12) Enterprise Java Beans

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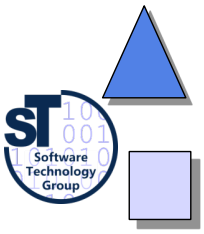
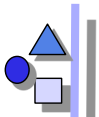


1. Basics
2. Different Kinds of Beans
3. EJB in 2.0
4. EJB in 3.0
5. Evaluation

Obligatory Reading

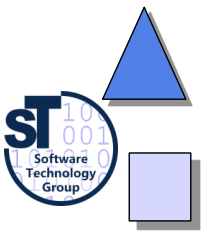
- Sun's enterprise bean tutorial
  http://java.sun.com/javaee/reference/tutorials/index.jsp
- Szyperski, Chap 14
- http://xdoclet.sourceforge.net
- EJB 3.0 Features
  http://java.sun.com/developer/technicalArticles/J2EE/intro_ee5/

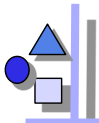


Literature

- JBoss EJB 3.0 Documentation
  http://docs.jboss.org/ejb3/app-server/
- http://developers.sun.com/docs/web/swdp/r1/tutorial/doc/toc.html
- 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.
  http://java.sun.com/javaee/5/docs/tutorial/doc/JavaEETutorial.pdf
- 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.

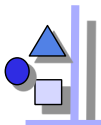
12.1 Basics





Basics of Enterprise Java Beans (EJB)

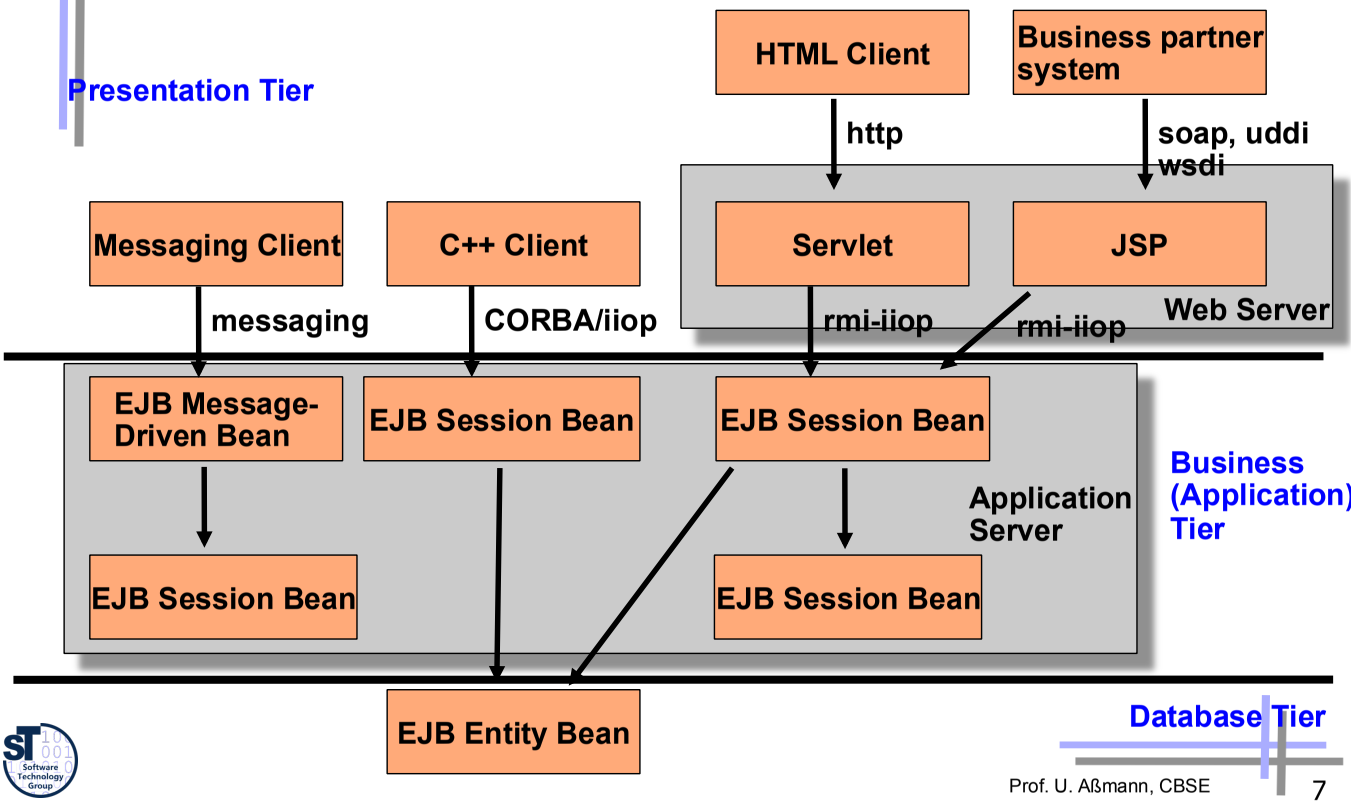
- Developed by SUN, now Oracle
  - Server-side component architecture for building distributed OO business applications in Java
  - Separation of business logic and lower-level concerns (e.g., networking, transactions, persistence, ...) into *implicit middleware*
- EJB 1.0 1998, EJB 2.0 2001, current 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

