DDS in Low-Bandwidth Environments

Workshop on Real-time, Embedded and Enterprise-Scale Time-Critical Systems

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Agenda

- DDS in Low-Bandwidth environments
  - Motivations
  - DDS Behaviour out-of-the-box
    - Poor performance
    - Reasons
    - Optimizations Required
    - Performance after optimizations
    - Available Market Products/ Success Cases
  - Optimization Details
    - Discovery
    - Data Compression
    - Protocol

Motivations

DDS in Low Bandwidth Enviroments

Motivations

- Currently, DDS main market is Defense
  - Defense applications use intensively radio & satellite links
- Features of Tactical Radio & Satellite links:
  - Low Bandwidth: Even 2400 bps or less.
  - Shared Bandwidth: Even 32 nodes or more.
  - Disconnections and Packet Loss
  - High lantency.

Motivations (II)

- Radio link typical Capabilities:
  - VHF Radio (Range 20 km): < 64 kbps shared
  - UHF Radio (Range 1 km): <1 Mbps shared
  - 4-32 nodes sharing bandwidth in the same Radio net.
  - High latency, Packet loss, disconnections
- Satellite link typical capabilities
  - Channel bandwidht: from 64 kbps to several Mbps
  - High latency, Packet loss, disconnections

Motivations (III)

- Real Example: Spanish Army
  - Uses VHF, UFH and Satellite links intensively for Data Transmisions.
  - Propietary comms solutions for their different C2 systems
    - Poor Performance
    - Lack of Interoperability

DDS Behaviour out-of-the-box

DDS in Low Bandwidth Enviroments

DDS Behaviour out-of-the-box

- Very Long discovery times
- Very Low effective throughput
- Example: 6 nodes, VHF Radios (4800 bps-shared), RTI DDS
  - Discovery: >45 Min! (unusable)
  - Effective throughput: <100 bps! (unusable)

Poor performance: Reasons

- Chatty discovery protocol
  - Requires dozens of messages for a single system
  - Number of messages = K* (Number of Nodes)^2
- Large Protocol Headers
  - RTPS tipical header is 56 bytes long
- DDS does not compress data.
- Qos default values are not the best suited for this scenario.

Optimizations required

- Discovery: Reduce the number of messages
  - Should be of the order of number of nodes
  - The payload of the discovery messages should be small
- Protocol:
  - Reduce header length
- Compress data and metadata
- Use Multicast for data, metadata & heartbeats
- Qos: Set up according bandwidth and latency
- Nack Based Reliability, Use of flow controllers, Type optimization…

Performance after optimizations

- Discovery:
  - Number of messages = O(number of nodes)
  - Very small message payload, 100-150 bytes.
- RTPS Headers
  - Reduced from 56 to 26 bytes
- Data Compression:
  - 50%-80% of compression for tipical C2 data
- Multicast for Data, Discovery metadata and heartbeats
- Nack Based Reliability, Use of flow controllers, Type optimization…

Performance Example

- Example: 6 nodes, VHF Radios (4800 bps-shared), RTI DDS

	Out of the Box	Optimized
Discovery Time	>45 min	**<20 seg**
Effective data throughput	<100 bps	**>2000 bps (*1)**

(*1) Radio Effective bandwidth decreases with number of nodes.

- Example app: C2 system: squadrons of 6 tanks
  - Quick System Startup
  - Update position and status every 5 seconds
  - Bandwidth Room for alarms, tactical chat, enemy positions, etc.

Available Market Products

- eProsima Low Bandwidth Plugins for RTI DDS
  - eProsima LB Discovery Plugins
  - eProsima LB Compression Transport
  - eProsima LB Optimized RTPS Transport
  - eProsima LB Simulation Transport
    - Allow Radio/Satellite link simulation
  - All plugins can be used together.
- Success Case: Spanish Army
  - Spanish Army selected DDS for C2 interoperability.
  - Intensive use of VHF Radios
  - Implemented already in three main C2 systems.

Available Market Products (II)

- OpenSplice Supports ZLIB compression and static discovery
- OpenDDS, CoreDx, others: ?

Discovery Optimization Details

DDS in Low Bandwidth Enviroments

Overview

- What is discovery?
- Discovery phases
  - Participant discovery phase
  - Endpoint discovery phase
- eProsima LBDP
  - Endpoints Plugin: LBEDP
  - Participant Plugin: LBPDP
- User Traffic Hints.

What is discovery?

