CMPS310 Software Engineering

Fall 2021

Lecture 10

Component-Deployment Diagrams
and
Modeling to Programming

Review: Diagrams in UML

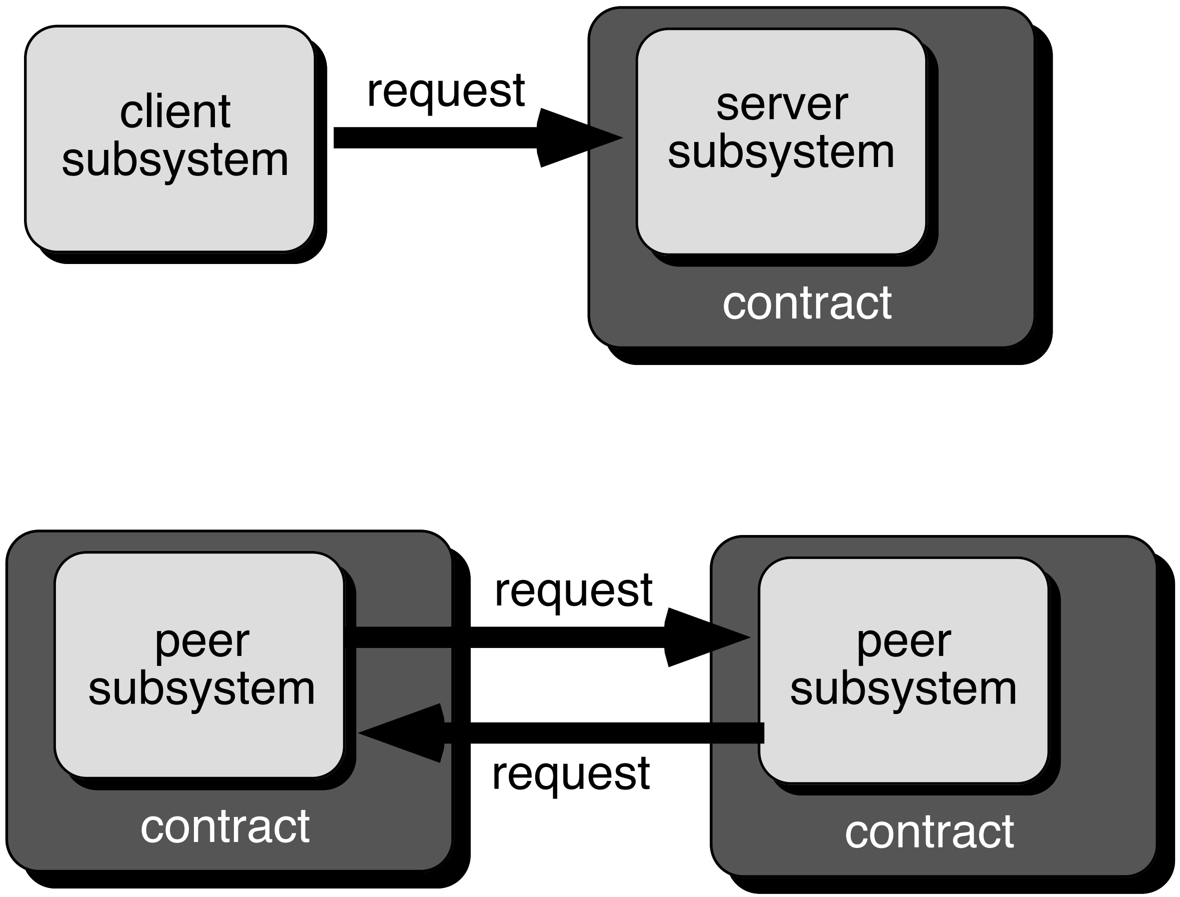
1. Class Diagram
2. Object Diagram
3. Component Diagram
4. Deployment Diagram

Structural Diagrams

5. Use Case Diagram
6. Sequence Diagram
7. Collaboration Diagram
8. State Diagram
9. Activity Diagram

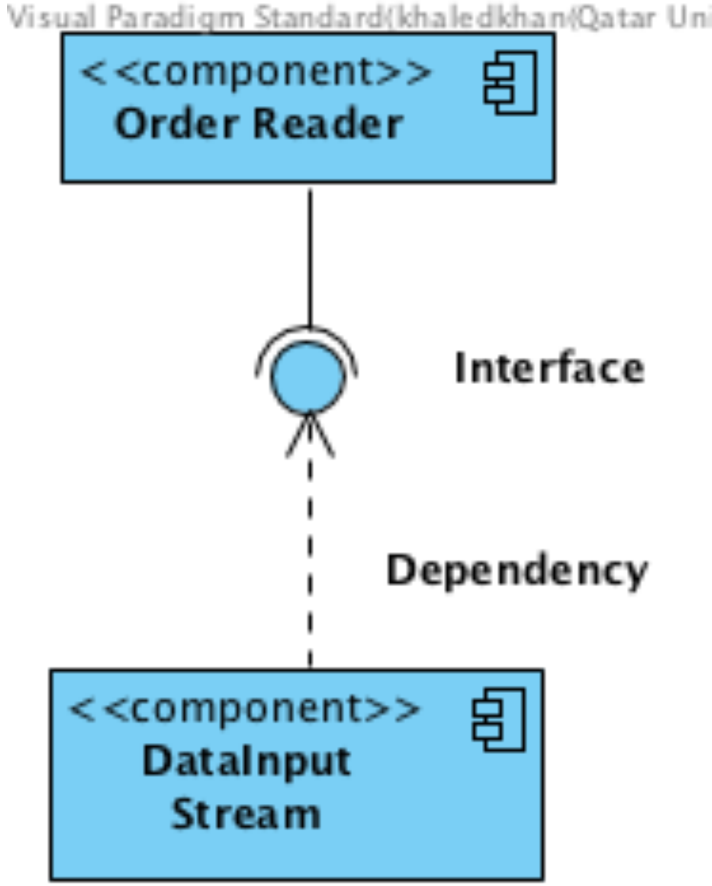
Behavioral Diagrams

Systems and subsystems: Basic Concepts



UML Basic: Components and Interfaces

- Lollipops ("short-hand notation")



Breaking a System into Subsystems?

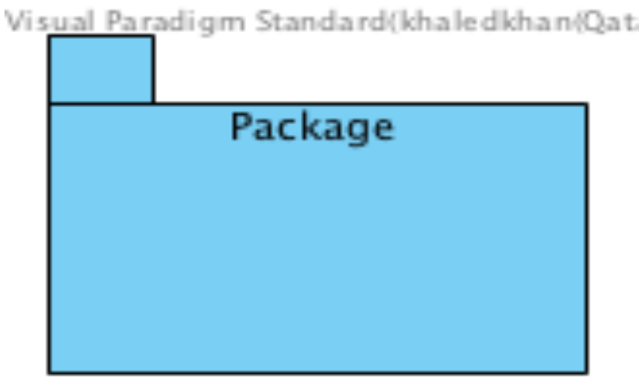
- Roman principle: Divide & conquer
  - Split up a large system into manageable parts
- In structured methods: functional decomposition
- In OO: Group classes into higher level units:

Packages
(conceptual; at development time)

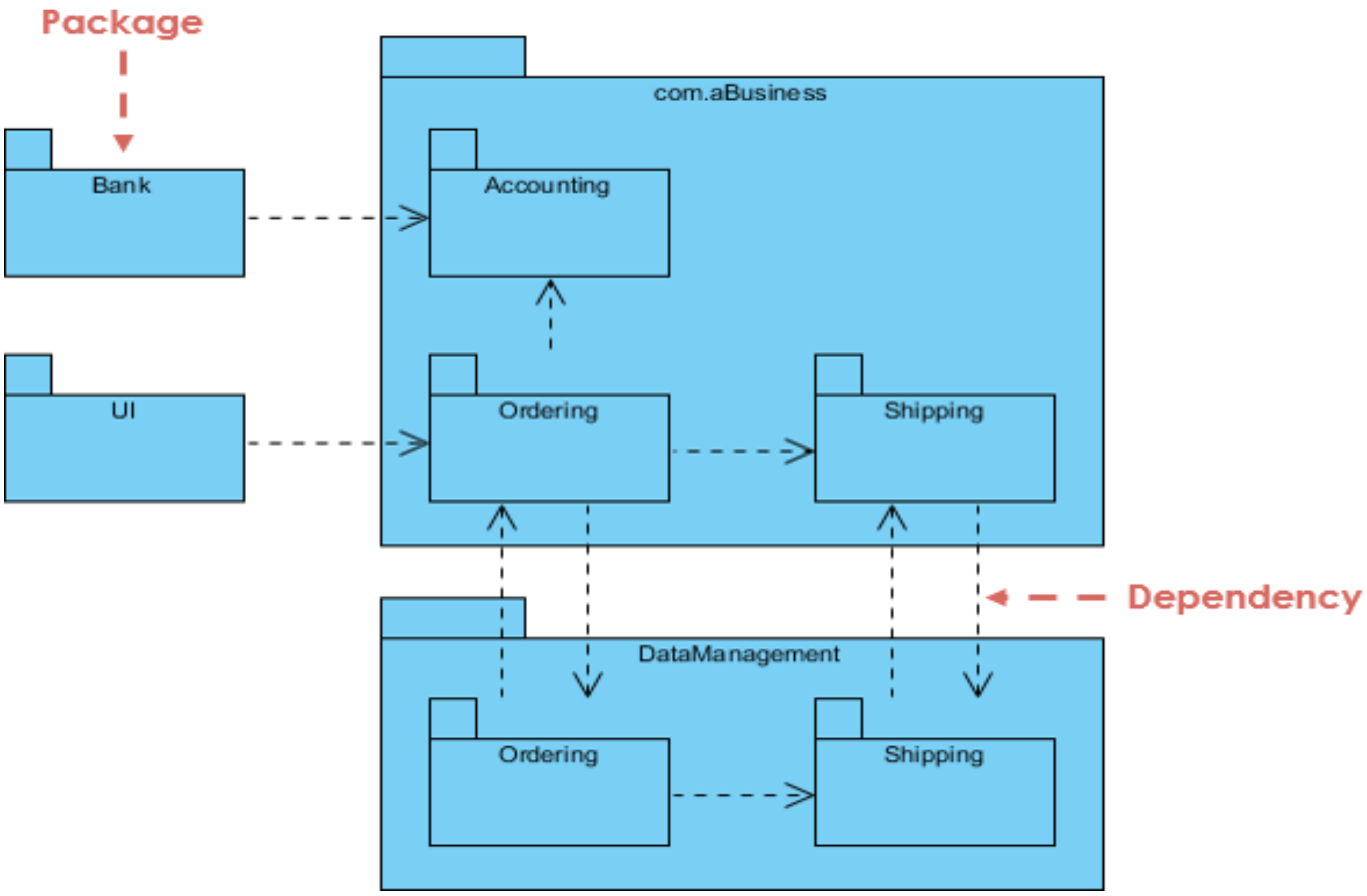
Components
(physical; at run time)

Packages

- Package Diagram can be used to simplify complex class diagrams, it can group classes into packages.
- A package is a collection of logically related UML elements.
- Packages are depicted as file folders and can be used on any of the UML diagrams.
- General purpose mechanism for organizing elements into groups
- Package forms a namespace
  - Names are unique within ONE package
  - UML assumes an anonymous root package

