DDS: A Next-Generation Approach to Building Distributed Real-Time Systems

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The Real-Time Middleware Experts

2010 Masterclass
http://www.rti.com

Outline

- Overview of Technology
  - Background
  - Applications
  - Data-Centric Pub-Sub
  - Quality of Service
  - Add-on components
- Application development cycle
- Architecting data-centric systems & modeling the Data
- Protocol, Performance & Scalability.
- Integrating external and legacy systems.
- Future directions and Standards:

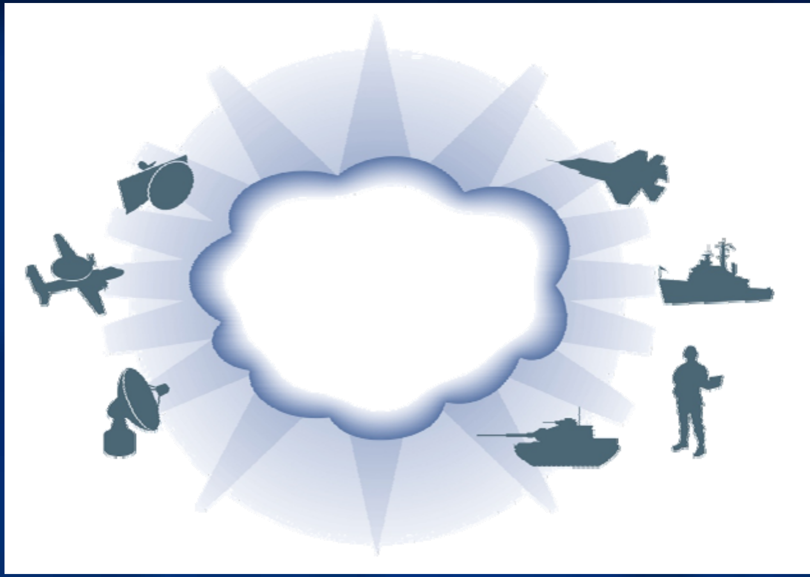
Challenge:
More Data, More Speed, More Sources

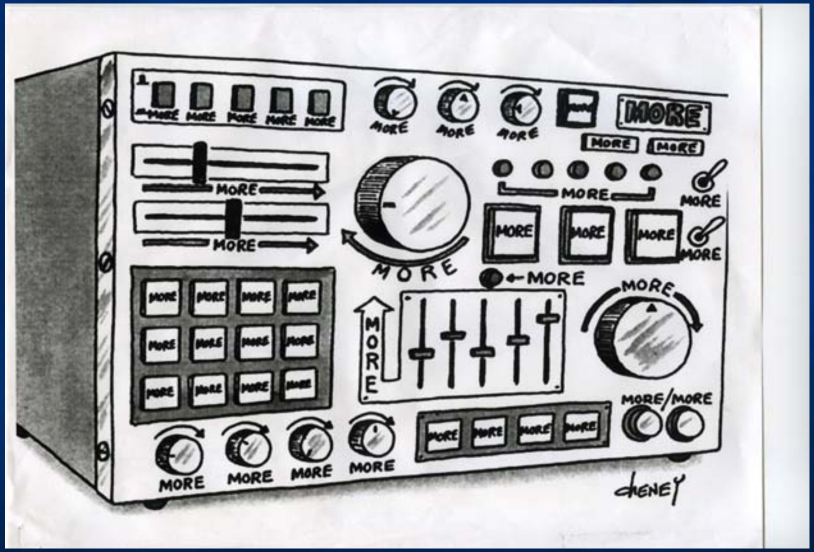
TRENDS:

- Growing Information Volume
- Lowering Decision Latency
- Increasing System Availability
- Accelerating technology insertion and deployment

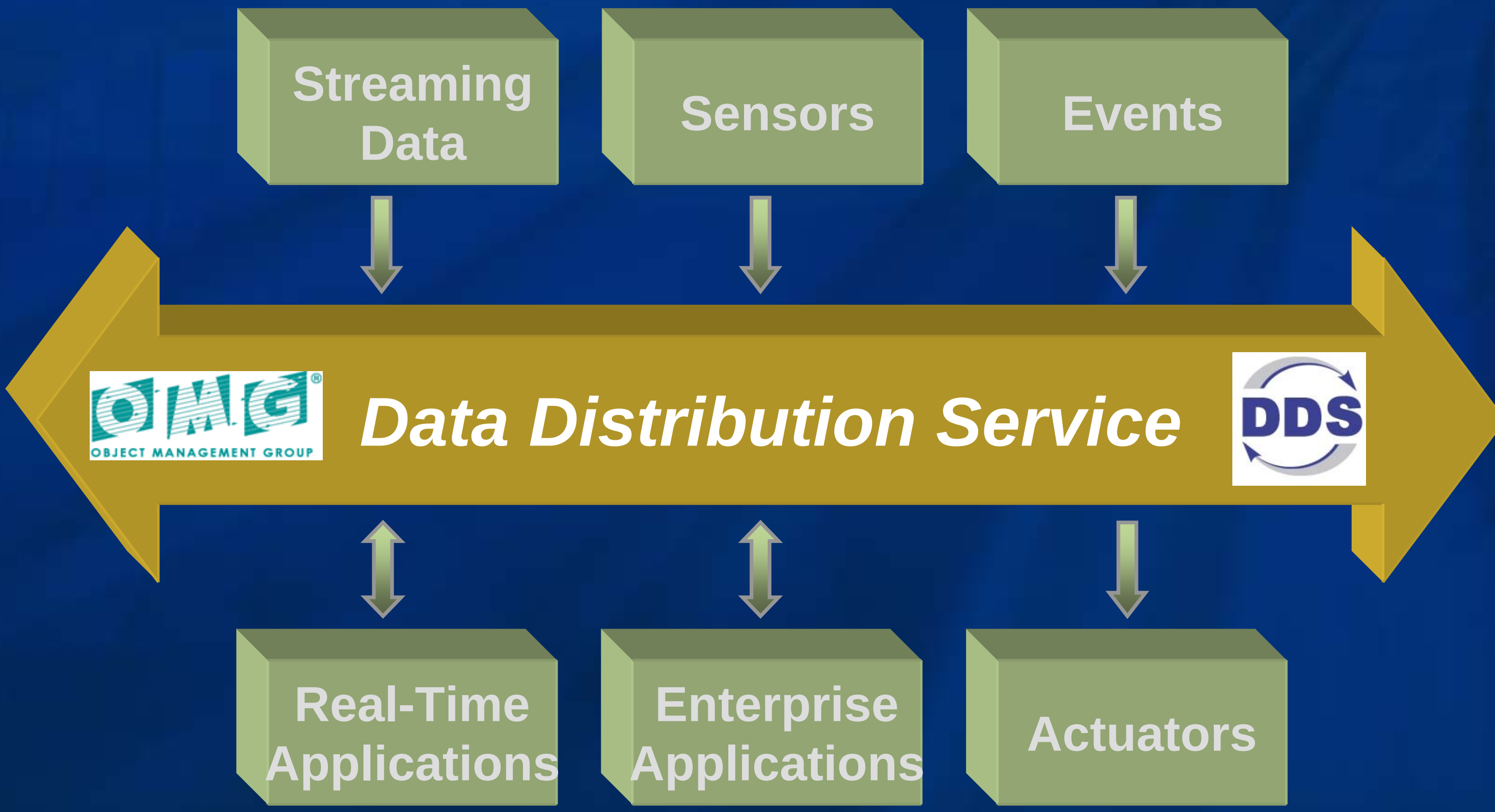
Next-generation systems needs:

- Performance
- Scalability
- Robustness & Availability
- Platform Integration & Evolution
- Safety-Critical Certification
- Security





Solution: Standards-based Integration Infrastructure for Real-Time Applications



Architecture for the next-generation systems

- Existing technologies are reaching robustness/performance/scalability limits
- RTI DDS brings a fundamental new architecture and approach
  - Fully decentralized, peer-to-peer, "no bottlenecks" architecture
  - Superior Wire Protocol
  - Powerful data-centric model
  - Built-in Robustness and High-Availability
  - Standards-based, multi-platform

Single-lane traffic
No prioritization

Brokers as choke-points

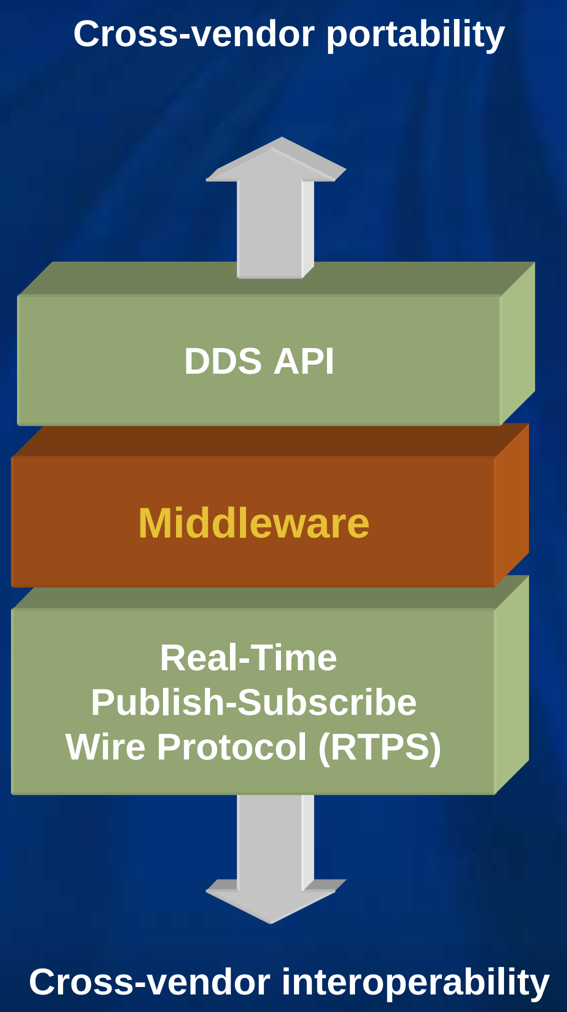
RTI Approach

History: DDS the Standards

- Data Distribution Service for Real-Time Systems
  - API for Data-Centric Publish-Subscribe distributed systems
  - Adopted in June 2003
  - Revisions: 2004, 2005, 2006
  - Spec version 1.2: formal/2007-07-01
- Interoperability wire protocol
  - Adopted in July 2006
  - Revised in July 2007
  - Spec version 2.1: formal/2009-01-05
- Related specifications
  - UML Profile for DDS
  - DDS for Light-Weight CCM
  - Extensible Topics for DDS(*)
- Multiple (7+) Implementations

Open Architecture

- Vendor independent
  - API for portability
  - Wire protocol for interoperability
- Multiple implementations
  - 7 of API
  - 4 support RTPS (+1 non-DDS)
- Heterogeneous
  - C, C++, Java, .NET (C#, C++/CLI)
  - Linux, Windows, VxWorks, other embedded & real-time
- Loosely coupled



RTI DDS Application Examples

Aegis Weapon System

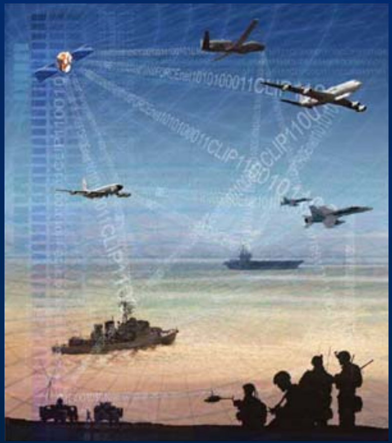
Lockheed Martin

Radar, weapons, displays, C2

B-1B Bomber

Boeing

C2, communications, weapons



Common Link Integration Processing (CLIP)

Northrop Grumman

Standards-compliant interface to legacy and new tactical data links

Air Force, Navy, B-1B and B-52

ScanEagle UAV

Boeing

Sensors, ground station

Advanced Cockpit Ground Control Station

Predator and SkyWarrior UAS

General Atomics

Telemetry data, multiple workstations

RoboScout

Base10

Internal data bus and link to communications center

RTI DDS Application Examples

Multi-ship simulator

FORCE Technology

Controls, simulation display

Mobile asset tracking

Wi-Tronix

GPS, operational status over wireless links

Highway traffic monitoring

City of Tokyo

Roadway sensors, roadside kiosks, control center

Driver safety

Volkswagen

vision systems, analysis, driver information systems

Medical imaging

NMR and MRI

Sensors, RF generators, user interface, control computers

Automated trading

Automated Trading Desk (ATD, now Citigroup)

Market data feed handlers, pricing engines, algorithmic trading applications

RTI DDS Application Examples

Full-immersion simulation

National Highway Transportation Safety Authority

Migrated from CORBA, DCOM for performance

Air-Traffic Management

INDRA.

Deployed in

UK, Germany, Spain

Standards, Performance, Scalability

Industrial Control

Schneider Electric

VxWorks-based PLCs

communicate via RTI-DDS

Signal Processing

PLATH GMBH

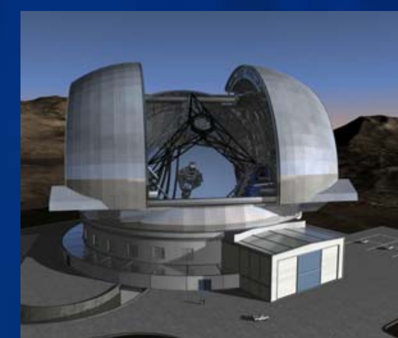
RTI supports modular programming across product line

Large Telescopes

European Southern Observatory

Performance & Scalability

1000 mirrors, 1sec loop



Radar Systems

AWACS upgrade

Evolvability, Mainteinability, and supportability

Standards Focus

- Object Management Group
  - Board of Directors member
  - Authored DDS and RTPS specs, co-chair SIG
- Open Group
- Network Centric Operations Industry Consortium (NCOIC)
  - Chair Open Standards and Patterns Working Group
- STAC Benchmark Council
- Support and integrate with:
  - DDS, RTPS, JMS, SQL, Web Services, CORBA, UML, HLA, JAUS, Eclipse, IPv6…

Corporate Background

- Founded by Stanford researchers
- Focused on real-time middleware
- Solid financials
  - 16-year track record of growth
- Real-Time Market Leader
  - #1 market share in embedded middleware of all types[1]
  - 70+% worldwide share of DDS market[2]
- 50/50 software and services

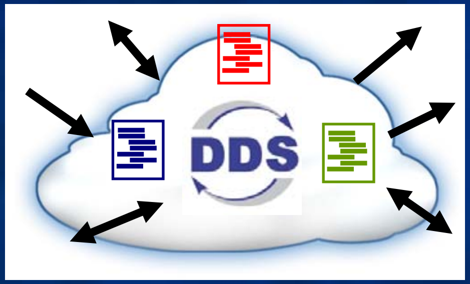
[1]Embedded Market Forecasters
[2]VDC Analyst Report

RTI Supports all Phases of Development

Services Capabilities	Engagement Timeline	Description
Workshop	2 days	Introduction to RTI products and capabilities
QuickStart	2+ days	In-depth training on RTI DDS API, QoS policies, and common architecture patterns
Support	On-Demand	Web-portal, phone and email customer lauded support
Architecture Study	3-4 weeks	Custom design review, risk analysis and architecture recommendations
Design Support Package	4+ weeks	Support hardware & software integration, architecture design, performance tuning, on-site debugging, implementation support
Integration & Development	SOW supported	Custom feature, tool and software development support
Ports	As needed	RTI tools and software on your special, purpose built hardware

RTI Global Presence

Benefits of the DDS approach



Simple & Powerful Data-Centric Pub-Sub Model

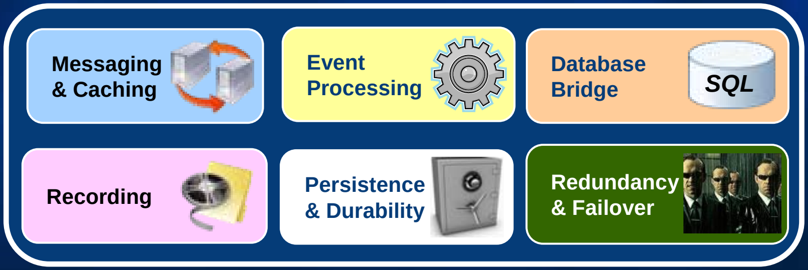
- Reduces Risk and Development/Integration Time
- Enhances effective performance by delivering the right data to the right place with the right QoS
- Standards-based: API and Protocol

1. Unsurpassed Performance and Scalability

- Priority-aware no choke-points architecture

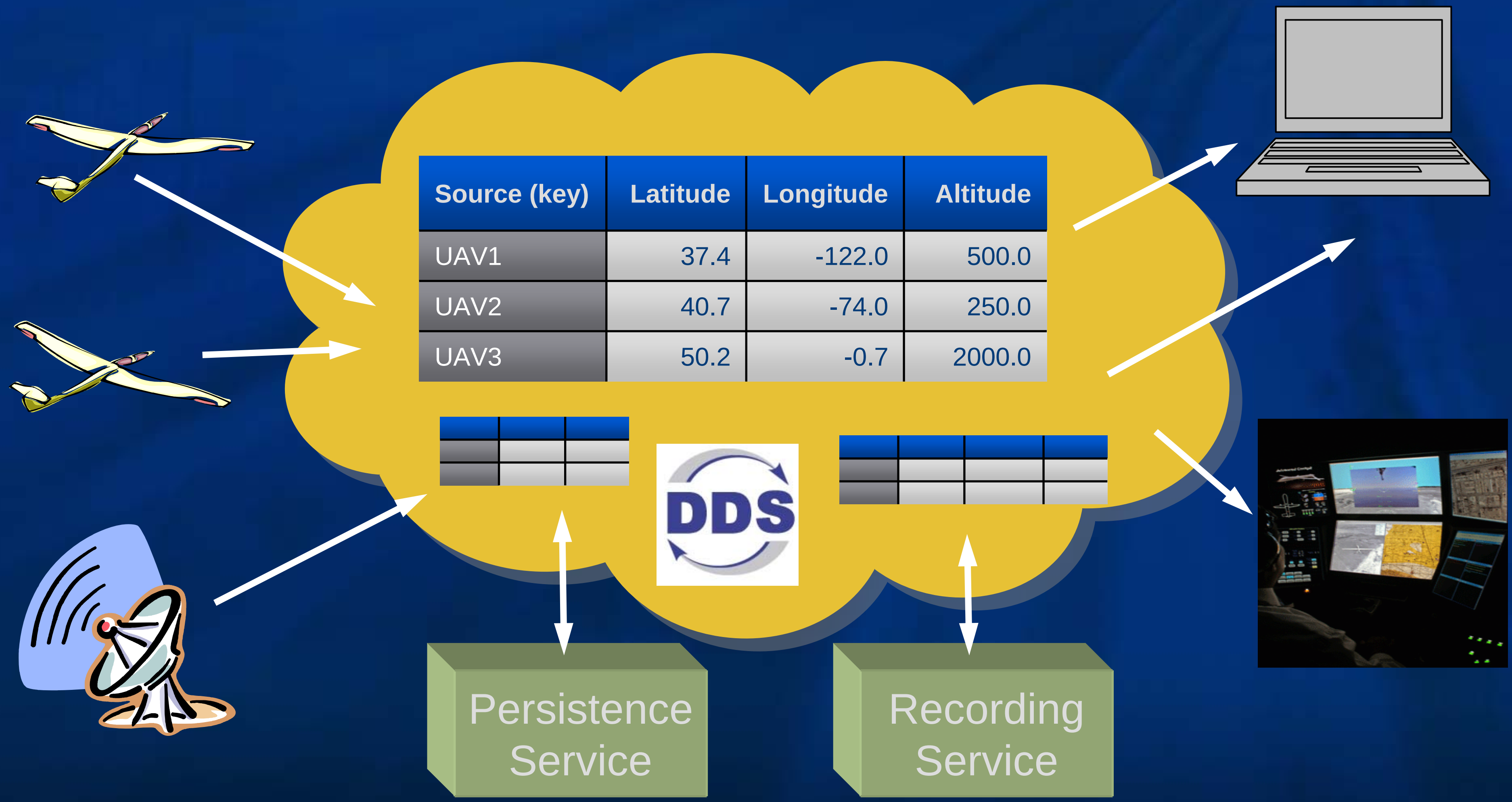
2. Builds higher quality systems and lowers TCO

- Built-in high-value capabilities
- Handles Availability & other "hard problems"
- Easy to maintain and Evolve
- Leverage multicore



Data-Centric Pub-Sub Model

Essentially a virtual, decentralized global data space



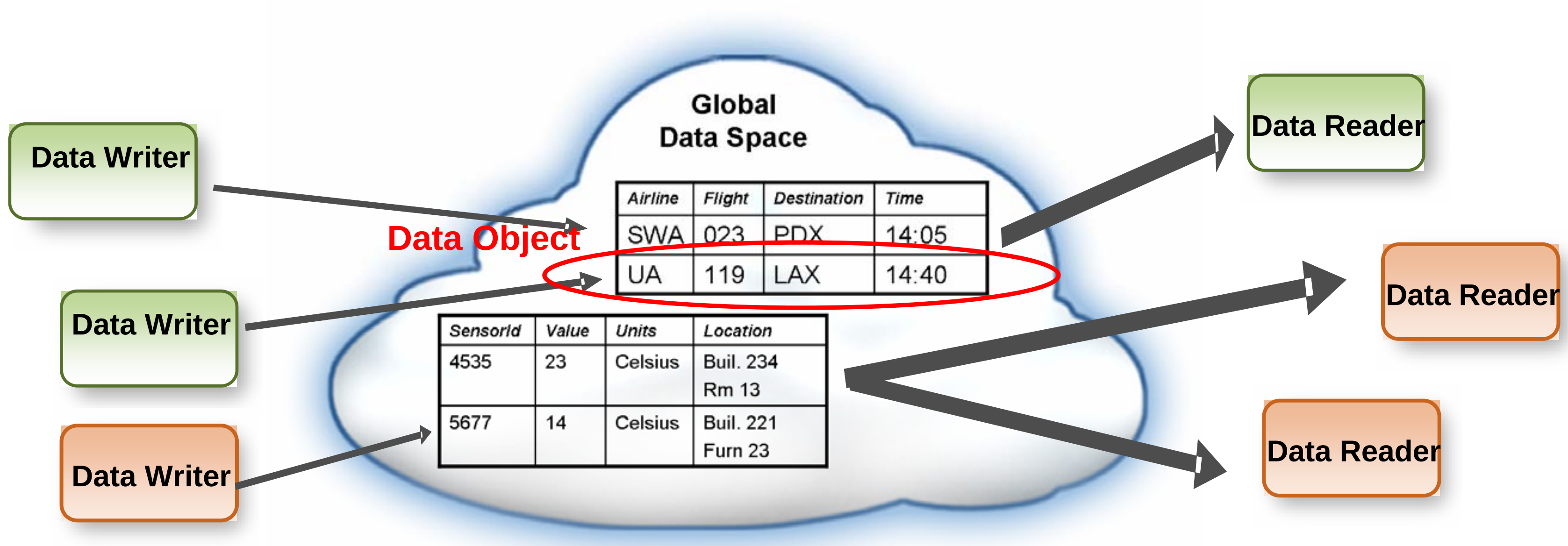
Source (key)	Latitude	Longitude	Altitude
UAV1	37.4	-122.0	500.0
UAV2	40.7	-74.0	250.0
UAV3	50.2	-0.7	2000.0

Data-Centric Model

example

"**Global Data Space**" generalizes Subject-Based Addressing

- Data objects addressed by **DomainId, Topic** and **Key**
- **Domains** provide a level of isolation
- **Topic** groups homogeneous subjects (same data-type & meaning)
- **Key** is a generalization of **subject**
  - **Key** can be any set of fields, not limited to a "x.y.z …" formatted string



Data-Centric Model

example

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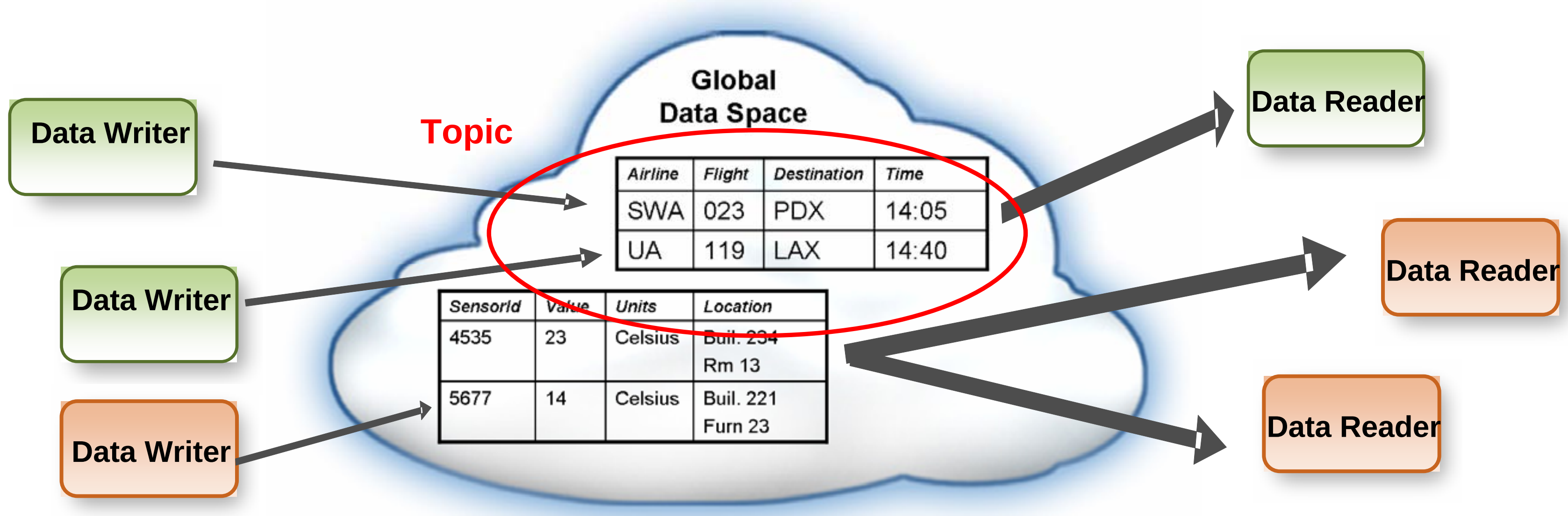

