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Real-time Data Distribution for Airborne Systems

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Agenda

- IMA approach, an ARINC & APEX Overview
- APEX Communication system analysis
- What could DDS bring to ARINC platforms
- Challenges and initial results
- Conclusion

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IMA approach, ARINC & APEX Overview

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Aerospace Technological Trends

- The all-IT on board reality
  - More computers, Entertainment units, Visual displays …
- Pressure on Development cost
  - A need for COTS certified software platforms for avionics
  - Taking full advantage of the HW horsepower increase
  - Shrinking Development/Certification cycles
- Pressure to increase on board safety
- Pressure to increase aircraft payload

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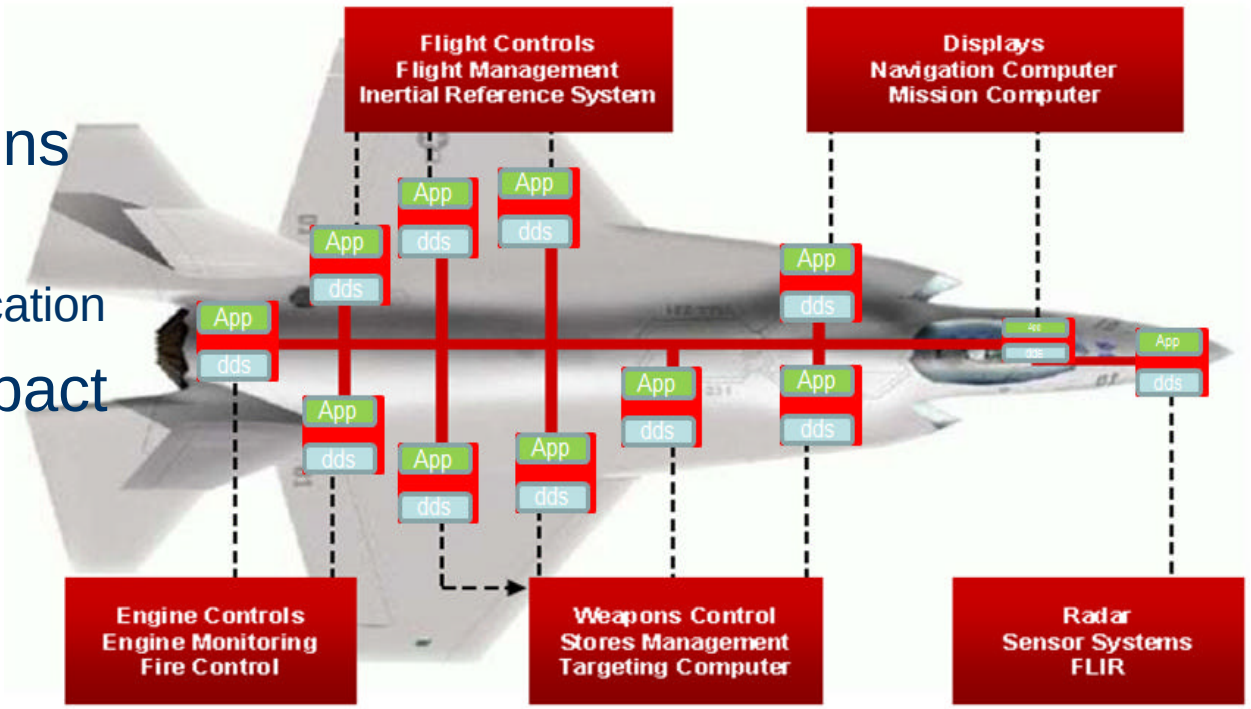
Federated Approach principals and impacts

- Increase safety by segregating and reinforcing applications isolation
  - e.g. 1 board **?** 1 Application
- Increase cost and impact system performance
- Make HW integration more complex
- Don't take full advantage of the HW computational resources and multi-core architectures



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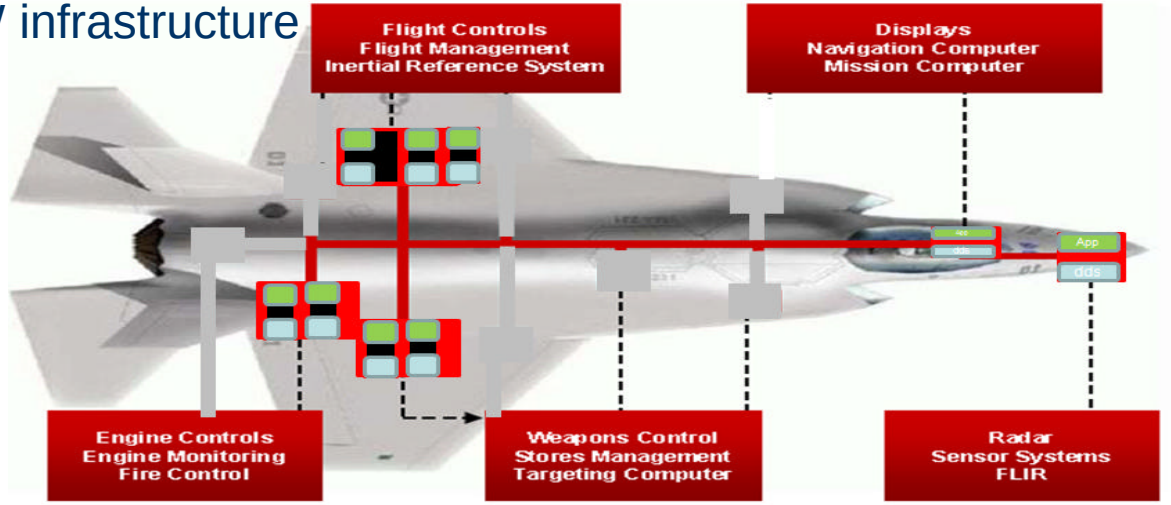
Integrated Modular Avionic Approach principals and impacts

- IMA goals
  - Move to more system integration with no compromise on safety and performance
  - Ease system Validation and Certification
- Pros
  - Make HW and SW integration and certification easier and less expensive
  - Foster SW Modularity, Reuse and Portability.
  - Increase Fault-tolerance by fostering N-modular redundancy
  - **Reduce Weight, Wiring in the aircraft , Power consumption**
- Cons
  - SW integration more complex unless carefully thought and well handled by SW infrastructure



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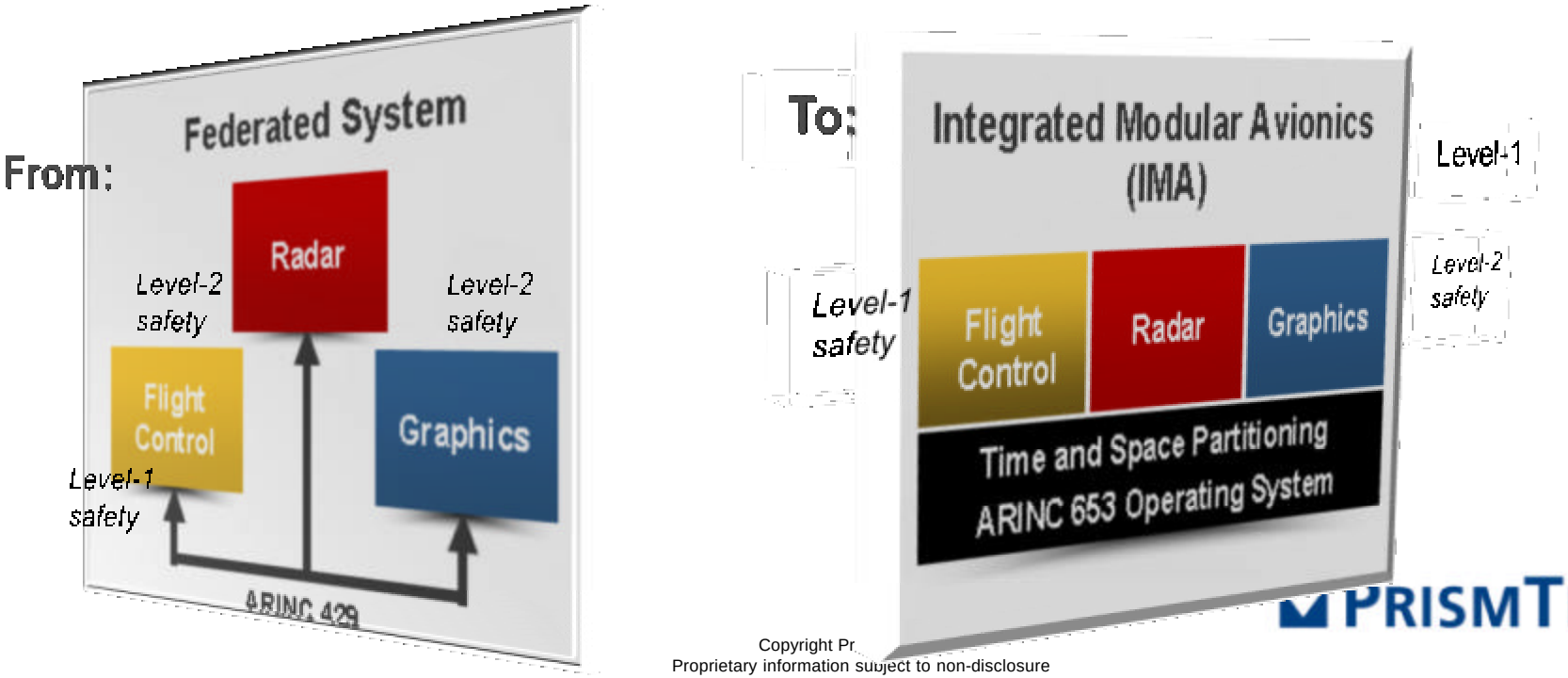
Aeronautical Radio INC 653, toward more integration

