12) Enterprise Java Beans

12.1 Basics

Obligatory Reading

- Sun's enterprise bean tutorial
- Szyperski, Chap 14
  http://xdoclet.sourceforge.net
- EJB 3.0 Features
  http://java.sun.com/developer/technicalArticles/J2EE/intro_ee5/

Literature

- JBoss EJB 3.0 Documentation
  http://docs.jboss.org/ejb3/app-server/
  http://java.sun.com/developer/technicalArticles/Interviews/community/bien_qa.html
- The Java EE 5 Tutorial. For Sun Java System Application Server 9.1.
  Sun Microsystems, Sept. 2007.
- Ed Roman: Mastering EJB. Wiley & Sons.
  http://www.theserverside.com/books/wiley/masteringEJB/index.jsp
- B. Tate, M. Clark, B. Lee, P. Linskey: Bitter EJB. Manning Publications Co.
Basics of Enterprise Java Beans (EJB)

- Developed by SUN, now Oracle
  - Server-side component architecture for building distributed OO business applications in Java
  - Separation of business logic and lower-level concerns (e.g., networking, transactions, persistence, ...) into implicit middleware
- EJB 1.0 1998, EJB 2.0 2001, current version is 3.0
- EJB integrates several principles:
  - Adapters (Interceptor)
  - Container as application server for transparency of transaction and persistency
  - A simple XML-based composition language

Ingredients of EJB

- Component Model
  - Static components contain classes
  - Dynamic components contain objects
  - **Session Beans**: for business logic and application algorithms
  - **Message-Driven Beans**: Same function as session beans
    - Called by sending messages instead of calling methods
    - Have a message queue, react to an asynchronous message connector
  - **Entity Beans**: for business objects (data)
    - Persistent object that caches database information (an account, an employee, an order, etc)
  - Component factory (Home bean)
  - Customization possible by deployment descriptors
- Composition Technique
  - Adaptation/Glue:
    - Transparent distribution (Almost, see local/remote interfaces)
    - Transparent network protocols
    - Transparent transaction and persistency
  - No connectors
- Some common application servers
  - JBoss – free software [www.jboss.org](http://www.jboss.org), Apache Geronimo
  - BEA’s WebLogic, IBM’s WebSphere, Oracle’s Oracle 11g

Interactions in an EJB Component System (Where are the Beans?)

- Presentation Tier
  - HTML Client
    - http
    - soap, uddi, wddi
  - Messaging Client
  - C++ Client
- Business partner system
- Servlet
  - http
  - rmi-iiop
  - CORBA/iiop
  -Messaging
- JSP
- Application Server
- Business (Application) Tier
- Web Server
- EJB Message-Driven Bean
  - rmi-iiop
  - EJB Session Bean
  - rmi-iiop
- EJB Session Bean
  - EJB Entity Bean
  - Database Tier

The Container/Application Server

- Container (application server)
  - The container is a wrapper (Decorator, Interceptor) of the bean
    - In a container, some business logic may run on the server, hiding the direct data access
    - The container manages the beans
    - Factory: create; Repository: find, remove
  - The container provides middleware services the beans can use (implicit middleware)
    - Write only business logic
    - Declare the middleware services that you need (transactions, persistence, security, resource management, ... etc)
    - The middleware services are provided automatically
    - In explicit middleware (see CORBA), middleware services have to be addressed by the programmer
- Some common application servers
  - JBoss – free software [www.jboss.org](http://www.jboss.org), Apache Geronimo
  - BEA’s WebLogic, IBM’s WebSphere, Oracle’s Oracle 11g
**Implicit Middleware by Interceptors (Decorators)**

![Diagram of implicit middleware by interceptors](image)

- **Client**
- **Stub**
- **Skeleton**
- **Distributed Object (Bean)**
- **Request Interceptor**
- **Transaction Service**
- **Security Service**
- **Database Driver**
- **Network**

