

Middleware and Distributed Systems

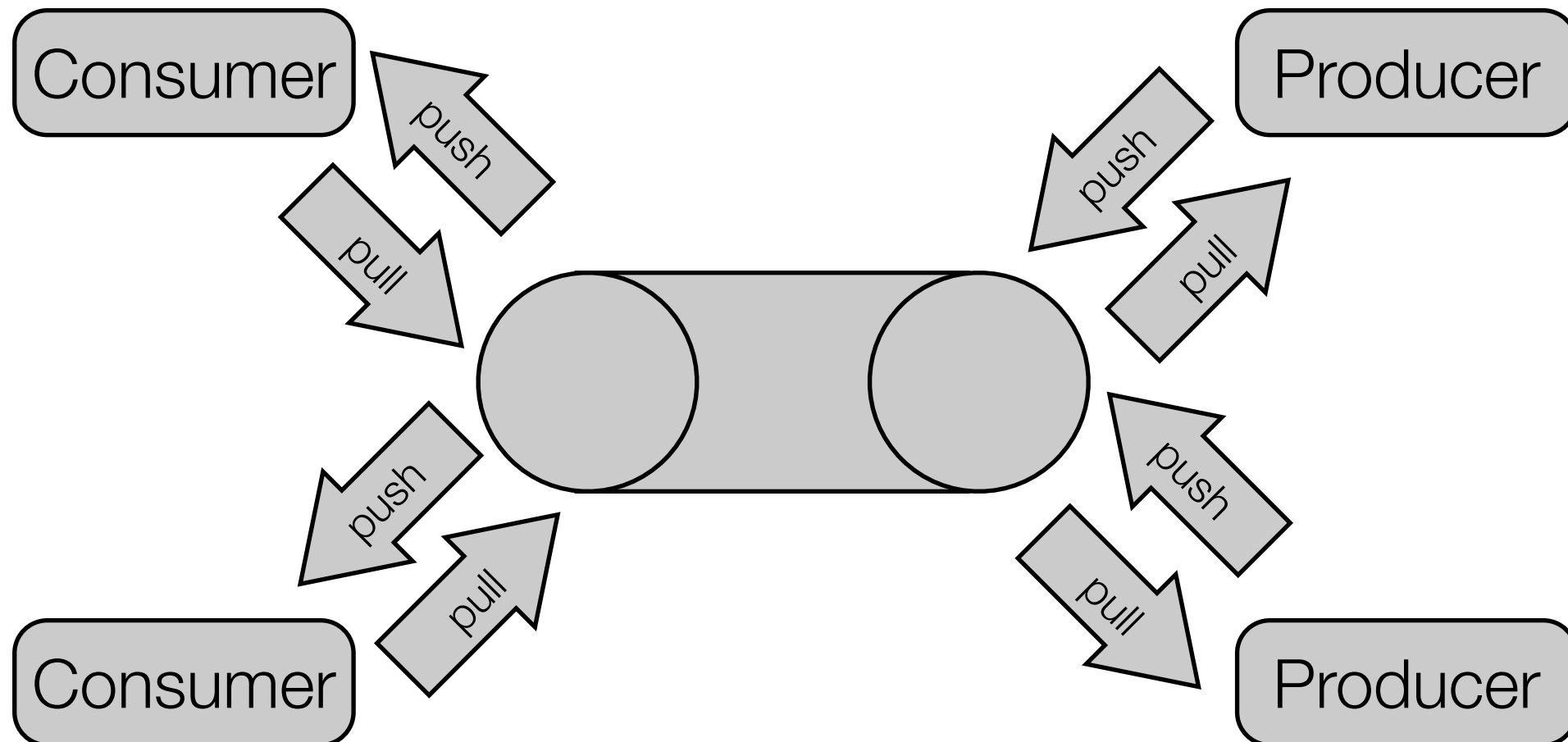
Message-Oriented Middleware

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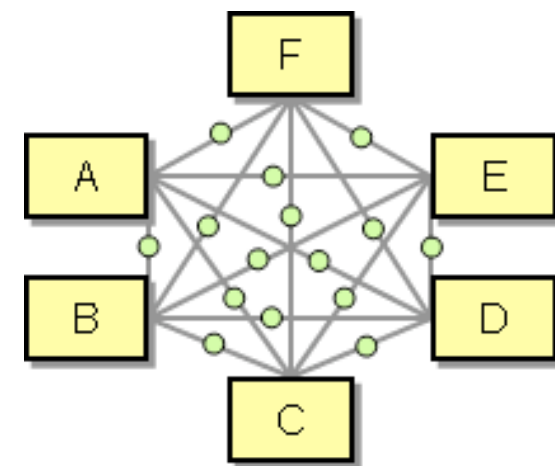
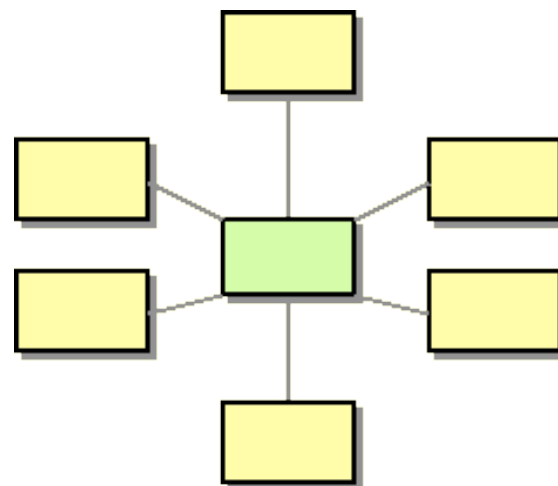
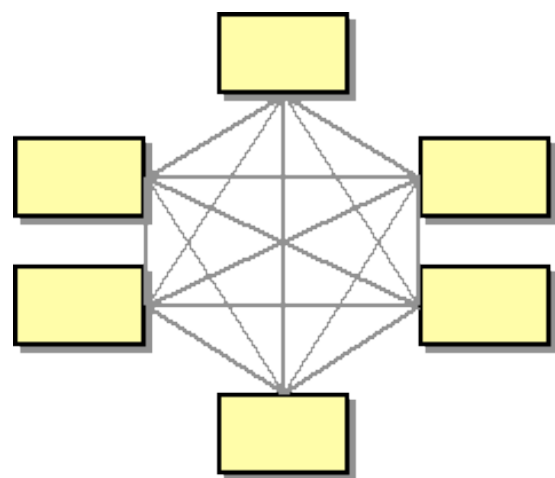
- Middleware for communication of messages between clients
- Focus on non-blocking communication style
 - Producer gives message to middleware
 - Consumer gets message from middleware
- Application responsibility for message structure, transparent to middleware
- Reliability through store-and-forward principle
- Loose coupling - decoupling of communication in space, in time, syntactically and semantically

Push / Pull Model



Message Brokers

- MOM provider can transform / alter the format of the message content
- 'Hub and spoke' architecture
 - Completely connected graph of nodes - $n/2*(n-1)$ edges (even more with directed graph)
 - Decoupling of sender and receiver through hub (think of FedEx)
- Protocol translation and data translation
 - Common meta-format, otherwise same scalability problem for translators



Messaging Models

- Point-to-point
 - Producing client sends message to consuming client through queue
 - Possibility of multiple producers
 - Each message delivered to only once to one of the consumers
- Publish / Subscribe
 - For one-to-many or many-to-many distribution of messages
 - Subscription to topic / channel, no restriction on client role
 - All subscribed clients receive the message, if available

Persistent Message Queues

- Message queue
 - Persists message until delivery
 - Referred to using a logical name, managed by queue manager
 - Many attributes: message length, max depth, persistence, ...
- Concept of persistent queues originates from TP monitors [Bernstein90]
 - Reliable management of transaction requests
 - Recoverable queue ('stable memory of elements') for client / server
 - Queue repository, queue manager