- **ARINC 653 is the industry specification for Integrated Modular Avionics**
- Re-enforce application isolation through computational environment Partitioning
  - OS partition can be seen as VM-Ware with its own execution environment
  - Partitioning in space and time
- **ARINC 653 OSs and applications are typically certified per DO-178B**



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APEX overview and Communication, System Analysis

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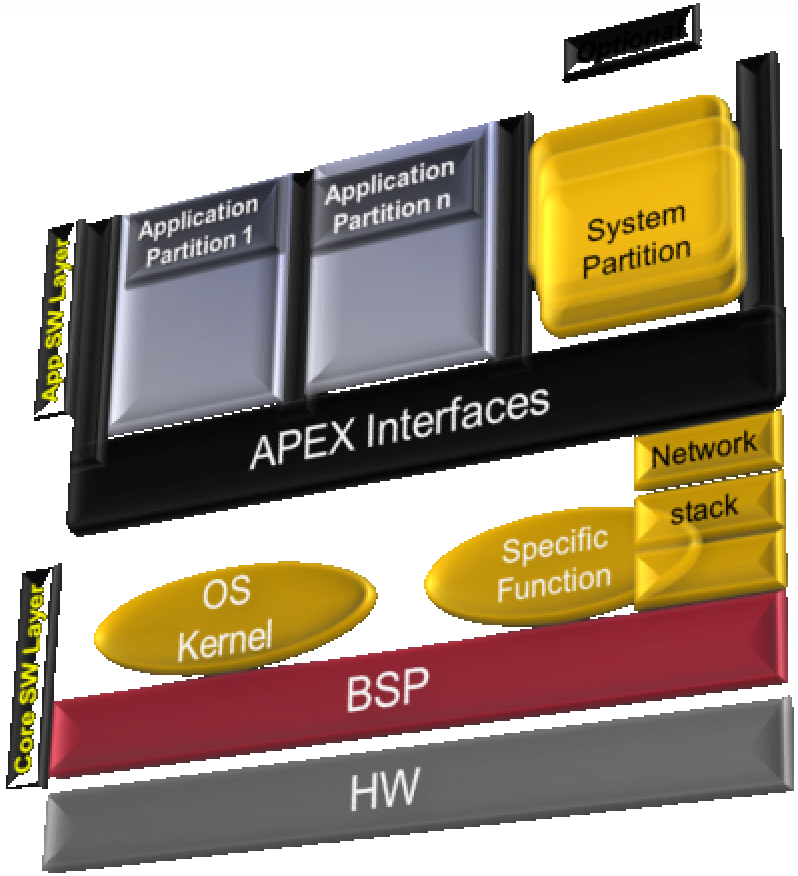
ARINC 653 Framework architecture

- Primary objective: definition of a G.P **APplication EXecutive** APIs to push toward GPP computers for avionics

- **APEX**: Interface between an avionics computer OS & the embedded application SW
  - Defines a set of OS facilities & Services
  - Fosters Aircraft to Aircraft SW portability to minimize recertification effort
  - Supports of different safety levels modules coo-running on the same core.



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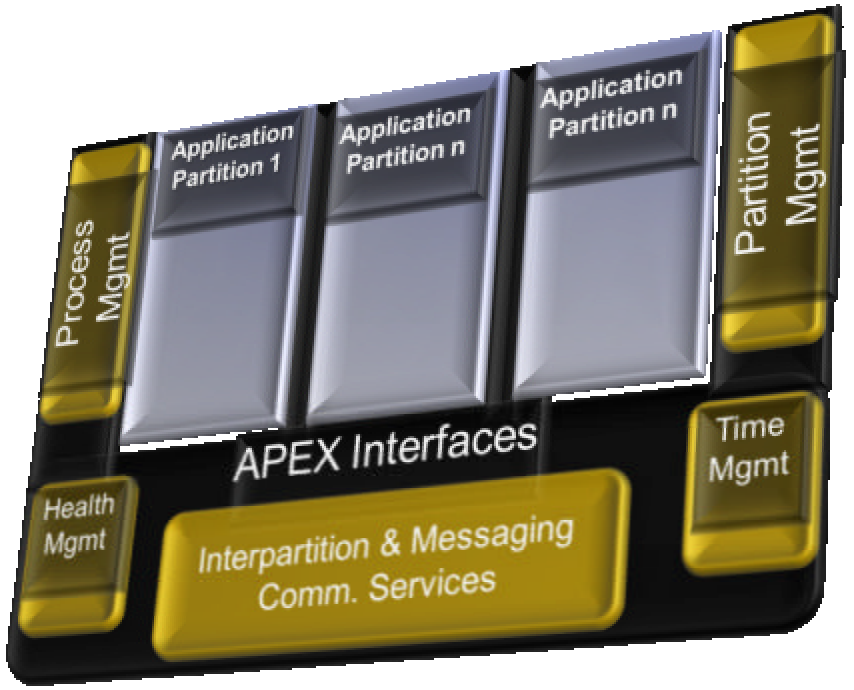
ARINC control services (i.e routines)

- Time, Partition and Process management
  - Let partitions control their processes (PERIODICWAIT/TIMEWAIT/RELENISH)
  - Priority Preemption, Deadlines …
- Inter-intra and Inter-module partition and process Communication management
- Health and Error Monitoring
  - Cold/ Warm Restarts



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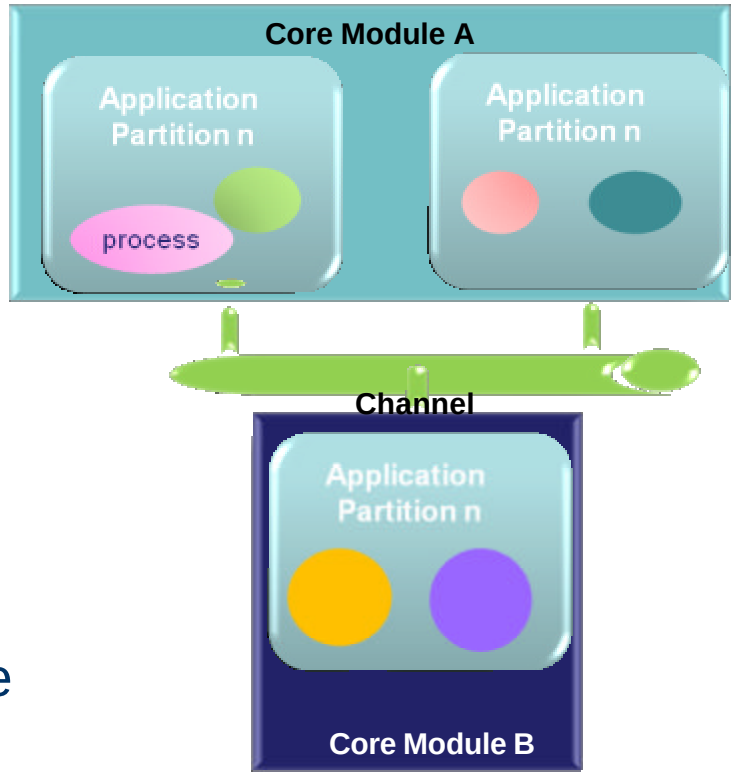
APEX Inter-partition/module Communication

- Comm. between partitions, or between partitions and external entities use the same services, and are independent of the underlying transport
- Comm. is identical regardless of application locations
  - reside on the same core module, or on different core modules
- Messages oriented comm. assured via Channel concept:
  - A logical route between one source and one or more destinations
  - Channel's end points are ports
  - Channels have two transfer modes
    - Sampling
    - Queuing



Interpartition comm. Through channel & ports

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Channel Transfer Sampling mode

- Successive messages of the same type are overwritten
  - Message remains in the source port until it is transmitted or it is overwritten
  - When it reaches destination port new occurrence overwrites the current message if not read
  - Provides access to the latest occurrence
  - Each occurrence cannot be transmitted more than once
  - Message ordering is provided
  - Refresh Rate is supported
    - Indicates the maximum acceptable age of a message from the time it was received at the destination port.

