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CdS Laurea Magistrale (MSc) in
Computer Science Engineering

Mobile Systems M course (8 ECTS)
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08 – Support to Mobile Messaging and Event Management

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Decoupled Communications: Messaging

As already stated, ***relevance of decoupling*** in communication and interaction among mobile distributed components

Sometimes ***message exchange*** is even used as the general term to indicate the primary type of ***mobile communication middleware*** (see *S. Tarkoma, "Mobile Middleware"*) to highlight the importance of decoupling

Any mobile messaging solution must define:

- Principles and architecture
- Message ***syntax***
- ***Protocol*** for message exchange
- ***Locator***

Sometimes protocol term is used to include also syntax and locator…

Messaging: Principles and Architecture

Primary principle: ***loose coupling*** (via ***standard and open protocols/formats***)

In real systems, also ***extensibility***. How to?

- ***Version identifiers included in messages*** (non-recognized versions are considered as errors; back-compatibility?)
- ***Formats with extension points***
- ***Forward compatibility with possibility to ignore*** message parts that are not recognized (example of application of *robustness principle*)

Usually ***middleware APIs*** to allow applications to use communication facilities; sometimes ***middleware with visibility*** of requirements for data exchange and their semantics

Marshalling/unmarshalling management:

- ***Implemented at the application level***
- ***Code may be automatically generated*** (typically based on approaches like Interface Description Language – IDL – which is considered at development time)
- ***Introspection*** (higher expressive power for developers but typically more expensive at runtime)

How to agree on data format?

- ***Specification*** (usual approach of Internet protocols with messages in binary format)
- ***Negotiation***
- ***Receiver-makes-right*** (sender uses its native formats and specifies metadata to indicate which formats are used)

Primary types of message formats:

- Binary (ASN.1, …) or text-based (XML, JSON, …)

Messaging: Protocols

In addition to the usual protocol properties for communication in distributed systems (headers with metadata and payload, also application-layer metadata, message types and with which exchange patterns, …), special accent on ***connection management***

- Protocols that "mimic" transport layer, with application-level connection in 1:1 relationship with transport-level connection
- ***More often protocols that decouple the two aspects*** (***persistent session feature over multiple and temporary transport connections***; see TCP and change of dynamic IP address, or SIP…)

«Pure» end-to-end perspective or usage of mediators up to the application level?

Wide usage of ***store-and-forward architectures and protocols*** (decoupling in time, optimization of implementations for reliability, violation of end-to-end principle)

Messaging: Protocols

Classical schemes for message exchange: one-way, two-way, request-response, subscribe-notify, conversation, …

Relevant:

- Role at transport layer (***initiator-listener***), not necessarily the same as for the application/messaging levels
- Usual distinction ***blocking vs. non-blocking***
  - ***Polling method***, usually with object (***promise or future***) given to the sender; possible to make either inspect or blocking claim
  - ***Callback***

Which of the two schemes facilitates more the development of mobile applications and/or for mobile systems?

Messaging: Locator

We are used to ***locators strongly tightened to network addresses***

But also locators more articulated and complex, e.g., which include port numbers (transport) or paths (URLs)

In mobile systems ***many types of locators***, also non IP-based, in particular in the past when IP was not so dominant

Anyway, even nowadays, possibility of:

- ***“Transparent” locators***, typically implemented as URIs and codified in XML (it increases the level of abstraction + decoupling)
- ***“Opaque” locators***, as in CORBA. Need of middleware to generate and use opaque locators

Is mobility management a network-layer issue? Of course, given what we have already widely discussed in the course, NOT ONLY…

Often it is written that *mobile hosts are managed as second-class citizens*; ***towards locators independent from network layer***…

Messaging: Design for Mobility

Usual general considerations on:

- ***Valuable role of proxies,*** e.g., to split transport connections in two parts (breaking the end-to-end principle)
- ***Problems of Network Address Translation*** (NAT) when mobile nodes are willing to offer services (see also FTP and IRC…)

In addition:

- ***Ability to complete the scheme of message exchange*** even if communicating entities move
- Exploitation of classic transport-level connections is usually preferred
- ***Simple syntax and reduced message content***, also considering compression facilities
- ***Security at message level***: with SSL-like approaches (connection-level security), which kind of issues if end-to-end principle is broken? ***Message-level security with security applied to (parts of) the payload, not to headers***; of course, also combination of connection and message

Messaging: Reliability

As usual:

- Distinction between ***end-to-end and hop-by-hop***
- Basic technique with ***acknowledgement and re-transmissions*** (also at the application level)

ACK types:

- Regular
- Cumulative
- Negative
- Piggy-backed

In-order delivery? Sometimes it can be sacrificed for efficiency motivations

Indeed, reliability reduction due to performance motivations is a well-known concept (DNS, NTP, SIP, … typically use UDP)

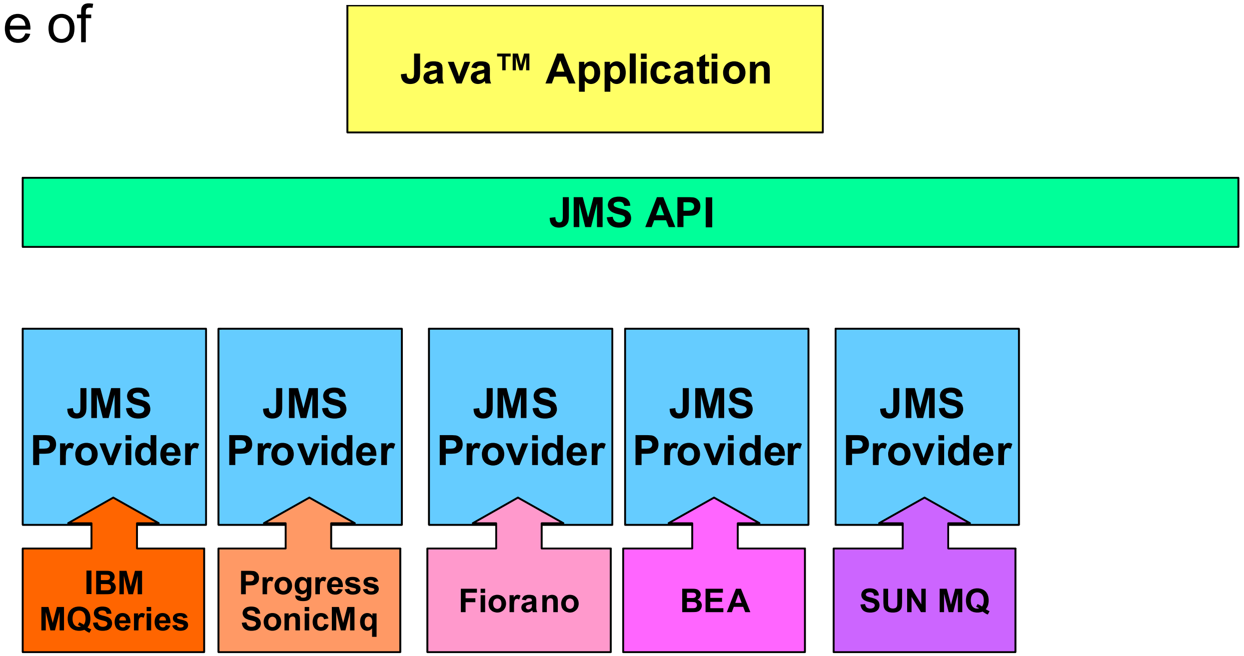
Messaging Examples: Java Message Service (JMS)

- Possibility to ask for ***only-once semantics for message delivery*** (more precisely once-and-only-once for persistent usage, at-most-once for non-persistent usage)
- ***Decoupling in time thanks to durable destinations***
- Partial time coupling for topics: it can be reduced via ***durable subscriptions***
- Possibility of ***non-blocking reception via listeners***
- Usage of ***ConnectionFactory***
- Messages sent within a session (via a given Session object) towards the same destination ***benefit from in-order delivery property***
- ***Three types of ACK*** (lazy, automatic, and client-side)