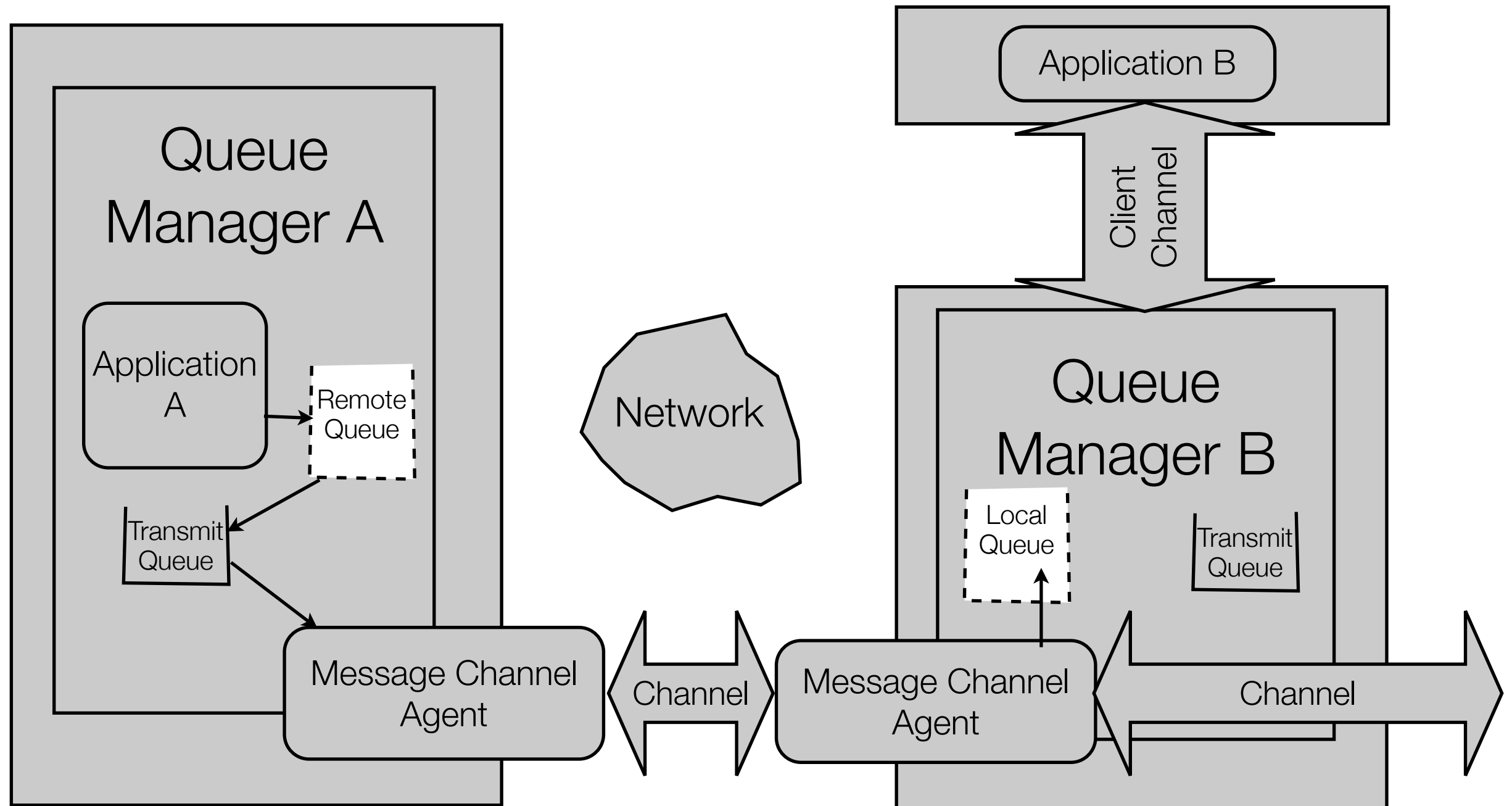
Queue Formats

- FIFO queues
- FIFO queues with priorities
- Public queue: Open access for all clients
- Private queue: Requires client authentication
- Temporary queue: Created for finite period of time or duration of a condition
- Journal queue: System keeps a copy of every message
- Connector / bridge queue: Acts as proxy between proprietary MOM systems
- Dead-Letter / Dead-Message queue: Final sink for undeliverable or expired messages

Message Delivery

- Configuration of message delivery options per queue
 - at-most-once, at-least-once, once-and-once-only delivery
 - Time-to-live (TTL) for messages
- Guaranteed message delivery
 - MOM saves pending messages on persistent storage
 - Consumer must confirm message receiving
- Certified message delivery
 - Consumption report sent to the producer

IBM MQSeries Example



Message Filtering

- Consumer / receiver demands selection of messages
- Typical filtering on properties of the message, sometimes on payload
- Boolean expression, SQL WHERE clause syntax
- Different filter types
 - Topic / Channel-based
 - Subject-based: Message subject as general property, string matching
 - Content-based: Parsing and check of payload information („stock_symbol=SUN“)
 - Pattern-based: Inspection of content over different messages („sock_symbol=SUN AND ms_price < 50\$“)

Transactional Messaging

- Group tasks into a single unit of work
 - All message delivery is completed, or all will fail together
 - Messages are not forwarded to the consumer until transaction commit by the sending producer
 - Messages are not removed from the MOM until transaction commit by the receiving consumer
 - Typically represented by transactional queue
- Local transactions within a single resource manager
- Global transactions with multiple (heterogeneous) distributed resource managers, and external transaction coordinator
- Queued Transaction Processing (QTP): Queues as transactional resources

Commercial Products

- TIBCO Rendezvous
- IBM Websphere MQ (MQSeries)
- Sun ONE Messaging Server
- Microsoft Message Queue Server (MSMQ)
- Sonic MQ -> ESB
- Common focus on:
 - Guaranteed message delivery features
 - Scalability regarding message throughput
- Few standardization attempts (AMQP)

CORBA Event Service

- Alternative to RPC-based client-server communication
- CORBA event service: Standardized interfaces from OMG (1995 - 2004)
 - Extension with CORBA notification service
- Event: “something that happens”, event consumer and event supplier
- Notification: Message that informs about some kind of event
- Push (active producer) and pull (active consumer) model
- Single source, (possibly) multiple recipients
 - Source does not know all consumers
 - Non-blocking sending of message
 - Typed communication (untyped communication through *any* type)

