Component Middleware

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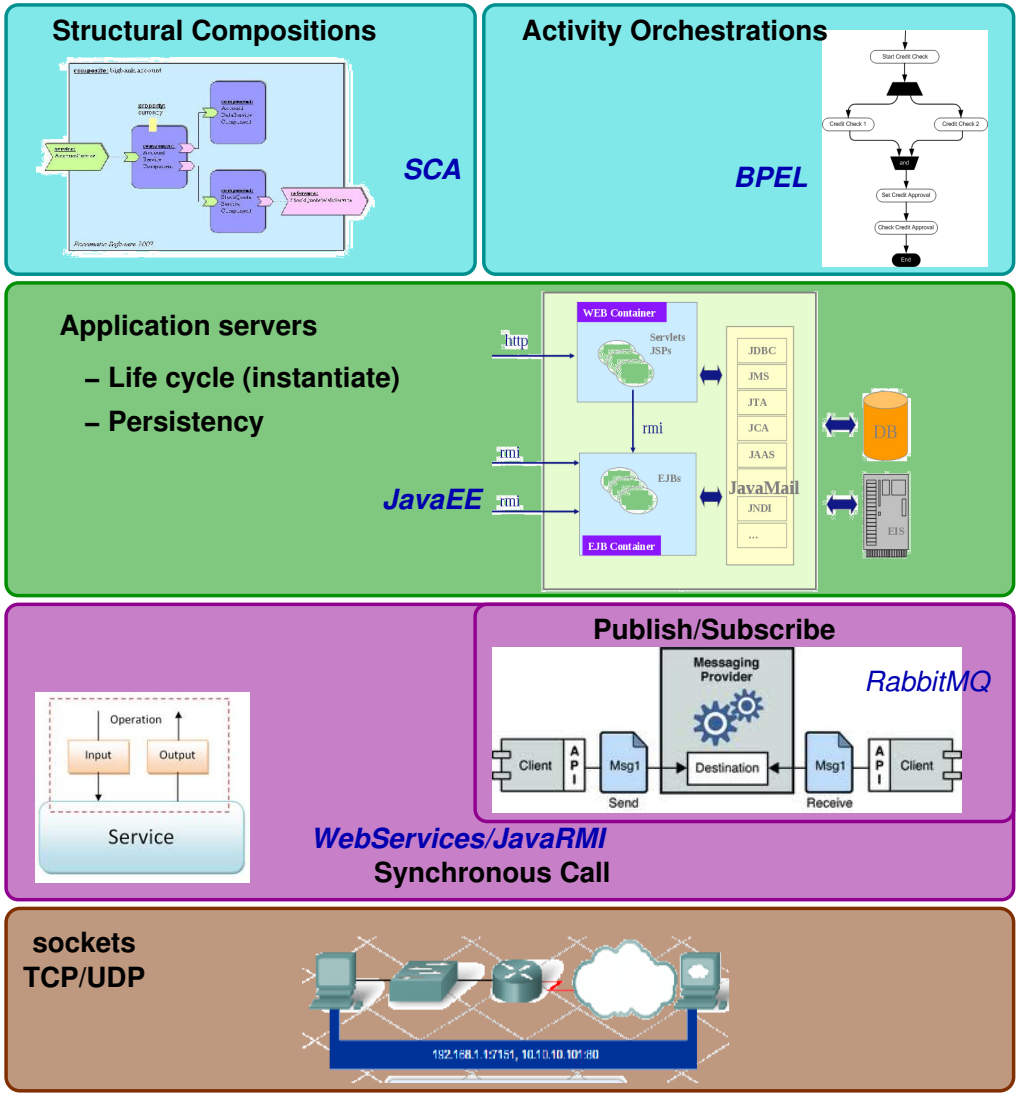
Foreword


Structural Compositions
SCA
Activity Orchestrations
BPEL
Application servers
– Life cycle (instantiate)
– Persistency
JavaEE
WEB Container
Servlets
JSPs
EJBs
EJB Container
http
rmi
JDBC
JMS
JTA
JCA
JAAS
JavaMail
JNDI
DB
EIS
Publish/Subscribe
RabbitMQ
Messaging Provider
Client
API
Msg1
Send
Destination
Receive
Operation
Input
Output
Service
WebServices/JavaRMI
Synchronous Call
sockets
TCP/UDP

Outline

1 Introduction

1.1 Limits of object-oriented programming

- A lot of tasks must be done manually
  - Object instantiation
  - Service invocation via direct access to object reference + explicit method call
  - Definition of dependencies between classes
  - Almost no tool for application deployment (installation of executable files on the various sites)
- Applications structure difficult to understand (= set of files)
- Difficult to modify or extend an existing application
  - communication mode
  - modification of system/technical services
  - assembly
- Building an application using black-box classes makes it difficult
  - to introduce new references to other objects
  - to inherit from other classes

1.2 Motivations for Component Based Development

Programming in the large versus programming in the small

- Applications are built by assembling existing components
- Notion of connector: Components are connected with one another defining a software architecture
- Formalism to describe interactions between components
- Formalism to describe the deployment of components
- Separation of concerns: Separate functional from non-functional or extra-functional aspects to allow for more reusability
- Focus on application concerns (functional) rather than technical problems (extra-functional)

1.3 What is a component ?

No consensus on a unique definition. Each platform has its own definition !

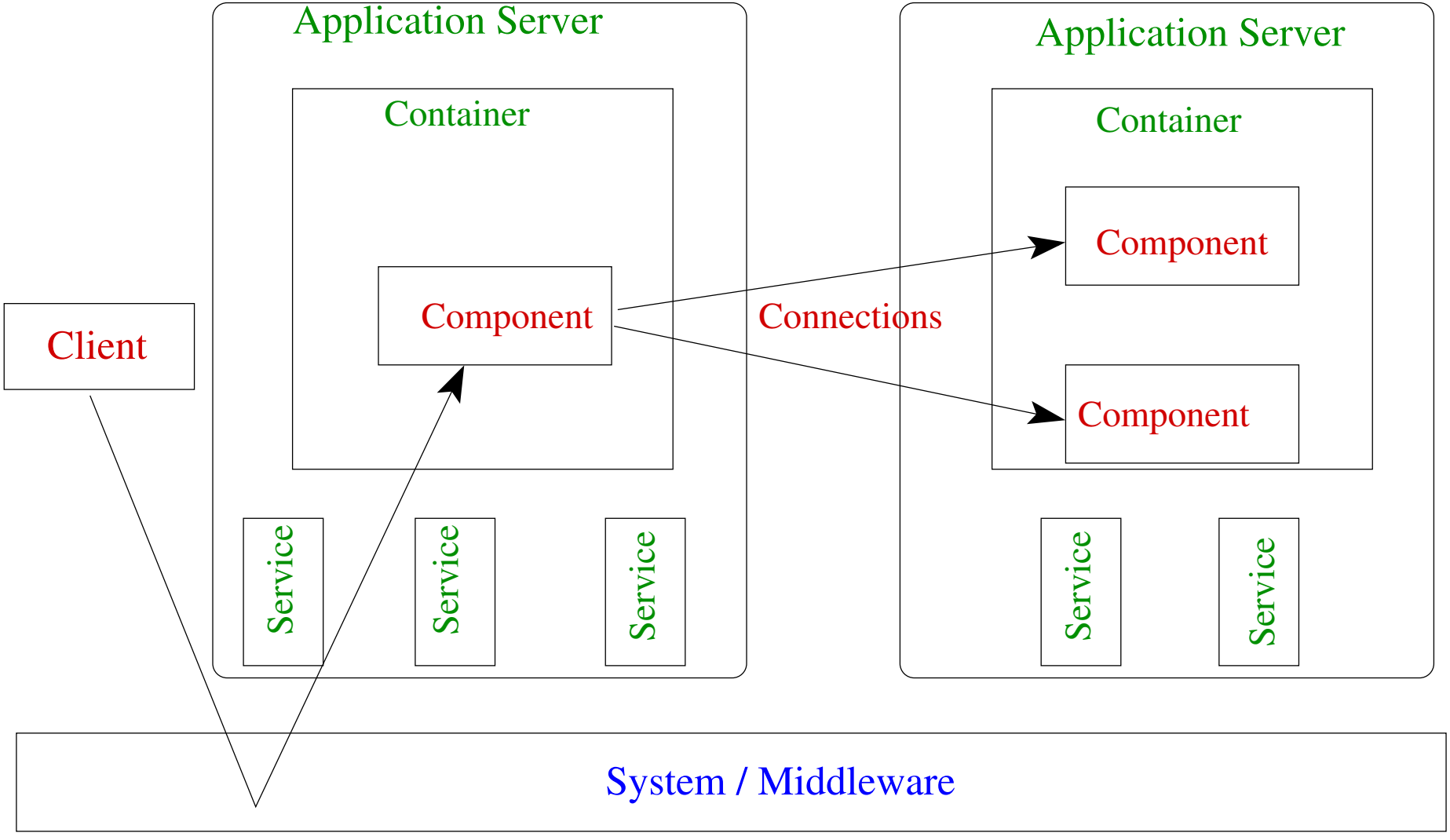
- According to [1]:
  - A unit of composition with contractually specified interfaces and explicit context dependencies only. A software component can be deployed independently and is subject to composition by third parties.
  - Context dependencies: required interfaces and execution environments (platforms)
  - A binary unit - not source code!
    - This means that a class library is not a component
  - No persistent state - a component is not an instance of itself
    - Much like classes are not objects