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Channel Transfer Queuing mode

- Each new Instance of a message may carry uniquely different data
- No overwriting allowed
- No message lost, unless the message queue is full

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APEX Limitation (1)

- No way to obtain a High level data representation
  - Data Object
  - Data streams , etc …
  - No built-in process to manage complex data consistency or data identity.
- No High level Data life cycle control
  - E.g No way to mange data history
    - beside the all or nothing history rule
- No way to manage data availability
- Limited way to manage data delivery
  - Reliable Sampling transfer not supported
  - Unreliable Queuing transfer not supported

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APEX Limitation (2)

- No way to build local data views
  - correlate and aggregate different data types
- No way to express data urgency
- No Explicit mechanism to manage data redundancy for FT
- No way to send data atomically
- No way to filter and Query data at runtime

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APEX Limitation (3)

- No connectivity with Open system architectures
  - native web based connectivity
  - ESB connectivity etc …
- No SOA support
  - Client-Service RMI interaction
  - WS
  - Corba or (none-corba)
- No interoperability protocol provided in ARINC653

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What could DDS bring to APEX

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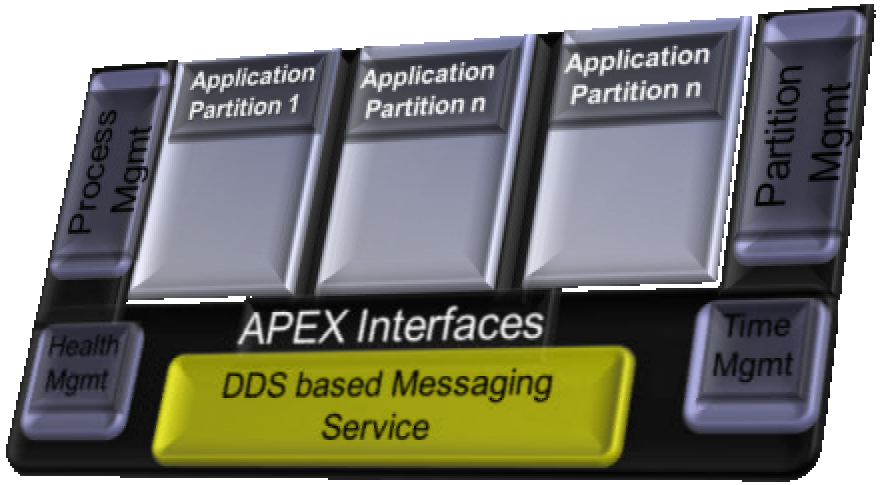
DDS as an APEX Messaging Service (1)

- Pros: Proves that DDS can handle all APEX comm. functionalities.



- DDS Provide interoperability
  - No port protocol provided in ARINC653

- Channel sampling mode supported through :
  - HistroryQoS set to keepLast
  - ReliableQoS set to BestEffort
  - LifespanQos+destinationTimestamp

- Channel Queuing mode supported through :
  - HistroryQoS set to keepAll
  - ResourceLimitQoS
  - Reliable QoS set to Reliable

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DDS as an APEX Messaging Service (2)

- Cons:
  - The approach does not fully take advantage of DDS nor bypass APEX comm. limitations
  - All ARINC compliant OSs provide already an efficient implementation of the APEX MS.
  - Dwarf DDS to a simple messaging system.

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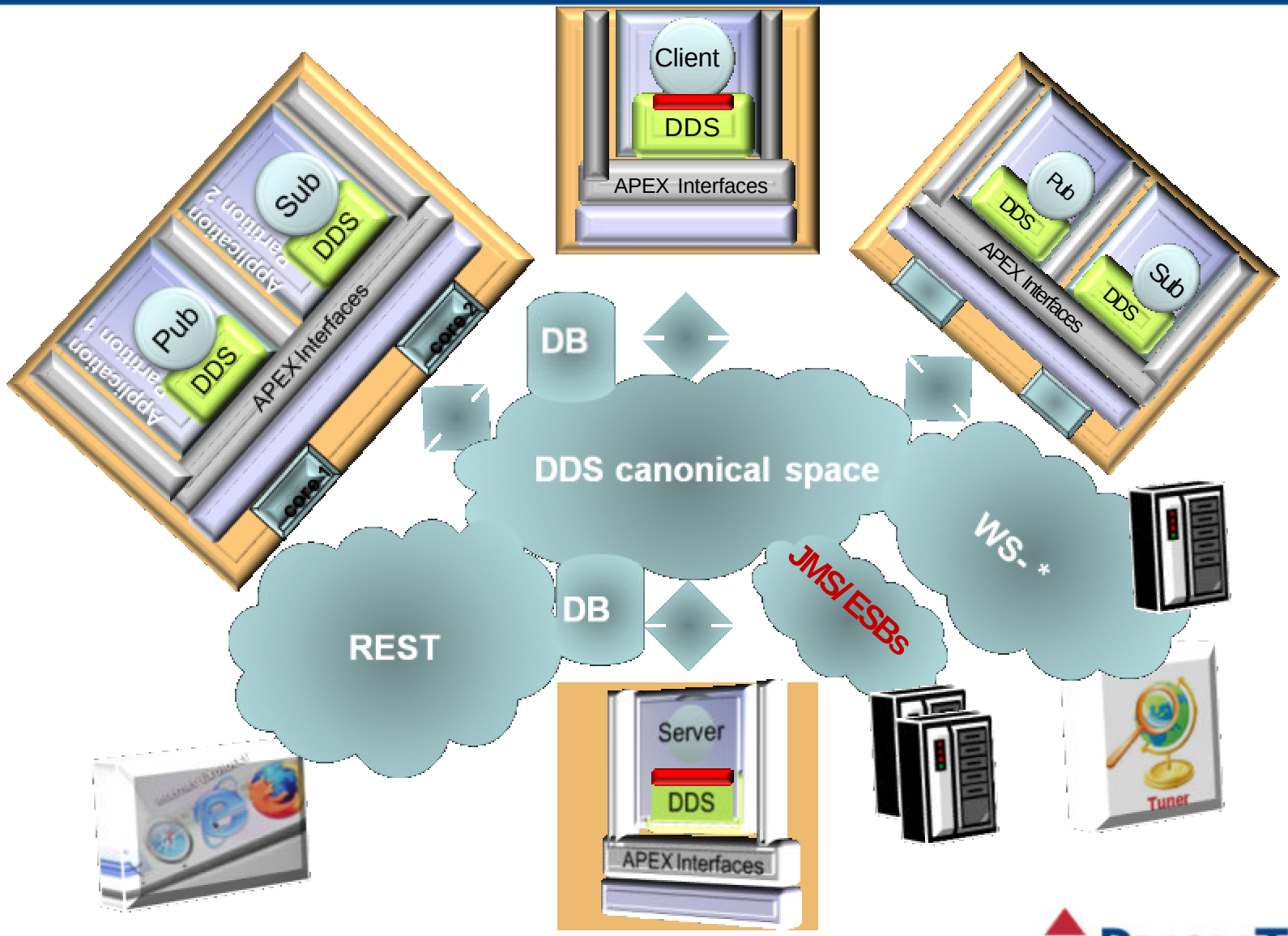
The need for Polymorphic Data Distribution Middleware



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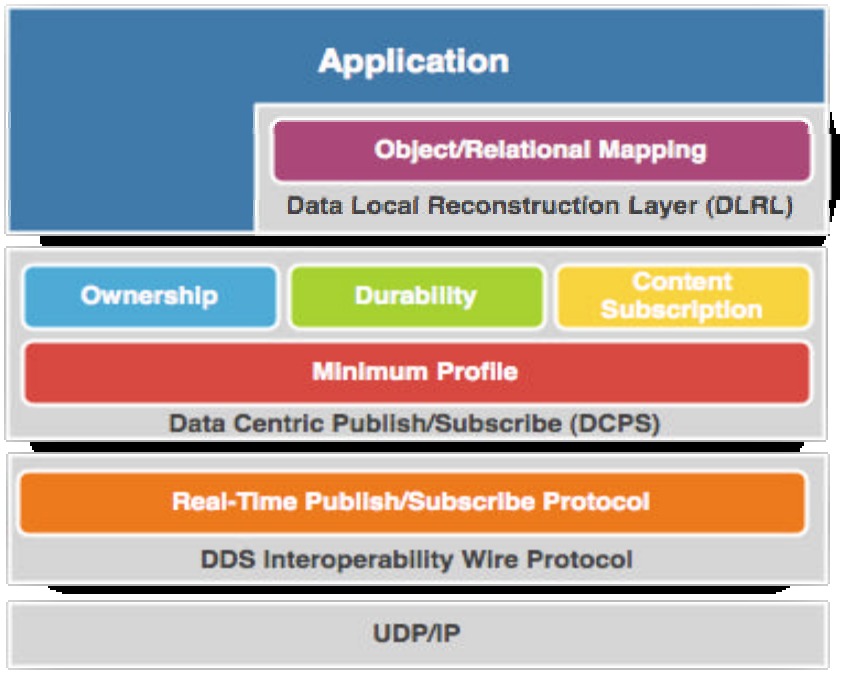
OMG Data Distribution Service for RT-Systems

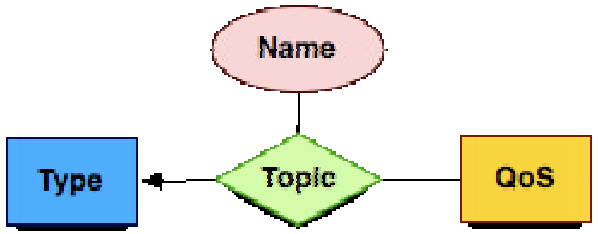
DDS for Real-Time Systems a Modular and customizable technology.

