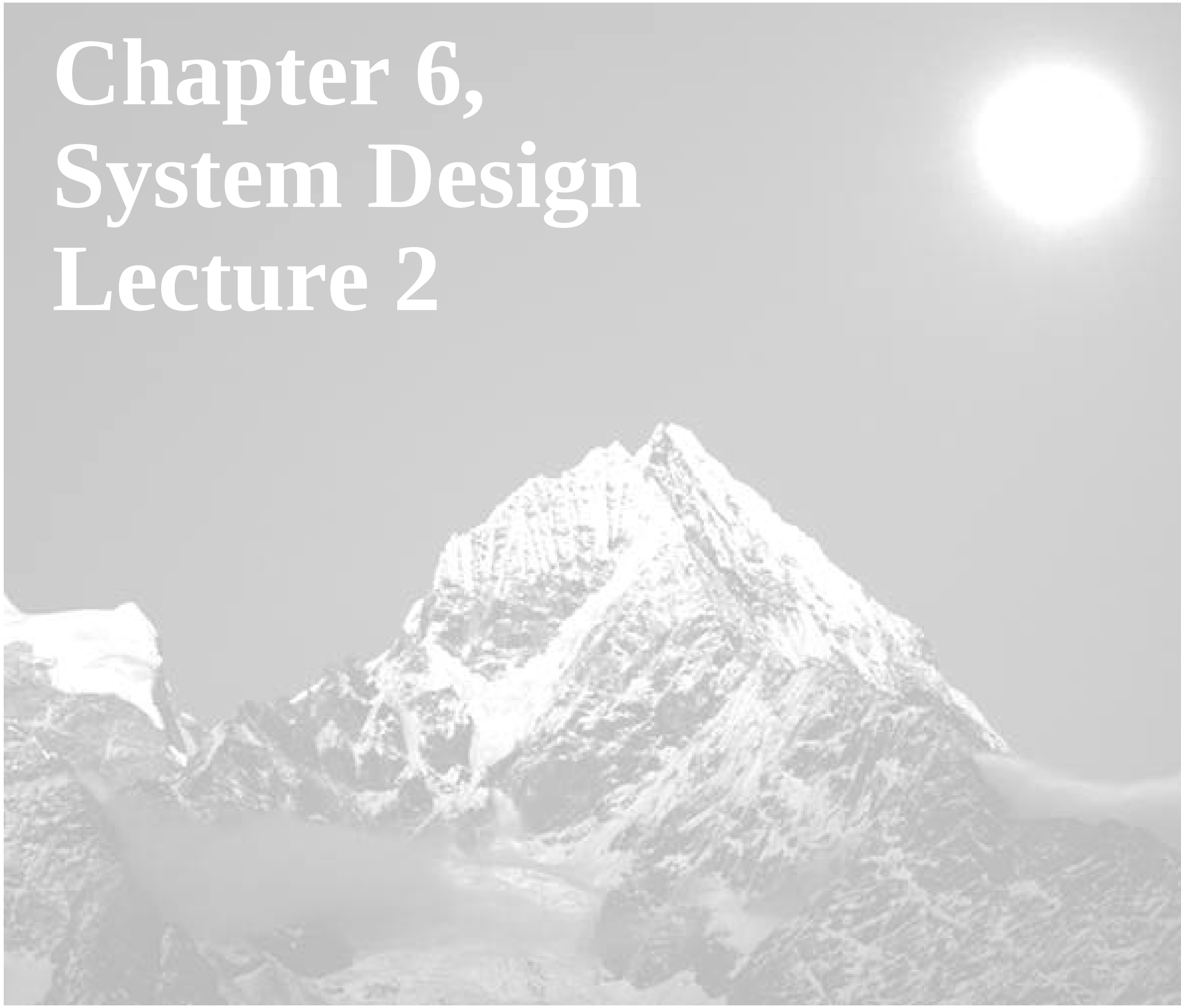
Object-Oriented Software Engineering

Conquering Complex and Changing Systems



Chapter 6, System Design Lecture 2

Odds And Ends: Remaining Lectures

- Week 2:
    - **January 10: System Design**
    - **January 11: Finish System Design, Start Design Patterns**
- Week 3:
    - **January 17: Guest Lecture (Frank Mang, Accenture)**
    - **January 18: Design Patterns**
- Week 4:
    - **January 24: Object Design I (Inheritance revisited, OCL, Contracts)**
    - **January 25: Object Design II (JavaDoc)**
- Week 5:
    - **January 31: Testing I**
    - **February 1: Testing II**
- Week 6:
    - **February 7: Client Acceptance Test**
    - **February 8: Software Lifecycle**
- Week 7:
    - **February 14 : Exam**