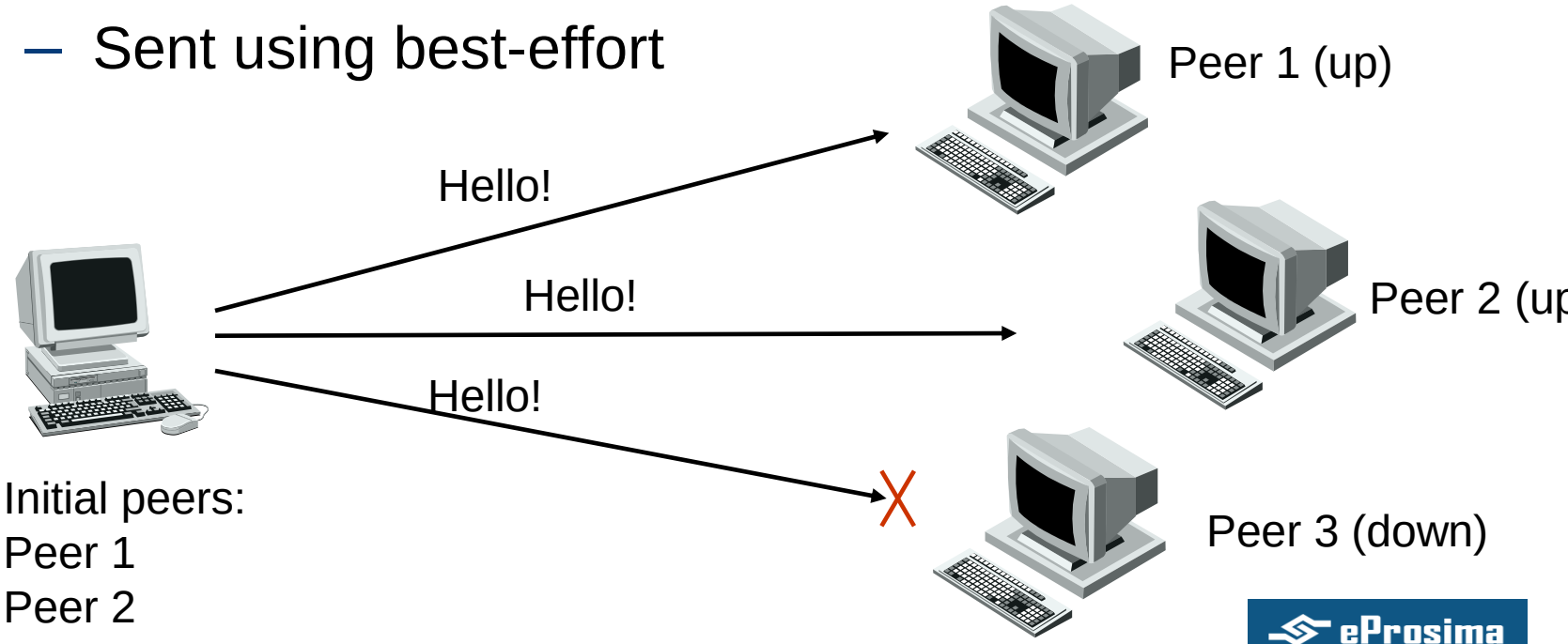
- The process by which domain participants find out about each other's entities
  - Each participant maintains database on other participants in the domain and their entities
- Happens automatically behind the scenes
  - "anonymous publish-subscribe"
- **Does not** cross domain boundaries
- **Dynamic** discovery
  - Participants must refresh their presence in the domain or will be aged out of database
  - QoS changes are propagated to remote participants

Discovery phases

- Two consecutive phases
  - **Participant discovery phase**
    - Participants discover each other
    - Best-effort communication
  - **Endpoint discovery phase**
    - Participants exchange information about their datawriter and datareader entities
    - Reliable communication
- Steady state traffic to maintain liveliness of participants