1.3.1 Characterization of a component

A software module

- That is a contractual specification by exporting some attributes, properties and methods
- That provides interfaces to other components and requires some interfaces from other components
- That has no persistent state
- That has pre- and post-conditions
- That is configurable by setting properties
- That is independently deployable and composable

1.4 Runtime environment of a component I



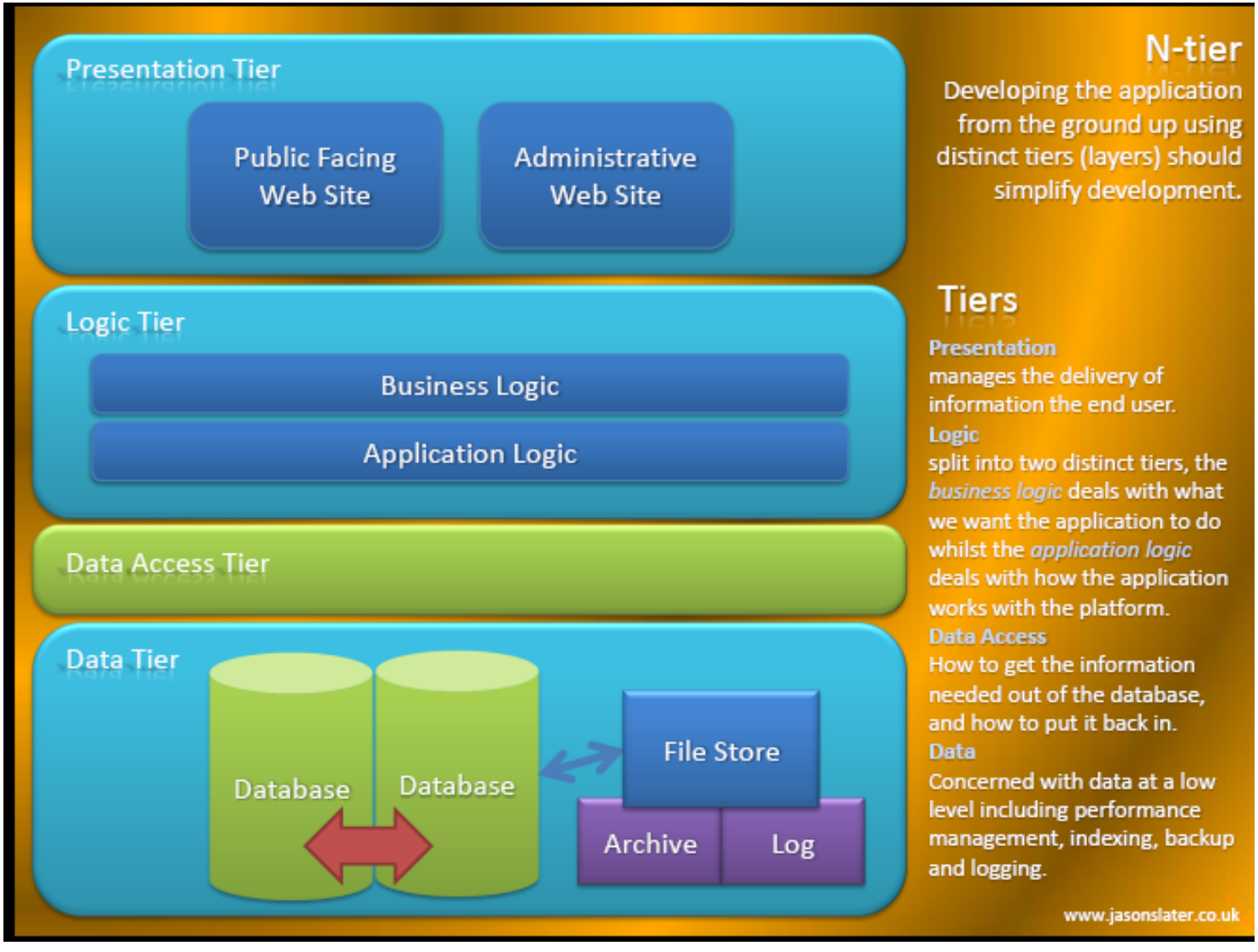
1.4 Runtime environment of a component II

- Container
  - Encapsulates components
  - Provides system/technical services
  - Maintains connections between components
  - Deals with invocations and events
- Application server
  - Runtime environment for containers
  - mediator between the containers and the system/middleware

1.4.1 Technical services

- Resource Management
  - Ressource pooling
  - Activation/deactivation mechanism
- Naming and directory
- Synchronous/asynchronous communication
- Transaction
- Persistence
- Security

1.5 Multi-tier Architecture



1.5.1 The 6 roles in component development I

1. Component Provider

- Develops components
- Provides component metadata: structural information (component logical name, transaction demarcation, persistence requirements...) and component external dependencies
- Metadata may be expressed in annotations or in an XML deployment descriptor

2. Application Assembler

- Assembles application components into a single deployable unit
- Defines security roles for application clients, method permissions...