Overview

System Design I (previous lecture)

0. Overview of System Design

1. Design Goals

2. Subsystem Decomposition

System Design II

3. Concurrency

4. Hardware/Software Mapping

5. Persistent Data Management

6. Global Resource Handling and Access Control

7. Software Control

8. Boundary Conditions

3. Concurrency

- Identify concurrent threads and address concurrency issues.
- Design goal: response time, performance.

- Threads
    - **A *thread* of control is a path through a set of state diagrams on which a single object is active at a time.**
    - **A thread remains within a state diagram until an object sends an event to another object and waits for another event**
    - **Thread splitting: Object does a nonblocking send of an event.**

Concurrency (continued)

- Two objects are inherently concurrent if they can receive events at the same time without interacting
- Inherently concurrent objects should be assigned to different threads of control
- Objects with mutual exclusive activity should be folded into a single thread of control (Why?)

Concurrency Questions

- ♦ Which objects of the object model are independent?
- ♦ What kinds of threads of control are identifiable?
- ♦ Does the system provide access to multiple users?
- ♦ Can a single request to the system be decomposed into multiple requests? Can these requests be handled in parallel?

Implementing Concurrency

- Concurrent systems can be implemented on any system that provides
  - **physical concurrency (hardware)**

or

  - **logical concurrency (software): Scheduling problem (Operating systems)**

4. Hardware Software Mapping

- This activity addresses two questions:
  - **How shall we realize the subsystems: Hardware or Software?**
  - **How is the object model mapped on the chosen hardware & software?**
    - **Mapping Objects onto Reality: Processor, Memory, Input/Output**
    - **Mapping Associations onto Reality: Connectivity**
- Much of the difficulty of designing a system comes from meeting externally-imposed hardware and software constraints.
  - **Certain tasks have to be at specific locations**