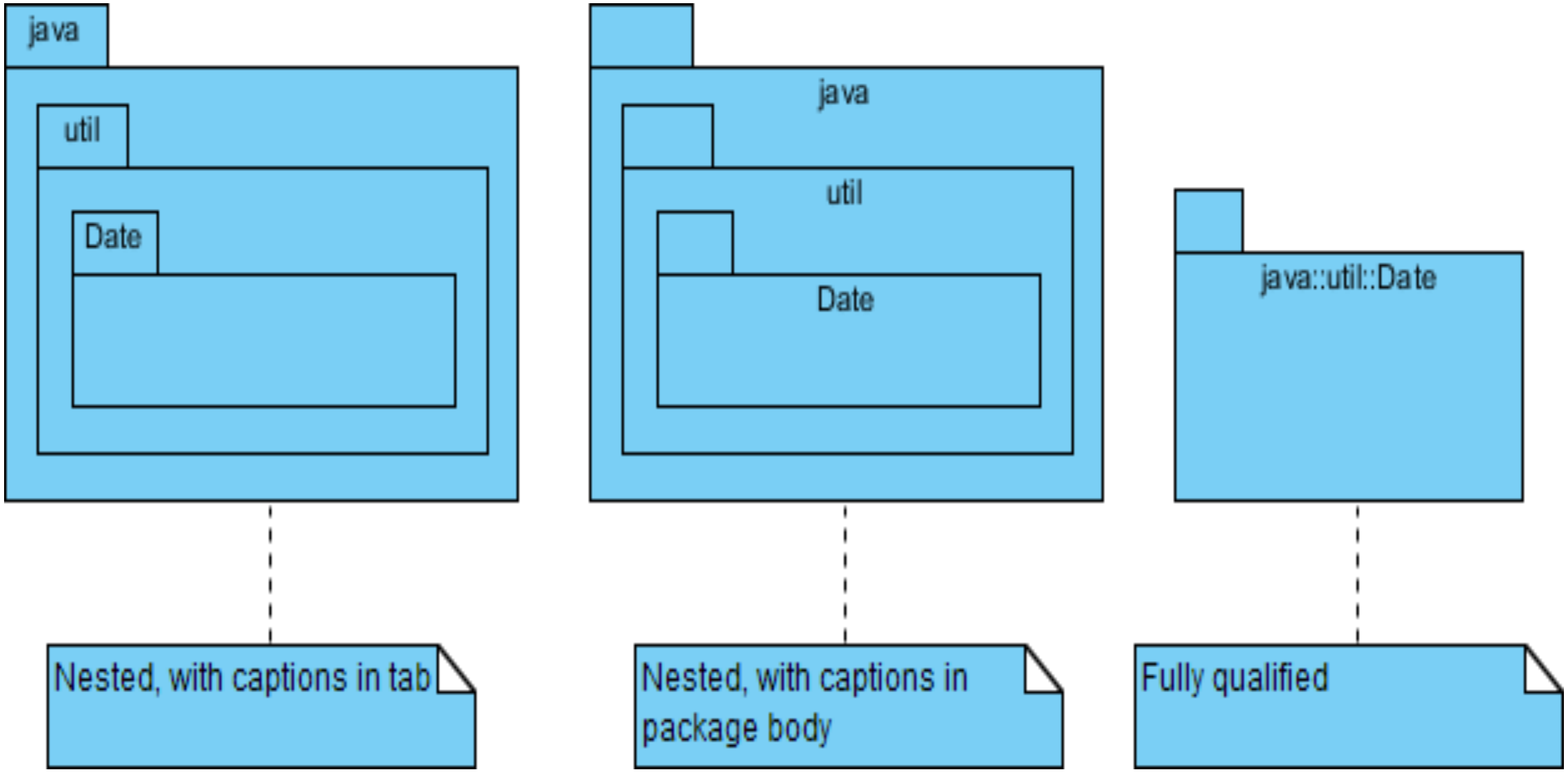


Example of Package Diagram

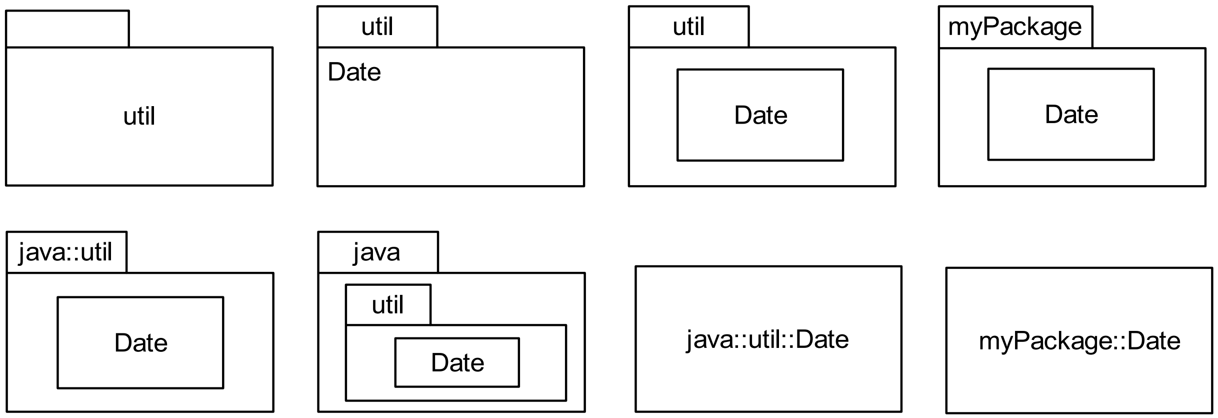


Notations of Package Nesting and Hierarchy

- All three diagrams are correct and equivalent to each other

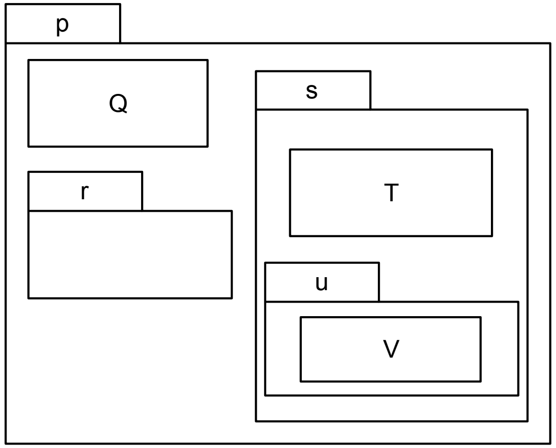


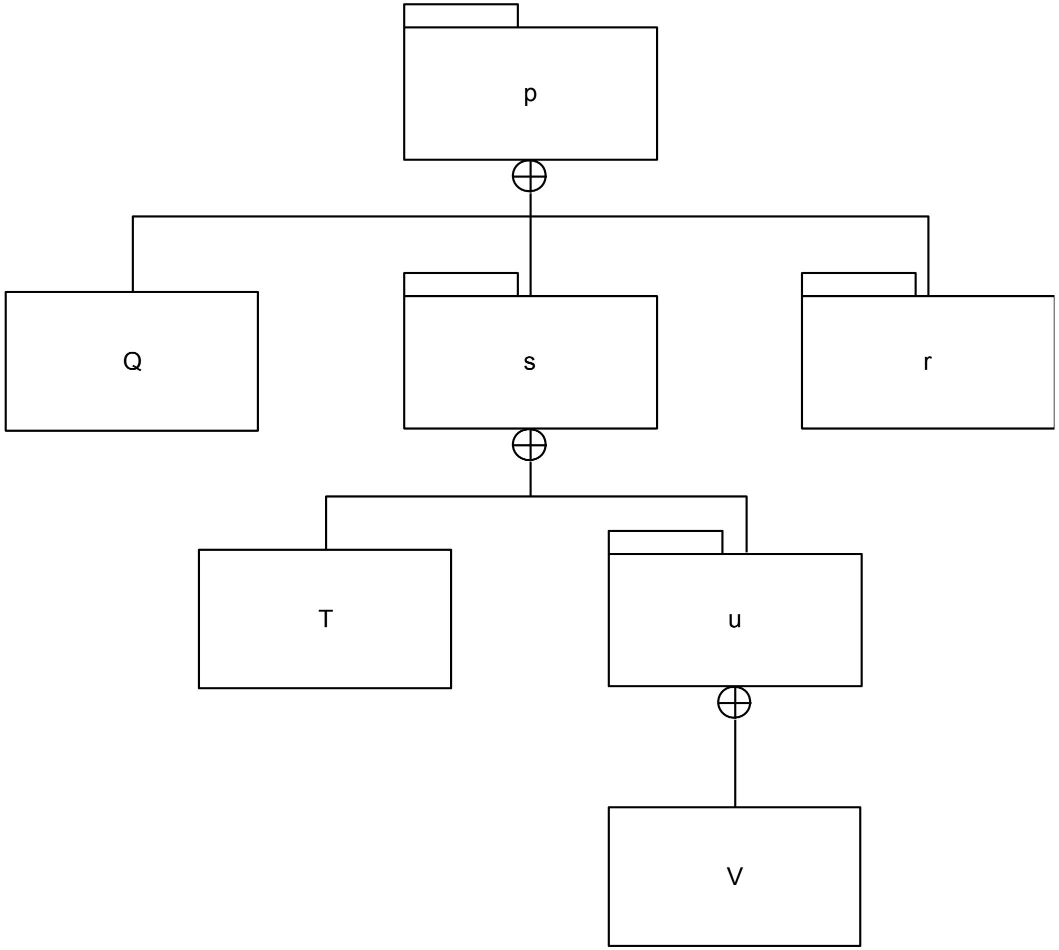
Packages



- Classes are basic structural units in an OO system
- In large systems with hundreds of classes, **need to group the classes together into *packages***
- A *package* in UML can be a collection of **any packageable UML elements** but it is most commonly a collection of classes
- A package may contain other packages (subpackages)
- A package in UML corresponds to a package in Java or a namespace in C++
- Each package is a namespace
  - There must never be more than one class within a package with any given name
  - Classes in different packages can have the same name
- If several teams working on a project, each could work on a different package
  - Would mean they don't have to worry about name clashes
- To distinguish between classes with the same name in different packages, use *fully qualified name*
  - e.g., java::util::Date, myPackage::Date
- UML package icon is a tabbed folder
  - Can show just name or contents too
    - If just name shown, then can be written in the middle of the icon, otherwise name written on tab
  - Can show all details of class or even class diagram within package
  - At other extreme, can just list names of classes within the package icon

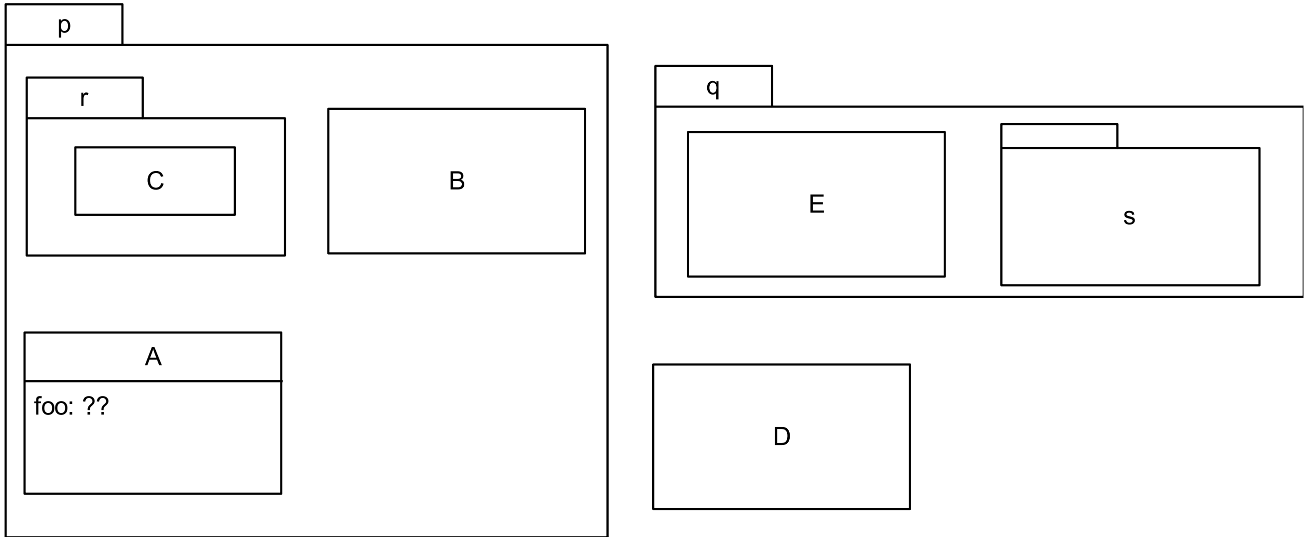
Package Membership





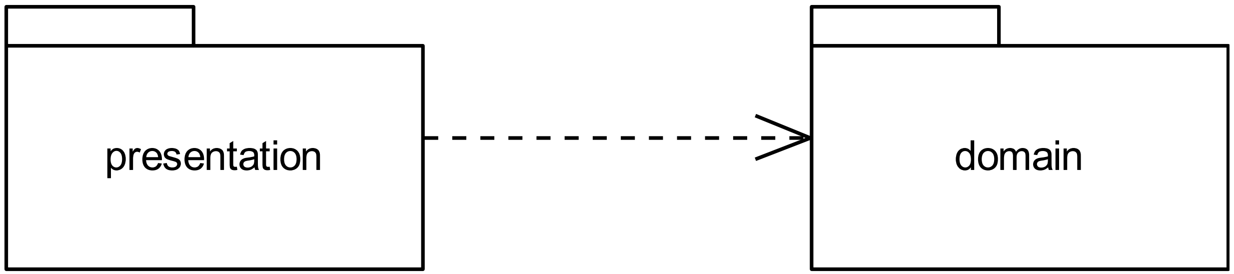
- These diagrams convey the same information

