Java EE Architecture, Part Three

Content

- Requirements on the Integration layer
- The Database Access Object, DAO Pattern
- Frameworks for the Integration layer

Requirements on the Integration Layer

- Performance
  - The SQL must make use of stored procedures, prepared statements, indexes and so on.
  - Good knowledge about the database and the DBMS is required.
  - The O/R mapping technology (e.g. JPA) must be configured to use caches, lazy loading etc in an efficient way.
  - DBMS tuning is not included in this course.
  - JPA tuning is mentioned *very* briefly below.

Requirements on the Integration Layer

- Concurrency
  - Must behave correct even if the same entity is updated concurrently by different threads.

Requirements on the Integration Layer

- Low coupling between business and resource
  - The very purpose of the integration layer is to separate business and resource.
  - The definition is adapted to the needs of the business layer and the implementation to the data store.
  - Shall it be possible to change DBMS without updating the business logic?

Requirements on the Integration Layer

- O/R-mapping
  - Conversion between rows in the database and objects in Java.
  - How are relations, inheritance and other object oriented paradigms mapped to the database?

Requirements on the Integration Layer

- Primary keys
  - When and by who are they generated?
  - How do we ensure that they are unique?

Requirements on the Integration Layer (cont)

- What data shall be used for communication with business?
  - Not primitive data since that would lead to very long and complicated method signatures.
  - May the business logic objects themselves be used?

The Database Access Object, DAO Pattern

- The responsibility of a DAO is to handle database calls.
- It should have no dependencies on the business layer and should contain no business logic.
- Its public interface is designed to meet the needs of the business layer.

DAO, an example

```
public class ProductDao {

    @PersistenceContext(unitName = "productPU")
    private EntityManager em;

    public Collection loadProductsByCategory(String category) {
       Query query = em.createQuery(
           "from Product as p where p.category = :category");
       query.setParameter("category", category);
       return query.getResultList();
    }
    //Other database access methods.

}
```

Frameworks for the Integration Layer

- Java Persistence API (JPA) (Sun, part of Java EE)
- Hibernate (JBoss)

A Comparison

- JPA and Hibernate have very similar architecture and functionality.
- Since JPA is part of Java EE and quite easy to use it should be the default choice.
- Choose Hibernate if there are specific reasons, like existing applications, developer knowledge or some particular feature.

A Comparison (cont)

- JPA contains only definitions, it does not contain the implementation (provider) that makes the actual database calls.
  - Hibernate contains both definition and implementation.
- When using JPA a provider is needed. Java EE ships with EclipseLink (Oracle).
  - Another idea is to use Hibernate as provider.

JPA: Java Persistence API

JPA Home Page:

`http://www.oracle.com/technetwork/java/javaee/tech/persistence-jsp-140049.html`

Specification:

`http://www.jcp.org/en/jsr/detail?id=220`

JPA Architecture

- Configured with annotations
- Easy to call from both Spring and EJB.
- Transactions are propagated from calling framework.
- Entities are plain java objects.
- Reads entity's byte code and uses post compilation when needed.

Entity

- Persistent object
  - Typically in the model.
- Typically (but not necessarily) one entity per table and one instance per row in that table.
- Either fields or properties (JavaBeans style) are persisted.
  - If fields or properties are persisted is decided either explicitly by the **Access** annotation or implicitly by the location of other annotations (close to fields or properties).
- Object/Relational (O/R) mapping with annotations to map objects to underlying relational data store.

Requirements for Entity Classes

- Annotated with the **javax.persistence.Entity** annotation.
- **public** or **protected**, no-argument constructor.
  - May have other constructors as well.
- Must not be declared **final**. Nor methods or persistent instance variables may be declared **final**.

Requirements for Entity Classes (cont)

- Persistent instance variables must be declared **private**, **protected**, or package-private, and can only be accessed directly by the entity class's methods.
- Instance variables must not be accessed by clients of the entity.