1.5.1 The 6 roles in component development II

3. Deployer

- Uses information provided by the component provider and the assembler
- Resolves component dependencies
- Deploys the application in an operational environment including a container and a server

4. Server Provider

- Responsible of distributed transaction management, distributed objets management, low-level system tasks
- OS vendor, Middleware vendor or DBMS vendor

1.5.1 The 6 roles in component development III

5. Container Provider

- Provides deployment tools and runtime support for components
- Focus on the development of a scalable, secure, transaction-enabled container

6. System Administrator

- Responsible for the configuration and administration of the enterprise's computing and networking infrastructure
- Oversees the well-being of the deployed applications
- Monitors the log of non-application exceptions and errors logged by the container
- Takes actions to correct the problems caused by exceptions and errors

1.6 Technologies for component middleware I

- Entreprise Java Beans
  - Supported by Eclipse Foundation, as part of Eclipse Enterprise for Java (EE4J) initiative `https://projects.eclipse.org/projects/ee4j`
  - Initially developed by Sun Microsystems in 2005, then sponsored by Oracle until 2019
  - Application server: Jakarta EE 9 `https://jakarta.ee/specifications/platform/9.1/`
  - ONE LANGUAGE, MANY PLATFORMS
- .NET
  - Supported by Microsoft `https://docs.microsoft.com/en-us/dotnet/`
  - MANY LANGUAGES (C#, F#, or Visual Basic), MANY PLATFORMS (Initially only on Windows)

1.6 Technologies for component middleware II

- Spring Framework
  - Supported by Spring `https://spring.io/projects/spring-framework`
  - Relies on dependency injection and aspects
  - Lightweight application server enriched with a wide ecosystem

- CORBA Component Model (CCM)
  - Supported by the Object Management Group (OMG) www.omg.org
  - EJB specification can be seen as a subset of CCM specification
  - MANY LANGUAGES, MANY PLATFORMS

2 Overview of EJB Technology

2.1 What is EJB ?

- Enterprise Java Beans
- Java component model for distributed enterprise applications, released by Sun in 1998
- EJB 3.0 specification (2006) - JSR 220
- EJB 3.1 specification (2009) - JSR 318
- EJB 3.2 specification (2013) - JSR 345
- Definitions [2, 3]:
  - EJB are standard server-side components for component transaction monitors (CTM)
  - EJB technology defines a model for the development of reusable Java server components that encapsulate the business logic of an application

2.1.1 The Java Community Process (JCP)

- www.jcp.org
- International developer community whose charter is to develop and evolve Java technology
  - specifications,
  - reference implementations,
  - and technology compatibility kits.
- Company, organization, or individual can be member

2.2 EJB Container

- Runtime environment for creation and lifecycle management of bean instances
- Gives access to a set of standardized services to beans
- Provides a context with:
  - Configuration properties
  - References to other components
  - References to technical services

2.2.1 EJB Container — Provided services I

- Includes many Java technologies, that can be used independently of EJB
- Java 2 Platform, Standard Edition (J2SE) APIs
  - RMI-IIOP - remote method invocation based on CORBA Interoperable Inter-ORB Protocol
  - JDBC (Java DataBase Connectivity)
  - JSP (Java Server Pages) — Web clients
  - JAXP (Java API for XML Processing)
  - Java IDL — adds CORBA capability to the Java platform

2.2.1 EJB Container — Provided services II

- Current services are frozen
- Research initiatives (s.a. Objectweb JOnAS) provide extensible containers with pluggable services

- EJB APIs (javax package, now jakarta package in Eclipse implementation), including Java Persistence (JPA)
- Asynchronous communication: Java Messaging Service (JMS), JavaMail
- Connector
- Transaction: UserTransaction interface of JTA, Java Transaction Service (JTS) (specification based on CORBA Object Transaction Service)
- Security: Java Security API
- Web Services: JAX-RPC, JAX-WS, JAX-RS

2.2.1 EJB Container — Provided services III

- Lifecycle service — Java Naming and Directory Interface
  - Instances passivation
    - Temporary saving of a bean when container needs memory
  - Instances pooling
    - For performance reasons, the container can instantiate less beans than there are clients
    - Then several clients share the same bean
    - Possible only for beans without instance variables
  - Pooling of connections to the Database
    - All the beans of a server share a pool of connections to the DB
    - Connections remain open and are used by beans

2.3 Java EE at a glance

- Java Platform, Enterprise Edition
- Application server technology based on EJBs
- Targets scalability, accessibility, security, integrity, and other requirements of enterprise-class applications
- Java API for RESTful Web Services (JAX-RS)
- Contexts and Dependency Injection (CDI)
- Bean Validation: same set of validations can be shared by all layers of an application
- Java Server Faces (JSF) supports Ajax

2.3.1 Families of Java EE APIs

Web Application

Servlet, WebSocket,
JavaServer Faces,
JSON-P, JSON-B, etc.

Enterprise Application

EJB, CDI, BV, JPA,
Batch, JMS, JTA, JavaMail,
JCA, Concurrency, etc.