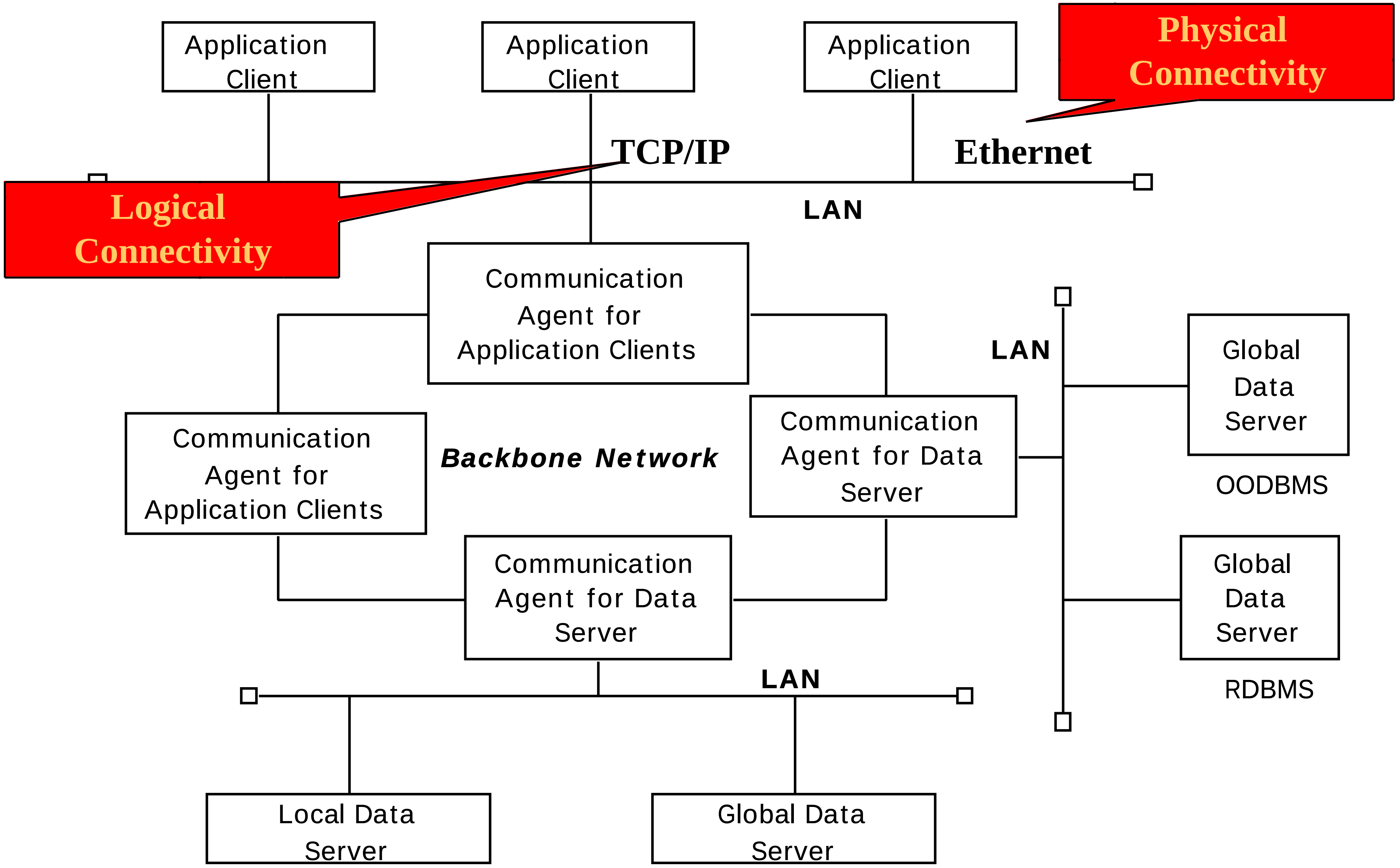
Mapping the Objects

- Processor issues:
  - **Is the computation rate too demanding for a single processor?**
  - **Can we get a speedup by distributing tasks across several processors?**
  - **How many processors are required to maintain steady state load?**
- Memory issues:
  - **Is there enough memory to buffer bursts of requests?**
- I/O issues:
  - **Do you need an extra piece of hardware to handle the data generation rate?**
  - **Does the response time exceed the available communication bandwidth between subsystems or a task and a piece of hardware?**

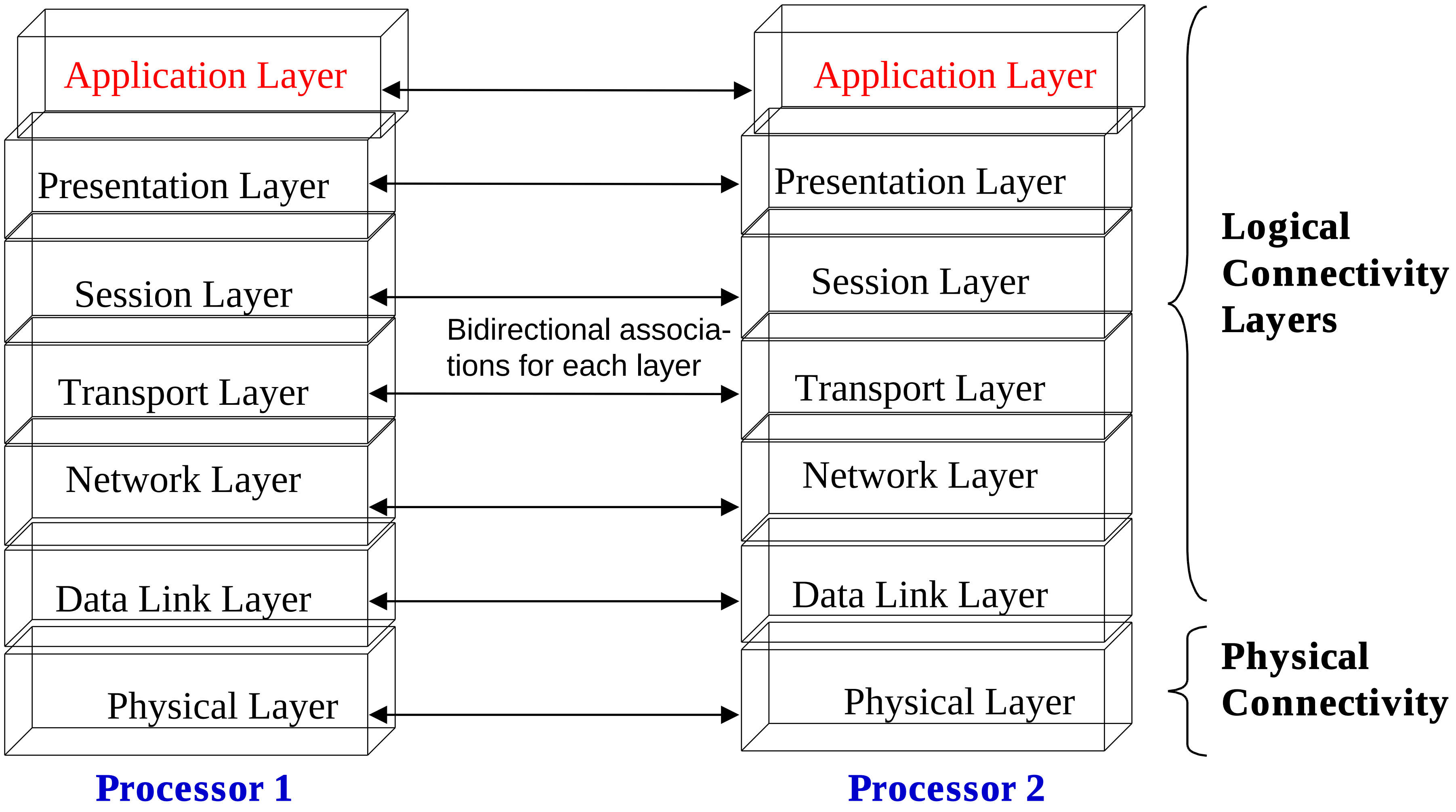
Mapping the Subsystems Associations: Connectivity