**The Parts of an EJB - The Enterprise Bean Class**

- The implementation of the bean looks different depending on which kind of bean
  - Session beans
    - Business-process-related logic
    - e.g., compute prices, transfer money between accounts
  - Entity beans
    - Data-related logic
    - e.g., change name of a customer, withdraw money from an account
  - Message-driven beans
    - Message-oriented logic
    - e.g., receive a message and call a session bean

**Parts - Overview**

- Bean class
- Home – a factory
- Local interface [3.0: annotation]
- Remote interface [3.0: annotation]
- Deployment descriptor

**The Parts of an EJB - The EJB Object**

- The enterprise bean is not called directly
  - Instead an EJB object is generated by the container (facade object, proxy)
  - The EJB object filters the input and intercepts calls and delegates them to the bean
  - The EJB object is responsible for providing middleware services

![Diagram of EJB object](image)
The Parts of an EJB
- The Remote Object Interface

- The interface to the bean that the client sees
  - Must contain all methods the bean should expose
- As the EJB object lies between the client and the bean, it has to implement this interface
  - Must extend `javax.ejb.EJBObject`

```java
public interface Bank extends javax.ejb.EJBObject {
    public Account getAccount(String name)
        throws java.rmi.RemoteException;
    public void openAccount(String name)
        throws java.rmi.RemoteException;
}
```

The Parts of an EJB
- The Home Object

- How does the client get hold of an EJB object?
  - The EJB object can exist on a different machine
  - EJB promotes location transparency, so the client shouldn't have to care where the EJB object is located
- An EJB object factory and repository is needed: The home object
  - Create EJB objects
  - Find existing EJB objects
  - Remove EJB objects

The Parts of an EJB
- The Home Object and Interfaces

- The home object needs a home interface (factory)
  - Defines methods for creating, finding and removing EJB objects
- The communication uses Java RMI over IIOP
  - If an argument is serializable, it is sent as pass-by-value
  - RMI can also simulate pass-by-reference
  - A serialized stub for the remote object is sent instead

The Parts of an EJB
- Local Interfaces

- Optionally, you can provide local interfaces
  - local interface corresponding to remote interface
  - local home interface corresponding to home interface
- When beans are located locally it is possible to use local calls

Remote:
- Client calls a local stub
- Marshalling
- Stub calls skeleton over a network connection
- Unmarshalling
- EJB object is called, performs middleware services
- Bean is called
- Repeat to return result

Local:
- Client calls a local object
- Local object performs middleware services
- Bean is called
- Control is returned to the client
**Drawbacks of Using Local Interfaces**

- They only work when calling beans in the same process
  - Code for local interfaces differs from code for remote interfaces
  - To switch between local and remote calls it is necessary to change the code
  - Location transparency is not preserved
- The marshalling of parameters is by reference
  - This is different from remote calls which are by value
  - There is a definite speed gain...
  - ...but it can be error-prone because the semantics are different from remote calls
- Horrible: this should be encapsulated in a connector!

**The Parts of an EJB**

- The Deployment Descriptor
  - An XML file in which the middleware service requirements are declared (There is a DD-DTD)
    - Bean management and lifecycle requirements
    - Transaction, persistence, and security requirements
  - Composition of beans (references to other beans)
    - Names: Name, class, home interface name, remote-interface name, class of the primary key
    - States: type (session, entity, message), state, transaction state, persistency management - how?
  - The application assembler may allocate or modify additional different information
    - Name, environments values, description forms
    - Binding of open references to other EJB
    - Transaction attributes

**Example of a Deployment Descriptor**

```xml
<!DOCTYPE ejb-jar PUBLIC "-//Sun Microsystems, Inc.//DTD Enterprise JavaBeans 2.0//EN" "http://java.sun.com/dtd/ejb-jar_2_0.dtd">

<ejb-jar>
  <enterprise-beans>
    <session>
      <ejb-name>Bank</ejb-name>
      <home>com.somedomain.BankHome</home>
      <remote>com.somedomain.Bank</remote>
      <local-home>com.somedomain.BankLocalHome</local-home>
      <local>com.somedomain.BankLocal</local>
      <ejb-class>com.somedomain.BankBean</ejb-class>
      <session-type>Stateless</session-type>
      <transaction-type>Container</transaction-type>
    </session>
  </enterprise-beans>
</ejb-jar>
```