- "**Minimum Profile**": provides basic Pub&Sub capabilities and QoS management
- "**Durability profile**": provides data persistency QoS
- "**Content Subscription**": provides content awareness and filtering
- "**Ownership**": Provides data ownership management for Fault tolerance
- "**DLRL**": provides Data Object View
- **DDS Interoperability Wire Protocol**, V2.1



Relational Modeling

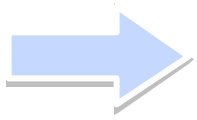
- **Modeling.** Information model can be represented by means of Entity Relationship (ER) diagrams
- **Topics.** Entities, represented by means of Topics, are in turns an association between a data **type** & a set of **QoS** & identified by a unique name (like tables in an RDBMS)
- **Data Types.** The data type associated to a Topic is often a structured type expressed in IDL
- **Instances.** Key values in a datatype uniquely identify an instance (like rows in table)
- **Correlation.** SQL Expressions can be used to correlate information by means of key values




```
struct Flight {
    string    call_sign;
    string    origin;
    sting     dest;
    aircraft  string;
};
#pragma keylist Flight
call_sign;
```

SELECT * FROM Flights f
WHERE destination == 'CDG'

call_sign	origin	dest	aircraft
AZ101	FCO	CDG	Airbus 330
AF102	CGD	GTW	Airbus 310
BA103	GTW	MCM	BOENG 737



call_sign	origin	dest	aircraft
AZ101	FCO	CDG	Airbus 330
BA103	GTW	CGD	BOENG 737

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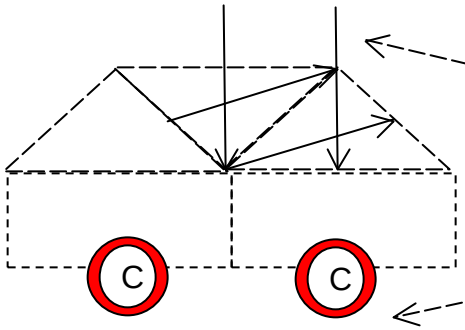
High level data representation

- Beyond messaging, DDS brings the ability to locally reconstruct complex views on data from basic pieces
  - Using the Multi-topic reconstruction capability
  - Using Object Oriented data representation



Single consistent view

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High level data representation

- Beyond messaging, DDS brings the ability to locally reconstruct complex views on data from basic pieces
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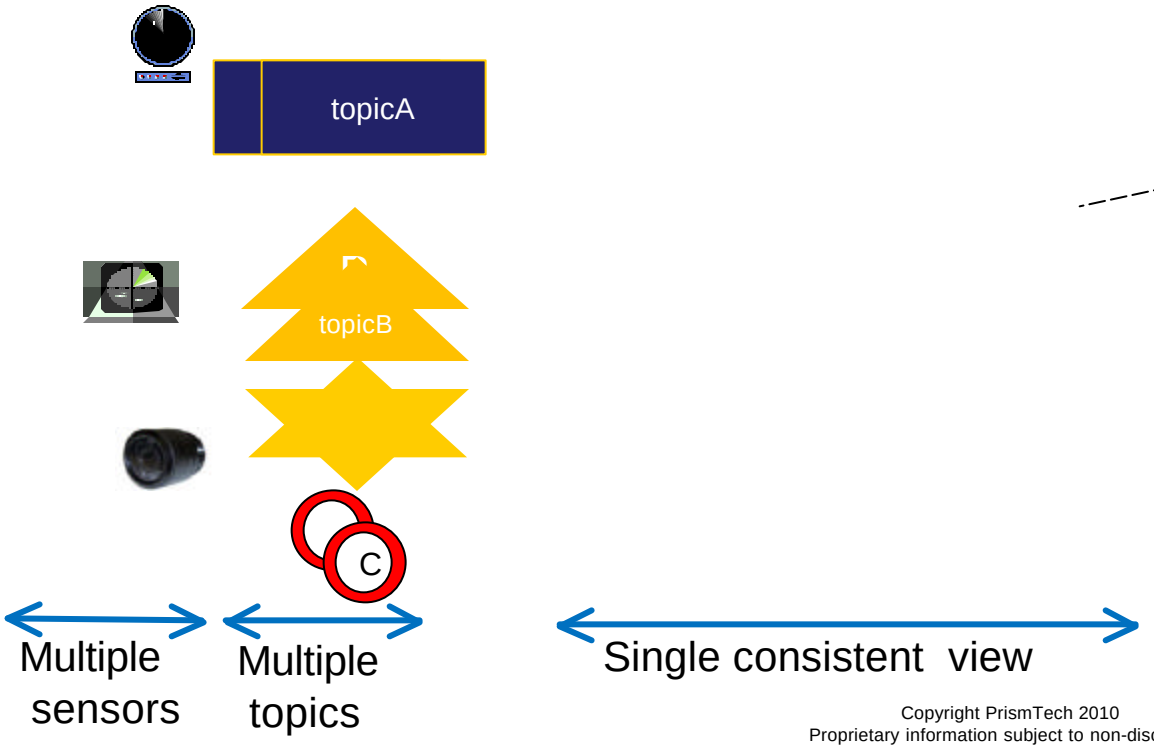

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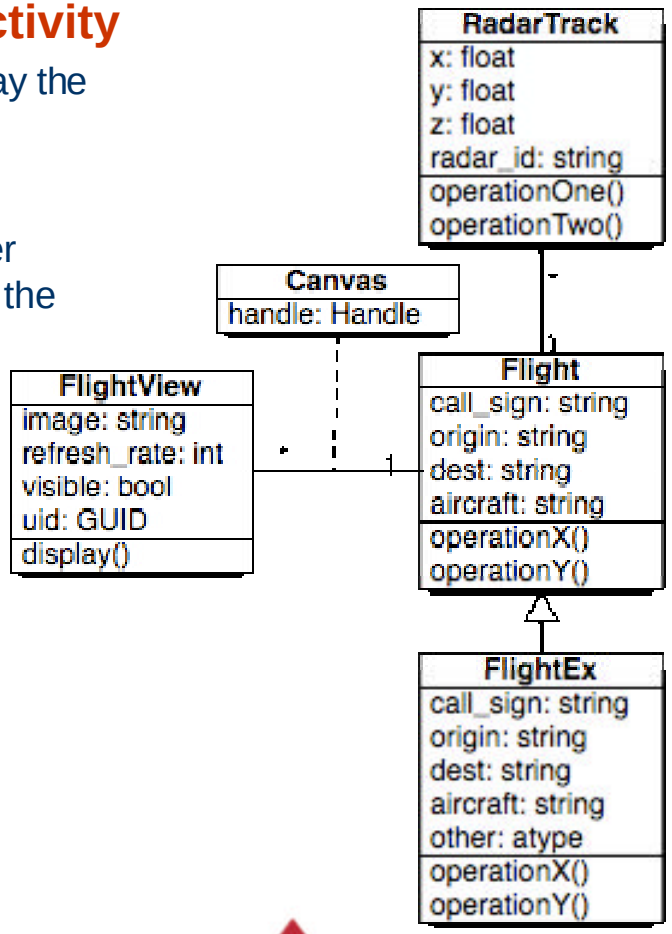
Object-Oriented Modeling

Unleashing the power of Objects...

- DDS supports ***true*** **Object Oriented Distributed Information Modeling** providing:
  - **Reduced Complexity & Improved Productivity**
    - Focus on the architecture & business logic, while hiding away the details involved with the diffusion of shared objects state
  - **Encapsulation**
    - Attributes are only accessible through dedicated getter/setter operations, i.e., don't need to the messaging middleware or the application to have privileged access to business objects representation
  - **Local Operations**
    - Besides getters/setters, all other kind of manipulations be done using custom operations
  - **Inheritance**
    - Single inheritance supported for DLRL Objects
  - **Navigable Relationships**
    - Single Relationships
    - Multi Relationships (Set, Map, List)



