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Intelligent Event Processing in Quality of Service (QoS) Enabled Publish/Subscribe (Pub/Sub) Middleware

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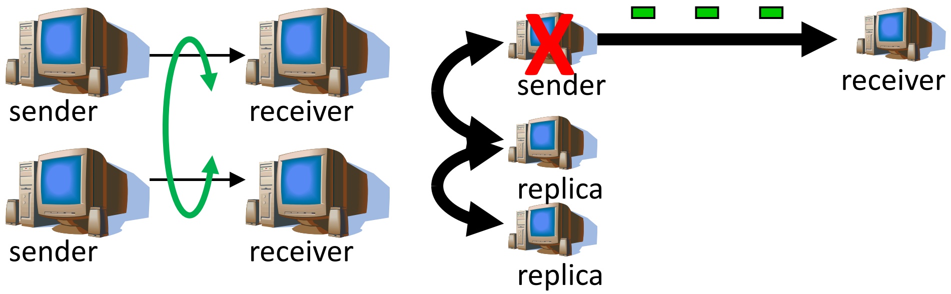
Intelligent Event Processing

Context: Event Processing Systems

- Wide range of application domains
  - Ambient assisted living
  - Fractionated satellite systems
  - Weather monitoring
  - Disaster recovery
  - Stock quote update systems …

Challenge: Supporting QoS & Managing Complexity

- Wide range of QoS needed
- Examples: low latency, reliable event delivery, coordinated data streams, fault tolerance
- Interacting QoS demands

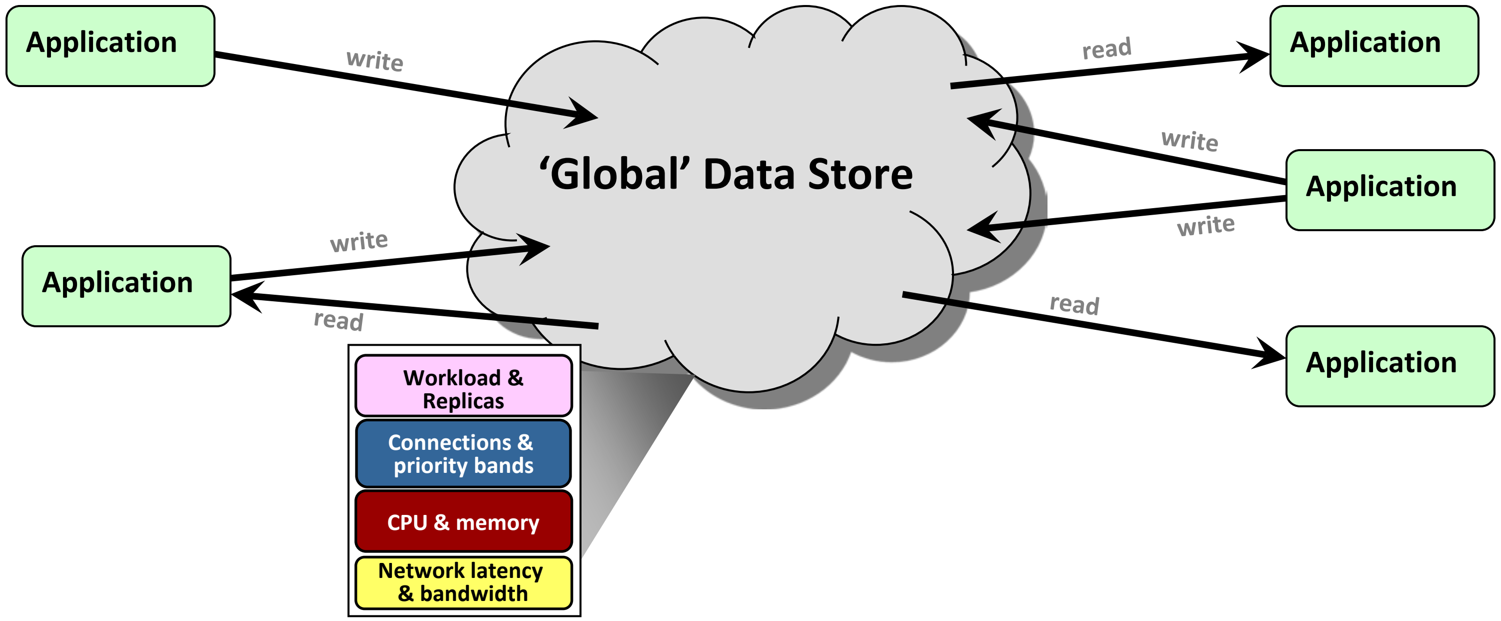


Solution: QoS-enabled Pub/Sub Middleware

- Intelligent processing of events
  - QoS primitives for low level functionality
  - Patterns for higher level functionality

QoS-enabled Pub/Sub Middleware Case Study

Object Management Group's Data Distribution Service (DDS)