Stock Exchange Example

```
interface StockExchange;
struct StockQuote
{
    string stock_id;
    StockExchange market_place;
    double current_quote;
    Time current_time;
};
interface Subscriber
{
    void receive (in ::StockQuote current_quote);
};

interface StockExchange
{
    void subscribe (in ::Subscriber customer);
};
```

CORBA Event Service Interfaces

```
interface PushConsumer {
    void push (in any data) raises(Disconnected);
    void disconnect_push_consumer();
};

interface PushSupplier {
    void disconnect_push_supplier();
};
```

```
interface PullSupplier {
    any pull () raises(Disconnected);
    any try_pull (out boolean has_event)
        raises(Disconnected);
    void disconnect_pull_supplier();
};

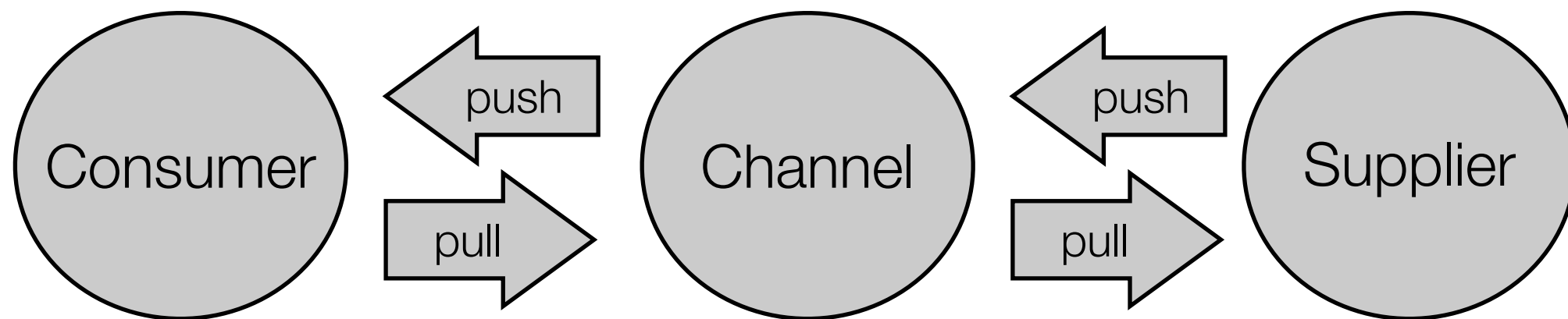
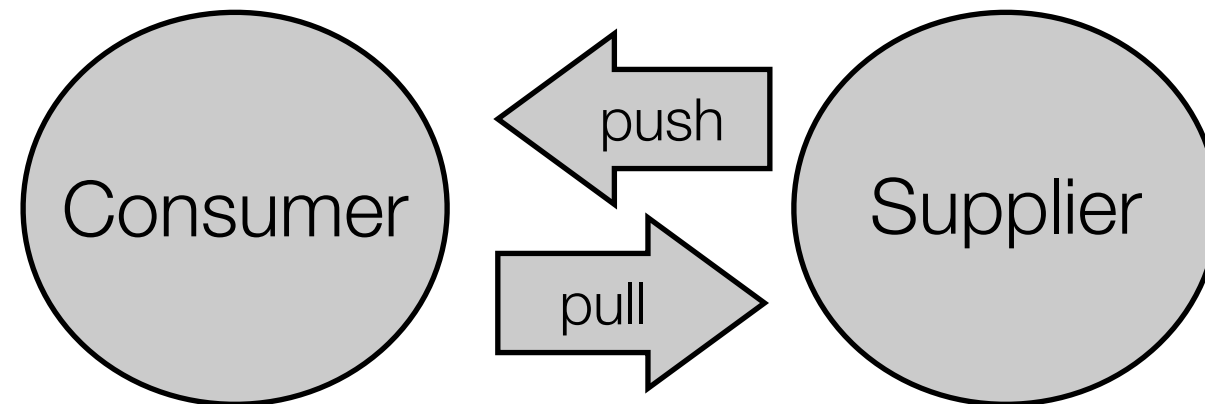
interface PullConsumer {
    void disconnect_pull_consumer();
};
```

Stock Exchange Example - 2nd try

```
interface StockExchange2;
struct StockQuote
{
    ...
    StockExchange2 market_place;
    ...
};
interface Subscriber2 : ::CosEventComm::PushConsumer
{};

interface StockExchange2 : ::CosEventComm::PushSupplier
{
    void subscribe (in ::Subscriber2 customer);
};
```