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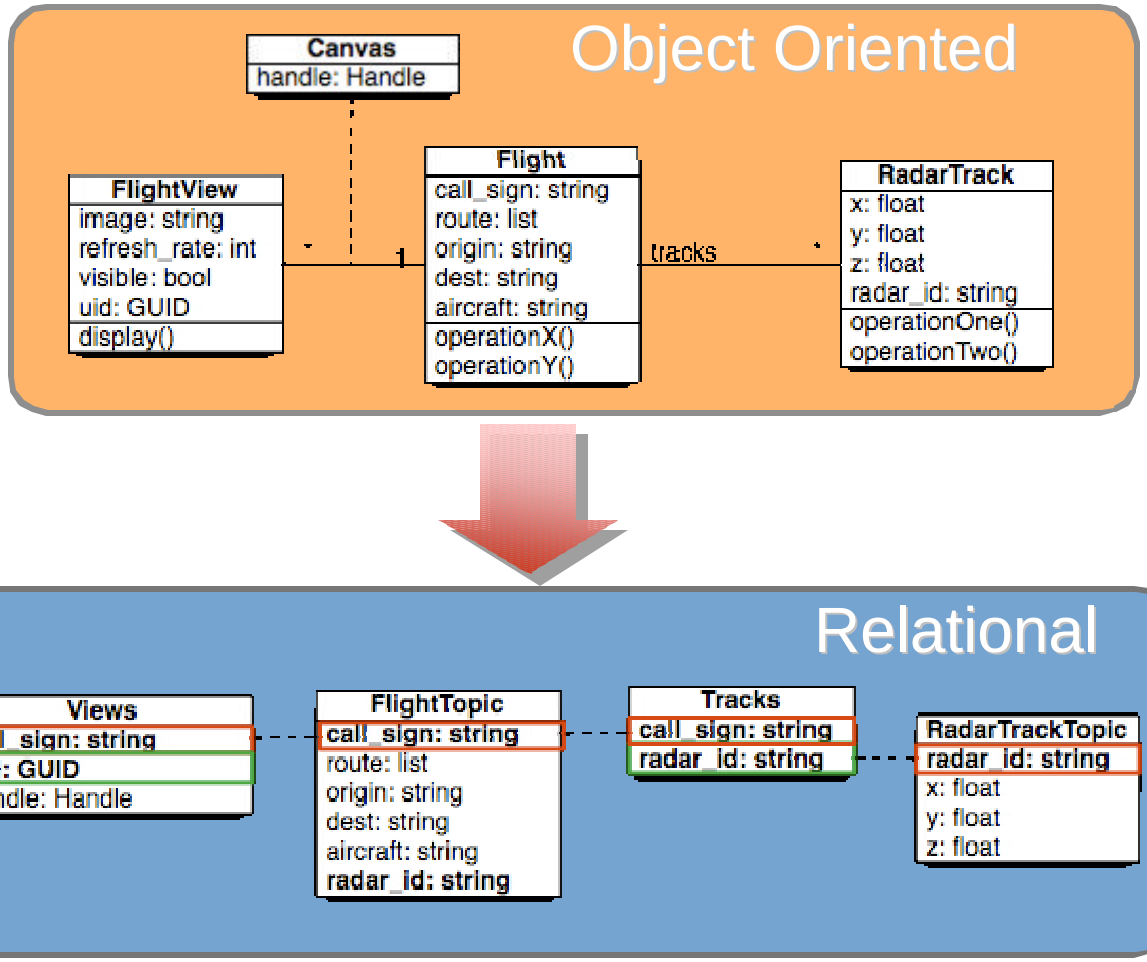
High Data representation :Object/Relational Mapping

OO ? Relational

? Middleware can automatically manage the generation & association between the Object-Oriented Model & the Relational Model



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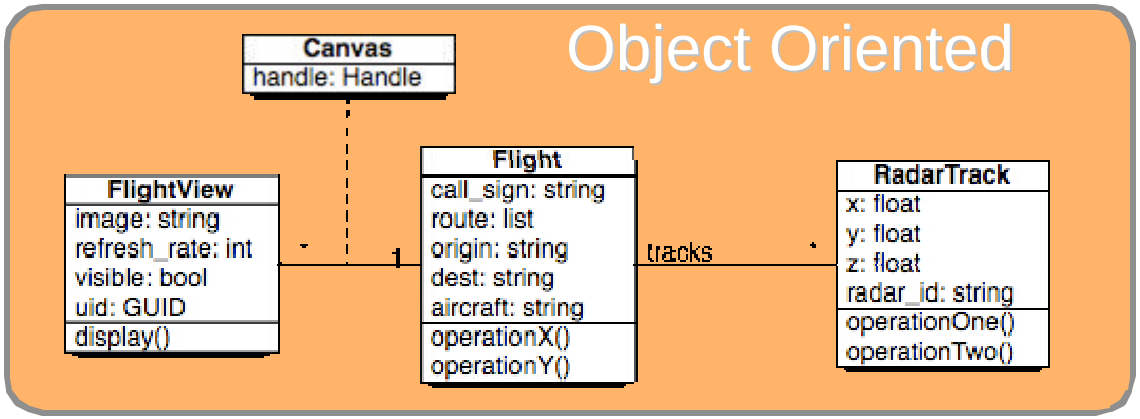
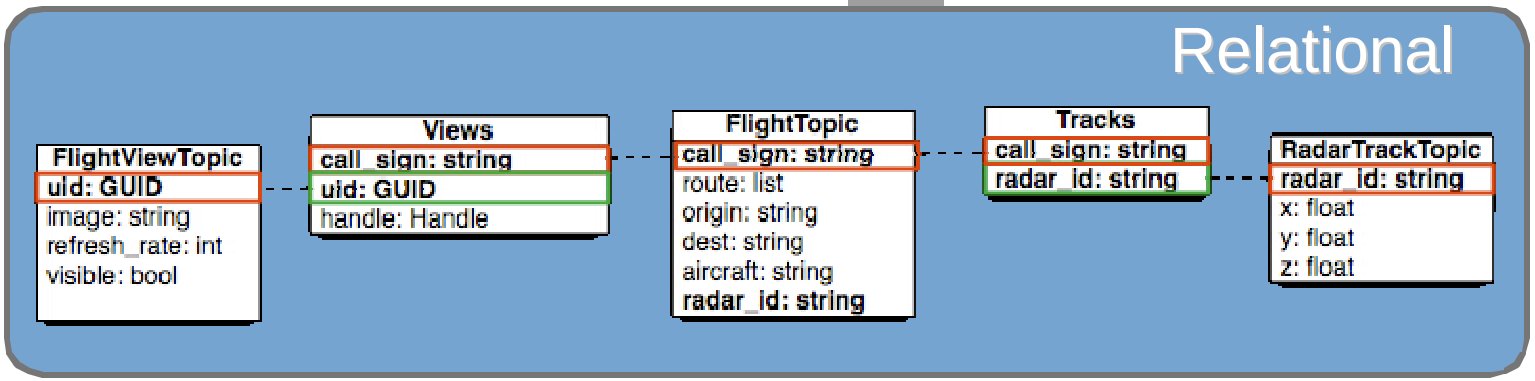
High Data representation : Object/Relational Mapping

Relational ? OO

- ? The Object/Relational Mapping can be specified by the user
- ? Multiple Object/Relational Mappings are possible





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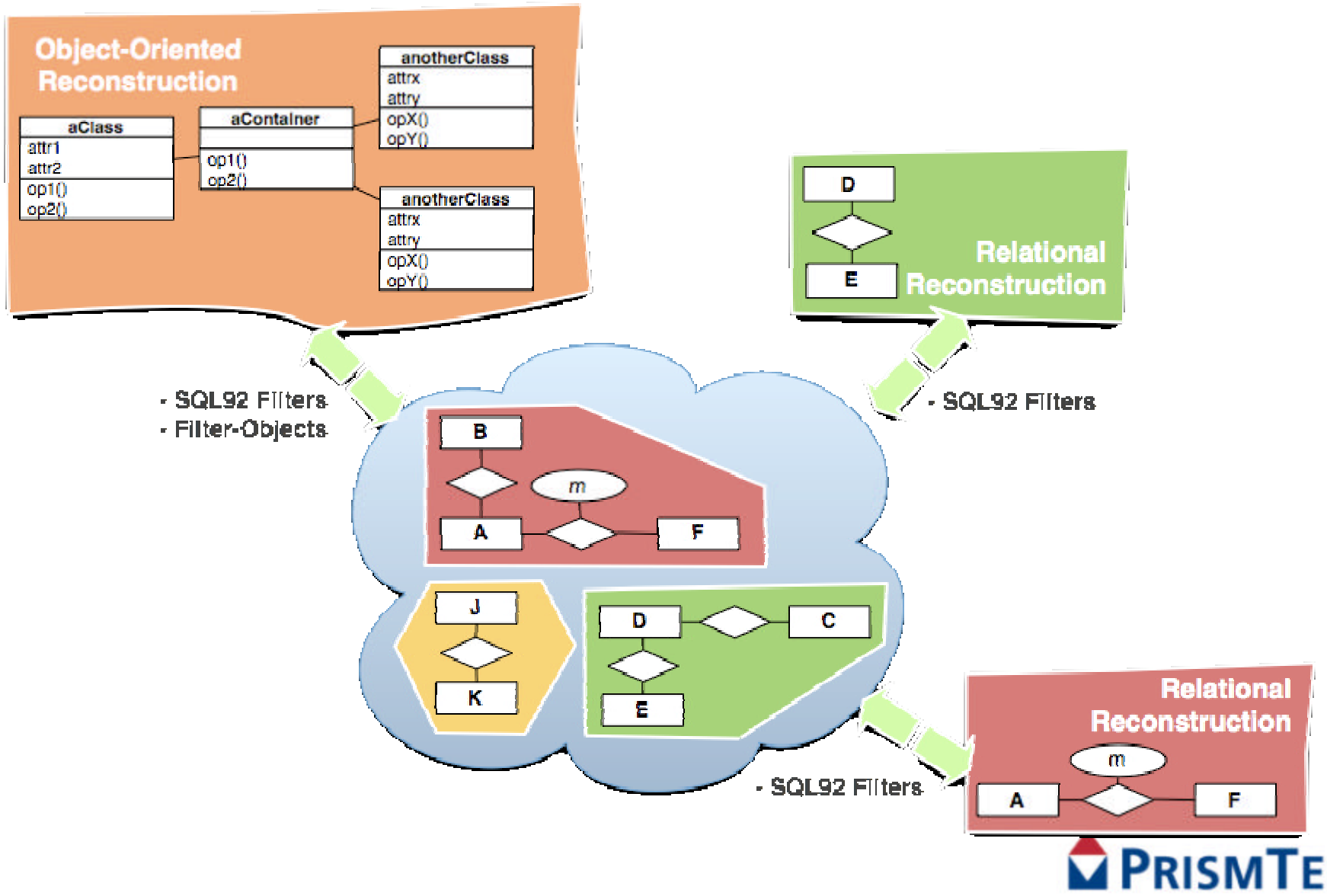
High Data representation : the Big Picture