**The Parts of an EJB (2.0)**

- Putting It All Together
  - Finally all the above mentioned files are put into an EJB-jar file
    - bean class
    - home (and local home) interface
    - remote (and local) interface
    - deployment descriptor, i.e., the composition specification
    - (possibly vendor-specific files)
**Deployment of an EJB**

- The deployment of a bean is a new step in component systems we have not yet seen.
- The application server is notified of the new bean by:
  - using a command-line tool,
  - dropping the EJB in a specific directory,
  - or in some other way.
- The EJB-jar file is verified by the container.
- The container generates an EJB object and home object.
- The container generates any necessary RMI-IIOP stubs and skeletons.

**Roles in the EJB Software Process**

- **Bean provider** (bean producer) is an application expert:
  - Builds a EJB-jar with application specific methods, deployment-descriptor, remote, home interface.
- **Application assembler** composes EJB to larger EJB, i.e., applications units:
  - She extends the deployment-descriptors.
- **Employer** (deployer) puts the EJB into a environment, consisting of a EJB Server and Container (Adapter):
  - Is the EJB connected to a EJB-Container, it is configured and usable.
- **Server-provider** is a specialist in transaction management and distributed systems:
  - Provides basic functionality for distribution.
- **Container-provider** (container provider) delivers the container tools for configuration and for run time inspection of EJB:
  - The Container manages persistency of Entity Beans, generation of communication code (glue code) to underlying data bases.

**How to Find a Home Object**

- To achieve location transparency the machine address of the home object should not be hard-coded.
- Instead the Java Naming and Directory Interface (JNDI) is used to lookup home objects:
  - JNDI is a standard interface for locating resources, similar to the Corba name service.
  - Only the address to the JNDI server is needed.
  - JNDI provides a mapping between the name of a resource and its physical location.

**The Entire Process**

1. Retrieve home object reference
2. Return home object reference
3. Create a new EJB object
4. Create EJB Object
5. Return EJB object reference
6. Invoke business method
7. Delegate Request to bean
12.2 A Closer Look at the Different Kinds of Enterprise JavaBeans

(only 2.0)

Session Beans Overview

- Reusable components that contain logic for business processes
  - The lifetime of a session bean is roughly equivalent to the lifetime of the client code calling it
  - A session bean is nonpersistent
- Two kinds of session beans
  - Stateful
  - Stateless

```java
SessionBean
- setSessionContext(SessionContext context)
  The bean can query the SessionContext for information concerning the container
- ejbCreate()
  Used to perform initialization when the bean is created
- ejbPassivate()
  Used by stateful session beans, explained later
- ejbActivate()
  Used by stateful session beans, explained later
- ejbRemove()
  Used to release any resources the bean has been holding before it is removed
```

Stateless Session Beans

- Handle single request conversations
  - Conversations that span a single method call
  - Does not hold a conversational state
- The bean may be destroyed by the container after a call or it has to be cleared of old information
- Examples of stateless session beans
  - A user verification service
  - An encoding engine
  - Any service that given some input always produces the same result

Pooling Stateless Session Beans

- Stateless session beans can easily be pooled (reused) to allow better scaling
  - They contain no state

```
Client
 invoke()

EJB Object
 invoke()

Remote Interface

Stateless bean pool

Bean

EJB Container/Server
```
**Stateful Session Beans**
- Handles drawn-out conversations
  - E-commerce web store with a shopping cart
  - Online bank
  - Tax declaration
- Thus it has to retain its state between invocations