Event Channel as Middleman



CORBA Event Channel Usage

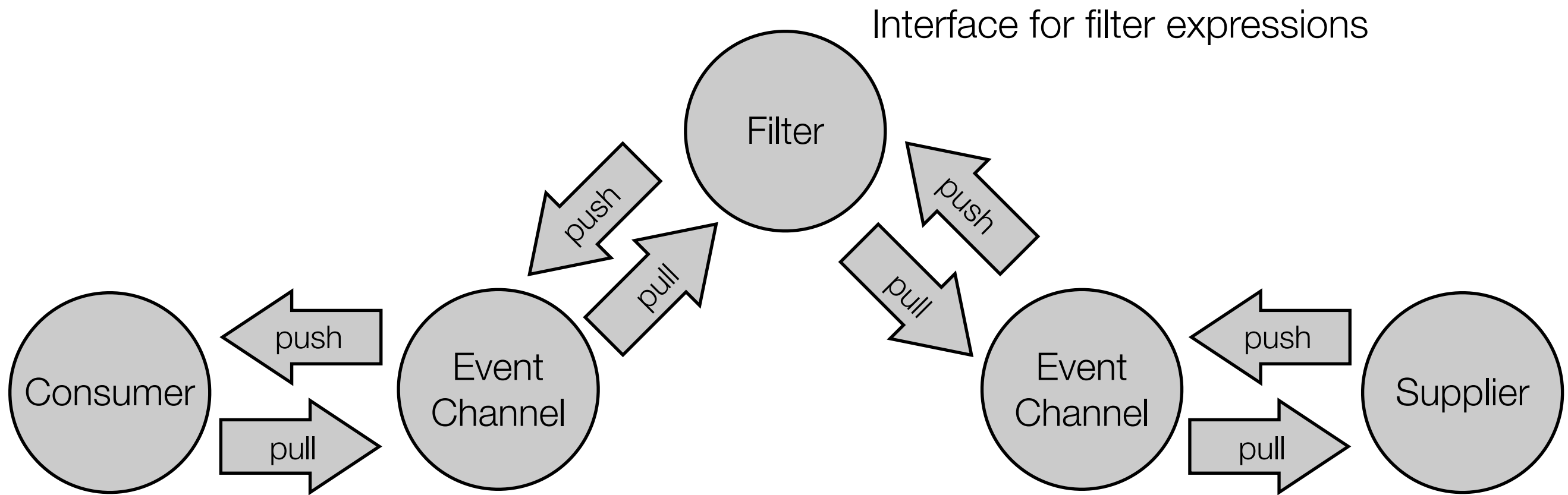
```
interface Channel
  : ::CosEventComm::PushSupplier,
  : ::CosEventComm::PushConsumer {
void register_supplier (
  in ::CosEventComm::PushSupplier supplier);
void register_consumer (
  in ::CosEventComm::PushConsumer consumer);
};
```

```
interface MyConsumer : ::CosEventComm::PushConsumer
{};
```

```
interface MySupplier : ::CosEventComm::PushSupplier
{};
```

CORBA Event Filters

- Subscriber might be only interested in specific notifications
- Demands interface for filter installation



CORBA Notification Service

- Wide usage of Event service, several proprietary extensions
- Extended event service in CORBA 3 -> Notification Service
- Filter objects
 - Interfaces to add, remove and modify constraints on message values
- Quality of service
 - Interfaces for control over notification delivery characteristics
 - Examples: discard policy, earliest delivery time, expiration time, max events per consumer, ordering policy, event priority, re-connection
- Demands general standardized event structure

Structured Notification Event

- Header with fixed and variable part
 - domain_name: vertical industry domain (telco, finance, health care)
 - type_name: type of event within domain (StockQuote, VitalSigns)
 - event_name
 - Optional header fields, some standardized names
 - *EventReliability / ConnectionReliability* (short): 0 - best effort, 1 - persistent
 - *Priority* (short): -32.767 ... 0 ... 32.767
 - *StartTime, StopTime or Timeout* for delivery
- Body with filterable data and raw data

CORBA Notification QoS Levels

Property	Per-Message	Per-Proxy	Per-Admin	Per-Channel
EventReliability	X			X
ConnectionReliability		X	X	X
Priority	X	X	X	X
StartTime	X			
StopTime	X			
Timeout	X	X	X	X
StartTimeSupported		X		X
StopTimeSupported		X		X
MaxEventsPerConsumer ¹		X		
OrderPolicy		X	X	
DiscardPolicy ¹		X	X	
MaximumBatchSize ²		X	X	
PacingInterval ²		X	X	X

AnyOrder
 FifoOrder
 PriorityOrder
 DeadlineOrder

AnyOrder
 FifoOrder
 LifoOrder
 PriorityOrder
 DeadlineOrder

Structured Event IDL

```
module CosNotification {  
    ...  
    struct FixedEventHeader {  
        _EventType event_type;  
        string event_name;  
    };  
  
    struct EventHeader {  
        FixedEventHeader fixed_header;  
        OptionalHeaderFields variable_header;  
    };  
  
    struct StructuredEvent {  
        EventHeader header;  
        FilterableEventBody  
            filterable_data;  
        any remainder_of_body;  
    }  
    ...  
}
```

```
struct _EventType {  
    string domain_name;  
    string type_name;  
};
```

```
typedef string Istring;  
typedef Istring PropertyName;  
typedef any PropertyValue;  
struct Property {  
    PropertyName name;  
    PropertyValue value; };  
typedef sequence<Property> PropertySeq;  
typedef PropertySeq OptionalHeaderFields;  
typedef PropertySeq FilterableEventBody;
```

