Component Middleware

Sophie Chabridon

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2 Introduction

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2.1 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
2.2 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)
2.3 What is a component?

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

- According to [Szyperski, 1998]:
  - 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
2.4 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
2.5 Runtime environment of a component
2.5.1 Runtime environment of a component (cont.)

- **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
2.5.2 Technical services

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

N-tier
Developing the application from the ground up using distinct tiers (layers) should simplify development.

Tiers
Presentation
manages the delivery of information to the end user.
Logic
split into two distinct tiers, the business logic deals with what we want the application to do whilst the application logic deals with how the application works with the platform.
Data Access
How to get the information needed out of the database, and how to put it back in.
Data
Concerned with data at a low level including performance management, indexing, backup and logging.

www.jasonslater.co.uk
2.7 The 6 Roles in Component Development

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...

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
2.7.1 The 6 Roles in Component Development (cont.)

4. **Server Provider**
   - Responsible of distributed transaction management, distributed objects management, low-level system tasks
   - OS vendor, Middleware vendor or DBMS vendor

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
2.8 Main component middleware

- **Entreprise Java Beans**
  - Supported by Oracle
  - Application server: Java EE
    - [http://www.oracle.com/technetwork/java/javaee](http://www.oracle.com/technetwork/java/javaee)
  - ONE LANGUAGE, MANY PLATFORMS

- **.NET**
  - Supported by Microsoft
    - [msdn.microsoft.com/net](http://msdn.microsoft.com/net)
  - MANY LANGUAGES, ONE PLATFORM (Windows)

- **Spring Framework**
  - Supported by Spring
    - [http://projects.spring.io/spring-framework/](http://projects.spring.io/spring-framework/)
  - Relies on dependency injection and aspects
  - Lightweight application server enriched with a rich ecosystem

- **CORBA Component Model (CCM)**
  - Supported by the Object Management Group (OMG)
    - [www.omg.org](http://www.omg.org)
  - Extends the EJB model
  - MANY LANGUAGES, MANY PLATFORMS
♦ Vendor-neutral specification
3 Overview of EJB Technology

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3.1 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
  - 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
3.2 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
3.3 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
3.3.1 EJB Container — Provided services

- Includes many Java technologies, that can be used independently of EJB
- Java 2 Platform, Standard Edition v8 (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
3.3.2 EJB Container — Provided services (cont.)

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

- EJB 3.2 APIs (javax package), including Java Persistence (JPA 2.1)
- Asynchronous communication: Java Messaging Service (JMS 2.0), JavaMail 1.5
- Connector
- Transaction: UserTransaction interface of JTA 1.2, Java Transaction Service (JTS) (specification based on CORBA Object Transaction Service)
- Security: Java Security API
- Web Services: JAX-RPC 1.1, JAX-WS 2.0, JAX-RS 2.0
3.3.3 EJB Container — Provided services (cont.)

- 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
3.4 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 for the Java EE Platform (CDI)
- Bean Validation: same set of validations can be shared by all layers of an application
- Java Server Faces (JSF) 2.0 supports Ajax
3.4.2 Java EE - Specifications
3.4.3 Java EE Architecture

!!! Diagram of Java EE Architecture !!!
3.4.4 Java EE — 3-tier Architecture
3.4.5 Java EE — 3-tier Architecture (cont.)

- **Client**
  - ♦ Heavy weight client — Java application (or possibly other language)
  - ♦ Light weight client — Web navigator

- **Application Server**
  - ♦ Reference implementation : Java EE 7 GlassFish (Oracle)
  - ♦ 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...)
3.5 EJB types

- **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)
3.5.1 EJB types (cont.)

- **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.
3.6 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.
- **@Local**: Applied to the session bean class or local business interface to designate a local 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.
Main EJB3 Annotations (cont.)

- **@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 only be specified if container-managed transaction demarcation is used. 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`
Main EJB3 Annotations (cont.)

- **@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 service endpoint interface (SEI) of the web service. 
  