Data-Centric Model

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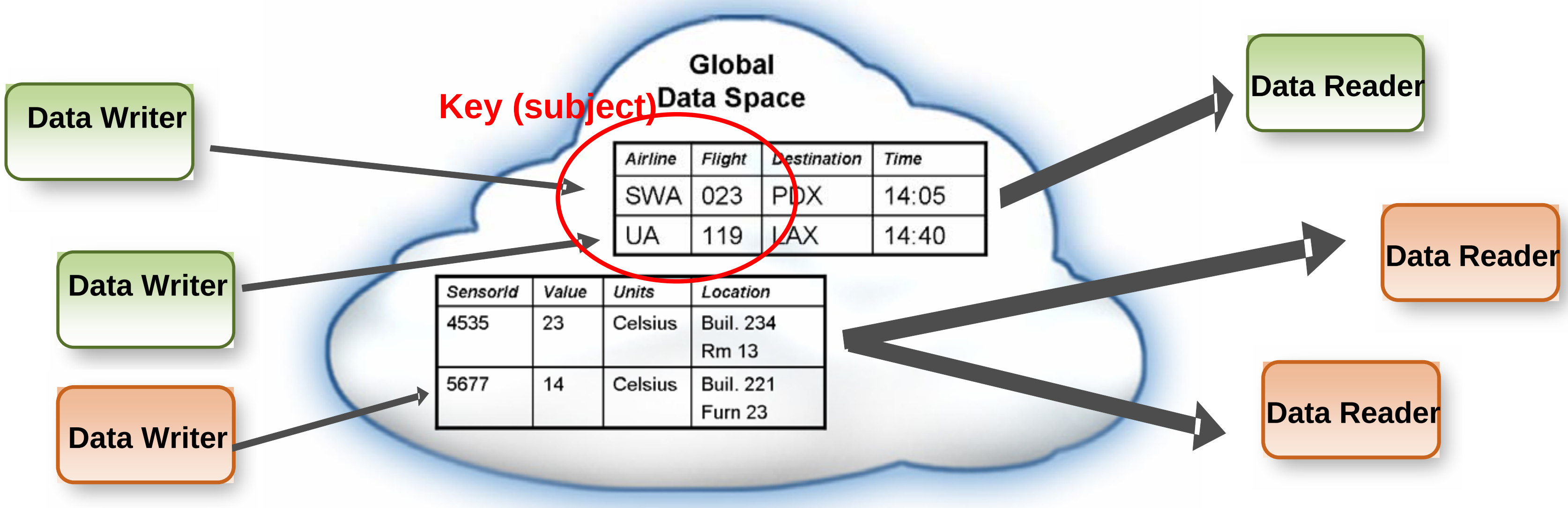
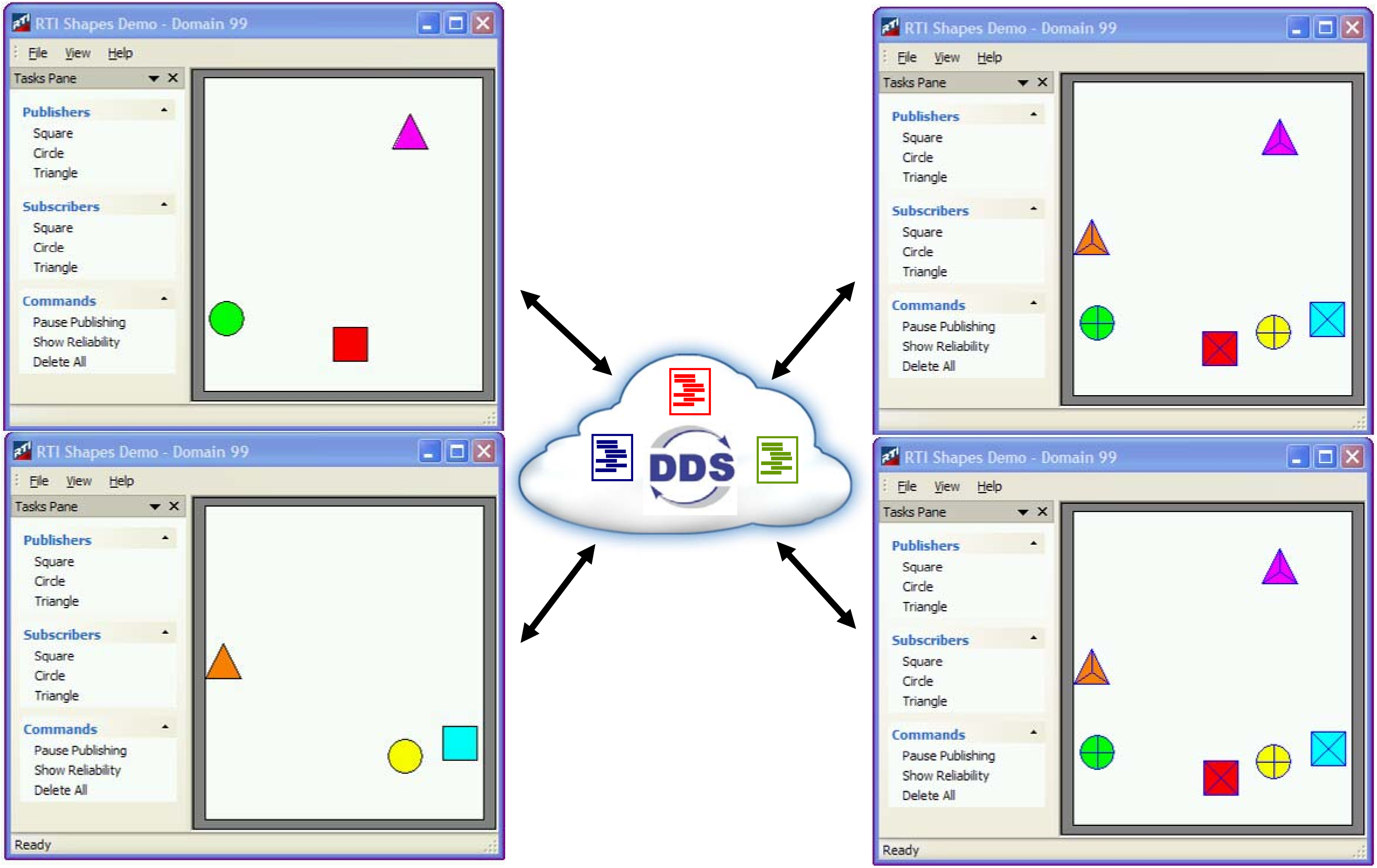


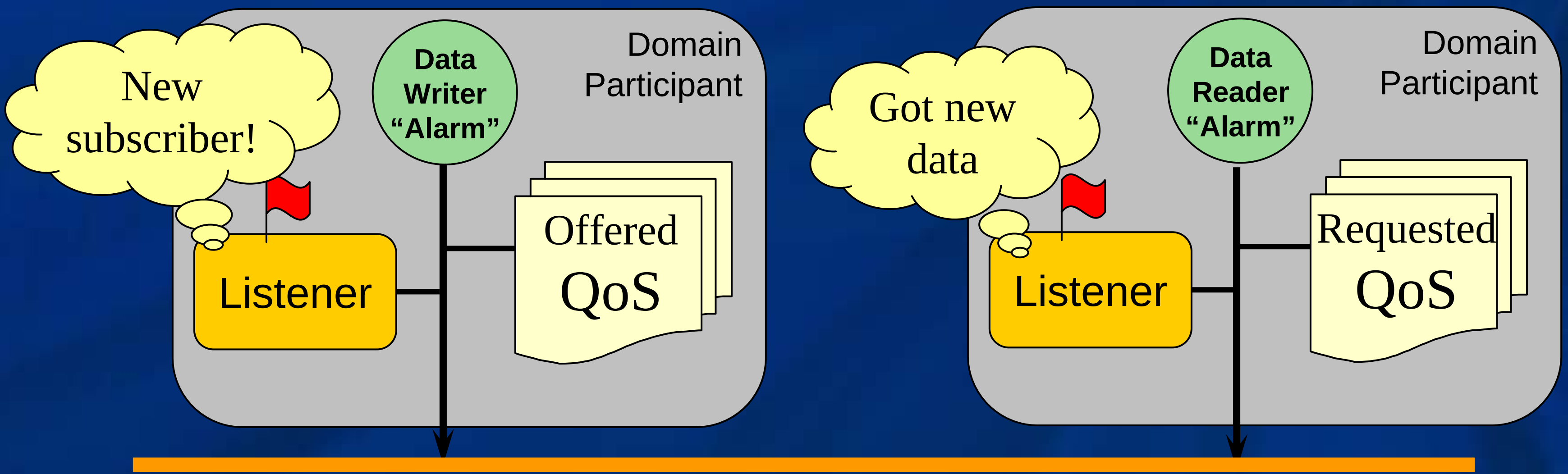
Demo: Publish-Subscribe

ShapesDemo



DDS communications model

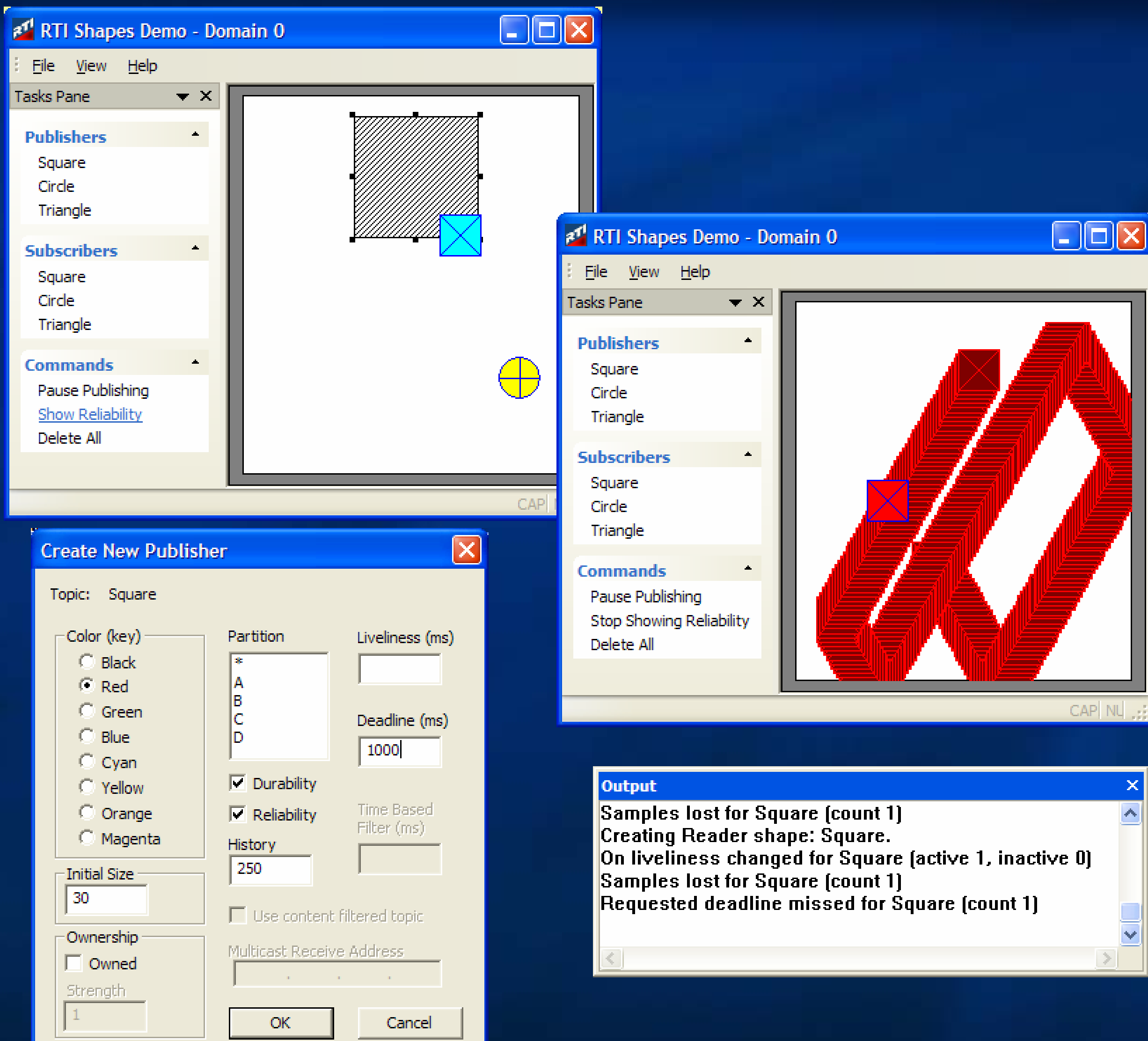
example



- **Participants** scope the global data space (domain)
- **Topics** define the data-objects (collections of subjects)
- **Writers** publish data on Topics
- **Readers** subscribe to data on Topics
- **QoS Policies** are used configure the system
- **Listeners** are used to notify the application of events

ShapesDemo

Demo: Real-Time Quality of Service



- Content filter
- Time-based filter
- History
- Deadline

Analyzer

Real-Time Quality of Service (QoS)

Volatility

Infrastructure

Delivery

QoS Policy
DURABILITY
HISTORY
READER DATA LIFECYCLE
WRITER DATA LIFECYCLE
LIFESPAN
ENTITY FACTORY
RESOURCE LIMITS
RELIABILITY
TIME BASED FILTER
DEADLINE
CONTENT FILTERS

QoS Policy
USER DATA
TOPIC DATA
GROUP DATA
PARTITION
PRESENTATION
DESTINATION ORDER
OWNERSHIP
OWNERSHIP STRENGTH
LIVELINESS
LATENCY BUDGET
TRANSPORT PRIORITY

User QoS

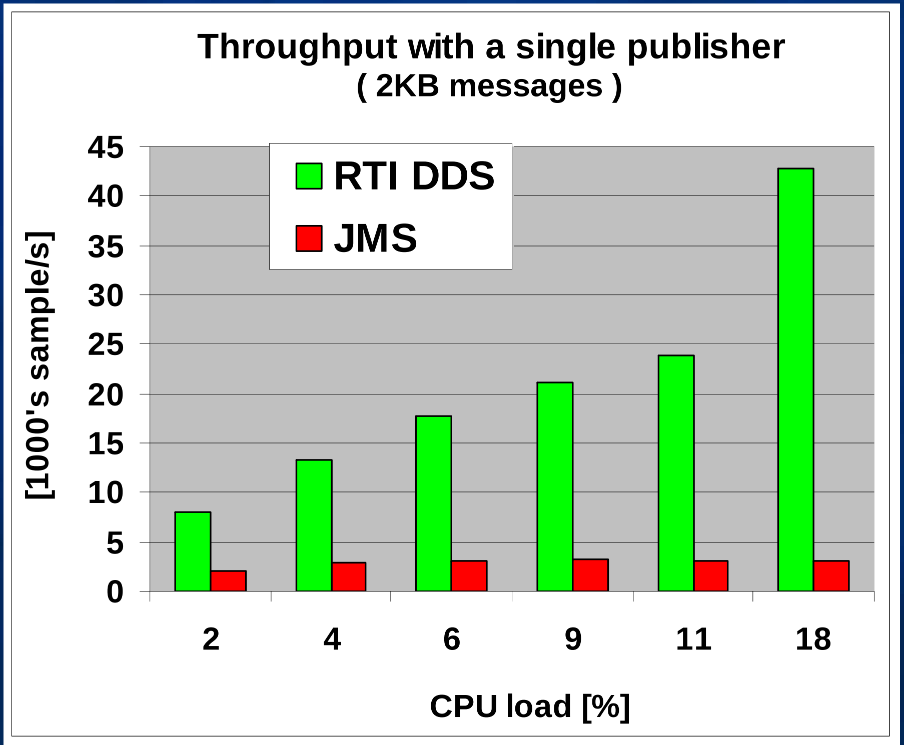
Presentation

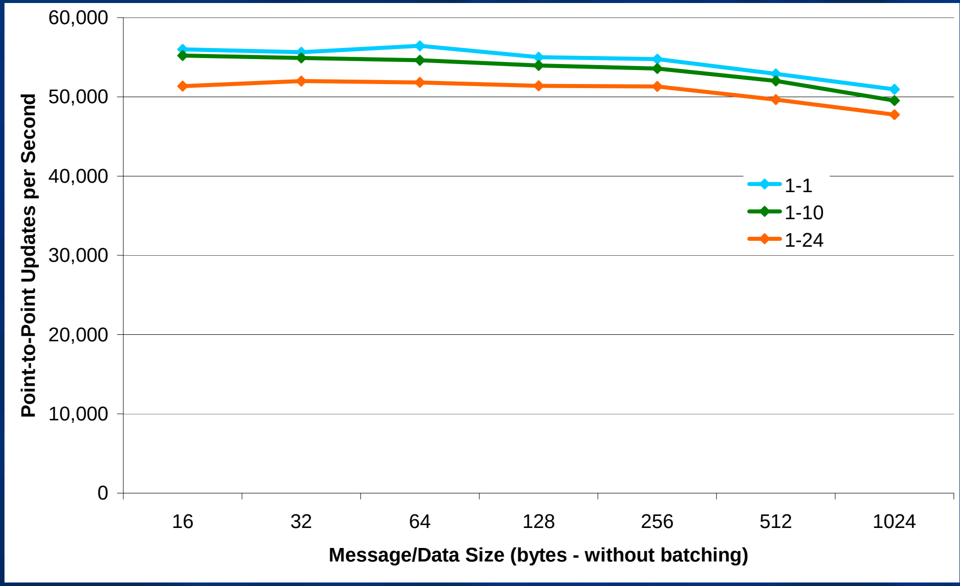
Redundancy

Transport

20X Faster than JMS / Broker-based solutions

RTI DDS is about 20X faster than JMS

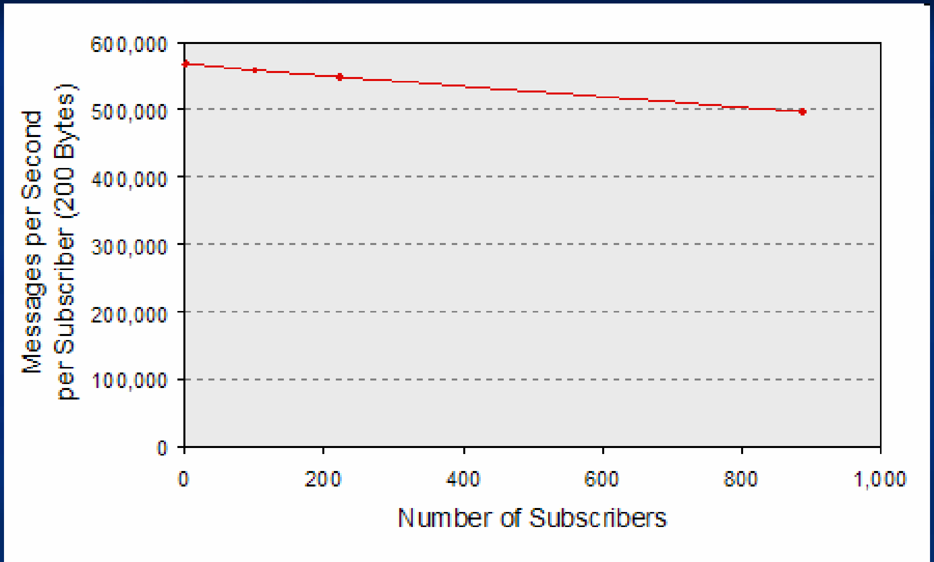


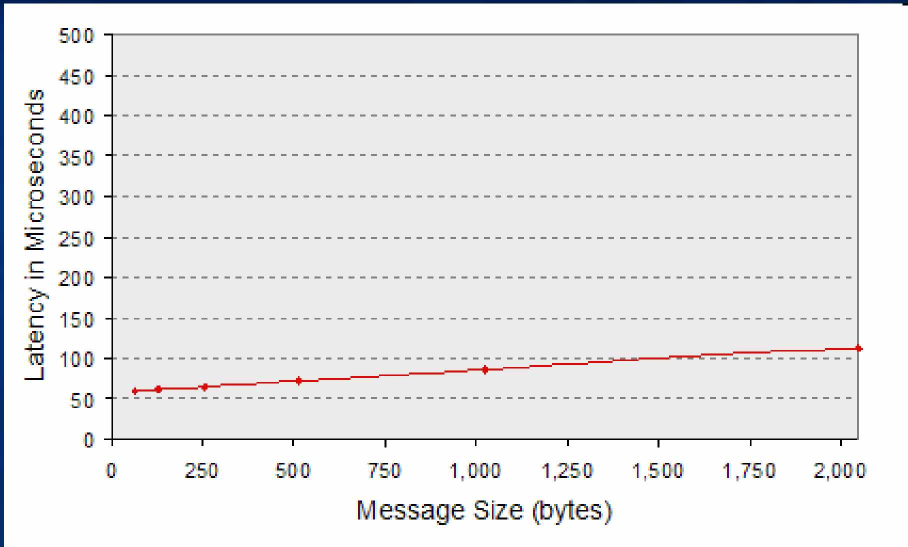


RTI DDS reliable multicast exhibits near perfect scalability

Platform: Linux 2.6 on AMD Athlon, Dual core, 2.2 GHz

DDS Is Scalable





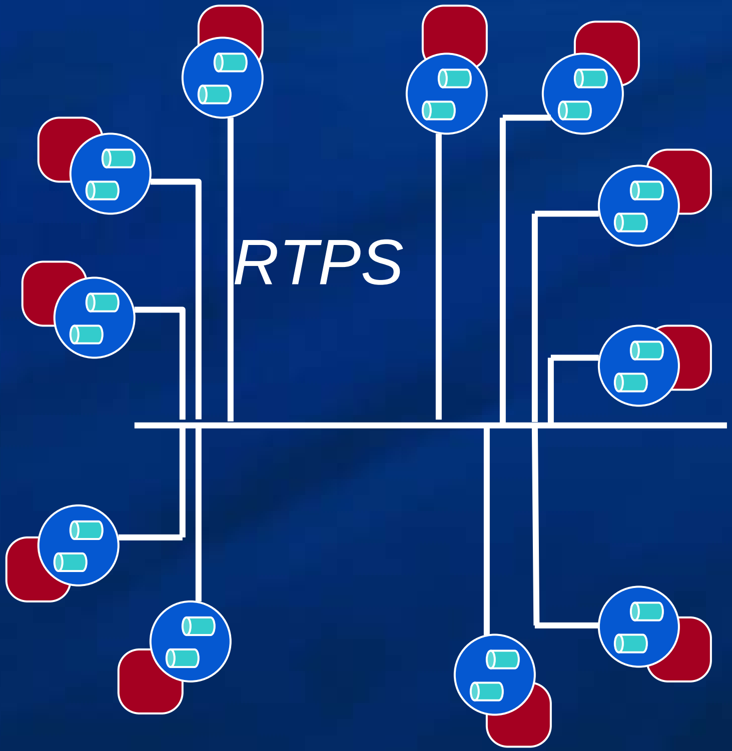
- Going from 1 to 888 subscribers of the same data has only a 10% impact on throughput

- Ultra-low latency and jitter
  – Deterministic
  – No intermediaries

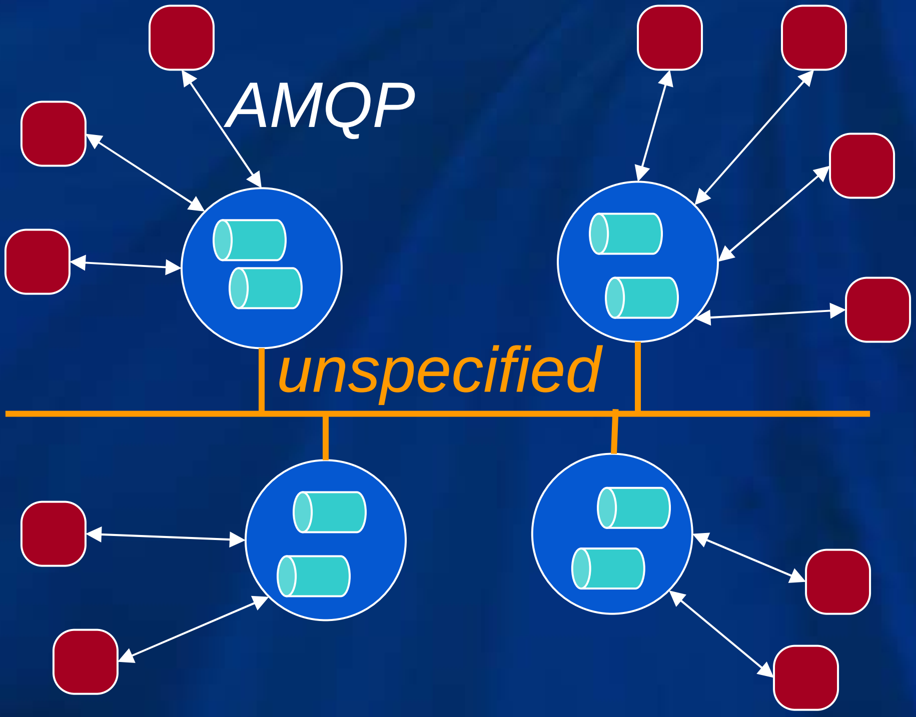
http://www.rti.com/products/dds/benchmarks-cpp-linux.html

Realizing Performance & Scalability

RTI DDS Approach



Others: Broker-based middleware

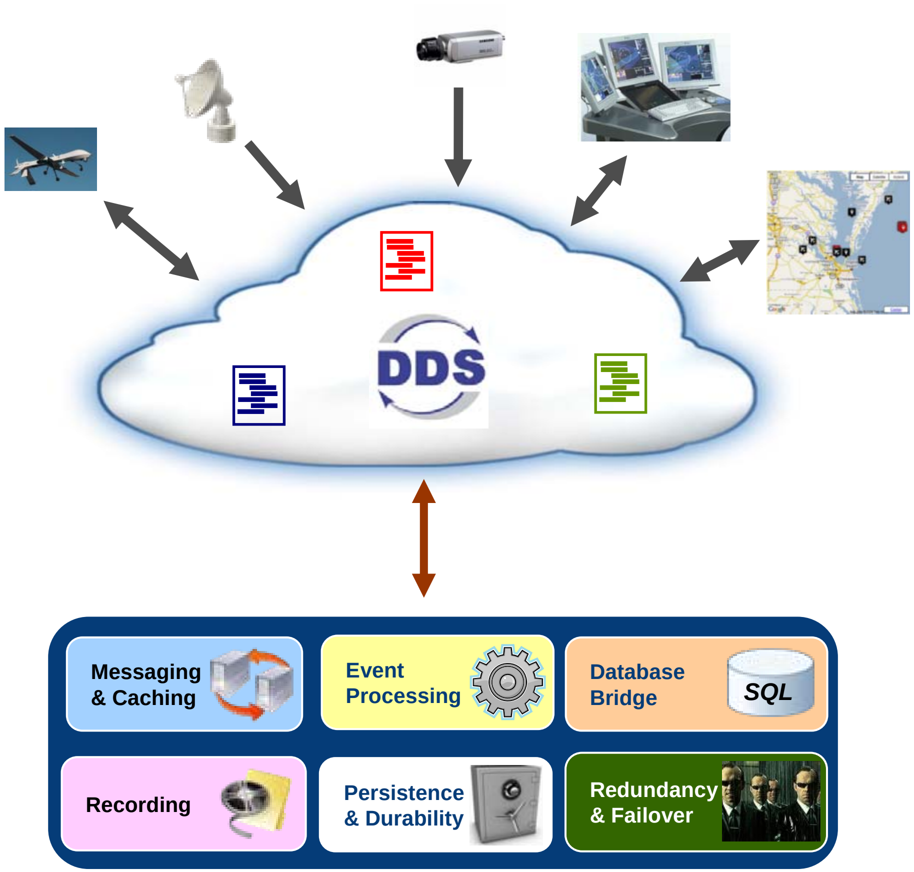


- *DDS operates peer-to-peer, without brokers*
- *DDS uses RTPS, an Advanced Multi-Session protocol supporting Reliable Multicast*

DDS Enables Higher quality, Lower TCO Systems

Pre-built components address many challenging use-cases

- Presence
- Discovery
- Historical Cache
- Durable Data
- Availability
- Redundancy & Failover
- Recording
- Database Connectivity
- Web Accessibility
- Transformation
- Event Processing
- WAN Routing
- Security Guard Hooks



Outline

- Overview of Technology
- Application development cycle
  - How to begin. Hello world example.
  - Defining data in XML and XSD
  - Development and Run-time Tools: Ping, Spy, Analyzer, Wireshark, Excel
  - Discovery and Builtin-Topics
  - Configuring QoS via XML files
- Architecting data-centric systems & modeling the Data
- Protocol, Performance & Scalability.
- Integrating external and legacy systems.
- Future directions and Standards:

Hands-on Example (C++)

Type Definition

MyType.idl

rtiddsgen

MyType.sln

MyType.h

MyTypeSupport.c

MyTypePublisher.cpp

MyTypeSubscriber.cpp

compiler

Publisher.exe

Subscriber.exe

Three minutes to a running app!!