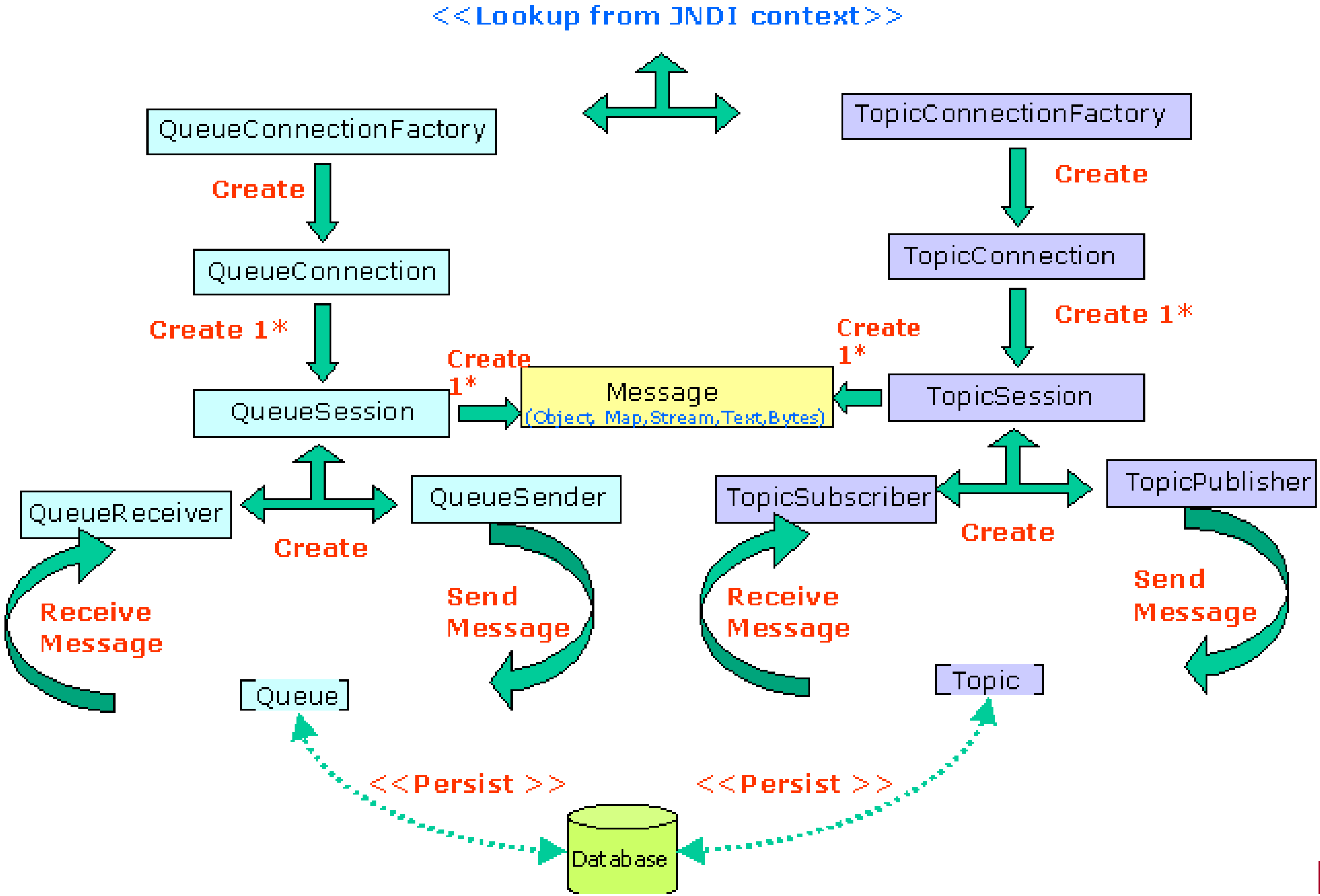
Design Goals in JMS

JMS is part of the J2EE platform. Goals:

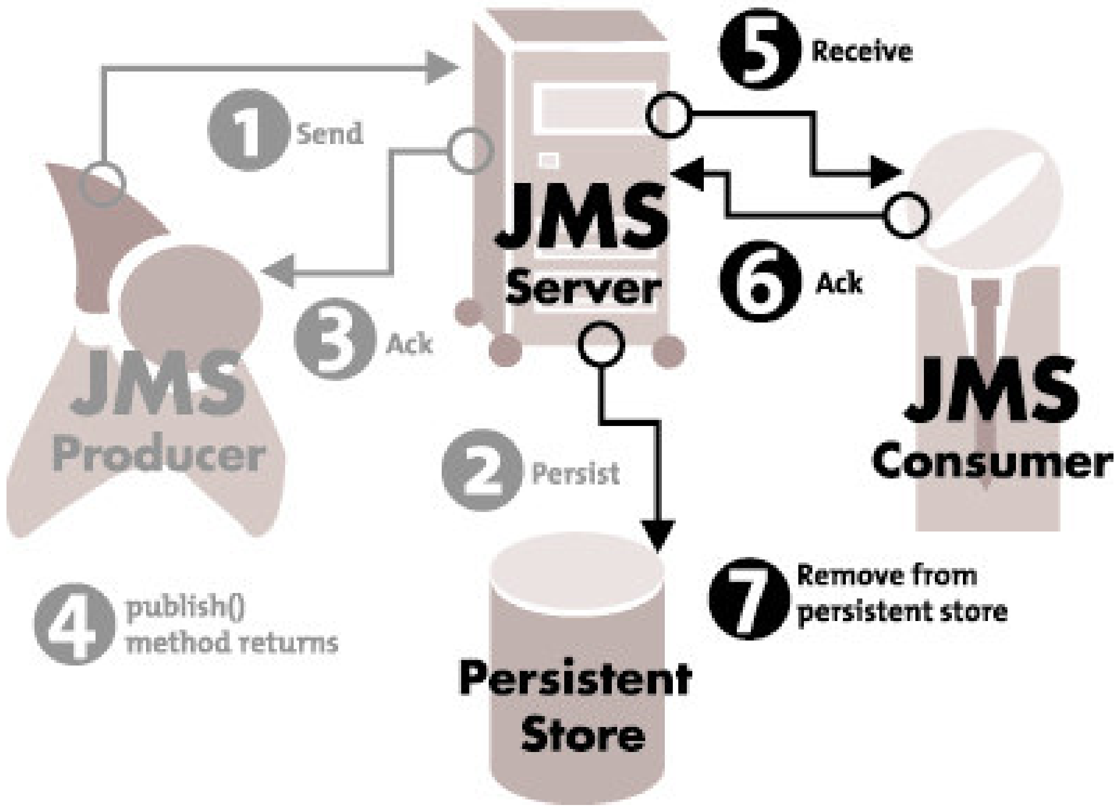
- ***Compliance/similarity*** with APIs of ***existing messaging systems***
- ***Independency*** from vendors of messaging systems
- Coverage of most common facilities that are offered in messaging systems
- It promotes the usage of Java technology



“Graphical Summary” of JMS APIs



Reliability through ACKs: e.g., Automatic ACKs



- ***Producer-side and consumer-side*** perspectives
- Differences between ***persistent and non-persistent cases***
- When is it possible to have ***duplicated messages***?
- When is it possible to have ***message losses***?

- In addition, ***three differentiated types of ack***

Persistency: Two Delivery Modes

- ***PERSISTENT***
  - Default
  - It specifies to ***JMS provider to guarantee*** that the message ***is not lost when in transit***, e.g., because of a failure at the JMS provider
- ***NON_PERSISTENT***
  - ***It does NOT request storing messages*** at the JMS provider side
  - Better performance results

SetDeliveryMode() method in the MessageProducer interface

- **`producer.setDeliveryMode(DeliveryMode.NON_PERSISTENT);`**
- ***Extended form***: **`producer.send(message, DeliveryMode.NON_PERSISTENT, 3,10000);`**

Priority and Expiration in Message Delivery

- 10 priority levels
  - from 0 (lowest) to 9 (highest)
  - default = 4

Usage of setPriority() method of MessageProducer interface, e.g., `producer.setPriority(7);`

or the extended form `producer.send(message, DeliveryMode. NON_PERSISTENT, 7, 10000);`

- Expiration: possibility to ***configure TTL*** via setTimeToLive() of the MessageProducer interface
  - `producer.setTimeToLive(60000);`
  - Or extended form, `producer.send(message, DeliveryMode.NON_PERSISTENT, 3, 60000);`

Messaging Examples: CORBA Messaging

CORBA Messaging specification includes:

- Asynchronous Messaging Interface (AMI)
  - Possibility of both ***polling and callback*** (callback is passed as CORBA object, therefore even not in the same addressing space of client)
- Time Independent Invocation (TII) to specify which CORBA objects play the ***role of router*** for the message
  - Rationale: sender and recipient may be temporarily disconnected
  - They compose a ***store-and-forward network***

CORBA locator = Interoperable Object Reference (IOR), with different profiles depending on binding protocol

Messages in binary format = Common Data Representation (CDR)

Extreme flexibility in the choice of the protocol

CORBA AMI: Callback Mode

Callback: client provides callback method to be invoked by the support after service completion via a given ***fire-and-forget (automatically invoked)***