**Pooling Stateful Session Beans**
- Pooling becomes more complicated
  - Beans must be swapped from physical memory to disk
- A stateful session bean has to implement:
  - `ejbPassivate()`: Called to let the bean release any resources it holds before it gets swapped out
  - `ejbActivate()`: Called right after the bean has been swapped in to let it acquire the resources it needs

**Activation of a Stateful Session Bean**
1. Invoke business method
2. Retrieve passivated bean state
3. Reconstruct bean
4. Call `ejbActivate()`
5. Invoke business method

**Life Cycle of a Stateless Session Bean**
1. `Class.newInstance()`
2. `setSessionContext()`
3. `ejbCreate()`
4. Business method
5. `ejbRemove()`

**Pool of equivalent method-ready instances**
Life Cycle of a Stateful Session Bean

Bean instance does not exist

1. Class.newInstance()
2. setSessionContext()
3. ejbCreate()

ejbRemove()
ejbPassivate()
ejbActivate()

Ready
Passive

Business method

Message-Driven Beans

Why?
- Performance
  - Asynchronous process means that clients don't have to wait for the bean to finish
- Reliability
  - With RMI-IIOP the server has to be up when the client is calling it.
  - With a message-oriented middleware (MOM) that supports guaranteed delivery, the message is delivered when the server gets back online
- Support for multiple senders and receivers
  - RMI-IIOP is limited to one client talking to one server

Characteristics of Message-Driven Beans

- MDBs don't have a home, local home, remote or local interface
- MDBs have a single, weakly typed business method
  - onMessage() is used to process messages
  - MDBs don't have any return values
  - However, it is possible to send a response to the client
  - MDBs cannot send exceptions back to clients
- MDBs are stateless
- MDBs can be durable or nondurable subscribers
  - durable means that the subscriber receives all messages, even if it is inactive

12.3 Entity Beans in 2.0
**Entity Beans Overview**

- Entity beans are persistent objects that can be stored in permanent storage
  - Live on the entity or database layer of the 3-tier architecture
  - The entity bean data is the physical set of data stored in the database
- An entity bean consists of the same files as a session bean
  - remote/local interface
  - home/local home interface
  - the enterprise bean class
  - the deployment descriptor
- Two kinds of entity beans
  - Bean-managed persistent or container-managed persistent

**Features of Entity Beans**

- Entity bean instances are a view into a database
  - The bean and the data in the database are conceptually the same
  - Entity beans survive failures: persistent
- Several entity bean instances may represent the same underlying data
  - An entity bean has a primary key to uniquely identify the database data
  - Entity bean instances can be pooled
    - must implement ejbActivate() and ejbPassivate()
- Entity beans are found with special finder methods

**How is Persistence Achieved?**

- Serialization
  - Very expensive to query objects stored using serialization
  - consider getting all accounts with a specific amount of money
- Object-relational mapping (relational databases)
  - Map the object to a relational database when it is stored
  - Allows advanced queries and visualization
  - The mapping is either hand-coded or achieved by finished products
- Object databases
  - Persistent store that holds entire objects, no mapping step
  - Queries possible by using an object query language (OQL)
  - Supports relationships between objects
  - Predictable scalability and performance
  - Strong integrity and security
  - Object databases haven't taken off so Object-relational mappings are normally used

**Pooling Entity Beans**

Diagram showing the relationship between EJB Container/Server and Entity Beans, with Bean Pool containing multiple instances.
Loading and Storing an Entity Bean

1: ejbLoad()
2: Read from database
3: Business methods
4: ejbStore()
5: Write to database

EJB Container/Server

Entity Bean Instance

Database

Bean-Managed Persistent Entity Beans (BMP Beans)