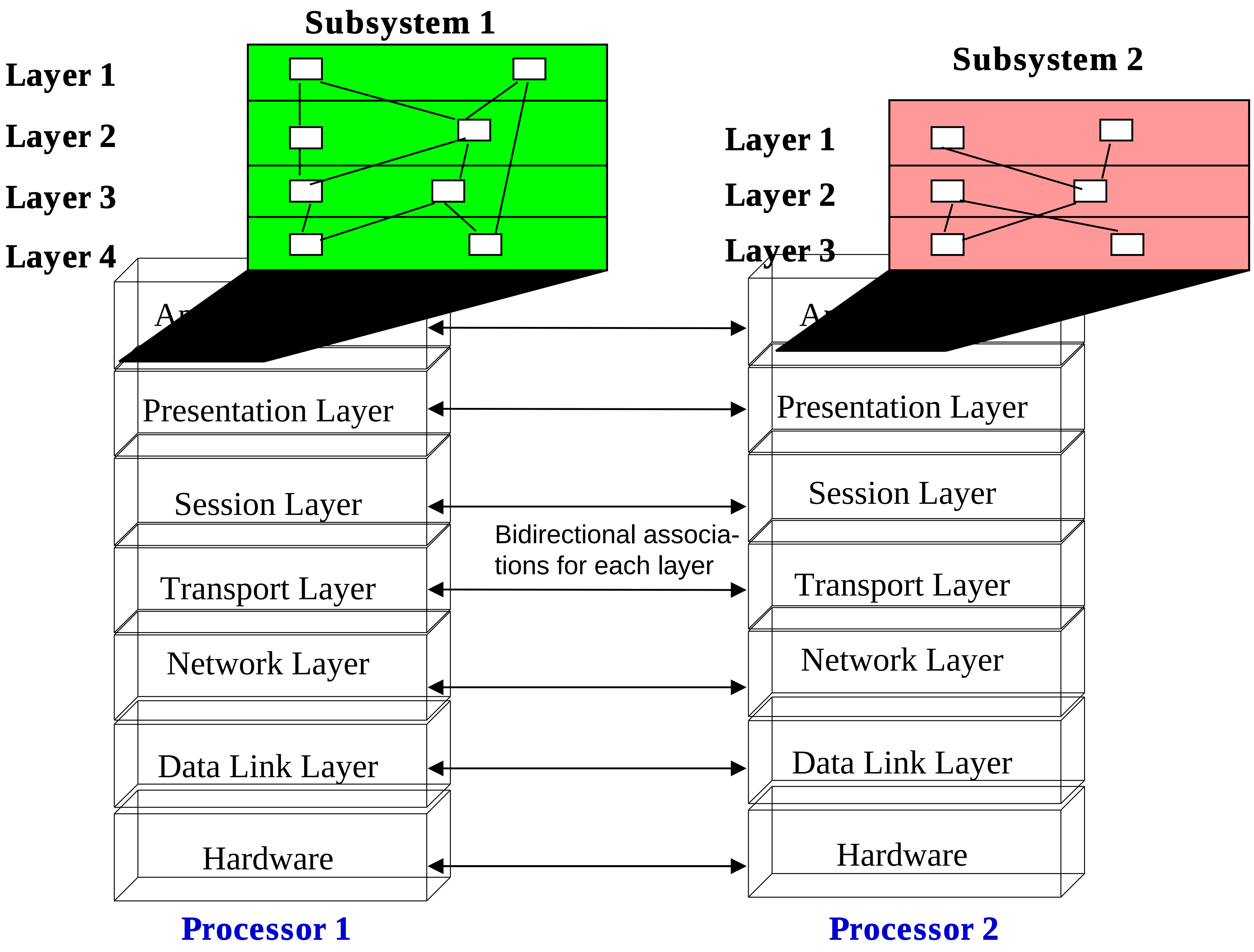
- Describe the *physical connectivity* of the hardware
  - **Often the physical layer in ISO’s OSI Reference Model**
    - **Which associations in the object model are mapped to physical connections?**
    - **Which of the client-supplier relationships in the analysis/design model correspond to physical connections?**
- Describe the *logical connectivity* (subsystem associations)
  - **Identify associations that do not directly map into physical connections:**
    - **How should these associations be implemented?**