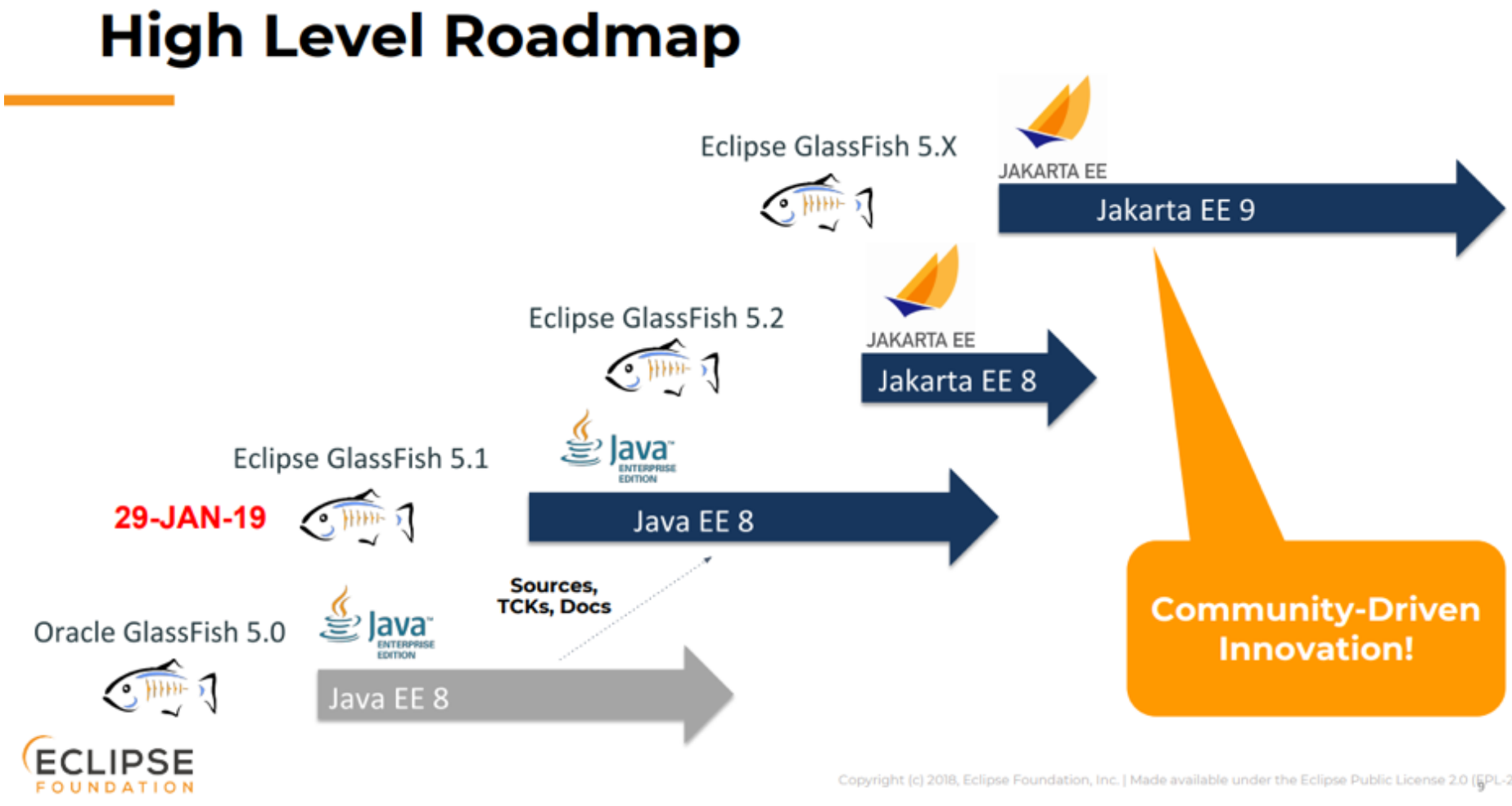
Web Services

JAX-RS, JAX-WS, SAAJ,
JAXP, JAXB, StAX, etc

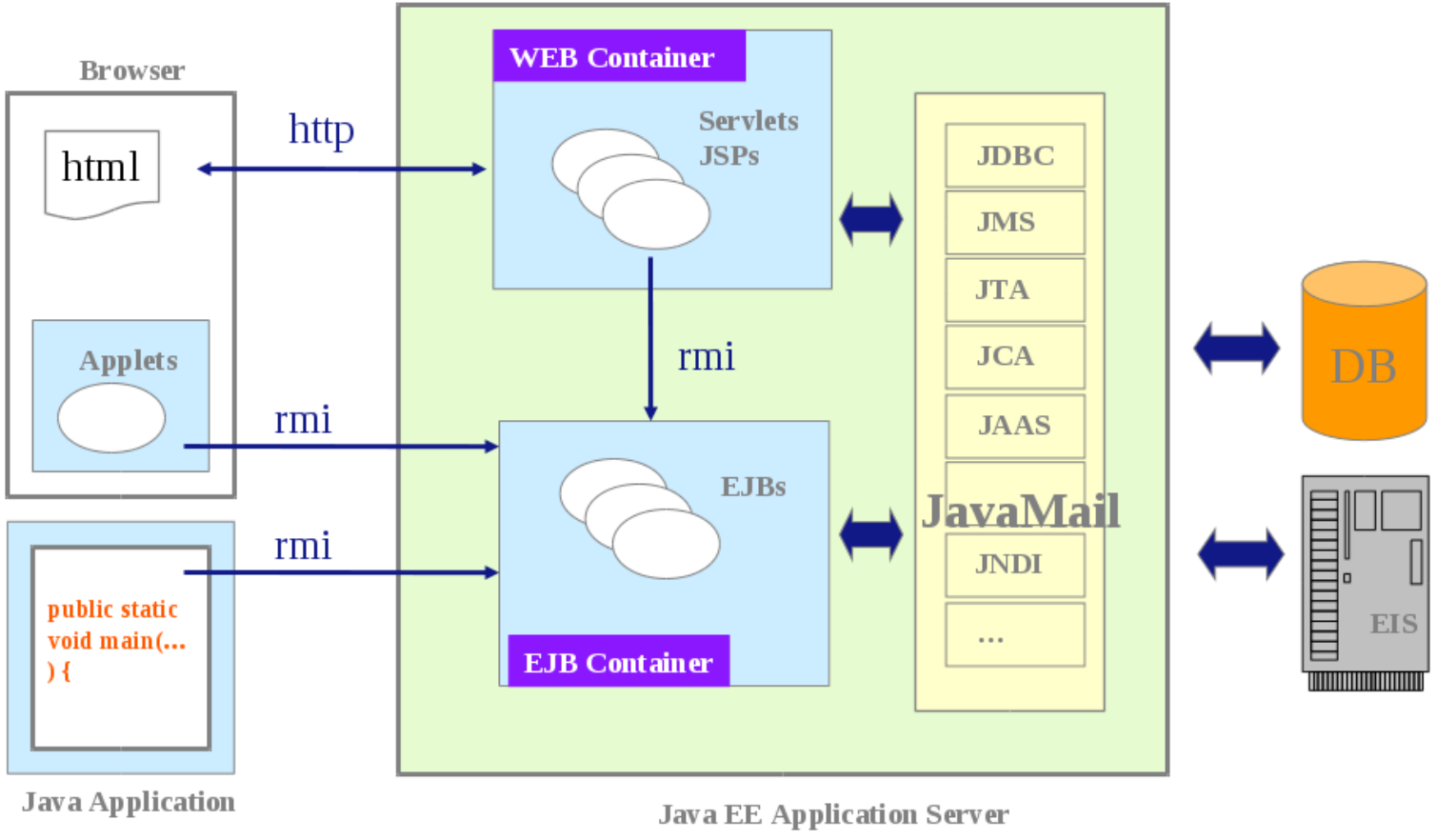
Management / Security

JMX, Management,
Security, JACC, JASPIC, etc.