Participant discovery phase

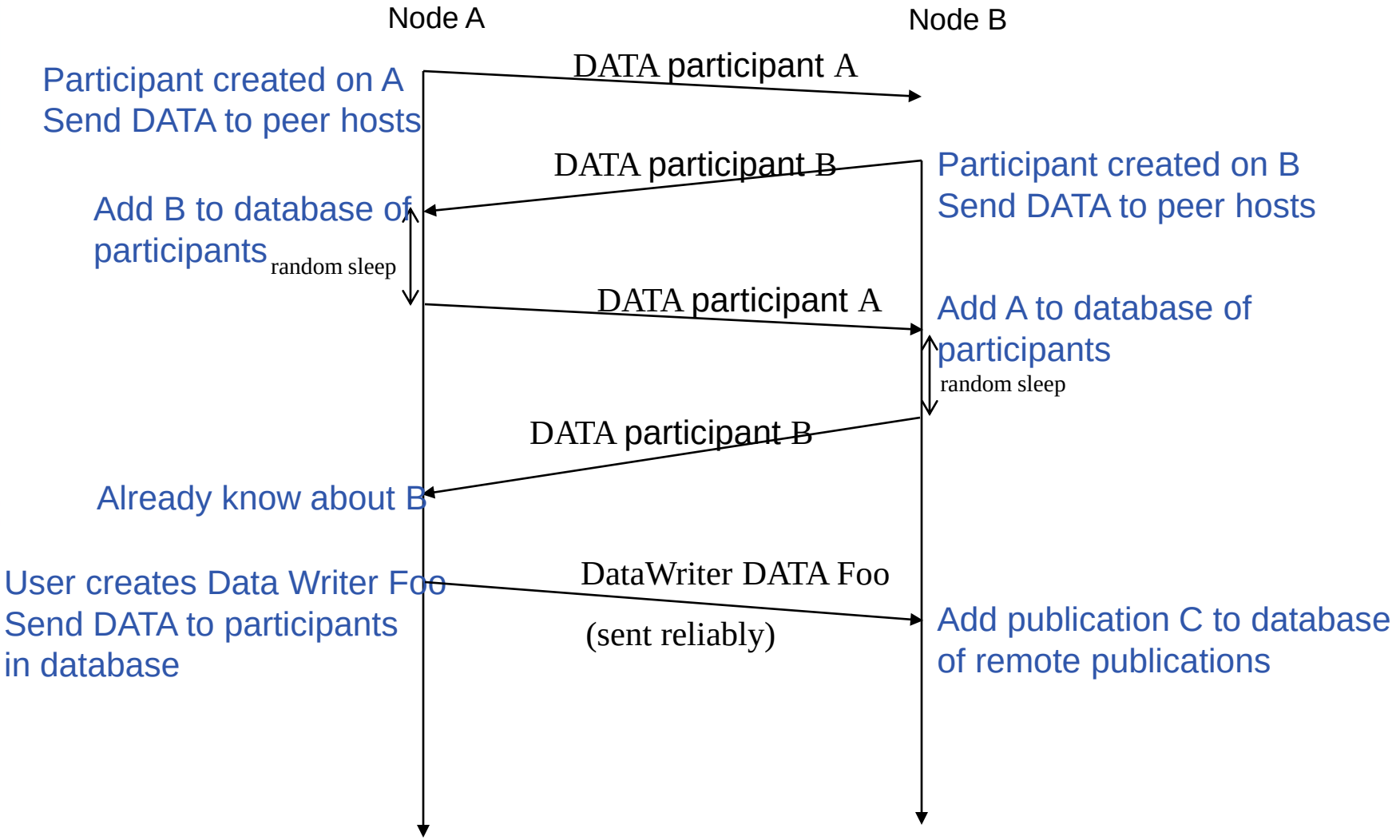
- Participants periodically announce their presence using RTPS DATA message
  - Contains participant GUID, transport locators, QoS
  - Initially sent to all participants in “initial peers” list, then sent periodically to all discovered participants
  - Sent using best-effort



