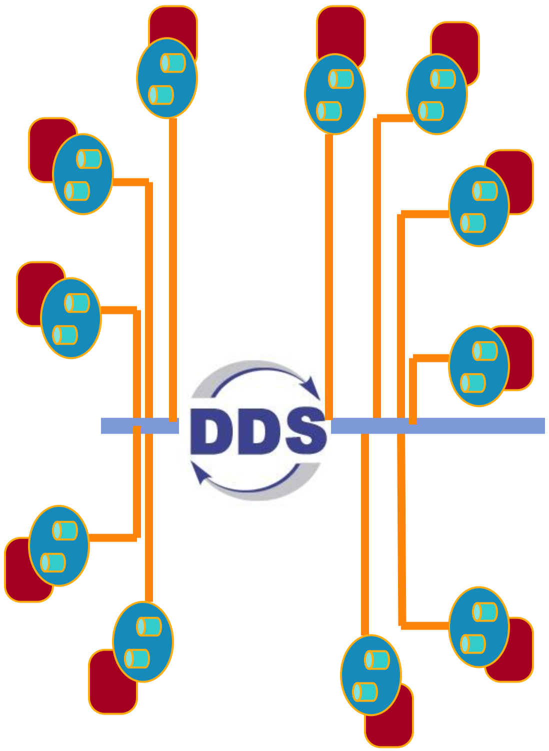
DDS Protocol and Features

DDS Protocol:
Features Optimized for IIoT

- Peer to peer no brokers or servers
- Adaptable QoS, including prioritization
- Reliable even over unreliable transports
- Any size data automatic fragmentation
- Automatic Discovery and Presence without configuration
- Decoupled execution start/stop apps in any order
- Redundant sources, sinks, paths, networks
- Efficient use of resources (network, CPU, memory)
- High performance near-native “wire” speeds
- Scalable no N^2 network connections
- Secure end-to-end communications



DDS Protocol Case Study:
Medical Device Domain

- Communication Requirements:
  - Components on **FPGA's** (embedded **RTOS**), Atoms (**Embedded Linux**), Desktop (**Windows**), Tablets (**Android, iOS**)
  - Networks: directly connected wired Ethernet, local area WiFi, Internet
  - Some very **low latency** requirements, some **secure** communication requirements, over different networks

- Benefits provided by DDS:
  - Code reuse among devices
  - Common API for sending and receiving data between distributed device components
  - Flexible architecture: ability to move software components to different devices late in the development cycle without schedule impacts
  - Ability to quickly and easily create test programs and emulators to emulate hardware components not yet available to developers (buttons, switches, lights on medical device)