Typical Informal Example of a Connectivity Drawing



Logical vs Physical Connectivity and the relationship to Subsystem Layering




Subsystem 1
Layer 1
Layer 2
Layer 3
Layer 4
Subsystem 2
Layer 1
Layer 2
Layer 3
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Hardware
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Hardware
Bidirectional associa-
tions for each layer
Processor 1
Processor 2

Hardware/Software Mapping Questions

- What is the connectivity among physical units?
  - **Tree, star, matrix, ring**
- What is the appropriate communication protocol between the subsystems?
  - **Function of required bandwidth, latency and desired reliability, desired quality of service (QOS)**
- Is certain functionality already available in hardware?
- Do certain tasks require specific locations to control the hardware or to permit concurrent operation?
  - **Often true for embedded systems**
- General system performance question:
  - **What is the desired response time?**

Connectivity in Distributed Systems

- If the architecture is distributed, we need to describe the network architecture (communication subsystem) as well.
- Questions to ask
  - **What are the transmission media? (Ethernet, Wireless)**
  - **What is the Quality of Service (QOS)? What kind of communication protocols can be used?**
  - **Should the interaction asynchronous, synchronous or blocking?**
  - **What are the available bandwidth requirements between the subsystems?**
    - **Stock Price Change -> Broker**
    - **Icy Road Detector -> ABS System**