1. Define your data
2. Create your project
3. Build
4. Run: publisher   subscriber

Aux:

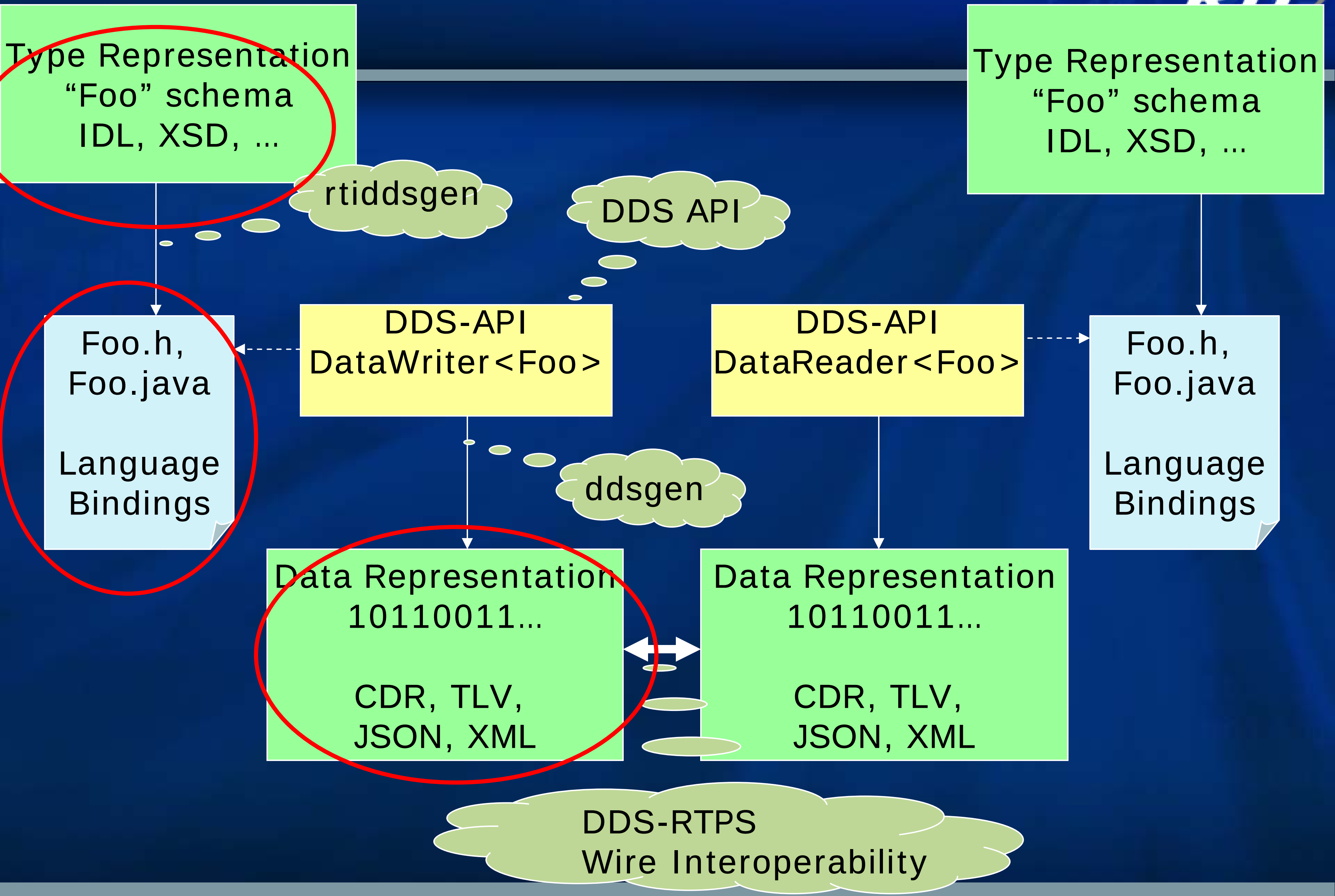
File Browser

Console

Delete Files

rtiddsspy

Alternatives beyond IDL and CDR



Alternative Type Description Languages

rtiddsgen supports 4 alternative ways to define types:

- All are equivalent
- You can convert between all these formats

- IDL
  - + Simple, Compact, Similar to C/C++/Java
  - + Allows type sharing with CORBA
  - - Perceived as “legacy”
  - - Limited tool support
- XML
  - + Good tool support and syntax validation
  - + Familiar to a large community. Fashionable
  - - More verbose. Custom Syntax
- XSD
  - + Good tool support
  - + Commonly used as a type-description language
  - - Cumbersome syntax for certain types. Not human friendly
- WSDL
  - + Same as XSD and allows type sharing with Web-Services
  - - Same as XSD

Exercise:
- Start with an IDL Type
  - Convert to XML
  - Convert to XSD
- Start with an XML-defined type
  - Convert to IDL
  - Convert to XSD

rtiddsgen Details

```
rtiddsgen [-d <outdir>] [-language <C|C++|Java|C++/CLI|C#>]
          [-namespace] [-package <packagePrefix>]
          [-example <arch>] [-replace] [-debug]
          [-corba [client header file]] [-optimization <level of optimization>]
          [-stringSize <Unbounded strings size>]
          [-sequenceSize <Unbounded sequences size>]
          [-notypecode] [-ppDisable] [-ppPath <path to the preprocessor>]
          [-ppOption <option>] [-D <name>[=<value>]]
          [-U <name>] [-I <directory>] [-noCopyable] [-use42eAlignment]
          [-help] [-version] [-convertToIdl | -convertToXml | -convertToXsd |
            -convertToWsdl]
          [[-inputIdl] <IDLInputFile.idl> | [-inputXml] <XMLInputFile.xml> | [-inputXsd]
      <XSDInputFile.xsd> | [-inputWsdl] <WSDLInputFile.wsdl>]
```

- *DefinitionFile* can be IDL, XSD and XML file
- *-example* generates example pub/sub apps and makefiles for compilation.
- *-replace* replaces everything that's generated. Use if the data type definition has changed. Always use with caution if you've made modifications.

IDL vs. XML: IDL Example

```
struct MemberStruct{
  short sData;
}

typedef MemberStructType; //@top-level false
```

IDL vs. XML: XML Example

```
<?xml version="1.0“
      encoding="UTF-8"?>
<types   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
         xsi:noNamespaceSchemaLocation="../rti_dds_topic_types.xsd">

  <struct name="MemberStruct"
          topLevel="false">
    <member name="sData“ type="short"/>
  </struct>

  <typedef name="MemberStructType"
           type="nonBasic“
           nonBasicTypeName="MemberStruct“
           topLevel="false"/>
</types>
```

IDL vs. XSD: XSD Example

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:dds="http://www.omg.org/dds" xmlns:tns="http://www.omg.org/IDL-
Mapped/" targetNamespace="http://www.omg.org/IDL-Mapped/">
  <xsd:import namespace="http://www.omg.org/dds"
schemaLocation="rti_dds_topic_types_common.xsd"/>
  <xsd:complexType name="MemberStruct">
    <xsd:sequence>
      <xsd:element name="sData" minOccurs="1" maxOccurs="1"
type="xsd:short"/>
    </xsd:sequence>
  </xsd:complexType>
    <!-- @topLevel false -->