Relationships between Packages



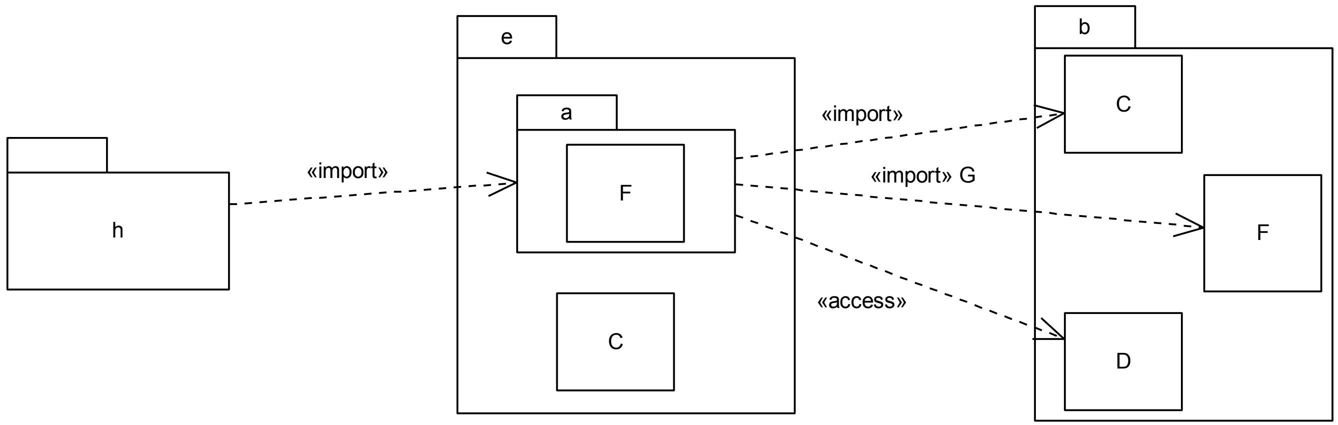
- Element/component can refer to other elements/components that are in its own package and in enclosing packages without using fully qualified names
- Element x must use fully qualified name to access element in package that does not contain x
- foo can be of class B or D
- foo can be of class q::E or r::C

Packages and Dependencies



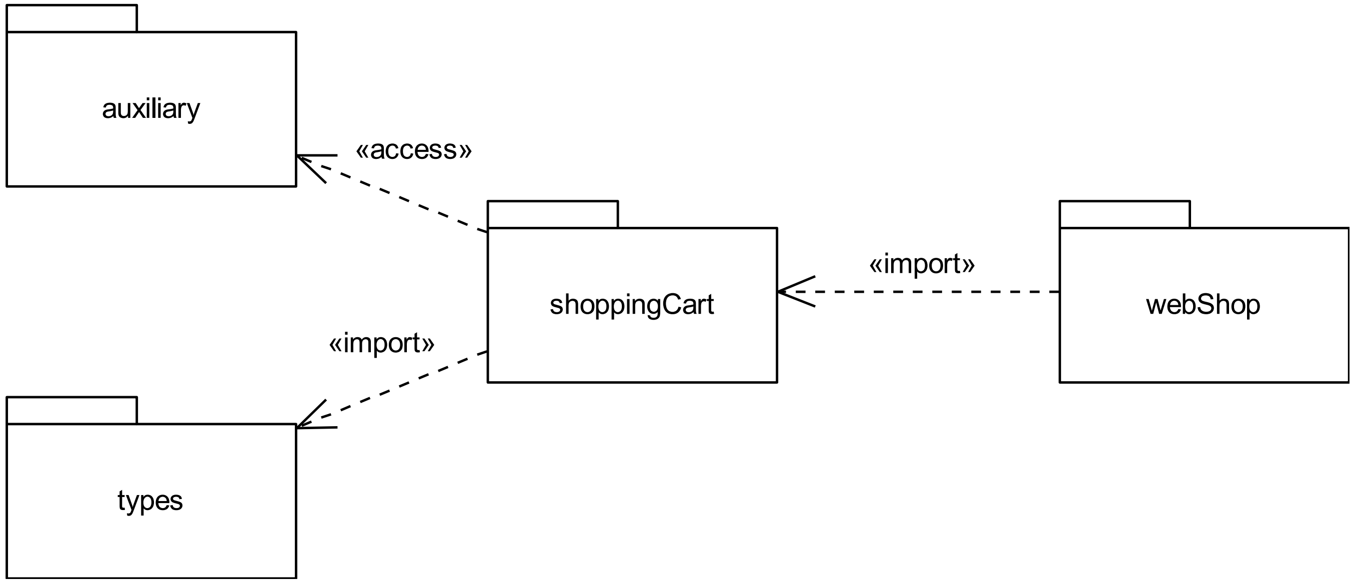
- Package diagram shows packages and their dependencies
- Package A depends on package B if A contains a class which depends on a class in B
  - Inter-package dependencies summarise dependencies between classes

Element Import



- Element/component import identifies an element in another package and allows the element to be referenced using its name without a qualifier
- Element import indicated by dashed arrow with open arrowhead from importing package to imported element and labelling arrow with
  - Keyword <<import>>, if visibility of imported element within importing package is public, and
  - Keyword <<access>>, if visibility of imported element within importing package is private
- In above example
  - Class **b::C** is referred to as just **C** in package **a**, and has public visibility within package **a**
  - Imported class **C** hides outer class **e::C** which must be referred to by its fully qualified name (before import, **C** referred to **e::C** in package **a**)
  - Class **b::F** is imported into package **a**, but there is already a class called **F** in **a**, therefore cannot import **b::F** without aliasing it
    - Class **b::F** is referred to as **G** in package **a**
  - Imported class **b::D** can be referred to as **D** in package **a**, and has private visibility within package **a**
  - Package **h** imports package **a** which means that, in **h**, **b::C** is referred to as **C** and **b::F** is referred to as **G**
    - **b::D** is not accessible from **h** because its visibility in **a** is private

Package Import



- A package import is a directed relationship that identifies a package whose members are to be imported by a namespace (package)
- Importing namespace adds names of members of imported package to its namespace
- Conceptually equivalent to having an element import to each individual member of the imported namespace
- Notated using dashed line with open arrowhead from importing namespace to imported package, labelled with keyword
  - <<import>> if package import is public and
  - <<access>> if package import is private
- If package import is public, then imported elements will be visible outside of importing package, while if it is private, they will not be visible
- In example above, elements in **types** are imported to **shoppingCart** and then further imported to **webShop**
- But elements of **auxiliary** only accessible from **shoppingCart**, not **webShop**

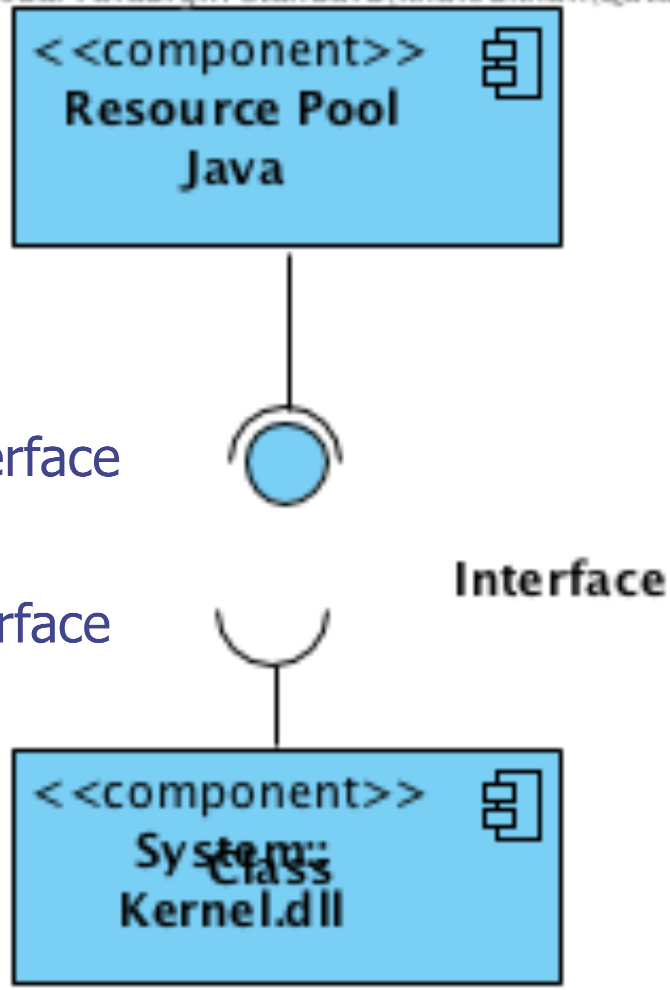
Component Diagram

- A component in UML represents **a modular part of a system**.
- The behavior is defined in terms of required and provided interfaces.
- A component has an external view with public properties and operations
- It has also an internal view with private properties and realizing classifiers.
- Component Diagram: High-Level Interaction and Dependencies Among Software Components
- Captures the Physical Structure of the Implementation
- Built as Part of Architectural Specification
- Purposes:
  - Organize Source Code
  - Construct an Executable Release
  - Specify a Physical Database
- Main Concepts: Component, Interface, Dependency, Realization
- Developed by Architects and Programmers

Component Symbol

Provided interface

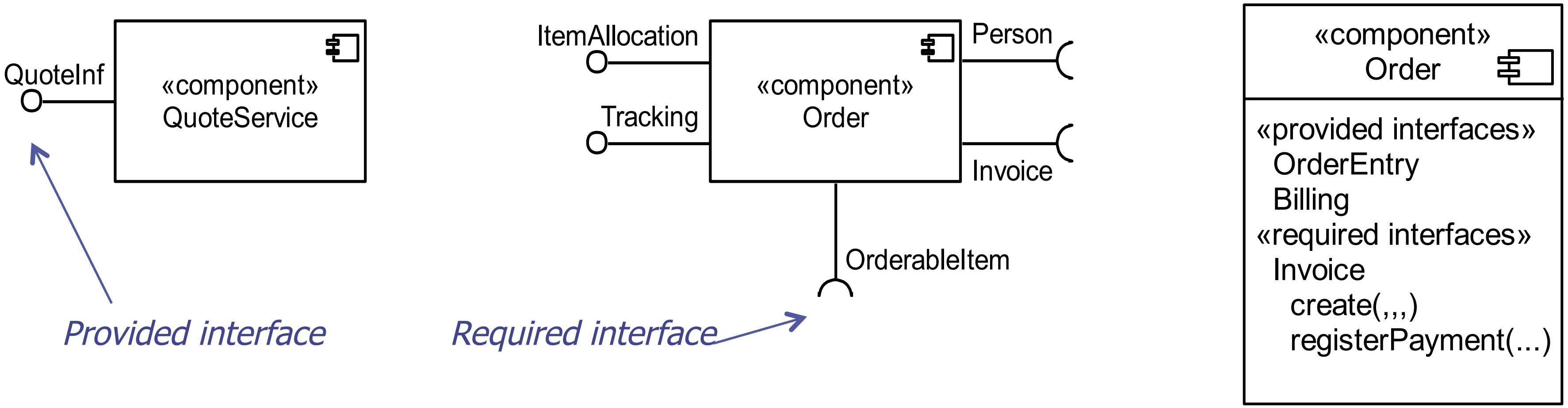
Required interface



Components

- UML defines a ***component*** to be
  - "a modular unit with well-defined interfaces that is replaceable within its environment" (UML Superstructure Specification, v.2.0, Chapter 8)
- Component-based design emphasises reuse
  - Component is an autonomous unit within a system
- Component defines its behaviour in terms of **provided** and **required interfaces**
  - A component may be replaced with another if they both provide and require the same interfaces
- In UML, a component is a special type of class
  - However, a component will often be a collection of collaborating classes
- A component can therefore have attributes and operations and may participate in associations and generalizations
- A component ***provides*** **interfaces that it realizes** and exposes to its environment
- A component may **require interfaces from other component**s in its environment in order to be able to provide all its functionality
- *External* or "Black box" view on a component considers its publicly visible properties and operations
- *Internal* or "White box" view on a component considers its private properties and *realizing classifiers* (i.e., the classes and other elements inside the component) and shows how the behaviour of the component is realized internally