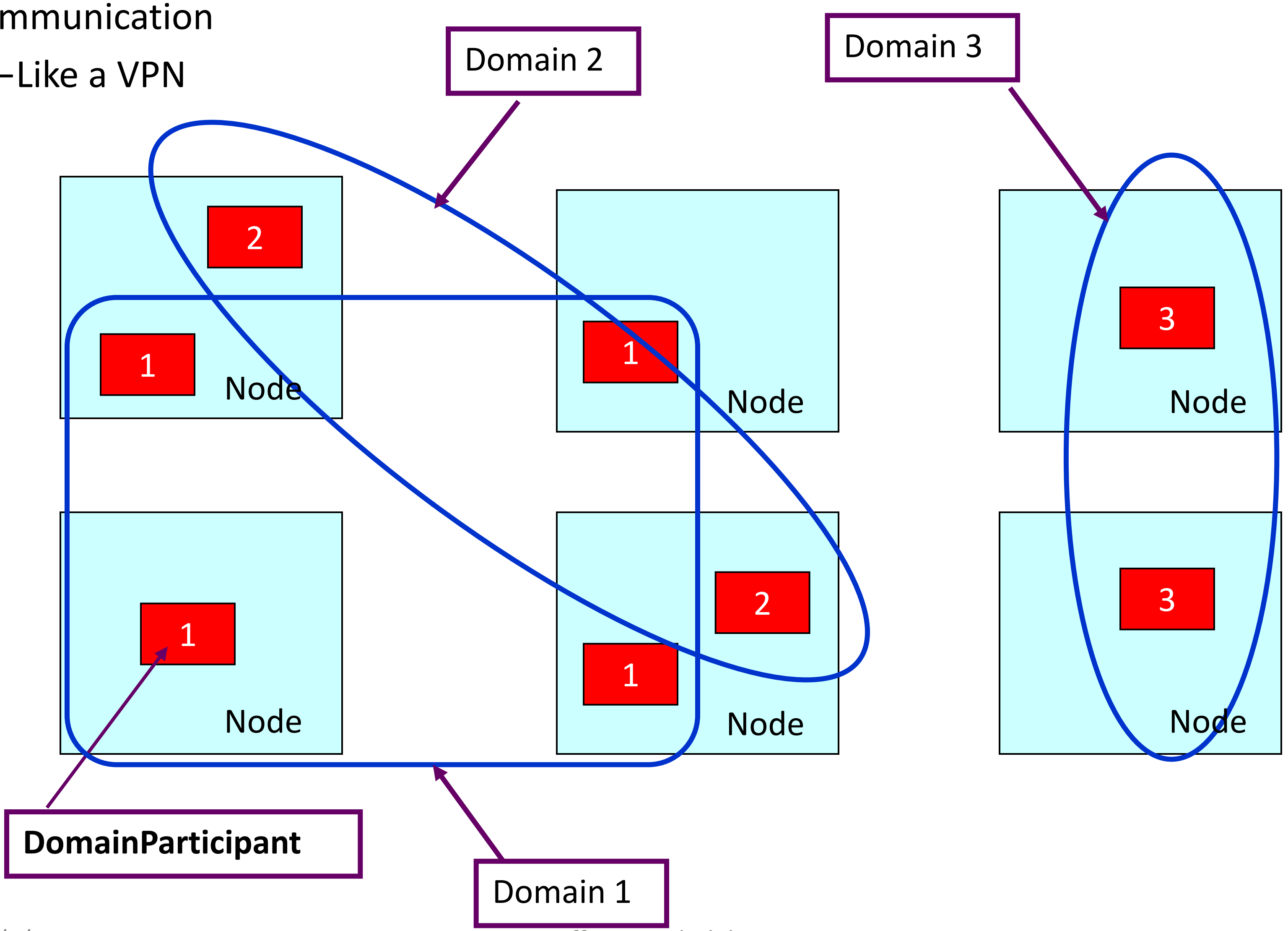


DDS provides flexibility, power, & modular structure by decoupling:

- **Location – anonymous pub/sub**
- **Redundancy – any number of readers & writers**
- **QoS – async, disconnected, time-sensitive, scalable, & reliable data distribution at multiple layers**
- **Platform & protocols – portable & interoperable**

DDS Domains & Domain Participants

- The domain is the basic construct used to bind individual applications together for communication
  - —Like a VPN

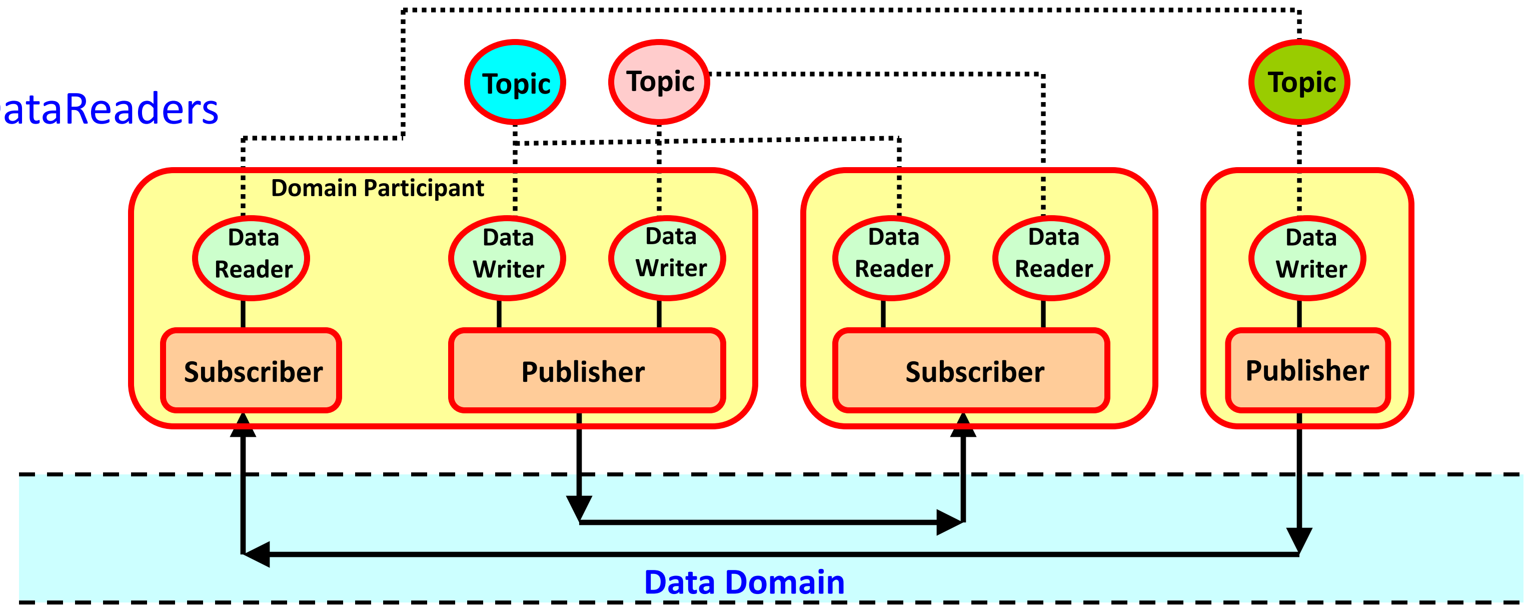


DDS Entities

DDS Entities include

- DomainParticipants
  - Entry points
- Topics
  - Typed data
- Publishers
  - Manage DataWriters
- Subscribers
  - Manage DataReaders

- Data can be accessed in two ways
  - Wait-based (synchronous calls)
  - Listener-based (asynchronous callbacks)
- Sophisticated support for filtering
  - e.g., Topic, Content-FilteredTopic, or MultiTopic
- Configurable via (many) QoS policies



QoS Policies Supported by DDS

- DDS entities (i.e., topics, data readers/writers) configurable via QoS policies
- QoS tailored to data distribution in distributed realtime & embedded (DRE) information systems
  - DEADLINE
    - Establishes contract regarding rate at which periodic data is refreshed
  - LATENCY_BUDGET
    - Establishes guidelines for acceptable end-to-end delays
  - TIME_BASED_FILTER
    - Mediates exchanges between slow consumers & fast producers
  - RESOURCE_LIMITS
    - Controls resources utilized by service
  - RELIABILITY (BEST_EFFORT, RELIABLE)
    - Enables use of real-time transports for data
  - HISTORY (KEEP_LAST, KEEP_ALL)
    - Controls which (of multiple) data values are delivered
  - DURABILITY (VOLATILE, TRANSIENT, PERSISTENT)
    - Determines if data outlives time when they are written
  - … and many more …
- Request/offered compatibility checked by DDS, helps to manage complexity

Types & Keys

- A DDS Type is represented by a collection of data items.
  - e.g. "IDL struct" in the CORBA Platform Specific Model (PSM)

```
struct AnalogSensor {
   string sensor_id; // key
   float value; // other sensor data
};
```