- The developer is required to provide the implementation to map the instances to and from storage
  - Java Database Connectivity (JDBC)
- BMP beans have to implement `javax.ejb.EntityBean`:
  - `setEntityContext(javax.ejb.EntityContext)`
    - The context can be queried of information regarding the container
  - `unsetEntityContext()`
  - `ejbRemove()`
    - Removes the data from the persistent storage
  - `ejbActivate()`
    - Lets the bean allocate resources after being swapped in
  - `ejbPassivate()`
    - Called before the bean is swapped out so it can release resources
  - `ejbLoad()`
    - Loads database data into the bean
  - `ejbStore()`
    - Stores the data in the bean to the database

Bean-Managed Persistent Entity Beans

- BMP beans also have to other kinds of methods relating to storage
  - `ejbCreate()`
    - Used to create new entries in the database (optional)
  - Finder methods
    - `ejbFindXXX()`
    - Must have at least one: `ejbFindByPrimaryKey()`
    - Normally contains database queries
      - e.g., `SELECT id FROM accounts WHERE balance > 3000`
  - `ejbHomeXXX()` methods
    - Performs simple services over a set of beans
- A BMP entity bean consists of
  - Bean-managed state fields, persistable fields that are loaded from the database
  - Business logic methods: Performs services for clients
  - EJB-required methods: Required methods that the container calls to manage the bean

Example - Bean-Managed State Fields

- AccountBean.java

```java
import java.sql.*;
import javax.naming.*;
import javax.ejb.*;
import java.util.*;

public class AccountBean implements EntityBean {
    protected EntityContext context;

    private String accountID;
    private String ownerName;
    private double balance;

    public AccountBean() { }

    public void deposit(double amount) {
        balance += amount;
    }

    public void withdraw(double amount) {
        if (amount < balance) {
            balance -= amount;
        }
    }

    public void getBalance() {
        return balance;
    }

    ...cont...
```

...cont...
Example - Business Logic Methods

```java
public void ejbHomeGetTotalBankValue() {
    PreparedStatement pStatement = null;
    Connection connection = null;
    try {
        connection = getConnection();
        pStatement = connection.prepareStatement("select sum(balance) as total from accounts");
        ResultSet rs = pStatement.executeQuery();
        if (rs.next()) { return rs.getDouble("total"); }
    } catch (Exception e) {
        ...
    } finally {
        try {
            if (pStatement != null) pStatement.close();
        } catch (Exception e) {
            ...
        }
        try {
            if (connection != null) connection.close();
        } catch (Exception e) {
            ...
        }
    }
}
```

Example - Required Methods

```java
public void ejbRemove {
    PreparedStatement pStatement = null;
    Connection connection = null;
    AccountPK pk = (AccountPK) context.getPrimaryKey();
    String id = pk.accountID;
    try {
        connection = getConnection();
        pStatement = connection.prepareStatement("delete from accounts where id = ?1");
        pStatement.setString(1, id);
        pStatement.executeQuery();
    } catch (Exception e) {
        ...
    } finally {
        try {
            if (pStatement != null) pStatement.close();
        } catch (Exception e) {
            ...
        }
        try {
            if (connection != null) connection.close();
        } catch (Exception e) {
            ...
        }
    }
```

Container-Managed Persistency in 2.0

- TemplateMethod design pattern with generated hook class implementation

Container-Managed Persistent Entity Beans (CMB)

- The container performs the storage operations
  - This gives a clean separation between the entity bean and its persistent representation
  - The container generates the persistence logic
- The CMP entity bean is always abstract
  - The container generates a concrete subclass
- The CMP entity beans have no declared fields
  - Also the get/set method implementations are generated by the container from the deployment descriptor
- CMP beans get an abstract persistence schema
  - An abstract persistence schema is declared in the deployment descriptor so the container will know what to generate
- There is a query language, EJB Query Language (EJB-QL. Example
  - SELECT OBJECT(a) FROM Account AS a WHERE a.balance > ?1
Example: TemplateMethod Pattern

```java
import javax.ejb.*;
public abstract class ProductBean implements EntityBean {
    protected EntityContext context;
    public abstract String getName();
    public abstract void setName(String name);
    public abstract String getDescription();
    public abstract void setDescription(String description);
    public abstract double getBasePrice();
    public abstract void setBasePrice(double basePrice);
    public abstract String getProductID();
    public abstract void setProductID(String productID);

    public void ejbActivate() { }
    public void ejbRemove() { }
    public void ejbPassivate() { }
    public void ejbLoad() { }
    public void ejbStore() { }
    public void setEntityContext(EntityContext ctx) { context = ctx; }
    public void unsetEntityContext() { context = null; }
    public void ejbPostCreate(String productID, String name, String description, double basePrice) { }
    public String ejbCreate(String productID, String name, String description, double basePrice) {
        setProductID(productID);
        setName(name);
        setDescription(description);
        setBasePrice(basePrice);
        return productID;
    }
}
```