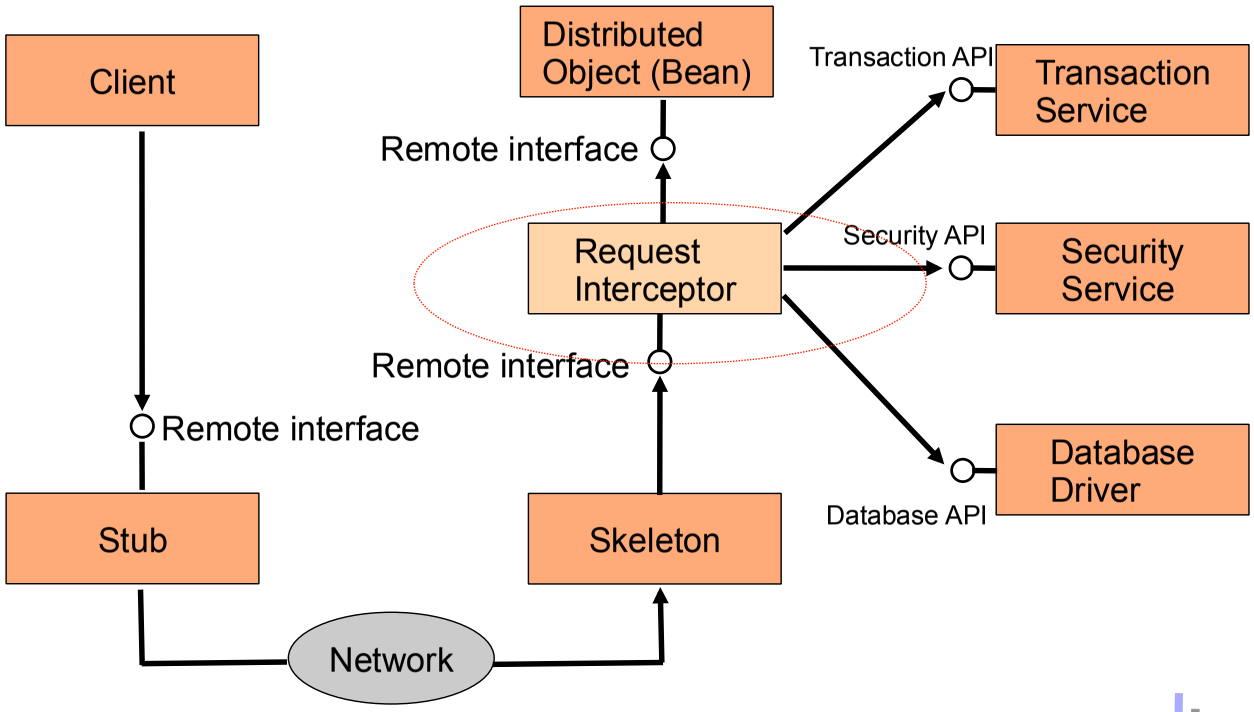
Interactions in an EJB Component System (Where are the Beans?)



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, Apache Geronimo
  - BEA's WebLogic, IBM's WebSphere, Oracle's Oracle 11g

Implicit Middleware by Interceptors (Decorators)



The Parts of an EJB - The Enterprise Bean Class

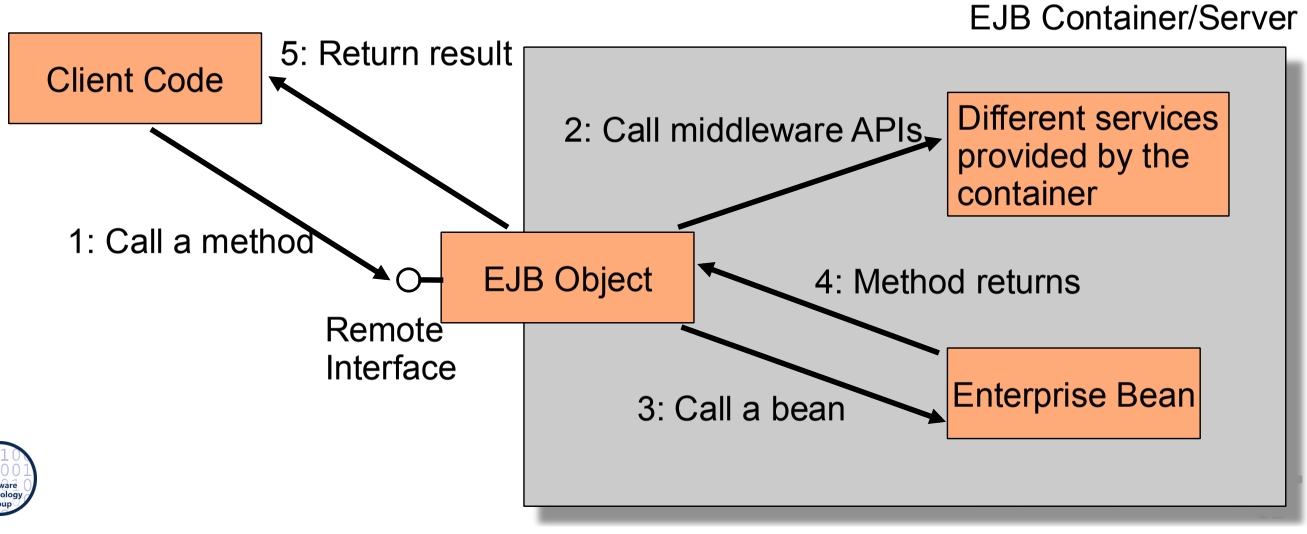
- The implementation of the bean looks different depending on which kind of bean
- Session beans
  - Business-process-related logic
  - e.g., compute prices, transfer money between accounts
- Entity beans
  - Data-related logic
  - e.g., change name of a customer, withdraw money from an account
- Message-driven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



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`

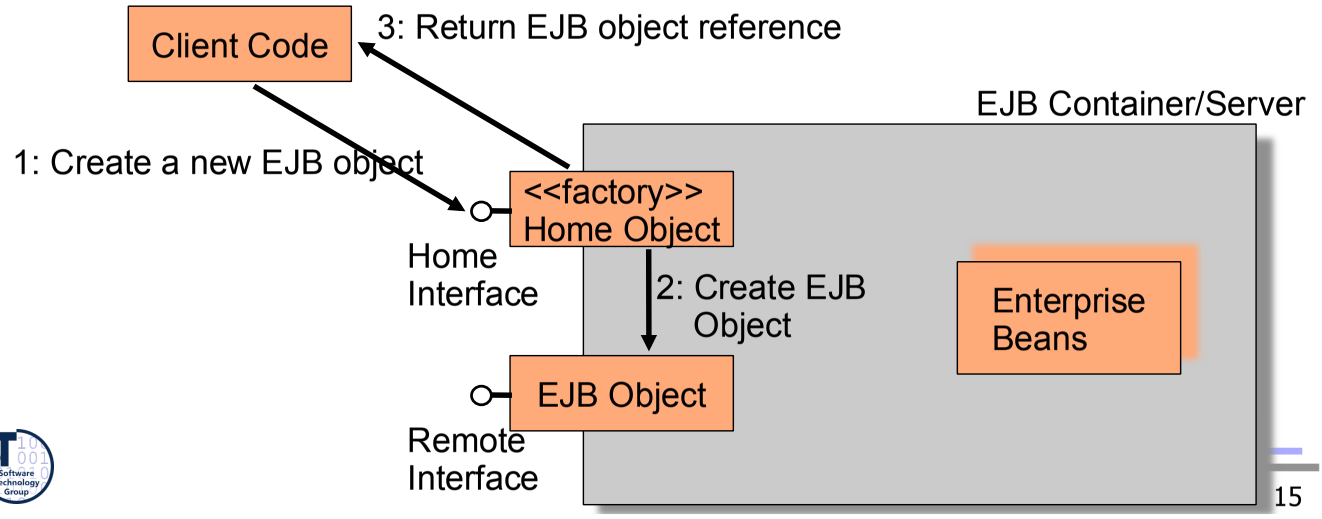
```
public interface Bank extends javax.ejb.EJBObject {

        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

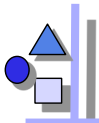
- Optionally, you can provide local interfaces
  - local interface corresponding to remote interface
  - local home interface corresponding to home interface
- When beans are located locally it is possible to use local calls

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

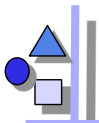
Local:

- 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

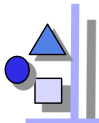
- An XML file in which the middleware service requirements are declared (There is a DD-DTD)
  - Bean management and lifecycle requirements
  - Transaction, persistence, and security requirements
- Composition of beans (references to other beans)
  - Names: Name, class, home interface name, remote-interface 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