  <xsd:complexType name="MemberStructType">
    <xsd:complexContent>
      <xsd:restriction base="tns:MemberStruct">
        <xsd:sequence>
          <xsd:element name="sData" type="xsd:short" minOccurs="1"
maxOccurs="1"/>
        </xsd:sequence>
      </xsd:restriction>
    </xsd:complexContent>
  </xsd:complexType>
    <!-- @topLevel false -->
</xsd:schema>
```

ShapesDemo

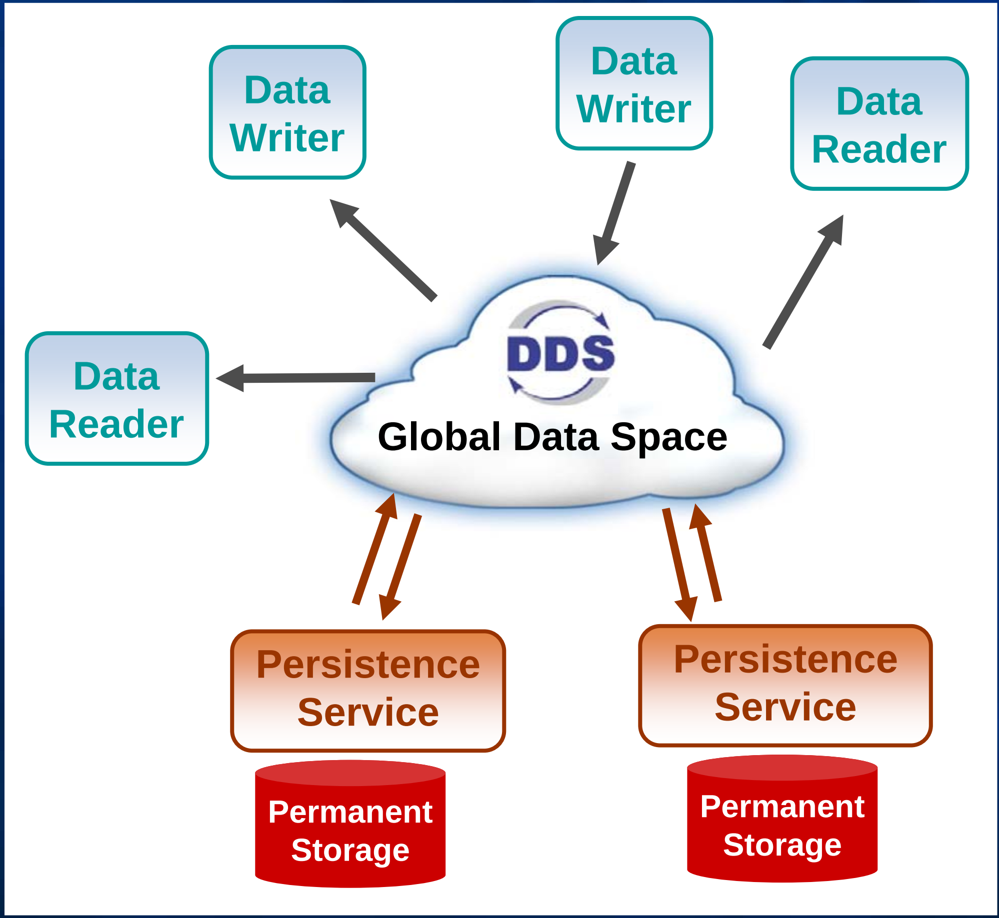
Persistence_svc

Data Persistence

A standalone service that persists data outside of the context of a DataWriter

Can be configured for:

- **Redundancy**
- **Load balancing**
- **Direct for performance**
- **Relay/Transactional**
- **Redundant/ Fault-tolerant**



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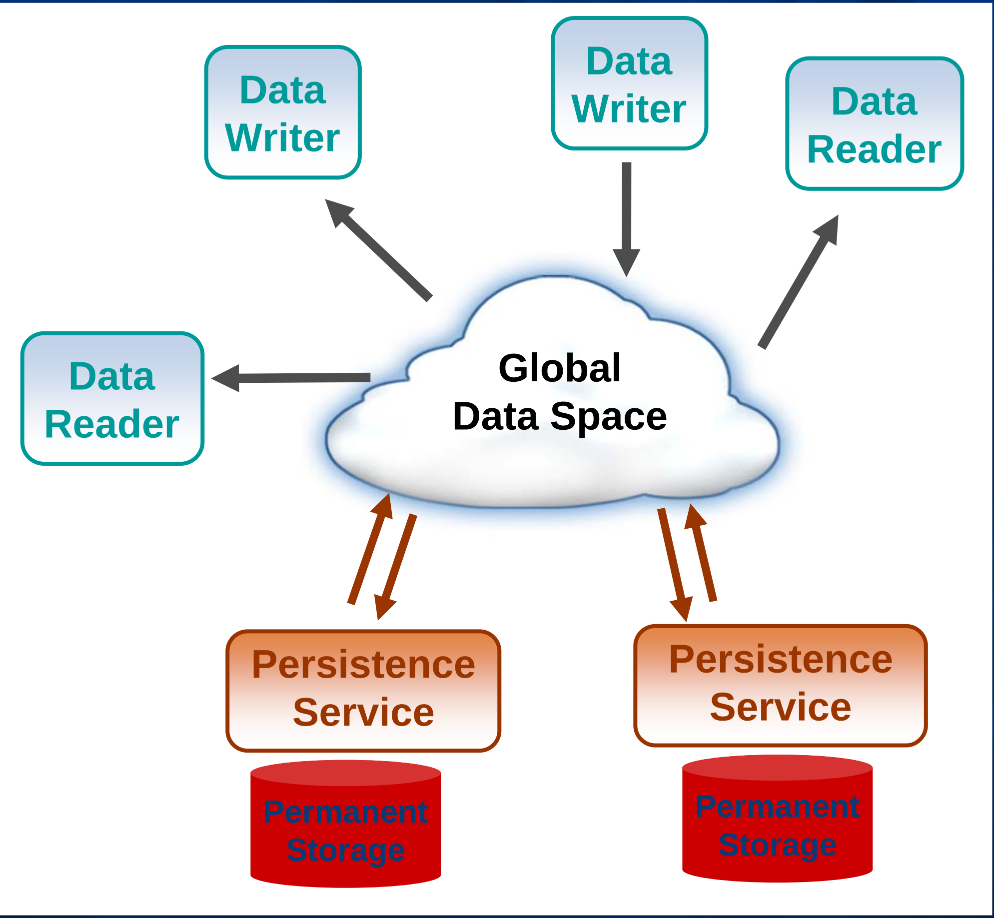
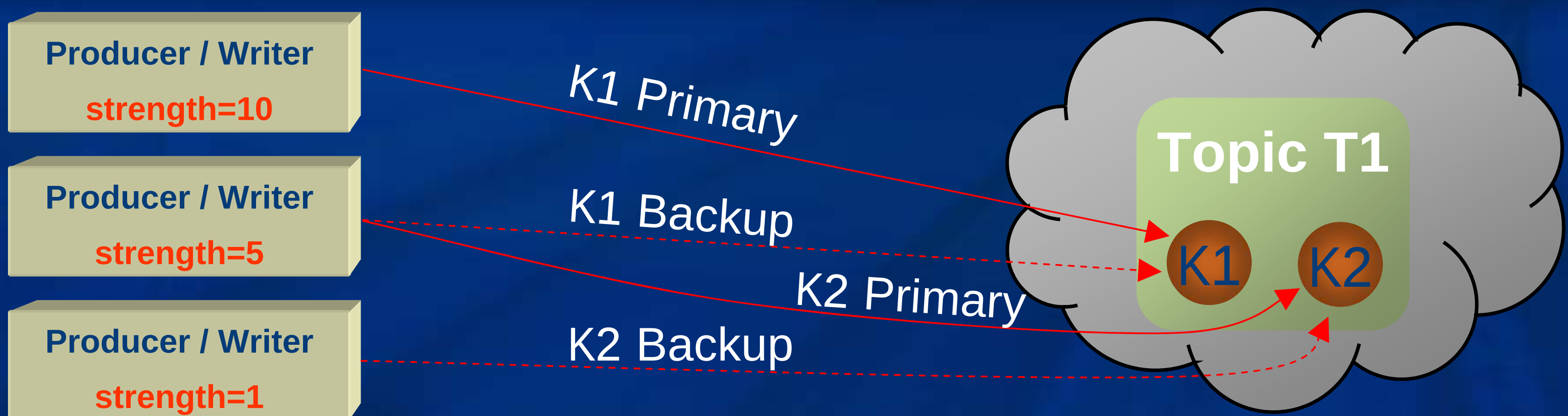


Demo:

1. PersistenceService
2. ShapesDemo
3. Application failure
4. Application re-start
5. Persistence Svc failure
6. Application re-start

ShapesDemo

Ownership and High Availability

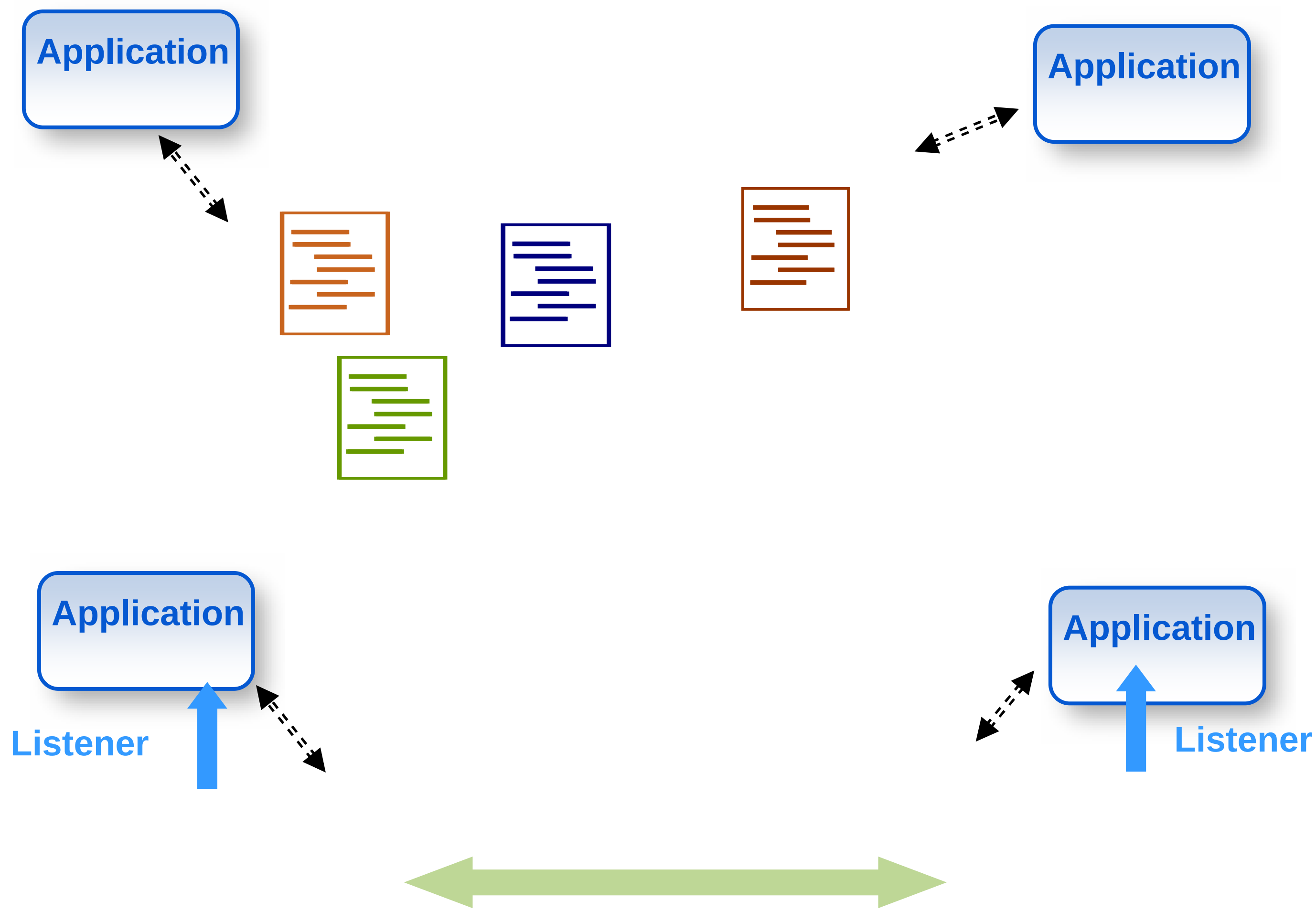


- Owner determined per Topic and Key
- Only writer with highest strength can publish a Key
- Automatic failover when highest strength writer:
  - Loses liveliness
  - Misses a deadline
  - Stops writing the subject
- Shared Ownership allows any writer to update any object

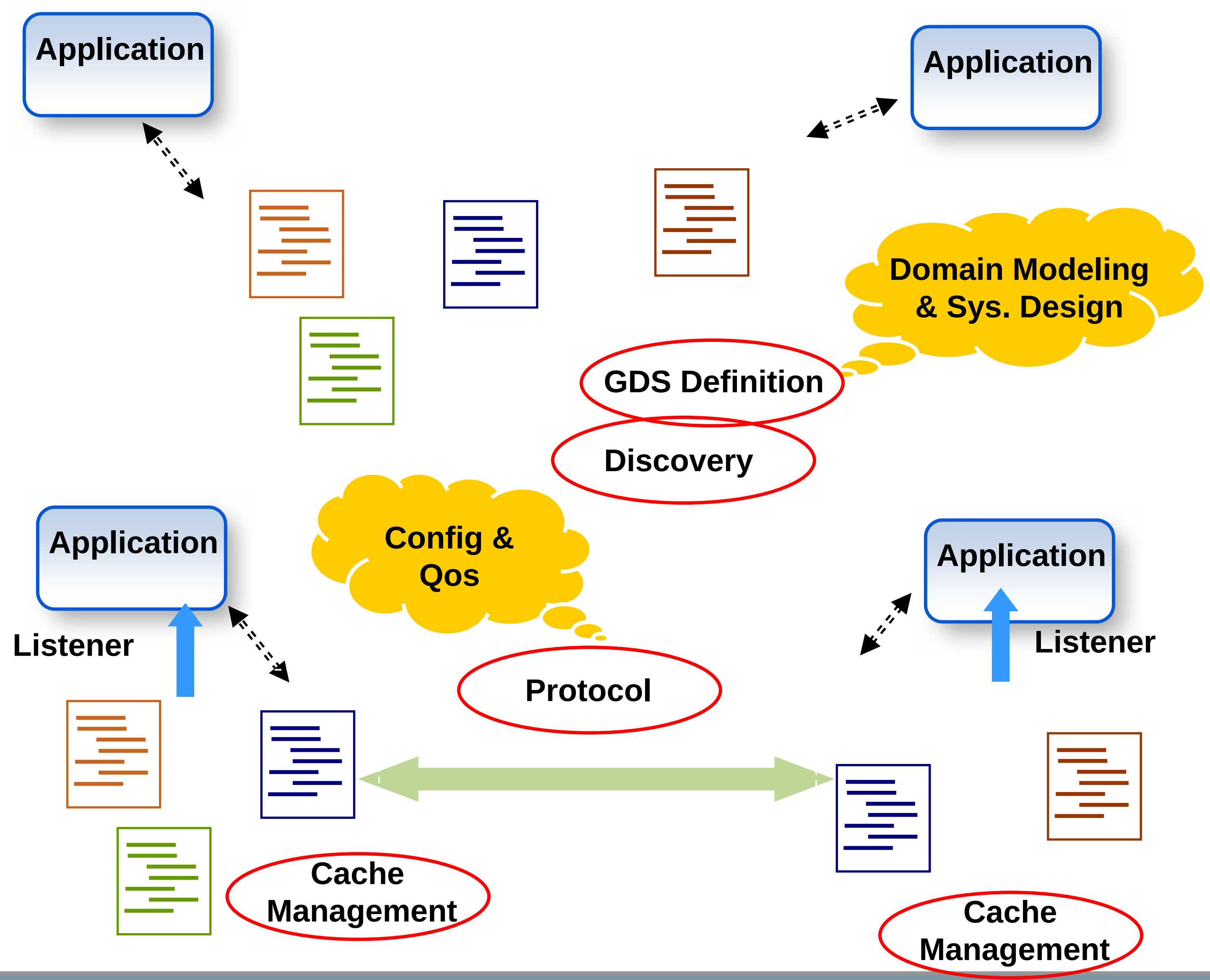
Outline

- Overview of Technology
- Application development cycle
- Architecting data-centric systems & modeling the Data
  - Examples: News example, Data Streaming, Commands, Video
  - Data Persistence with Examples
  - Using DynamicData
- Protocol, Performance & Scalability.
- Integrating external and legacy systems.
- Future directions and Standards:

Components/Mechanics of the GDS



Components/Mechanics of the GDS



Designing a Data-Centric System

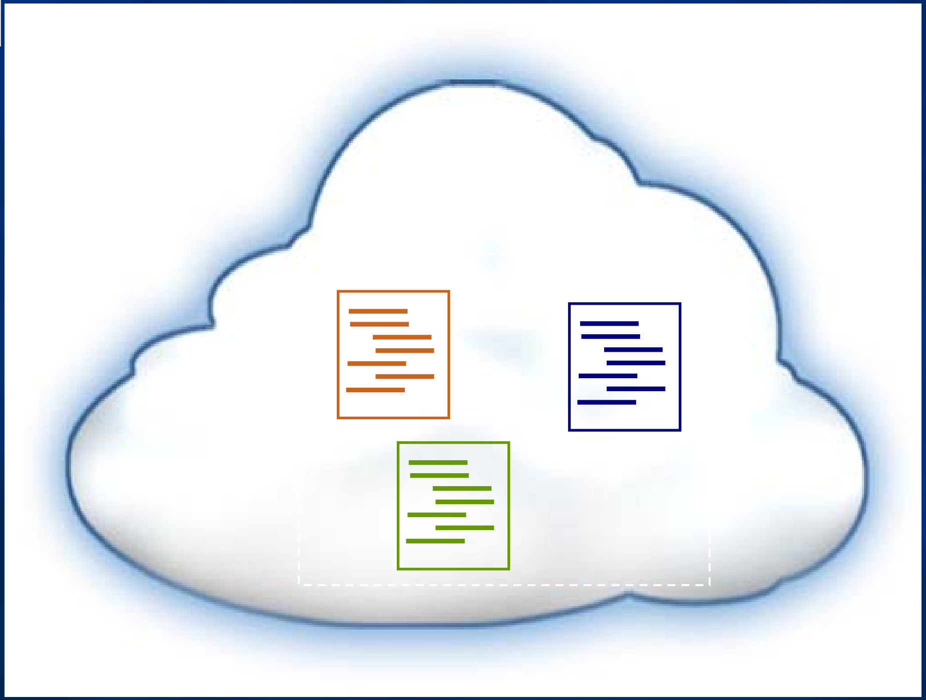
- Define/Model the Global Data Space
- Configure the Cache Management
- Configure Discovery
- Configure the Protocol

- Configure/Use hooks for
  - Fault detection
  - Controlled access

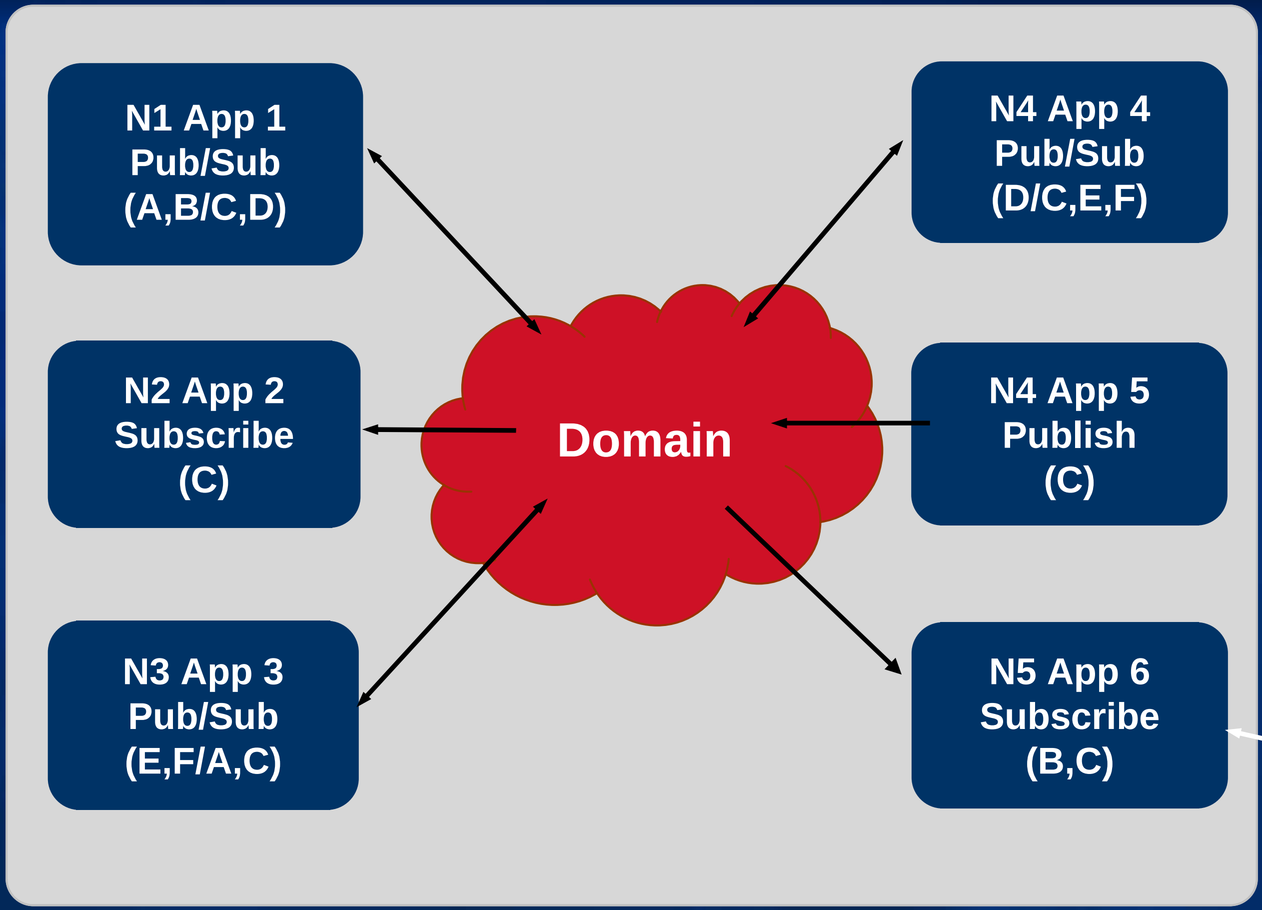
Global Data Space / Global State

- Identify the number of domains

- Domain Information model
  - Topics
  - Types
  - Keys
  - Ownership



Domain and Domain Participants

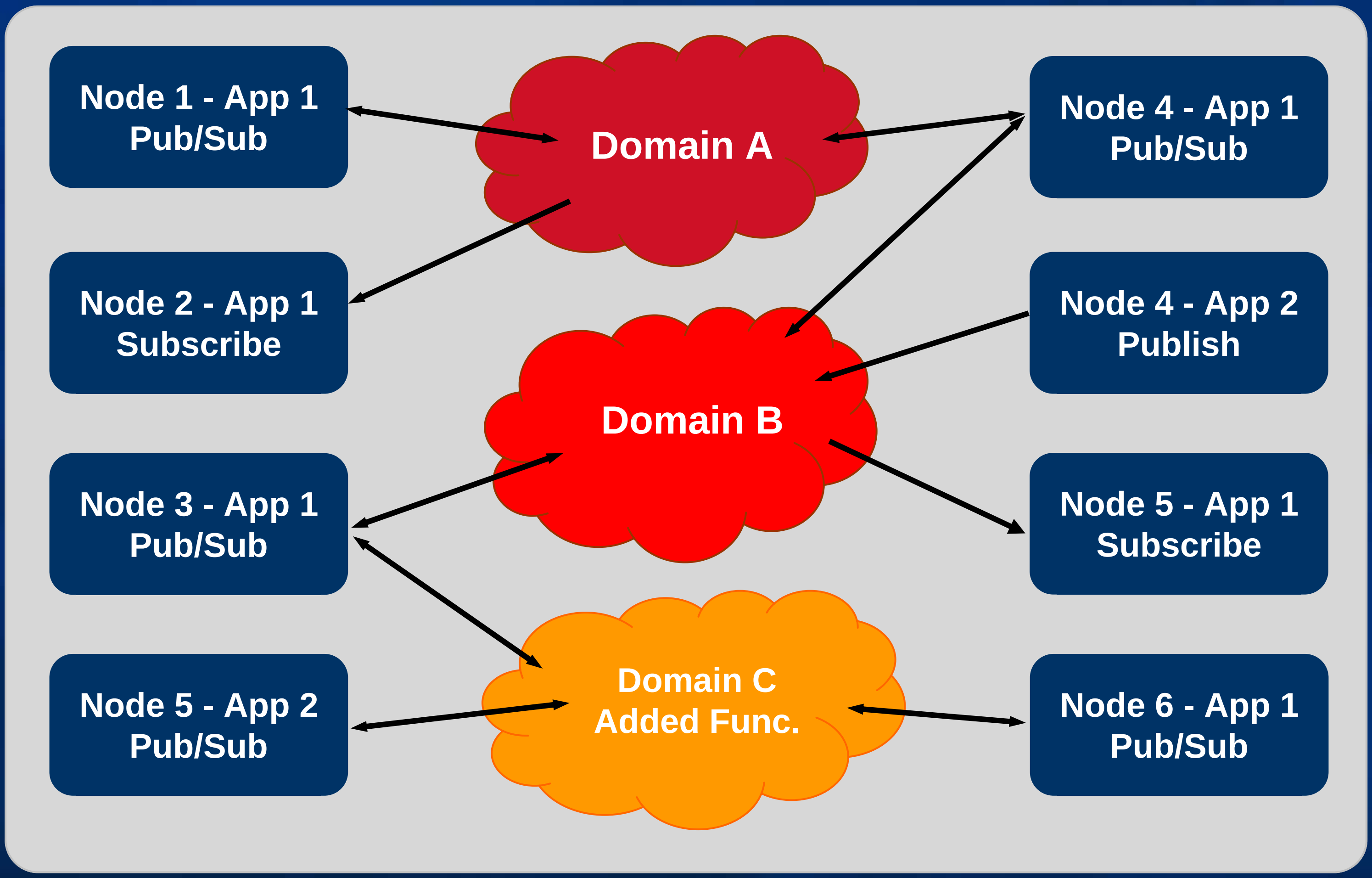


Single ‘Domain’ System

- Container for applications that want to communicate
- Applications can join or leave a domain in any order
- New Applications are “Auto-Discovered”
- An application that has joined a domain is also called a “Domain Participant”

Domain and Domain Participants

Using Multiple domains for Scalability, Modularity & Isolation



demo_domain_0 **Multiple Domain System** demo_domain_1

Topics & Datatypes, Keys & Subjects

Topic "MarketData"

Data-type (name-type-value pairs)

source	type	symbol	Exchange	volume	bid	ask
OPRA		IBM	NYSE	200000	118.30	118.36
OPRA		AAPL	NASDAQ		171.20	171.28
RTFP	EQ					

Key fields → Subject

Additional fields (payload)

Topic "OrderEntry"

Exchange	type	Symbol	Order num	number	limit	stop	expiration
NYSE	BUY	IBM	11956	500	120	-	DAY
NYSE	BUY	IBM	11957	1000	124.5	124	DAY
NASDAQ	SELL	AAPL	11958	400	-	160	DAY

Subject

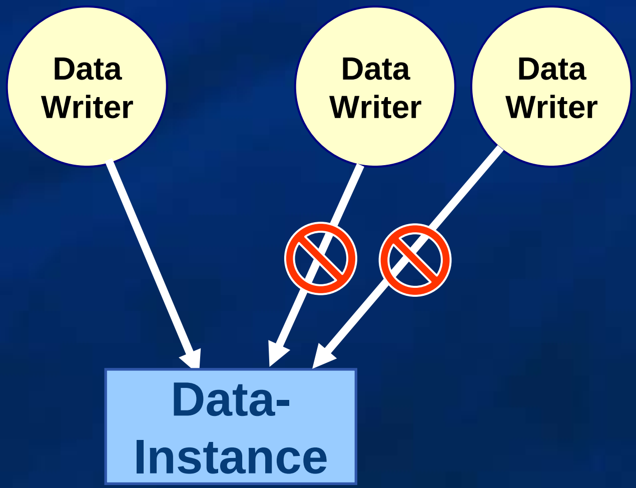
Key fields

demo_filters

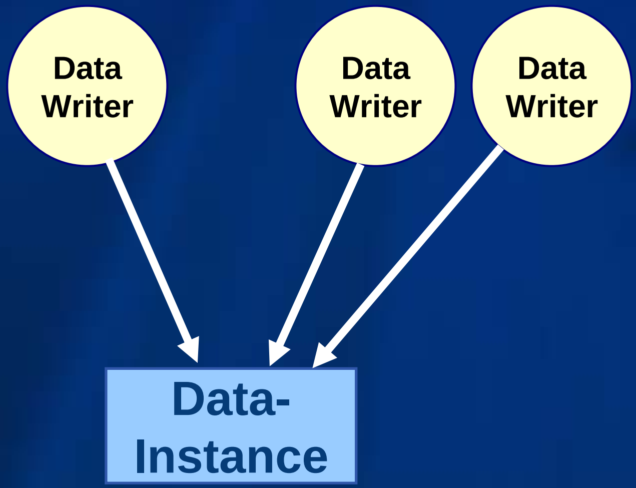
QoS: Ownership

Specifies whether more than one DataWriter can update the same instance of a data-object

Ownership = EXCLUSIVE
"Only highest-strength data writer can update each data-instance"



Ownership = SHARED
"All data-writers can each update data-instance"



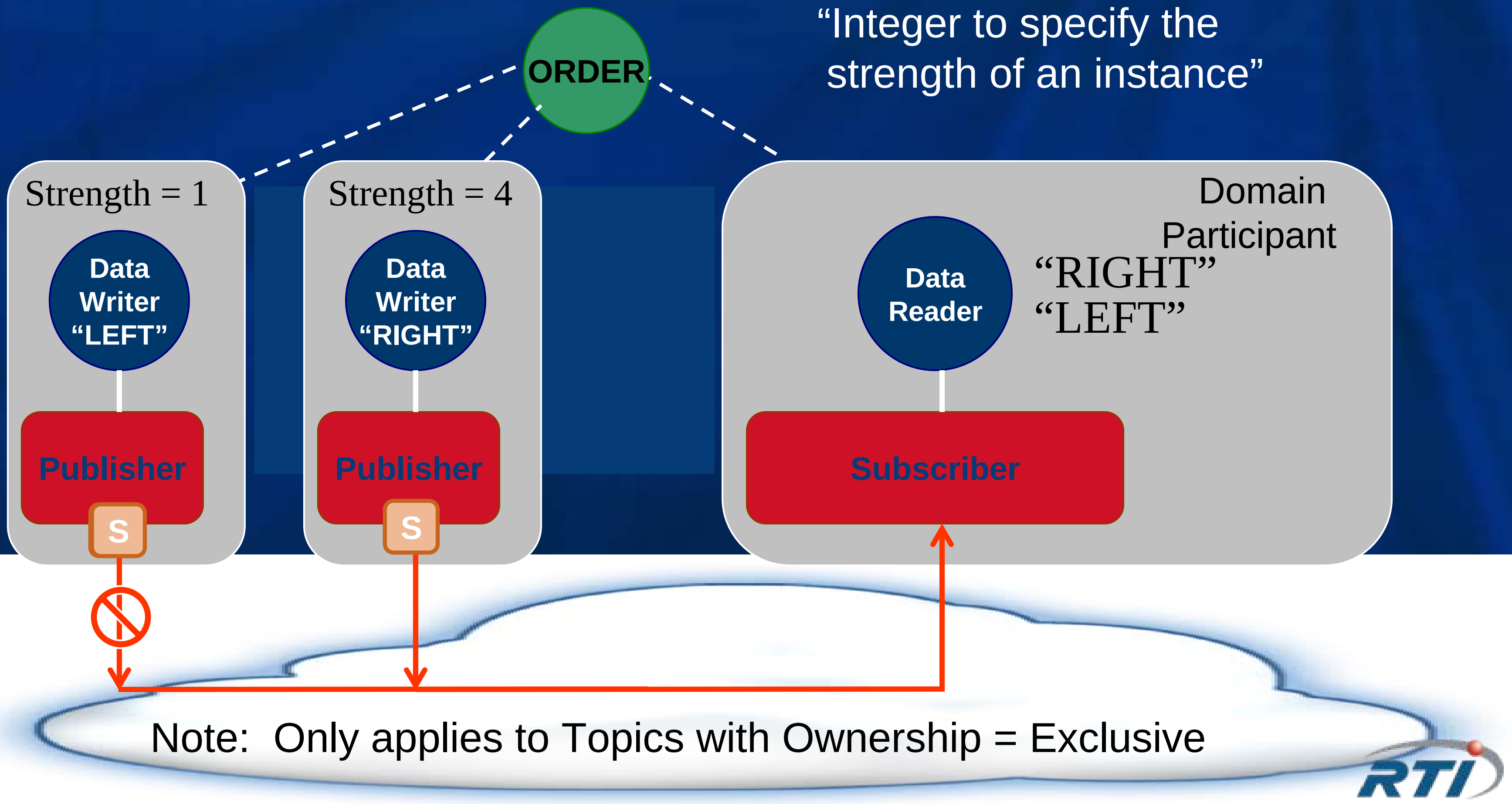
Provides fast, robust, transparent replacement for fail-over and/or take-over.

QoS: Ownership Strength

demo_ownership

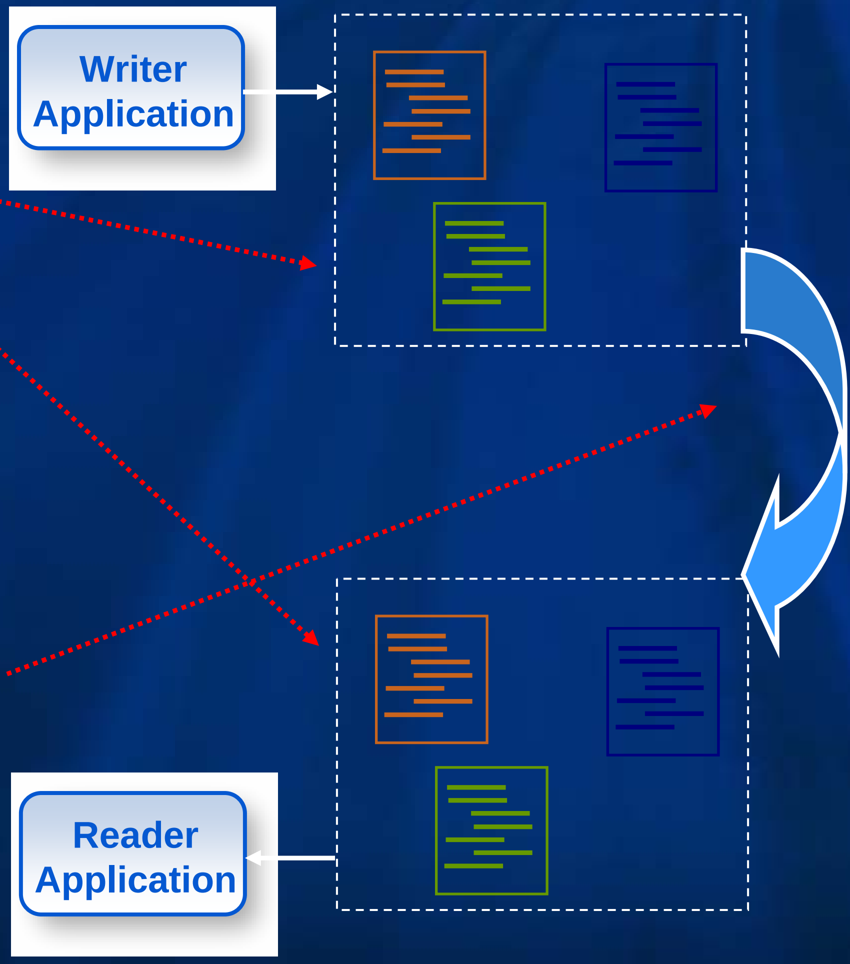
Specifies which DataWriter is allowed to update the values of data-objects

OWNERSHIP_STRENGTH