CMP Entity Beans – Deployment Descriptor

- You have to declare how the container should generate methods and fields
- ...declarations of interfaces, etc ...
  ```xml
  <cmp-field>
    <field-name>productID</field-name>
  </cmp-field>
  <cmp-field>
    <field-name>name</field-name>
  </cmp-field>
  <cmp-field>
    <field-name>description</field-name>
  </cmp-field>
  <cmp-field>
    <field-name>basePrice</field-name>
  </cmp-field>
  
  .. queries ...
  ```

EJB and Others

- Interceptors and Decorators
  - The Interceptor of a bean is like a decorator
  - It can be overwritten and extended from outside the EJB
  - User can write filters for EJB
  - JBoss uses this for aspect-oriented EJB (see later)
- EJB was formed after Microsoft's MTS (now COM+)
  - COM+ is in .NET
  - Models are somewhat similar
- Corba Component Model (CCM) is also similar

 XDoclets

- An XDoclet is a plugin into the XDoclet framework
- The XDoclet framework is a doclet, i.e., a Javadoc extension
- XDoclets define new tags (xtags), used for metadata
  - Tags can have attribute lists
    - /* @ejb.bean type = "CMP" name="client" view-type="local" */
- Tags steer code generation
  - XDoclet compiler reads the Java source files, evaluates commented tags and generates additional code
**Use of XDoclets**

- Generation of
  - Deployment descriptors
  - Default interfaces
  - Implementation stubs

- Example [from XDoclet documentation]

```java
/** Account
@see Customer
@ejb.bean name="bank/Account" type="CMP"
  jndi-name="ejb/bank/Account"
  primkey-field="id"
@ejb.finder signature="jara.util.collection findAll()"
  unchecked="true"
@ejb.transaction type="required"
@ejb.interface remote-class="test.interfaces.Account"
@version 1.5 */
```

---

**12.4. EJB 3.0**

- Only the bean class is specified
  - Rest of the classes is generated from metadata annotations

```
  <<bean class>> ProductBean
  <<generated>> Transaction
  <<generated>> Interceptors
  <<generated>> RemoteInterface
  <<generated>> Persistency
  <<generated>> HomeInterface
  <<generated>> RemoteHome Interface
  <<generated>> HomeObject
```

- EJB 3.0 heavily uses metadata markup to generate all dependent interfaces and code
Marking in EJB 3.0 – Annotation Types

Bean class annotations refer to classes and create interfaces with adapters:

```java
@Entity
public class AccountBean implements Account {
    public void deposit (double money) {...}
}
```

```java
@Stateless
@Stateful
@MessageDriven
@Local
@Remote
@RemoteHome
@LocalHome
```

From [EJB 3.0 Features]

Method Callback Annotations

The default methods can be adorned with user-written filters (before, after, and around advices)

```java
@PrePassivate
void signalPassivation() {
    System.out.writeln("passivating bean now...");
}
```

```java
@PreDestroy
@PrePersist
@PostPersist
@PreActivate
@PostActivate
@PrePassivate
@PostPassivate
@CallbackListener
```

From [EJB 3.0 Features]