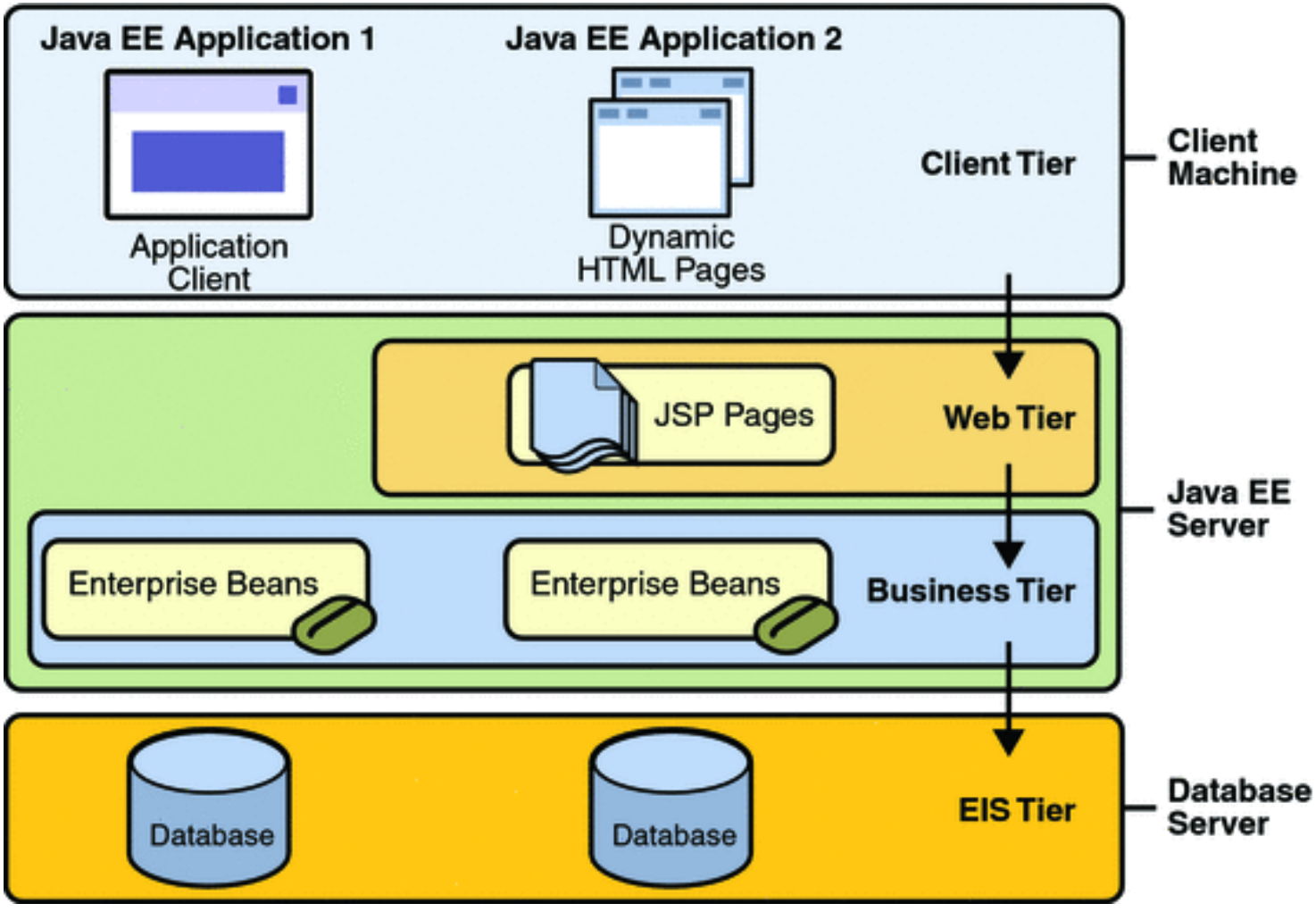
2.3.2 From Java EE to Jakarta EE



2.4 Java EE Architecture



2.4.1 Java EE — 3-tier Architecture I



2.4.1 Java EE — 3-tier Architecture II

- Client
  - Heavy weight client — Java application (or possibly other language)
  - Light weight client — Web navigator
- Application Server
  - Reference implementation: GlassFish (Eclipse Foundation)
  - Commercial products: WebSphere (IBM), WebLogic (BEA)...
  - Open source distributions: jBoss, JOnAS (Objectweb), Geronimo, OpenEJB...
- DBMS (DataBase Management System)
  - Provide storage support for application data
  - Mostly using a relational DBMS (Oracle, SQL Server, PostGreSQL...)

2.5 EJB types I

- Entity Beans
  - Model real-world objects (e.g. Owner, Account) that exist in persistent storage (DBMS or other storage accessible using JDBC [Java Database Connectivity])
  - Persistent state is maintained through all method and server invocations
  - Identified by a primary key
  - Object-Relational mapping
  - Implementation using JPA (Java Persistence API)

2.5 EJB types II

- Session Beans
  - Model client activities
  - Perform a task or process, and are therefore transient
  - Do not exist outside a client session
  - No persistent state
  - Two kinds of session beans: stateless and stateful
  - Manage actions that may cross entity beans or go outside the concern of an entity bean
    - e.g. Teller may authenticate the user and transfer funds between accounts
    - e.g. Statement may include transactions from multiple accounts
- Message-Driven Beans (since EJB 2.0)
  - Listener processing messages asynchronously
  - Only a bean class. No interface.

2.5.1 Main EJB3 Annotations

- @EJB: Denotes a reference to an EJB business interface or home interface.
- @PersistenceContext: Used to express a dependency on an EntityManager.
- @Stateful: Used to annotate a class as a stateful session bean component.
- @Stateless: Used to annotate a class as a stateless session bean component.
- @Remote: Applied to the session bean class or remote business interface to designate a remote interface of the bean.
- @MessageDriven: Specifies a message-driven bean. A message-driven bean is a message consumer that can be called by its container.

Stateless Session Bean — Calculator Example

- @TransactionManagement: Declares whether a bean will have container-managed or bean-managed transactions.
- @TransactionAttribute: Applies a transaction attribute to all methods of a business interface or to individual business methods on a bean class.

  Can be specified on the bean class or on methods of the class that are methods of the business interface.

  Possible values:

  - *MANDATORY*
  - *REQUIRED* (default)
  - *REQUIRES_NEW*
  - *SUPPORTS*
  - *NOT_SUPPORTED*
  - *NEVER*

- @WebService: Used on a class or an interface to define a Web service.
- @WebMethod: Indicates whether the method is part or not of the interface

2.5.2 Bean development

- An EJB has a remote interface to be accessed by clients
  - Describes the provided services (methods)
  - No longer required for session beans
- Possibly an EJB may provide an interface for local access
  - Describe the provided services offered to local clients
  - Same as remote services, or different ones (enables optimisation)
  - Can only be used within the same JVM as the EJB
  - Gets compiled by the ejb compiler to create local stubs for container to interpose transactions, access control, etc. on invocations.
- An implementation class

2.5.3 Interfaces

- Remote Interface *@Remote*
  - Interface presented to the outside world (contract definition) specifying the business methods provided by the bean
  - Gets compiled by the ejb compiler to create RMI stubs and skeletons
  - Stubs are used by RMI to translate a method invocation to wire format
  - Skeletons are used by RMI to translate wire format to a method invocation
- NB: A client application never interacts with a bean class directly; It uses the methods of the bean's interface.

2.6 Session Beans

- Model business process being performed by a single client involving one or more entity beans
- Life duration linked to client's one
- Two types of session bean
  - Stateful session bean
    - maintains the conversational state between a client and the session bean
    - may be serialized out and passivated to conserve system resources
    - will be serialized in and activated when needed in the future
    - e.g. Teller session bean logged into and transfers funds between accounts
  - Stateless session bean
    - does not maintain conversational state
    - to be used for generic tasks, to read persistent data
    - e.g. Statement that is given a list of accounts or an owner to generate a textual report for
    - consumes the least amount of resources among all the bean types

Stateless Session Bean — Calculator Example

- Calculator session bean: Simple calculator with 4 operations
- Implementation code:
  - Remote business interface (Calculator)
  - Session bean class (CalculatorBean)

```
import jakarta.ejb.Remote;   // Formerly javax package

@Remote
public interface Calculator {
     public double add(double n1, double n2);
     public double sub(double n1, double n2);
     public double mul(double n1, double n2);
     public double div(double n1, double n2);
}
```

Stateless Session Bean — Calculator Example - Implementation class

Possible to name a bean: @*Stateless*(*name* = "*myCalculator*")

```
import jakarta.ejb.Stateless;

@Stateless(name = "myCalculator")
public class CalculatorBean implements Calculator {
     public double add(double n1, double n2) {return n1+n2;}
     public double sub(double n1, double n2) {return n1-n2;}
     public double mul(double n1, double n2) {return n1*n2;}
     public double div(double n1, double n2) {return n1/n2;}
}
```

Stateless Session Bean — Calculator Example - Client side

2 ways to get the reference of the business interface

- dependency injection:

```
@EJB   Calculator myCalc;
```

- look-up in JNDI directory using the `lookup` method povided by `EJBContext` interface and the bean interface name

```
import javax.naming.*; // NB: No change to this package name
public class myClient {
     public static void main(String args[]) throws Exception {
          Context myContext = new InitialContext();
          Calculator myCalc =
     (Calculator) myContext.lookup("myCalculator");
          double result = myCalc.mul(2,4);
}
}
```

Stateless Session Bean — No-interface view

- When a bean does not have a remote interface, possible to access directly to the bean implementation class via the no-interface view
- But never use the new operator to acquire the reference
- A no-interface view is a variant of a local view that exposes the non-static public methods of the bean class
- 2 ways to get the reference of the no-interface view of a session bean
  - dependency injection:

```
@EJB   CalculatorBean myCalc;
```

  - look-up in JNDI directory using the `lookup` method povided by `EJBContext` interface and the bean interface name

```
@Resource SessionContext myContext;
...
CalculatorBean myCalc =
       (CalculatorBean) myContext.lookup("myCalculator");
```

Stateful Session Bean — Cart Example

- Cart session bean: represents a shopping cart in an online bookstore.
- The bean's client can add a book to the cart, remove a book, or retrieve the cart's contents.
- Implementation code:
  - Remote business interface (Cart)
  - Session bean class (CartBean)