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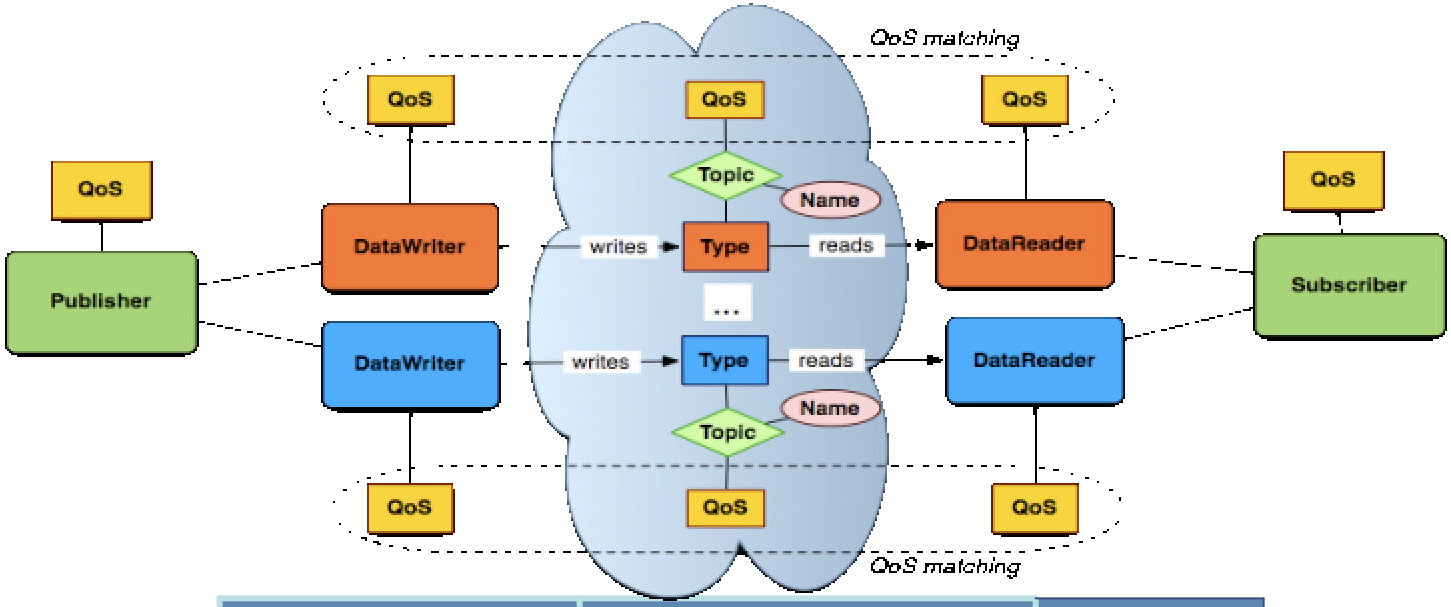
DDS Data High availability and Urgency managent



QoS Policy	SEMANTIC	QoS Classes
DURABILITY	Data Persistency for later joiners	**Data Availability**
LIFESPAN	Time to live interval	
HISTORY	History depth	

QoS Policy	SEMANTIC	QoS Classes
DEADLINE	Policy to set Data Writing rate (W.freq)	**Data Urgency**
LATENCY BUDGET	maximum acceptable delay of a sample	
TRANSPORT PRIORITY	Help setting priority at transport	

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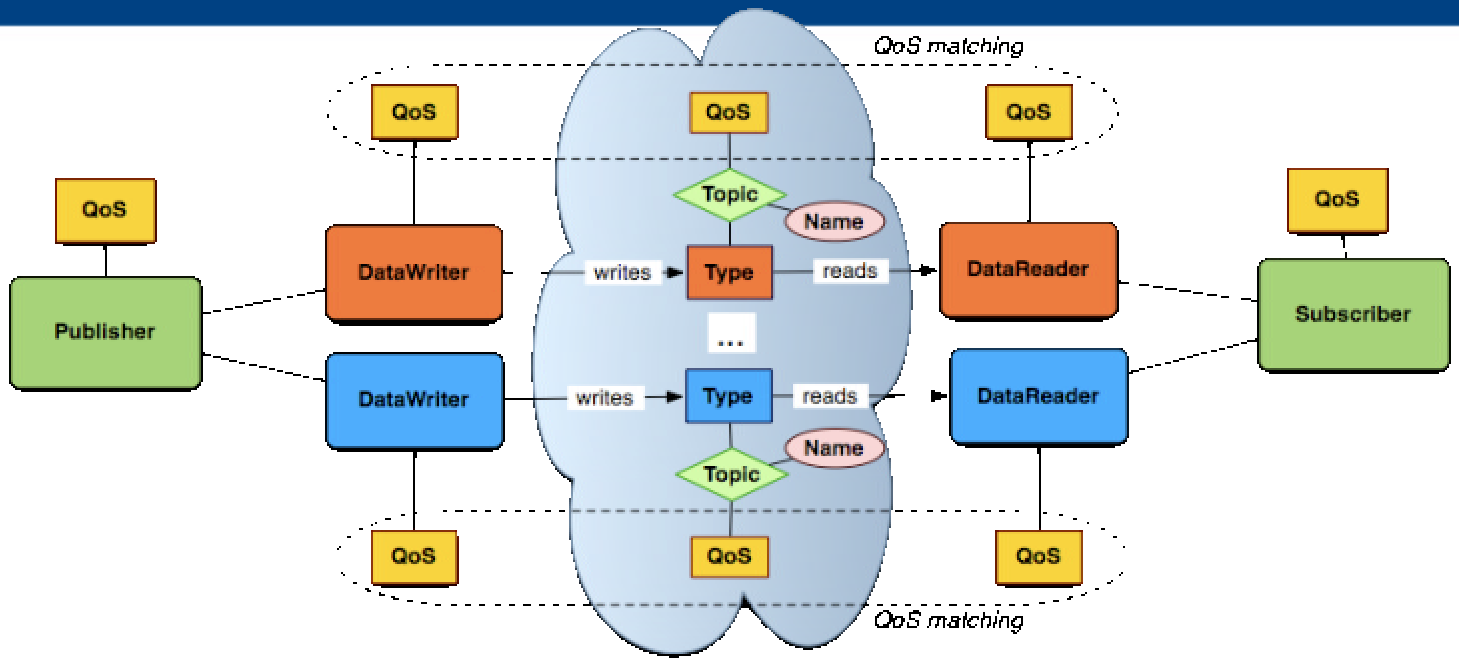
DDS Data Life Cycle management



QoS Policy	SEMANTIC	QoS Classes
WRITER DATA LIFECYCLE	Data instance disposal management	Data Lifecycle
WRITER DATA LIFECYCLE	Samples autopurge management	

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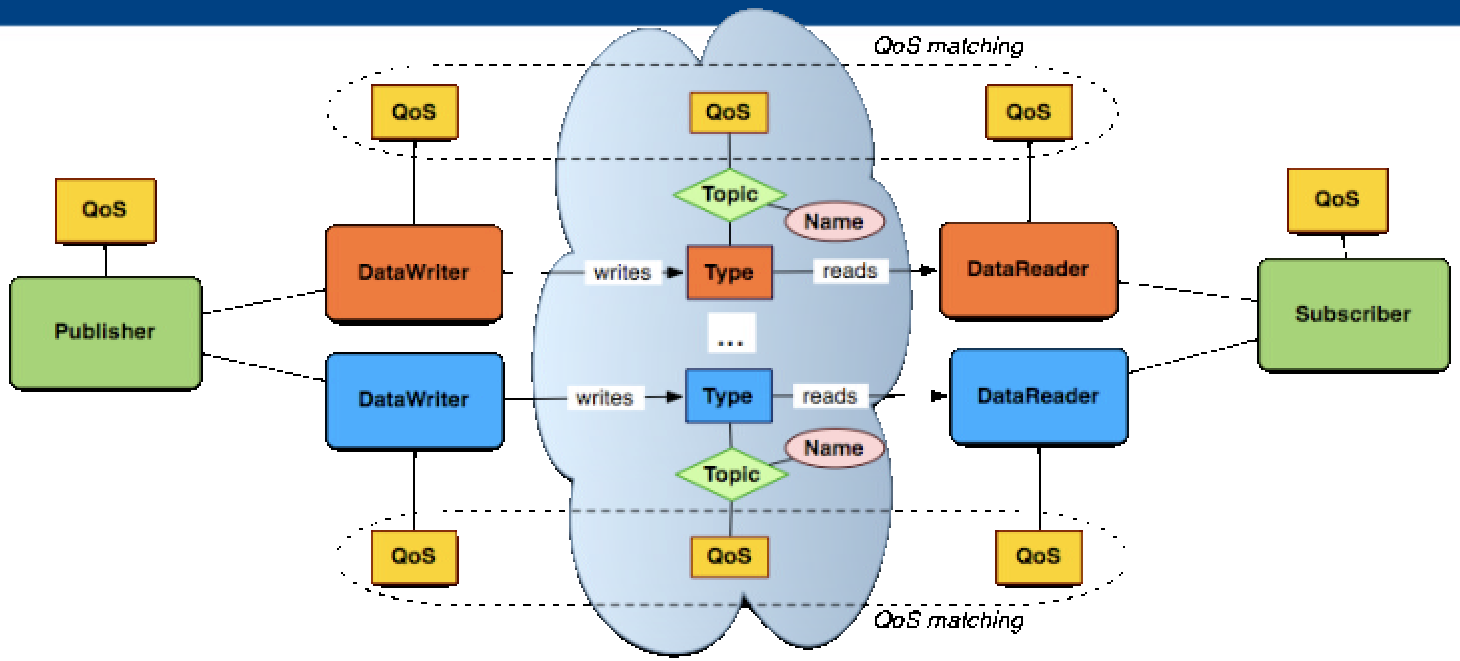
DDS Data Delivery management