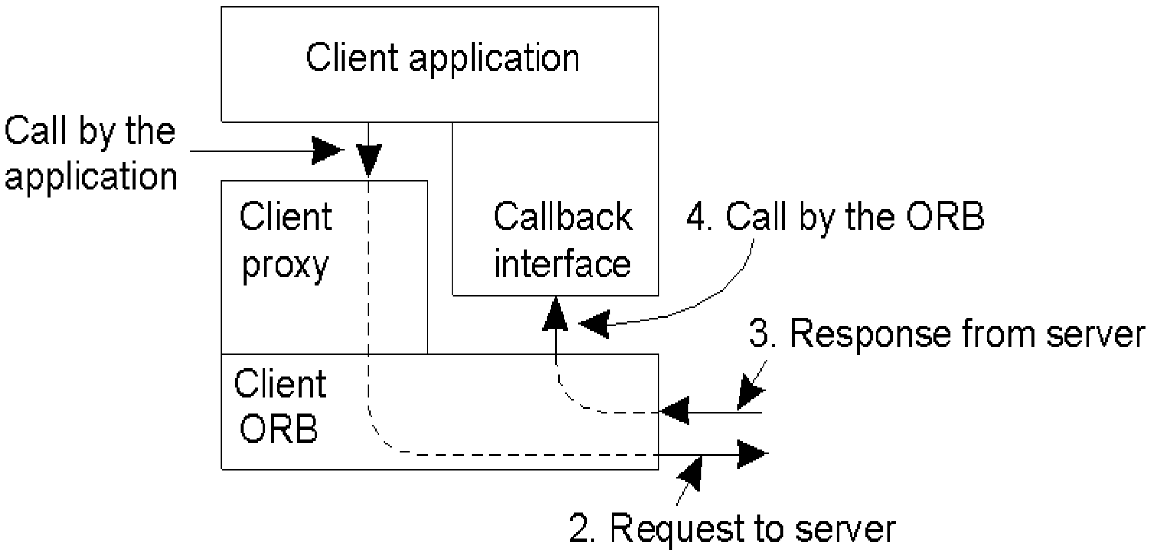
In place of: `int somma (in int i, in int j, out int somma)`

```
void  sendcallback_somma (in int i, in int j)
void  callback_somma (in int success, in int somma)
```

Usage of two methods by changing ***only client implementation*** *and* ***NOT any service part***

Client invokes **sendcallb…**

ORB invokes **callback_som…**



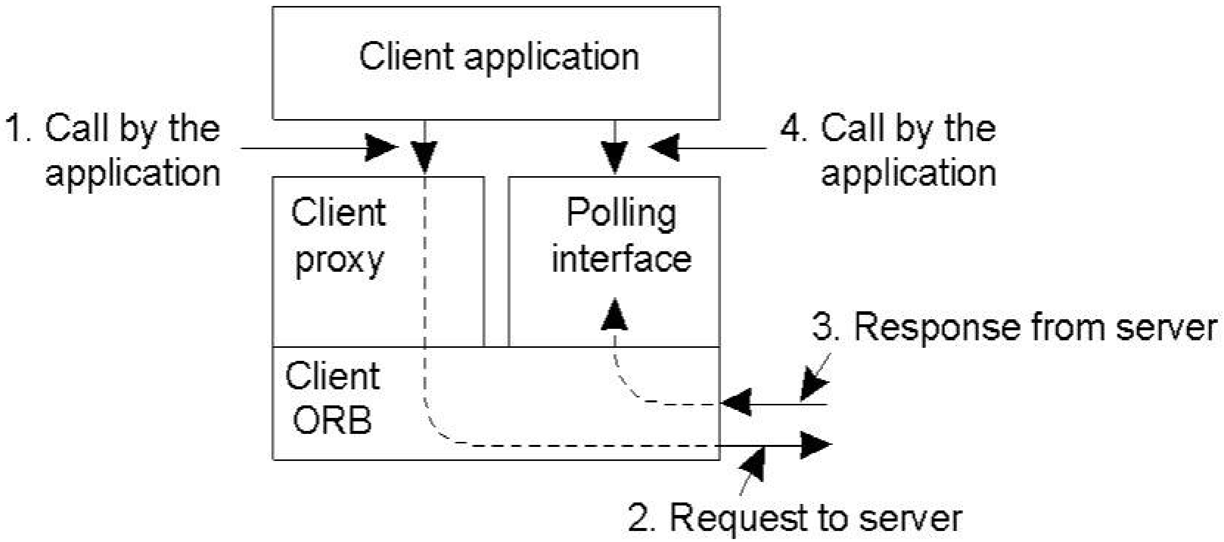
CORBA AMI: Polling Mode

Asynchronous polling: client decides ***when and whether*** to interrogate a method to check completion of remote operation (by collecting results); this method is ***created by the messaging support***

In place of: `int  somma (in int i, in int j, out int somma)`

```
void  sendpoll_somma (in int i, in int j)
void  pollsomma (out int success, out int somma)
```

Result is collected on request by invoking ***pollsomma operation that is autom. generated by CORBA support***



Messaging Examples: Extensible Messaging and Presence Protocol (XMPP)

Essentially designed for instant messaging

RFC 3920 is oriented and similar to the existing implementation of the Jabber protocol; good popularity and widespread utilization thanks to the adoption by *Google, Twitter, Facebook*, …

It includes ***publish/subscribe mechanisms*** (see the following slides…) ***to update presence and state, and for service discovery***

Client-server model: client sends an XMPP dataflow to a server, after parameter negotiation

Peer-to-peer model: servers coordinate together for delivery to recipients

Usage of so-called ***stanzas***, of three types:

- *Message stanza* – one-to-one communication, similar to emails
- *Presence stanza* – simple pub/sub mechanism, communication is transferred to all subscribers
- *Info/Query stanza* –request-response mechanism

Messaging Examples: Extensible Messaging and Presence Protocol (XMPP)

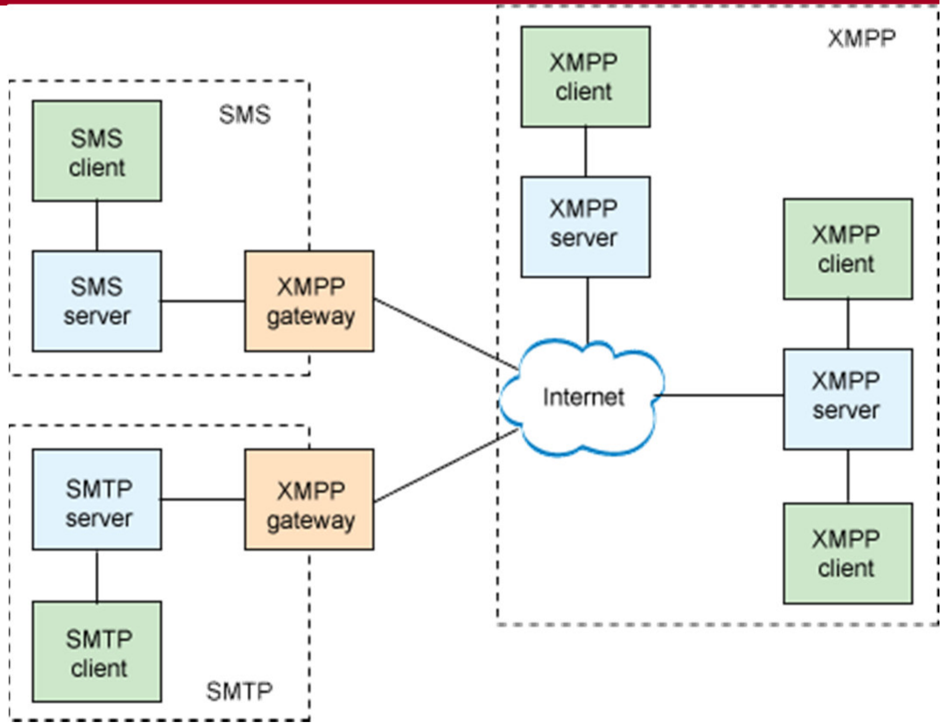
XMPP messages are streams codified in XML