```
<!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>
```

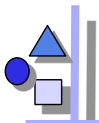

The Parts of an EJB (2.0) - Putting It All Together

- 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



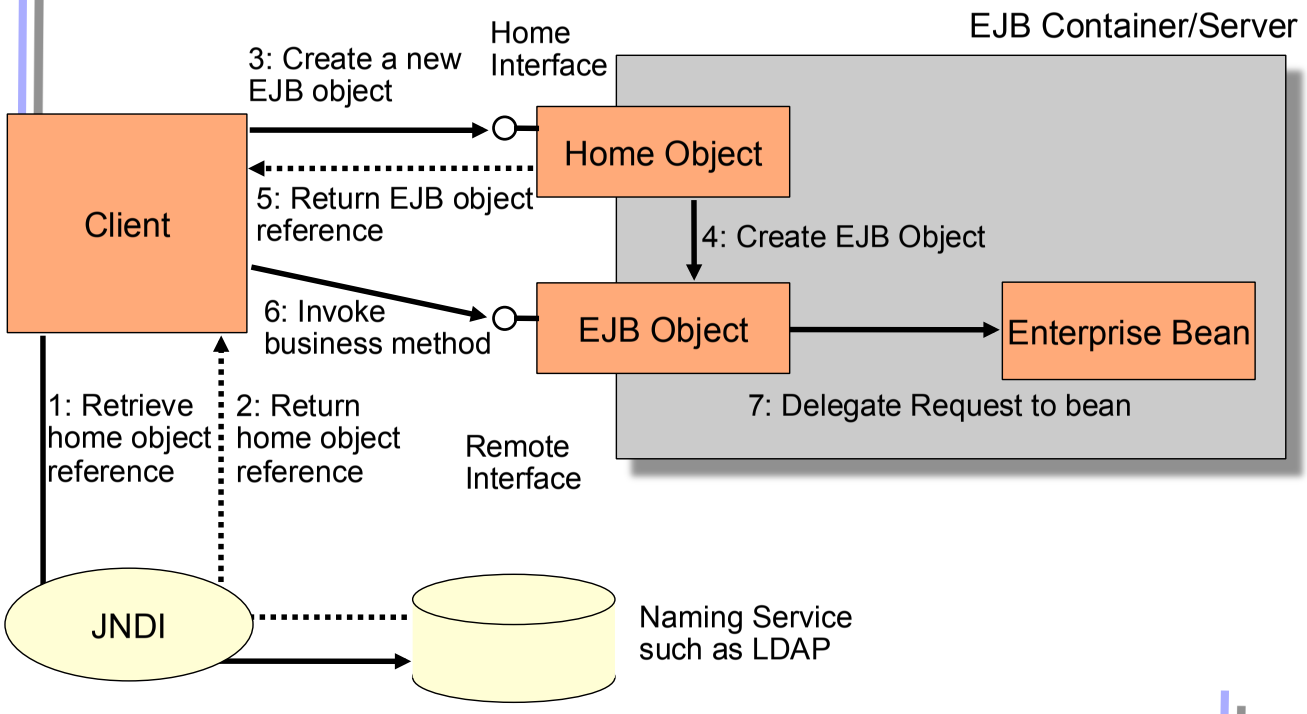
Roles in the EJB Software Process

- *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

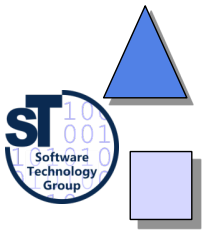
- To achieve location transparency the machine address of the home object should not be hard-coded
- Instead the Java Naming and Directory Interface (JNDI) is used to lookup home objects
  - JNDI is a standard interface for locating resources, similar to the Corba name service
  - Only the address to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

The Entire Process



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.ejb.SessionBean

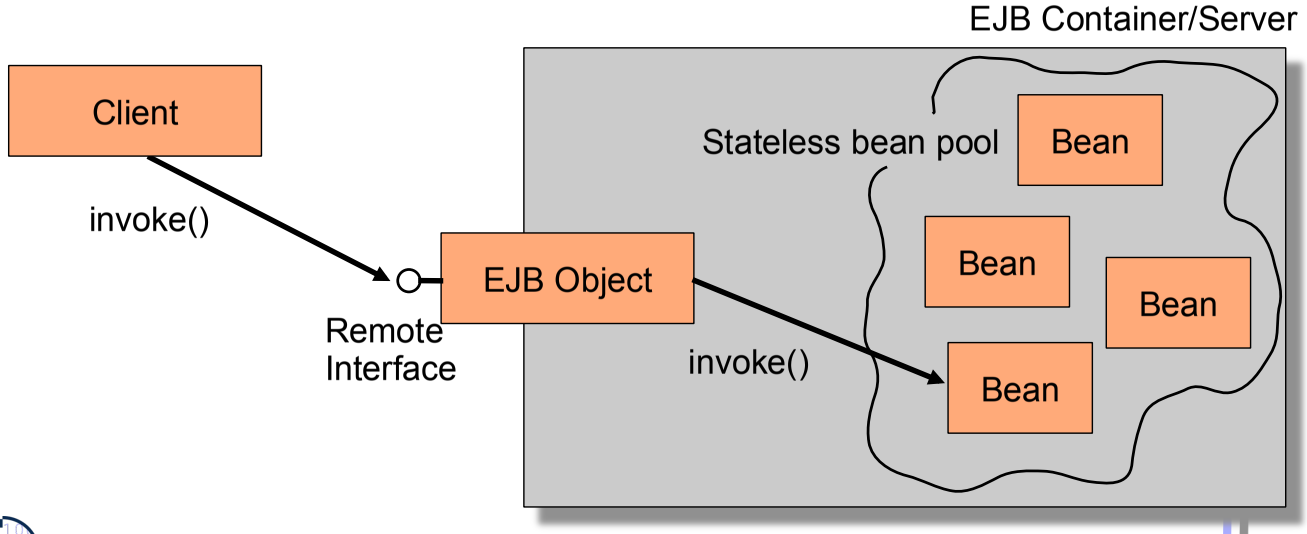
- **`setSessionContext(SessionContext context)`**
  The bean can query the SessionContext for information concerning the container
- **`ejbCreate()`**
  Used to perform initialization when the bean is created
- **`ejbPassivate()`**
  Used by stateful session beans, explained later