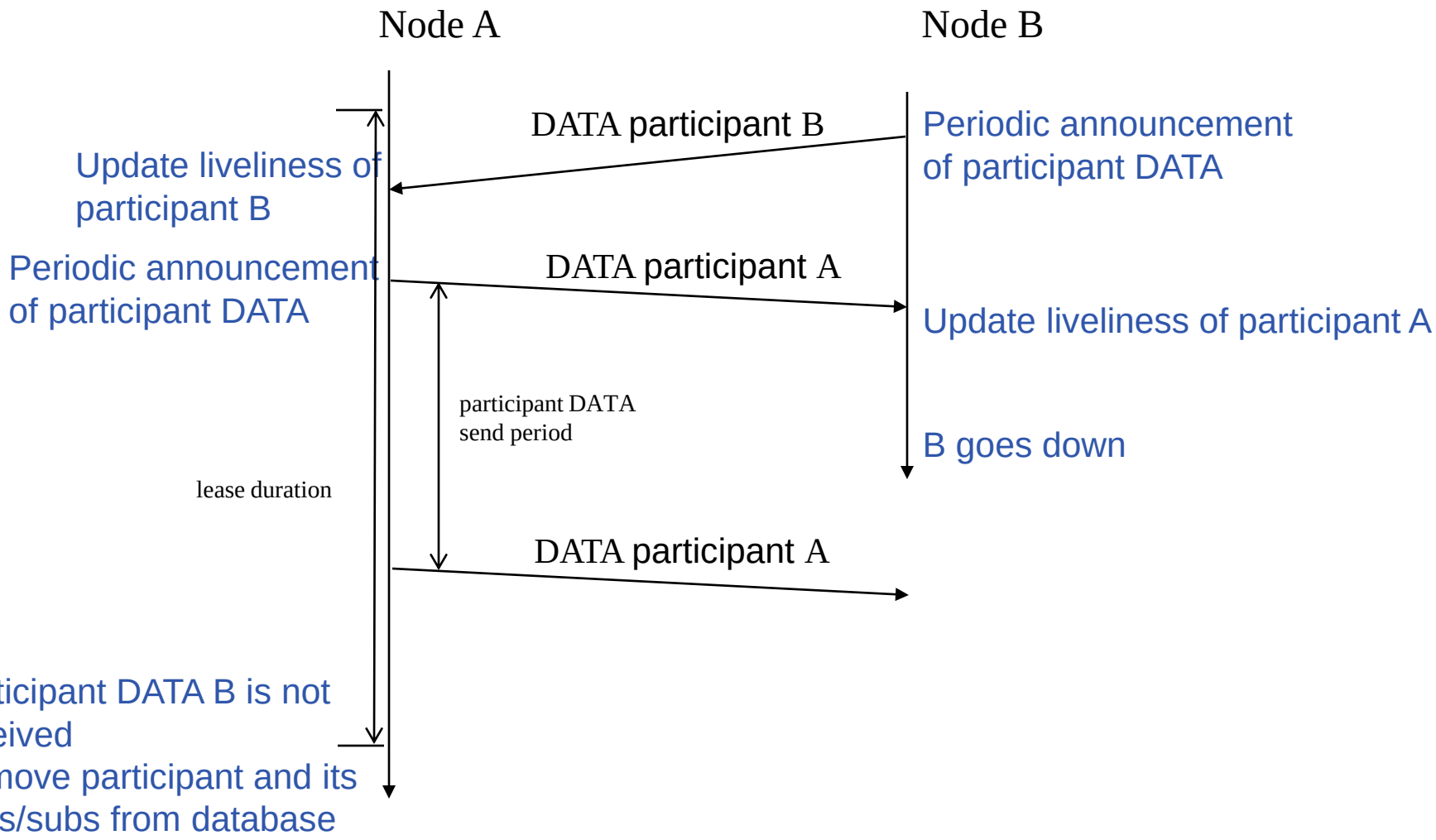
Endpoint discovery phase

- DataWriter/DataReader discovery
  - Send out pub/sub DATA to every new participant
  - NACK for pub/sub info if not received from a known participant
  - Send out changes/additions/deletions to each participant
- Uses reliable communication between participants
- DDS matches up local and remote entities to establish communication paths

