Asynchronous Messaging

Unil | HEC | dop lab

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distributed object programming lab

Fundamental idea

- □ Provide a communication abstraction that decouples collaborating distributed entities
  - □ Time decoupling ⇒ asynchrony
  - □ Space decoupling ⇒ anonymity
- □ Asynchrony ⇒ persistence of messages
- □ Anonymity ⇒ extra level of indirection

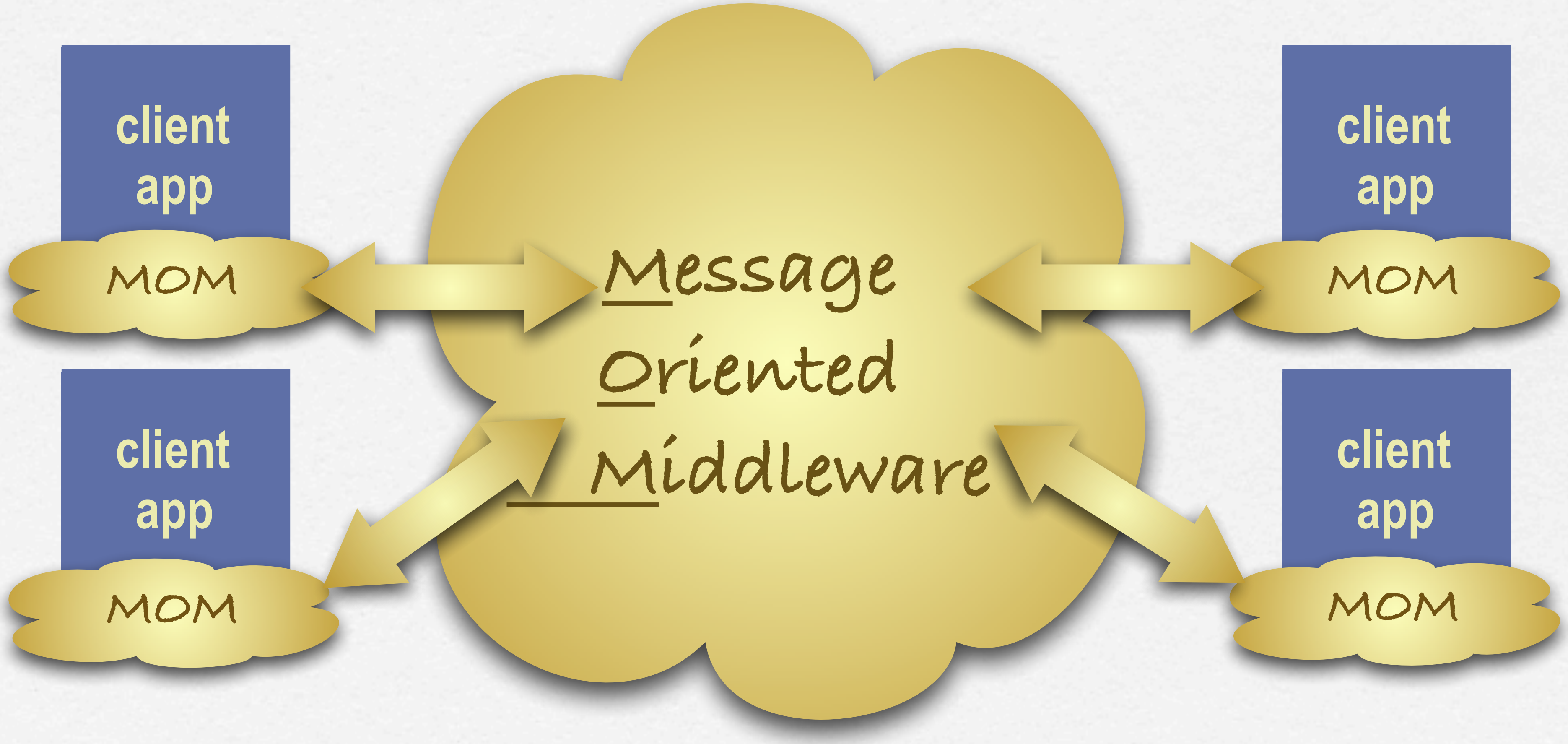
Message-Oriented Middleware

- □ A Message-Oriented Middleware (MOM) is a software layer acting as a kind of "middle man" between distributed entities
- □ A MOM is independent of the programming language, i.e., messages can be exchanged between distributed entities written in any language*
- □ Most software companies offer middleware products that fall in the MOM category, e.g., IBM MQ Series, Oracle AQ, Sun Java System Message Queue, Microsoft Message Queueing, etc..