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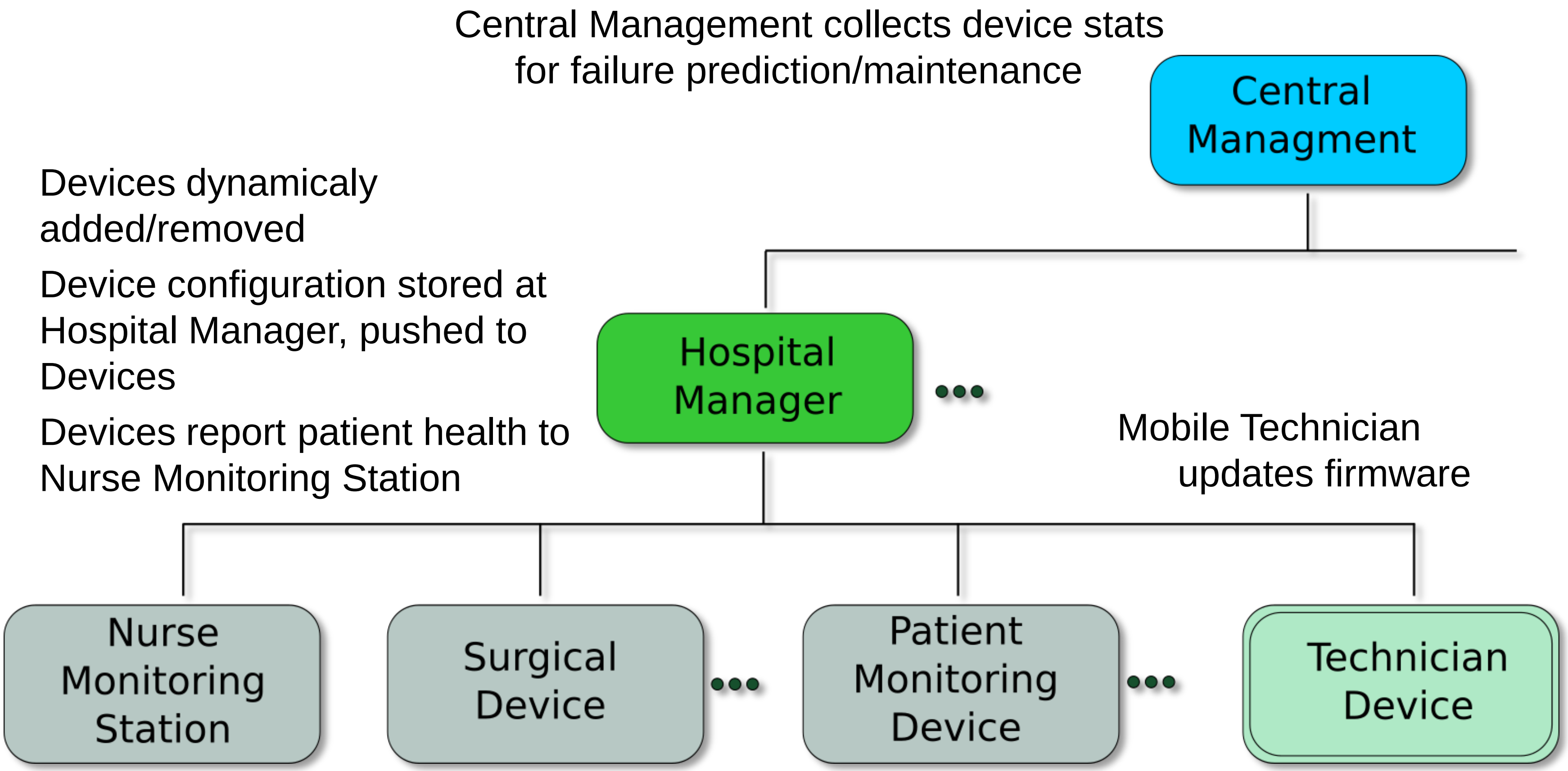
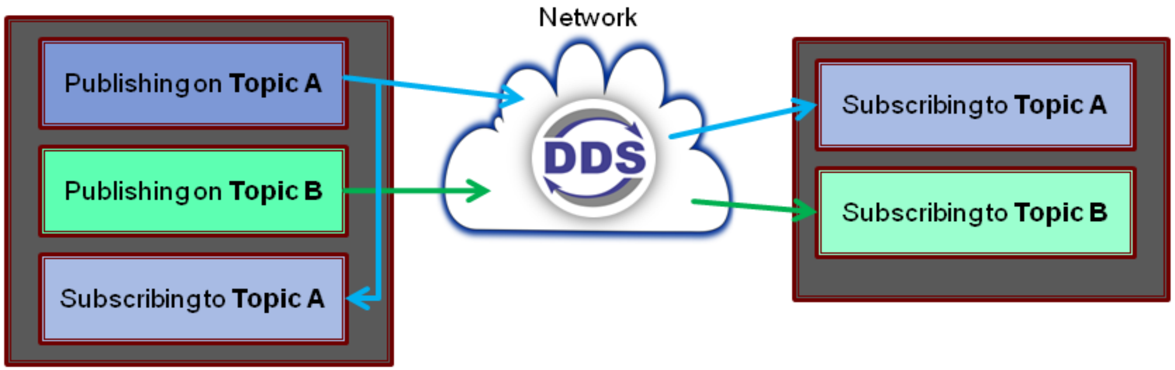
DDS Protocol Case Study:
Medical Device Domain

- Devices dynamicaly added/removed
- Device configuration stored at Hospital Manager, pushed to Devices
- Devices report patient health to Nurse Monitoring Station