Requirements for Entity Classes (cont)

- Persistent fields or properties may be of the following types:
  - Any primitive type
  - Time specification classes, that is **java.util.Date** or **java.util.Calendar**
  - Any **Serializable** type
  - Enums
  - Any entity type
  - Collections (**java.util.Collection**, **java.util.List**, **java.util.Set** or **java.util.Map**) of entities.
  - Embeddable classes (explained below).

Persistent Fields

- Persistence runtime accesses entity class instance variables directly.
- All fields not declared **transient** and not annotated **Transient** will be persisted.

Persistent Properties

- Persistence runtime accesses entity state via the property accessor methods.
- All properties not annotated **Transient** will be persisted.
- Property accessor methods must be **public** or **protected**.

Persistent Properties (cont)

- The following accessor methods must exist for each property:
  - **Type getProperty()**
  - **void setProperty(Type type)**

Primary Keys

- Each entity has a unique object identifier, a primary key.
- A simple (non-composite) primary key must correspond to a single persistent field or property of the entity class.
  - The **Id** annotation is used to denote a simple primary key.

Composite Primary Keys

- Typically used when mapping from databases where the primary key is comprised of several columns.
- Composite primary keys must be defined in a primary key class.

Composite Primary Keys (cont)

- Composite primary keys must correspond to either a single persistent property or field, or to a set of single persistent properties or fields in the primary key class.
- Composite primary keys are defined using the **javax.persistence.EmbeddedId** and **javax.persistence.IdClass** annotations.

An example

```
package account;

import java.io.Serializable;
import javax.persistence.Entity;
import javax.persistence.GeneratedValue;
import javax.persistence.GenerationType;
import javax.persistence.Id;

@Entity
public class Account {

   @Id
   private int acctNo;
   private String firstName;
   private String lastName;
   private int balance;
```

An example (cont)

```
 public Account() {
}
public Account(int acctNo, String firstName, String lastName,
            int balance) {
  this.acctNo = acctNo;
  this.firstName = firstName;
  this.lastName = lastName;
  this.balance = balance;
}

public int getAcctNo() {
  return acctNo;
}

// More business methods.
```

Context

- A persistence context is a set of managed entity *instances* that exist in a particular data store.
- A context is the scope under which entity *instances* exist.

EntityManager

- The **EntityManager** interface defines the methods that are used to interact with the context, for example create, remove and find.
- Each **EntityManager** instance is associated with a single context.

EntityManager (cont)

- Applications that are container-managed (for example EJB applications) can obtain entity managers with injection:

```
@PersistenceContext
EntityManager em;
```

  - The container will create an entity manager instance and store it in the em field.
- The container will assure that all entity managers used in the same transaction will handle the same context.

Persistence Unit

- Applications that are not container-managed (for example servlet application and Java SE applications) must call EntityManagerFactory to have an entity manager created:

```
@PersistenceUnit
EntityManagerFactory emf;
EntityManager em = emf.createEntityManager();
```

Persistence Unit (cont)

- Persistence Unit
  - Defines the entities that are managed by an entity manager.
  - Defines where to store the entities persistently.

Entity Instance's Life cycle

- The life cycle of an entity instance is managed by the **EntityManager**.
- Entity instances are in one of four states: *new*, *managed*, *detached*, or *removed*.

Entity Instance's Life cycle (cont)

- ***New*** entity instances have no persistent identity and are not yet associated with a persistence context.
- ***Managed*** entity instances have a persistent identity and are associated with a persistence context.

Entity Instance's Life cycle (cont)

- ***Detached*** entity instances have a persistent identify and are not currently associated with a persistence context.
- ***Removed*** entity instances have a persistent identity, are associated with a persistent context, and are scheduled for removal from the data store.

Entity Instance's Life cycle (cont)

```
@PersistenceContext
 EntityManager em;
 ...
 public LineItem createLineItem(Order order, Product product, int
 quantity) {
     LineItem li = new LineItem(order, product, quantity); // new
     order.getLineItems().add(li);
     em.persist(li); // managed
 }
```

- The entity (**li**) is *new* after this statement.
- The entity is *managed* after this statement.