*provided a library exists to access the MOM

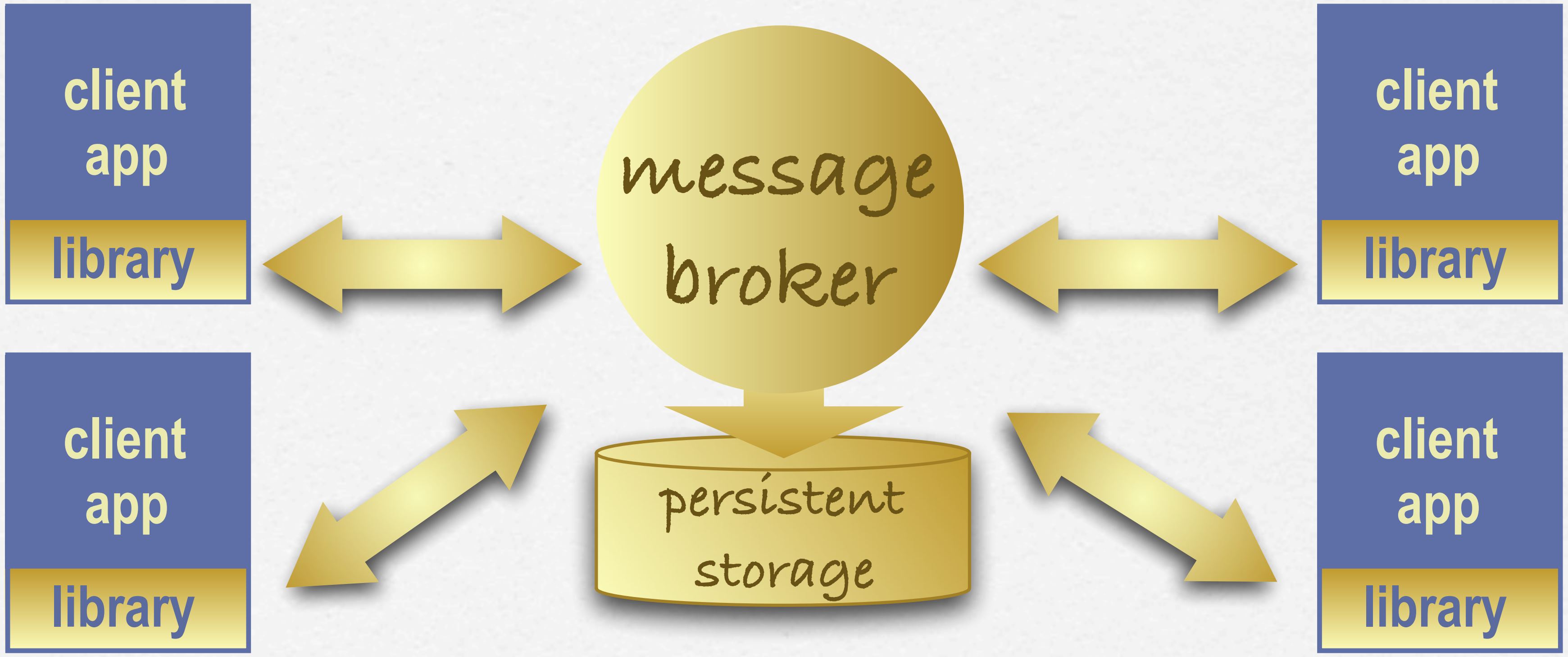
Broker & client library

- □ A MOM is often based on a message broker and a client library.



Broker & client library | Example

□ A MOM is often based on a message broker and a client library.



Communication models

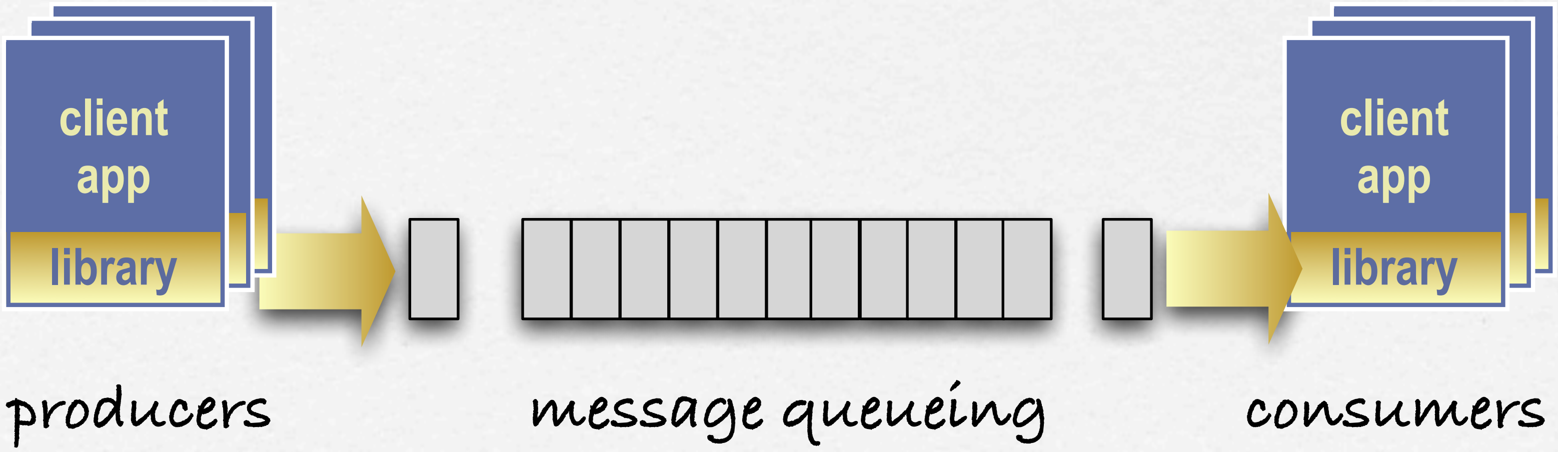
- □ Point-to-point model
  One-to-one communication between message producers and consumers, where each message is consumed by one and only one consumer
- □ Publish/Subscribe (pub/sub) model
  One-to-many communication where producers publish messages and all consumers that have subscribed receive them
- □ In both models, the notion of message is key