Component Notation

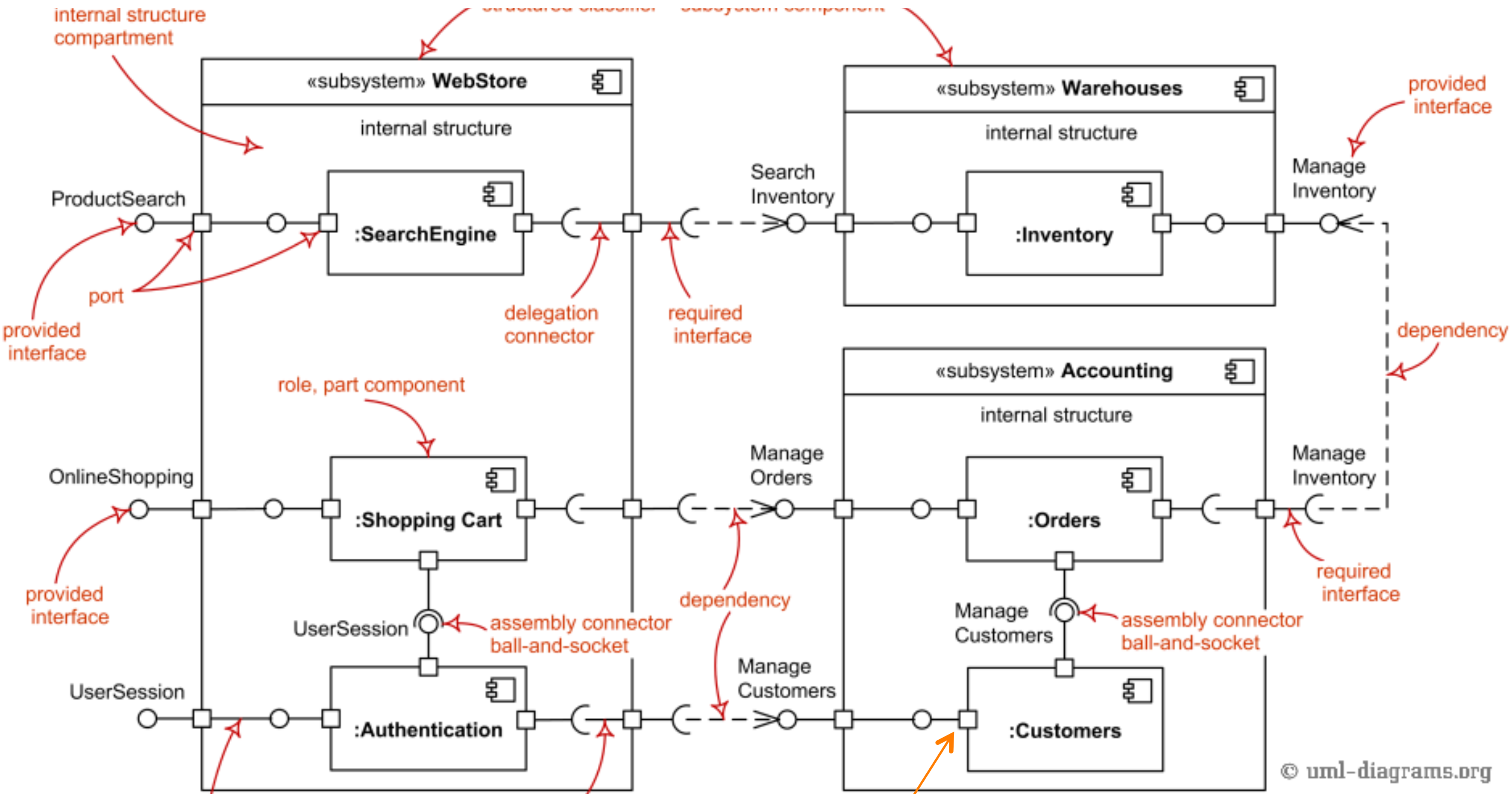


- Component icon is a class icon with the keyword <<component>>
  - Optionally can include a component icon in the top, right-hand corner
- A component has its behavior defined in terms of
  - *provided interfaces,* and
  - *required interfaces*

  potentially exposed via **ports**
- Black-box view shows only interfaces provided and required either using "ball-and-socket" notation or listed in a compartment of the component rectangle

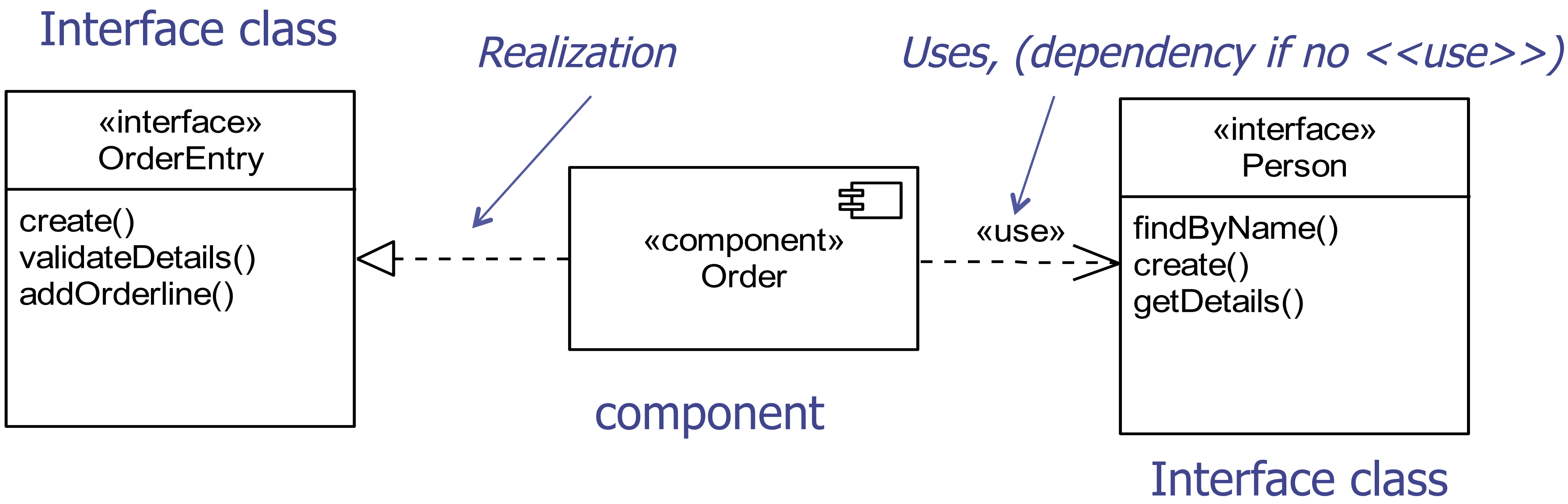
Component Diagram Notations

Subsystem components



- A **delegation port** is a connector that links the external contract of a component (as specified by its ports) to the realization of that behavior.
- A **simple port**

Internal White-box View on Components

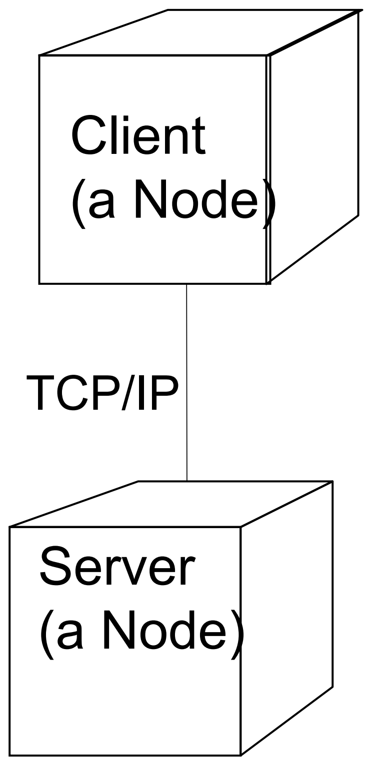


- Interfaces can also be displayed in full using class icons, use
  - Dashed arrow with white triangle head for provided interfaces and
  - Dashed arrow with open arrowhead with keyword <<use>> for use.
  - The same arrow without <<use>> is dependency

Components versus Classes

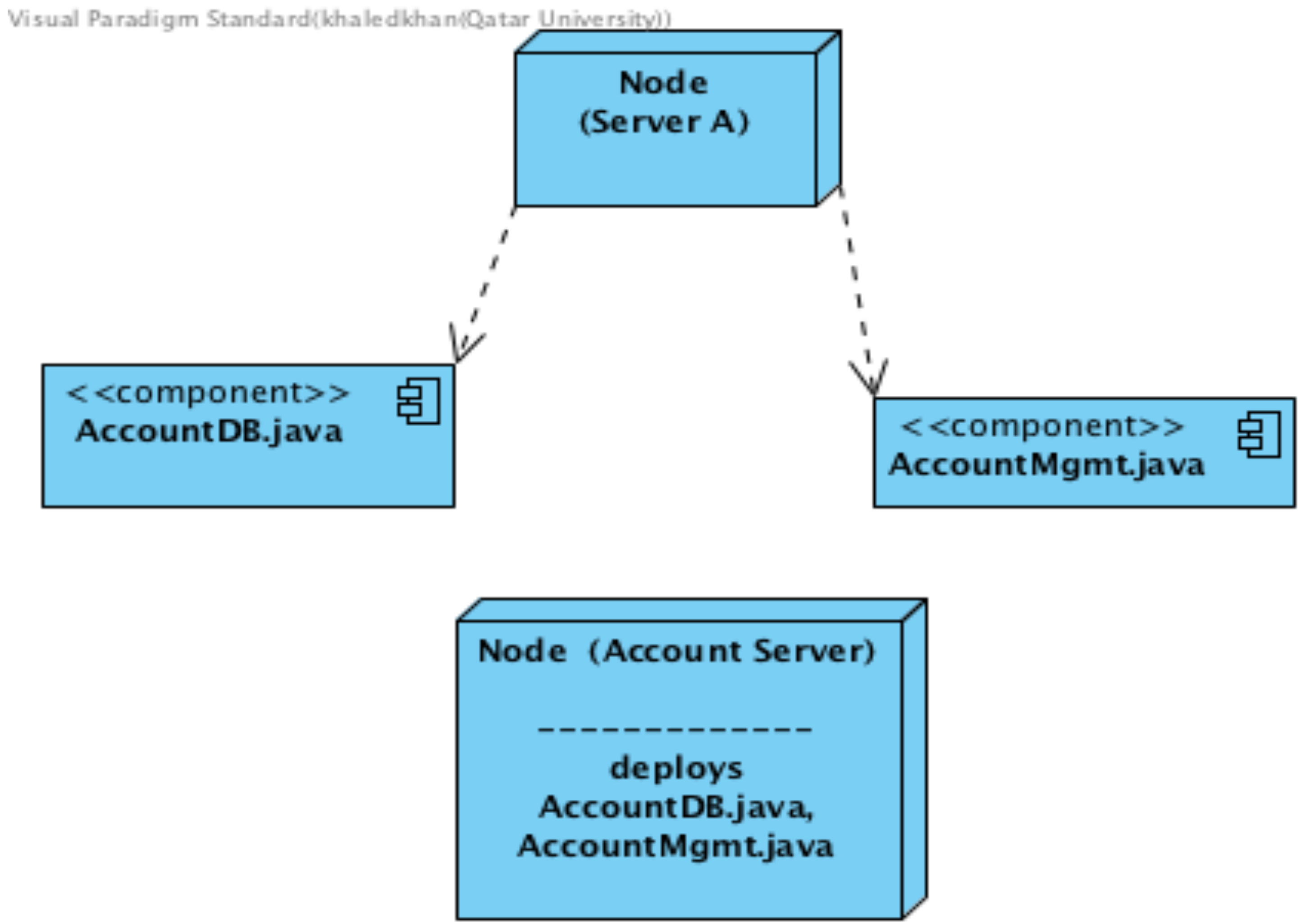
- Both have names and realize interfaces
- Class
  - Logical abstraction
  - Attributes and operations
- Component
  - Physical thing that exist on machines
  - Physical packaging of logical things (classes, interfaces, …)
  - Only has operations (only reachable thru its Interface)