Discovery start-up traffic



Discovery steady-state traffic

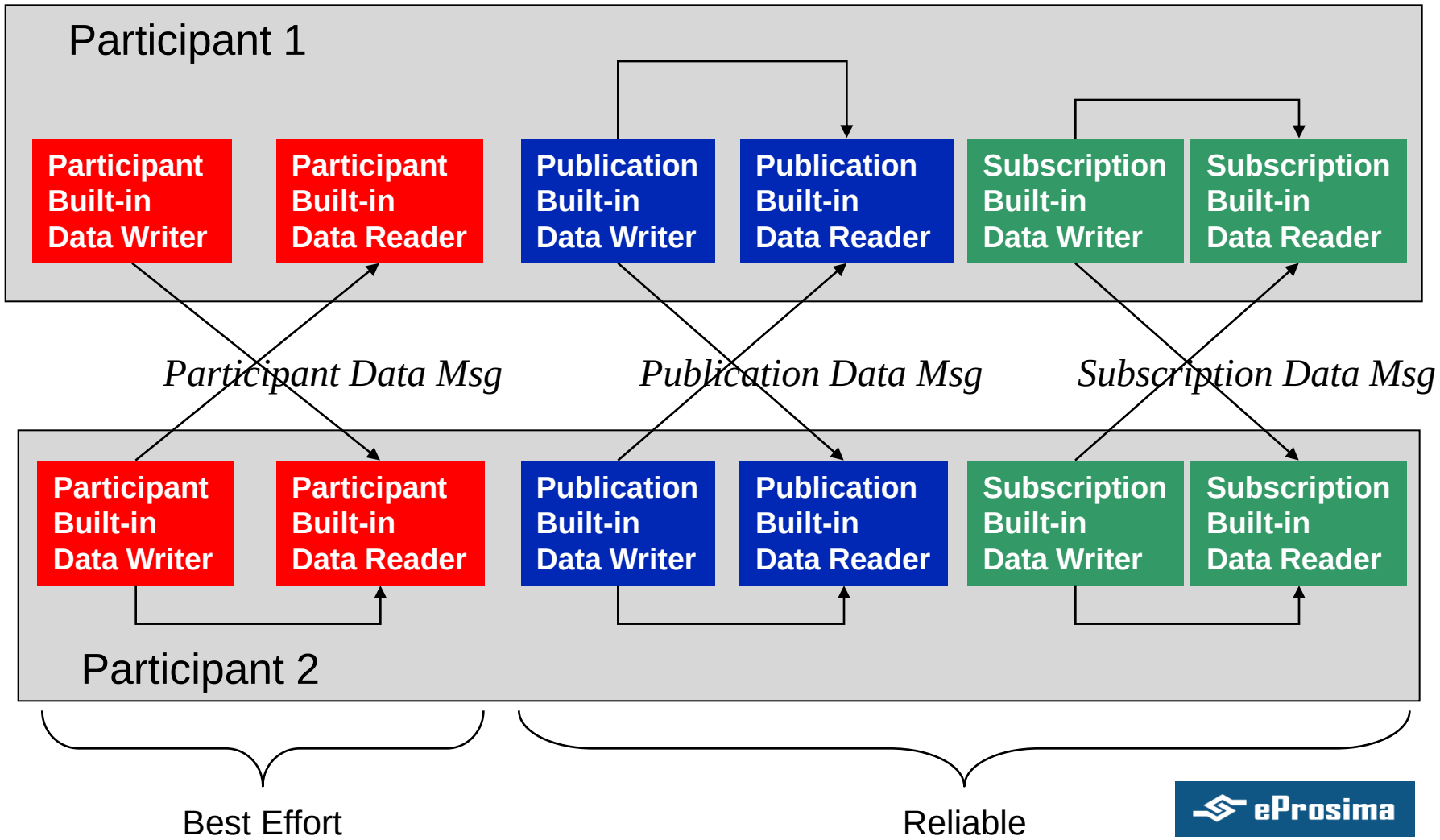


Discovery Implementation

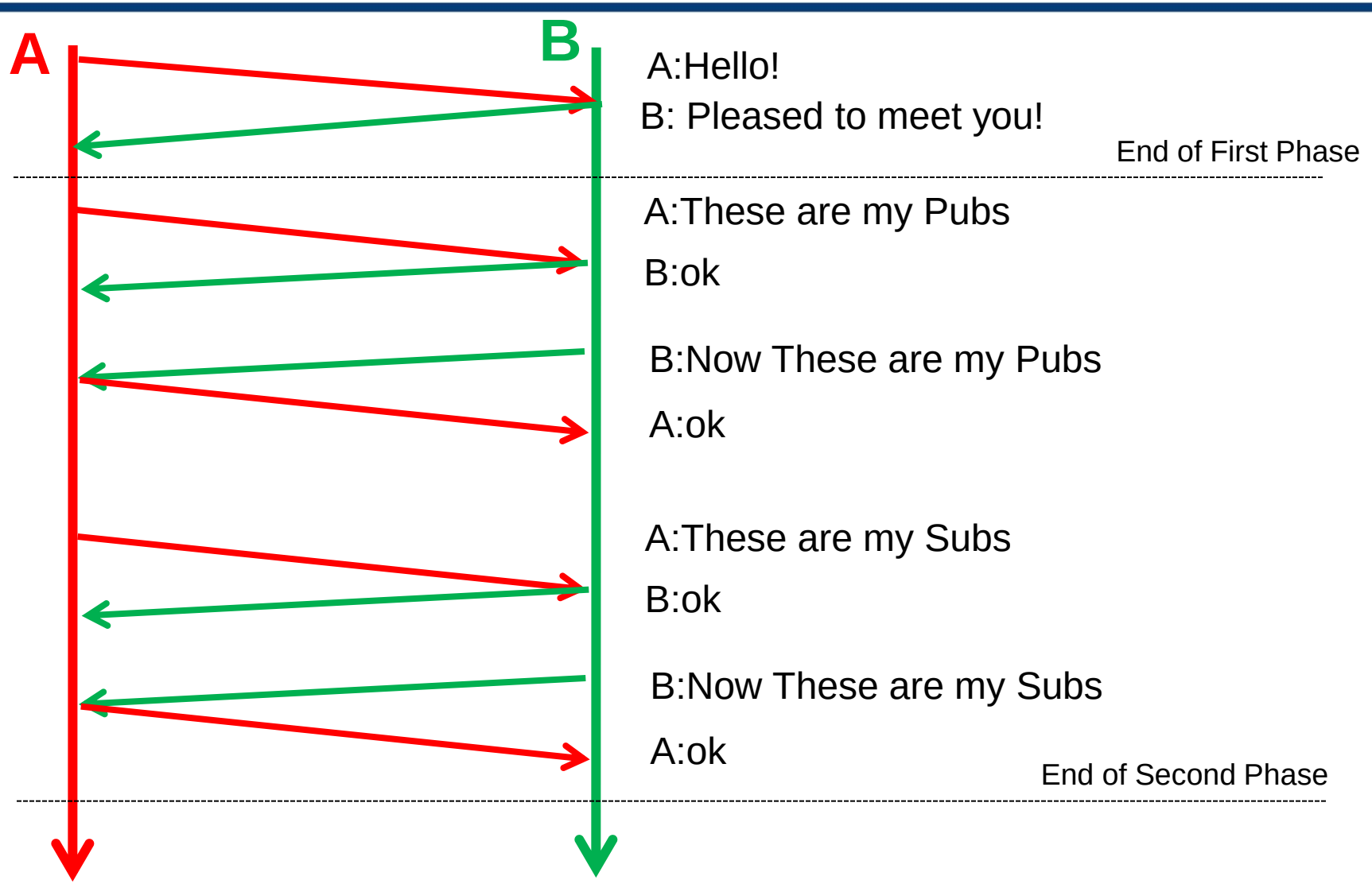
- Discovery is implemented using DDS entities known as Built-in Data Writers and Built-in Data Readers
  - Uses same infrastructure as user defined Data Writers/Data Readers
  - Participant data is sent best effort
  - Publication/subscription data is sent reliably

- Three Built-in topics (keyed):
  - DCPSParticipant
  - DCPSPublication
  - DCPSSubscription