Point-to-Point

□ Each message is received by only one consumer

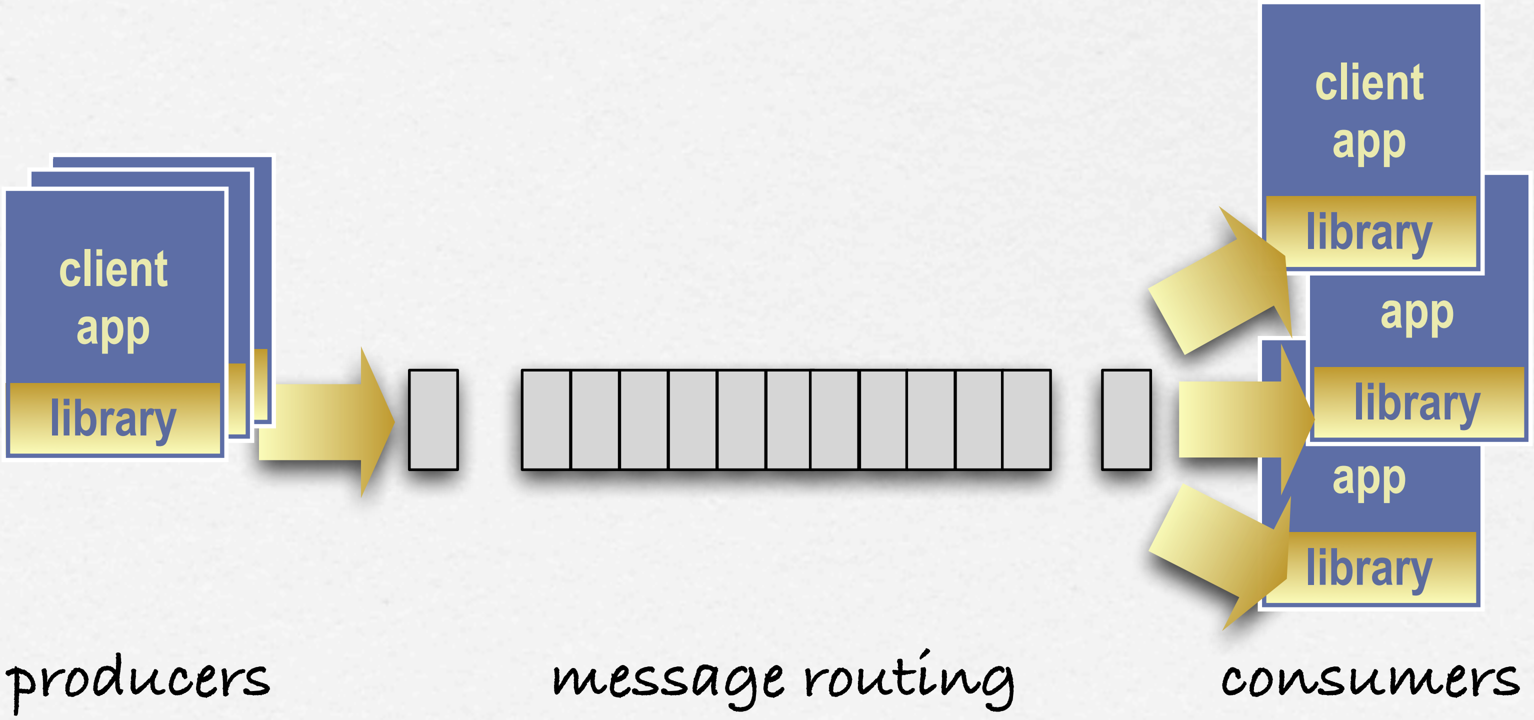
□ Messages are placed in a queue and are persisted until they are consumed

□ This model can be used to load-balance tasks
Caveat: fifo processing cannot be guaranteed



Publish/Subscribe

- □ Each message is received by all subscribers
- □ Messages are not persisted by default
- □ There exists various message routing variant:
    - □ topic-based
    - □ content-based
    - □ location-based
    - □ ...