Deployment Diagram and Nodes



- Show physical relationship among software & hardware components
- Show where components of a distributed system are located
- Nodes: Computational units (most often: Hardware)
- Connections: Communication paths over which the system will interact

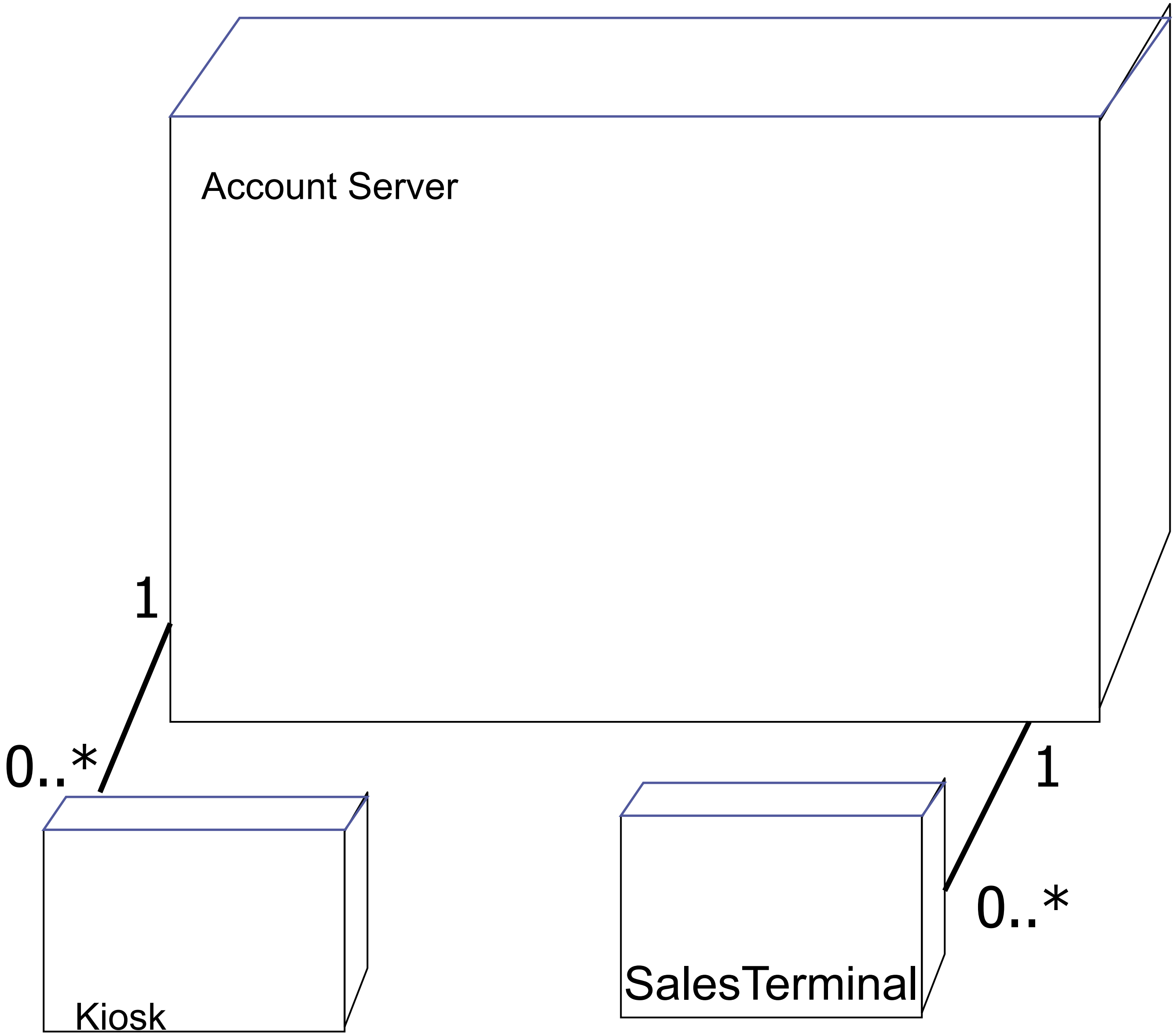
Node and Component Example



Deployment Diagram

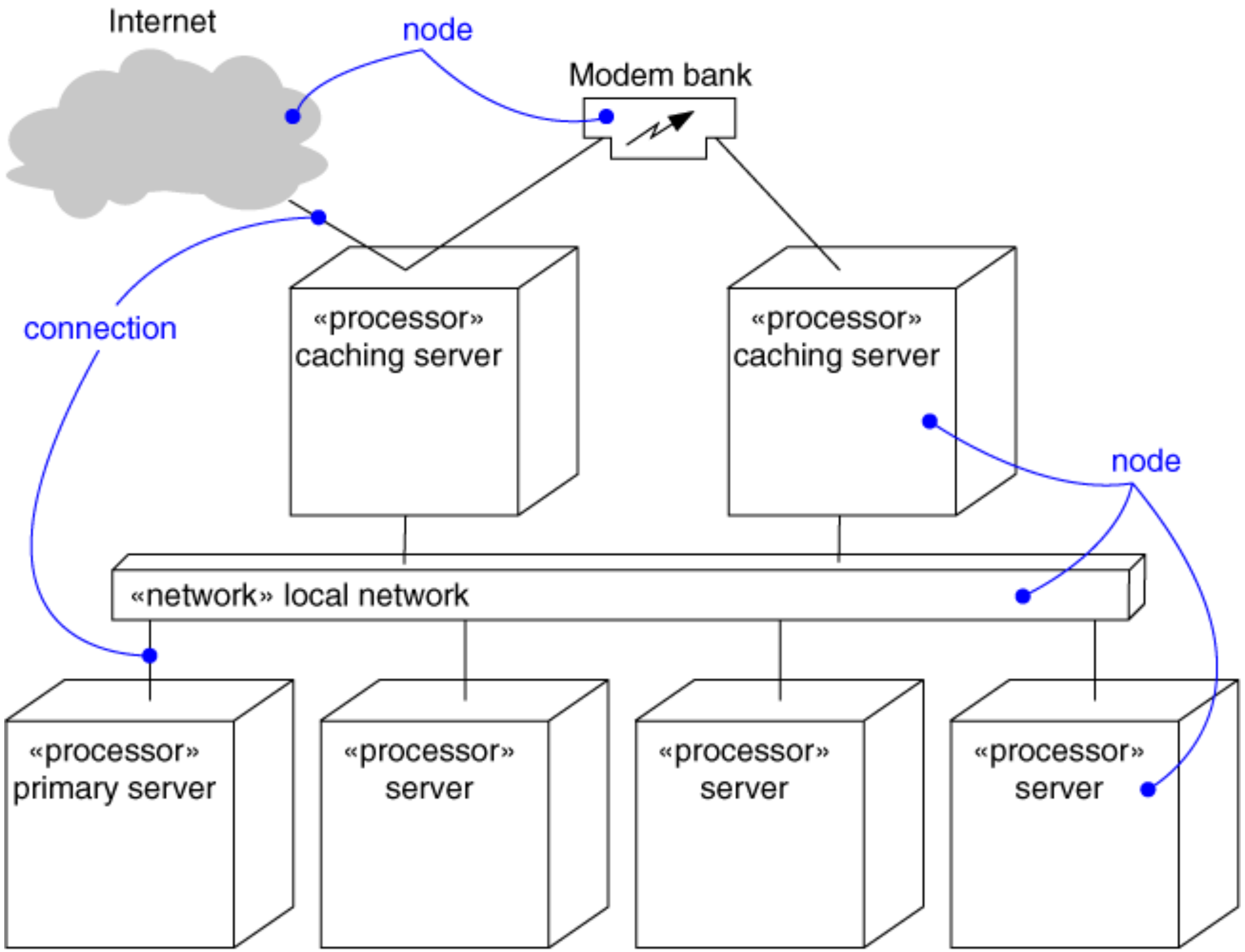
- Deployment Diagram: Focus on the placement and configuration of components at runtime
- Captures the topology of a system's hardware
- Built as part of architectural specification
- Purposes:
  - Specify the distribution of components
  - Identify performance bottlenecks
- Main concepts: Node, Component, Dependency, Location
- Developed by architects, networking engineers, and system engineers