RELIABILITY	Data delivery guaranteed level	**Data Delivery**
PARTITION	topic instance Logical partition	
DESTINATION ORDER	Determine logical order among changes made by Publishers	

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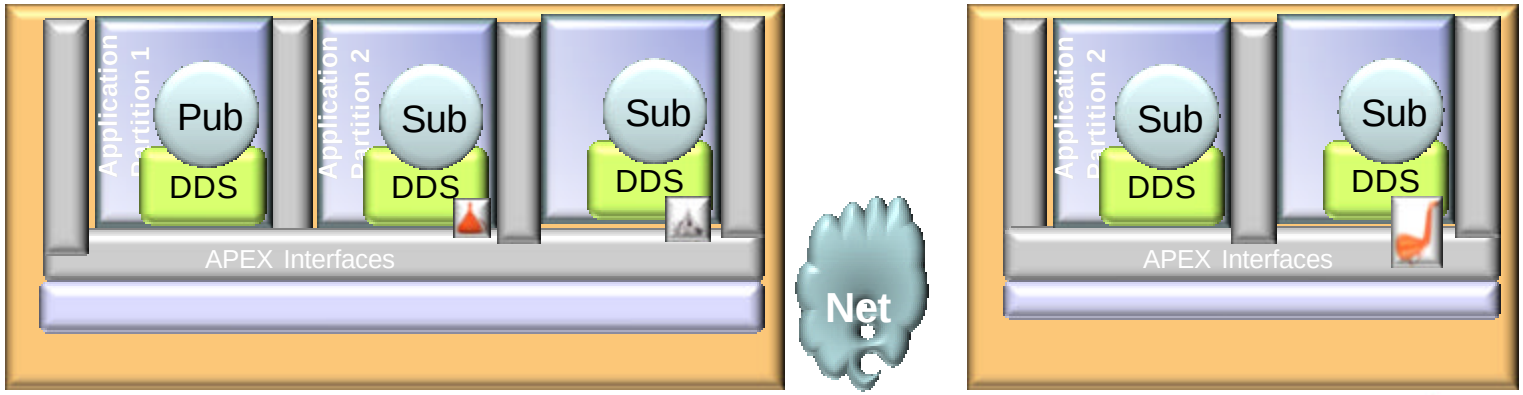
Content subscription management,

- Filtering
  - An Ability to apply Logical expression at low level data stream to get meaningful application data exclusively



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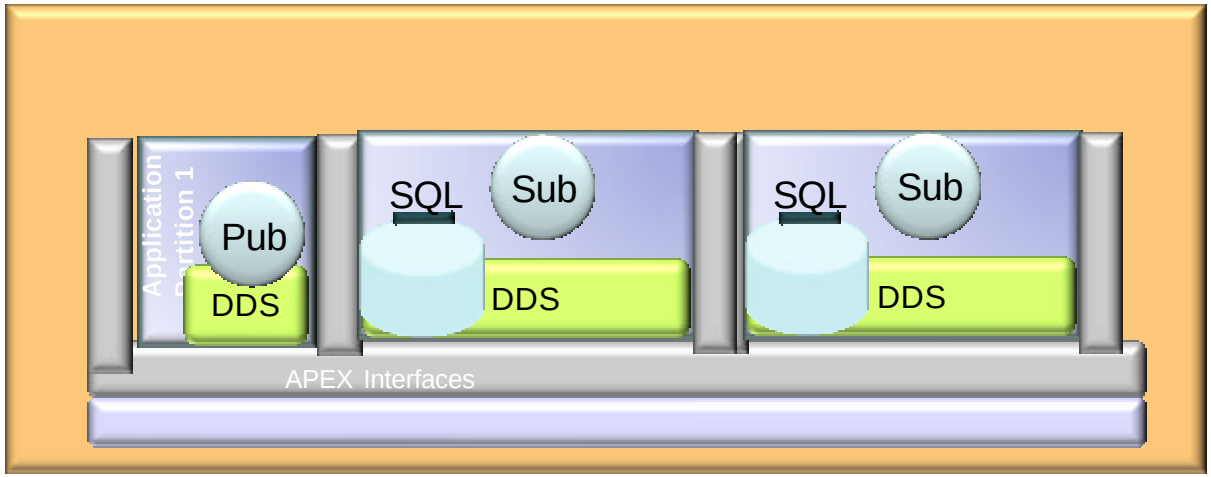
Content subscription management,

- Querying
  - An Ability to build local caches and apply complex SQL 92 queries
  - A powerful mechanism to build and manage highly available, recoverable and, in memory local databases



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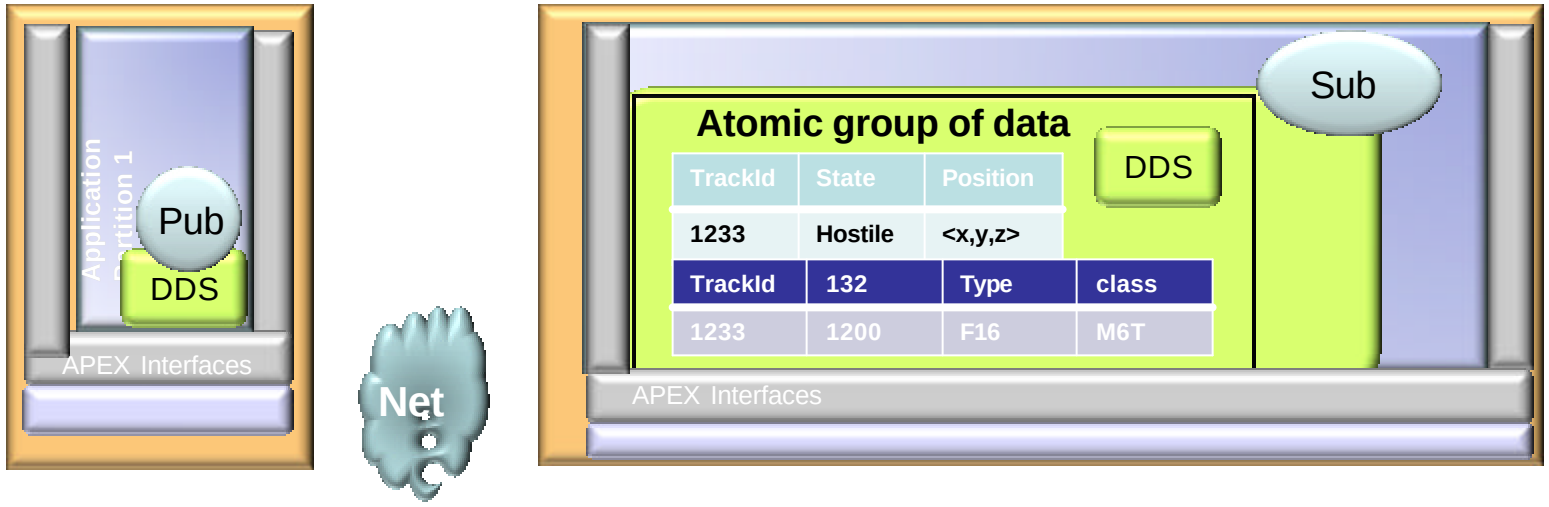
Atomic data transfer

- All or Nothing semantic
- Data scope could involve several datatypes (topics)
- Publishing side defines the Atomic data group
- DDS Presentation QoS
  - Coherent_change = True
  - Access_scope = Group/Topic/instance
  - Access_ordeer = True