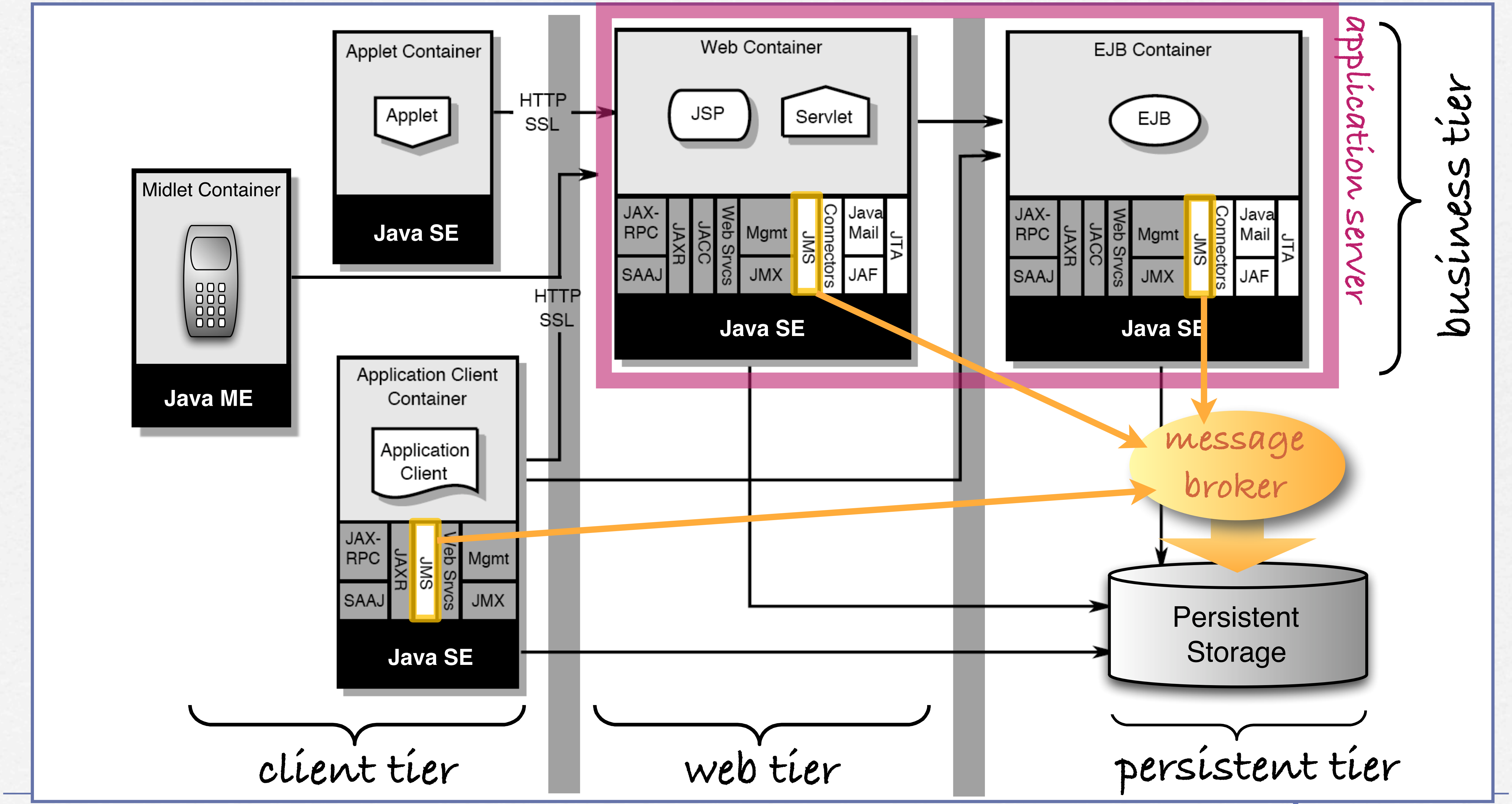


Java Messaging Service

- □ The Java Messaging Service (JMS) defines the asynchronous messaging standard of the Java EE platform

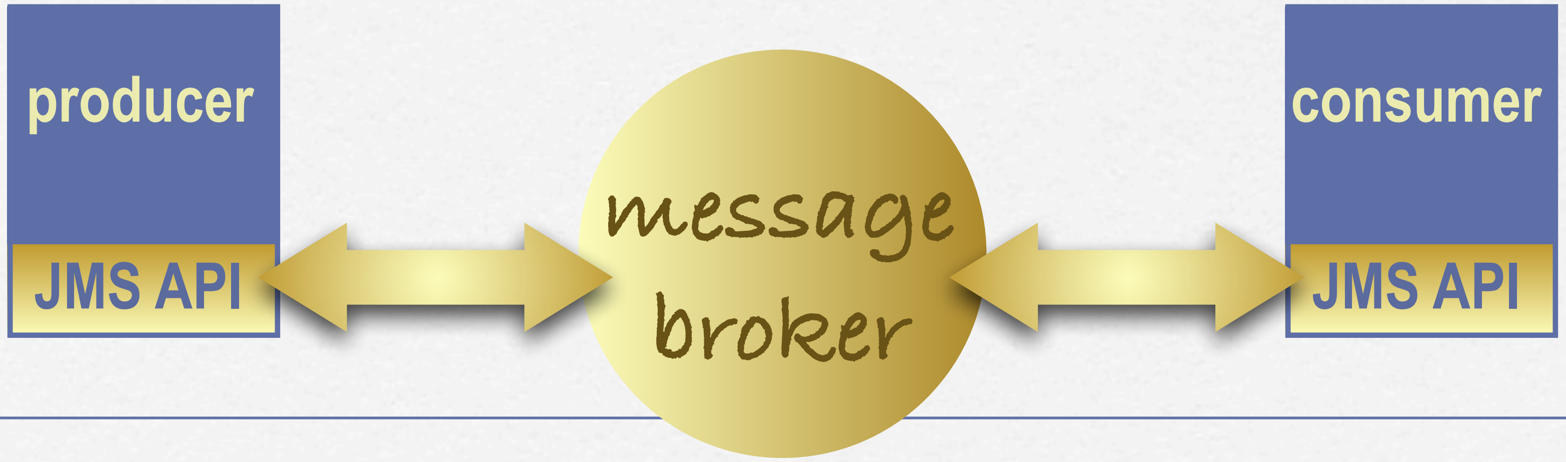
- □ JMS follows the general Java EE philosophy:
  - □ JMS is a specification
  - □ JMS implementations rely on existing products (IBM MQ Series, Oracle AQ, Sun Java System Message Queue, etc.)
  - □ JMS-based applications are portable across any JMS-compliant implementation

JMS & Java EE


Applet Container
Applet
Java SE
HTTP
SSL
Midlet Container
Java ME
Web Container
JSP
Servlet
JAX-RPC
SAAJ
JAXR
JACC
Web Srvcs
Mgmt
JMX
JMS
Connectors
Java Mail
JAF
JTA
Java SE
EJB Container
EJB
JAX-RPC
SAAJ
JAXR
JACC
Web Srvcs
Mgmt
JMX
JMS
Connectors
Java Mail
JAF
JTA
Java SE
application server
business tier
HTTP
SSL
Application Client Container
Application Client
JAX-RPC
SAAJ
JAXR
JMS
Web Srvcs
Mgmt
JMX
Java SE
message broker
Persistent Storage
client tier
web tier
persistent tier