"Integer to specify the strength of an instance"



Configure the Cache Management

- Cache State Content
  - History
  - Lifespan
  - Persistence
  - Resources
- Reader Cache View
  - Partitions
  - Content-Based Filter
  - Time-Based Filter
  - Order

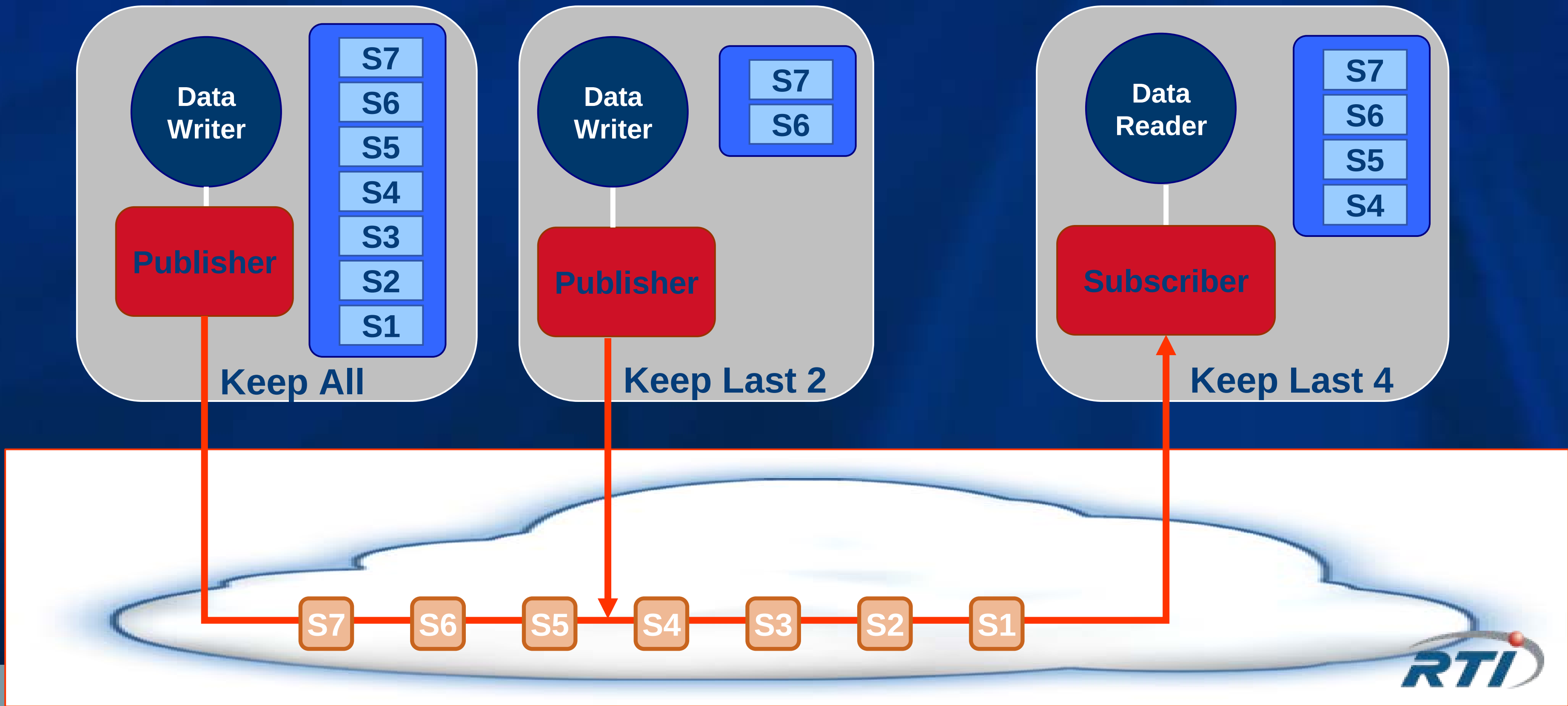


QoS: History – Last x or All

KEEP_ALL:
Publisher: keep all until delivered
Subscriber: keep each sample until the application processes that instance

KEEP_LAST: "depth" integer for the number of samples to keep at any one time

demo_history



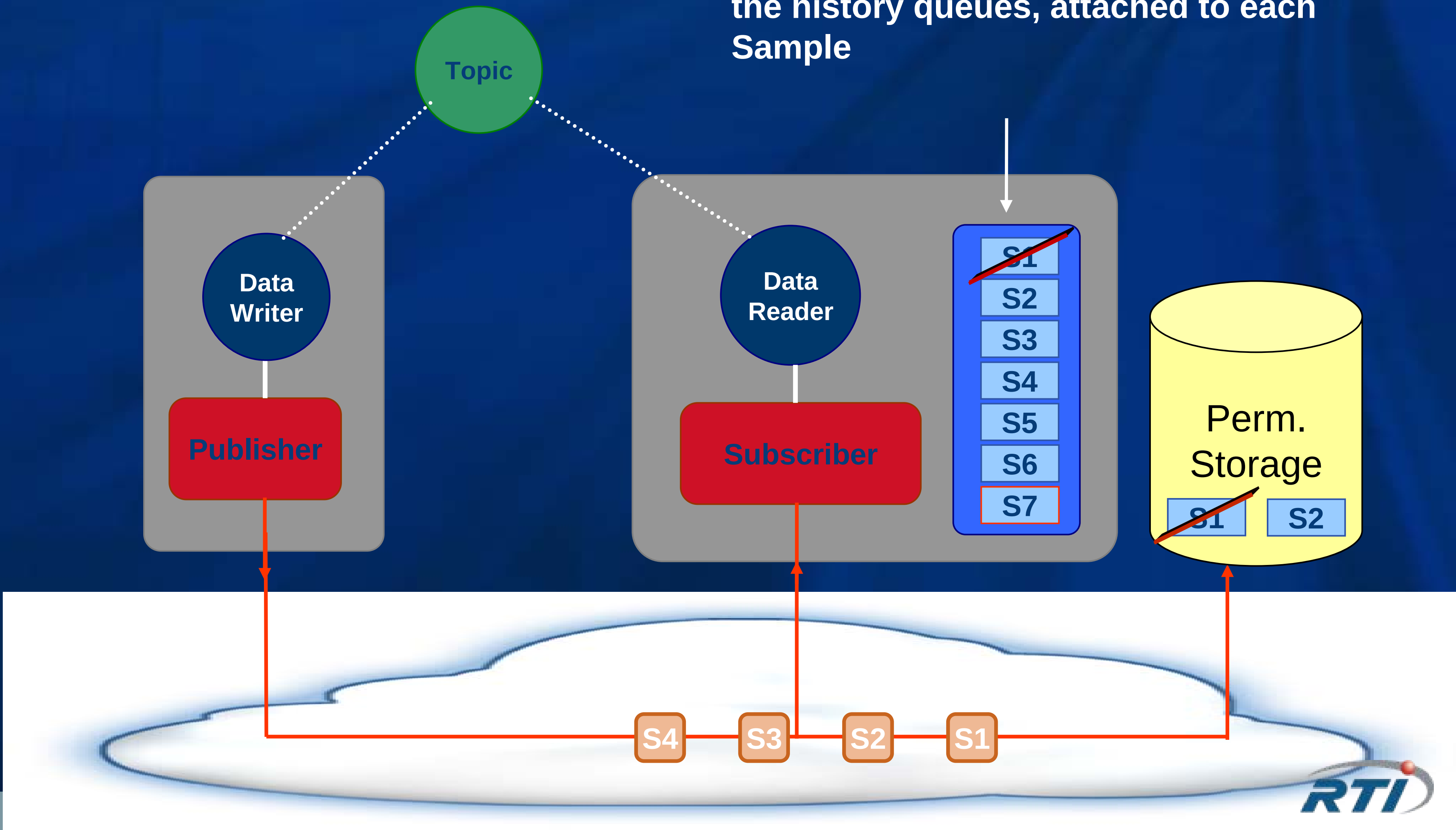
QoS: Lifespan

[lifespan_pub]

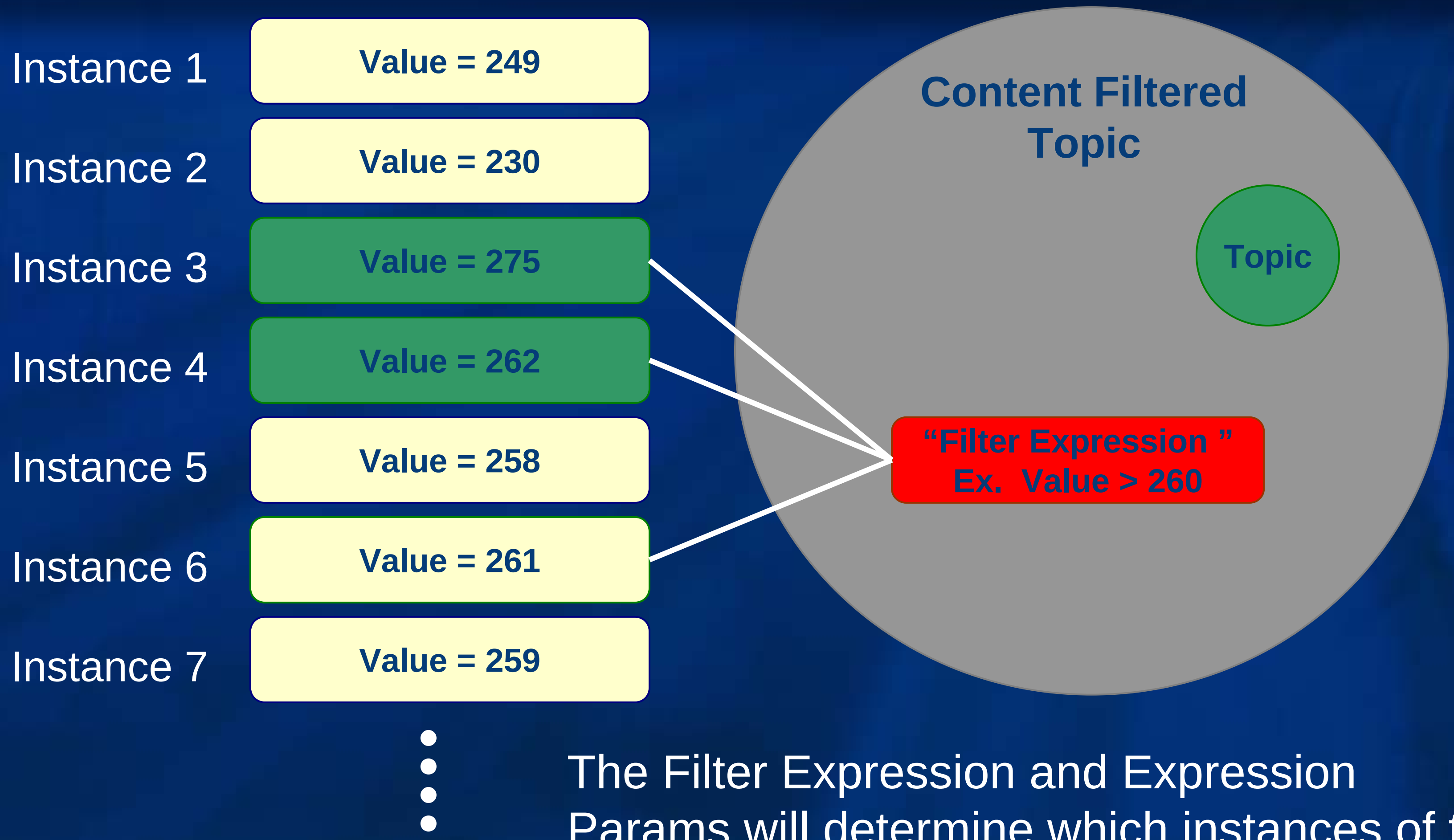
[lifespan_sub]

User can set lifespan duration

Manages samples in the history queues, attached to each Sample



Content-Based Filtering



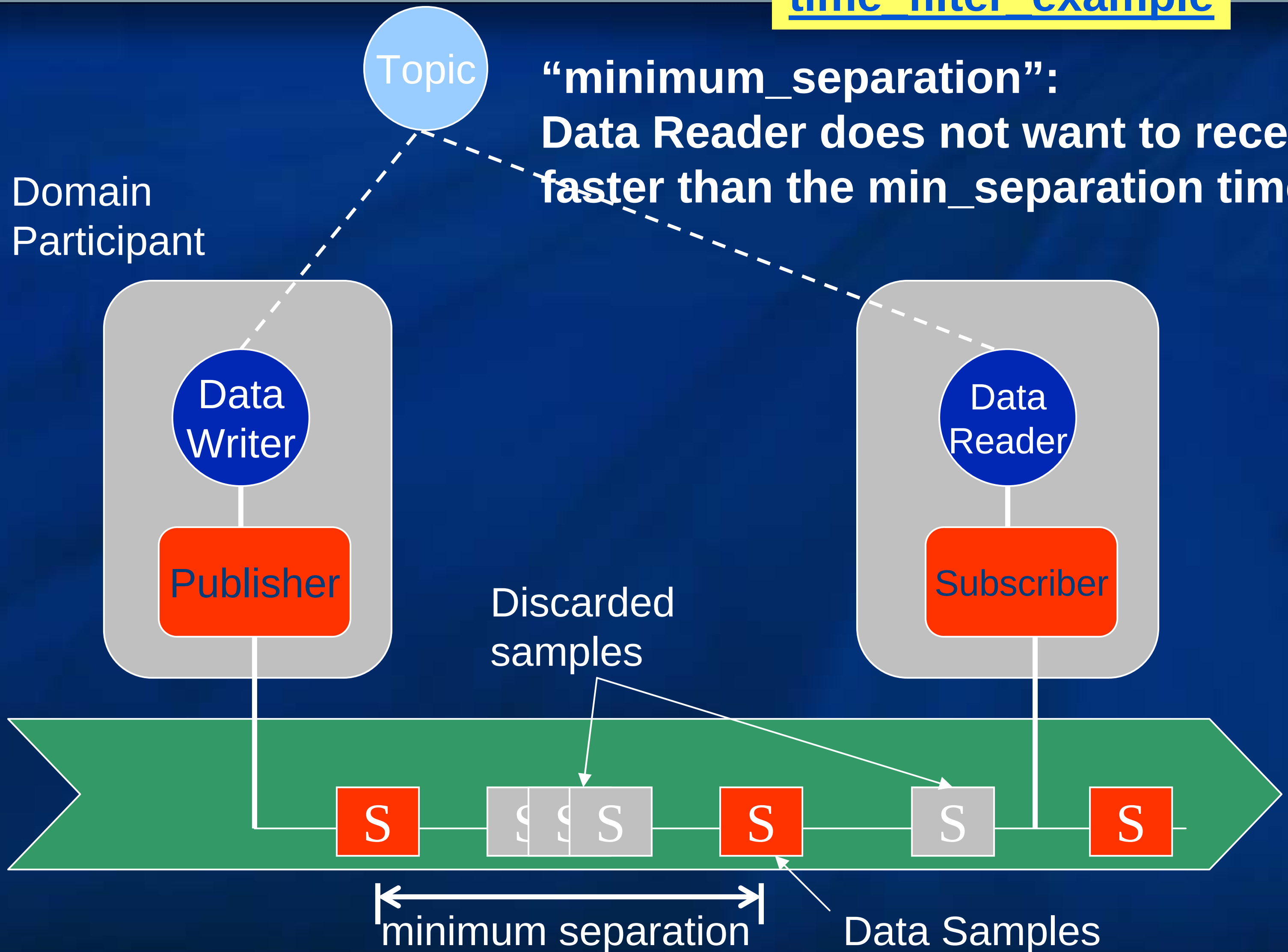
The Filter Expression and Expression Params will determine which instances of the Topic will be received by the subscriber.

content_filter_example

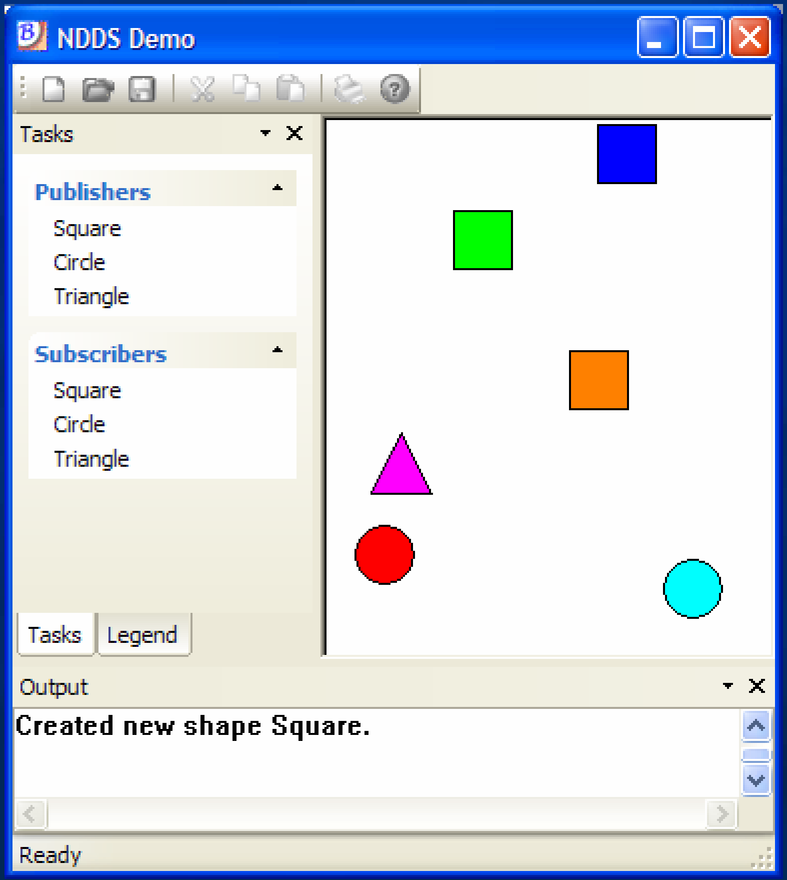
QoS: TIME_BASED_FILTER

time_filter_example

"minimum_separation":
Data Reader does not want to receive data faster than the min_separation time



Cache Management in Action

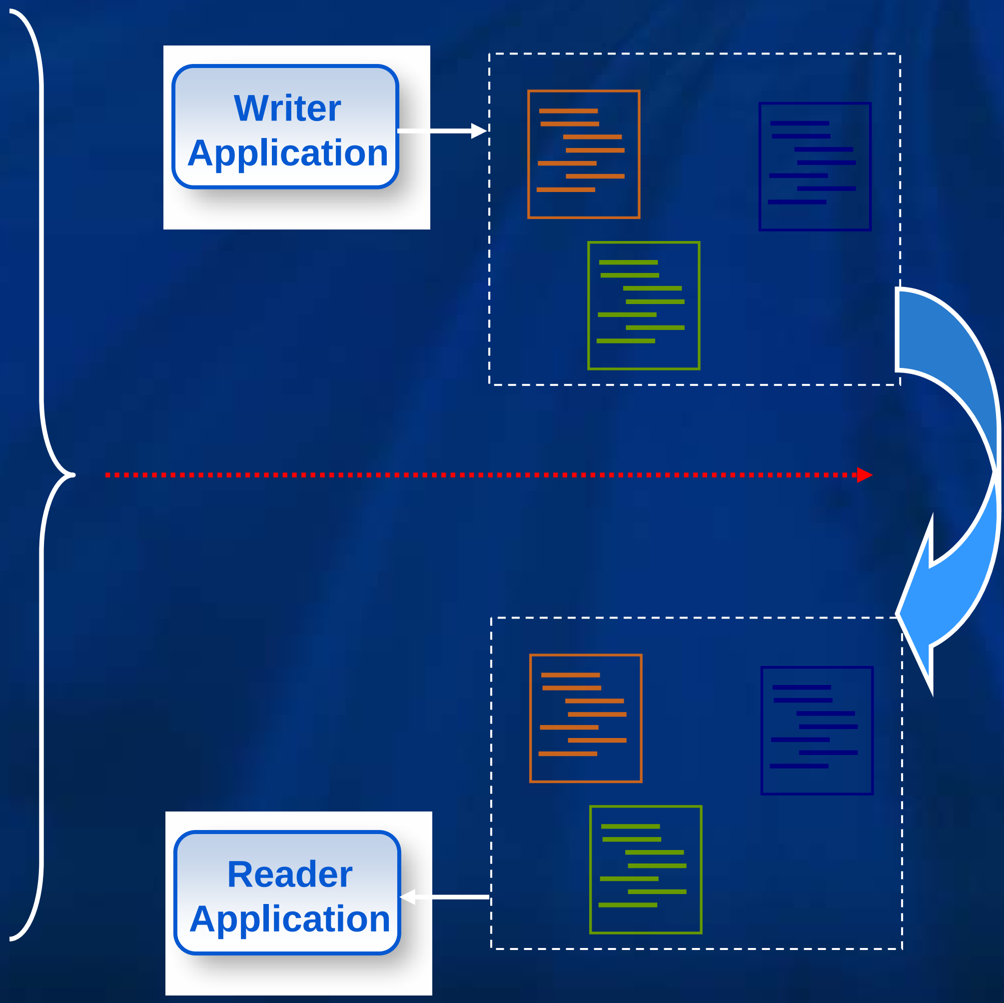


- Topics
  - Square, Circle, Triangle
  - Attributes
- Data types (schemas)
  - Shape (color, x, y, size)
    - Color is instance Key
  - Key
    - Color field used for key
- QoS
  - History, Partition
  - Time-Based Filter
  - Content-Based Filter

demo

Configure the Protocol

- Discovery
- Reliability
- Batching
- Liveliness
- Flow Control
- Asynchronous write
- Network Configuration
  - Enabled Transports + transport properties
  - Multicast addresses
  - Transport Priority
- OS settings
  - Threads
  - Memory



Tunable Reliability Protocol

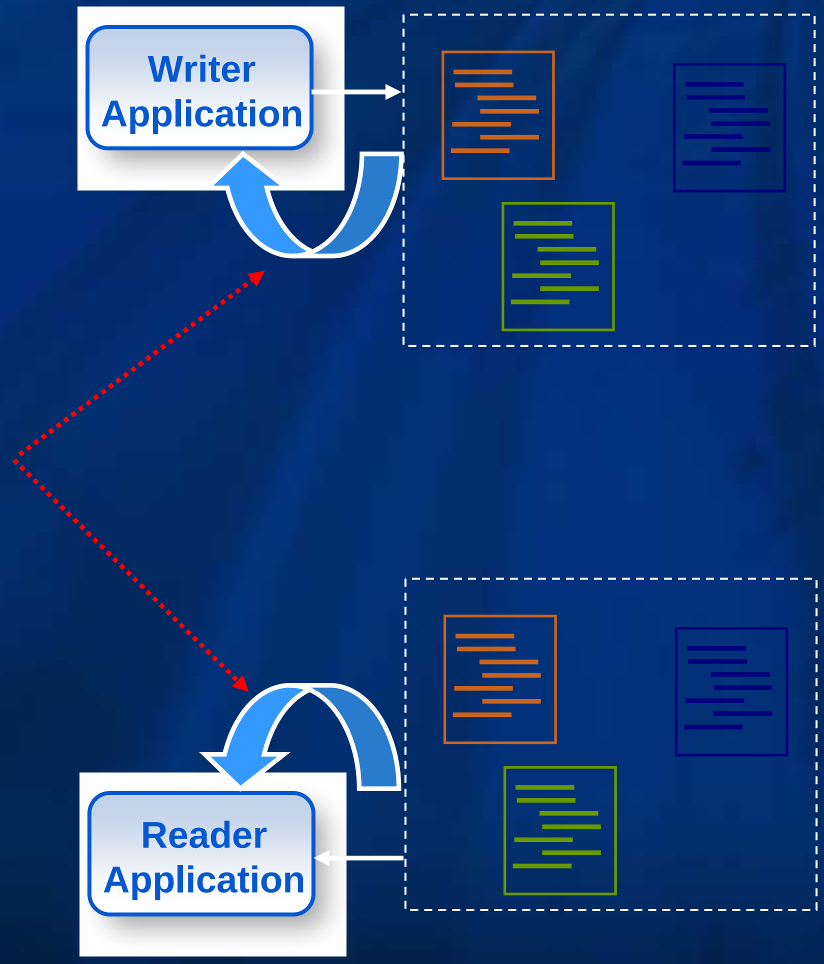
- Configurable AckNack reply times to eliminate storms
- Fully configurable to bound latency and overhead
  - Heartbeats, delays, buffer sizes
- Performance can be tracked by senders and recipients
  - Configurable high/low watermark, Buffer full
- Flexible handling of slow recipients
  - Dynamically remove slow receivers

Reliable

- Guaranteed Ordered Delivery
- “Best effort” also supported

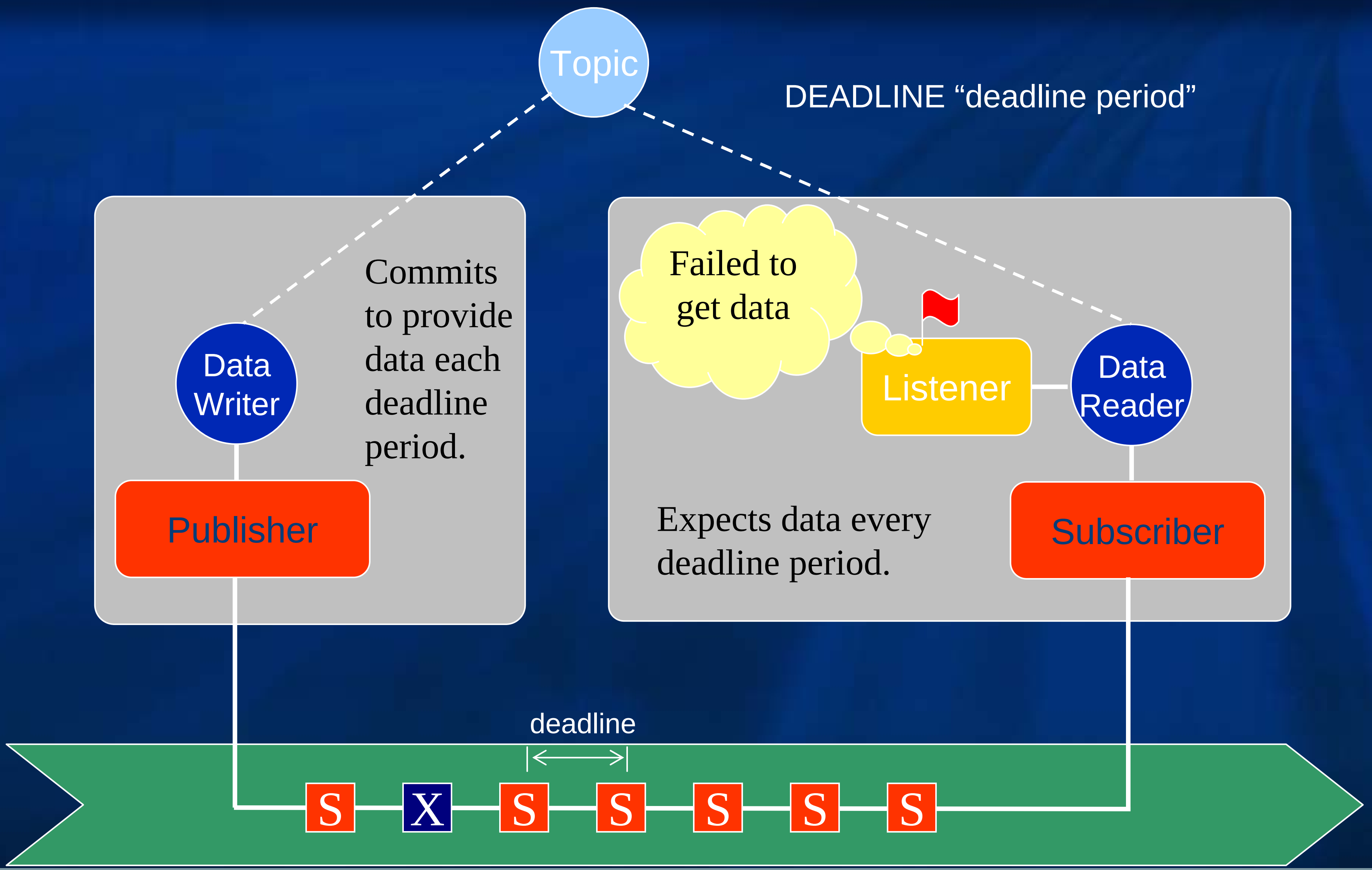
Configure Notifications, Fault Detection & Management

- Listeners
- Deadline Qos
- Liveliness Qos
- Built-in Readers
- Notification of matching



QoS: Deadline

deadline_example

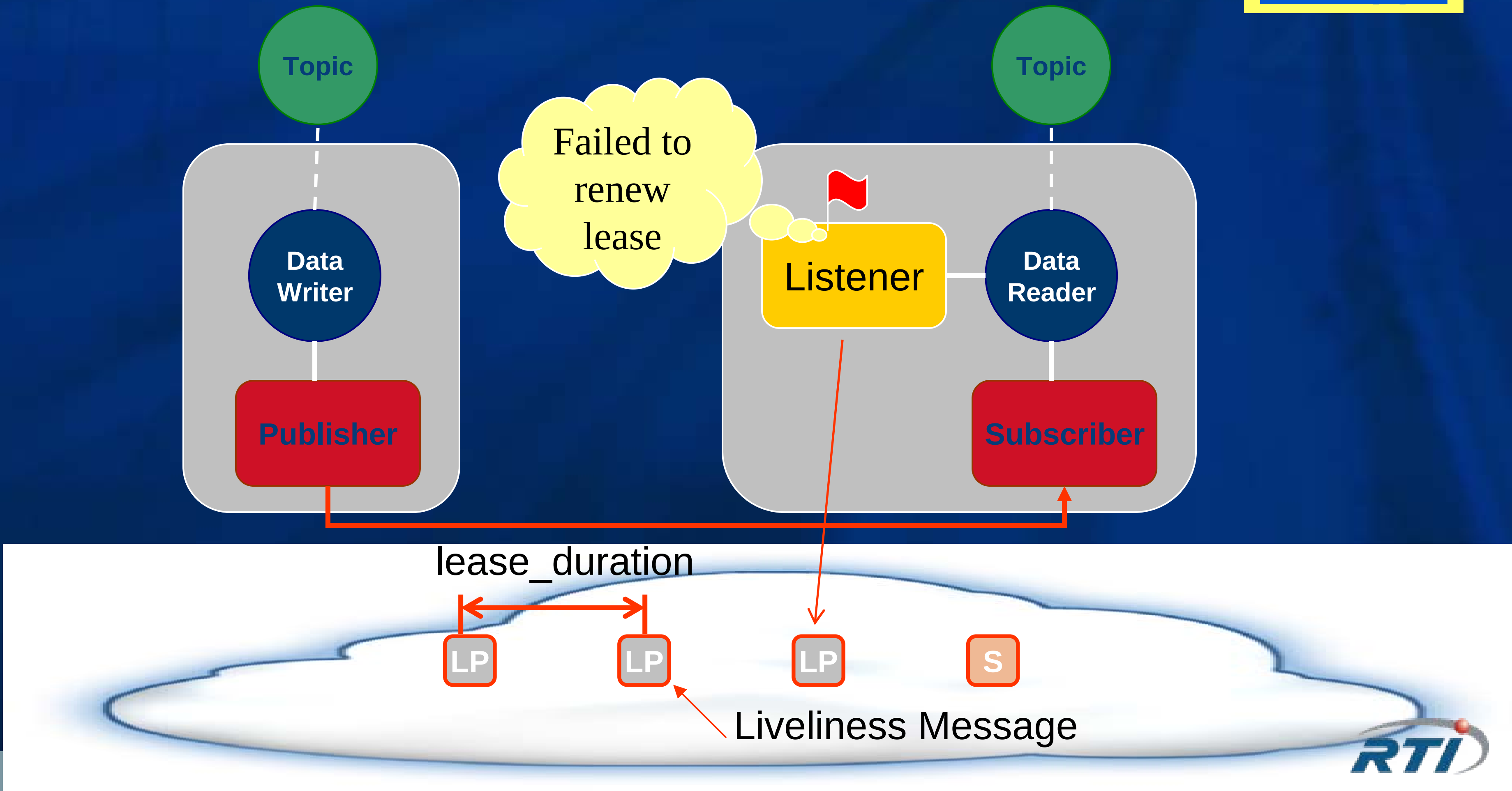


QoS: Liveliness – Type and Duration

liveliness_example

Type: Controls who is responsible for issues of 'liveliness packets'
- AUTOMATIC = Infrastructure Managed
- MANUAL = Application Managed

kill_apps



Exercise: How could “chat rooms” be implemented?

- Different Topics for each Chat room?
- Map to Partitions?
- Add field to the message and use content-filtered Topics?
- Same as before and also make room part of the Key?
- Others?

Discuss pros and cons of each approach

Exercise: How could we implement Ground control stations that monitor UAVs

- Different Topics for each UAV?
  - Or use Keys?
- Different Domains for each Ground Station?
  - Or Partitions?
- How to control multiple UAVs from the same ground station?
- How to switch the ground station that controls the UAV?
- How to do failover between ground stations?
- How to direct a message to one or all UAVs?
- How to detect loss of connection to an UAV?

Discuss pros and cons of each approach

Outline

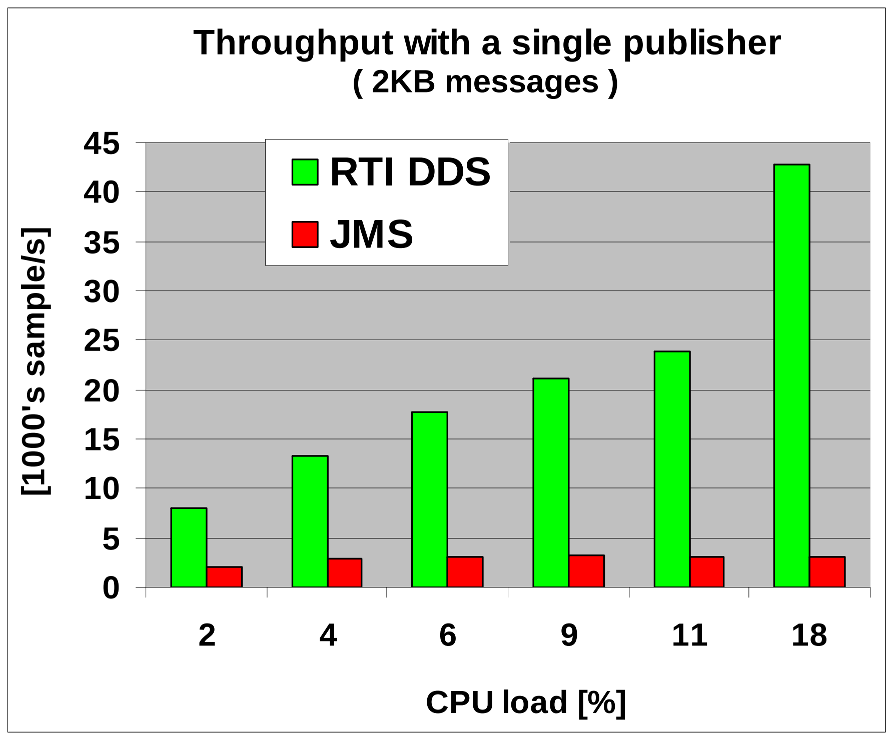
- Overview of Technology
- Application development cycle
- Architecting data-centric systems & modeling the Data

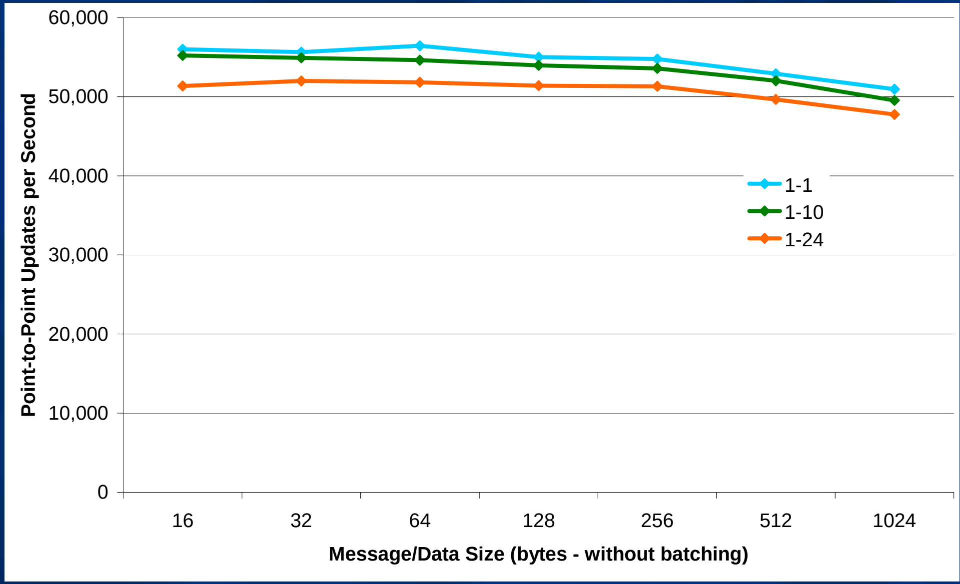
- Protocol, Performance & Scalability.
  - Details on Reliable Protocol
  - Latency and Throughput
  - Using RTI's LatencyTest and Perftest
  - Batching
  - Asynchronous writes & FlowController
  - Maximizing latency and Throughput