Stateful Session Bean — Cart Example — Interface

```
import java.util.List;
import jakarta.ejb.Remote;

@Remote
public interface Cart {
    public void initialize(String person) throws BookException;
    public void initialize(String person, String id)
        throws BookException;
    public void addBook(String title);
    public void removeBook(String title) throws BookException;
    public List<String> getContents();
    public void remove();
}
```

Stateful Session Bean — Cart Example — Implementation class

```
import java.util.ArrayList;
import java.util.List;
import jakarta.ejb.Remove;
import jakarta.ejb.Stateful;

@Stateful
public class CartBean implements Cart {
    String customerName;
    String customerId;
    List<String> contents;
    public void initialize(String person) throws BookException {
        if (person == null) {
            throw new BookException("Null person not allowed.");
        } else { customerName = person; }
        customerId = "0";
        contents = new ArrayList<String>();
    }
```

Stateful Session Bean — Cart Example — Implementation class (cont.)

```
...

    public void addBook(String title) { contents.add(title); }

    public void removeBook(String title) throws BookException {
        boolean result = contents.remove(title);
        if (result == false) {
            throw new BookException(title + " not in cart.");
        }
    }
    public List<String> getContents() { return contents; }

    @Remove // The container will remove the bean
    public void remove() { contents = null;  }
}
```

Stateful Session Bean — Cart Example — Client side

From the client's perspective, the business methods appear to run locally, but they actually run remotely in the session bean.

```
cart.create("Duke DeEarl");
...
cart.addBook("Bel Canto");
 ...
List<String> bookList = cart.getContents();
...
cart.removeBook("Gravity's Rainbow");
```

2.6.1 Asynchronous Method Invocation

- Control returned to the client by the container before the method is invoked on the session bean instance
- Use Java SE concurrency API to retrieve the result, cancel the invocation, or check for exceptions
- Useful for long-running operations or to improve application response time
- The result implements java.util.concurrent.Future <V > interface, "V" is the result value type

Asynchronous Method Invocation — Session bean side

- Annotate a method or a class with @Asynchronous (jakarta.ejb.Asynchronous)
- Asynchronous methods return either void or an implementation of the Future <V >interface
- Result is returned to the container, not directly to the client

```
@Asynchronous
public Future<String> processPayment(Order order)
throws PaymentException {
    ...
    String status = ...;
    return new AsyncResult<String>(status);
}
```

Asynchronous Method Invocation — Session bean side

- Check whether the client requested the invocation to be cancelled with method jakarta.ejb.SessionContext.wasCancelled

```
@Asynchronous
public Future<String> processPayment(Order order) throws PaymentExcep
    ...
    if (SessionContext.wasCancelled()) {
        // clean up
    } else {
        // process the payment
    }
    ...
}
```

2.6.2 Asynchronous Method Invocation — Client side

- Retrieve result using Future <V >.get() methods (synchronous method)
- Use Future <V >.isDone to check wether processing has completed
- Call Future <V >.cancel(boolean mayInterruptIfRunning) to cancel the method invocation
- Method Future <V >.isCancelled returns true if the invocation was cancelled

2.7 Entity Beans I

- Represent a business object in a persistent storage mechanism
- Can be shared by multiple clients
- Can be linked to other entity beans (like relations in a relational DBMS)
- Primary key required
  - Defined using @*Id* annotation,
  - Possible key types (or of the properties or fields of a composite primary key): java primitive types (and associated wrapper classes), String, Date

2.7 Entity Beans II

- Object/relational mapping annotations to map entities and entity relationships to relational tables
  - Each EB class is mapped to one relational table
  - table name = class name by default
  - or use annotation @*Table*(*name* = "...")

- 2 exclusive modes for the definition of table columns
  - *property-based access*: annotate getter methods
  - *field-based access*: annotate attributes

Entity Bean — Example

```
@Entity
public class Book implements Serializable {
    private String bookId;
    private String author;
    private String title;
    public Book() { }
    public Book(String author, String title) {
        this.author = author;
        this.title = title;                    }
    @Id
    @GeneratedValue(strategy=GenerationType.AUTO)
    public String getBookId() { return this.bookId;          }

    public String getTitle() { return this.title;            }
    public void setTitle(String title) { this.title=title; }
    ...
}
```

2.7.1 Multiplicities in Entity Relationships

1. One-to-one: Each entity instance is related to a single instance of another entity.
2. One-to-many: An entity instance can be related to multiple instances of the other entities.
3. Many-to-one: Multiple instances of an entity can be related to a single instance of the other entity.
4. Many-to-many: The entity instances can be related to multiple instances of each other.

Multiplicities in Entity Relationships — One-ToMany example

```
@Entity
public class Author {
private long id;
private String name;
private Collection<Book> books;

public Author() { books = new ArrayList<Book>(); }
public Author(String name) {this.name = name; }

@OneToMany
public Collection<Book> getBooks() {return books; }

public void addBook(String title) {
Book aBook = new Book(this.name, title);
getBooks().add(aBook);
}  }
```

2.7.2 Persistence management mode

- Persistence can be managed in two ways:
  - Container-managed (CMP)
    - Simplest to develop
    - Bean code contains no database access calls
  - Bean-managed (BMP)
    - The client is required to explicitly write persistence logic by providing implementation methods for Home interface
    - More flexibility in how state is managed between the bean instance and the database
    - Used when deployment tools are inadequate

2.7.3 Entity Manager

- Entry point of the persistence service
  - Creates and removes persistent entity instances
  - Finds entities by the entity's primary key
  - Allows queries to be run on entities

- Associated with a persistence context
  - Defines the scope under which particular entity instances are created, persisted and removed

Container-Managed Entity Manager

- Propagation of the persistence context automatically to all application components that use the EntityManager instance within a single JTA (Java Transaction Architecture) transaction.
- To obtain an EntityManager instance, *inject* the entity manager into the application component:

```
@PersistenceContext
EntityManager em;
```

Application-Managed Entity Manager

- Each EntityManager creates a new, isolated persistence context
- Life cycle of EntityManager instances managed by the application: The EntityManager and its associated persistence context are created and destroyed explicitly by the application.
- To obtain an EntityManager instance, first get an EntityManagerFactory instance:

```
@PersistenceUnit
EntityManagerFactory emf;
```

- Then, obtain an EntityManager from the EntityManagerFactory instance:

```
EntityManager em = emf.createEntityManager();
```

How to use the Entity Manager — Example

```
import jakarta.ejb.*;
import jakarta.persistence.*;
public class BookDBAO {

  @PersistenceContext
  private EntityManager em;

  public void init() {
    Book b1 = new Book("Charles Beaudelaire","Les Fleurs du Mal");
    Book b2 = new Book("Jules Verne","Voyage au centre de la Terre");
    em.persist(b1);
    em.persist(b2);
  }
}
```