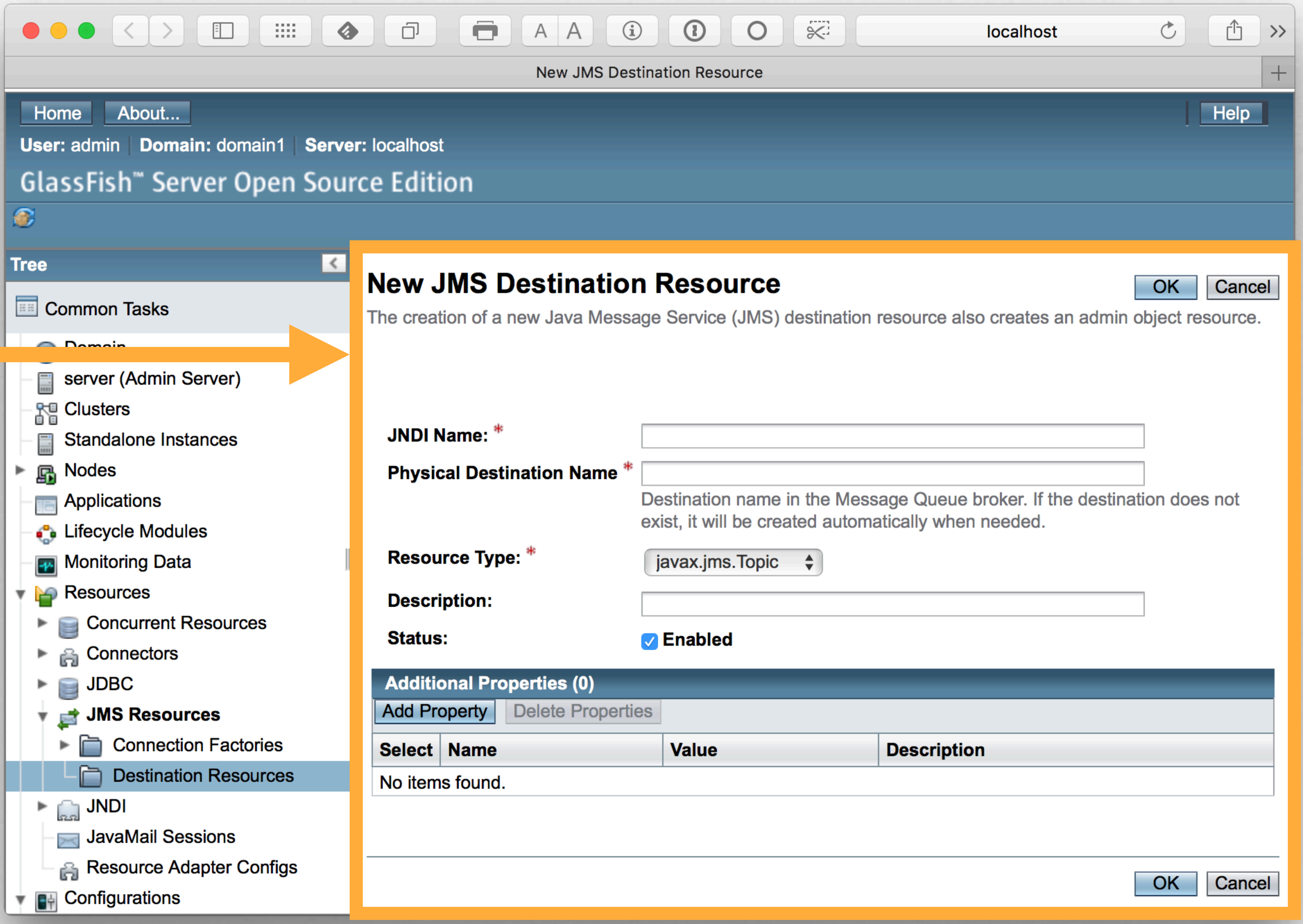
Execution time

- □ A producer creates messages & sends them via the JMS API, specifying a message destination
- □ A consumer receives messages via the JMS API, specifying a message destination and an optional message selector
- □ A JMS-compliant product provides an implementation of the JMS API in the form of a client library that knows how to communicate natively with the message broker



Deployment time

- □ Start the message broker (usually via the Java EE application server)
- □ Create the adequate destinations
- □ Install the JMS client library on the producer & the consumer, and start them