DDS Protocol: Discovery and Liveliness

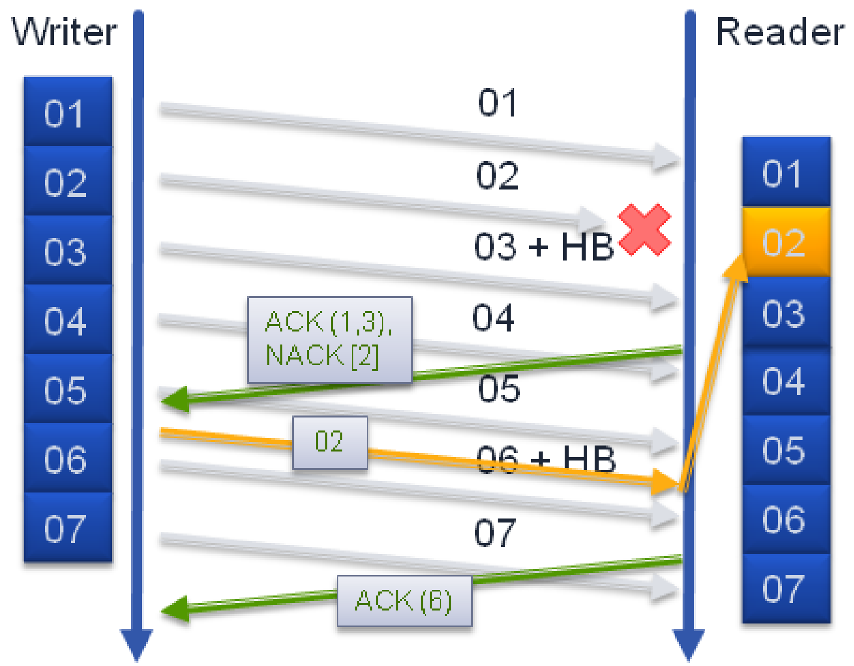
- DDS provides Dynamic Discovery of publishers and subscribers
  - Application does not know or configure DDS endpoints: they can be on the same machine or across a network
  - Simply indicate intent to publish or subscribe to data and let DDS do the rest



- DDS Liveliness manages existence of peers
  - Exiting cleanly or not
  - Coming back online

DDS Protocol:
Reliability

- Configurable **Reliable** data communications
  - Even on unreliable and intermittent networks
  - Using UDP (MULTICAST and UNICAST)
- DDS Reliability protocol Addresses
  - Dropped Packets
  - Out of Order Samples
  - Communication Disconnects
  - Application Re-Starts



DDS Protocol:
Durability

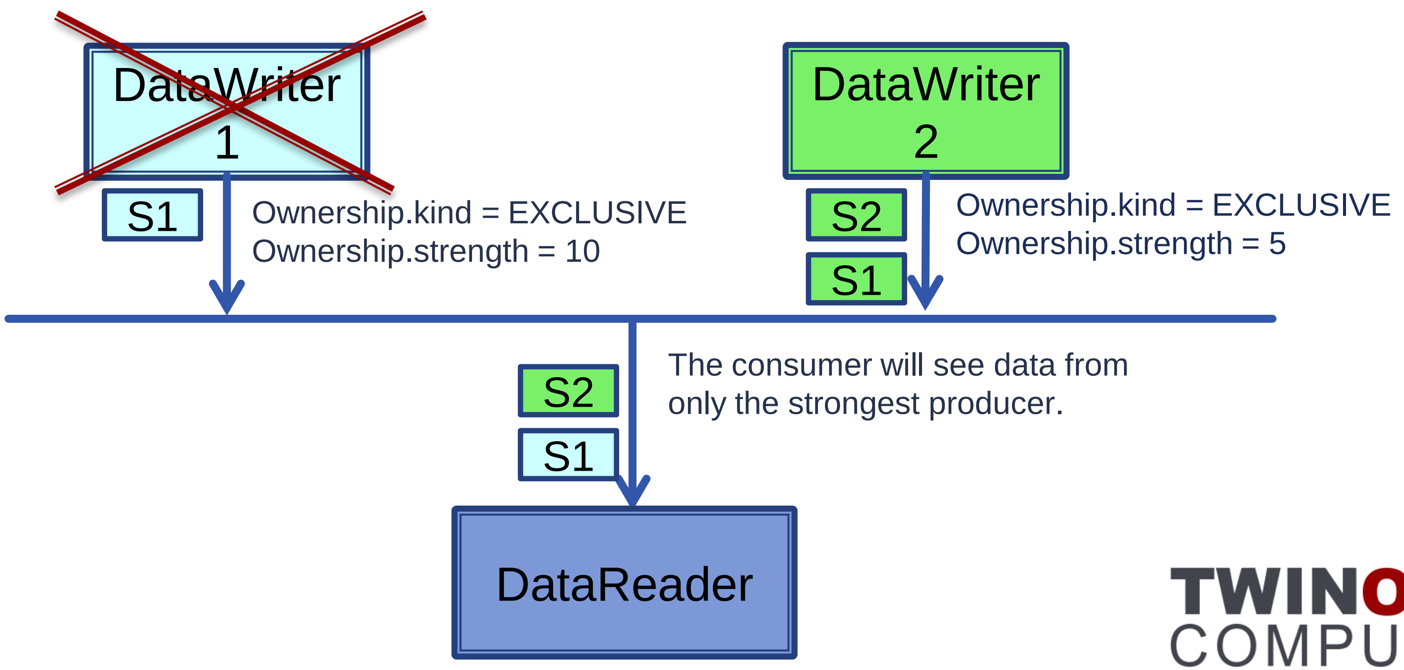
- DDS provides configurable **Durable** data communications