Custom Interceptors

[From EJB 3.0 Features]
// Provides profiling logic in a business method (with interceptors)
/* The interceptor class */
public class ProfilingInterceptor {
    @AroundInvoke // indicates that this is the interceptor method
    public Object profile(InvocationContext invocation) throws Exception {
        long start = System.currentTimeMillis();
        try {
            return invocation.proceed(); // this statement would call the withdraw method
        } finally {
            long time = start - System.currentTimeMillis();
            Method method = invocation.getMethod();
            System.out.println(method.toString() + " took " + time + " (ms)");
        }
    }
}

/* The bean class */
public class BankAccountBean implements BankAccount {
    @PersistenceContext EntityManager entityManager;
    @Interceptors (ProfilingInterceptor.class)
    public void withdraw(int acct, double amount) { ... } 
    public void deposit(int acct, double amount) { ... }
}
```

From [EJB 3.0 Features]

Transaction Control with Attributes

Classes and methods may receive transaction attributes

- **Required**: bean joins the client's transaction
- **RequiresNew**: bean starts new transaction
- **NotSupported**: interrupt transaction, execute without it
- **Supported**: bean joins the client's transaction, otherwise executes without transaction
- **Mandatory**: bean joins the client's transaction, otherwise signals error

[The Java 2 EE tutorial]
@TransactionAttribute(NOT_SUPPORTED)
@Stateful
public class TransactionBean implements Transaction {
    ...
    @TransactionAttribute(REQUIRES_NEW)
    public void firstMethod() {...}
    @TransactionAttribute(REQUIRED)
    public void secondMethod() {...}
    public void thirdMethod() {...}
    public void fourthMethod() {...}
}
```
12.5 Evaluation of EJB

as composition system

Component Model

- Mechanisms for secrets and transparency: very good
  - Interface and implementation repository
  - Location, transaction, persistence transparency
  - Life-time of service hidden, states hidden
  - Communication protocol can be replaced (RMI-IIOP, CORBA-IIOP)
- (Limited) local parameterization by deployment descriptors
  - The services to use are specified
  - The storage mechanisms for CMP entity beans can be modified
- Deployment of EJB supported
  - Code generation of stubs
- Standardization: Good
  - Technical vs. application specific vs. business components
- EJB 2.0 is quite heavy; 3.0 is slimmer
  - Not a universal technique for everything
  - The goal is to make enterprise systems easier to implement and maintain

Composition Technique

- Mechanisms for connection
  - Mechanisms for locating
    - JNDI
  - Mechanisms for adaptation
    - RMI – stubs, skeletons
  - Mechanisms for gluing
    - Container producing glue code
- Mechanisms for aspect separation
  - Middleware services declared in the deployment descriptor
- Mechanisms for Meta-modeling
  - with Java reflection and metadata annotations
- Scalability
  - Pooling ensures scaling

Composition Language

- The deployment descriptor language is a simple composition language
- Limited:
  - Glue code is provided by the container
  - Services can be added/removed/modified by changing the deployment descriptor
  - CMP entity beans can be customized by changing the deployment descriptor
**EJB - Component Model**

- Secrets
- Development environments
- Business services
- Infrastructure
- Binding points
- Parameterization
- Types
- Distribution
- Location
- Transparency
- Contracts

**EJB – Composition Technique and Language**

- Connection
- Adaptation
- Product quality
- Extensibility
- Software process
- Metacomposition
- Aspect Separation
- Scalability

**EJB as Composition Systems**

- Component Model
  - Contents: binary components
  - Binding points: standardized interfaces
- Composition Technique
  - Adaptation and glue code implicit
  - Automatic persistency and transactions
- Deployment descriptor

**What Have We Learned**

- EJB is big, not for everything
- Allows the developer to focus on business logic
- Provides very useful services, like transparency, persistence, security, networking independence, etc
- Can interoperate with CORBA
- It is a well-defined standard by SUN
- It works in symbiosis with several other APIs
  - JNDI, RMI, JDBC, JMS, etc
The End