New JMS Destination Resource

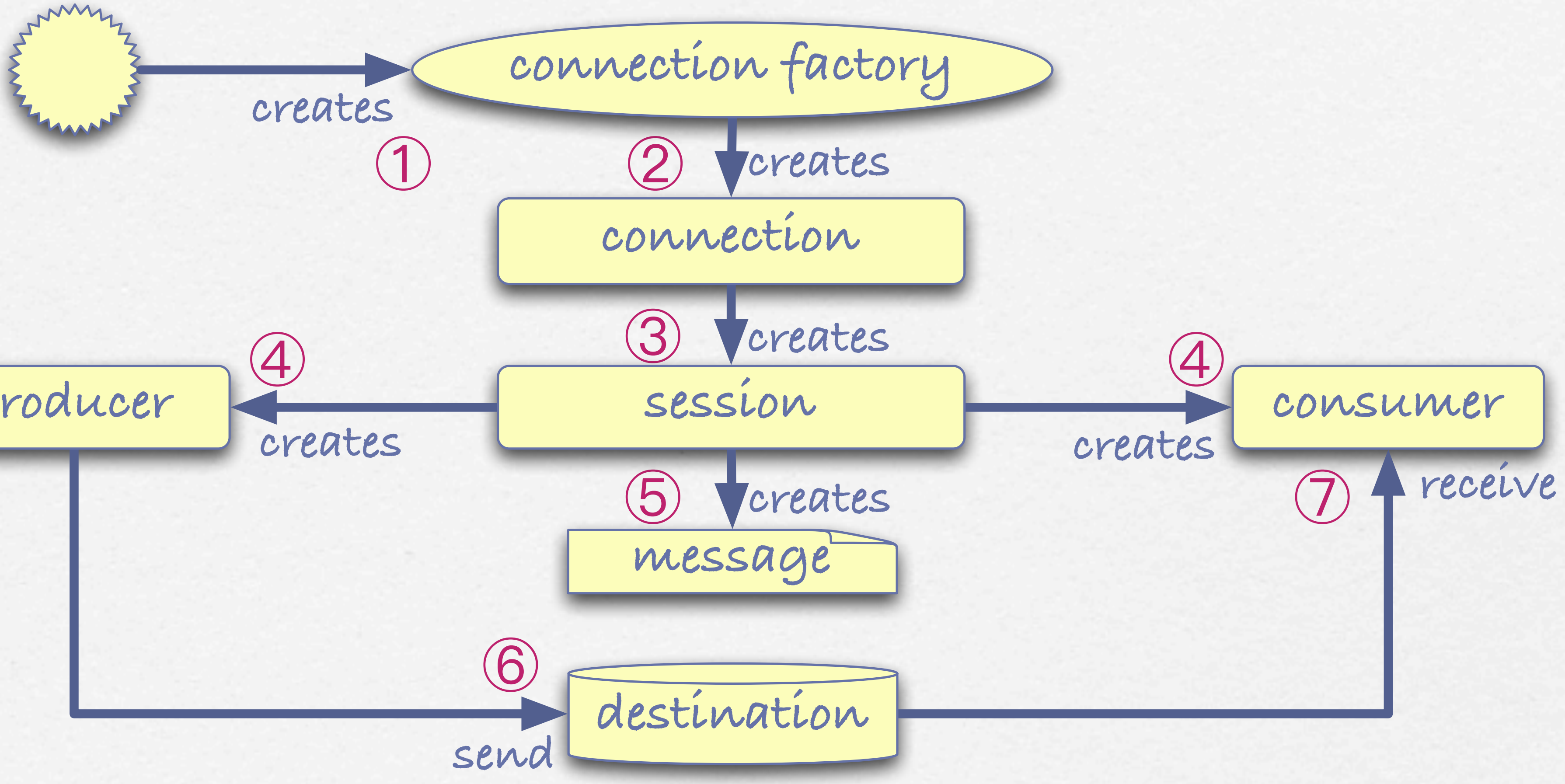
The creation of a new Java Message Service (JMS) destination resource also creates an admin object resource.

JNDI Name: *	
Physical Destination Name *	Destination name in the Message Queue broker. If the destination does not exist, it will be created automatically when needed.
Resource Type: *	javax.jms.Topic
Description:	
Status:	☑ Enabled

Additional Properties (0)

Select	Name	Value	Description
No items found.			

Unified programming model



Two communication models:

- □ point-to-point (destination = queue)
- □ publish/subscribe (destination = topic)

Development: publisher

```
public class NewsPublisher {
    static boolean moreNews= true;
    public static void main(String[] args) {
        String topicName= args[0];  String fileName= args[1];
①       TopicConnectionFactory connectionFactory = new com.sun.messaging.TopicConnectionFactory();
        TopicConnection connection= null;
        try {
②           connection= connectionFactory.createTopicConnection();
③           TopicSession session= connection.createTopicSession(false, Session.AUTO_ACKNOWLEDGE);
            Topic topic= session.createTopic(topicName);
④           TopicPublisher publisher = session.createPublisher(topic);
⑤           TextMessage message = session.createTextMessage();
            BufferedReader newsFeed = new BufferedReader(new FileReader(fileName));
            while (moreNews) {
                String theNews= getNextNews(newsFeed);
                message.setText(theNews);
                System.out.println("Publishing \"" + message.getText() + "\"");
⑥               publisher.publish(message);
            }
        } catch (Exception e) {
            System.out.println("Exception occurred: " + e.toString()); System.exit(1);
        }
    }
    ...
```

Development: subscriber

```
public class NewsSubscriber implements MessageListener {
    public static void main(String[] args) {
        String topicName= args[0];
        TopicConnectionFactory connectionFactory = new com.sun.messaging.TopicConnectionFactory();
        TopicConnection connection = null;
        try {
            connection = connectionFactory.createTopicConnection();
            TopicSession session = connection.createTopicSession(false, Session.AUTO_ACKNOWLEDGE);
            Topic topic= new com.sun.messaging.Topic(topicName);
            TopicSubscriber subscriber = session.createSubscriber(topic);
            MessageListener listener= new NewsSubscriber();
            subscriber.setMessageListener(listener);
            connection.start();
            synchronized (listener) { listener.wait(); }
        } catch (Exception e) {
            System.out.println("Exception occurred: " + e.toString()); System.exit(1);
        }
    }
⑦   public void onMessage(javax.jms.Message message) throws Exception {
        String theNews = ((TextMessage) message).getText();
        System.out.println("Learning that \"" + theNews + """);
        if (theNews.endsWith("There are no more news."))
            synchronized (this) { this.notify(); }
    }
    ...
```