- **`ejbActivate()`**
  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

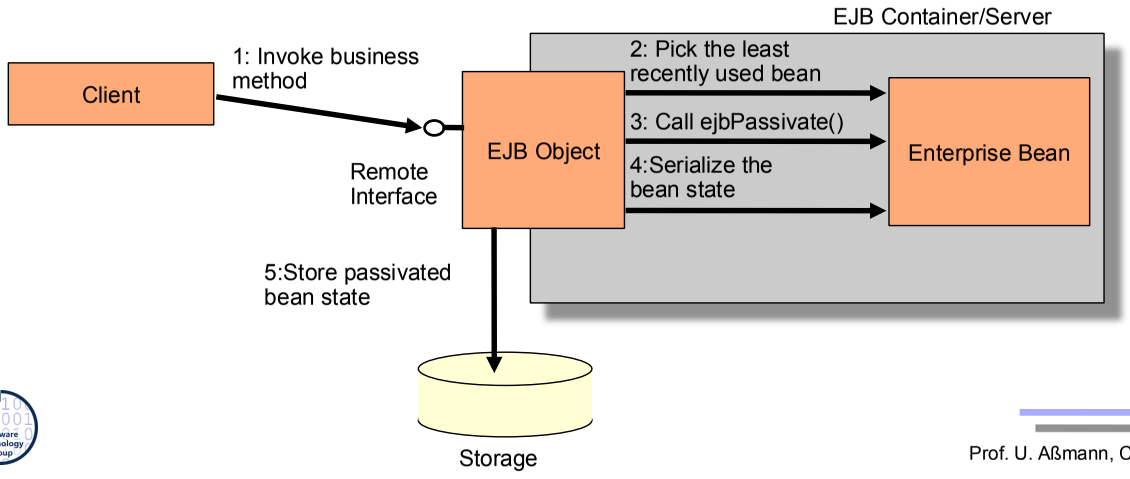


Stateful Session Beans

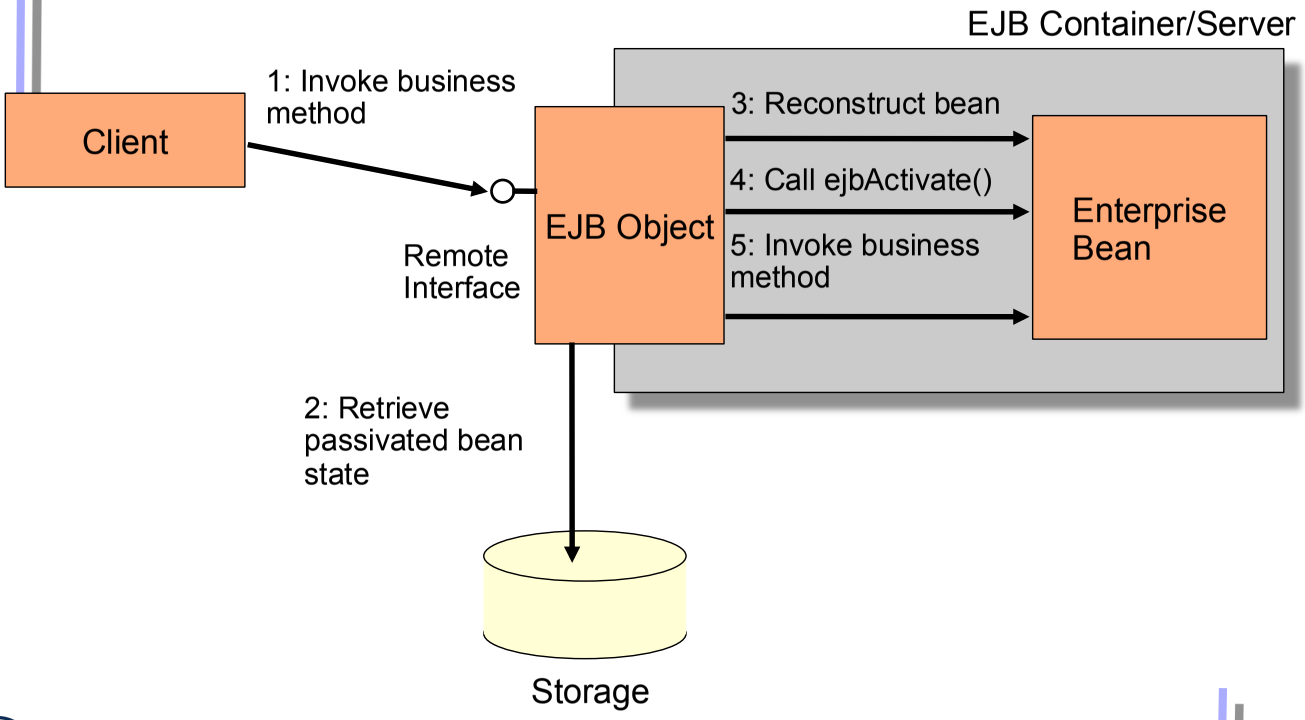
- Handles drawn-out conversations
  - E-commerce web store with a shopping cart
  - Online bank
  - Tax declaration
- Thus it has to retain its state between invocations

Pooling Stateful Session Beans

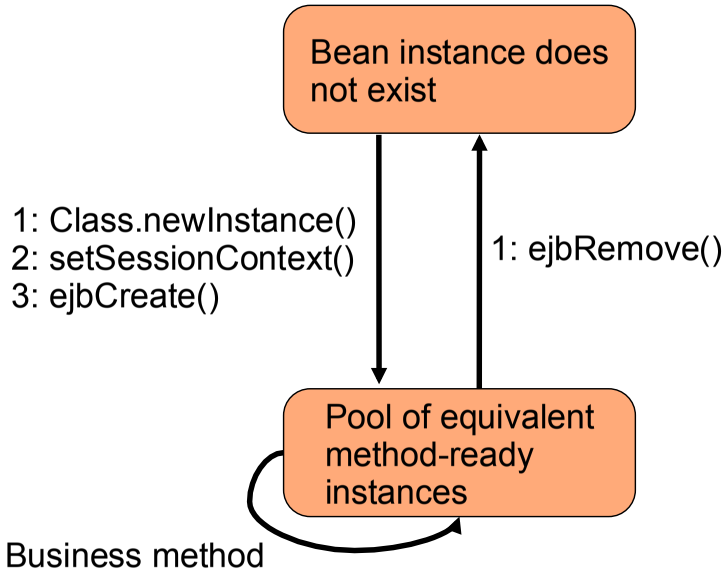
- Pooling becomes more complicated
  - Beans must be swapped from physical memory to disk
- A stateful session bean has to implement:
  - ejbPassivate(): Called to let the bean release any resources it holds before it gets swapped out
  - ejbActivate(): Called right after the bean has been swapped in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



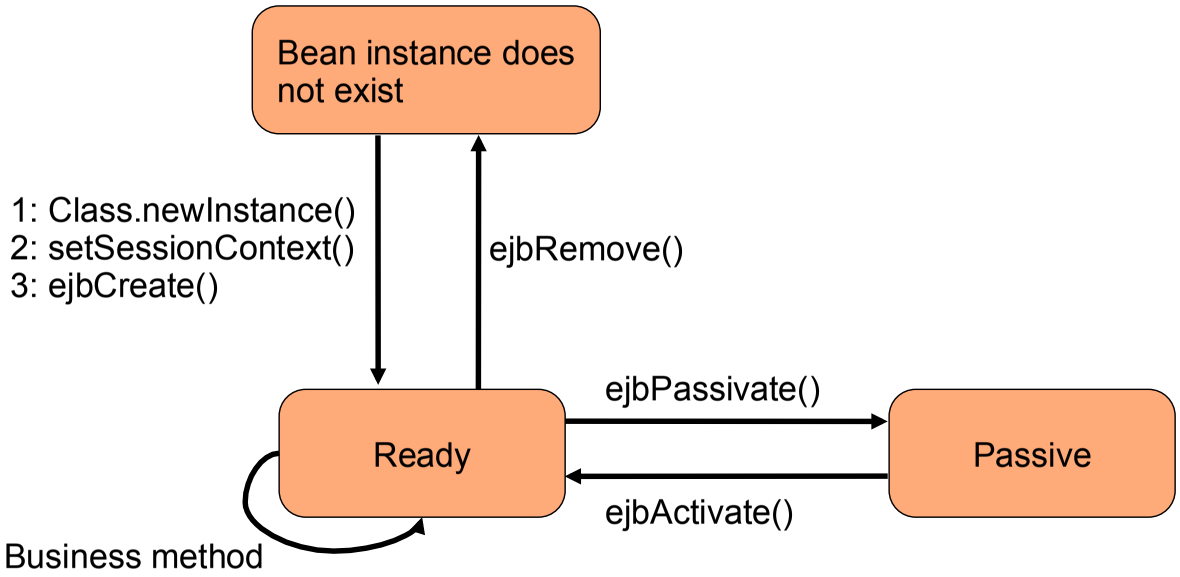
Activation of a Stateful Session Bean



Life Cycle of a Stateless Session Bean



Life Cycle of a Stateful Session Bean



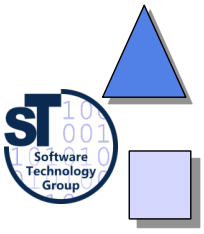
Message-Driven Beans

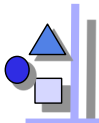
- Why?
  - Performance
    - Asynchronous process means that clients don't have to wait for the bean to finish