Notification Service Constraint Language

- Extended version of CORBA Trading service constraint language
 - Special token “\$” for current event and any run-time variable
 - Reserved variable “\$curtime”
 - Vendor extensions have “:” prefix

```
$type_name == 'CommunicationsAlarm' and not  
($event_name == 'lost_packet')
```

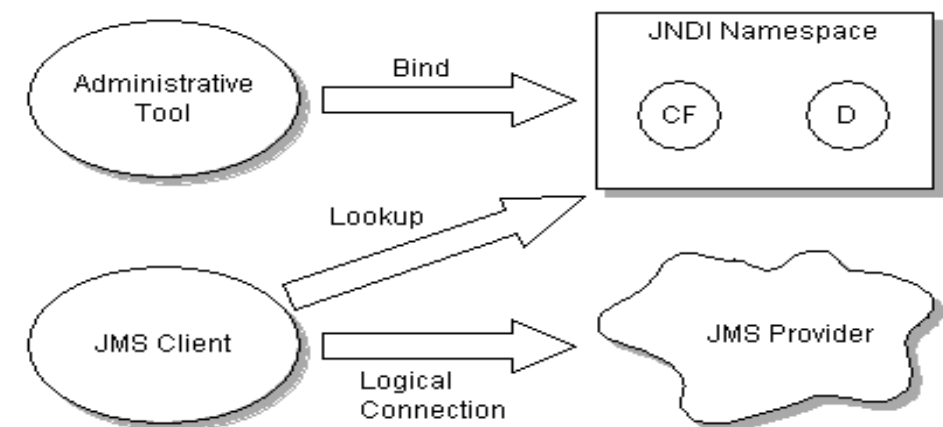
```
$type_name == 'CommunicationsAlarm' and  
$priority >= 1 and $priority <= 5
```

```
$origination_timestamp.high + 2 < $curtime.high
```

```
exist $threshold._type_id and $threshold._type_id == 'short'
```