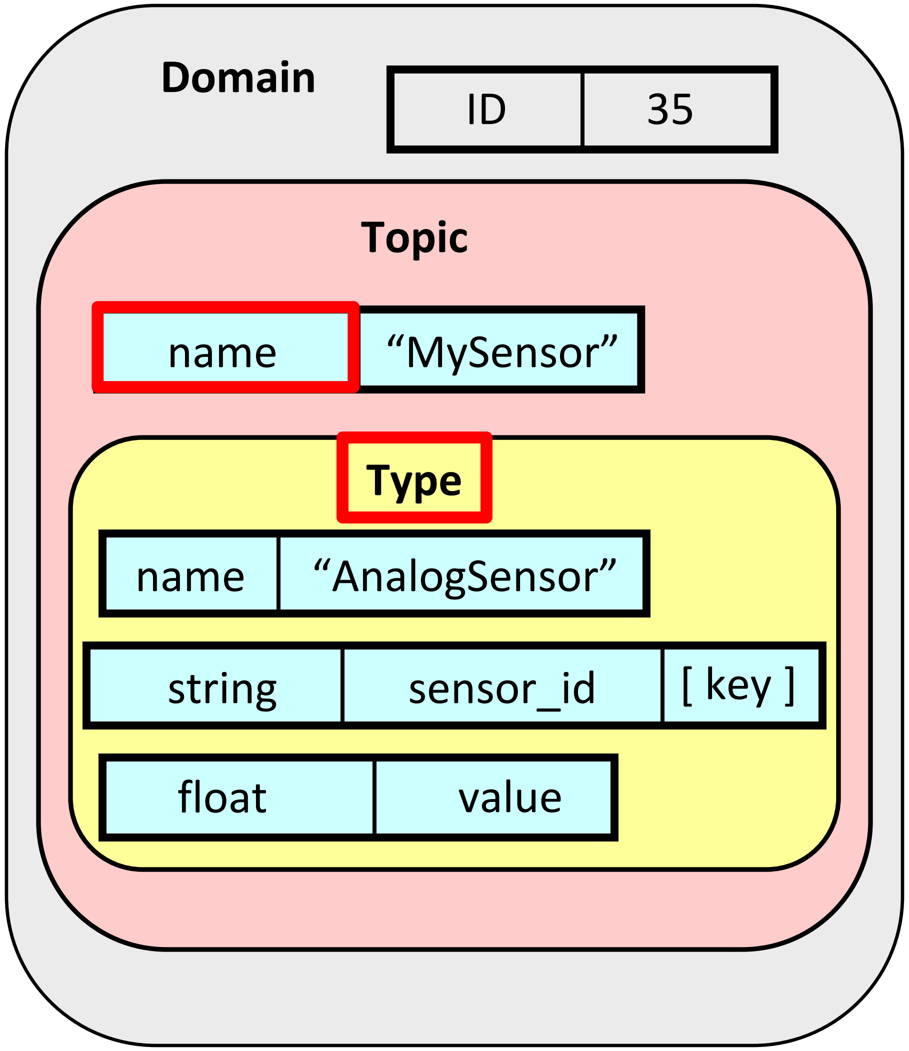
- A subset of the collection is designated as the Key.
  - The Key can be indicated by IDL annotation in CORBA PSM, e.g.,

```
#pragma DDS_KEY AnalogSensor::sensor_id
```

- The type is manipulated by means of automatically-generated typed interfaces.
  - IDL compiler may be used in CORBA PSM implementation
- A Type is associated with generated code:
  - `AnalogSensorDataWriter   // write values`
  - `AnalogSensorDataReader   // read values`
  - `AnalogSensorType // can register itself with Domain`

Topics

- A DDS Topic is the connection between data writers & data readers.
- A Topic is comprised of a Name and a Type.
  - Name must be unique in the Domain.
  - Many Topics can have the same Type.
- Provision is made for content-based subscriptions.
  - MultiTopics correspond to SQL `join`
  - Content-Filtered Topics correspond to SQL `select`.



Data Writers & Publishers

- Data Writers are the primary access point for an application to publish data into a DDS data domain
- The Publisher entity is a container to manage one or more Data Writers
- Publishers & Data Writers can have their own QoS policies
- User applications
  - Associate Data Writers with Topics
  - Provide data to Data Writers
  - Data is typically defined using OMG IDL
    - As strongly or weakly typed as desired

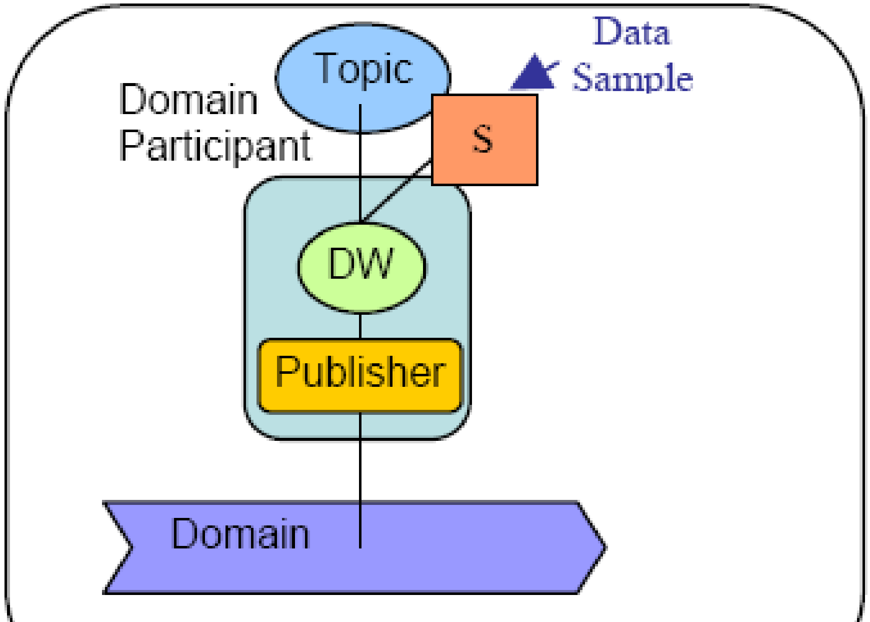


Fig. 7 Publication Model

Data Readers & Subscribers

- A Data Reader is the primary access point for an application to access data that has been received by a Subscriber
- Subscriber is used to manage one or more Data Readers
- Subscribers & Data Readers can have their own QoS policies
- User applications
  - Associate Data Readers with Topics
  - Receive data from Data Readers using Listeners (async) or Wait-Sets (sync)