2.7.4 Persistence Unit — persistence.xml file

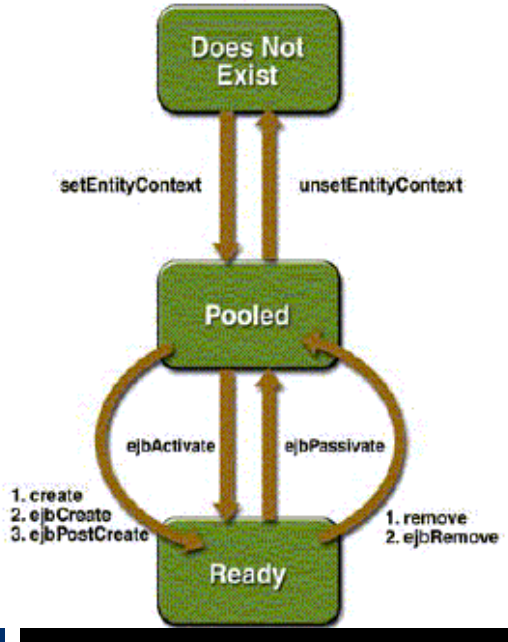
- Defines the set of all entity classes managed by EntityManager instances in an application
- Represents the data contained within a single data store
- Packaged with the application archive file
- XML elements:
  - *persistence* element: global schema, includes a persistence-unit element
  - *persistence-unit* element: name of a persistence unit and transaction type
  - optional *description* element
  - *jta-data-source* element: specifies the global JNDI name of the JTA data source

Persistence Unit — persistence.xml file — Example

```
<persistence>
    <persistence-unit name="OrderManagement">
        <description>This unit manages orders and customers.
            It does not rely on any vendor-specific features and can
            therefore be deployed to any persistence provider.
        </description>
        <jta-data-source>jdbc/MyOrderDB</jta-data-source>
        <jar-file>MyOrderApp.jar</jar-file>
        <class>com.widgets.Order</class>
        <class>com.widgets.Customer</class>
    </persistence-unit>
</persistence>
```

2.7.5 Entity Beans lifecycle

- The container manages a pool of entity bean instances.
- After a bean is instantiated, it is put in the pool. It is not associated to any data but it is ready for use.
- The methods *create* and *remove* are called by the client (via a session bean).
- All other methods are implemented by the entity bean and called by the container.



2.8 Transaction Service I

- Controls concurrent accesses to data by multiple programs
- In case of a system failure, transactions make sure that after recovery the data will be in a consistent state
- Guarantees ACID properties for transactions
  - Atomicity: Either all operations in the transaction complete successfully or none.
  - Consistency: The database is always in a valid state, so that two users see the same value for any given data item.
  - Isolation: Concurrent transactions give the same result as if they were performed in isolation.
  - Durability: The content of the database is stored on stable storage in a persistent way and will not be lost.
- Fully integrated within the EJB server
- Main advantage compared to the CORBA middleware

2.8 Transaction Service II

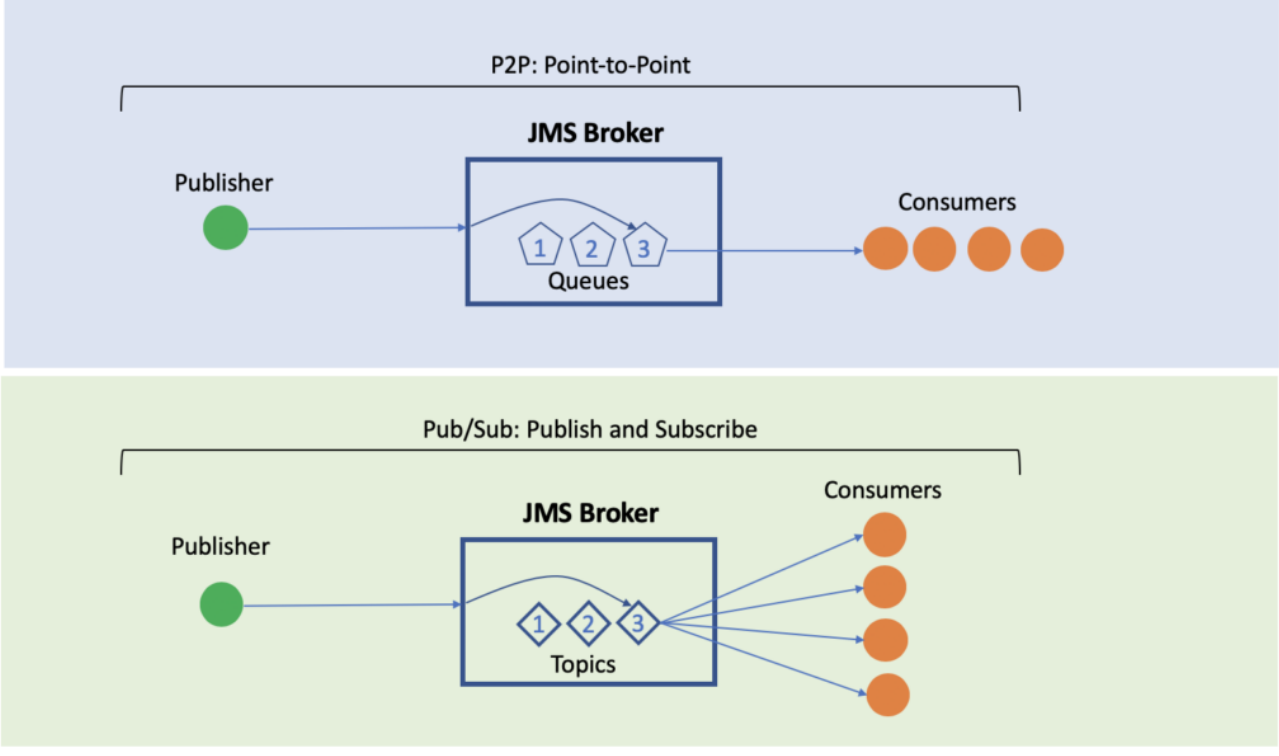
- Specifies standard Java interfaces between a transaction manager and the parties involved in a distributed transaction system
  - Resource manager
  - Application server
  - Transactional applications
- Transaction manager
  - Decides whether to commit or rollback at the end of the transaction in a distributed system and coordinates various resource managers
- Resource manager
  - Responsible for controlling the access to common resources in the distributed system

2.9 Message-driven Beans (MDB)

- Can implement any messaging type
- Handle asynchronous messages
- Useful for non-blocking calls
- Producer/consumer concept
- Stateless — state is lost between 2 messages processing
- All instances of a same MDB class are equivalent
- Can process messages from several clients
- No remote interface
- The container delivers messages to a MDB using the onMessage() method
- Same lifecyle as a stateless session bean