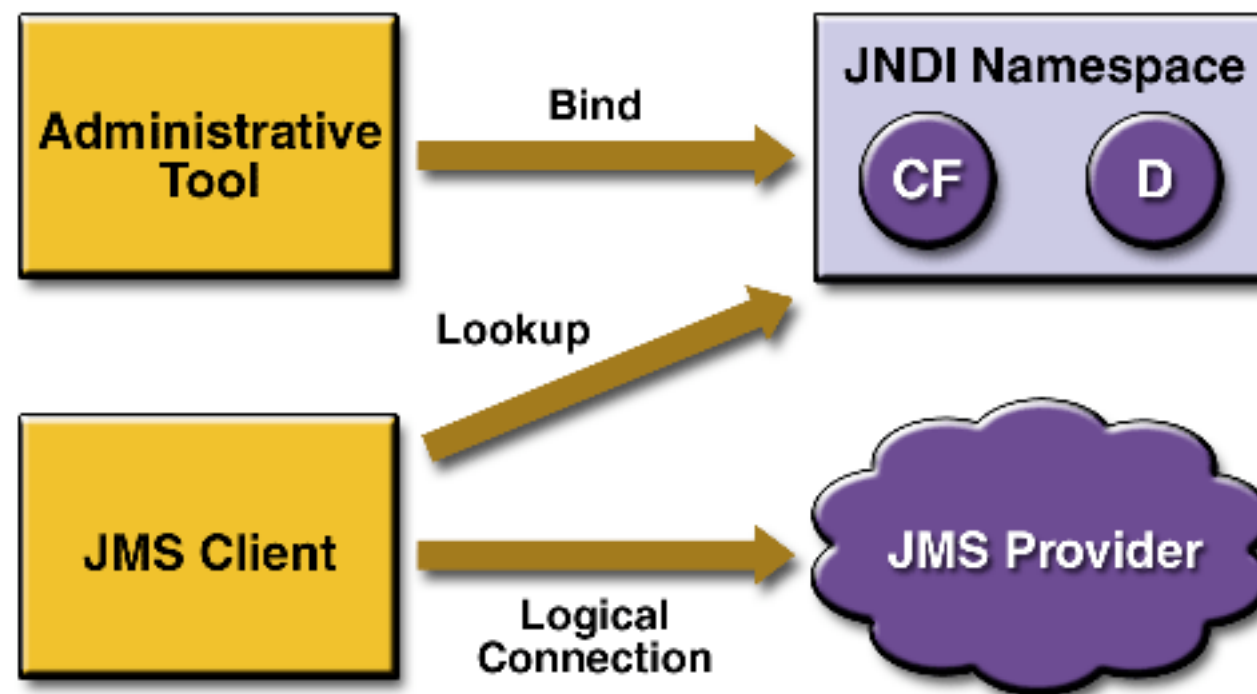

Java Messaging Service

- Client API specification for messaging in Java (JSR 914, 2001)
- „...common set of enterprise messaging concepts...“
- No wire protocol, no security, no error notification
- JNDI typically used to get administered JMS objects
 - Administrative tasks outside of client code
 - *ConnectionFactory* - used to create JMS provider connection
 - *Destination* - used for specifying the destination of messages

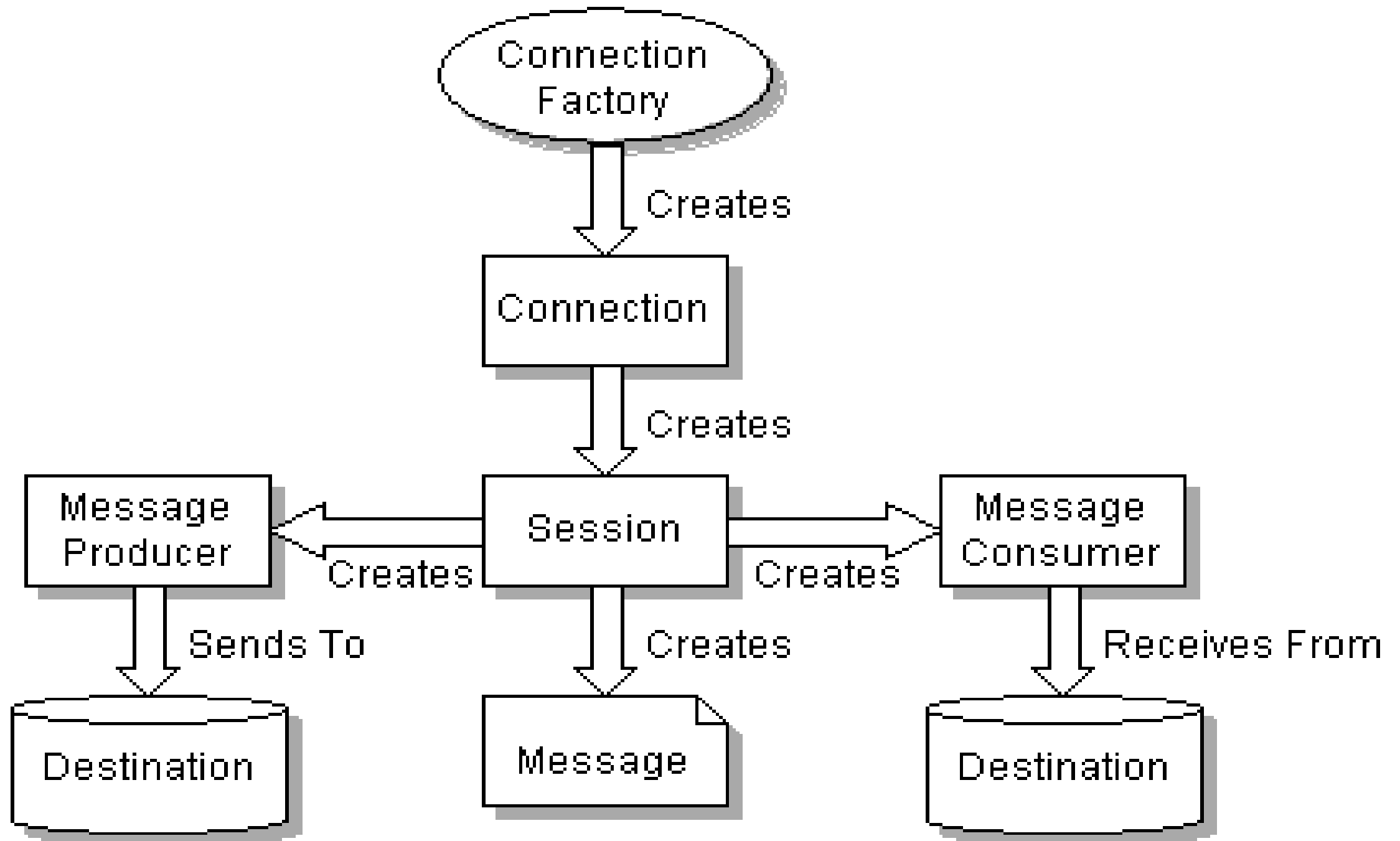


JMS Provider

- „...entity that implements JMS for a messaging product...“ - JAR file
- Producer gives message to provider for delivery
- Consumer gets message synchronously / asynchronously from provider