Entity Instance's Life cycle (cont)

```
public void removeOrder(Integer orderId) {
   try {
      Order order = em.find(Order.class, orderId);
      em.remove(order);
   }
```

- Entities are looked up with the **EntityManager** method **find** (more on queries below).
- Entities are removed with the **EntityManager** method **remove**.

Entity Instance's Life cycle (cont)

- The state of persistent entities is synchronized to the database when the transaction with which the entity is associated commits.
- To force synchronization of the managed entity to the database, invoke the `flush` method of the `EntityManager`.

Transactions

- Container-managed
  - The preferred way.
  - Can only be used when JPA entities stays in a transaction aware container (e.g EJB or Spring)
  - Transactions propagate from the calling container and are not handled by JPA code.
  - Use declarative transaction demarcation in the container.

Transactions (cont)

- Application-managed
  - The only choice if JPA is not used inside a transaction aware container.
  - Typically used when JPA is called from a standalone Java program or from a Servlet container.
  - Transaction must be started and stopped programmatically through the EntityTransaction interface.
  - Easy to make mistakes!

Embeddable classes

- Ordinary java class that is a persistent property or field of an entity.
- Have no identity and can not be shared between entities.
- Follow the same rules as entities (no-arg constructor, not **final** etc) except that they are annotated **@Embeddable** instead of **@Entity**.
- Its persistent fields/properties may be primitive types, other embeddable classes, entities or collections of these three kinds.

Relationships

- Relationships are persistent.
- Can be between two entities or between an entity and an embeddable class.
- Can be unidirectional or bidirectional.
- Can be one-to-one, one-to-many, many-to-one or many-to-many
- Changes cascade (if so is specified) when saved to the database.

Relationships, example

```
@Entity
public class Employee {
  private Cubicle assignedCubicle;

  @OneToOne
  public Cubicle getAssignedCubicle() {
    return assignedCubicle;
  }

  public void setAssignedCubicle(
         Cubicle cubicle) {
       assignedCubicle = cubicle;
  }
    ...
}
```

```
@Entity
public class Cubicle {
private Employee residentEmployee;

@OneToOne(mappedBy="assignedCubicle")
public Employee getResidentEmployee() {
    return residentEmployee;
}

public void setResidentEmployee(
    Employee employee) {
        residentEmployee = employee;
}
    ...
}
```

Relationships, direction

- Unidirectional relationships can only be navigated in one way.
  - Cascading updates
  - Searches
- Have relationship annotation only on one side.

Relationships, direction (cont)

- Bidirectional relationships can be navigated in both ways.
- Have relationship annotations on both sides.
- Inverse (not owning) side specifies that it is mapped by the property or field on the owning side.

```
@OneToOne(mappedBy="assignedCubicle")
```

Relationships, direction (cont)

- The relationship itself is persisted based on the owning side.
- The owning side has the foreign key.

Relationships, multiplicity

- The following annotations exist:
  - **OneToOne**
  - **OneToMany**
  - **ManyToOne**
  - **ManyToMany**
- For **OneToOne** and **ManyToMany** relationships any side may be the owning side.

Relationships, multiplicity (cont)

```
@Entity
public class Employee {
    private Department department;

    @ManyToOne
    public Department getDepartment() {
        return department;
    }

    public void setDepartment(Department department) {
        this.department = department;
    }
    ...
}
```

Relationships, multiplicity (cont)

```
@Entity
public class Department {
    private Collection<Employee> employees = new HashSet();

    @OneToMany(mappedBy="department")
    public Collection<Employee> getEmployees() {
        return employees;
    }

    public void setEmployees(Collection<Employee> employees) {
        this.employees = employees;
    }
    ...
}
```

Relationships, cascading updates

- Updates to the database may cascade along relationships.
  - Specified by the **cascade** element of the relationships annotations.
  - **ALL**, Cascade all operations
  - **MERGE**, Cascade merge operation
  - **PERSIST**, Cascade persist operation
  - **REFRESH**, Cascade refresh operation
  - **REMOVE**, Cascade remove operation

Relationships, cascading updates (cont)