Drawing Hardware/Software Mappings in UML

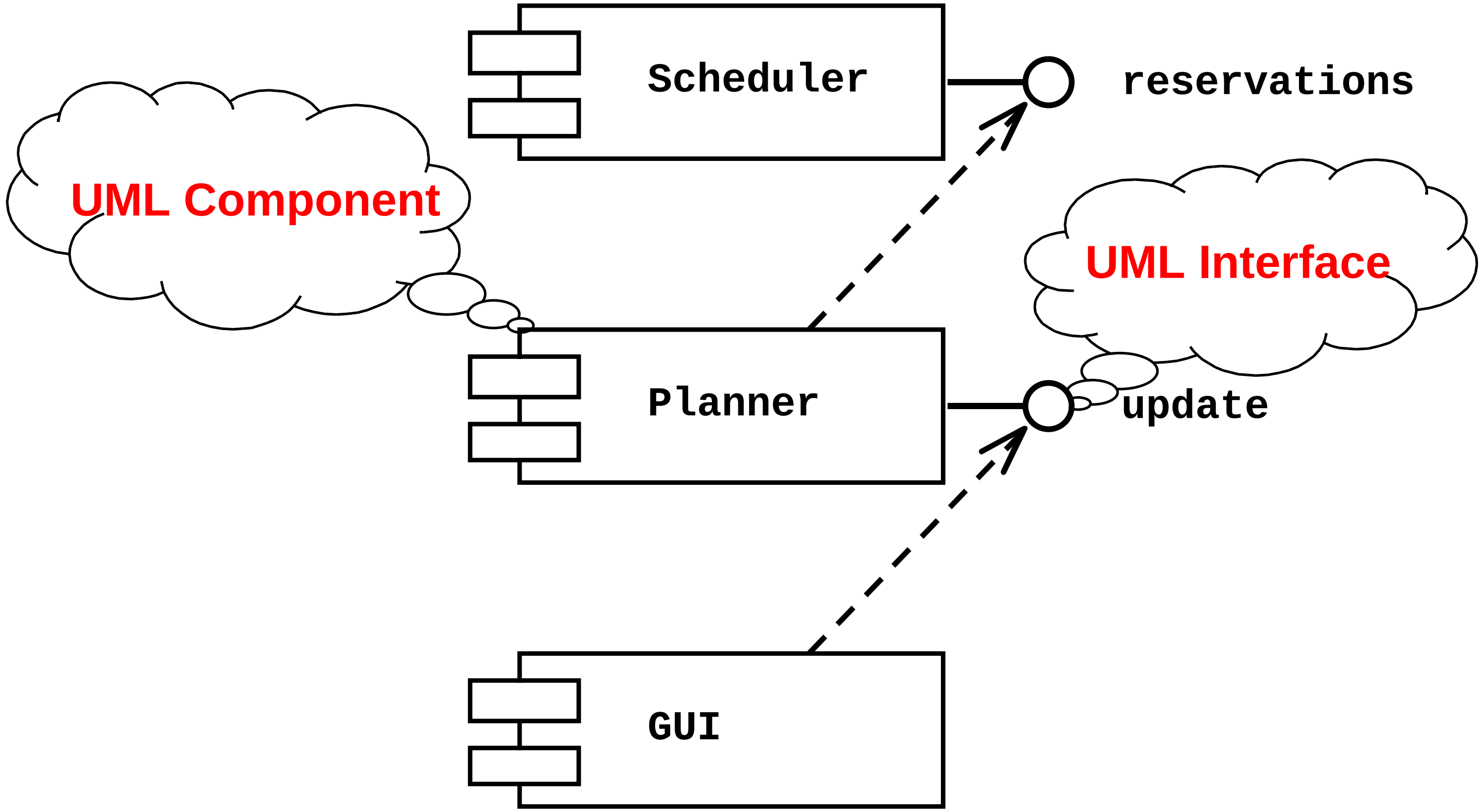
- System design must model static and dynamic structures:
  - **Component Diagrams for static structures**
    - **show the structure at design time or compilation time**
  - **Deployment Diagram for dynamic structures**
    - **show the structure of the run-time system**

- Note the lifetime of components
  - **Some exist only at design time**
  - **Others exist only until compile time**
  - **Some exist at link or runtime**

Component Diagram

- Component Diagram
  - **A graph of components connected by dependency relationships.**
  - **Shows the dependencies among software components**
    - **source code, linkable libraries, executables**
- Dependencies are shown as dashed arrows from the client component to the supplier component.
  - **The kinds of dependencies are implementation language specific.**
- A component diagram may also be used to show dependencies on a façade:
  - **Use dashed arrow the corresponding UML interface.**