JMS Relationships



JMS Interface Comparison

JMS Common Interfaces	PTP-specific Interfaces	Pub/Sub-specific interfaces
ConnectionFactory	QueueConnectionFactory	TopicConnectionFactory
Connection	QueueConnection	TopicConnection
Destination	Queue	Topic
Session	QueueSession	TopicSession
MessageProducer	QueueSender	TopicPublisher
MessageConsumer	QueueReceiver, QueueBrowser	TopicSubscriber

Developing a JMS Client

- Use JNDI to find a *ConnectionFactory*
- Use JNDI to find one or more *Destination* objects
- Use *ConnectionFactory* to establish connection with demanded delivery feature
- Use *Connection* to create a *Session*
- Create *Producer / Consumer* object through the *Session* to a particular *Destination*
 - Specific class depends on messaging model

JMS Messages

- Standardized message interfaces
- Message implementation by JMS provider
- Message header information
 - Common set of mandatory header fields for receiver
 - Facility for adding properties to header (standard, application-specific, provider-specific)
- Some predefined message body structures
 - Still no promise for interoperability !

JMS Message Header

- *JMSDestination*, *JMSDeliveryMode*
- *JMSMessageId*: Assigned by provider
 - Scope of uniqueness is implementation-specific
- *JMSTimestamp*: Time of delivery to provider
- *JMSCorrelationID*: might be used for relation of response message to request message
- *JMSRedelivered*: Indication for consumer
- *JMSType*: Reference to provider message repository, no defaults specified by JMS

JMS Message Header

- *JMSExpiration*: „...clients SHOULD not receive messages that have expired...“
- *JMSPriority*: 0-4 (normal), 5-9 (expedited)
- Administrator can override *JMSDeliveryMode*, *JMSExpiration* and *JMSPriority*

Header Fields	Set By
JMSDestination	Send Method
JMSDeliveryMode	Send Method
JMSExpiration	Send Method
JMSPriority	Send Method
JMSMessageID	Send Method
JMSTimestamp	Send Method
JMSCorrelationID	Client
JMSReplyTo	Client
JMSType	Client
JMSRedelivered	Provider

JMS Message Properties

- Additional set of optional header elements with “JMSX” prefix
- Set by provider on send
 - *JMSXUserId, JMSXAppId, JMSXProducerTXID*
- Set by provider on receive
 - *JMSXDeliveryCount, JMSXConsumerTXID, JMSXRecvTimestamp*
- Set by client
 - *JMSXGroupId, JMSXGroupSeq*

JMS Acknowledgment Modes

- Controlled at session level
- *AUTO_ACKNOWLEDGE*
 - Asynchronous mode: Handler acknowledges successful return (???)
 - Synchronous mode: Client has successfully returned from receive()
- *CLIENT_ACKNOWLEDGE*
 - Client calls acknowledge() by itself
- *DUPS_OK_ACKNOWLEDGE*
 - Lazy acknowledge which might lead to duplicates
 - Consumer must be able to handle duplicates
 - > reduces messaging overhead

JMS Message Types

- TextMessage: java.lang.String object
- MapMessage: Set of name/value pairs
- BytesMessage: Stream of bytes
- StreamMessage: Stream of Java primitive values, read sequentially
- ObjectMessage: Serializable Java object

	boolean	byte	short	char	int	long	float	double	String	byte[]
boolean	X								X	
byte		X	X		X	X			X	
short			X		X	X			X	
char				X					X	
int					X	X			X	
long						X			X	
float							X	X	X	
double								X	X	
String	X	X	X		X	X	X	X	X	
byte[]										X

JMS Example Code

```
import javax.naming.*;
import javax.jms.*;

Context c = new InitialContext();
ConnectionFactory cf = (ConnectionFactory) c.lookup("ConnectionFactory");
Queue stockQueue = (Queue)c.lookup("StockSource");
Connection connection = ConnectionFactory.createConnection();
Session session; // no TA, automated ack of messages
session = connection.createSession(false, Session.AUTO_ACKNOWLEDGE);
MessageProducer sender = session.createProducer(stockQueue);
String selector = new String("(StockSector = 'Technology')");
MessageConsumer receiver = session.createConsumer(stockQueue, selector);
connection.start();

MapMessage message = session.createMapMessage();
message.setString("Name", "SUNW");
message.setDouble("Value", stockValue);
message.setStringProperty("StockSector", "Technology");
sender.send(message);

MapMessage message = (MapMessage)receiver.receive();
```

Messaging In The Internet

MOM	Email
MOM message	SMTP message
Message queue	Mailbox
Consumer	POP3 client
Producer	SMTP client
Queue manager	MTA
Routing key	To: / Cc: address
Publish / Subscribe	Mailing list
Message filter	Server-side spam check
Message acknowledge	
Transactional messaging	
Time to live	