  - Reliability
    - With RMI-IIOP the server has to be up when the client is calling it.
    - With a message-oriented middleware (MOM) that supports guaranteed delivery, the message is delivered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

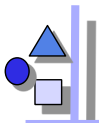
12.3 Entity Beans in 2.0





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*



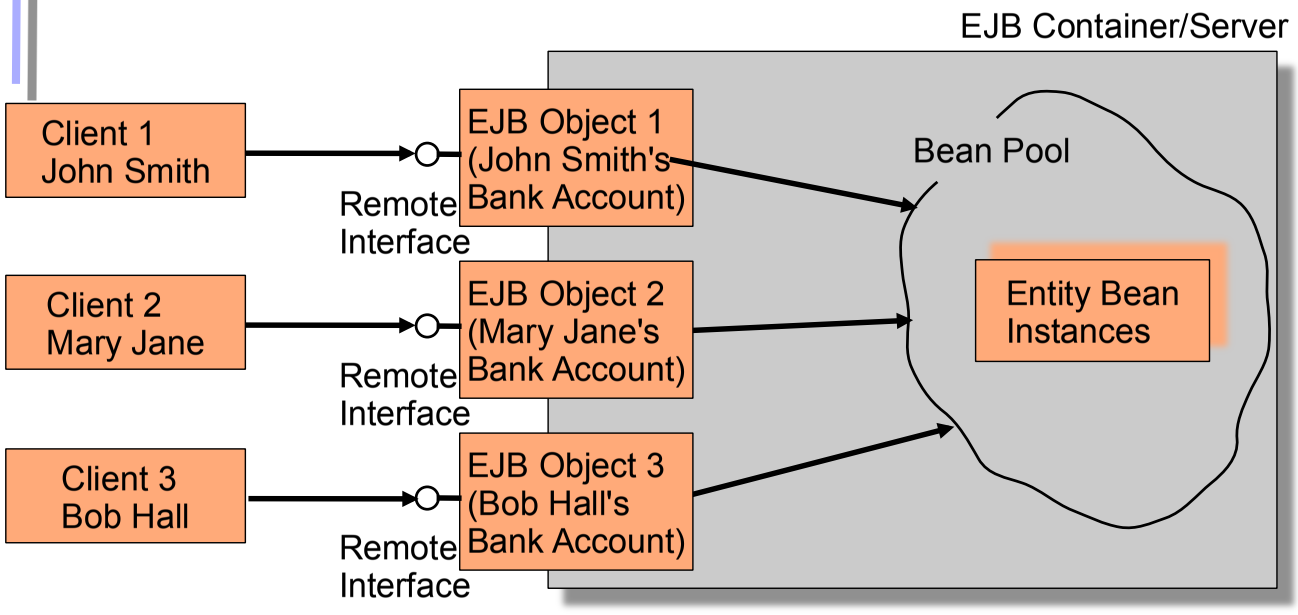
Features of Entity Beans

- 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

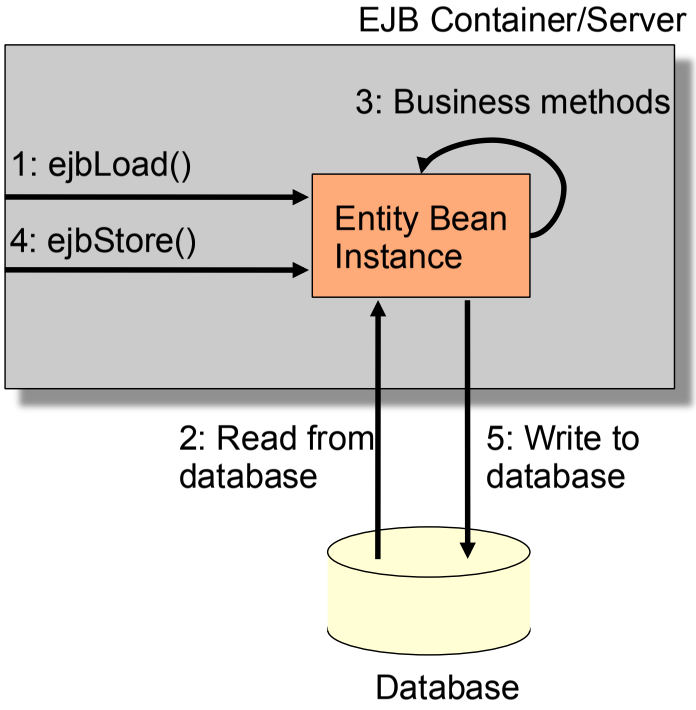
How is Persistence Achieved?

- 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

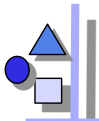


Loading and Storing an Entity Bean



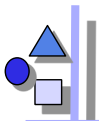
Bean-Managed Persistent Entity Beans (BMP Beans)

- 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

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

public class AccountBean implements EntityBean {
  protected EntityContext context;

  // Bean-managed state fields
  private String accountID;
  private String ownerName;
  private double balance;

  public AccountBean() { }

  ...cont...
```