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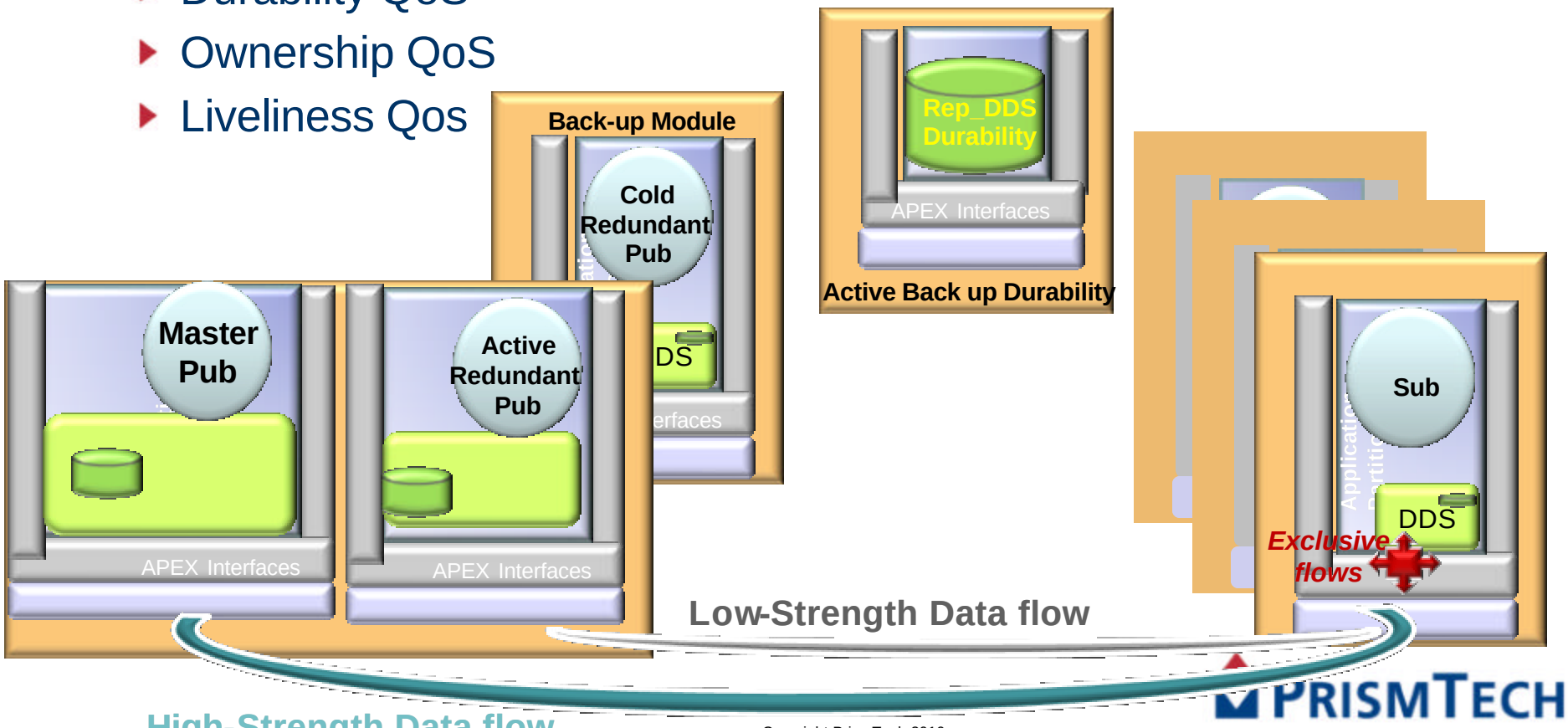
Fault-tolerance data support

- Support of Cold/Warm/Hot Standby and Active Replication models
- Relies on DDS Replicated Durabity services
  - Durability QoS
  - Ownership QoS
  - Liveliness Qos

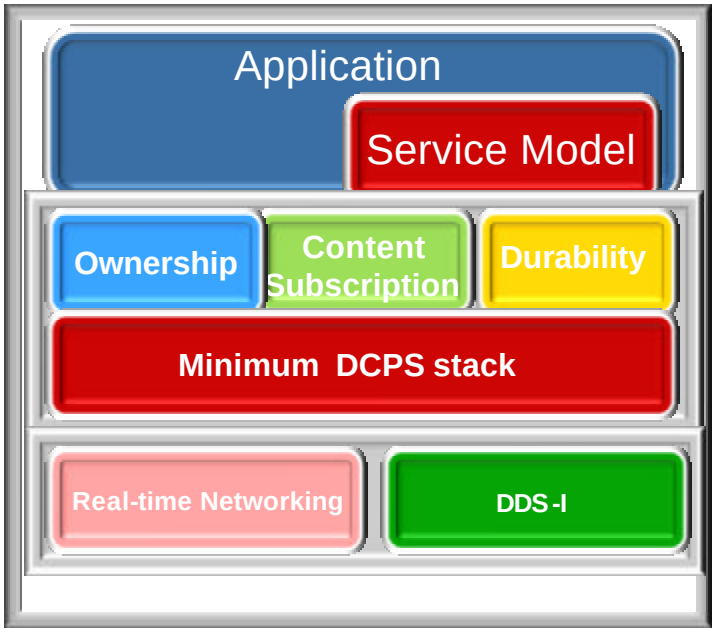


SOA Model support (1)

- **DDS as the single communication infrastructure for both R.M.I as Data Distribution**

Main advantages

- SOA Provides higher abstraction then sending requests and getting replies through topics
- Facilitated APEX applications design and implementation
- One Technology to learn and one platform have to maintained… **!**
- Useful for further integration with other SOA based systems



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SOA Model Support

- Services and data can be defined with same IDL language
- Synchronous and asynchronous invocations are supported as well as one-to-one and **one-to-may**
- Services can be dynamically discovered
  - taking advantage of DDS dynamic discovery

```
// Interface definition
interface EngineControler {
    long start();
    long stop();
    long setSpeed(in float s);
};
// Data definition
struct  Engine {
                long id;
                temperature t;
                kroseneCapacity c;
};
#Pragma keylist Engine id;
```

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Initial Results

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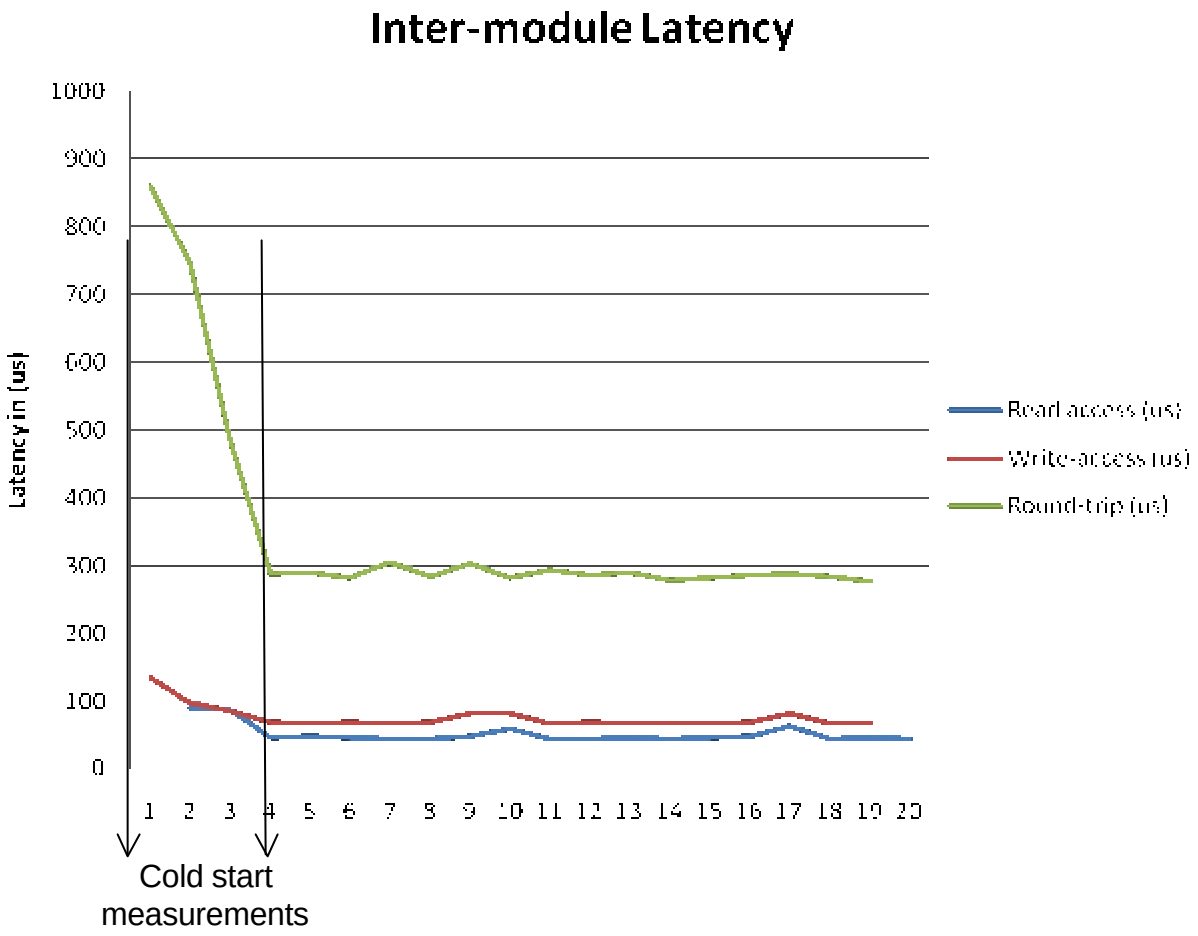
Initial results

- OpenspliceDDS has been ported on VxWorks 653 (Beta)
- Benchs with no time Partitioning
- Publishing partition on 8641D/dual Core, 1.5 Ghz
  - vxWorks653 v2.3
- Subscribing partition on mono core 8548, 1,3 Ghz
  - vxWorks653 v2.3



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Conclusion

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Conclusion

- DDS covers all APEX functionalities and beyond
- DDS boosts APEX based application development allowing the build of both Data Centric and Service Oriented applications
- DDS comes with **Modular** and **pre-Certifiable** profiles
- Provide connectivity to Web based component as well as other Enterprise messaging and database services
- **A middleware supplement should be added to the ARINC specification**
- **OpenspliceDDS** beta version has been ported to a VxWorks 653 ARINC OS.

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