Discovery Entities



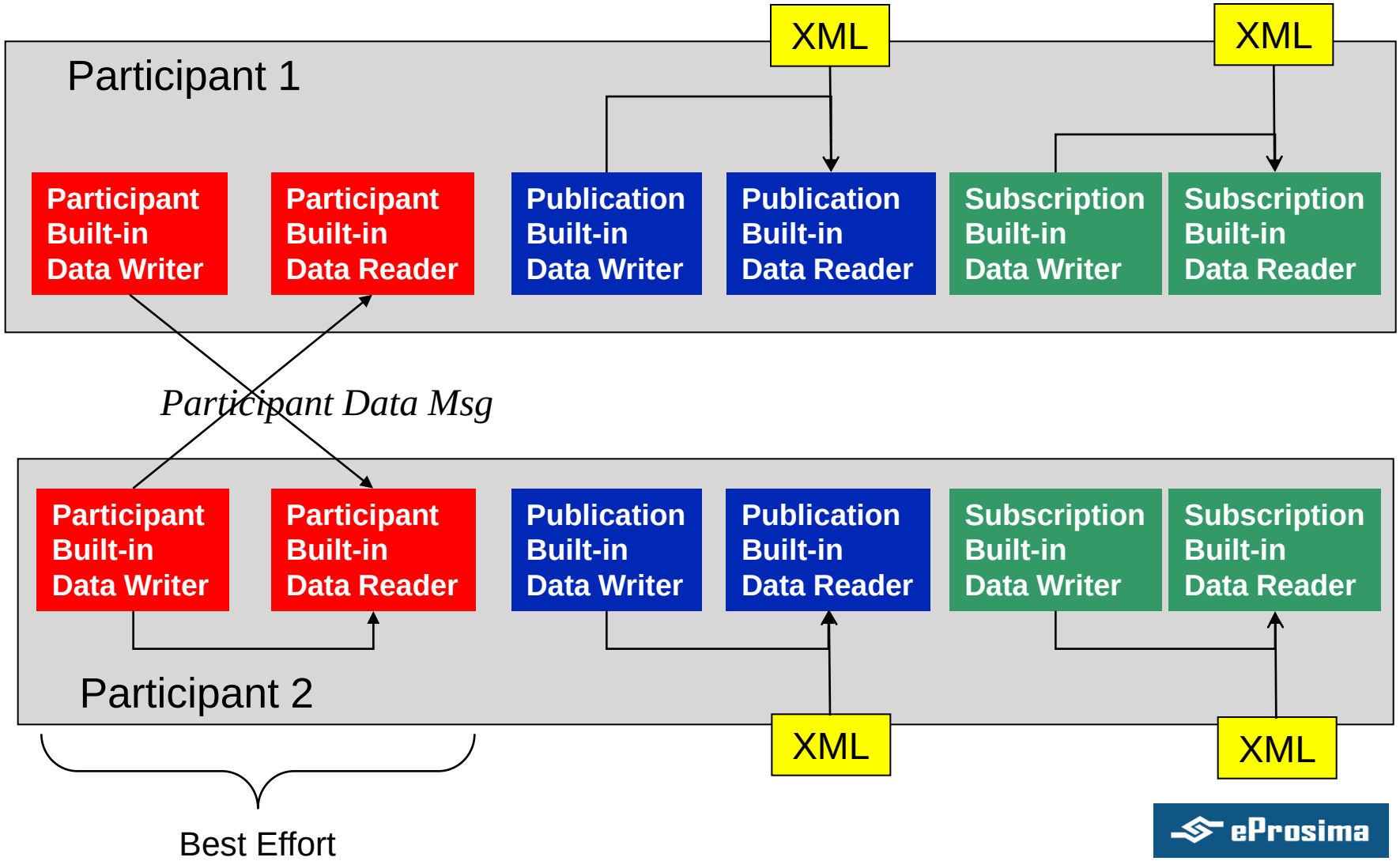
Discovery phases: Visually



Endpoints Discovery Optimization

- Goals:
  - Reduce the discovery information transmitted.
  - Reduce net traffic: Less Packets.
- Scenario:
  - We now most details of the participant applications in advance.
- Solution:
  - Suppress second discovery phase.
  - Information about endpoints stored in XML files.