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

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

public void getBalance() {
  return balance;
}

...cont...
```

Example - Business Logic Methods

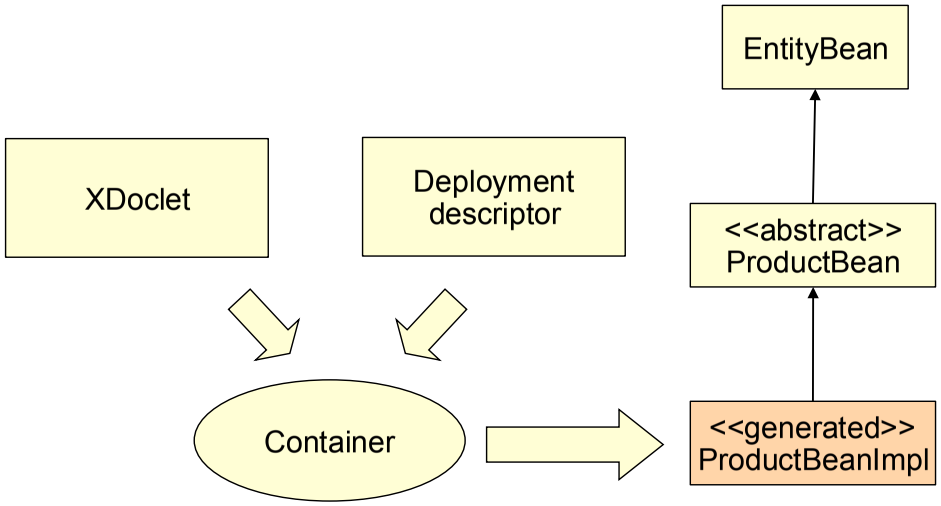
```
...cont...
public void ejbHomeGetTotalBankValue() {
  PreparedStatement pStatement = null;
  Connection connection = null;
  try {
    connection = getConnection();
    pStatement = connection.prepareStatement(
      "select sum(balance) as total from accounts");
    ResultSet rs = pStatement.executeQuery();
    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) { … }
  }
}

 ...cont...
```

Example - Required Methods

```
...cont...
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) { … }
  }  }
...
...cont...
```

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

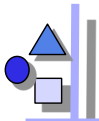
```
import javax.ejb.*;
public abstract class ProductBean implements EntityBean {
  protected EntityContext context;
  public abstract String getName();
  public abstract void setName(String name);
  public abstract String getDescription();
  public abstract void setDescription(String description);
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

Hook methods

CMP Entity Beans – Deployment Descriptor

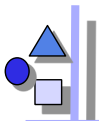
- You have to declare how the container should generate methods and fields

```
....declarations of interfaces, etc ....
  <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 ...
  <query>
    <query-method>
      <method-name>findByName</method-name>
      <method-params>
        <method-param>java.lang.String</method-param>
      </method-params>
    </query-method>
    <ejb-ql>
      <![CDATA(SELECT OBJECT(a) FROM ProductBean AS a WHERE name=?1)]>
    </ejb-ql>
  </query>
```



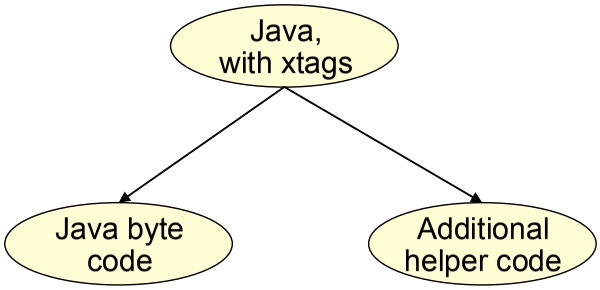
EJB and Others

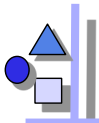
- Interceptors and Decorators
  - The Interceptor of a bean is like a decorator
  - It can be overwritten and extended from outside the EJB
  - User can write filters for EJB
  - JBoss uses this for aspect-oriented EJB (see later)
- EJB was formed after Microsoft's MTS (now COM+)
  - COM+ is in .NET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

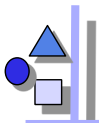




Use of XDoclets

- Generation of
  - Deployment descriptors
  - Default interfaces
  - Implementation stubs
- Example [from XDoclet documentation]