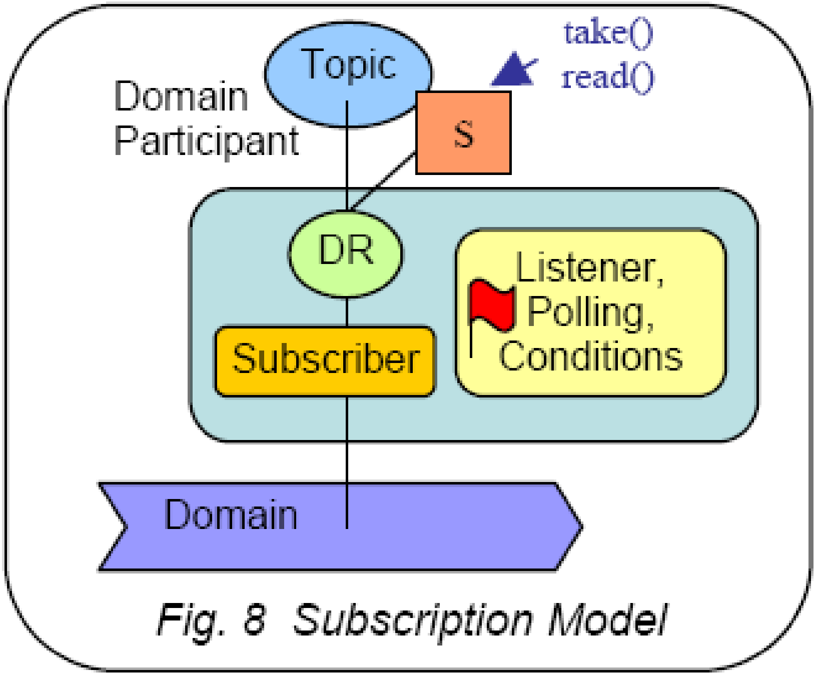
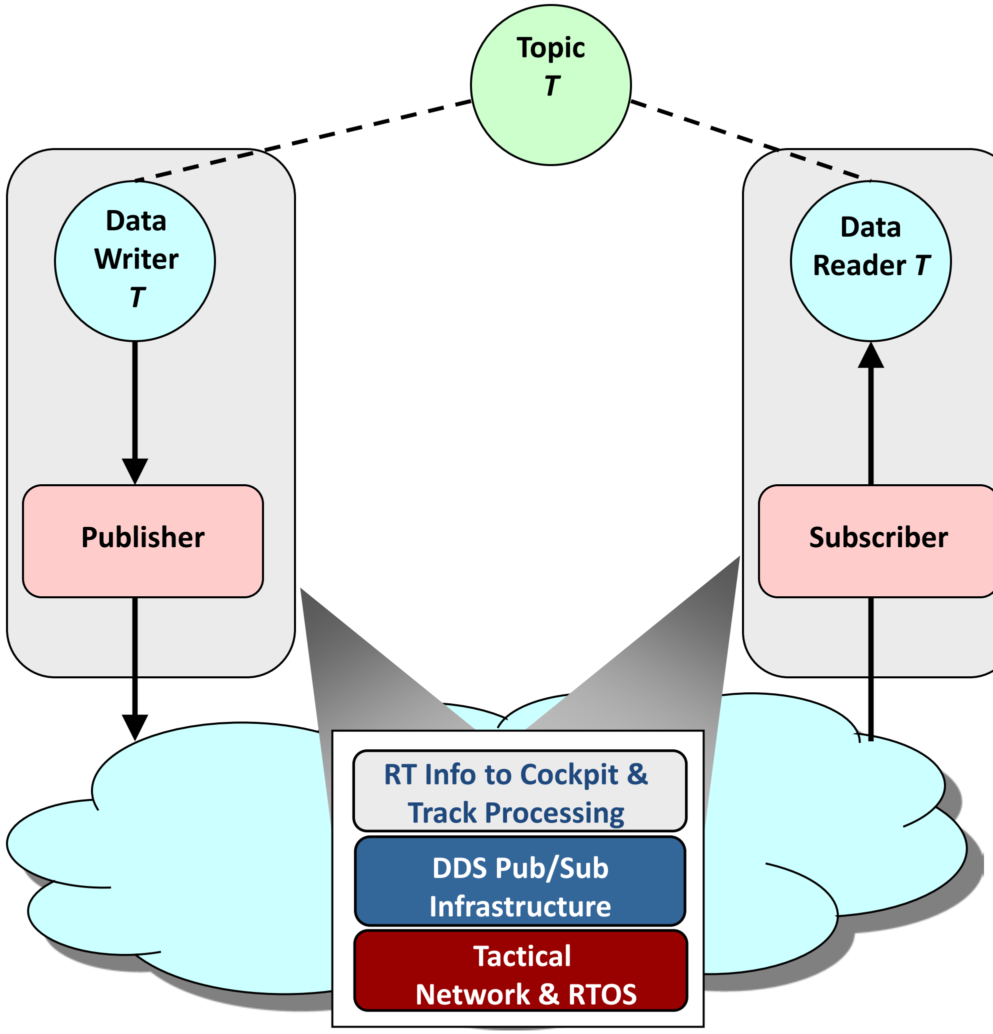


Fig. 8 Subscription Model

Overview of the Data Distribution Service (DDS)

- DDS is an highly efficient OMG pub/sub standard
  - e.g., fewer layers, less overhead



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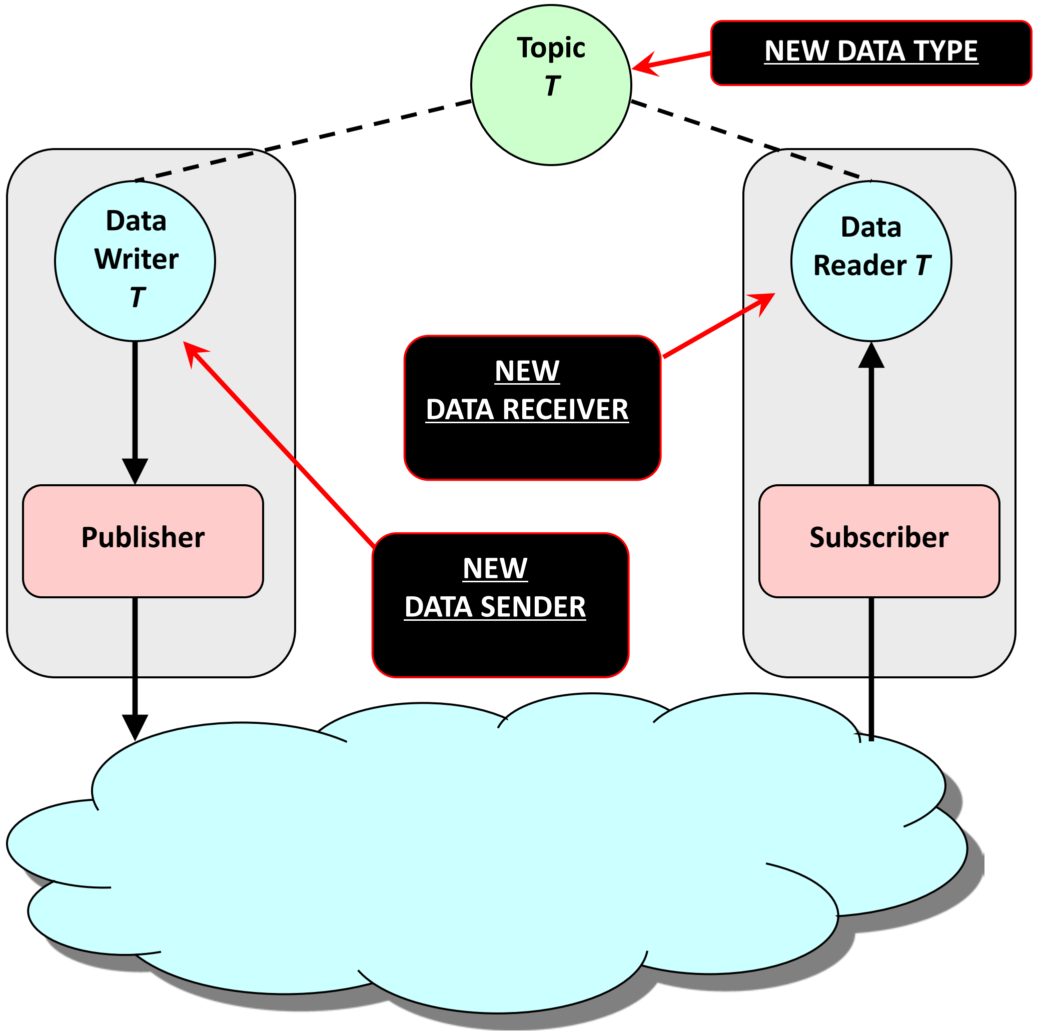