- DDS Durability addresses
  - How long data is published saved
  - If previously published data is sent to ‘late joining’ DataReaders

- Durability Options
  - Volatile: Published data is saved just long enough to be sent to currently matched Readers
  - Transient Local: Published data is saved for as long as the Data Writer is alive (until application exit)
  - Transient, Persistent: Published data is saved by an external service, through application restarts, machine reboots

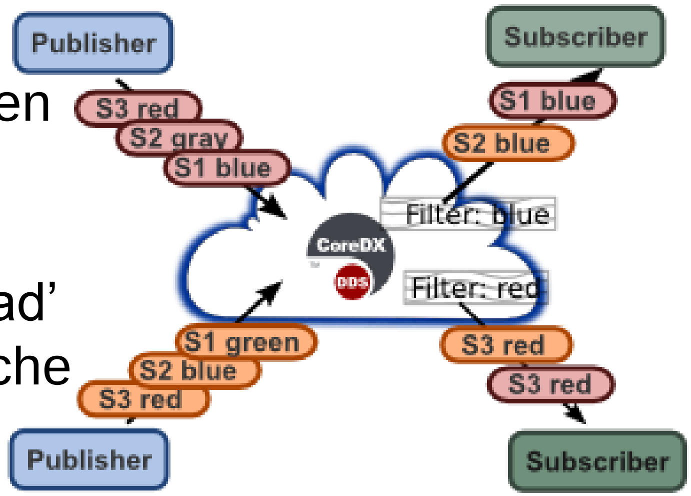
DDS Protocol:
Redundancy / Failover

- DDS provides configurable **redundancy** of published data
  - Subscribers receive one copy of data, even when multiple publishers are publishing (duplicate) data.
  - Publishers can fail, and subscribers will automatically receive data from remaining, active publishers



DDS Protocol:
Data Filtering

- Kinds of Filters:
  - Content Filters are specified by an SQL-like query
    - Same syntax as the “WHERE” clause in an SQL query
    - Filters can be applied at Reader or Writer
  - Time Based Filters are specified by a duration for minimum separation between samples
  - Read Filters allow the application to ‘read’ specific kinds of data from the Data Cache
    - Previously seen / Not seen
    - New data / Old data
    - Alive / Dead
    - Matching a content-based query