Example:

```
@OneToMany(cascade=REMOVE, mappedBy="customer")
public Set<Order> getOrders() {
   return orders;
}
```

Queries

- Query methods are in **EntityManager**.
- The **find** method can be used to find instances by primary key.

```
em.find(Order.class, orderId);
```

Queries (cont)

- The **createQuery** method is used to create dynamic queries, queries that are defined directly within an application's business logic.

```
@PersistenceContext
public EntityManager em;
...
public List findWithName(String name) {
    Query query =  em.createQuery(
        "SELECT c FROM Customer c WHERE c.name LIKE
:custName");
    query.setParameter("custName", name);
    return query.getResultList();
}
```

Queries (cont)

- The **createNamedQuery** method is used to create static queries, queries that are defined in meta data using the **NamedQuery** annotation.

```
@NamedQuery(
   name="findAllCustomersWithName",
   query="SELECT c FROM Customer c WHERE c.name LIKE :custName"
)

@PersistenceContext
public EntityManager em;
...
Query query = em.createNamedQuery("findAllCustomersWithName");
query.setParameter("custName", "Smith");
customers = query.getResultList();
```

Java Persistence Query Language, JPQL

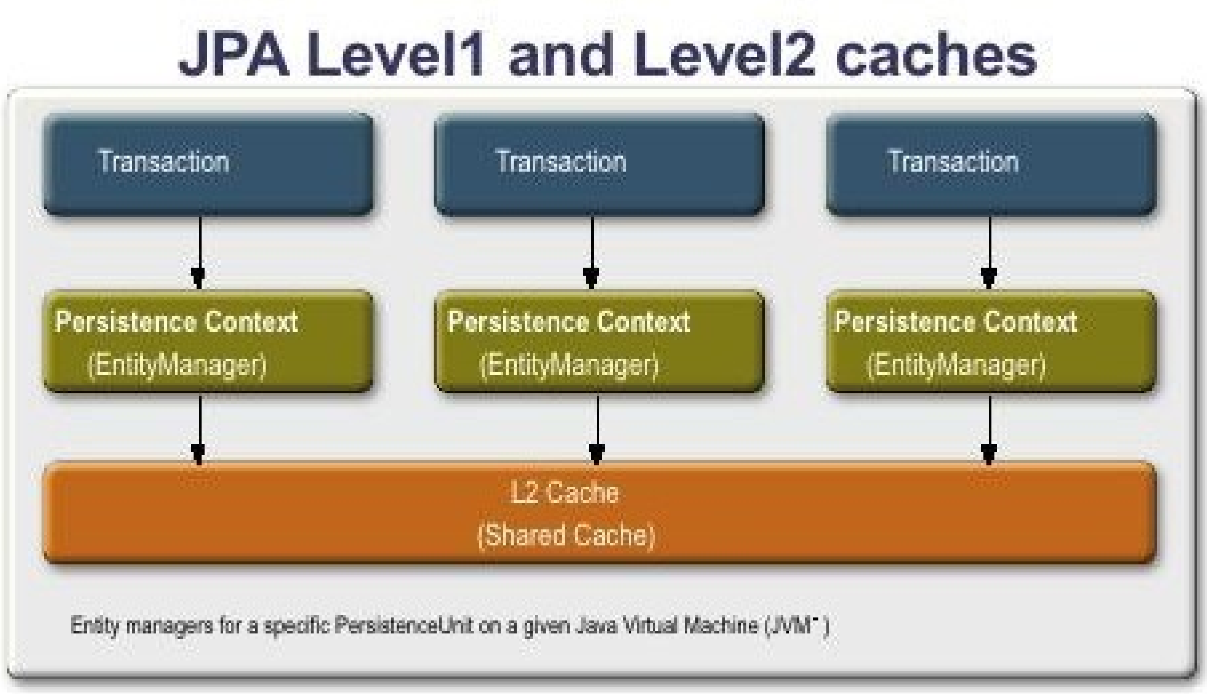
- The two preceding slides use Java Persistence query language.
  - SQL-like language.
  - See for example the Java EE tutorial or the specification.