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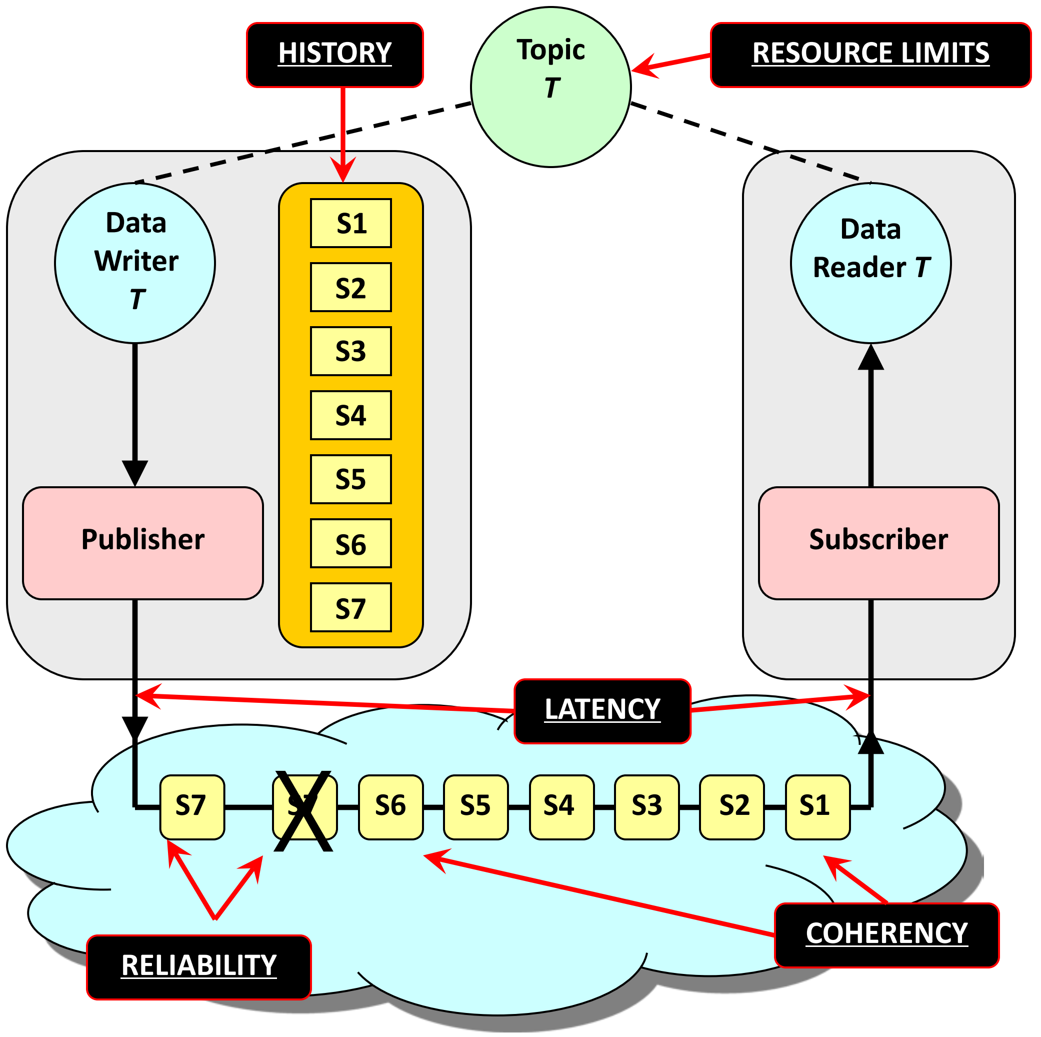
- DDS provides policies for specifying many QoS requirements of tactical information management systems, e.g.,
  - Establish contracts that precisely specify a wide variety of QoS policies at multiple system layers



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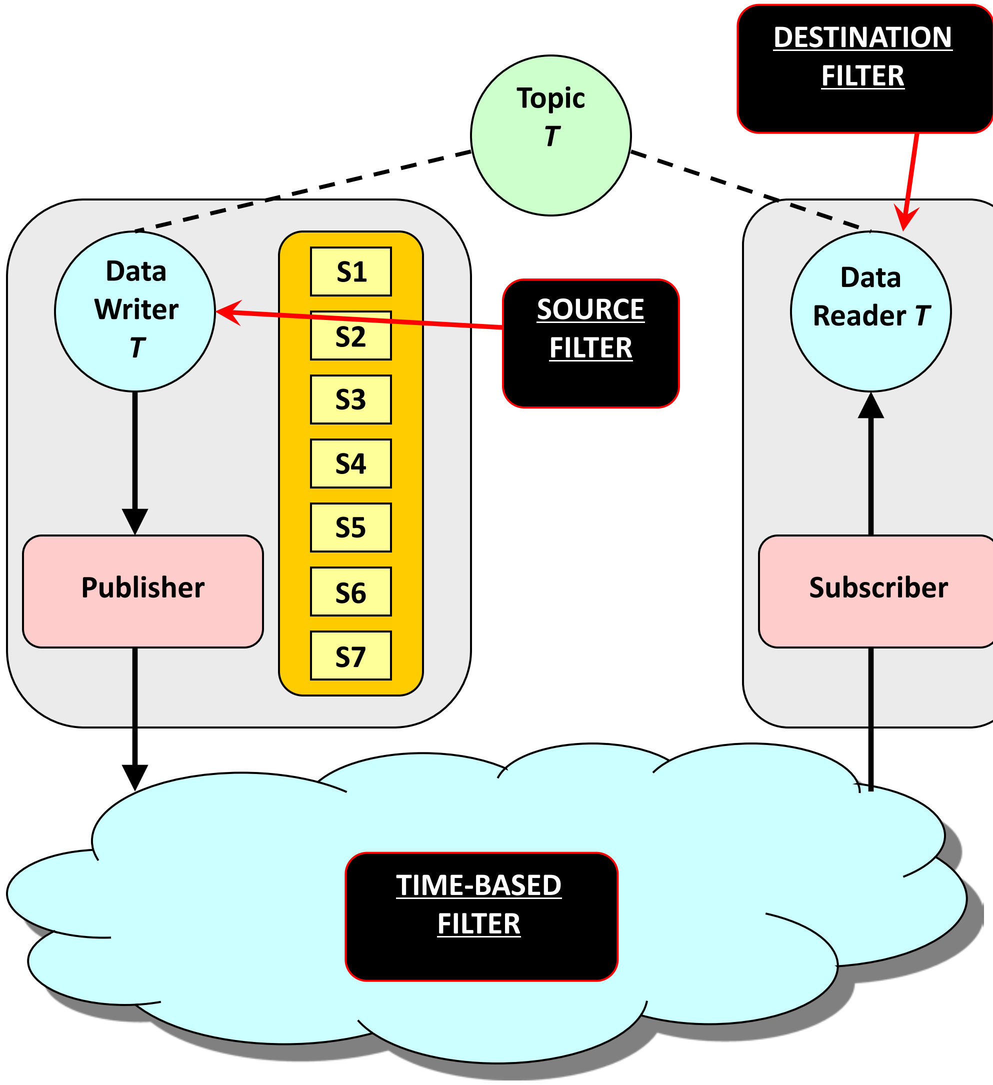
- DDS provides policies for specifying many QoS requirements of tactical information management systems, e.g.,
    - Establish contracts that precisely specify a wide variety of QoS policies at multiple system layers
    - Move processing closer to data