Endpoints Discovery Optimization



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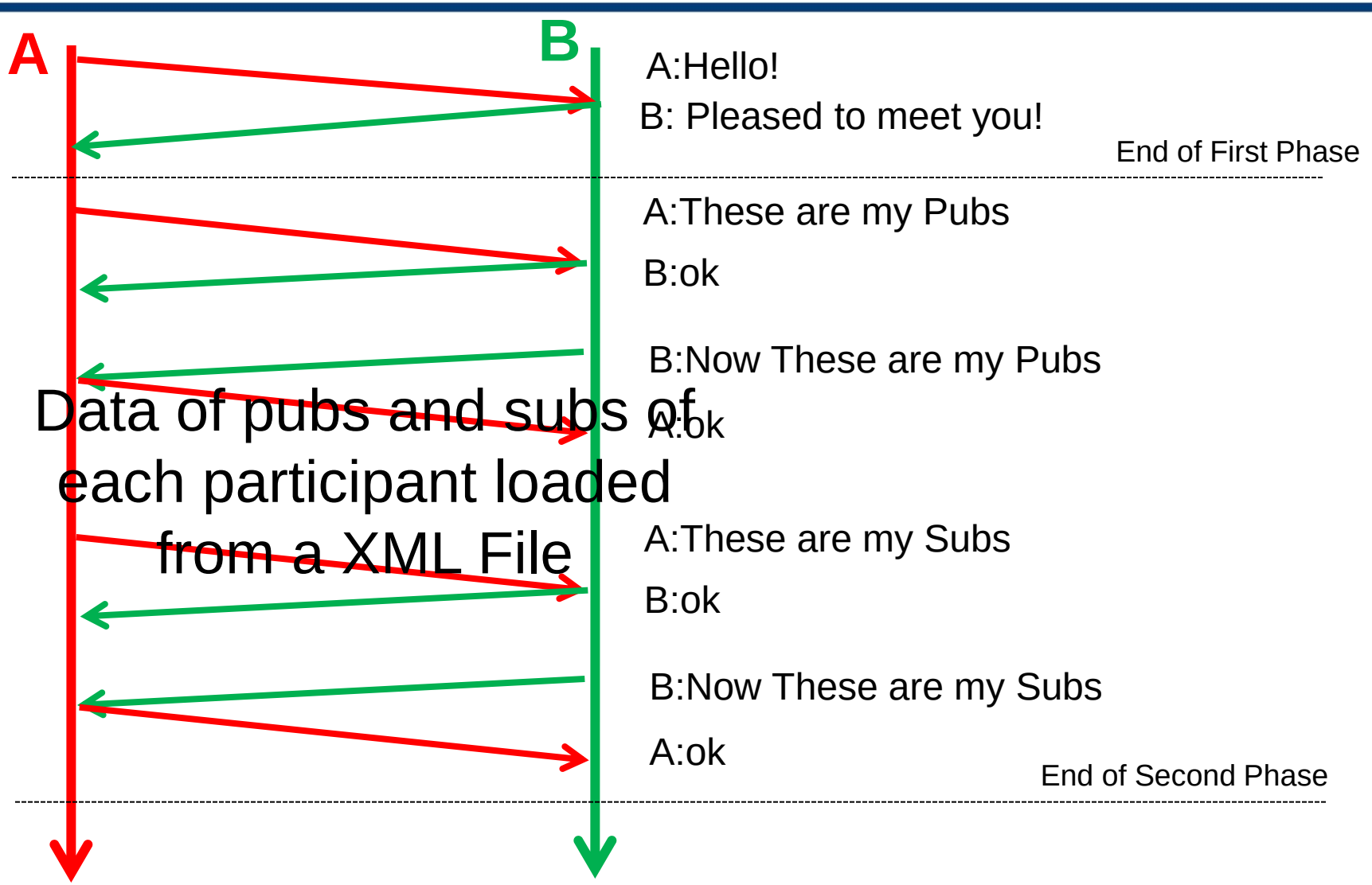
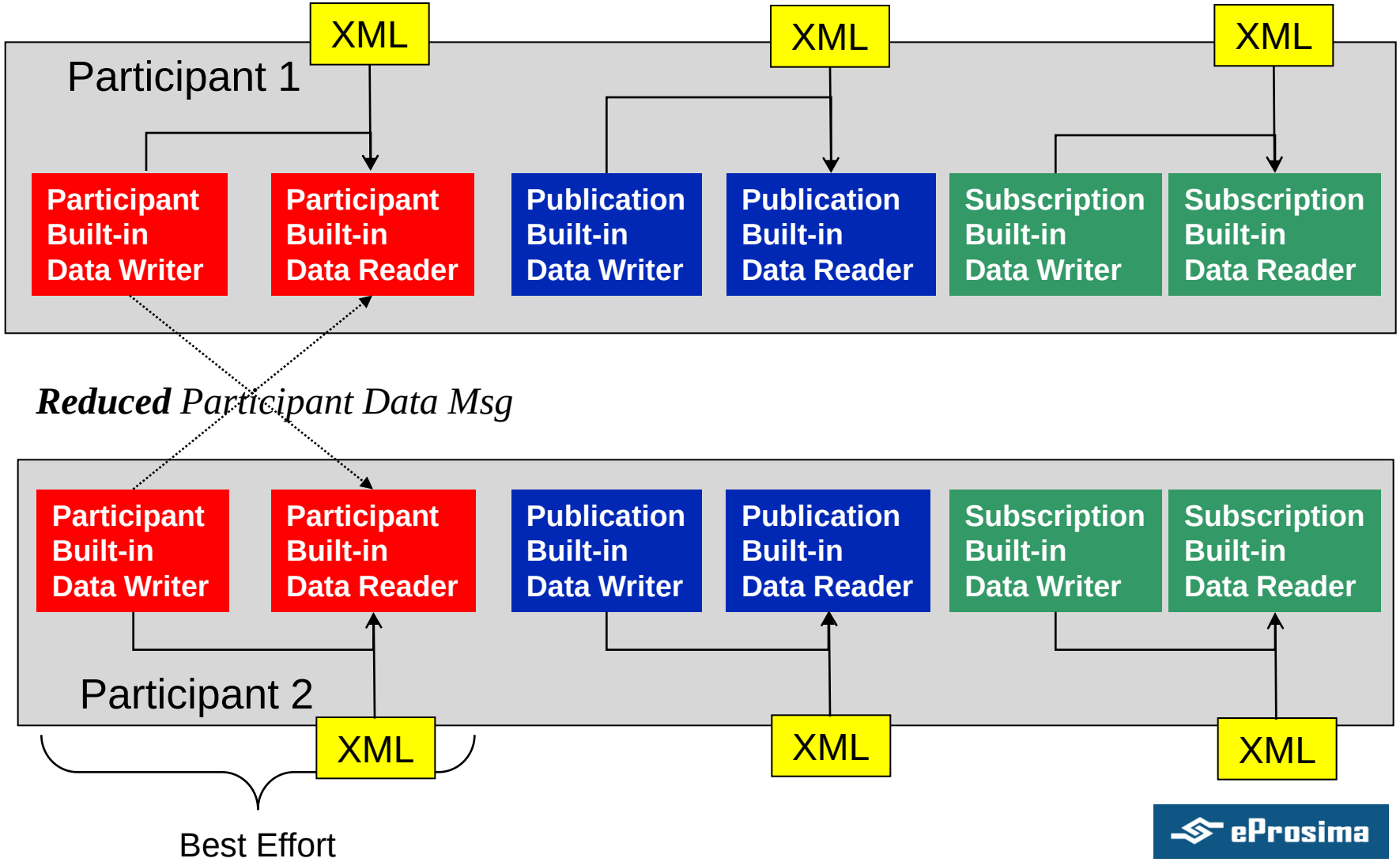
File Based Discovery