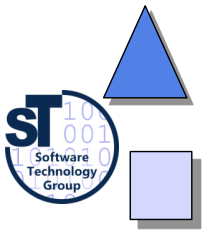
```
/** Account
  @see Customer
  @ejb.bean name="bank/Account" type="CMP"
            jndi-name="ejb/bank/Account"
            primkey-field="id"
  @ejb.finder signature="jara.util.collection findAll()"
              unchecked="true"
  @ejb.transaction type="required"
  @ejb.interface remote-class="test.interfaces.Account"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



- XDoclet is used now for many Java metadata-based applications
  - Hibernation (persistence)
  - Component markup
- Integration with ANT, the Java make tool
  - Definition of ANT tasks possible that collaborate with XDoclet

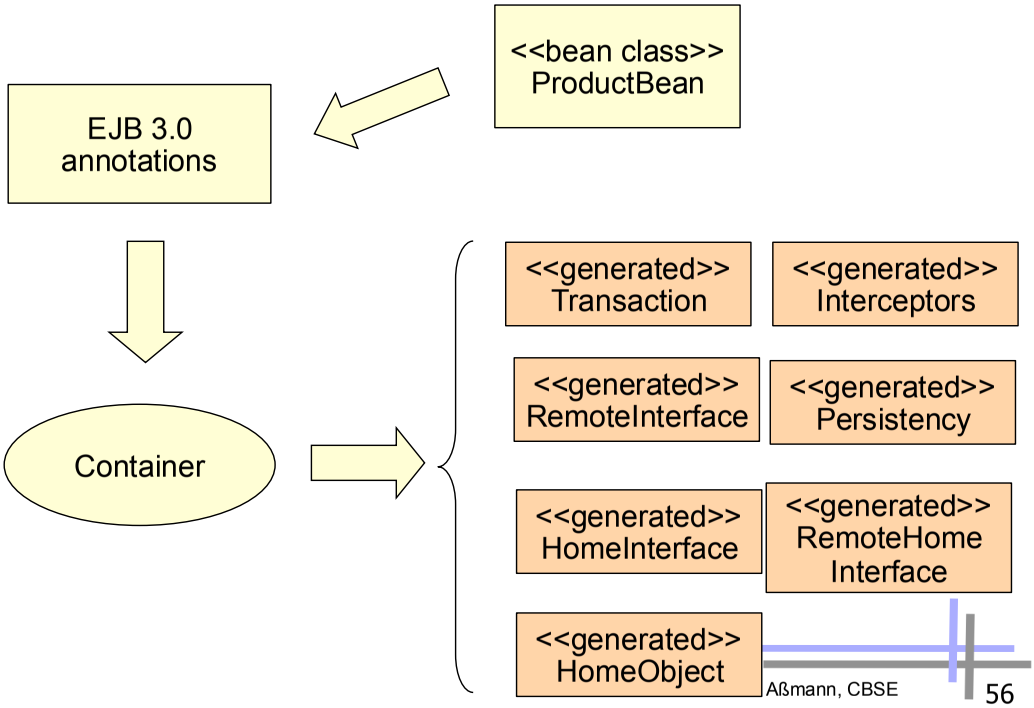
12.4. EJB 3.0

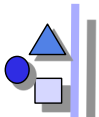
heavily uses metadata markup to generate all dependent interfaces and code



EJB 3.0

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





Marking in EJB 3.0 – Annotation Types

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

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

```
@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)*

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

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

[from EJB 3.0 Features]

```
/* Callback method defined inside a Listener class*/

public class AccountListener{

  @PostPersist
  insertAccountDetails(AccountDetails accountDetails){}

}
```

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 */
@Stateless
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) {  …   }
}
```

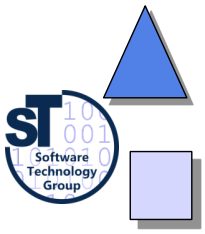

Transaction Control with Attributes

- 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() {...}
}
```

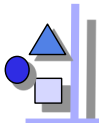
12.5 Evaluation of EJB

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



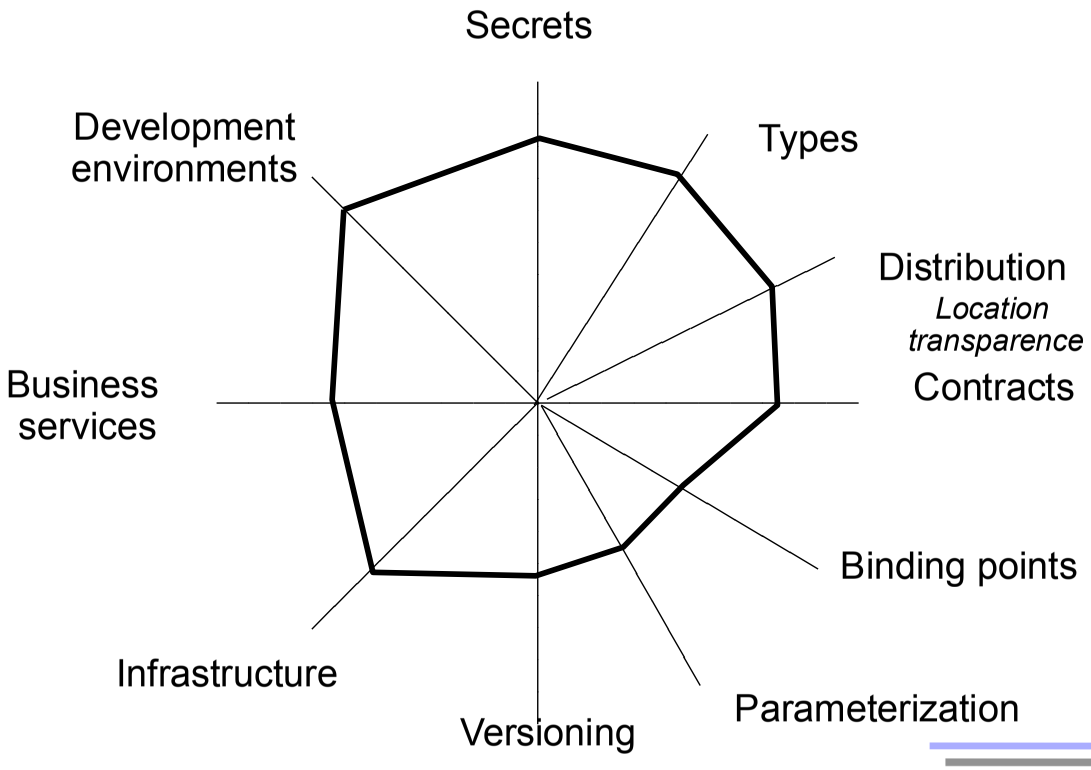
Composition Technique

- Mechanisms for connection
  - Mechanisms for locating
    - JNDI
  - Mechanisms for adaptation
    - RMI – stubs, skeletons
  - Mechanisms for glueing
    - 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