  *Exclude element false by default.*

- **@WebServiceRef**: Used on the client to reference web services.
3.7 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
3.7.1 Interfaces

- **Remote Interface**

  - 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.
3.8 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
3.8.1 Stateless Session Bean — Calculator Example

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

```java
import javax.ejb.Remote;
@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);
}
```
3.8.2 Stateless Session Bean — Calculator Example - Implementation class

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

```java
import javax.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;}
}
```
3.8.3 Stateless Session Bean — Calculator Example - Client side

2 ways to get the reference of the business interface

- dependency injection:
  ```java
  @EJB Calculator myCalc;
  ```

- look-up in JNDI directory using the lookup method provided by EJBCContext interface and the bean interface name

```java
import javax.naming.*;
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);
    }
}
```
3.8.4 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:
    ```java
    @EJB CalculatorBean myCalc;
    ```
  - look-up in JNDI directory using the lookup method provided by EJBContext interface and the bean interface name
    ```java
    @Resource SessionContext myContext;
    ...
    CalculatorBean myCalc =
    (CalculatorBean) myContext.lookup("myCalculator");
    ```
3.8.5 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)
3.8.6 Stateful Session Bean — Cart Example (cont.)

```java
import java.util.List;
import javax.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();
}
```
3.8.7 Stateful Session Bean — Cart Example — Implementation
class

import java.util.ArrayList;
import java.util.List;
import javax.ejb.Remove;
import javax.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;
        }
    }
}
3.8.8 Stateful Session Bean — Cart Example — Implementation class (cont.)

customerId = "0";
contents = new ArrayList<String>();

...

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
public void remove() { contents = null; }
}
3.8.9 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");
3.9 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
3.10 Asynchronous Method Invocation — Session bean side

- Annotate a method or a class with `@Asynchronous` (javax.ejb.Asynchronous)
- Asynchronous methods return either void or an implementation of the `Future<V>` interface

```java
@Asynchronous
public Future<String> processPayment(Order order) throws PaymentException {
    ...
    String status = ...;
    return new AsyncResult<String>(status);
}
```
3.11 Asynchronous Method Invocation — Session bean side (cont.)

- Result is returned to the container, not directly to the client
- Check whether the client requested the invocation to be cancelled with method `javax.ejb.SessionContext.wasCancelled`

```java
@Asynchronous
public Future<String> processPayment(Order order) throws PaymentException {
    ...
    if (SessionContext.wasCancelled()) {
        // clean up
    } else {
        // process the payment
    }
    ...
}
```
3.12 Asynchronous Method Invocation — Client side

- Retrieve result using `Future<V>.get()` methods (synchronous method)
- Use `Future<V>.isDone` to check whether 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
3.13 Entity Bean

- Represents 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
3.13.1 Entity Bean (cont.)

- **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
3.13.2 Entity Bean — Example

@javax.persistence.Entity
public class Book implements java.io.Serializable {
    private String bookId;
    private String author;
    private String title;
    public Book() {}
    public Book(String author, String title) {
        this.author = author;
        this.title = title;
    }
    @javax.persistence.Id
    @javax.persistence.GeneratedValue(strategy=javax.persistence.GenerationType.AUTO)
    public String getBookId() { return this.bookId; }
    public String getTitle() { return this.title; }
    public void setTitle(String title) { this.title = title; }
    ...
}
3.13.3 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.
3.13.4 Multiplicities in Entity Relationships — OneToMany example

```java
@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);
    }
}
```
3.13.5 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
3.13.6 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
3.13.7 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:

```java
@PersistenceContext
EntityManager em;
```
3.13.8 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:
  ```java
  @PersistenceUnit
  EntityManagerFactory emf;
  ```
- Then, obtain an EntityManager from the EntityManagerFactory instance:
  ```java
  EntityManager em = emf.createEntityManager();
  ```
3.13.9 How to use the Entity Manager — Example

import javax.ejb.*;
import javax.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);
    }
}
3.13.10 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
3.13.11 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>
```
3.14 Message-driven Beans (MDB)

- Can implement any messaging type. Most commonly, Java Message Service (JMS).
- 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 lifecycle as a stateless session bean
3.14.1 Message-driven Beans (MDB)

- 2 communications modes
  - Queue: n to 1
  - Topic: n to m

![Diagram showing the communication modes](image-url)
3.14.2 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
3.14.3 MDB development — Producer example

```java
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();
    } }
```
3.14.4 MDB development — Consumer example

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

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

    }

    ...

}
### 3.15 Transaction Service

- 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 both operations complete successfully or none
  - Consistency: e.g. an account must never have a negative balance
  - Isolation: several parallel transfers must give the same result as if they were performed successively
  - Durability: Account state must be persistent and stored on stable storage
- Example: banking transfer with debit then credit operations
- Fully integrated within the EJB server
- Main advantage compared to the CORBA middleware
3.15.1 Transaction Service (cont.)

- 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
4 Conclusion

Advantages

- Framework taking in charge an important number of technical services
- Components are dedicated to business aspects
- Packaging and deployment made easy

Restrictions

- Only Java
- Some domains are not yet addressed: real-time or embedded systems, mobile computing...
5 References

http://www2.lifl.fr/~seinturi/middleware/javaee.pdf
JSR345 : https://www.jcp.org/en/jsr/detail?id=345