An Example: Deployment Diagram



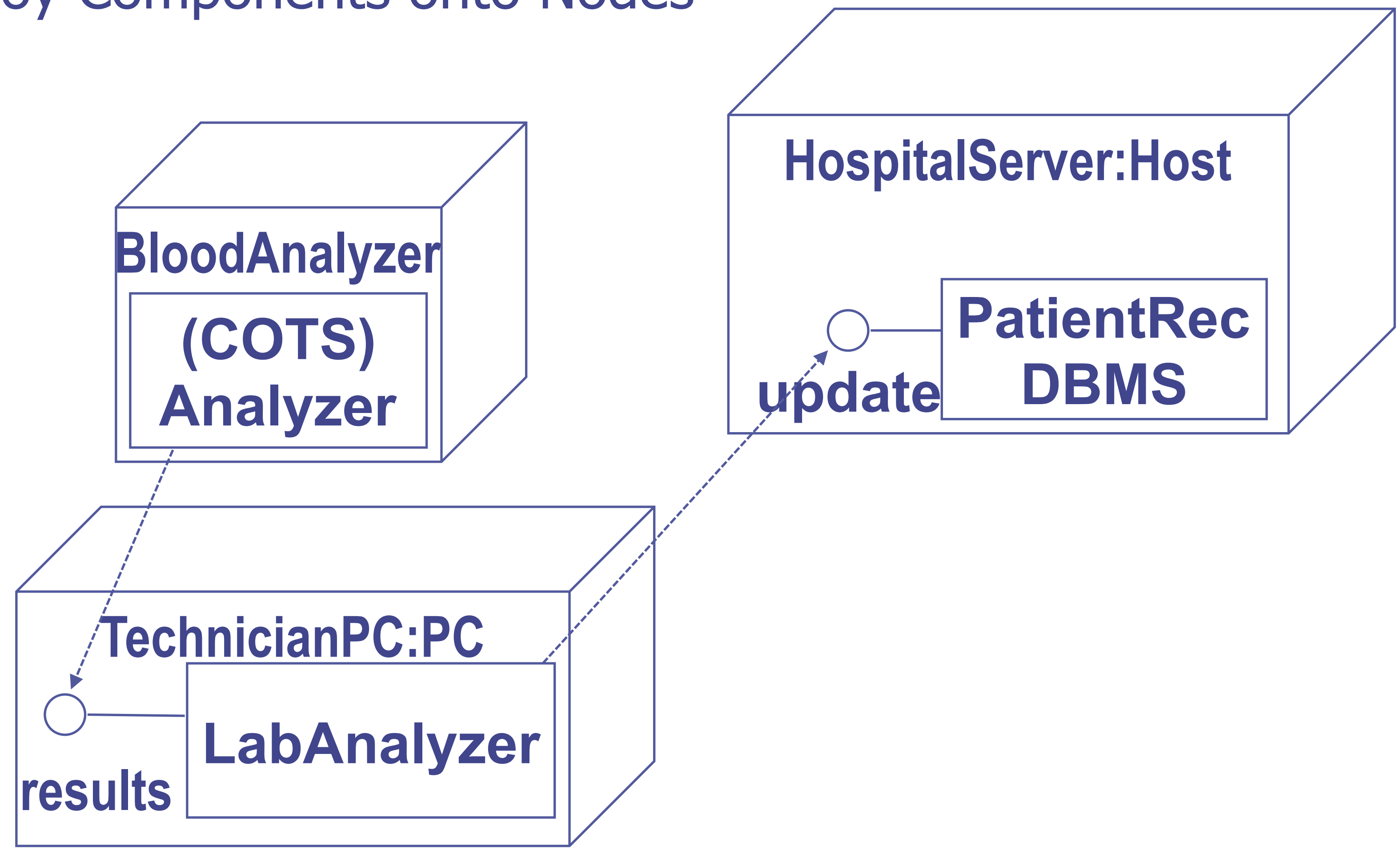
Topology of Deployment Diagram

- Captures the Topology of a system's hardware

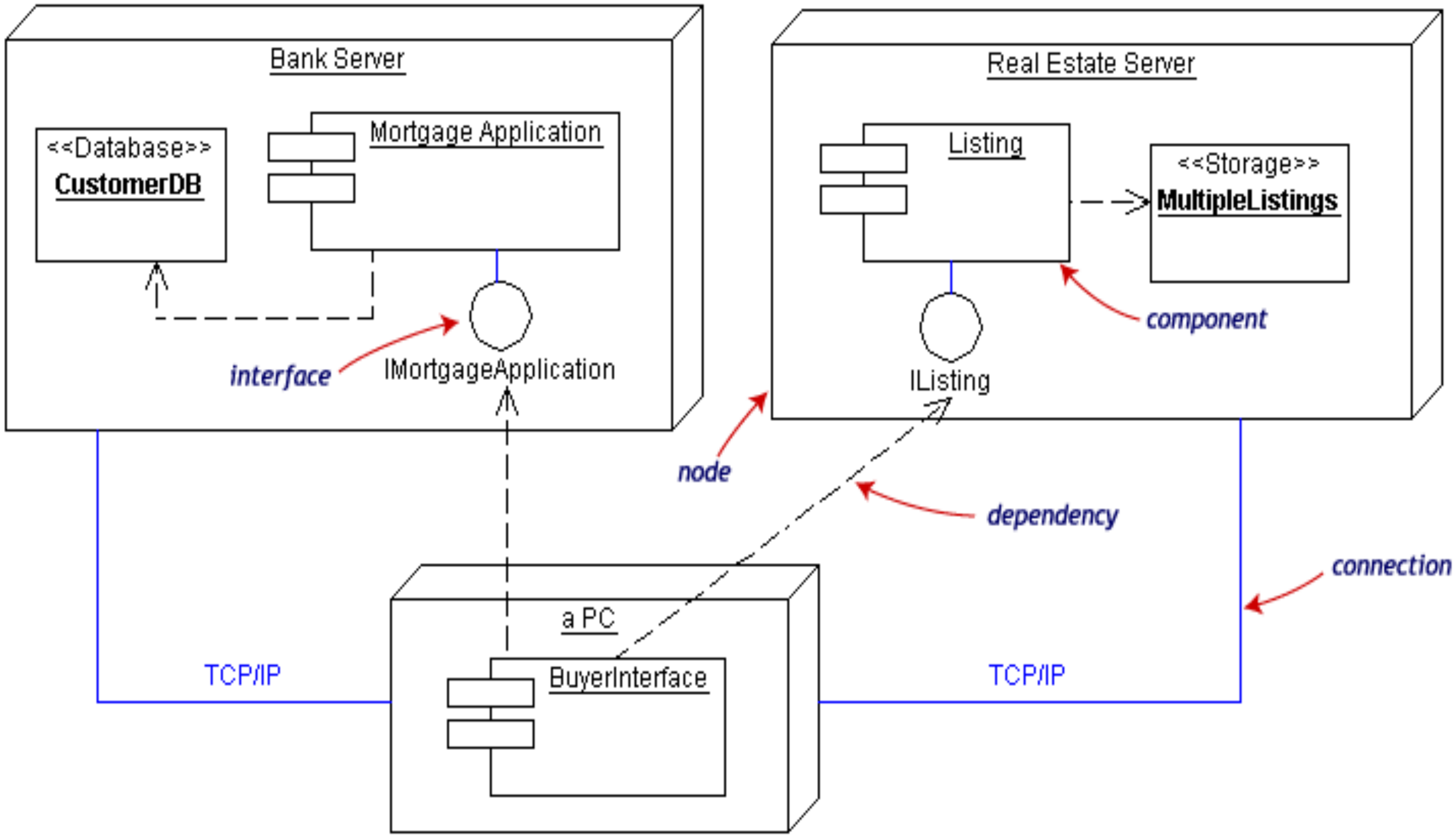


Deployment Components in the Nodes

- Deploy Components onto Nodes

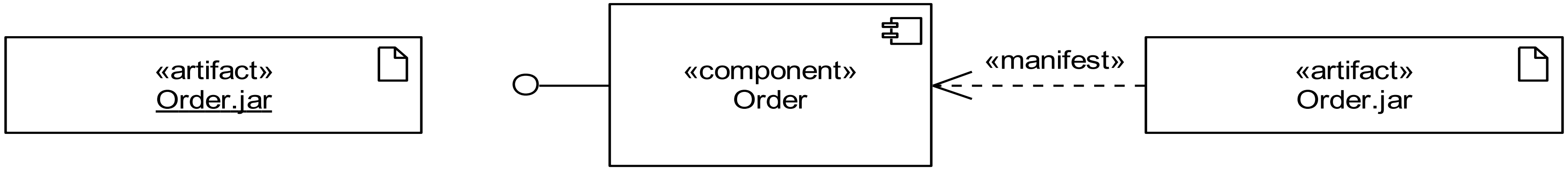


Combining Component and Deployment Diagrams



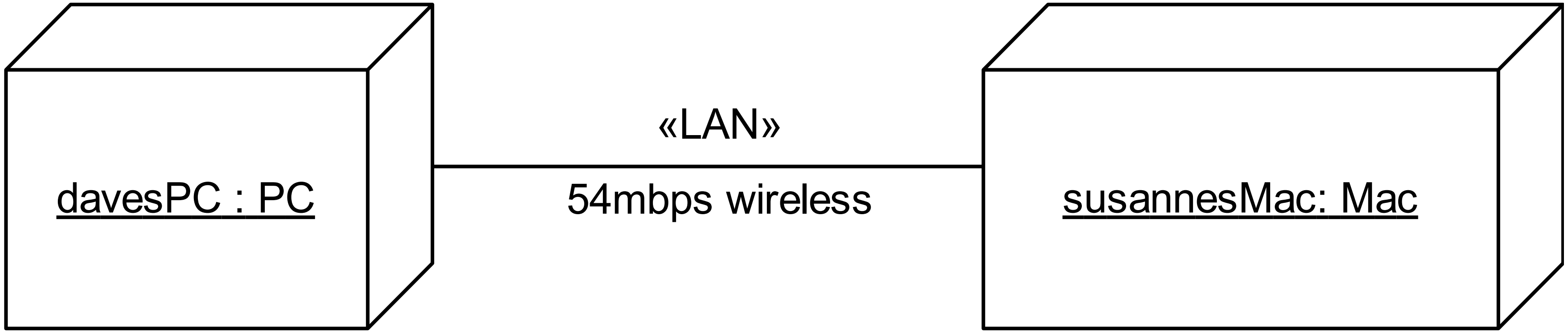
- Note: In this example, three components are shown in older version of UML

Artifacts



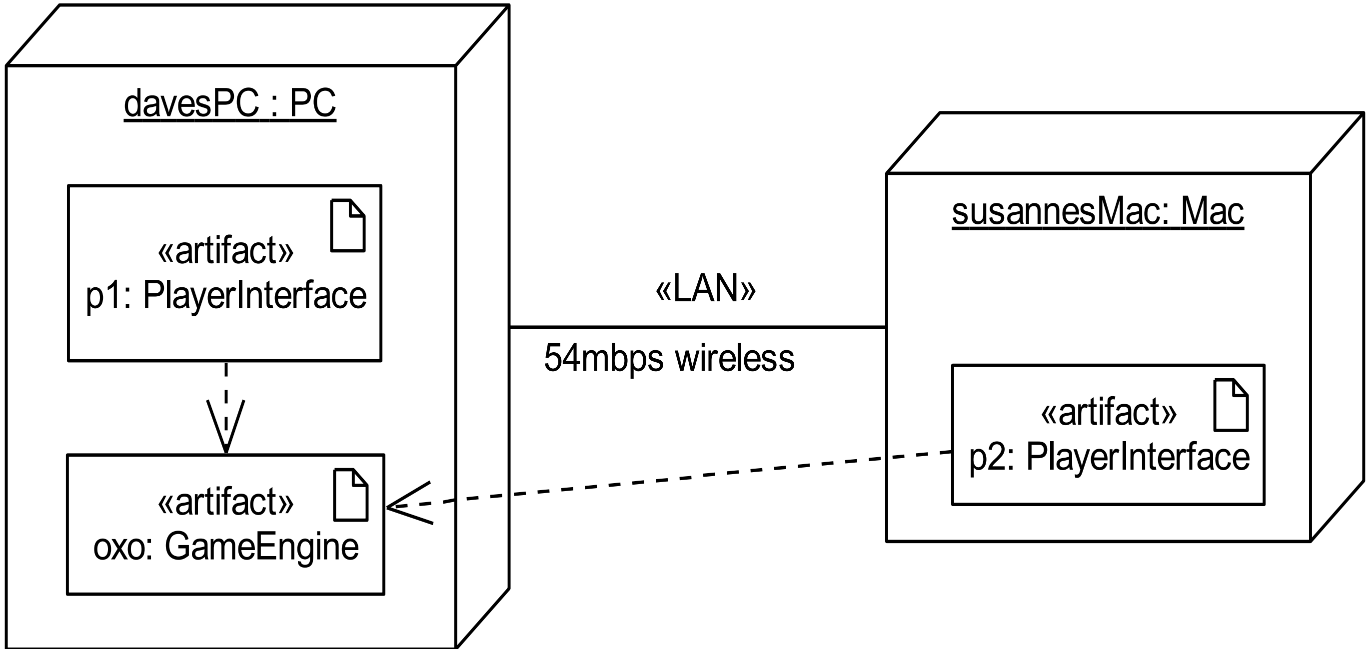
- An artifact is a concrete element in the physical world
- An *artifact* is the specification of a physical piece of information such as a binary executable, a database table or an implemented component such as a DLL or a Java class file
- Each artifact has a filename
- An artifact is represented by a normal class rectangle with the keyword <<artifact>> or an artifact icon in the top right corner
- Name of artifact may (optionally) be underlined
- Artifact is said to *manifest* model elements that are used to construct the artifact
  - Manifestation indicated by dependency arrow with keyword <<manifest>>

The Physical Layer



- Deployment diagram shows
  - The physical communication links between hardware items *(nodes)* (e.g., pcs, printers)
  - The relationships between physical devices *(nodes)* and processes *(artifacts)*
- Physical layer consists of the machines, represented by *nodes*, and the (physical) connections between them (e.g., cables), represented by *associations*
- Nodes have *node types*

Deploying Software Artifacts on Hardware Nodes



- Artifact shown inside a node shows that it runs on the node
- If an artifact depends on another artifact then there must be a physical link between the nodes on which they are deployed

Systems Modeling in UML and Coding

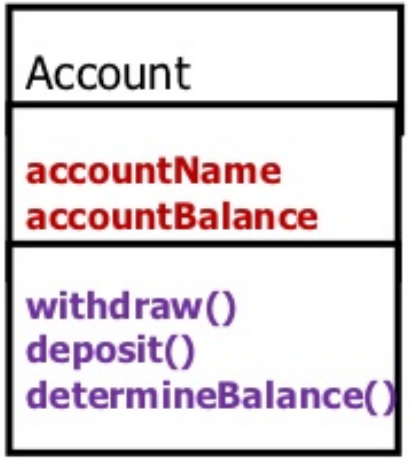
- We have finished presenting modeling (analysis and design) of software systems in UML
- WE have seen the following
  - Data Floe Diagram (DFD)
  - Use case diagram
  - Use case specification
  - Domain model and Class diagram
  - Sequence diagram
  - Component diagram
  - Package diagram
  - Deployment diagram.
- How to transform models to programming code?
- We will see some examples in the rest of this lecture as closing stuff.