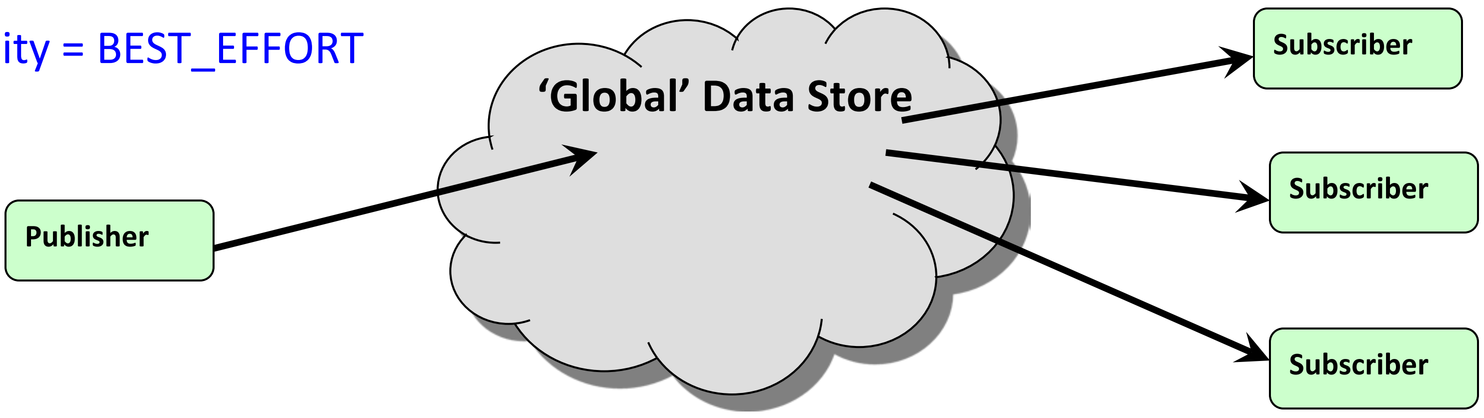
All QoS Policies in DDS

- Deadline
- Destination Order
- Durability
- Durability Service
- Entity Factory
- Group Data
- History
- Latency Budget
- Lifespan
- Liveliness
- Ownership
- Ownership Strength
- Partition
- Presentation
- Reader Data Lifecycle
- Reliability
- Resource Limits
- Time-Based Filter
- Topic Data
- Transport Priority
- User Data
- Writer Data Lifecycle

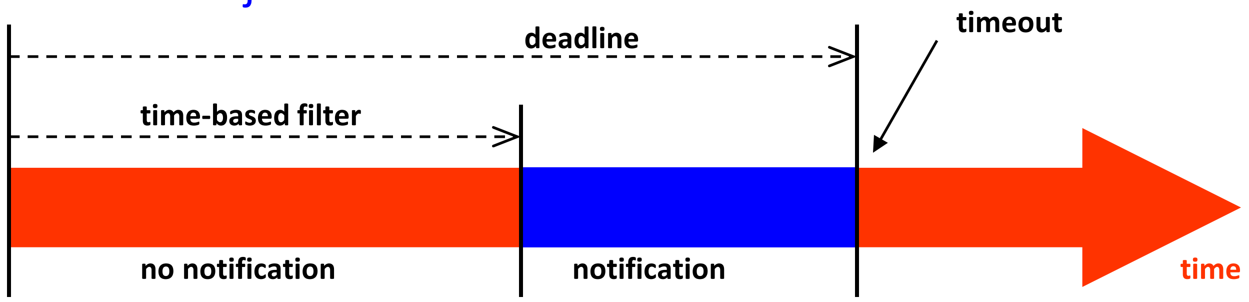
Detailed explanations in DDS specification

Best Effort Reliability QoS in DDS

QoS Reliability = BEST_EFFORT



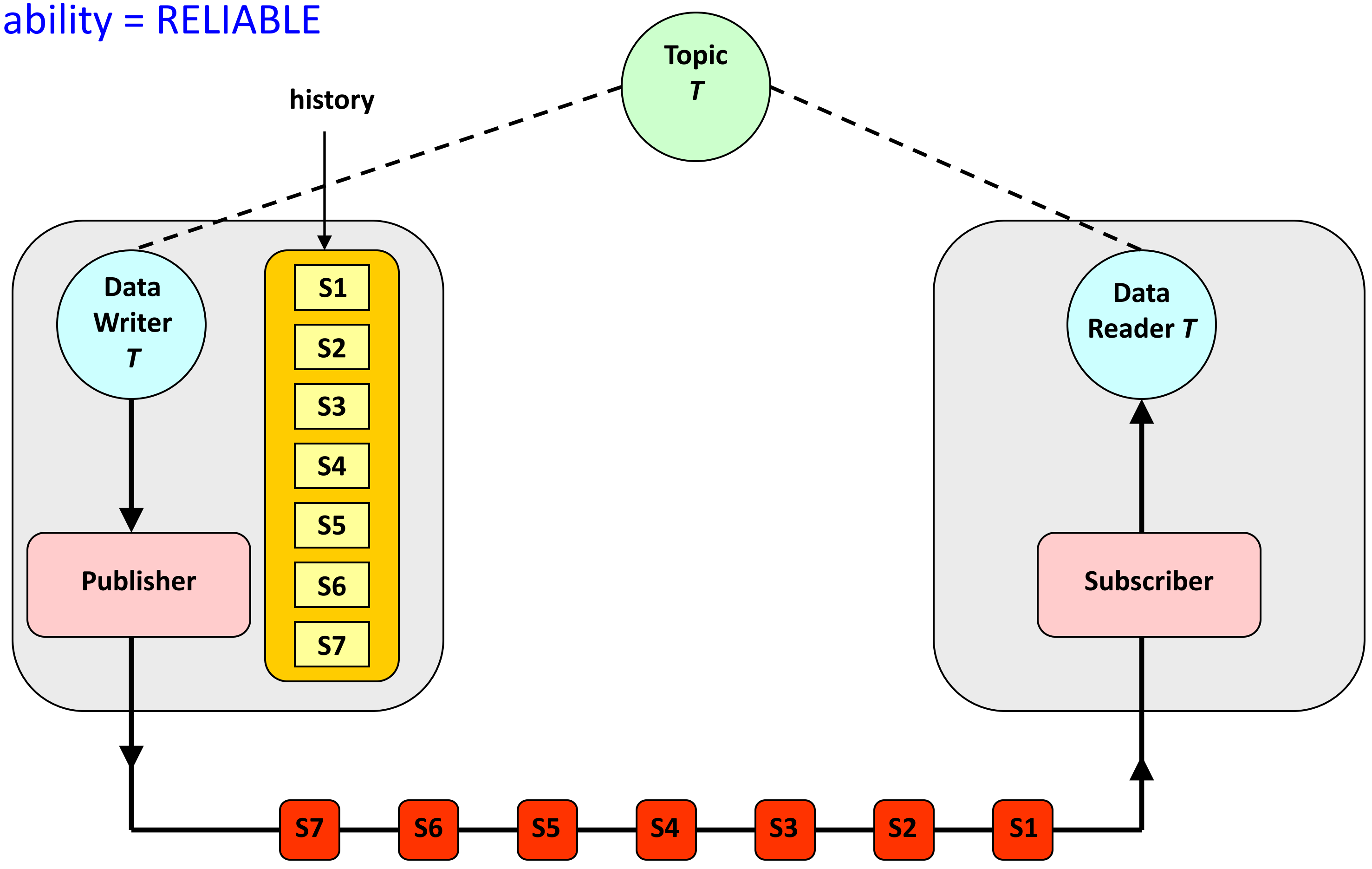
Notification of new data objects



- Very predictable
- Data is sent without reply
- Publishers and subscribers match and obey QoS Deadline policy settings
- Time-based Filter QoS policy gives bandwidth control