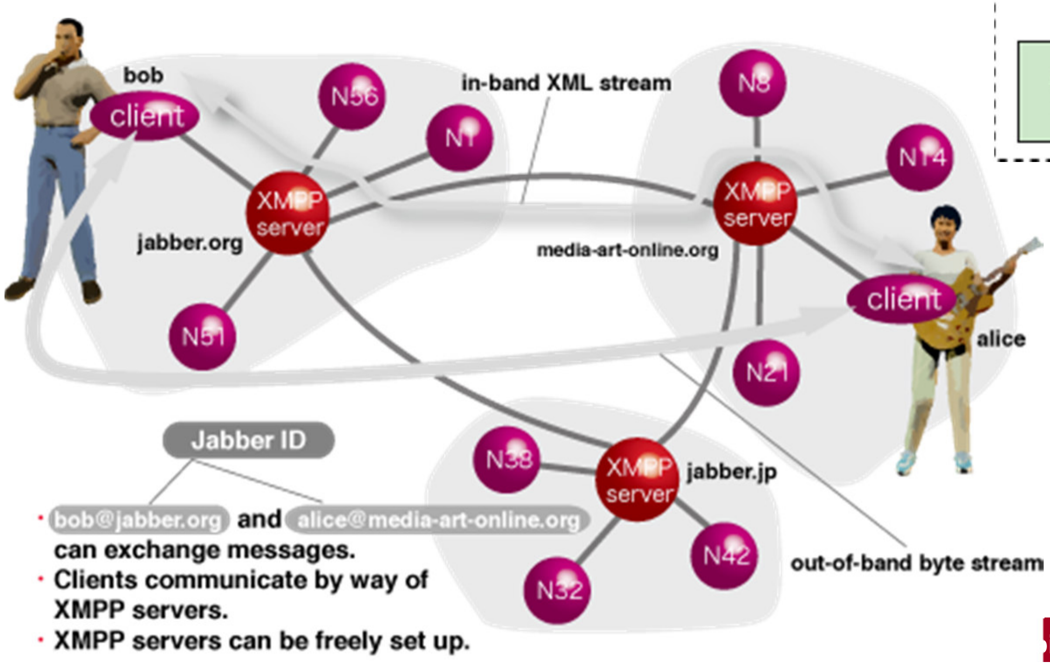
Given the widespread adoption, good candidate to support messaging in mobile systems, EVEN IF:

- Not specifically designed for mobile systems
- Expensive XML processing, expensive connection management in particular in terms of energy
- ***Expensive re-connections to XMPP server*** (need to re-establish a **new session of interaction per any new transport connection**, transmission of XML data that is non-negligible at each session start)

Android implements a specialized and proprietary variant of it, with non-XML-based protocol and NO creation of a new session per any new connection

Messaging Examples: Extensible Messaging and Presence Protocol (XMPP)





Messaging Examples: Web Services

SOAP is built on top of interaction model based on message exchange

- Architecture based on senders, receivers, and intermediate nodes
- Locator = HTTP URI
- ***Document-style SOAP***: ***messages as XML-based documents*** that have to be processed
- Possibility of ***different protocol bindings***, but definitely the most used one is HTTP, utilization of POST method (employed more as transport protocol, while ignoring its application semantics)
- In mobile environments, where HTTP is sometimes the only protocol practically usable because of firewalls and NAT, this use/misuse of HTTP could be considered as legitimate and become largely adopted…
- ***Also specification for binding to email and XMPP***

Messaging Examples: Representational State Transfer (REST)

REST is substantially a ***solution architectural style***, *Resource Oriented Architecture* (Roy Fielding, UCI PhD Thesis, 2000)

To promote ***client-server and stateless interaction, oriented to the usage of caching opportunities***, also with possibility of code-on-demand to clients

Any resource has a persistent identifier; idea to transfer NOT resources but their representations via HTTP protocol

Constraint: exchange of self-descriptive messages (languages for representation, negotiation of supported modes, …)

Messaging Examples: Representational State Transfer (REST)

Locator = HTTP URI

Three types of metadata included in HTTP headers:

- ***Resource metadata*** – about resources, e.g., timestamp about last modification
- ***Representation metadata*** – about transferred representation, e.g., its media type
- ***Control metadata*** – about message, e.g., its length and caching possibility

Notable example: ***RESTful Web services***

RESTful Web service as a simple Web service implemented by using HTTP and REST principles, thus resource collection with 3 well-defined aspects:

- ***URI base for service***, e.g., http://example.com/resources/
- ***Internet media type*** for data used in the service (usually JSON or XML)
- Set of service operations supported ***via HTTP*** method invocations (e.g., via POST, GET, PUT or DELETE)

Messaging Examples: Representational State Transfer (REST)

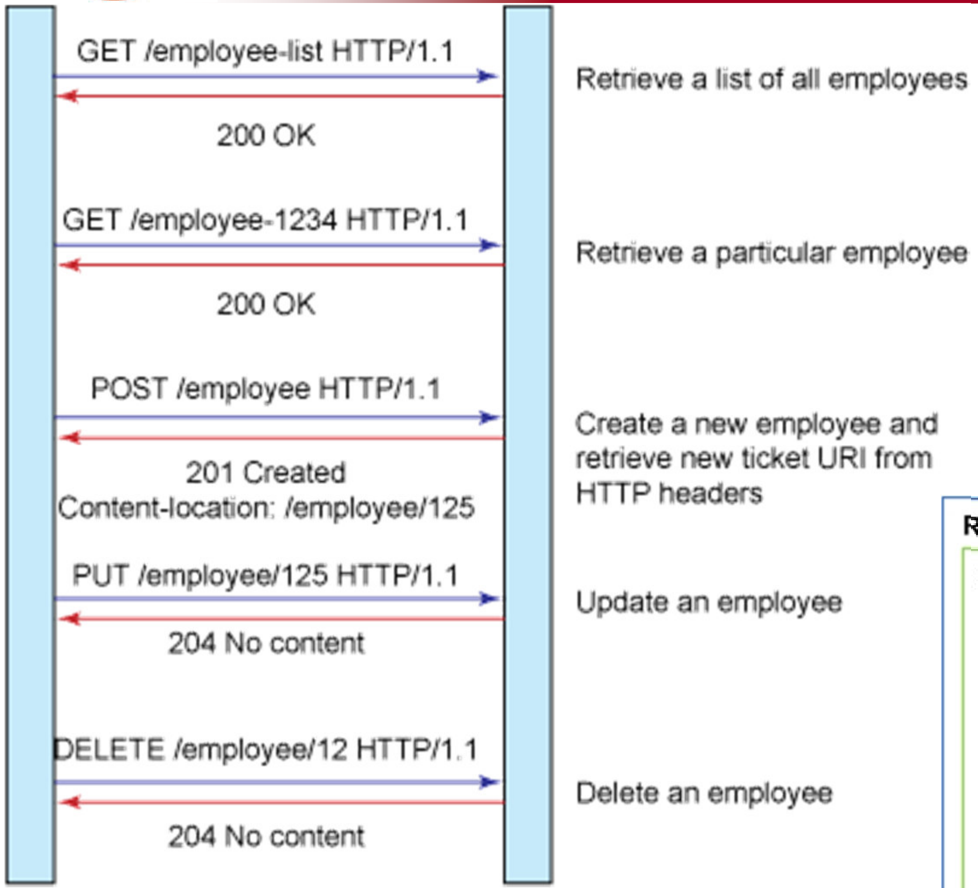
Notable example: ***RESTful Web services***

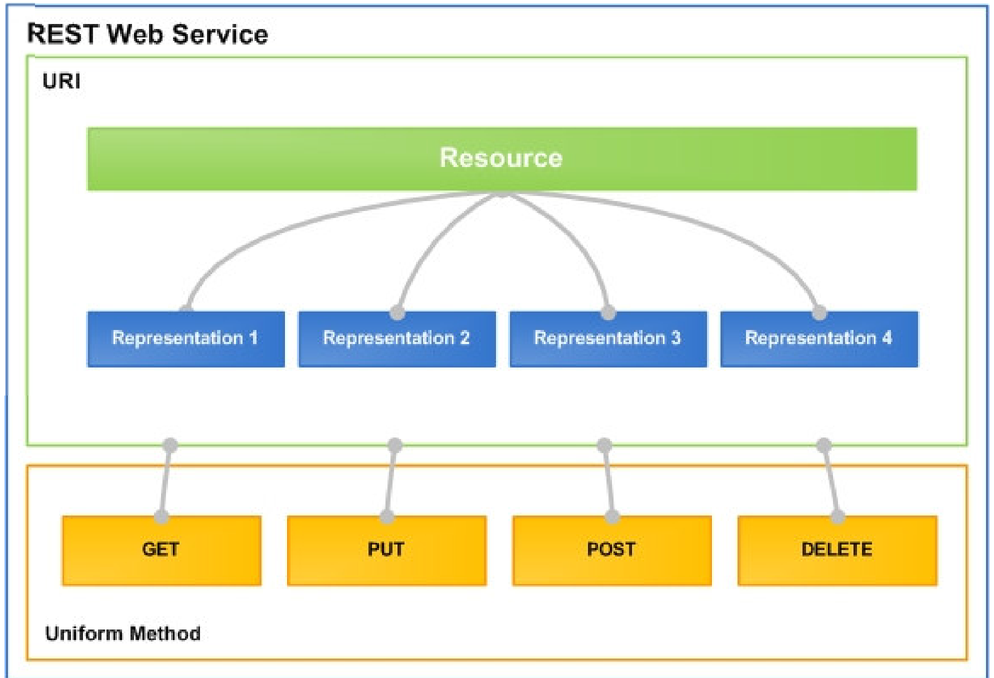
Risorsa	GET	PUT	POST	DELETE
URI for resource collection, e.g., http://example.com/resources/	To list all collection members	To replace the whole collection	To create a new element to be inserted in the collection	To remove the whole collection
URI for single element, e.g., http://example.com/resources/ef7d-xj36p	To obtain the representation of the targeted element, espressed in the appropriate Internet media type	To replace or create an element of the collection	To consider the element as a collection and to create a new element internally to it	To remove an element from the collection