DDS Performance and Scalability

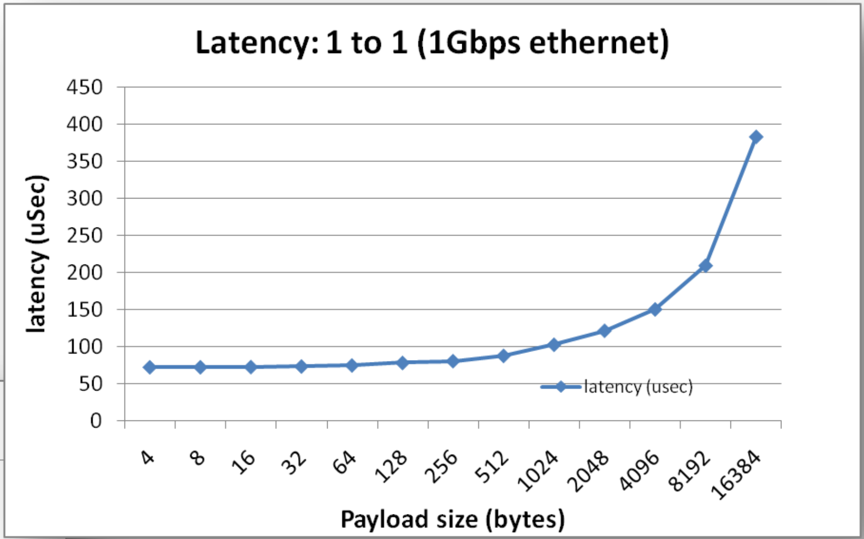
DDS Performance
Protocol Characteristics

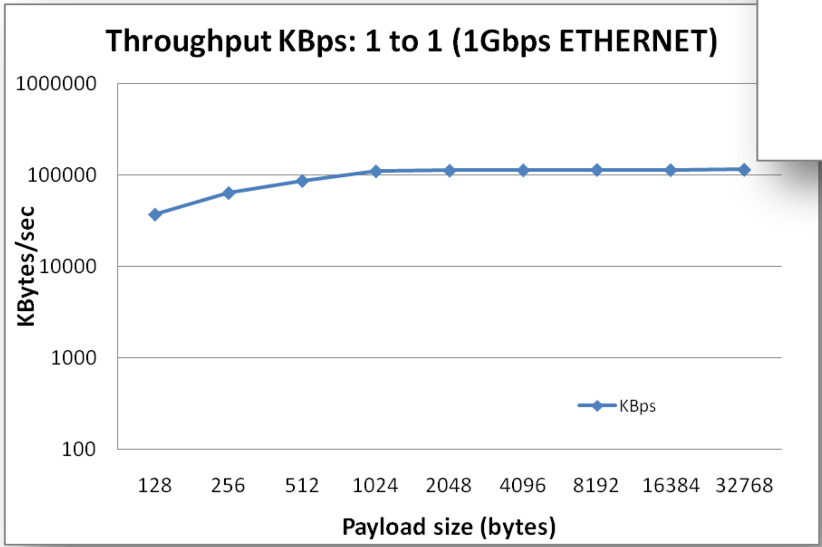
- DDS Specification written for near real-time and real-time systems
    - Specifies minimal data copies
        - Buffer loaning
    - Specifies compact encoding on the wire
        - Reducing bytes on the network
    - Specifies light-weight notification mechanisms
        - Asynchronous and Synchronous options available
    - Data types are specified at compile time
        - Allows optimized: marshalling, filtering, searching
    - Specifies UDP multicast (best effort and reliable protocols)
        - Reduced network overhead
        - High performance scalability
    - Intermediate brokers are not required
        - Allows direct peer-to-peer communications

DDS Performance: Network

Typical DDS Latencies:
50 – 200 microseconds

Typical DDS Throughput:
500 – 950+ Mbps





Typical DDS Stats:

100,000+ individual messages delivered per second – **to one subscriber!**

Multicast increases these numbers

Batching increases these numbers

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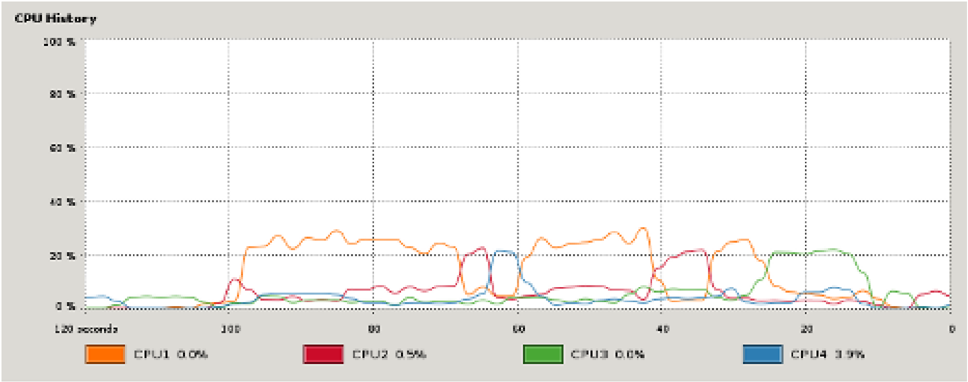
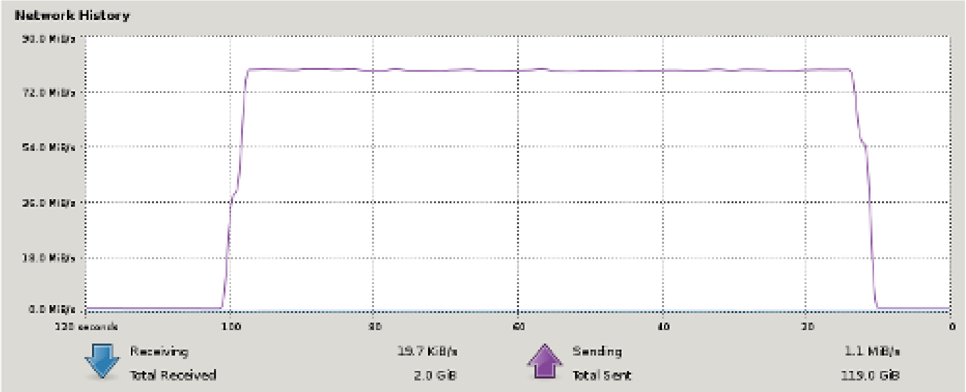
DDS Performance: CPU

Long running throughput test

- TX1024 byte messages
- Total throughput of over 700 Megabits/sec
- CPU utilization of a single core
  - doesn't exceed 30%
- With 4 cores, this equates to less than 10% of total CPU





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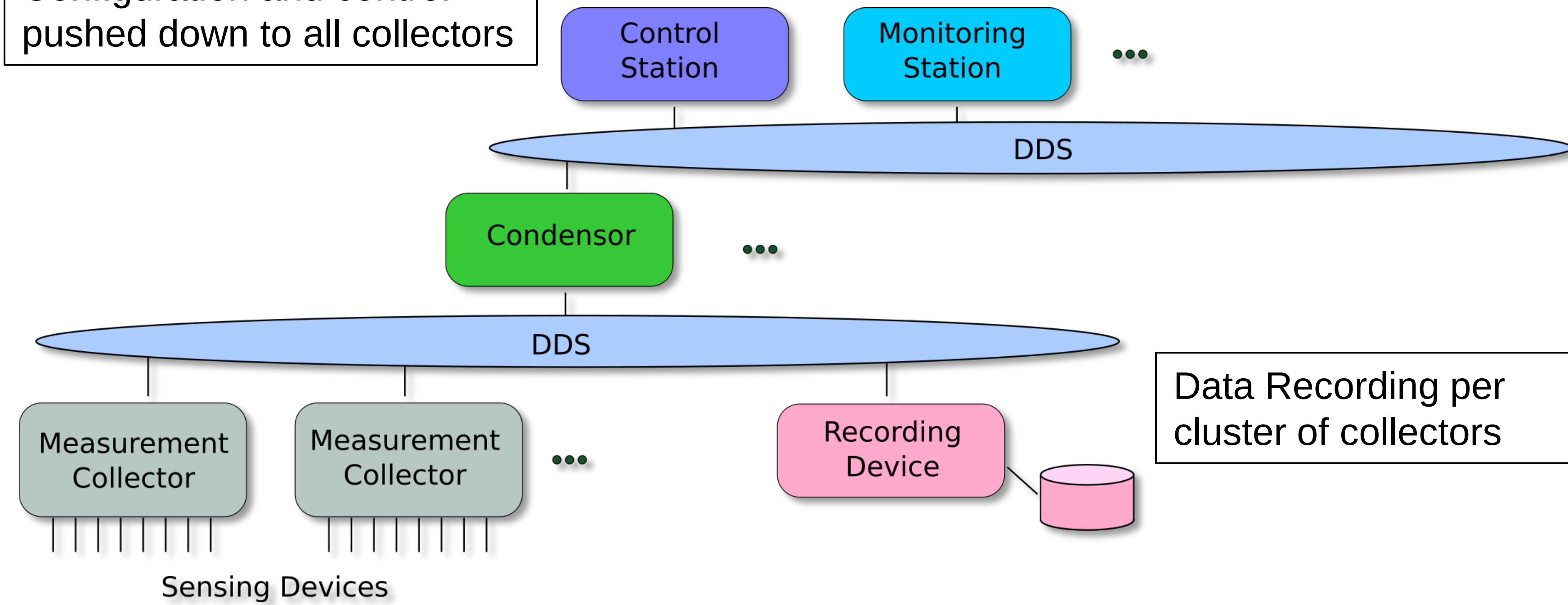
DDS Scalability Protocol Characteristics