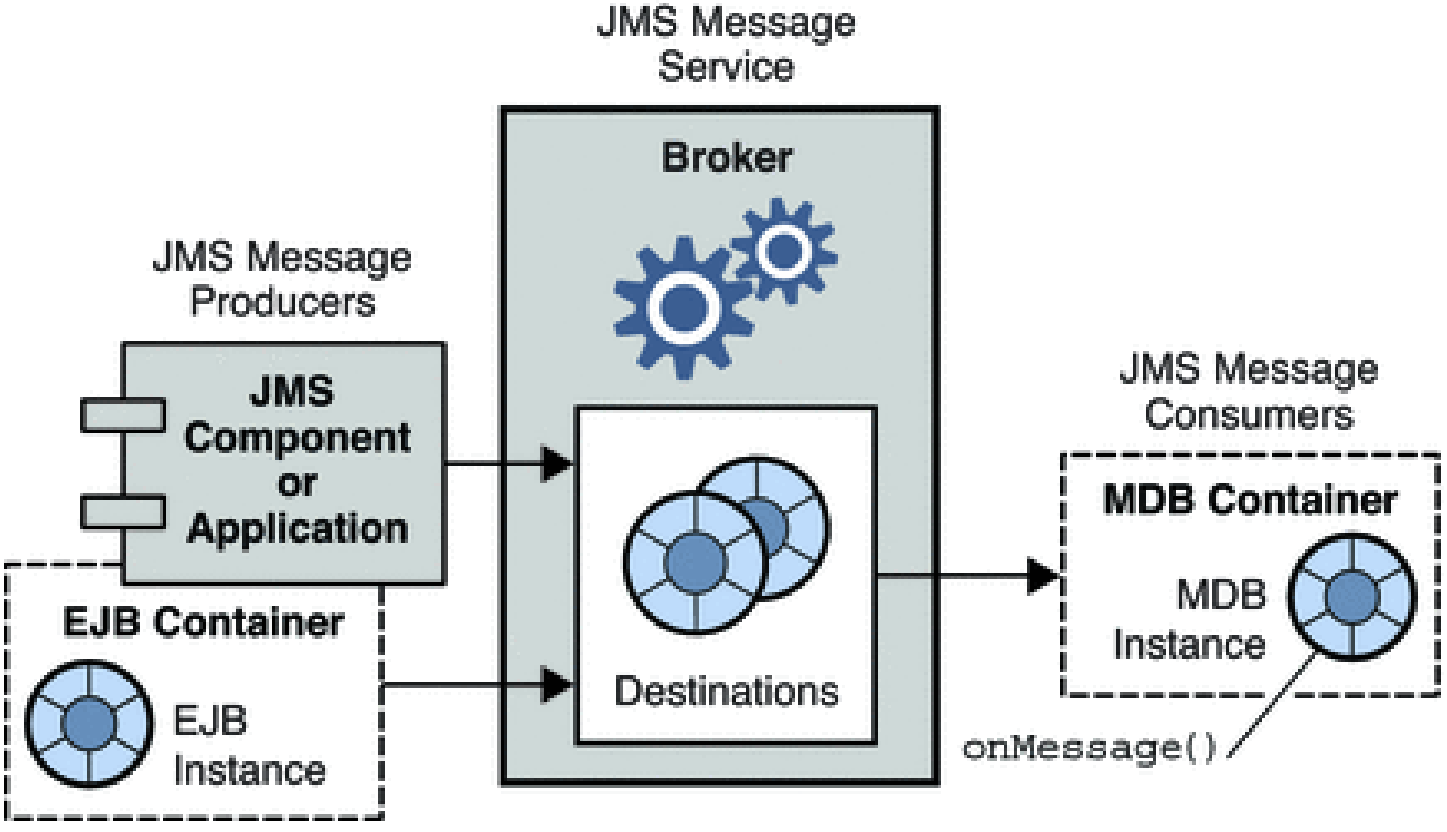
Message-driven Beans types (MDB)

- 2 communication modes
  - Queue: 1 to 1 or n to 1
  - Topic: 1 to n or n to m

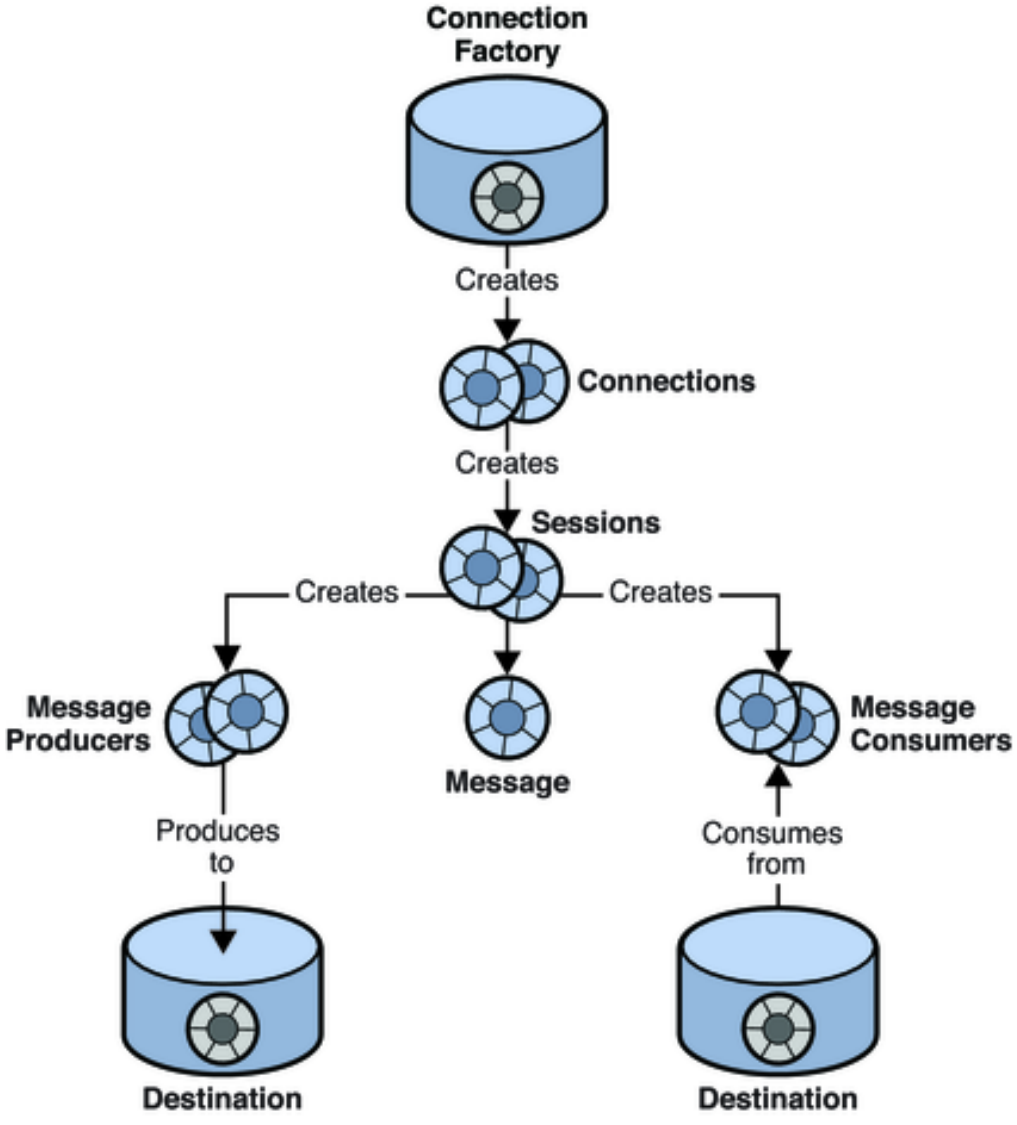


JMS architecture

The Java Message service provides MDB management



MDB development



MDB development

1. Create a connection using a ConnectionFactory
2. Create a session (possibly several sessions per connection):
   - period of time for sending messages on a queue or topic
   - may be transactional
3. Create a message
4. Send the message
5. Close the session
6. Close the connection

MDB development — Producer example

```
public class myProducer {
@Resource(mappedName="jms/ConnectionFactory")
private static ConnectionFactory connectionFactory;
@Resource(mappedName="jms/Queue")
private static Queue queue;
public void produce() {
/* 1 */ Connection connection = connectionFactory.createConnection()
/* 2 */ Session session = connection.createSession(false,
Session.AUTO_ACKNOWLEDGE);
MessageProducer messageProducer = session.createProducer(queue);
/* 3 */ TextMessage message = session.createTextMessage();
message.setText("This is a message ");
/* 4 */ messageProducer.send(message);
/* 5 */ session.close();
/* 6 */ connection.close();
} } }
```

MDB development — Consumer example

```
@MessageDriven(mappedName="jms/Queue")
public class SimpleMessageBean implements MessageListener {

public void onMessage(Message m) {
TextMessage message = (TextMessage) m;
message.getText();

...
}
}
```

3 References

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