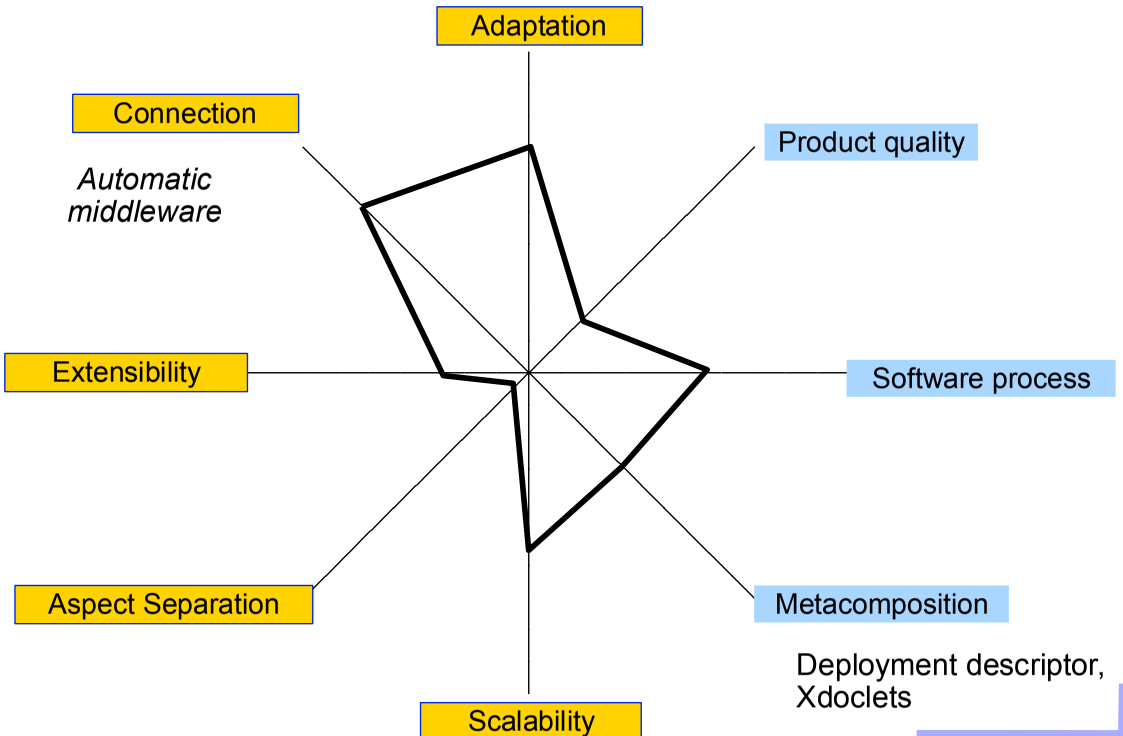
Composition Language

- 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

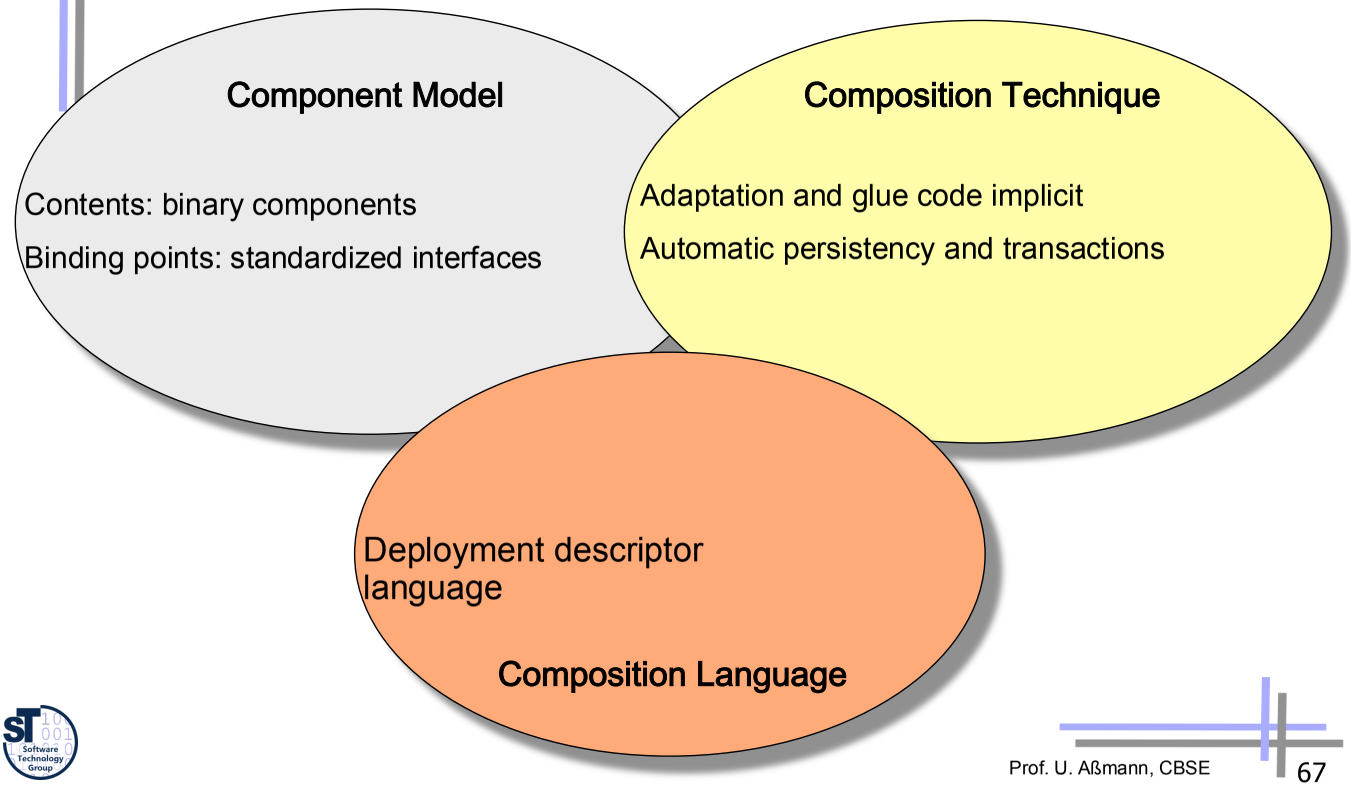
EJB - Component Model



EJB – Composition Technique and Language

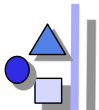


EJB as Composition Systems



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