Participant Discovery Optimization

- Goals:
  - Reduce even more the discovery information transmitted.
- Scenario:
  - We now most details of the participant applications in advance.
- Solution:
  - Reduce the participant information transmitted.
  - Information about participants stored in XML files.

LBPDP: Discovery Entities



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Results

- Number of messages = O(number of nodes)
- Very small message payload, 100-150 bytes
- Very low discovery times.

Data Compression Optimization details

DDS in Low Bandwidth Enviroments

Compression details

- Compression at Transport Level
- Several compression libs used
- Several modes of operation

Compression at transport level

- Compression at Transport Level
  - Stackable: Use it in any transport: UDP, Serial, Ad hoc…

Several compression libs

- Several compression libs used:
  - ZLIB
  - BZIP2
- Easy to add more by the user.
  - Through Public API.
- Tested:
  - LZO : LZO1X, LZO1B & LZO1F
  - UCL : UCL_NRV2B, UCL_NRV2D & UCL_NRV2E

Several modes of operation

- Several modes of operation:
  - Fixed Algorithm
  - Algorithm depending on packet size.
  - Automatic: when CPU is not the bottleneck, the plugin select the best algorithm for each package.

RTPS Optimization Details

DDS in Low Bandwidth Enviroments

Optimized RTPS: Overview

- Optimized RTPS for low bandwidth scenarios
- Implemented as a transport.

Optimized RTPS

- RTPS Optimizations:
  - RTPS Header from 20 bytes to 1 byte.
  - RTPS SubmessageHeader from 4 to 3 byte.
  - RTPS extraflags for DATA and DATA_FRAG eliminated (1 byte)
  - ReaderID and WriterID from 4 to 1 byte each (so 2^3 writers or readers per participant)
  - SequenceNumber from 8 to 5 or less bytes (more than enough for these scenarios)
  - …
- Save more than 30 bytes!

eProsima LB RTPS: Implemented as a transport

- Implemented as a transport
- Stackable:
  - Can be used with any transport and it is stackable, so for example you could use:
  - LB RTPS -> UDP
  - **LB RTPS -> Compression Transport -> UDP**

About eProsima

About eProsima

- Experts on middleware, focused on DDS.
- OMG Members.
- RTI DDS Distributor for Spain and Portugal.

About eProsima: Products And Services

- eProsima Products:
  - DDS based: Plugins, add-ons, adaptors, etc
- Services:
  - Communication modules, App development, DDS training, Support.
- R&D:
  - R&D Projects with enterprises and universities.
- Quality: ISO 9001
  - Design, Development, Marketing and Support of Software.

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Customers (I)

- **Amper Programas:**
  - BMS
  - Simacet (Main Spanish C2 System)
- **Cassidian**:
  - UAVs - Neuron, Atlante
    - Ground Station Comm Server
- **INDRA**:
  - Defense (BMS, UAV PASI)
  - Air Traffic Control,
  - SESAR, ATC Interoperability
- **Spanish Army**:,
  - IDT :Tactical Data Interface

Customers (II)

- Isdefe
- Spanish Army: JCISAT, DGAM
- CATEC-FADA: R&D Aerospatial
- Santa Barbara: Armoured Vehicles
- RTI
- GMV

Customers (III)

- Tecnobit: COSMOS, Reserved Projects.
- IKERLAN: R&D.
- Navantia: F105 (Aegis)
- Boeing: Atlantida, Swim suit

eProsima Products.- Index

- **eProsima Low Bandwidth Tools for DDS**:
  - Set of plugins to enable DDS communications over low bandwidth links, optimizing the protocol and compressing the data.
  - Includes a simulation plugin to simulate different links such Tactical Radios and Satellites
- eProsima Client-Server:
  - RPC over DDS
- eProsima DDS-Web Services Bridge
  - Enables DDS Enterprise Integration
- eProsima DDS Non-Intrusive Recorder.
  - Stores DDS communication history in a data base.

Thank you!

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