Examples of today's REST usage:

- Majority of ***Web blogs*** (download of XML files in *RSS/Atom format*, which contain links to other resources)
- ***Simple Storage Service (S3)*** by Amazon.com
- ***OpenStreetMap*** (REST interface)… and many many others

Messaging Examples: Representational State Transfer (REST)

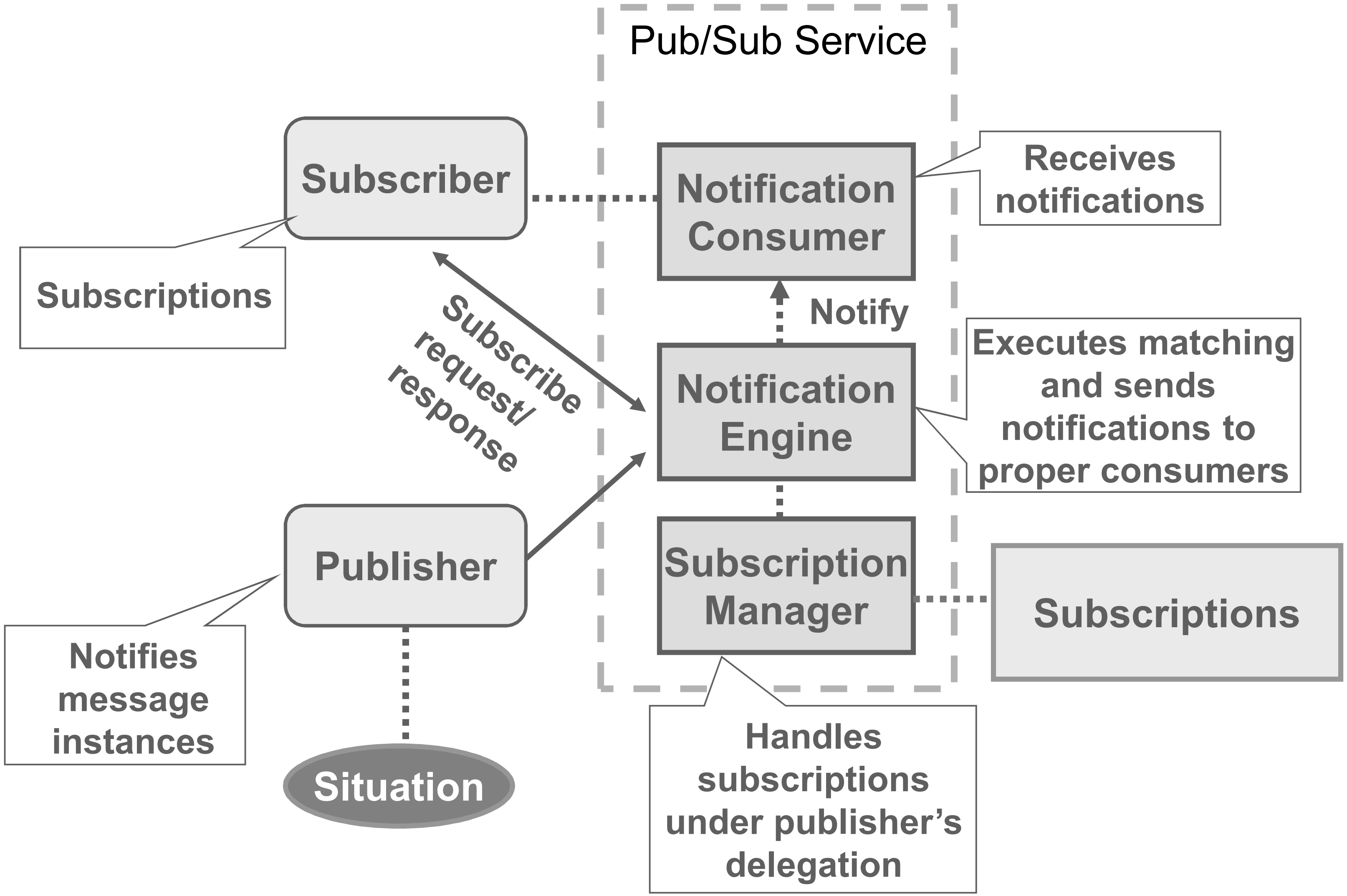




Event Management and Publish/Subscribe Systems

- ***Event delivery from publishers to subscribers***
  - Events as messages with content
  - ***One-to-many, many-to-many*** (traditional message systems are queue-based and one-to-one)
  - Often implemented based on ***messaging systems and on store-and-forward solutions***
- Comm. paradigm of frequent usage, in particular in mobile systems
  - ***Decoupling in space and time***
- Event system as ***logically centralized system***
  - Anonymous communication
  - Possibility to ***use filters*** (on headers or entire messages)
  - Basic primitives: subscribe, unsubscribe, publish, also with filters
- ***Different topologies for routing and different semantics*** associated to event sending/notification
- Associated operations are typically ***non-blocking*** (polling, callback)

General Architecture for Publish/Subscribe Systems



Event router or broker

- Works as mediator (decoupling) between publishers and subscribers
- Usage of ***routing table (also with filters)*** for local event dispatching or to indicate to which «near» router to forward in the case of distributed brokers (to achieve scalability, reliability, and high availability)
- ***Filters*** may be also based on ***content => content-based routing***
- Other non-functional requirements: notification within time deadlines (***bounded delivery time***), QoS, fault-tolerance, ordering (***causal order, total order***)

Possible router topologies:

- ***Centralized***
- ***Hierarchical*** (notifications always sent to master, i.e., root of the distribution tree)
- ***Cyclic, acyclic*** (peer-to-peer, cyclic allows redundancy but need of *minimum spanning tree techniques* to prevent from cycles)
- Based on ***rendez-vous point*** (special router that works as rendez-vous, typically for pre-determined types of events)

  Partially related: have you ever heard of ***Distributed Hash Tables (DHTs)***?

Interest Propagation and Subscriptions

One of the primary functions of a router is to ***propagate notifications to near routers that are interested*** in that event. To this purpose, how to propagate interests and subscriptions?

Properties to be achieved: reduced forwarding overhead, high performance, fast support to variations

- ***Simple routing***: any router knows all subscriptions in the global systems (subscription flooding), possibly with optimization of NO forwarding if subscription message has been already circulated
- ***Covering-based routing***: forwarding of only the more general subscription filters (*which possible issues with unsubscription?*)
- ***Merging-based routing***: it allows to merge different entries in routing table for the sake of table size optimization (usually combined with covering, here also unsubscription issues)

Notifications are usually distributed over ***reverse paths (wrt subscription paths)***

Decision about Message Routing

Depending on what is used to take message routing decisions, classification into:

- ***Channel/topic-based***: depending on the channel (usually named channel) on which the event is published. Pub/sub agreement on the channel name, also possibility of associated multicast address
- ***Subject-based***: depending on event subject, single field of info
- ***Header-based***: depending on a set of fields. For example, SOAP supports header-based routing for its messages
- ***Content-based***: possibly depending on the whole message content. Higher expressive power, higher costs

Also ***context+content-based routing***, particularly suitable for mobile systems/services with ***event filters that are context-dependent***

Java Model for Distributed Events

Also Java has a built-in ***model for event distribution, based on RMI***, e.g., used in Jini/River

- Based on ***Remote Event Listener*** (consumers are registered to receive given types of events from given objects, **`notify()`** method)
- ***Remote Event object returned back during notification*** (data, reference to source object, handback object, unique identifier)
- ***Lease mechanism***
- The specification includes possibility to define ***Distributed Event Adaptors that implement filters and QoS policies***
  - Idea to exploit handback object, returned by the event source, to transfer state and behavior (e.g., to implement event filters)