Criteria API

- The criteria API provides a way to generate queries in an object-oriented way with ordinary method calls, as opposed to the string manipulation used by JPQL.
- The advantage over JPQL is that it is type safe and that it is not required to know field names at compile time.
- The disadvantage is that notably more code is required to generate queries and that it is harder to read the queries.

Cache

- The JPA specification includes optional support for caching in the JPA provider (e.g. EclipseLink).
  - EclipseLink provides such a cache.
- This is called *second-level cache*, as opposed to the *first-level cache* which is maintained by the persistence context.

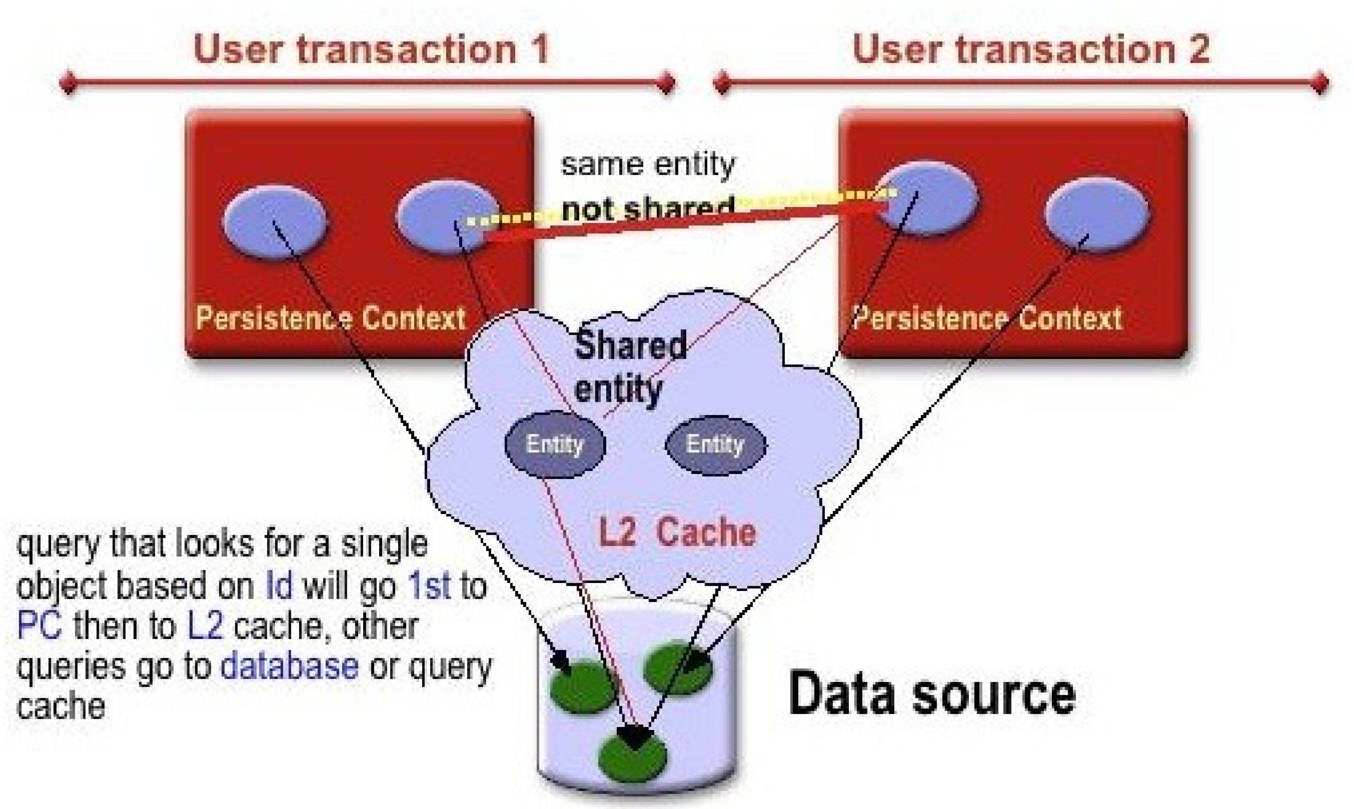

JPA Level1 and Level2 caches
Transaction
Transaction
Transaction
Persistence Context (EntityManager)
Persistence Context (EntityManager)
Persistence Context (EntityManager)
L2 Cache (Shared Cache)
Entity managers for a specific PersistenceUnit on a given Java Virtual Machine (JVM™)