Model to Code:
Transformation to Reality

Example: Class in UML

Class

- **Class** is a set of ***attributes*** and ***operations*** that are performed on the attributes.



UML-Defined Class in Java

```
Syntax    accessSpecifier class ClassName
          {
             instance variables
             constructors
             methods
          }
```

```
class Account
{
   private String accountName;
   private double accountBalance;

   public withdraw();
   public deposit();
   public determineBalance();
```

attributes

Operations/methods

Class and Objects in Java: Example

Class **Account**

```
class Account {
    private String accountName;
    private double accountBalance;

    public  withdraw();
    public  deposit();
    public  determineBalance();
} // Class Account
```

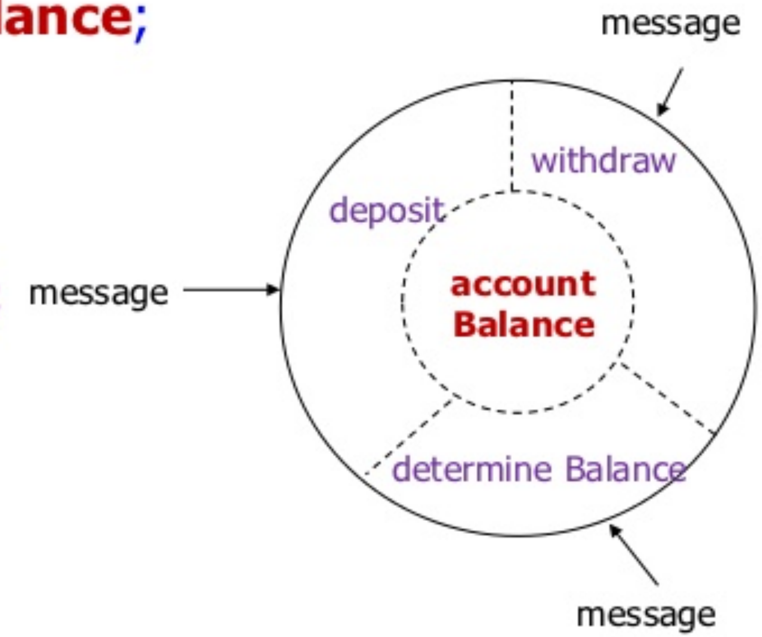
Creates a data type Account

Account acctX;

Object acctX (an instance of class Account)

Class in Java: Encapsulation

```
class Account {
   private double accountBalance;

   public withdraw();
   public  deposit();
   public  determineBalance();

} // Class Account
```



Association: Model to Code

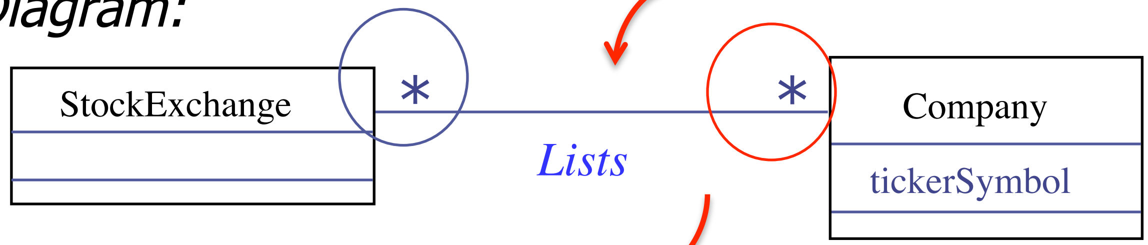
Java code:

```
Class Student {
    Course enrolls[4];
}

Class Course {
  Student have[];
}
```

From Problem Statement to Code

Problem Statement: A stock exchange lists many companies. Each company is identified by a ticker symbol

Class Diagram:



Java Code

```
public class StockExchange
  {
       private Vector m_Company = new Vector();
  };

public class Company
  {
       public int m_tickerSymbol;
       private Vector m_StockExchange = new Vector();
  };
```

An Association between StockExchange and Company classes

Visibility in Class: Java Example

Syntax

```
accessSpecifier class ClassName
{
   instance variables
   constructors
   methods
}
```

Example

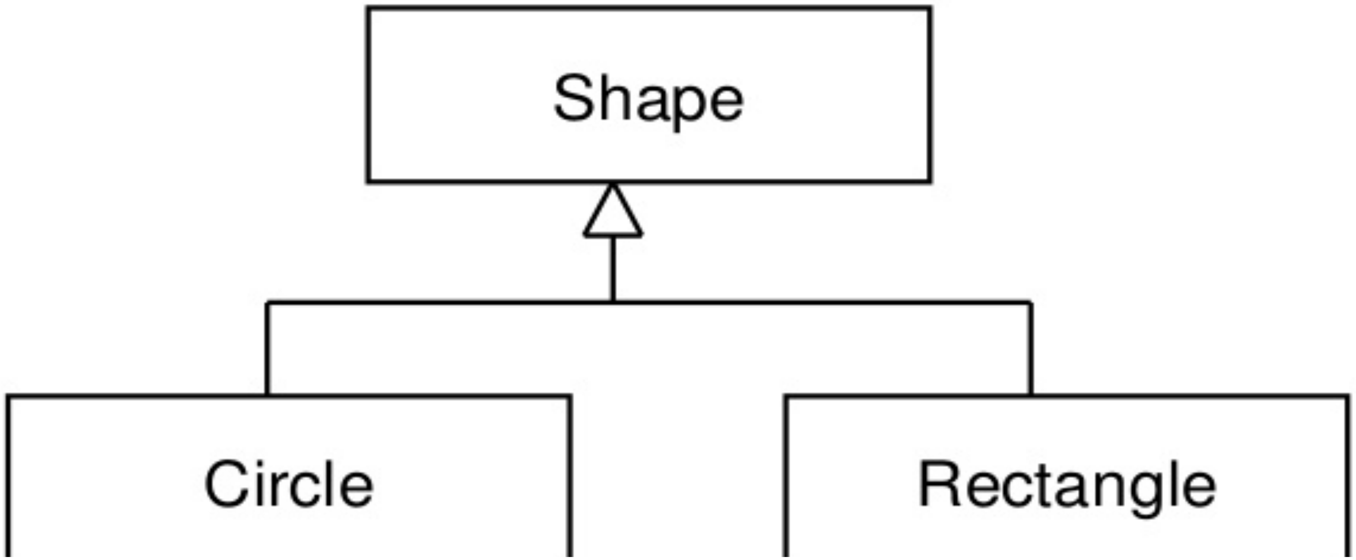
```
public class Counter
{
   private int value;

   public Counter(int initialValue) { value = initialValue; }

   public void count() { value = value + 1; }
```