- Integrating external and legacy systems.
- Future directions and Standards:

Performance & Scalability

RTI DDS is about 20X faster than JMS

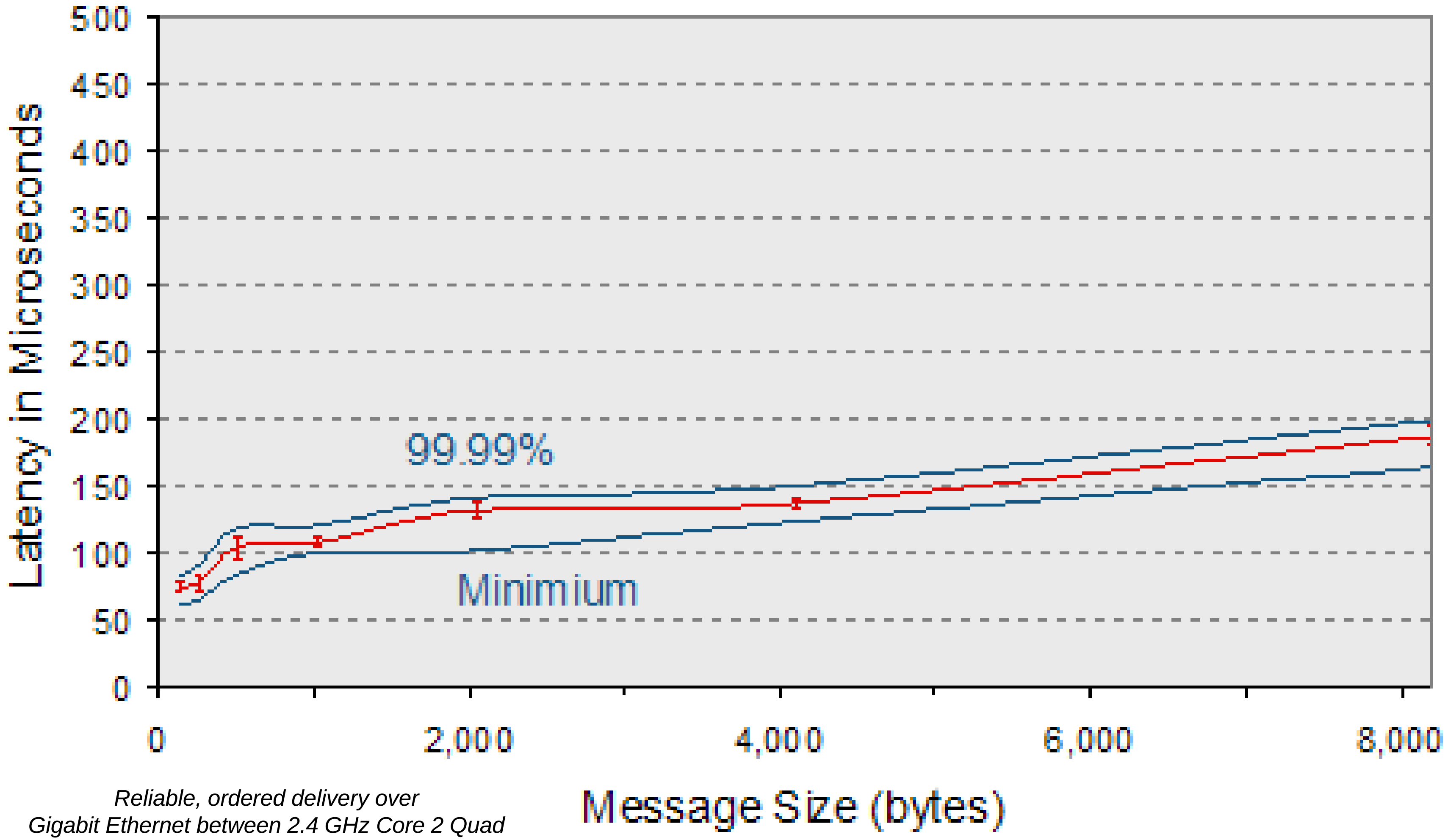




RTI DDS reliable multicast exhibits near perfect scalability

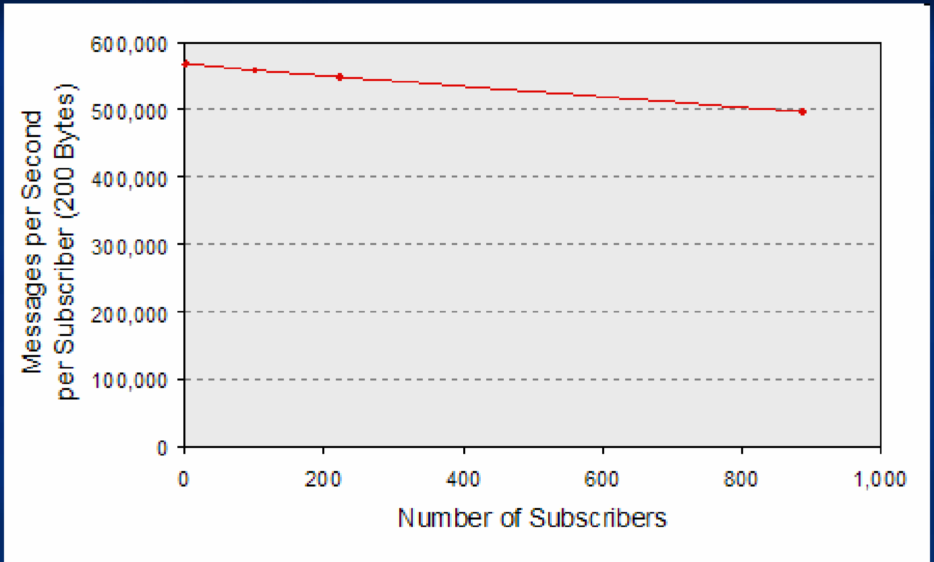
Platform: Linux 2.6 on AMD Athlon, Dual core, 2.2 GHz

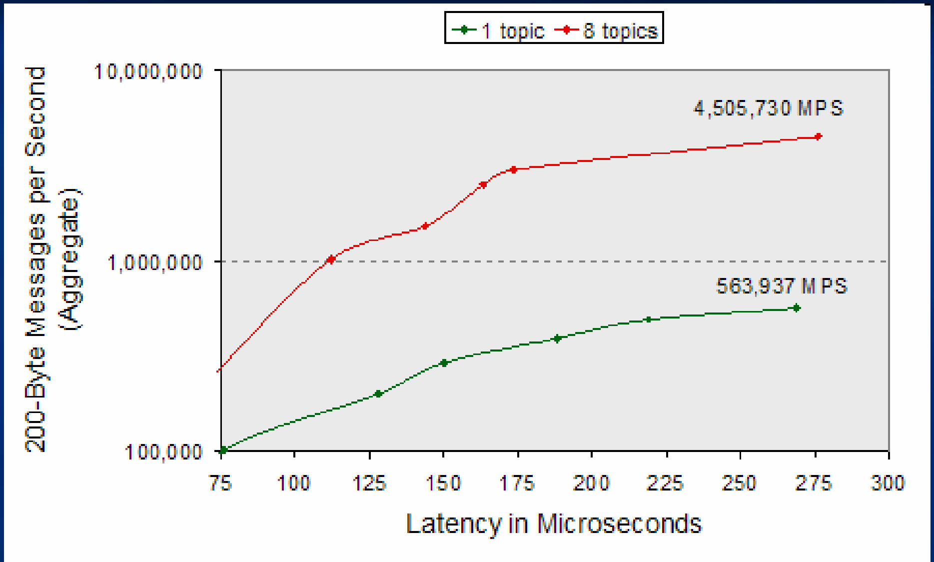
Extremely low latency and jitter



Reliable, ordered delivery over Gigabit Ethernet between 2.4 GHz Core 2 Quad processors running 32-bit Red Hat Enterprise Linux 5.0

Orders of magnitude more scalable than broker-based solutions



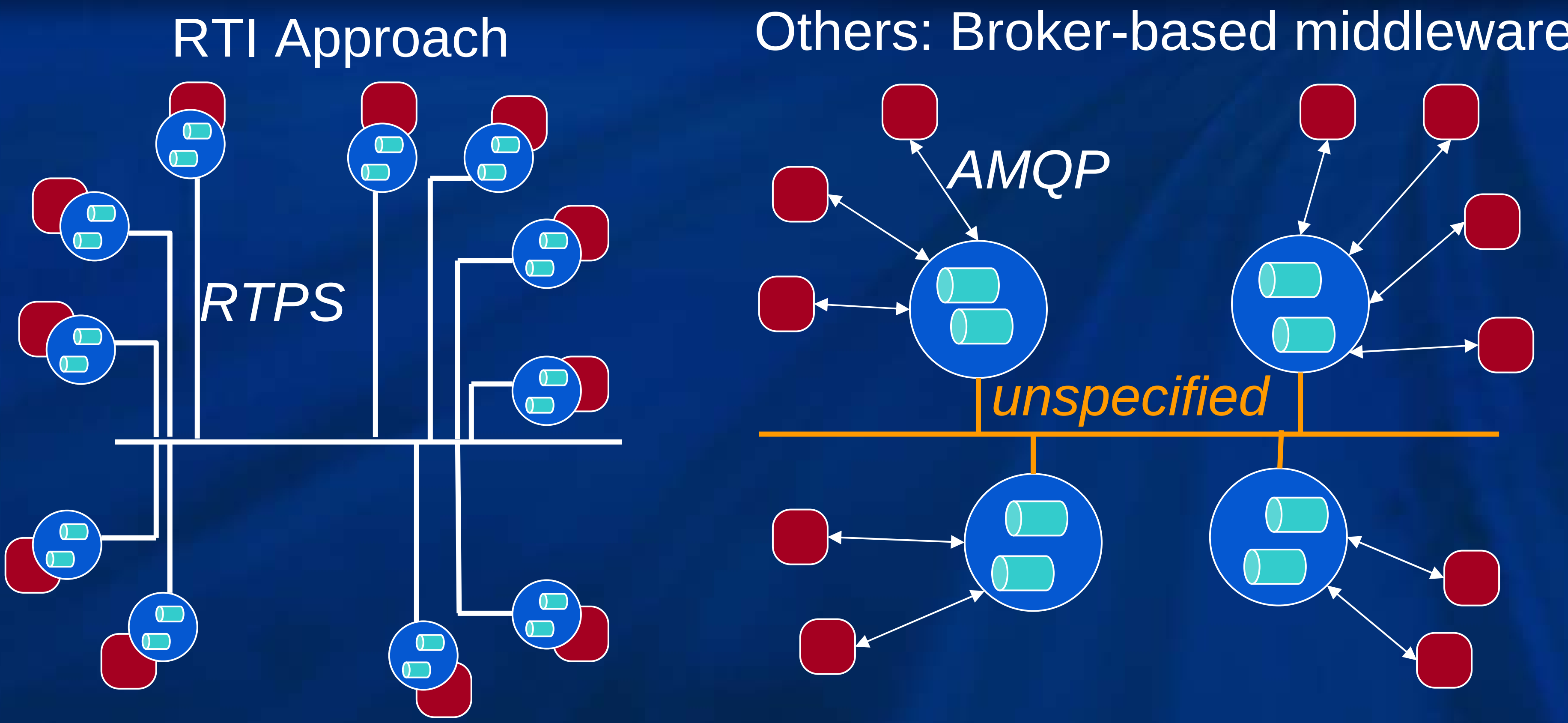


- Going from 1 to 888 subscribers of the same data has only a 10% impact on throughput

- New topics can be added to a system without impacting the latency and throughput on other topics
- Throughput with 8 topics is 8x the throughput with 1 topic

http://www.rti.com/products/dds/benchmarks-cpp-linux.html

Realizing Performance & Scalability

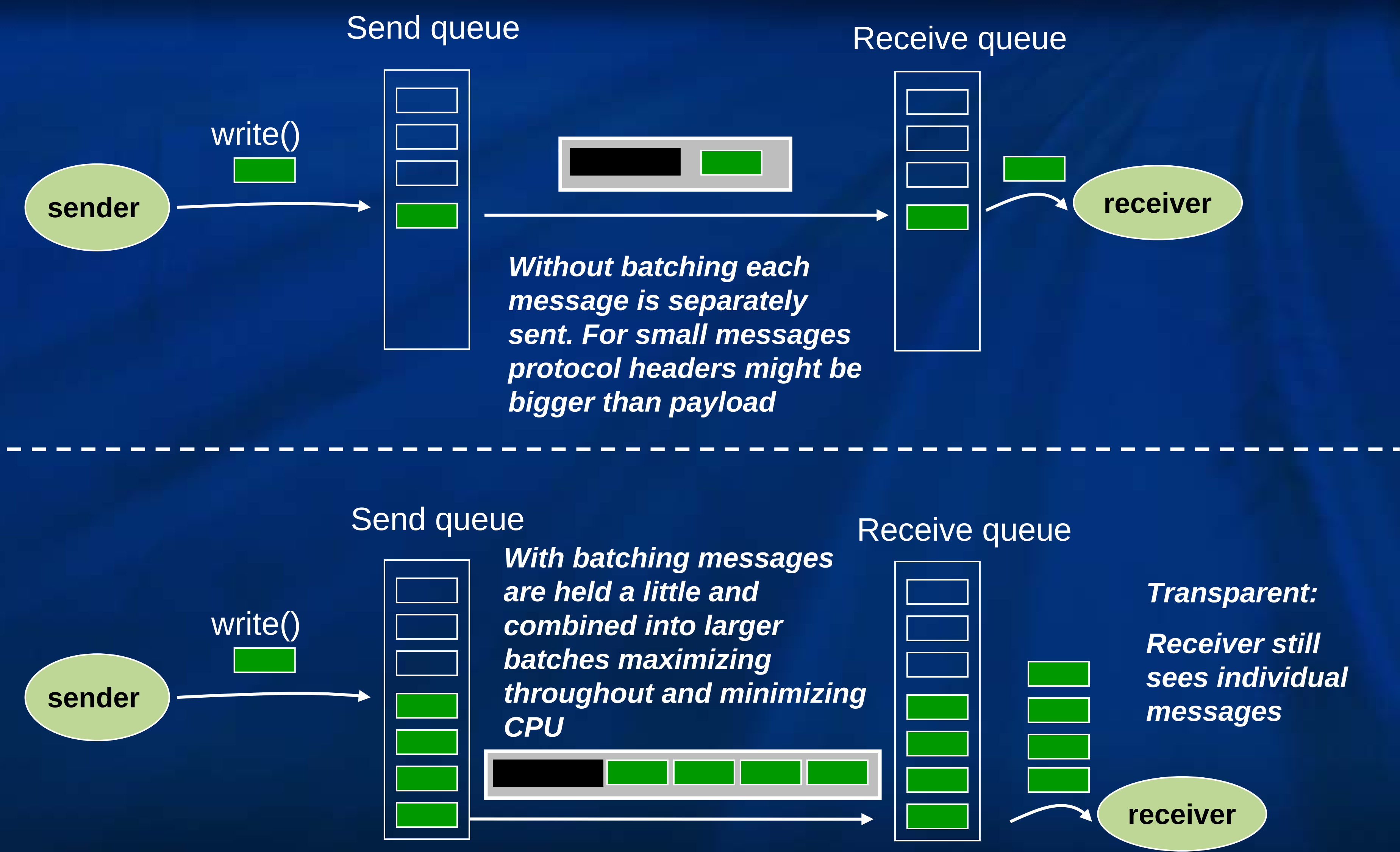


- *RTI operates peer-to-peer, without brokers*
- *RTI uses RTPS, an Advanced Multi-Session protocol supporting Reliable Multicast*

Advanced Scalability & Performance Techniques

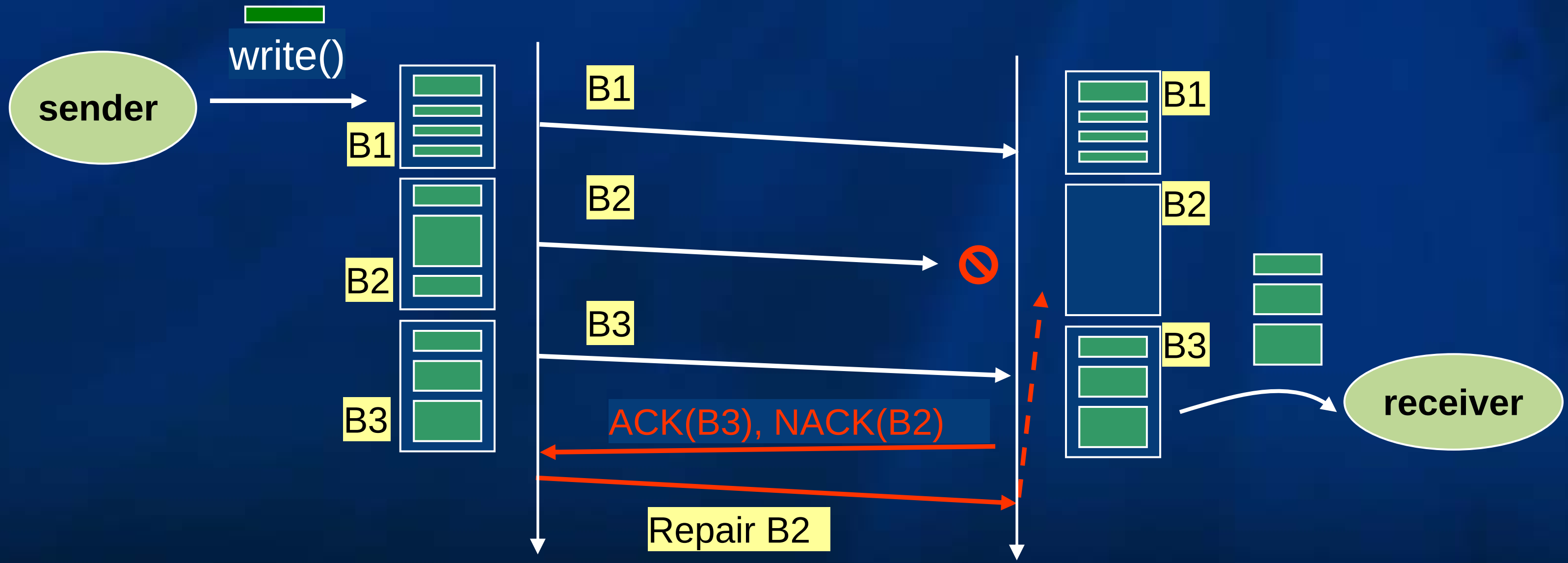
- Latency and Priority Aware message batching
- Content-Aware multi-channel reliable multicast
- Enhanced Reliable Protocol
  - Selective ACKs (SACKs) for Confirmed Reliability
  - NACK-only Reliable Protocol for Massive Scalability
- Smart caching integrated with the message protocol
- Content-Filtering at the source

Message Batching

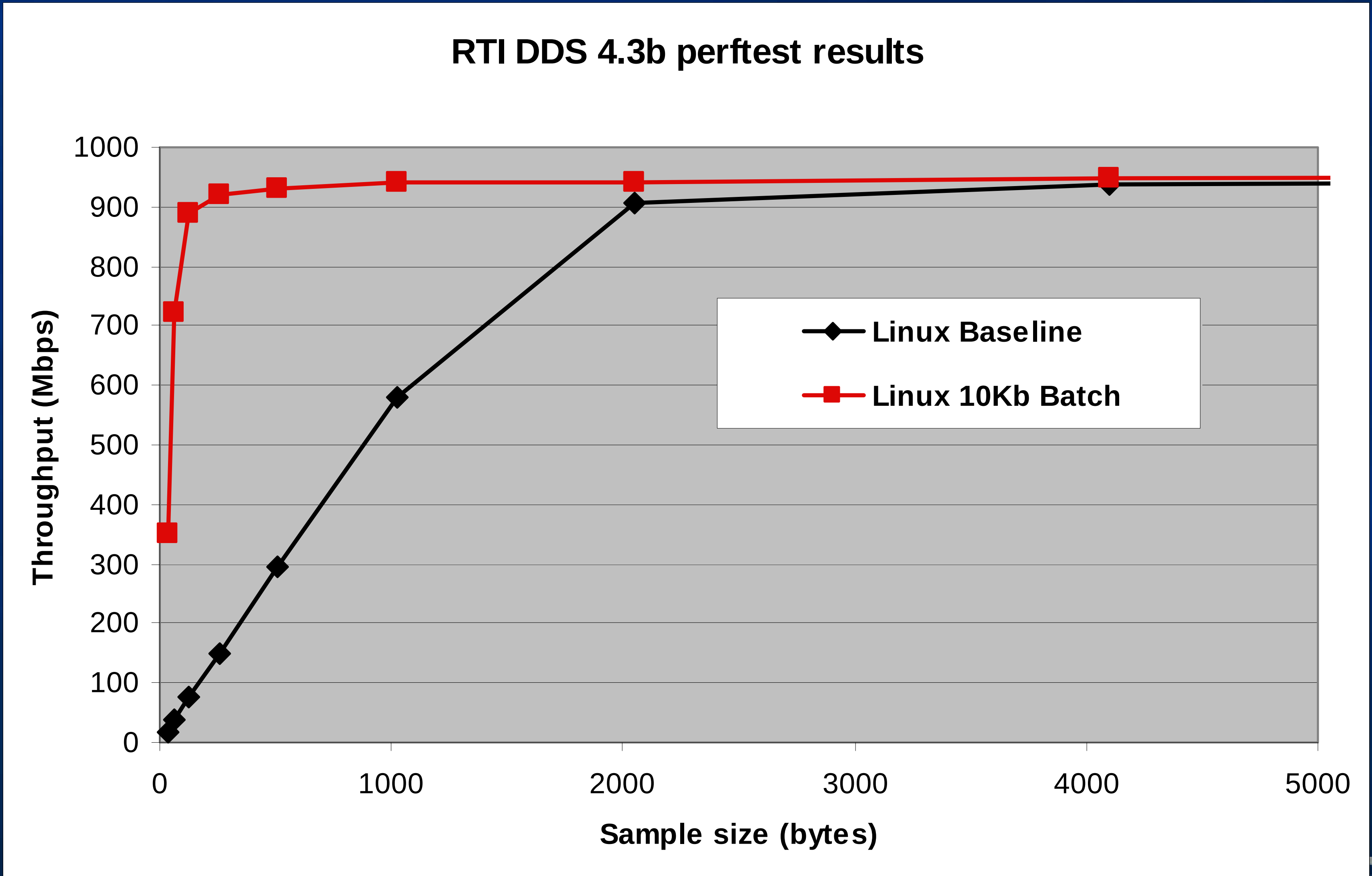


Reliability with Batching

- Reliability must work even when messages are batched
- ACK or NACK of individual samples would negate some of the benefits of batching…
- => Protocol must be batch aware so that it can ACK/NACK complete batches!



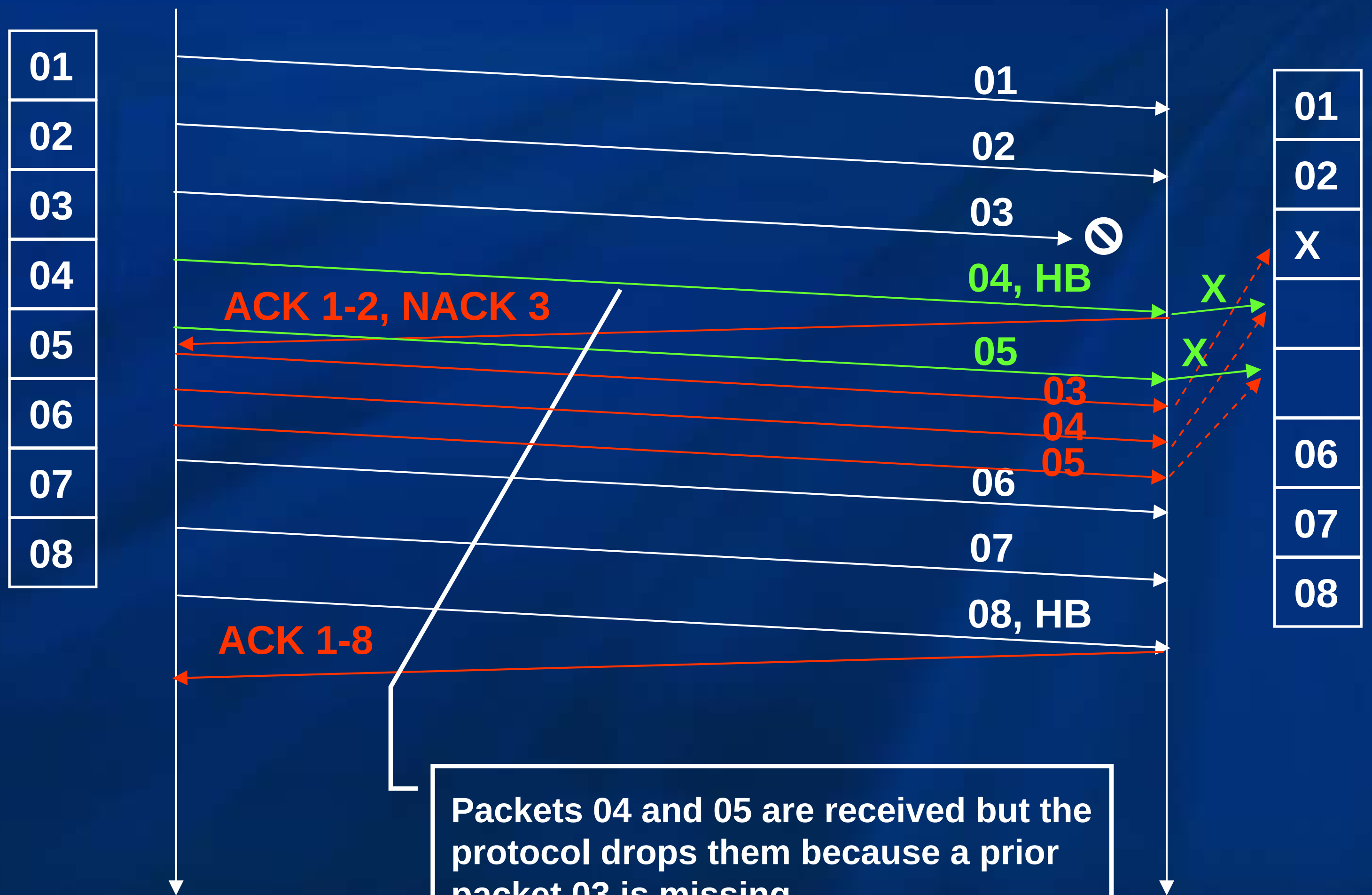
Batching is hard but it pays!



Classic (TCP Style) Reliable Protocol
No packet loss situation

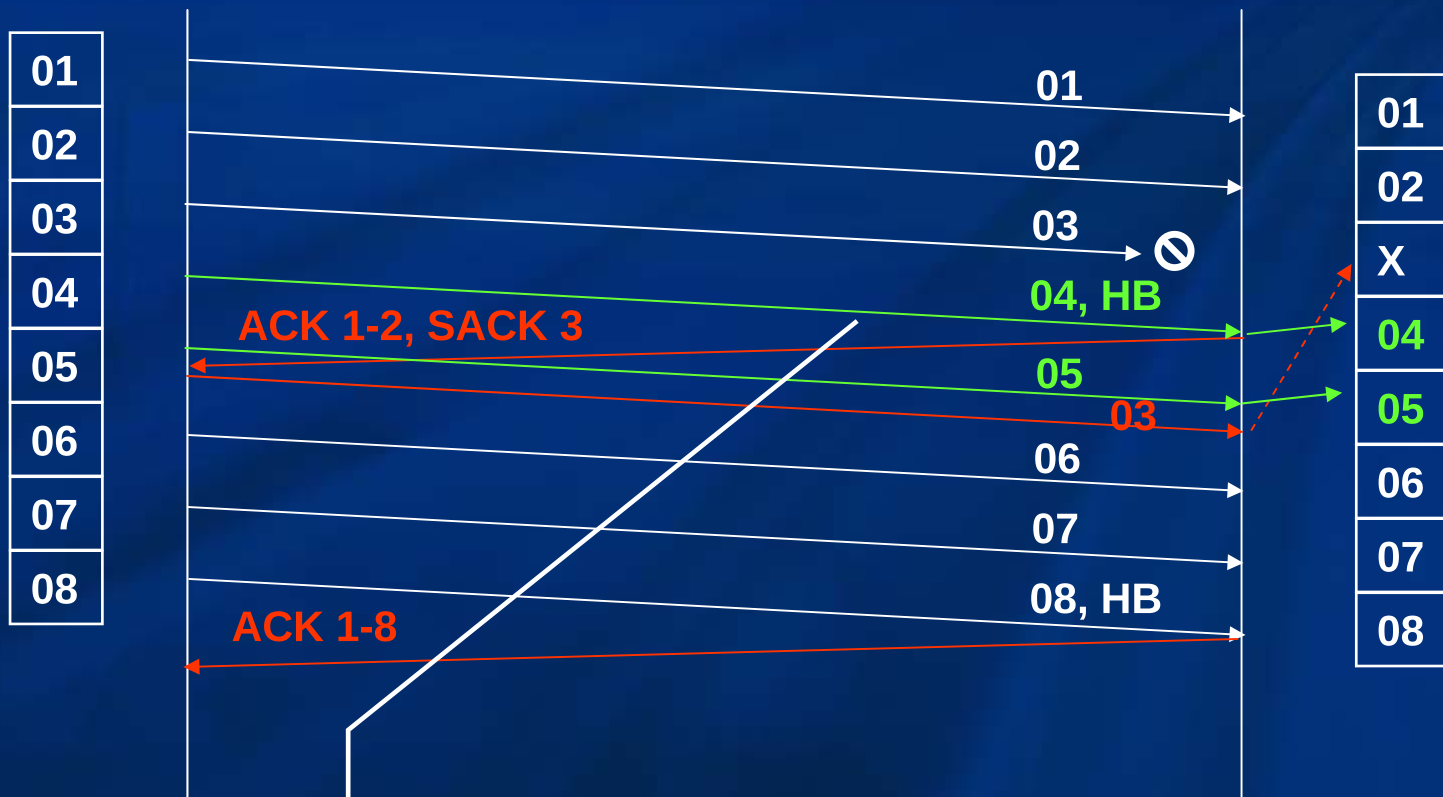
[ShapesDemo]

Classic (TCP Style) Reliable Protocol with some packet loss



Packets 04 and 05 are received but the protocol drops them because a prior packet 03 is missing.
This wastes valuable bandwidth

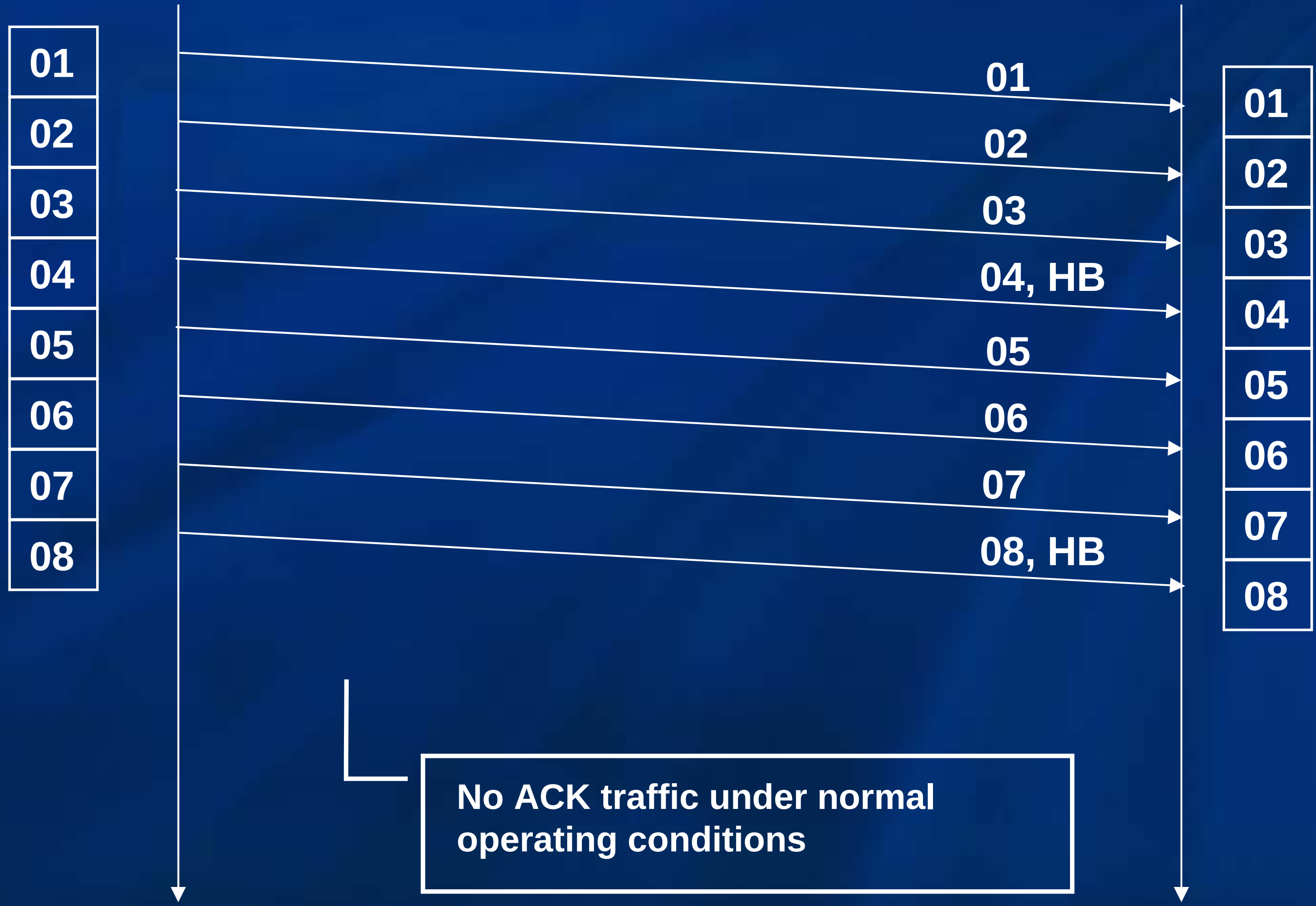
RTI DDS Reliability (Reader Cache + SACK) improves performance when packet loss occurs



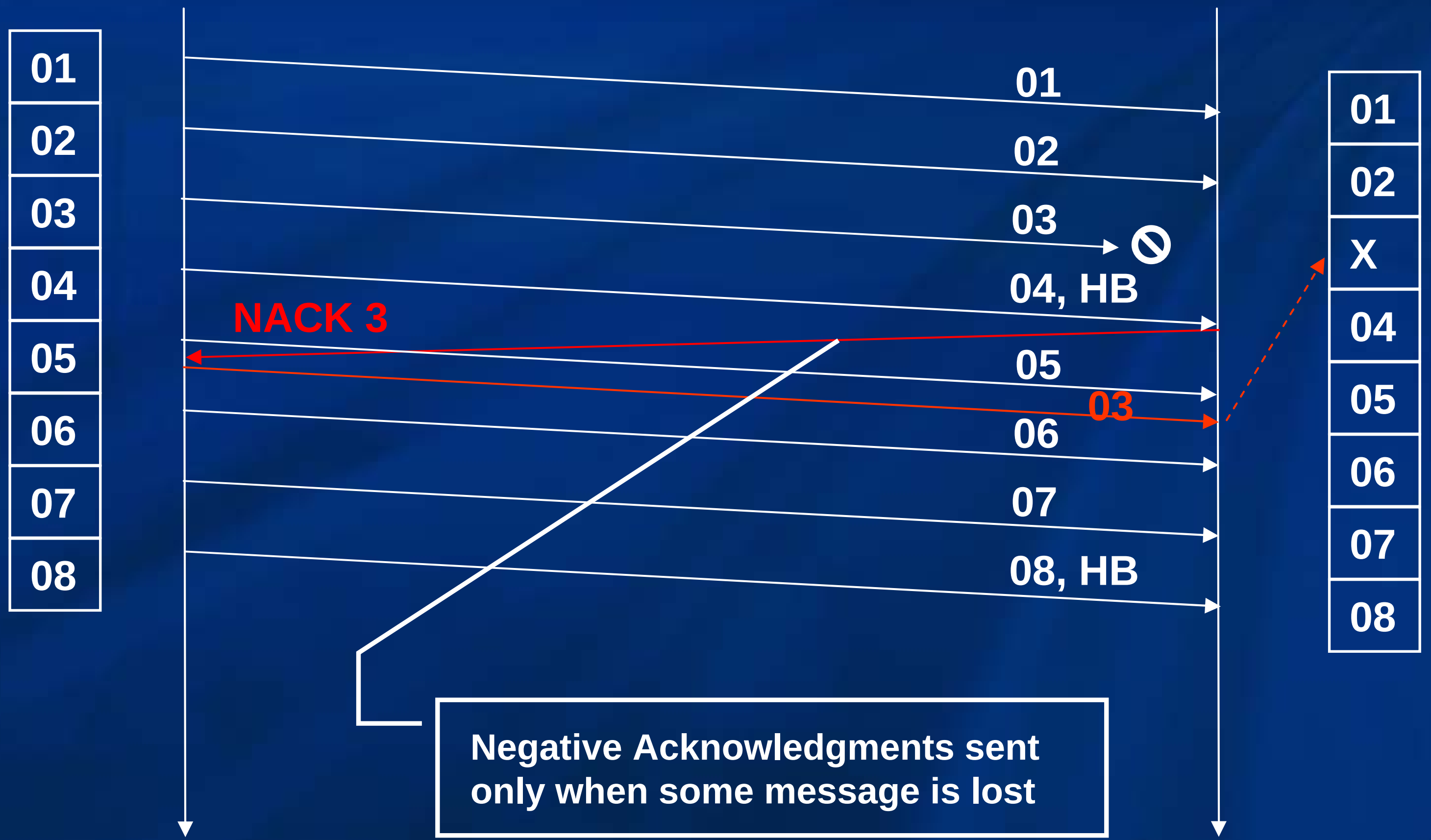
Packets 04 and 05 are received and cached waiting for the repair of 03.

No bandwidth is wasted.

RTI DDS NACK-only reliability eliminates ACK traffic if there no packet loss



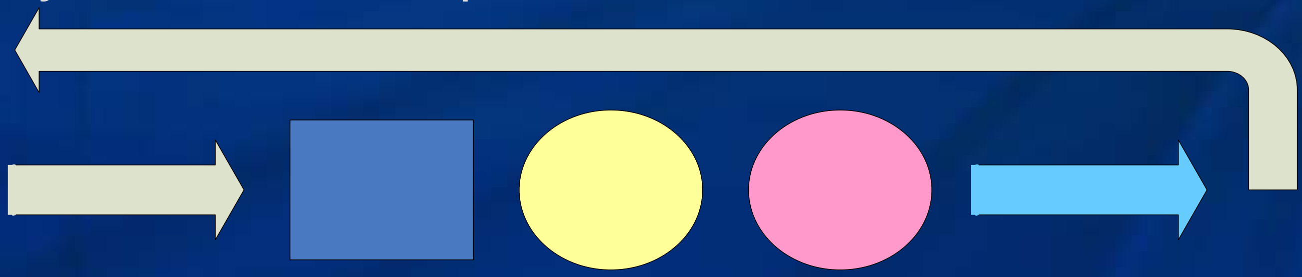
RTI DDS NACK-only reliability greatly reduces traffic even with packet loss



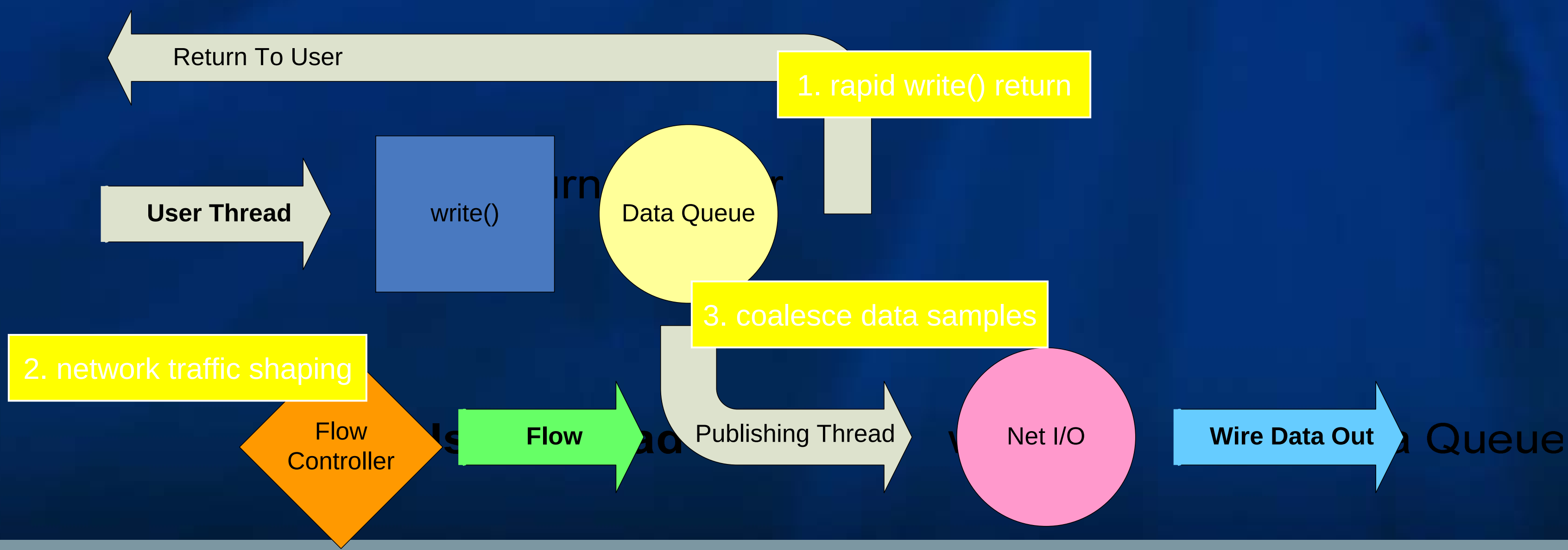
This approach is far more scalable when there are many subscribers

Asynchronous Publishing & Flow COntroller

- synchronous send path:



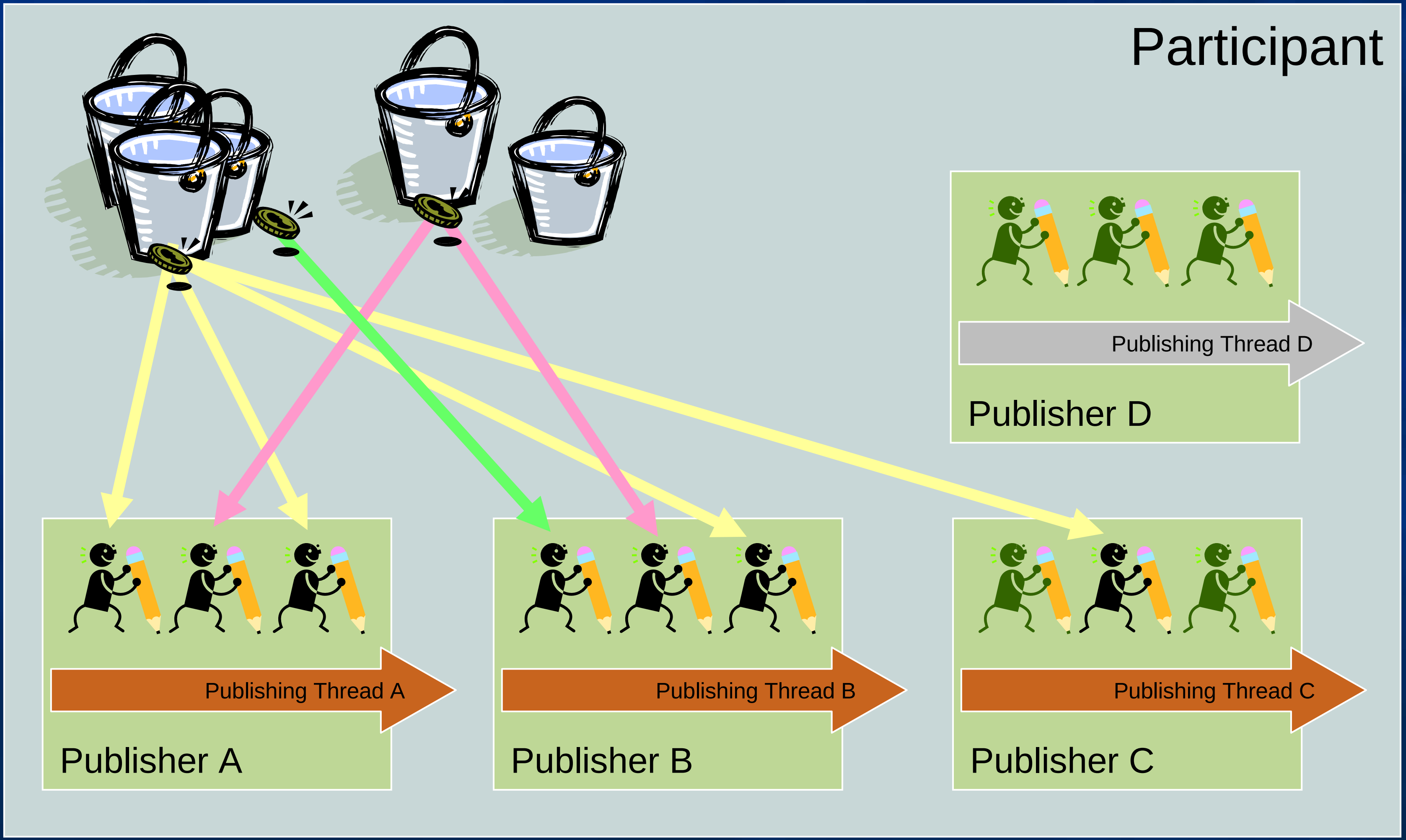
- asynchronous send path:



Qos Policies

- **DDS_PublishModeQosPolicy**
  - kind
    - *DDS_SYNCHRONOUS_PUBLISH_MODE_QOS*
    - *DDS_ASYNCHRONOUS_PUBLISH_MODE_QOS*
  - flow controller name
- **DDS_AsynchronousPublisherQosPolicy**
  - disable_asynchronous_write <FALSE>
  - thread
  - disable_asynchronous_batch <FALSE>
  - asynchronous_batch_thread

AP in Participant's World



Flow Controller Token Distribution

- basic token bucket
  - steady-state traffic
    - tokens_added_per_period
    - token_period
  - max burst control
    - max_tokens
  - Additional controls
    - tokens_leaked_per_period
    - all values can be DDS_LENGTH_UNLIMITED
  - piggyback discount (Token Exchange Rate)
    - bytes_per_token
- scheduling policy
  - round-robin (RR)
  - earliest-deadline-first (EDF)
    - deadline = time of write + DDS_DataWriterQos::latency_budget

Using Asynchronous Publishing

- DataWriter-side:

```
DDS_FlowControllerProperty_t property;

property.sched_policy = DDS_EDF_FLOW_CONTROLLER_SCHED_POLICY;
property.token_bucket.max_tokens               = A; //[0,    DDS_LENGTH_UNLIMITED]
property.token_bucket.tokens_added_per_period  = B; //[0,    DDS_LENGTH_UNLIMITED]
property.token_bucket.tokens_leaked_per_period = C; //[0,    DDS_LENGTH_UNLIMITED]
property.token_bucket.bytes_per_token          = D; //[1024, DDS_LENGTH_UNLIMITED]
property.token_bucket.period                   = E; //[0,    DDS_DURATION_INFINITE]

...

DDSFlowController *controller =
    participant->create_flowcontroller("superflow", property);
...
writer_qos.publish_mode.kind = DDS_ASYNCHRONOUS_PUBLISH_MODE_QOS;
writer_qos.publish_mode.flow_controller_name = "superflow";
//
// Set up History queue size to hold deferred issues!!!!!.
writer_qos.history.kind  = DDS_KEEP_LAST_HISTORY_QOS;
writer_qos.history.depth = z;  // <<<<<<<<<<<<<!!!!!!!!!!!!!<<<<<

...

writer->write(data_sample, ...);
... // Optional wait for pipe to empty
writer->wait_for_asynchronous_publishing(timeout);
... // Optional On-Demand trigger
controller->trigger_flow();
... // Optional Modify controller properties
controller->set_property();
```

- No changes on DataReader-side!!

Flow Controller Design Challenge

- Requirements;
  - Large 1 mbyte issue.
  - Transmit over period of 10 seconds
  - Low priority transmission
  - Transport buffer size set to 32K

- CONTROLLER:

```
property.sched_policy = ??;
property.token_bucket.max_tokens = ??
property.token_bucket.tokens_added_per_period  = ??
property.token_bucket.tokens_leaked_per_period = ??;
property.token_bucket.bytes_per_token          = ??;
property.token_bucket.period                   = ??
```

Flow Controller Design Challenge

- Requirements;
  - Large 1 mbyte issue.
  - Transmit over period of 10 seconds
  - Low priority transmission
  - Transport buffer size set to 32K
  - Cannot loose any issues

- CONTROLLER:

```
property.sched_policy = DDS_RR_FLOW_CONTROLLER_POLICY;
property.token_bucket.max_tokens                 = 1
property.token_bucket.tokens_added_per_period   = 1
property.token_bucket.tokens_leaked_per_period = unlimited;
property.token_bucket.bytes_per_token            = 32k;
property.token_bucket.period                     = 200ms
```

- Extra Credit Discussion:
  `What about reliable protocol properties?`

Outline

- Overview of Technology
- Application development cycle
- Architecting data-centric systems & modeling the Data
- Protocol, Performance & Scalability.
- Integrating external and legacy systems.
  - Routing Service
  - Systems of Systems
  - Cross Domain Solutions
  - Accessing Data over a WAN
  - Database Connectivity
  - Access over the Web
- Future directions and Standards:

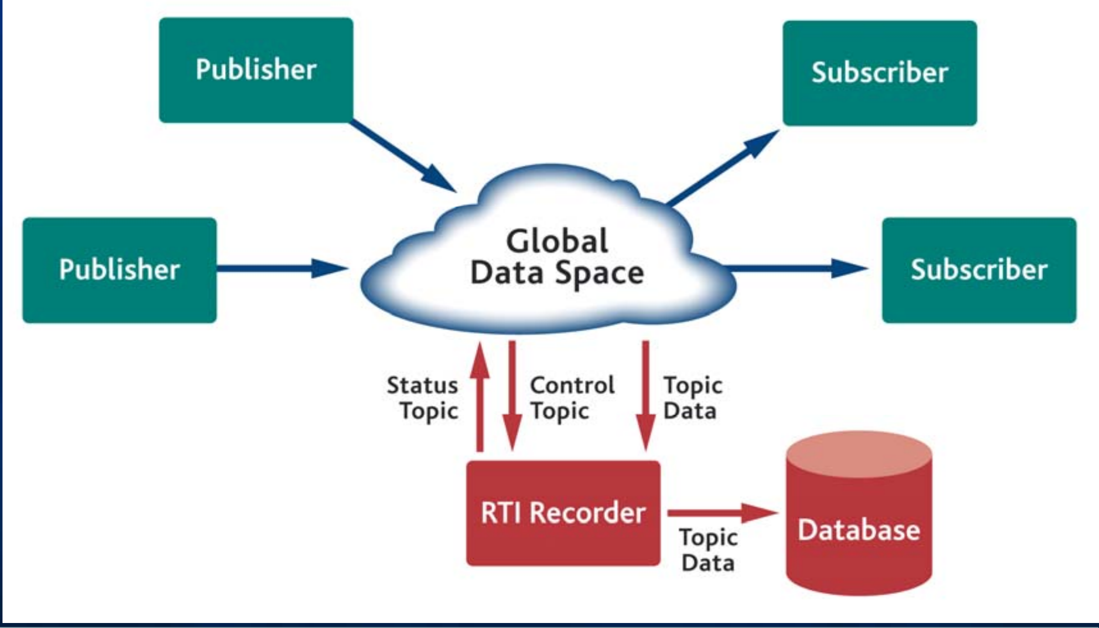
Real-Time Recording Service

- Applications:
  - Future analysis and debugging
  - Post-mortem
  - Compliance checking
  - Replay for testing and simulation purposes
- Record high-rate data arriving in real-time
- Non-intrusive – multicast reception

Demo:

1. **Start [RecordingService]**
2. **Start [ShapesDemo]**
3. **See [output files]**
4. **Convert to: [HTML] [XML]**
5. **View Data: [HTML] [XML]**

[sqlite] **[stop_all]**



Relational Database Integration

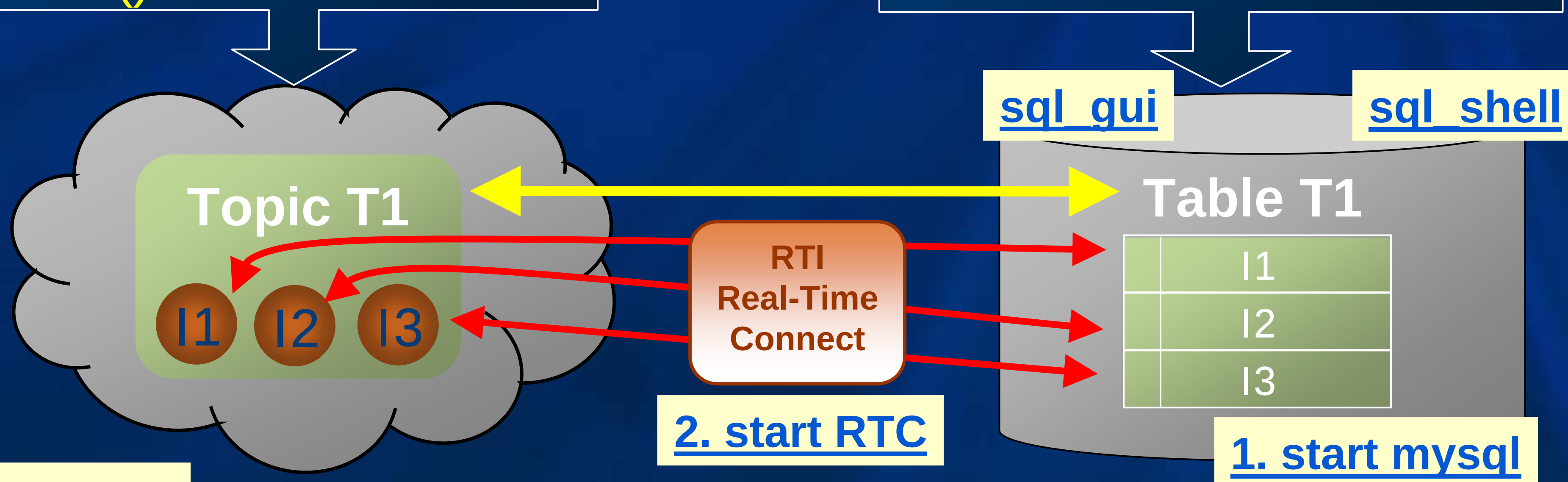
Publish-Subscribe Action

- Write()
- Read() & Take()
- Dispose()
- Wait() & Listener

ShapesDemo

Relational Actions

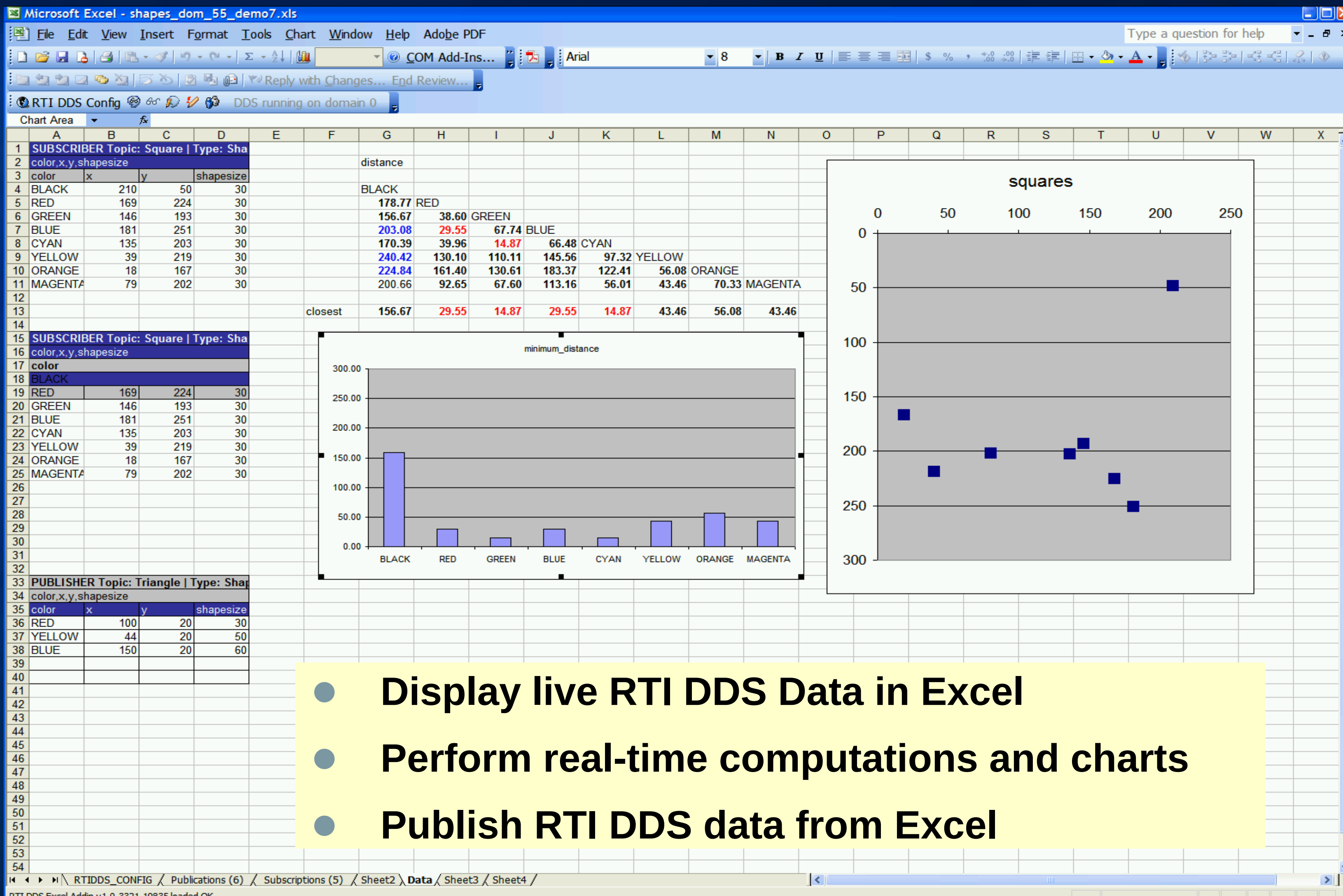
- UPDATE [2,3] & INSERT
- SELECT
- DELETE



stop_all

Event driven – The fastest way to observe database changes!

COTS tools: Excel – Interacting with your data

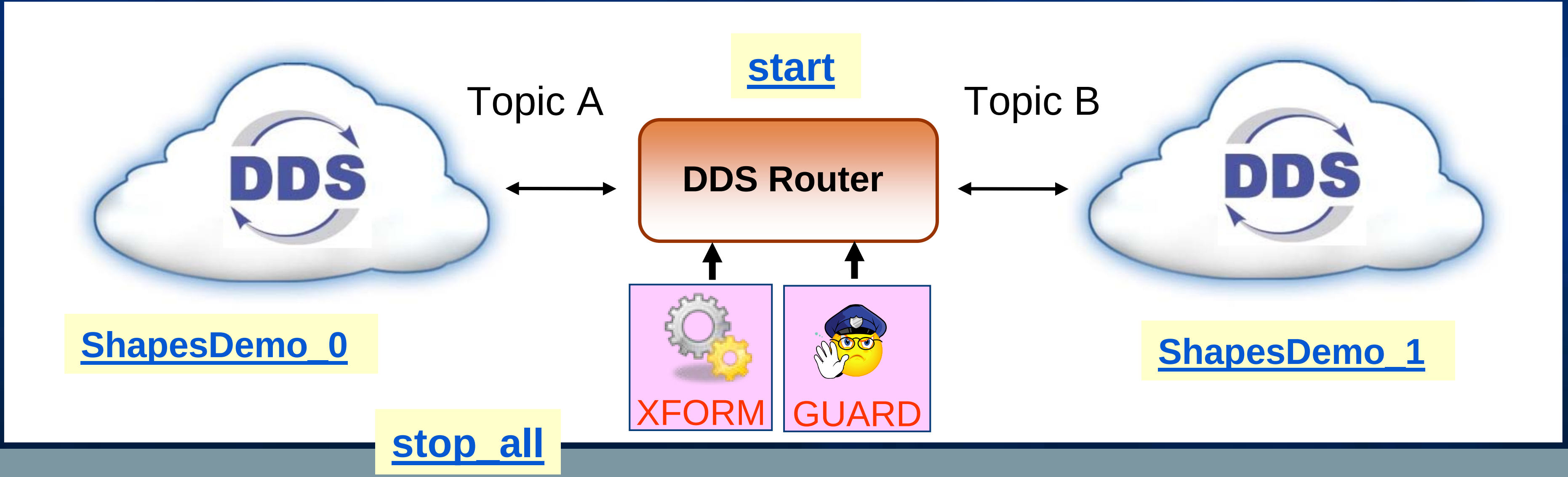


- **Display live RTI DDS Data in Excel**
- **Perform real-time computations and charts**
- **Publish RTI DDS data from Excel**

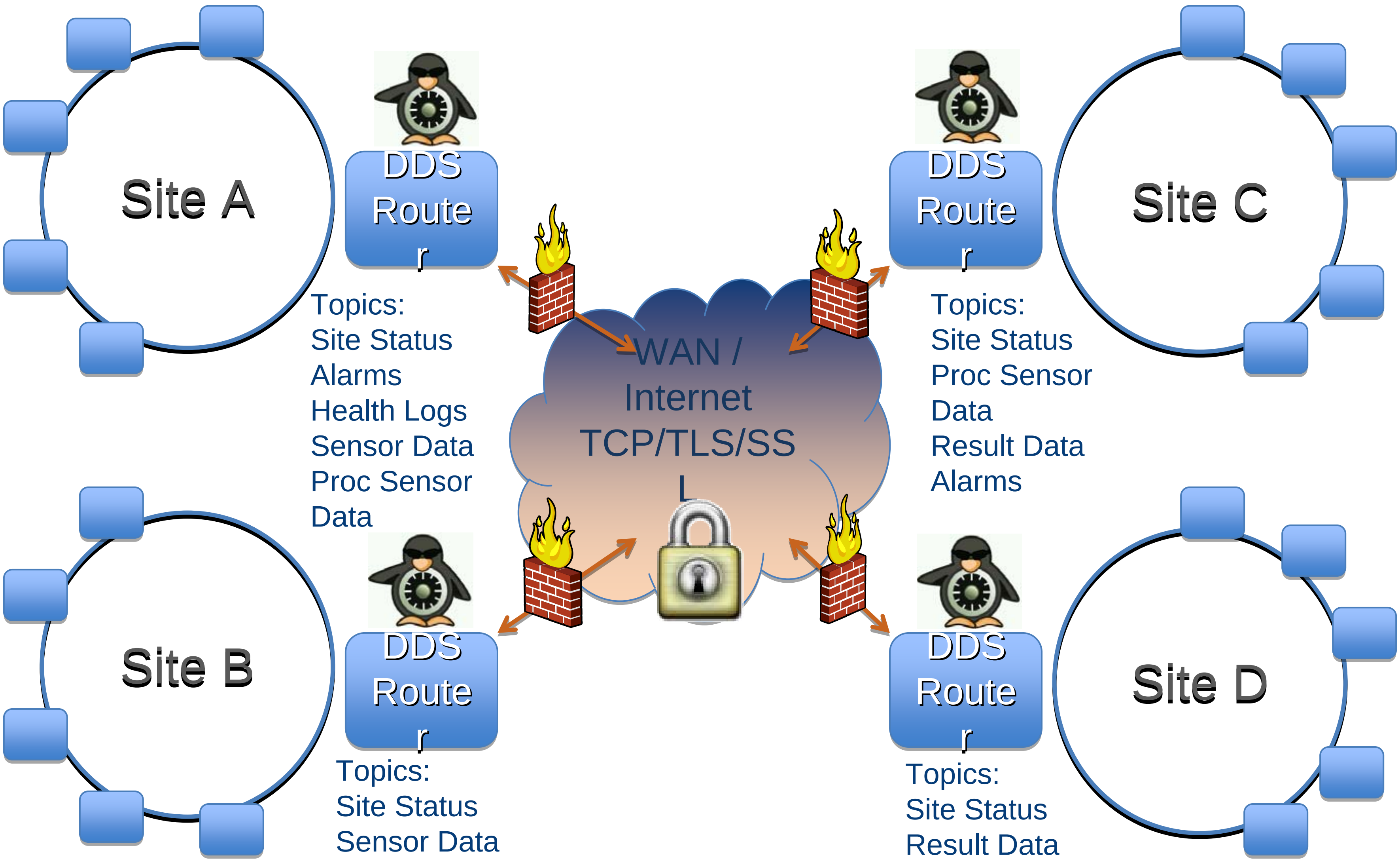
ShapesDemo blank saved demo

RTI Routing Service

- Selective, real-time data forwarding and transformation
- Can Change Topic Name and Topic Schema
  - Allows for custom transformations via “plugin”
  - Can filter/guard data
- QoS managed, can cache last-known value for data
- Dynamically configured
- Location independent deployment

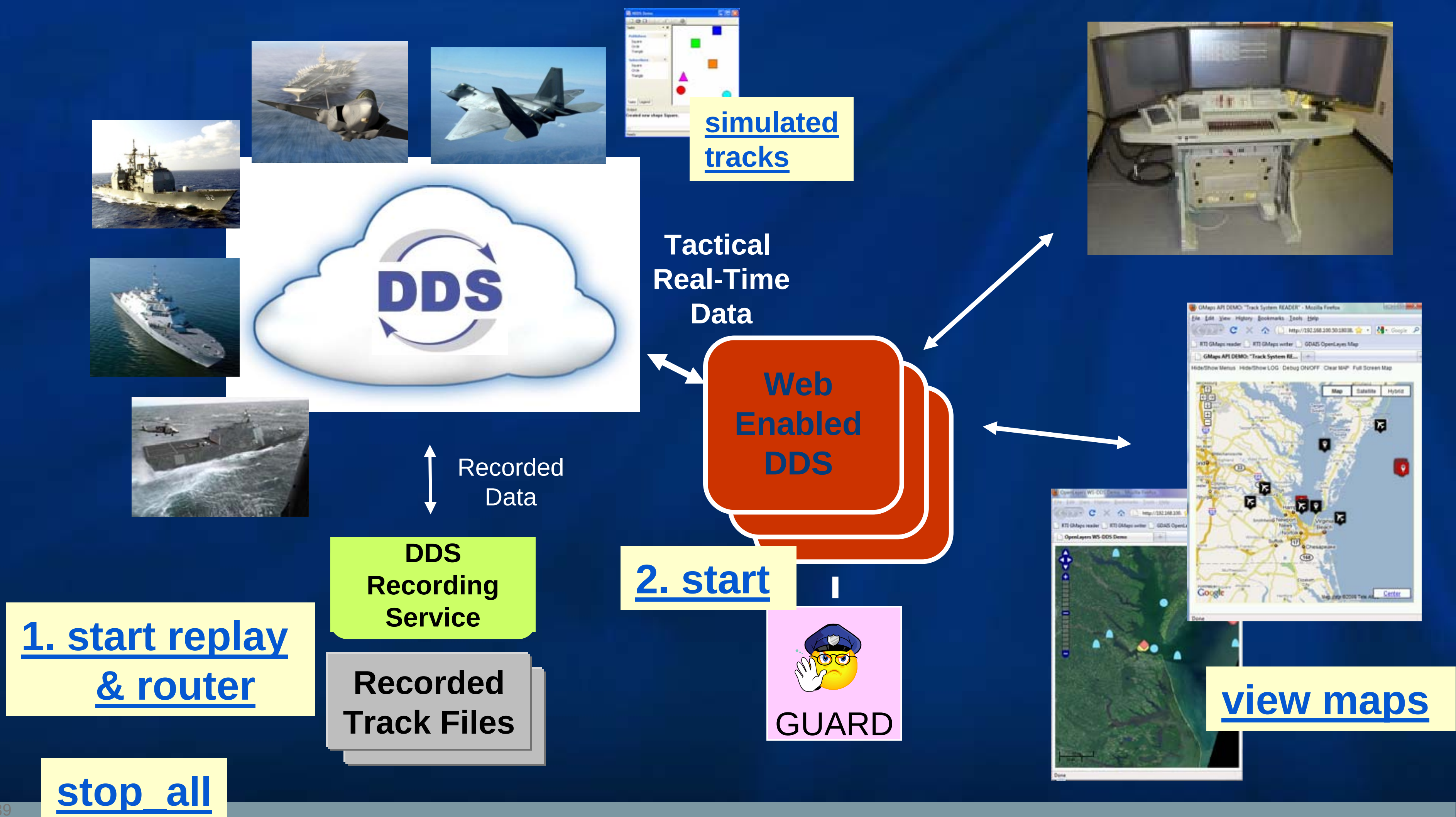


Global Scalability: LAN to WAN…
…without sacrificing Performance and Security



Web Accessibility

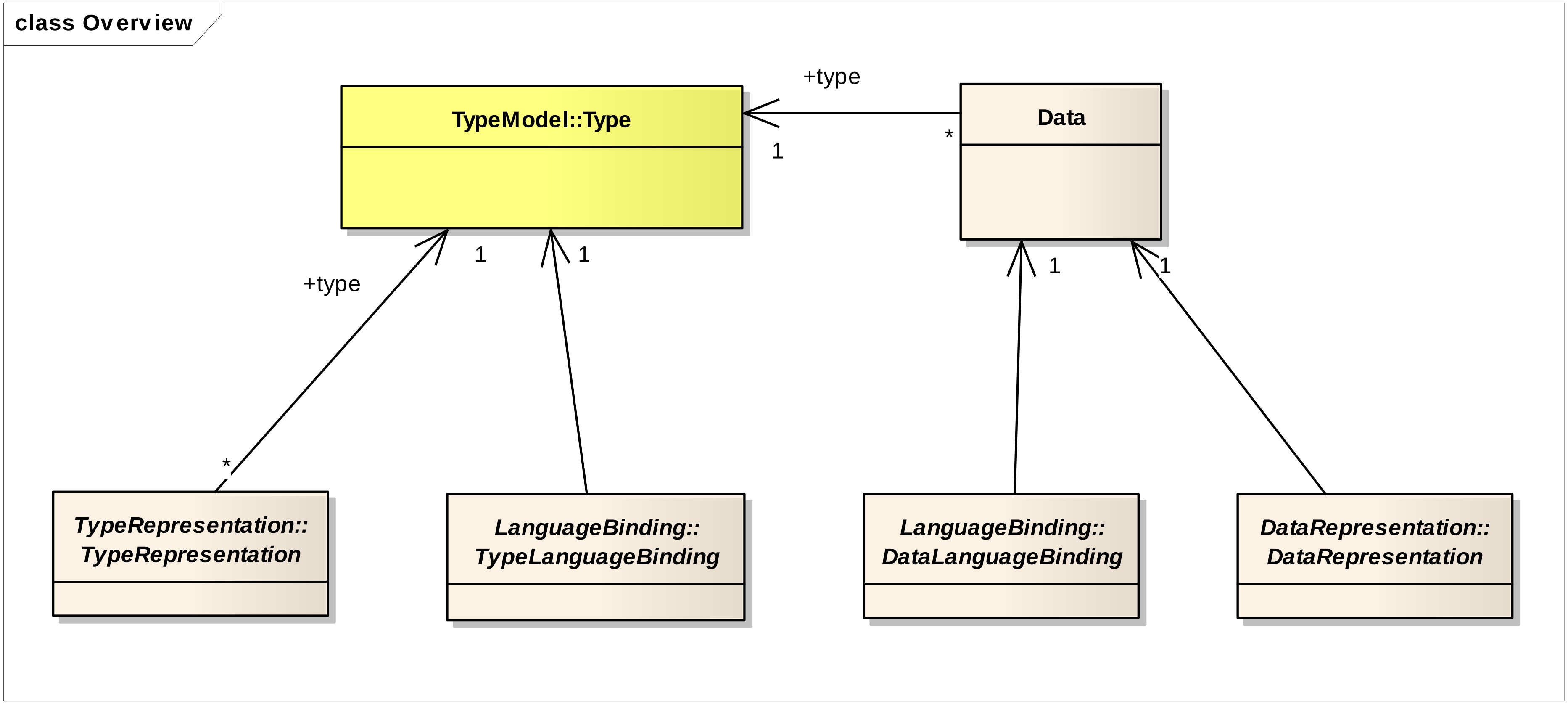
Direct access to real-time data from Web-Based Applications



Outline

- Overview of Technology
- Application development cycle
- Architecting data-centric systems & modeling the Data
- Protocol, Performance & Scalability.
- Integrating external and legacy systems.
- Future directions and Standards:
  - Extensible Topics for DDS
  - Web Enabled DDS
  - Standard C++ PSM for DDS
- Q&A

Extensible Dynamic Types Submission



Example: Current mechanisms

Type Definition

IDL:
Foo.idl

```
struct Foo {
  string<> name;
  long ssn;
};
```

Language Binding

IDL to Language Mapping:
Foo.h
Foo.cpp
FooTypeSupport.cpp

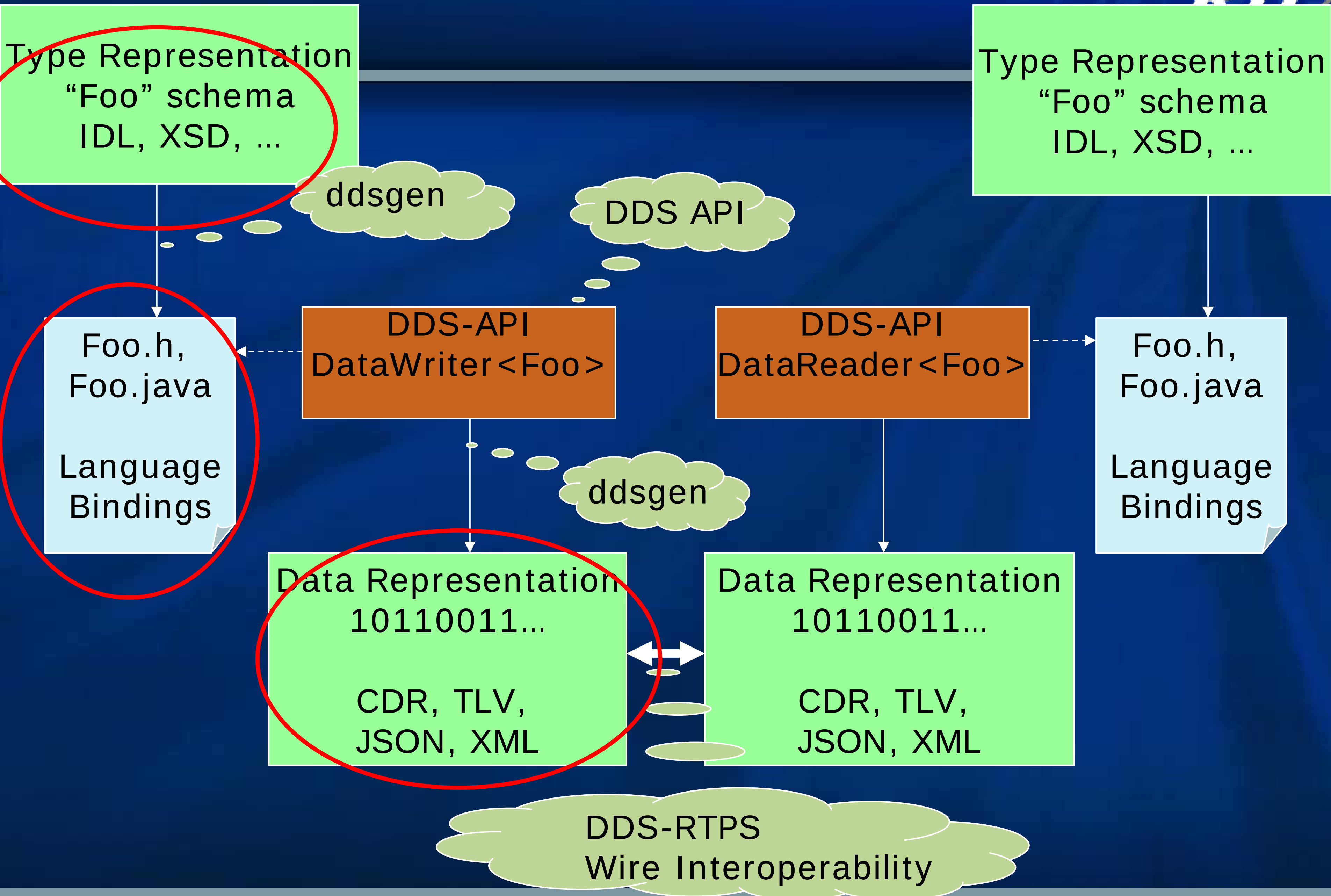
```
struct Foo {
  char *name;
  int ssn;
};

Foo f = {“hello”, 2”};
```

Data Representation

IDL to CDR:

```
00000006
68656C6C
6F000000
00000002
```

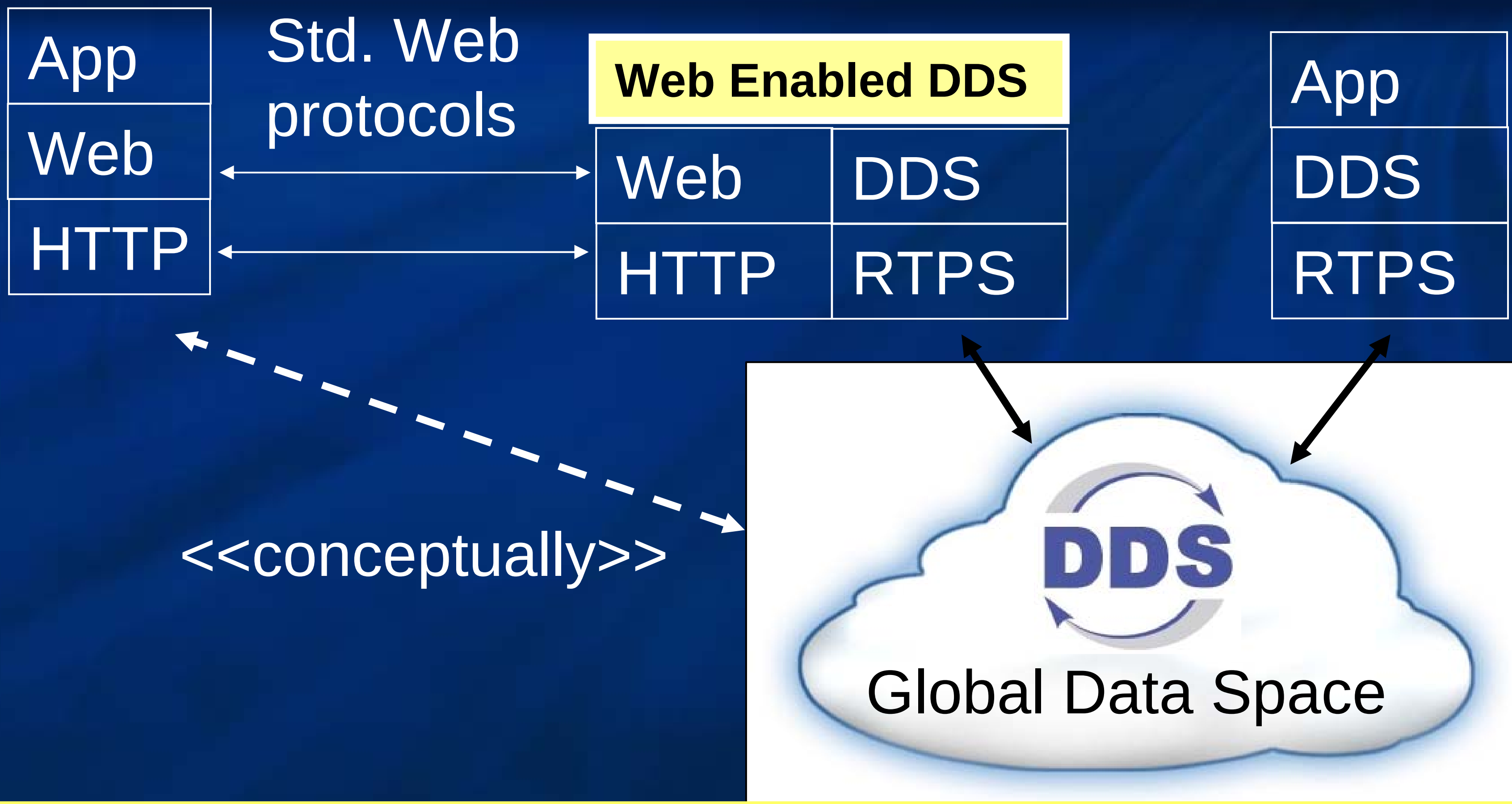
Type-Definition – Language Representation – Serialized encapsulation ... Each offers options



Web-Enabled Data-Centric Global Data Space

- Stateless access of data via application appropriate technologies and protocols
- Not a bridge, broker, or message router

Web Enabled DDS



A service that exposes DDS Global Data over Web Protocols:
Applications can interact with DDS directly over the Web
No need for bridges or special bindings for scripting languages

Day 2: Exercises

Gerardo Pardo-Castellote, Ph.D.
Co-chair OMG DDS SIG
CTO, Real-Time Innovations
gerardo.pardo@rti.com

The Real-Time Middleware Experts

- http://www.rti.com

Preparations

- Install RTI DDS:
  - Windows
    - Unzip: RTI_Masterclass2GO.zip
      - into directory C:\RTI
    - Execute: install_actions.bat
  - Linux
    - Boot your computer from the USB

- Test you can do the following
  - rtiddsgen -help

Install VisualStudio from the ISO's

- Copy the VS2008 and WindowsSDK ISO's
- Install DaemonTools
- Mount the ISOs as virtual drives
- Proceed with the installation
  - 1st the VS2008
  - 2nd the Platform SDK
- Test the installation by creating a "hello world" project compiling and running it

Exercise #0 - Hello World

Define you data type:

- Create a directory “HelloWorld”
- Create a file called hello.idl and open it in VisualStudio
- Add the following contents:

```
const long MSG_LEN=256;
struct HelloMsg {
    string<MSG_LEN> user; //@key
    string<MSG_LEN> msg;
};
```

Run rtiddsgen (for C++)

- rtiddsgen hello.idl -language C++ -example i86Win32VS2005 \
  -replace -ppDisable
- rtiddsgen hello.idl -language Java -example i86Win32jdk \
  -replace -ppDisable

- Look at the directory you should see:
  - hello-vs2005.sln
  - And Several other files…
- Open the Solution File (type hello-vs2005.sln on the console)
  - Look at HelloMsgPublisher.cxx
  - Look at HelloMsgSubscriber.cxx
- Build the Solution

Run rtiddsgen (for Java)

- rtiddsgen hello.idl -language Java -example i86Win32jdk \
  -replace -ppDisable

- Look at the directory you should see:
  - makefile_hello_i86Win32jdk
  - And Several other files…
    - Look at HelloMsgPublisher.java
    - Look at HelloMsgSubscriber.java

- You can use the makefile to build and the Java programs:
  - gmake –f makefile_hello_i86Win32jdk

Execute the program

- C++:
  - On one window run:
    - objs\i86Win32VS2005\HelloMsgPublisher.exe
  - On another window run:
    - objs\i86Win32VS2005\HelloMsgSubscriber.exe
- Java
  - On one window run:
    - gmake –f makefile_hello_i86Win32jdk HelloMsgPublisher
  - On another window run:
    - gmake –f makefile_hello_i86Win32jdk HelloMsgSubscriber
- You should see the subscribers getting an empty string…

Modify the program to produce something

- C++: Open HelloMsgPublisher.cxx in VisualStudio
- Java: Open HelloMsgPublisher.java in your preferred tool

- Look for the comment:
  /* Modify the data to be sent here */

- Add the line:

```
strcpy_s(instance->msg, MSG_LEN,
        "Hello this is gerardo");
```

Use your own name instead of “gerardo”

- Kill the Publisher, Rebuild the publisher and run it again

Playing with rtiddsspy

- Run rtiddsspy while the other applications are running
- Start and stop applications. What do you see in rtiddsspy

Exercise #1 – Shapes Publisher

- Create a new directory Shapes
- In the Directory create a file called ShapeType.idl
- Edit the file to have the following content:

```
const long COLOR_LEN=64;
struct ShapeType {
     string<COLOR_LEN>color; //@key
    long x;
    long y;
    long shapesize;
};
```

- Run:

rtiddsgen ShapeType.idl -language C++ -example i86Win32VS2005 –replace -ppNotRun

Exercise #2 – Using keys

- Create a new directory Chat
- In the Directory create a file called chat.idl
- Edit the file to have the following content:

```
const long NAME_LEN=64;
const long MSG_LEN=256;
struct ChatMsg {
    string<NAME_LEN>name; //@key
    long age;
    string<MSG_LEN> chatRoom;
    string<MSG_LEN> msg;
};
```

- Run:

rtiddsgen chat.idl -language C++ -example i86Win32VS2005 –replace -ppNotRun

Edit the chat_publisher.cxx

- Go to the line with comment: /* Main loop */
  - Add the line:

```
strcpy_s(instance->name,
           NAME_LEN, "Gerardo Pardo");
```

(Use your own name)

- Go to the line with comment:
  - /* Modify the data to be sent here */
  - Add the lines:

```
instance->age = count;
strcpy_s(instance->msg,
           NAME_LEN, “Como va todo?");
```

(Use your age and personalized message)

- Rebuild and execute

Exercise #3 Use Qos

- Set RELIABILITY
- Set HISTORY to KEEP_LAST or KEEP_ALL
  - Test different depths
- Use Partitions
  - Create several Partitions:
    - E.g. by ChatRoomName
  - Publish in your ChatRoom
  - Subscribe to one or more ChatRooms

Exercise #4 Use content filters

- Edit the chat_subscriber.cxx
- Add the lines:

```
DDSContentFilteredTopic *cftopic;
DDS_StringSeq filter_params;
filter_params.maximum(0);
cfTopic = participant->
          create_contentfilteredtopic(
          "Selected Chats", topic,
          "age > 4", filter_params);
```

- Look of the call to create_datareader
  - Replace “topic” with “cfTopic” in the paramater list.

Exercise #5 Use Exclusive Ownership

- Set up in pairs edit the chat_publisher.cxx and use the same “name” for both of you
- Re-run the publisher application you will see mixed messages.

- Edit the chat_publisher.cxx
- Before creating the data writer add the lines

```
publisher->get_default_datawriter_qos(dwq);
dwq.ownership.kind = DDS_EXCLUSIVE_OWNERSHIP_QOS;
dwq.ownership_strength.value = 10;
```

- Replace DDS_DATAWRITER_QOS_DEFAULT with dwq In the create_datawriter() call

- Edit the chat_subscriber.cxx
- Before creating the data reader add the lines

```
DDS_DataReaderQos drq;
subscriber->get_default_datareader_qos(drq);
drq.ownership = DDS_EXCLUSIVE_OWNERSHIP_QOS;
```

- Replace DDS_DATAWRITER_QOS_DEFAULT with drq in the create_datareader() call

Summary

- Reduces software lifecycle costs
  - Loose coupling
  - Replaces need for custom middleware in high-performance, real-time applications
- Reduces risk
  - Standards-compliant API and wire protocol
  - Multiple implementations
  - Widely adopted

- Most widely proven and mature implementation
- Highest performance
- Industry-leading expertise and services capability
- Free trial, research and IR&D licenses
- Comprehensive VxWorks support