- Scalability across all aspects
  - Network nodes, participants, topics, data instances
- Writer-side filtering
  - Only data of interest is sent on the network to the reader
- Unicast Scalability
  - Efficient UDP-based protocol with shared sessions
- Multicast Scalability (including reliability)
  - NACK-only reliability

- Additional tools to help manage large DDS networks
  - Bridging Tools: Extend DDS communications across multiple physical and logical network
  - Federation (data, discovery): Consolidate connections to reduce network, CPU, and memory usage for large numbers of DDS Entites

DDS Scalability Use Case:
Industrial Test Environment

Configuration and control pushed down to all collectors



Data Recording per cluster of collectors

15,000 total sensor measurement points
100-200 Hz update rate per measurement

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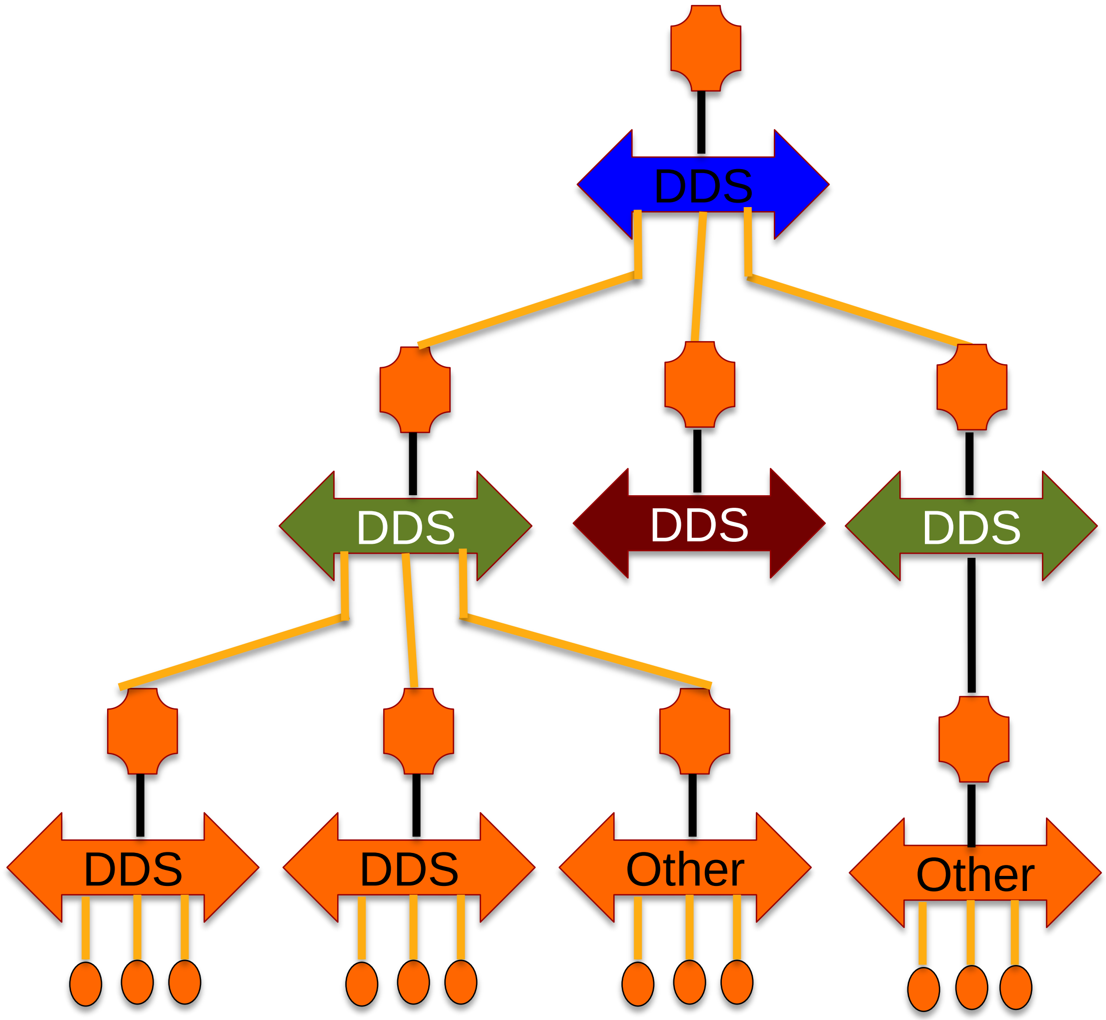
Comparing
DDS and other IoT Technologies