Java Model for Distributed Events

```
package net.jini.core.event;

public class RemoteEvent {
    public long getID();
    public long getSequenceNumber();
    public java.rmi.MarshalledObject getRegistrationObject();
}
```

Events generated in local components may transfer even quite complex object state. ***NOT distributed events: only info on how state retrieval is possible at runtime***

- Remote event as serializable object that can be transferred between listeners
- Idea, “stolen” from Xt Intrinsics and Motif solutions: ***to register clients by including handback objects, returned back with any event***

For example, a Jini taxi driver subscribes to taxi bookings while passing through a city area (handback includes location); when it receives an event, it can be informed of old location (at the moment of registration)

Possibility to register other objects for notification delegation: in this case, handback can work as “reminder” with info of subscribers *(stock broker model)*

Event registration

Jini/River does NOT specify how to register listeners at event sources; only specification to use a class as return value from subscription:

```
package net.jini.core.event;
import net.jini.core.lease.Lease;

public class EventRegistration implements java.io.Serializable {
    public EventRegistration(long eventID, Object source,
                             Lease lease, long seqNum);
    public long getID();
    public Object getSource();
    public Lease getLease();
    public long getSequenceNumber();
}
```

Therefore, the developer of event source has to implement:

```
public EventRegistration
   addRemoteEventListener(RemoteEventListener listener);
```

Java Model for Distributed Events

Java model for local events work with objects that are all in the same addressing space

Jini as community of distributed objects that cooperate through ***proxies***

For remote events, “*inversion of proxy direction*”

- For example, ***Jini client uses its proxy for service access and through it registers itself as listener***
  - Need for a proxy method to ***add event listeners***
- Proxy will invoke the “real” method for listener adding over the discovered resource
- Invocation of ***registration of local event to proxy***; invocation of proxy for remote resource registration

As if real resource ***obtains a proxy for the client to use in the notification chain***

OMG Distributed Data Service (DDS)

- ***OMG specification*** (neither based on CORBA nor highly interoperable) for ***data distribution service designed for real-time systems***
- Specification defines ***APIs for so-called publish/subscribe data-centric communication***; in other terms, DDS middleware offers abstraction of global data space that is accessible to all interested applications
- Usage of ***combination of Topic objects and keys*** to univocally identify ***instances within a datastream*** of the same topic
- ***Support to content filtering and QoS negotiation***
- Suitable for distributed propagation of signals, data, and events

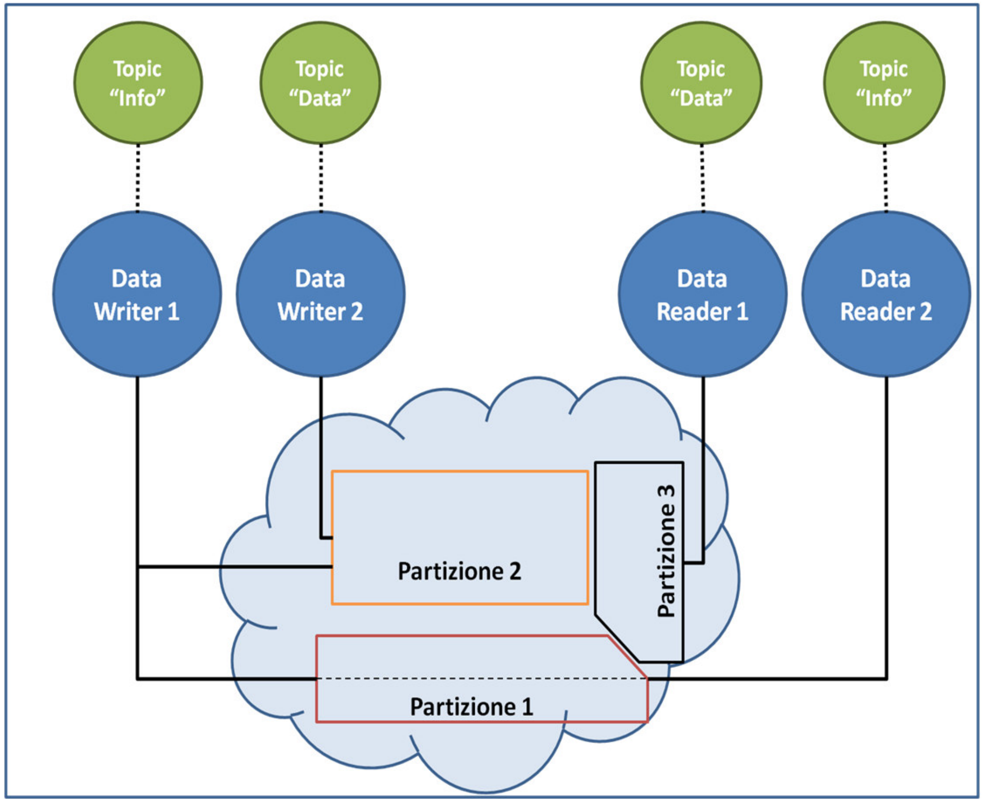
CORBA Event Service (NOT data-centric and with NO QoS support);

CORBA Notification Service (filters, QoS, but mandatory usage of CDR and IIOP)

Content Subscription: DDS Partitions

Partitions are namespaces to allow the ***logical splitting of a DDS domain***

Publisher/Subscribers can decide ***at runtime*** (and NOT at instantiation time as for JMS Topics) on which partitions to publish/subscribe data

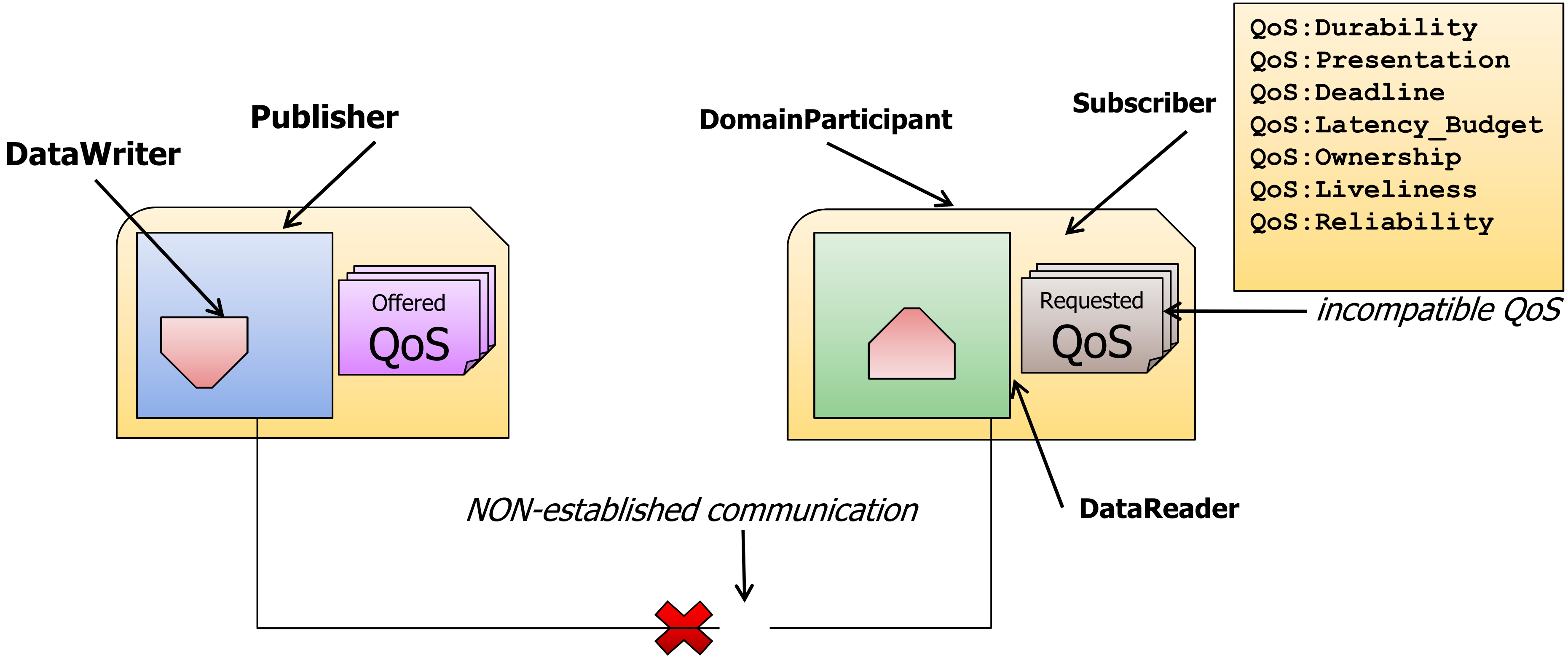


For a DataReader to receive messages from a DataWriter, there is the need to share ***both the same Topic and the same partition***