Development: producer

```
public class OrderProducer {
    public static void main(String[] args) {
        String queueName= args[0];
        ConnectionFactory connectionFactory = new com.sun.messaging.ConnectionFactory();
        Connection connection= null;
        try {
            connection= connectionFactory.createConnection();
            Queue queue= new com.sun.messaging.Queue(queueName);
            Session session= connection.createSession(false, Session.AUTO_ACKNOWLEDGE);
            MessageProducer producer = session.createProducer(queue);
            BufferedReader kbdIn = new BufferedReader(new InputStreamReader(System.in));
            TextMessage message = session.createTextMessage();
            while (true) {
                String order= askForOrder(kbdIn, 3);
                message.setText(order);
                System.out.println("Sending order [" + message.getText() + "]");
         ⑥      producer.send(message);
            }
        } catch (Exception e) {
            System.out.println("Exception occurred: " + e.toString()); System.exit(1);
        }
    }
    ...
```

Development: consumer

```
public class OrderConsumer implements MessageListener {
    public static void main(String[] args) {
        String queueName = args[0];
        ConnectionFactory connectionFactory = new com.sun.messaging.ConnectionFactory();
        Connection connection = null;
        try {
            connection = connectionFactory.createConnection();
            Session session = connection.createSession(false, Session.AUTO_ACKNOWLEDGE);
            Queue queue= new com.sun.messaging.Queue(queueName);
            MessageConsumer consumer = session.createConsumer(queue);
            MessageListener listener= new OrderConsumer();
            consumer.setMessageListener(listener);
            connection.start();
            synchronized (listener) { listener.wait(); }
        } catch (Exception e) {
            System.out.println("Exception occurred: " + e.toString()); System.exit(1);
        }
    }
⑦   public void onMessage(javax.jms.Message message) throws Exception {
        String order = ((TextMessage) message).getText();
        System.out.println("Passing order " + order + " on the market");
        if (order.equals("quit"))
            synchronized (this) { this.notify(); }
    }
    ...
```

Synchronous consumer

```
public class OrderSynchronousConsumer {
    public static void main(String[] args) {
        String queueName = args[0];
        ConnectionFactory connectionFactory = new com.sun.messaging.ConnectionFactory();
        Connection connection = null;
        try {
            connection = connectionFactory.createConnection();
            Session session = connection.createSession(false, Session.AUTO_ACKNOWLEDGE);
            Queue queue= new com.sun.messaging.Queue(queueName);
            MessageConsumer consumer = session.createConsumer(queue);
            connection.start();
            while (true) {
        ⑦       Message m = consumer.receive();
                ...
        } catch (Exception e) {
            System.out.println("Exception occurred: " + e.toString()); System.exit(1);
        }
    }
}
```

Message format & types

header
properties
body

- A JMS message is composed of three parts:
  - a header holding required fields for the client library and the message broker, e.g., priority, time-to-live, etc.
  - a list of optional properties, which act as meta-data used by the message selection mechanism
  - a body containing the actual data of the message
- There exists various types of messages, which differ in the type of data they carry in their body, e.g., **`Message`**, **`TextMessage`**, **`ObjectMessage`**, etc.

```
...
Message message = session.createMessage();
...
```

Message selectors

- By default, JMS provides topic-based pub/sub
- Thanks to message properties, JMS also support content-based pub/sub via message selectors
- A message selector is a string whose syntax is a subset of the SQL92 conditional expression syntax

On the publisher:

```
Message message = session.createMessage();
message.setStringProperty("name", "Bob");
message.setIntProperty("age", 30);
message.setStringProperty("address", "Lausanne");
```

On the subscriber:

```
String selector= "name LIKE 'Max' OR (age > 18 OR address LIKE 'Lausanne')";
TopicSubscriber subscriber = session.createSubscriber(topic, selector, false);
```

Quality of Service (QoS)

- Parameterized Quality of Service (QoS) is usually offered by MOM products
- In JMS, the level of QoS depends on the following parameters:
  - message ordering, time-to-live & priorities
  - acknowledgement modes
  - durable subscriptions
  - delivery modes
  - transactions

Order, priority & time-to-live

- JMS specifies that messages are received in the order in which they were sent with respect to a given session and a given destination (commonly called FIFO order)
- JMS specifies no order across destinations or across sessions sending to the same destination
- The notion of priority allows programmers to have finer control over ordering, via the **send()** method
- Programmers can also specify how long the message broker should keep a message, via a time-to-live parameter passed to the **send()** method

priority

time-to-live (in ms)

```
...
producer.send(aMessage, DeliveryMode.NON_PERSISTENT, 3, 5000);
...
```

Acknowledgement modes

- □ An acknowledgment informs the MOM (e.g., its underlying message broker) that the client has successfully received a message
- □ JMS supports three acknowledgment modes:

AUTO_ACKNOWLEDGE the session automatically acknowledges the receipt of each message

CLIENT_ACKNOWLEDGE the client acknowledges programmatically, invoking **acknowledge()** on each message

DUPS_OK_ACKNOWLEDGE more efficient variant of **AUTO_ACKNOWLEDGE** that can result is duplicate messages in case of failures

```
...
Session session= connection.createSession(false, Session.AUTO_ACKNOWLEDGE);
...
```

Delivery modes

- □ In JMS, there exists two delivery modes:

NON_PERSISTENT most efficient but less reliable, since messages are guaranteed to be delivered at most once, i.e., some might be lost, e.g., due to some failure (power outage)

PERSISTENT most reliable, since messages are guaranteed to be delivered once and only once; this is usually achieved by persisting sent messages on stable storage and keeping them until they are acknowledged

- □ The delivery mode can be specified at the producer level or each time a messaes is sent:

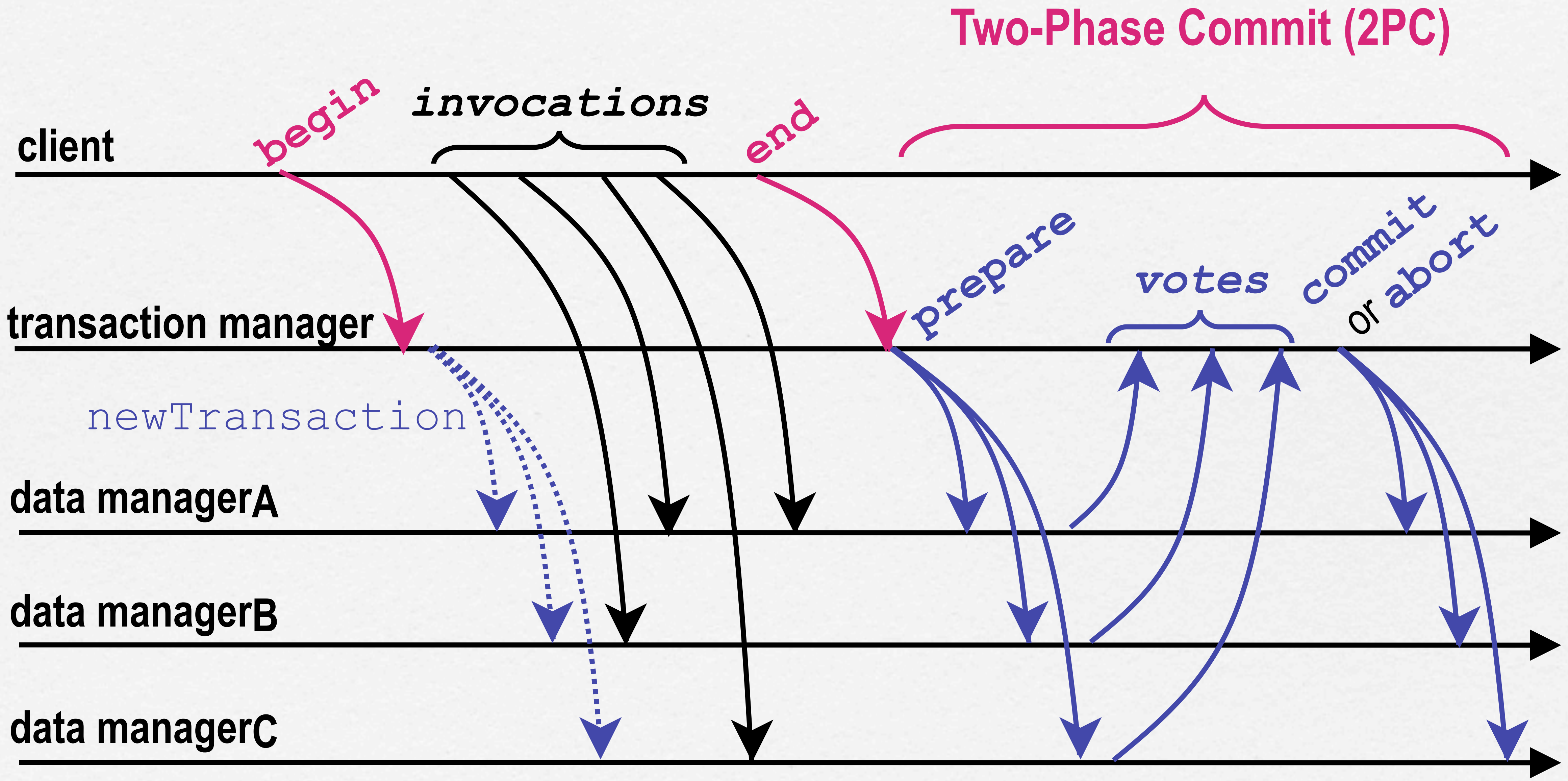
```
...
MessageProducer producer = session.createProducer(queue);
producer.setDeliveryMode(DeliveryMode.PERSISTENT);
producer.send(aMessage, DeliveryMode.NON_PERSISTENT, 0, 0);
...
```

Durable subscriptions

- □ With pub/sub, messages are only received by subscribers present at the time of the publication
- □ A durable subscriber is one that wants to receive all messages published on a topic, even those published when the subscriber is inactive, i.e., when it has no associated subscriber object
- □ In order to tell the message broker what messages are still to be received by a durable subscriber, the latter must provide a unique name

```
...
TopicSubscriber subscriber= session.createDurableSubscriber(topic, "Bob");
session.unsubscribe("Bob");
...
```

Transactions | Reminder



Transactions with JMS (1)

- A transaction allows a group of messages to be managed as a single unit of work
- In JMS, transactions are managed by the session
- The decision to have a session transacted must be taken at creation time:

```
...
Session session= connection.createSession(true, Session.AUTO_ACKNOWLEDGE);
...
```

- As soon as messages are sent or received via a transacted session, the transaction starts, i.e., sent/received messages are grouped as a one unit of work

Transactions with JMS (2)

- ❑ When method `commit()` or method `rollback()` is called on the transacted session, the current transaction terminates and a new one is started
- ❑ Transaction termination affects producers and consumers in the following manner:

Producer - what happens to messages sent during the transaction?

Commit all grouped messages are effectively sent

Rollback all grouped messages are disposed

Consumer - what happens to messages received during the transaction?

Commit all grouped messages are disposed

Rollback all grouped messages are recovered, i.e., they might be received again in the next transaction