Public interface

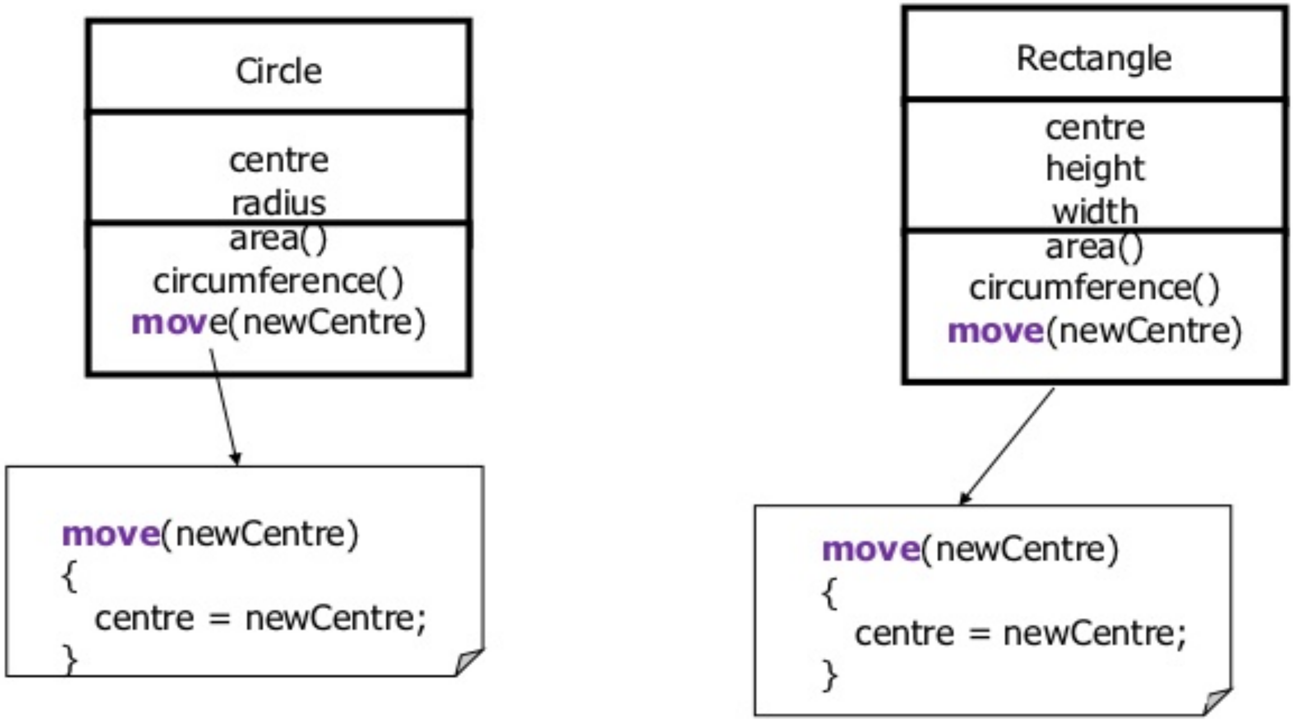
Private implementation

Generalization to Code: Example

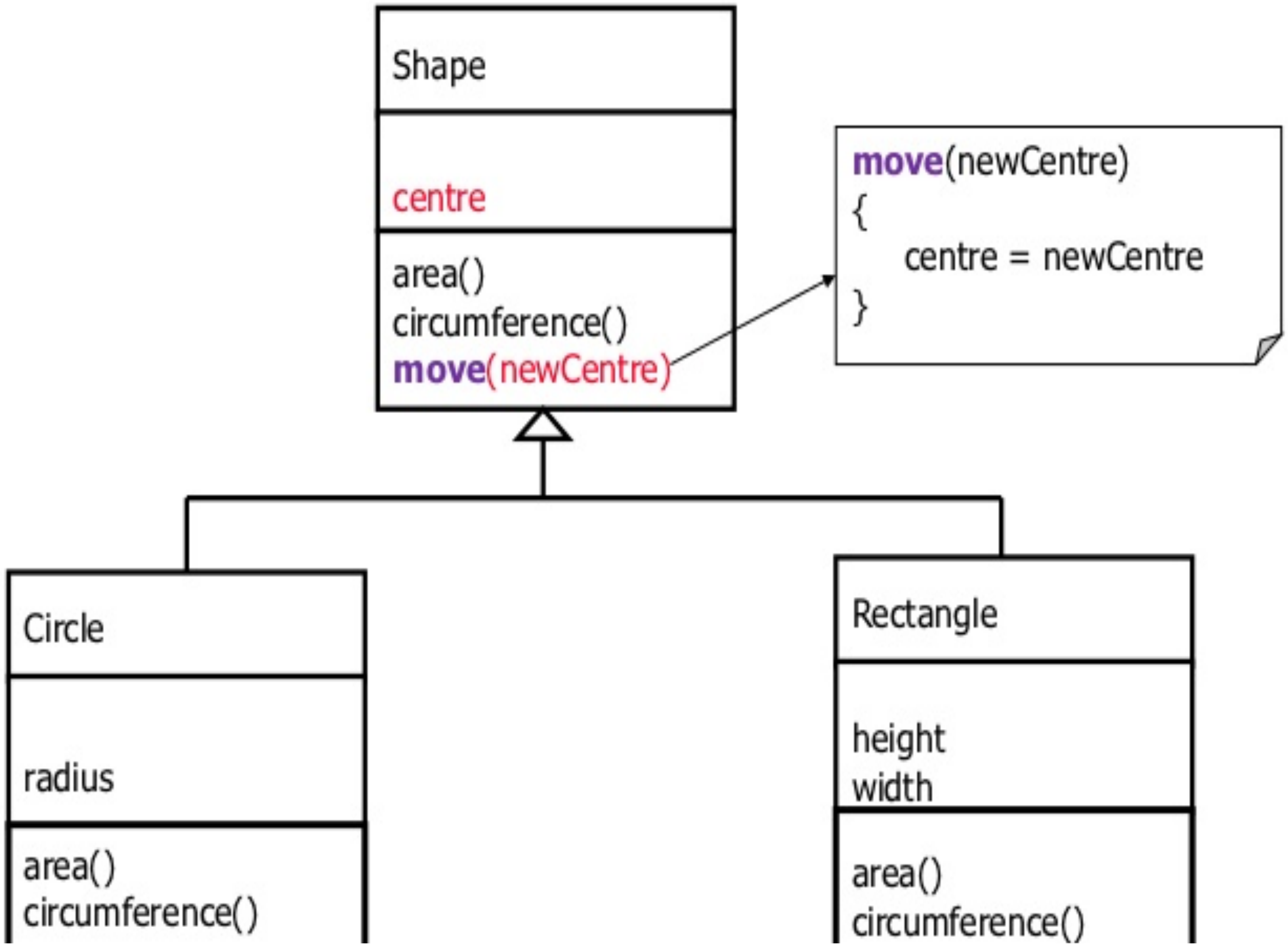
- Circle **Class** can be a sub**class** (inherited from) of a parent **class** - Shape



Use of Generalization for Reuse



Use of Generalization for Reuse



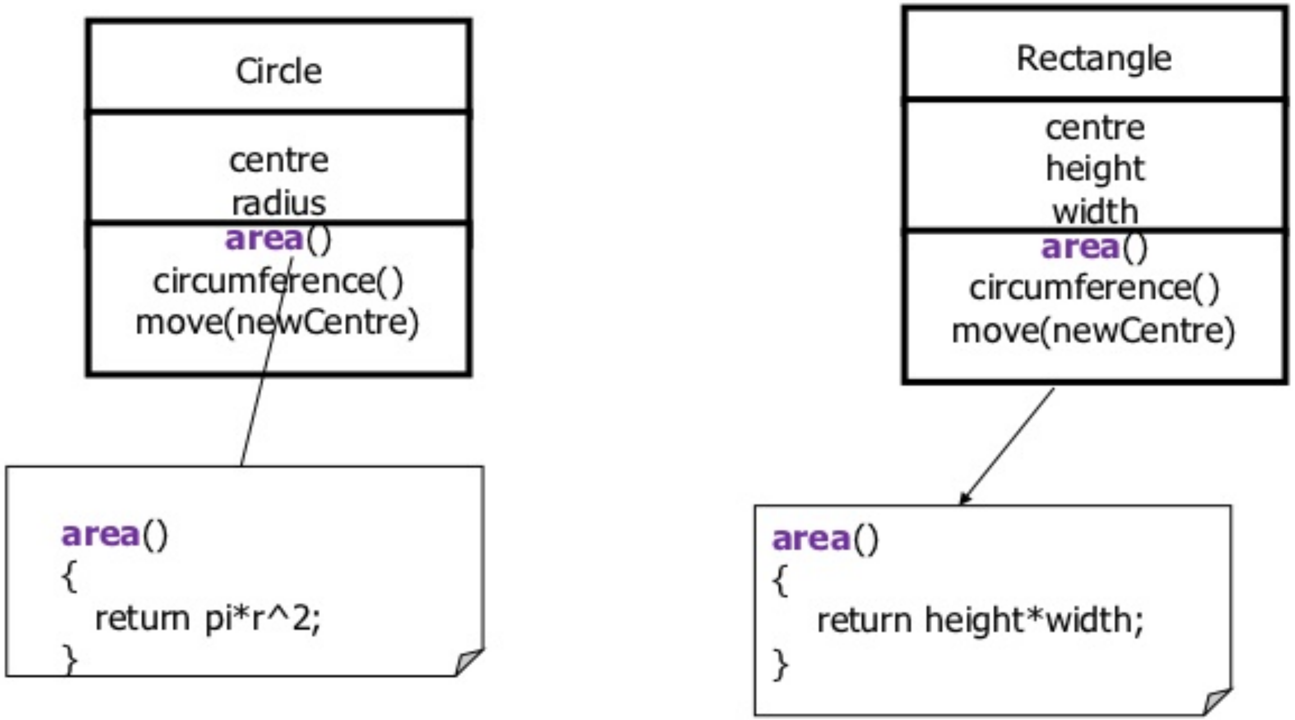
Specialization in Inheritance

Specialized behavior can be added to the child **class**.

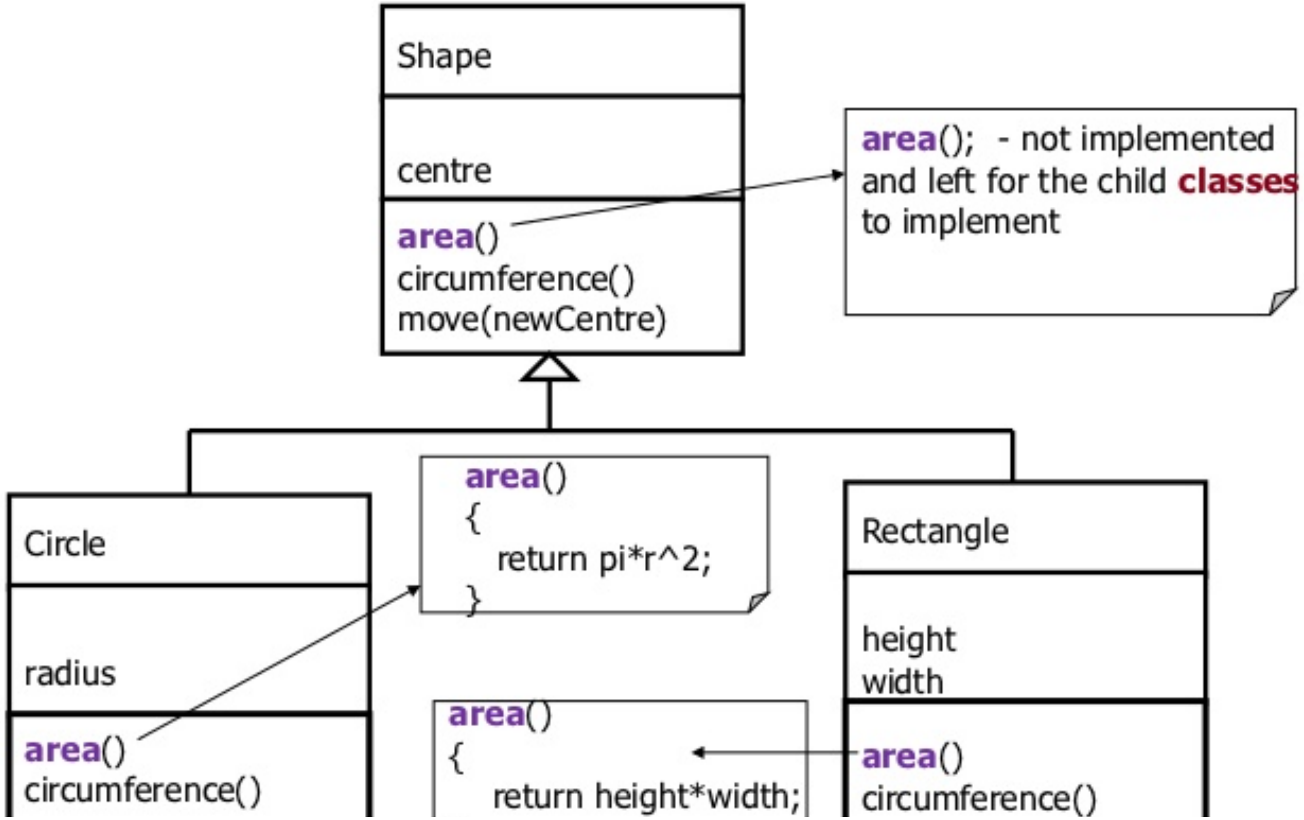
In this case the behaviour will be implemented in the child **class**.

- e.g. the implementation of **area**() method in the Circle **class** is different from the **area**() method in the Rectangle **class**.

Java Implementation of Specialized Class Model



Use of Generalization in Specialized Class Model

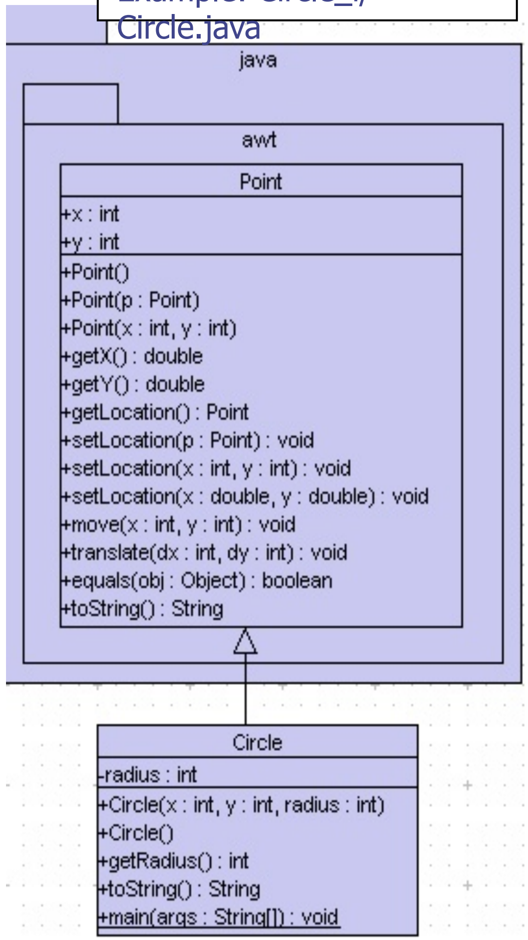


Use of Generalization: Common Interface

- All the **operations** that are supported for **Rectangle** and **Circle** are the same.
- Some **methods** have common implementation and others don't.
  - **move**() operation is common to classes and can be implemented in parent.
  - **circumference**(), **area**() operations are significantly different and have to be implemented in the respective classes.
- The **Shape class** provides a common interface where all 3 operations ***move(), circumference()*** and ***area()***.

Generalization in Code

Example: Circle_i/Circle.java




```
import java.awt.Point;
public class Circle extends Point {
  private int radius;

  public Circle() {
  }
  public int getRadius () {
    return radius;
  }
  // additional code
}
```

Instance variable: radius

Inherited from Point class

```
Circle c1 = new Circle();
System.out.println("x=" + c1.getX() + ", y=" + c1.getY());
System.out.println("radius=" + c1.getRadius());
```

Summary

- Packages
  - collections of related classes
  - defines a namespace
  - class visibility and facades
  - Element x must use fully qualified name to access element in package that does not contain x
  - Package dependencies
  - Importing elements and packages into a package: <<import>> and <<access>>
- Components
  - reusable modules
  - defined by interfaces required and provided
  - black box and white box views on components
- Artifacts, <<manifest>> key word
- Deployment diagrams
- Model to code