Partitions are considered to enforce a QoS policy

QoS Negotiation in DDS

- To allow a Subscriber receiving publications from a Publisher, ***QoS properties have to be compatible***
- Protocol of ***Request/Offer negotiation***



DDS supports different modes for message sending (e.g., best-effort, reliable) and personalized management of data persistence

Quality as Reliability

DDS identifies ***two QoS policies for message reliability***:

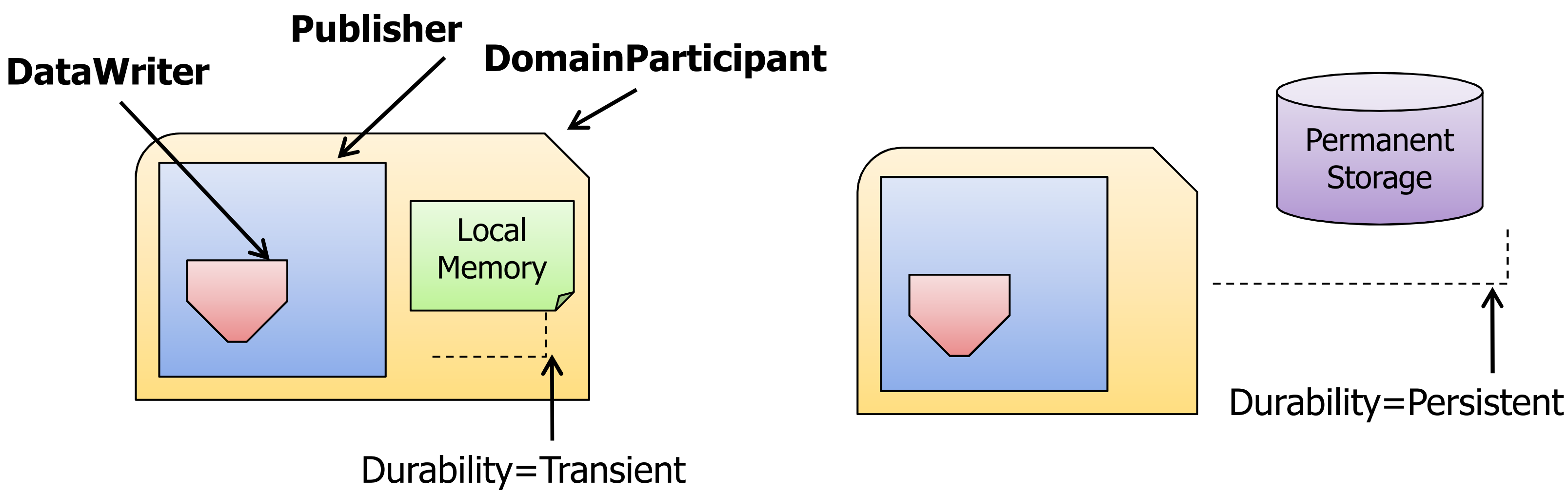
- ***BEST_EFFORT*** – ***NOT guaranteed*** that all messages are received, NOT guaranteed delivery order
- ***RELIABLE*** – guranteed that all messages are received and delivery order. Via Publishers that ***re-send*** data to Subscribers if needed and via Subscribers that send reception ***feedback (ack)***

In reliable case, all sent messages are ***kept in a history queue*** while waiting for being confirmed (publisher side) and processed by application (subscriber side); queue size can be defined, through ***HISTORY policy***

It is also possible to define ***how many resources*** (e.g., memory, max instances) to use to maintain data, through ***RESOURCE_LIMITS policy***

Quality as Durability

- Through ***Durability policy*** it is possible to define whether and how many data to be maintained at publisher side in order to enable their future successive request
- DDS supports 3 persistency types:
  - ***VOLATILE*** – No Instance History Saved
  - ***TRANSIENT*** – History Saved in Local Memory
  - ***PERSISTENT*** – History Saved in Permanent storage



DDS Quality: Additional Policies

DDS supports a wide set of other policies to define:

- ***Ordering of received messages*** (DESTINATION_ORDER - BY_RECEPTION_TIMESTAMP, BY_SOURCE_TIMESTAMP – ***eventual consistency, …***)
- ***Message priority*** (LATENCY_BUDGET)
- Exclusiveness on some given data types (OWNERSHIP)
- Data authentication and security (USER_DATA)
- ***Time constraints on message sending/delivery rates*** (TIME_BASED_FILTER)
- Fault detection and heartbeat (LIVELINESS)

More detailed technical documents at :

- Getting Started Guide
  www.rti.com/eval/rtidds44d/RTI_DDS_GettingStarted.pdf
- RTI DDS User's Manual
  www.dre.vanderbilt.edu/~mxiong/tmp/backup/RTI_DDS_UsersManual.pdf

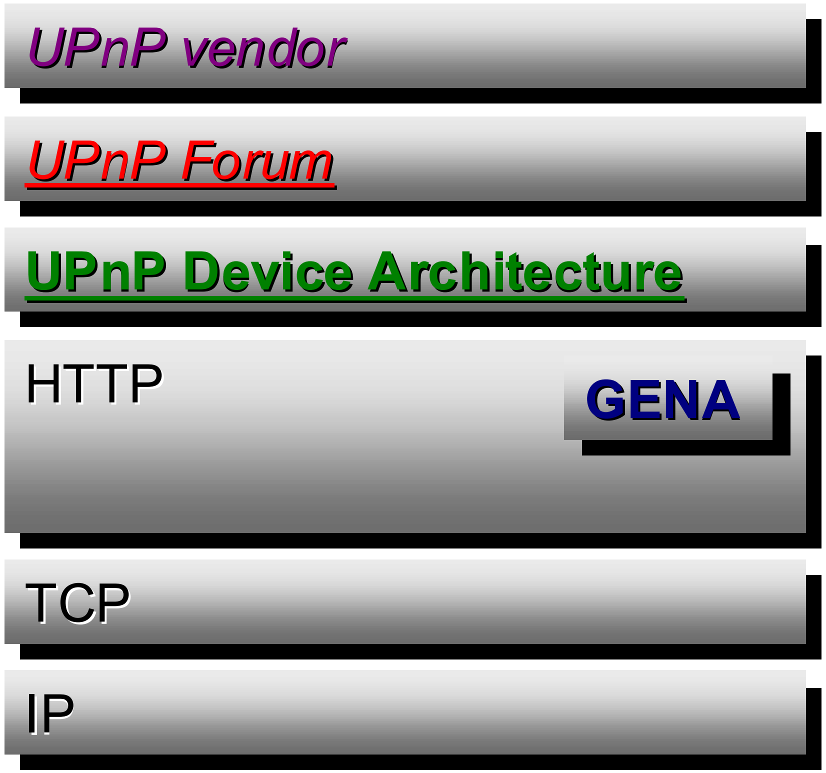
General Event Notification Architecture (GENA)

As already stated, used primarily in UPnP

- Control point is listener of modifications of device state
  - 0 obtains address
  - 1 discovers device
  - 2 determines XML descriptor
    - Obtains URL for eventing
  - 4 registers itself

Extreme simplicity:

Notification sending/reception via HTTP over TCP/IP or multicast UDP



GENA: Subscription

Control point has to register itself before being able to receive any event

SUBSCRIBE *publisher path* HTTP/1.1
HOST: *publisher host*:*publisher port*

CALLBACK: <*delivery URL*>
NT: **upnp:event**
TIMEOUT: Second-*requested subscription duration*

Device accepts subscription: it immediately sends a special event (initial) to control point with the value of all state variables

HTTP/1.1 200 OK
SID: uuid:*subscription-UUID*
TIMEOUT: Second-*actual subscription duration*

GENA: Notifications

When a state variable changes value at a device:

```
NOTIFY delivery path HTTP/1.1
HOST: delivery host:delivery port
CONTENT-TYPE: text/xml
 NT: upnp:event
 NTS: upnp:propchange
 SID: uuid:subscription-UUID
 SEQ: event key

 <e:propertyset xmlns:e="urn:schemas-upnp-org:event-1-0">
   <e:property>
     <variableName>new value</variableName>
   </e:property>
   Other (possible) names of variable and associated values
 </e:propertyset>
```

SIP Event Framework

Asynchronous notifications are essential to implement many SIP services (automated callback services, list of buddies who are currently online, message waiting services, ...)