Cache, Cont'd

- Cache tuning is one of the topics that are important for database performance.
- Information about JPA and EclipseLink caches can be found at the following URLs.
  - **`http://weblogs.java.net/blog/archive/2009/08/21/jpa-caching`**
  - **`http://wiki.eclipse.org/Introduction_to_Cache_%28ELUG%29`**

Locks

- As can be seen below, multiple transactions might be using the same entity instance in the L1 cache, the L2 cache and the database.
- Therefore, locking is required



Locks, Cont'd

- The most used locking mechanism is *optimistic locking*.
  - Allows concurrent accesses but detects them.
  - If concurrent access are detected the transaction is rolled back and an exception is thrown.
- Optimistic locking is the best alternative when conflicts are not so frequent, i.e. when updates are not frequent.

Locks, Cont'd

- Optimistic locking is implemented using a version number for the data (entity).
  - Whenever an entity instance is read, its current version number is also read.
  - When the instance is stored, the version in the database is compared to the Java object's version.
  - If the version numbers differ it means someone else updated the database and there is a conflict.

Optimistic Lock Example

- In the entities, add a version field.

```
    @Version
    @Column(name="OPTLOCK")
    private int versionNum;
```

- In the quires, specify the the found entities shall be optimistically locked.

```
    @NamedQuery(
        name = "findAccountWithName",
        query = "SELECT acct FROM Account acct WHERE
acct.owner.name LIKE :ownerName",
        lockMode = LockModeType.OPTIMISTIC_FORCE_INCREMENT)
```

Optimistic Lock Example, Cont'd

- Optimistic locking can also be specified in the entity manager using the **`lock`** or **`find`** methods.

More information on Locking

- **`http://blogs.sun.com/carolmcdonald/entry/jpa_2_0_concurrency_and`**

Lazy Loading

- Say that we have two entities, A and B, and that A has a reference to B. When A is loaded, B will also be loaded and it will be possible to access B writing something similar to **`a.getB()`**, provided that **`a`** is an instance of A.
- If entity B is never accessed in the program, then it was a waste of resources to read the B instance from the database.

Lazy Loading, Cont'd

- To avoid this unnecessary read, we can specify that B should be *lazy loaded*.
- This means that the instance of B will not be read from the database when the A instance is read, but when the B instance is accessed, that is when **`a.getB()`** is called.
- The opposite, that the B instance *is* read from the database when the A instance is read, is called *eager loading*.

Lazy Loading, Cont'd

- If we always use eager loading we might suffer severe performance penalties by loading (lots of) unused objects.
- Also lazy loading can bring performance penalties if used the wrong way.
  - Suppose that we load entity A, which has a one to many relation to B.
  - Also suppose that we will iterate through all B instances referenced by the A instance.
  - This means that there will be one separate database call for each instance of B instead of loading them all in the same call, which would be the case if eager load was used for B.

Lazy Loading, Cont'd

- Which loading strategy that is used can be specified in all relationship annotations, i.e **`OneToOne`**, **`OneToMany`**, **`ManyToOne`** and **`ManyToMany`**.
- More information about loading strategies can be found at **`http://blogs.sun.com/carolmcdonald/entry/jpa_performance_don_t_ignore`**

Performance Conclusion

- As seen from this very brief overview there are lots of properties related to performance of JPA and of the JPA provider.
- Also the DBMS itself provides caching, locking and lots of other configuration possibilities that are important for performance.
- The bottom line is that good knowledge about the O/R mapping technology and the DBMS is *necessary* to be able to write an efficient application.
  - However, this is not a mandatory part of this course.