	DDS	MQTT	AMQP	RESTful HTTP	CoAP	ZeroMQ
Designed for	Controlling & monitoring cyber-physical systems	Connecting remote devices to IT systems (telemetry)	Enterprise messaging (IT systems)	Serving web content	REST on constrained devices and networks	Socket-like high-performance messaging API
Peer-to-peer	✓			✓	✓	✓
Flexible Transport Protocols	✓				✓	✓
Publish/subscribe	✓	✓	✓		F	✓
Reliable multicast for scalability	✓					✓
Real-time QoS	✓					
Dynamic Discovery	✓					
Security built into the protocol	✓					

	DDS	MQTT	AMQP	RESTful HTTP	CoAP	ZeroMQ
[illegible] jitter	✓			✓	✓	✓
Support for latency-controlled transport protocols (such as UDP rather than TCP)	✓				✓	✓
Shared memory transport for efficient intra-node messaging	✓					
Publish/subscribe for efficient delivery of cyclic updates and low-latency delivery of asynchronous events	✓	✓	✓		F	✓
Pub/sub over multicast for low-latency broad data distribution	[illegible]					[illegible]
Reliable multicast for critical data and commands	✓					✓
Missed deadline notifications for hard real-time apps	✓					
Control over latency/throughput tradeoffs	✓					
Network and CPU efficient serialization (minimal run-time metadata)	✓					
Support for Resilient and Mission-Critical Systems						
No single point of failure or failover	✓			✓	✓	✓
Publish concurrently over redundant networks	✓					
Automatic failover between redundant publishers	✓					
Real-time notification when endpoints join or leave	✓					
Decoupled (islanded) subsystems continue to operate independently	✓			✓	✓	✓
Reconnected components/subsystems automatically synchronize state	✓					
Support for Deployment at Edge and Autonomy						
No centralized services to deploy or manage	✓			✓	✓	✓
Automatic discovery for zero configuration	✓				✓	
Communicate over unreliable networks (best effort)	✓	MQTT-SN only			✓	
Communicate reliably over unreliable networks	✓	MQTT-SN?			✓	
Support non-IP networks (e.g., radio, satellite)	✓	MQTT-SN?			✓	
Send data simultaneously over multiple transport protocols and networks (e.g., intra-machine, LAN and WAN)	✓					
Filter unsubscribed data at publisher to minimize network overhead	✓				✓	
Security						

DDS Connects
Diverse Platforms of the IIoT



DDS:

- Standardized platform support and interoperability
- Advanced protocols to support d2d, d2c, c2c communications
- Performance and Scalability to meet IIoT requirements

Twin Oaks Computing: Background

- Headquartered in Colorado, USA
  - World Wide Deployments
- Highly experienced executive and technical teams
- Background in embedded communication technologies
  - DDS, RTPS
  - Networking protocols
  - Device drivers
  - Embedded computing environments
- Creator of the World Leading Middleware for Safety Critical Systems: CoreDX DDS
  - Commercially Available since 2008
  - Fully Interoperable and Standards Compliant since 2009
  - 750,000+ deployments

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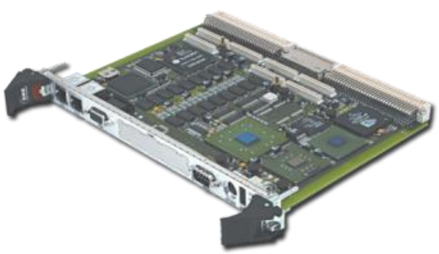
Questions?



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