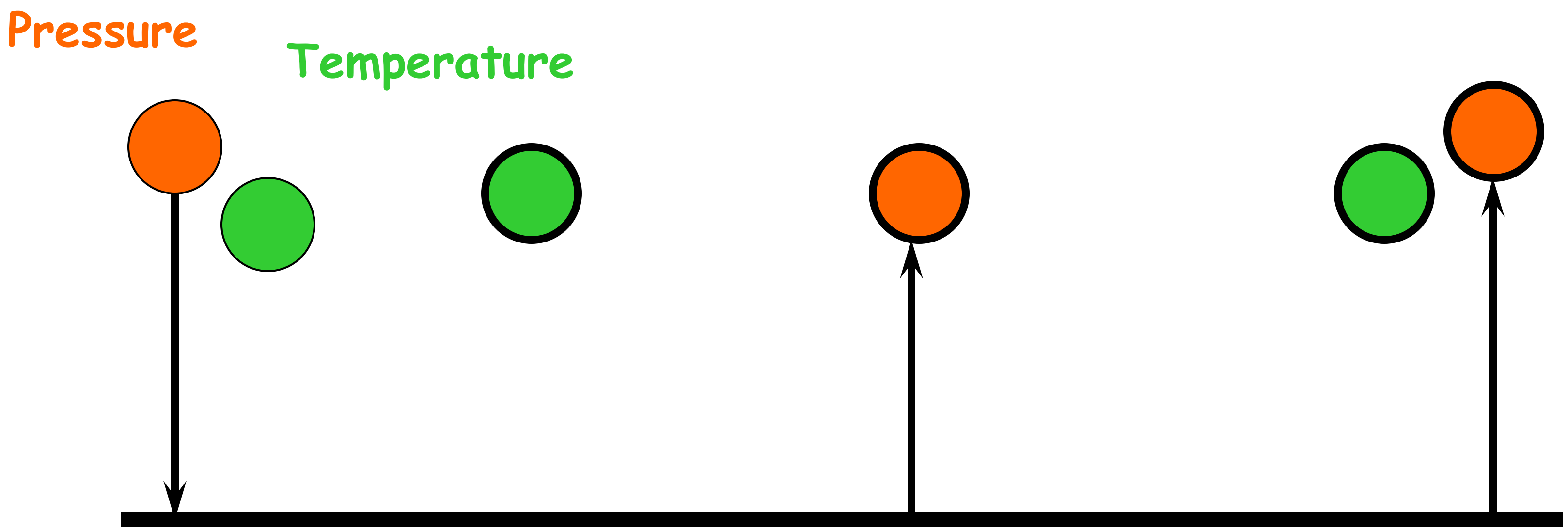
Reliable QoS in DDS

QoS Reliability = RELIABLE



Ordered instance delivery is guaranteed

Topic-Based Publish/Subscribe



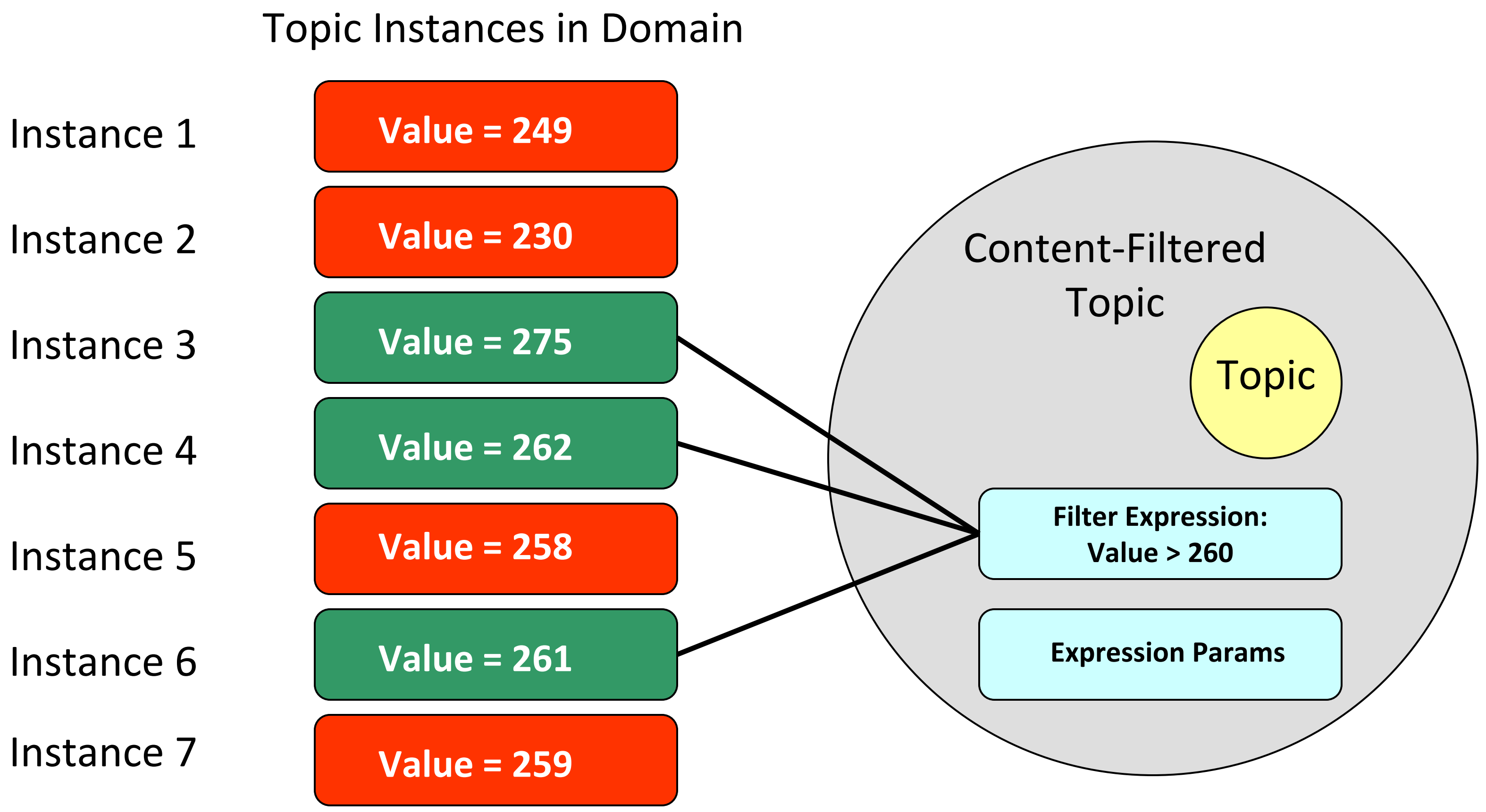
- **DataWriter** is bound (at creation time) to a single **Topic**
- **DataReader** is bound (at creation time) with one or more topics (**Topic, ContentFilteredTopic**, or **MultiTopic**)
  - **ContentFilteredTopic** & **MultiTopic** provide means for content-based subscriptions & "joins", respectively

Content-based Subscriptions

- **`ContentFilteredTopic`** (like a DB-selection)
  - Enables subscriber to only receive data-updates whose value verifies a condition.
  - *e.g.* subscribe to “Pressure” of type **`AnalogData`**
    - where “value > 200”
- **`MultiTopic`** (like a DB-join operation)
  - Enables subscription to multiple topics & re-arrangement of the data-format
  - *e.g.* combine subscription to “Pressure” & “Temperature” & re-arrange the data into a new type:

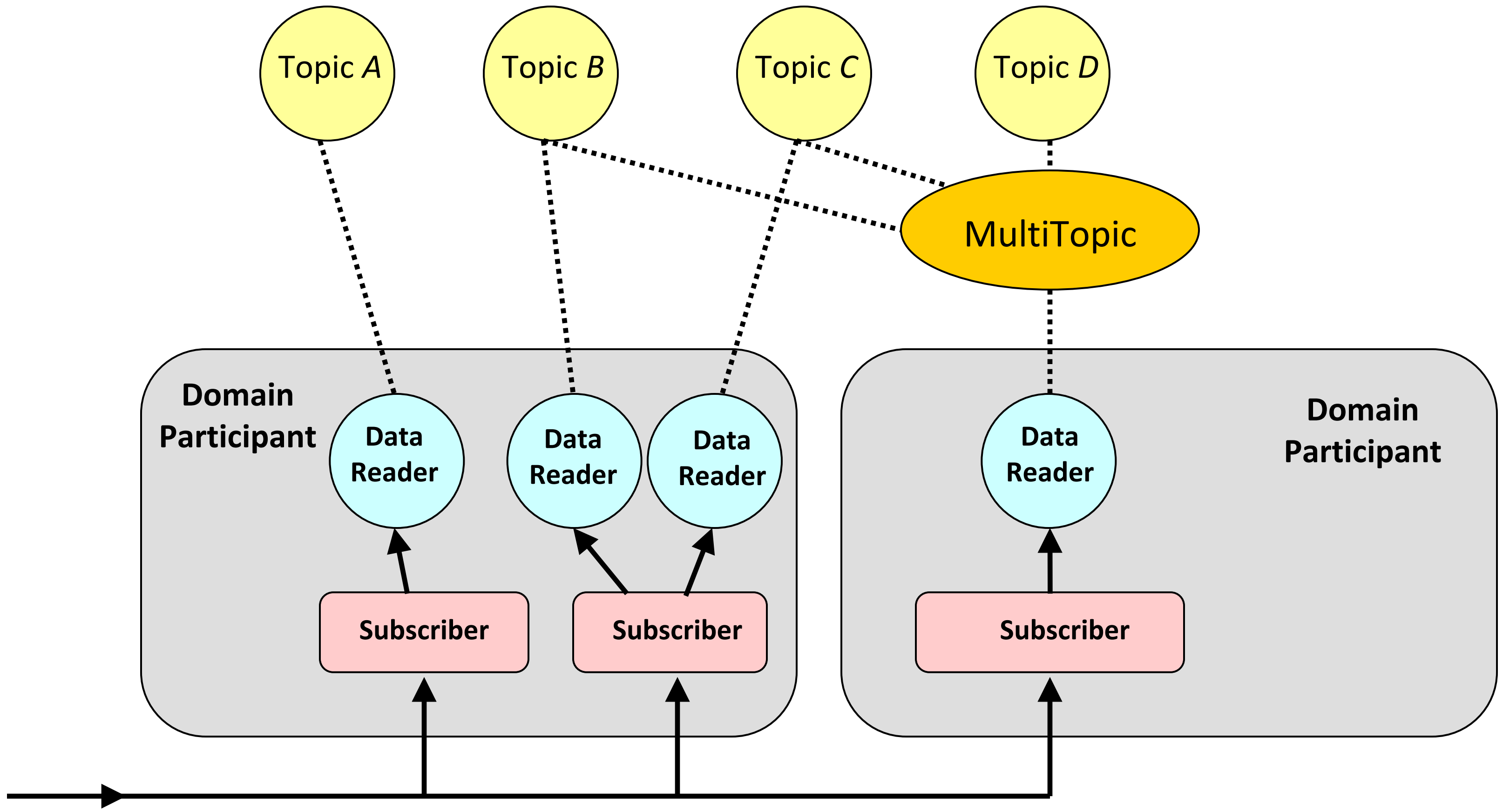
```
struct { float pres; float temp; };
```

DDS Content-Filtered Topics



Filter Expression and Expression Params determine which Topic instances the Subscriber receives.

DDS MultiTopic Subscriptions



MultiTopics can combine, filter, and rearrange data from multiple Topics.

QoS Pattern for Consistency

Goal: Have all data readers receive same data in same order from all data writers even in event of crash

Approach: Compose support for consistency using QoS primitives

DURABILITY
- **Set to PERSISTENT**
- **Data survives crash of the data writers/readers**

RELIABILITY
- **Set to RELIABLE**
- **Data sent from single writer received in order sent**

DESTINATION_ORDER
- **Set to SOURCE_TIMESTAMP**
- **Data sent from multiple writers received in order sent**

LIFESPAN
- **Set to INFINITE**
- **Designate data as valid until taken by reader**

Consistency Pattern

Durability

Reliability

Destination Order

Lifespan

QoS Pattern for Fault Tolerance

Goal: Have data writer fail over to replica if non-responsive

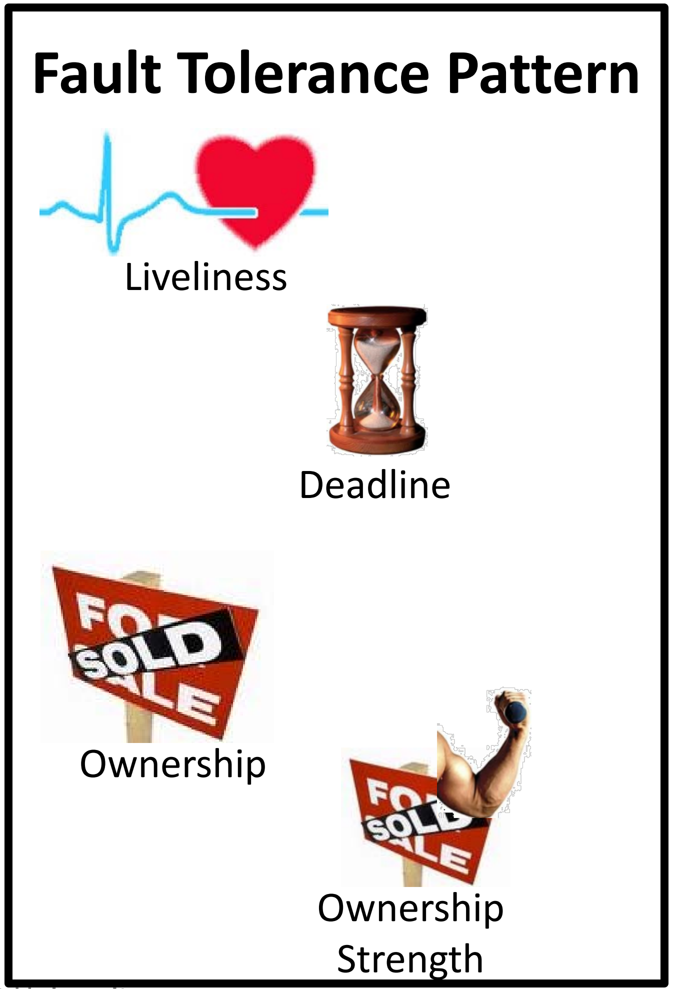
Approach: Compose support for fault tolerance using QoS primitives

LIVELINESS
- **Set to AUTOMATIC**
- **Loss of heartbeat triggers failover**

DEADLINE
- **PERIOD set to maximum latency of data**
- **Data not received within period triggers failover**

OWNERSHIP
- **Set to EXCLUSIVE**
- **Data only received from one data writer**

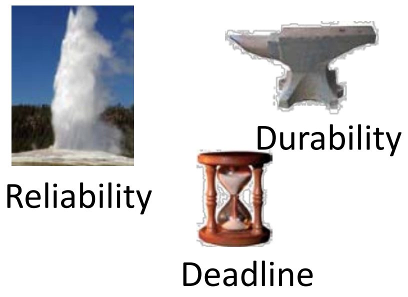
OWNERSHIP_STRENGTH
- **VALUE reflects order/importance of replica**
- **Determines who takes over after fault**



Concluding Remarks

Supporting & managing intelligent event processing can be challenging

- Wide range of QoS needed
- Complex interactions



QoS-enabled Pub/Sub middleware can help

- QoS primitives for low level functionality
- Patterns for higher level functionality

Additional resources

- OMG DDS specification (portals.omg.org/dds)
- DDS patterns
  - www.prismtechnologies.com/section-item.asp?snum=5&sid=83
  - www.omg.org/news/meetings/workshops/RT_2006_Workshop_CD/05-1_Hunt.pdf

Thank you for your time and attention

Soli Deo Gloria