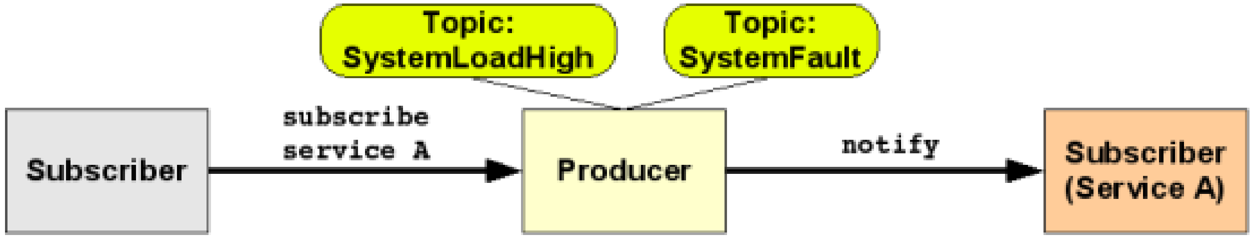
To this purpose, ***SIP Event Framework*** (RFC 3265), based on SUBSCRIBE and NOTIFY methods

- SIP events are identified through three elements: Request URI, event type, and message body (optional)
- Notable example: ***presence service, with so-called presentities and watchers***
  - Presence URI in the format **`pres:paolo@domain`**
  - ***Scalability issues***
  - Need for ***hierarchical organization*** into domains and ***actionf of even aggregation on localities*** to reduce number of notifications

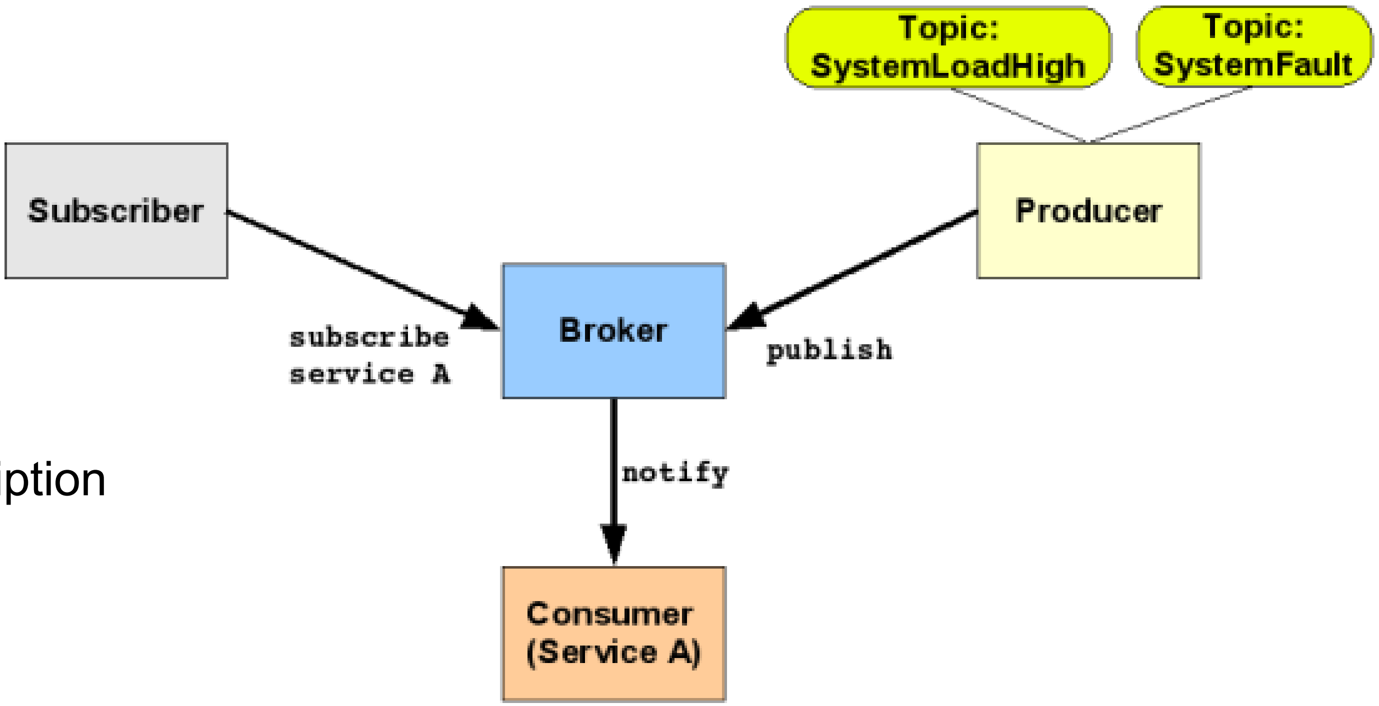
Web Services Event&Notification

Two key mechanisms to implement pub/sub for Web services: ***WS-Eventing and WS-Notification*** (standardization in 2006)

- ***WS-Eventing*** is the specification of protocol with which Web services have to ***make/accept registrations for event notification***
  - Mechanisms to create/remove subscriptions
  - Mechanisms to define ***expiration time*** and to allow renewal
  - ***Support to filters*** (different languages for filter definition may be used)
- ***WS-Notification*** is the specification to allow Web services ***to disseminate data to other Web services***
  - Also possibility of organizations oriented to interests (called topics) and ***interest-based filtering***
  - ***Distributed topologies for notification brokers***



Possible subscription from third parties (direct, with NO broker)



More usually, subscription through broker for better decoupling

Programming Example of WS-Event&Notification

For example, ***how to implement WS subscriber by using IBM WebSphere:***

- As usual, need to ***obtain WSDL file*** for notification broker and subscription manager services (resp. *NotificationBroker.wsdl* and *SubscriptionManager.wsdl*)
- If not yet available at client, need to execute wsimport to ***generate client stub***
- ***Look up at notification broker*** (need for reference to notification broker service)
- ***Instantiation of subscription request object and configuration of consumer reference***
- Instantiation of subscribe object to include subscription details, like reference to notification consumer

```
import org.oasis_open.docs.wsn.b_2.Subscribe;
import javax.xml.ws.wsaddressing.W3CEndpointReference;
import javax.xml.ws.wsaddressing.W3CEndpointReferenceBuilder;
// Crea oggetto subscription request. DEVE contenere
// ConsumerReference e PUO' includere filtro, InitialTerminationTime
// e SubscriptionPolicy
Subscribe subscribeRequest = new Subscribe();
W3CEndpointReference consumerReference = new
   W3CEndpointReferenceBuilder().address(consumerURI).build();
subscribeRequest.setConsumerReference(consumerReference);
```

Programming Example of WS-Event&Notification

Definition of ***topic expression as registration filter***

It is possible to associate a ***Filter object*** to registration request to indicate which events are relevant (***filter based on topic, message content, or both***). For example, topic-based filter (with IBM helper classes):

```
import com.ibm.websphere.sib.wsn.jaxb.base.FilterType;
import com.ibm.websphere.sib.wsn.jaxb.base.TopicExpressionType;
// To prepare the topic expression
topicExpression = topicNamespacePrefix + ":" + topicExpression;
TopicExpressionType topicExpressionType = new TopicExpressionType();
topicExpressionType.setExpression(topicExpression);
// To specify mapping from namespace prefix to topic namespace URI
topicExpressionType.addPrefixMapping(topicNamespacePrefix,
   topicNamespace);
// To specify dialect TopicExpression to use
topicExpressionType.setDialect(topicDialect);
// Filter instantiation
FilterType filter = new FilterType();
// To add expression to filter and needed configuration
// subscribe with filter
filter.addTopicExpression(topicExpressionType);
subscribeRequest.setFilter(filter);
```

Programming Example of WS-Event&Notification

Specification of registration duration and request sending

Two modes to specify expiration time for registration:

1) namespace URI and Qname objects
2) Helper factory = JAXB ObjectFactory

```
import javax.xml.bind.JAXBElement;
import javax.xml.datatype.DatatypeFactory;
import javax.xml.datatype.Duration;
// Option 1: Duration specification (one year from now)
DatatypeFactory factory = DatatypeFactory.newInstance();
Duration duration = factory.newDuration(”1Y”; JAXBElement<String>
   initialTerminationTime = new JAXBElement<String>(
     new QName("http://docs.oasis-open.org/wsn/b-2",
     "InitialTerminationTime"), String.class, duration.toString());
// Option 2:
org.oasis_open.docs.wsn.b_2.ObjectFactory objectFactory = new org.
   oasis_open.docs.wsn.b_2.ObjectFactory();
initialTerminationTime = objectFactory.createSubscribeInitial-
   TerminationTime(duration.toString());

subscribeRequest.setInitialTerminationTime(initialTerminationTime);
org.oasis_open.docs.wsn.b_2.SubscribeResponse
   subscribeResponse = port.subscribe(subscribeRequest);
```