Component Diagram Example

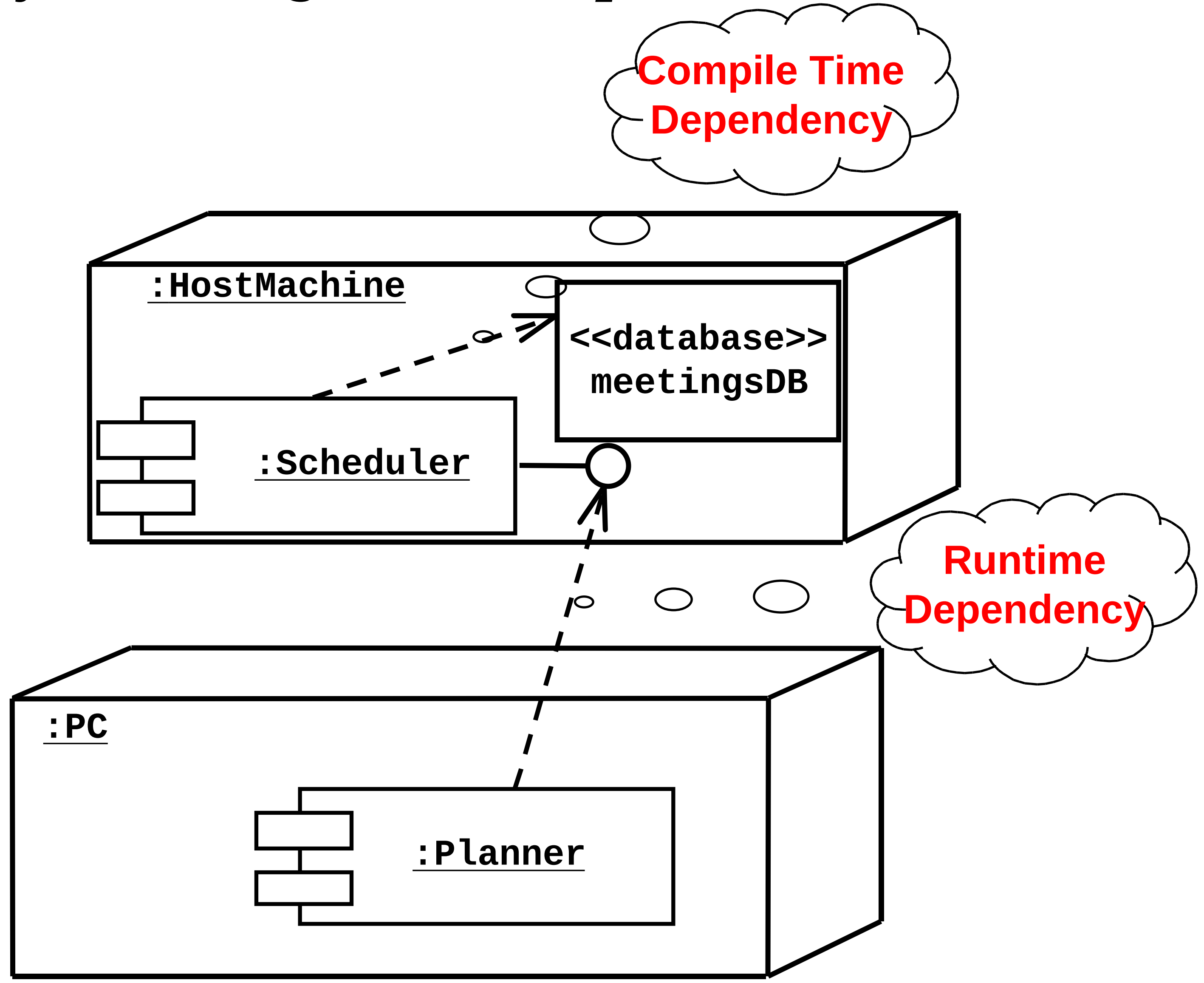


Deployment Diagram

- Deployment diagrams are useful for showing a system design after the following decisions are made
  - **Subsystem decomposition**
  - **Concurrency**
  - **Hardware/Software Mapping**

- A deployment diagram is a graph of nodes connected by communication associations.
  - **Nodes are shown as 3-D boxes.**
  - **Nodes may contain component instances.**
  - **Components may contain objects (indicating that the object is part of the component)**

Deployment Diagram Example



5. Data Management

- Some objects in the models need to be persistent
  - **Provide clean separation points between subsystems with well-defined interfaces.**
- A persistent object can be realized with one of the following
  - **Data structure**
    - **If the data can be volatile**
  - **Files**
    - **Cheap, simple, permanent storage**
    - **Low level (Read, Write)**
    - **Applications must add code to provide suitable level of abstraction**
  - **Database**
    - **Powerful, easy to port**
    - **Supports multiple writers and readers**

File or Database?

- When should you choose a file?
  - **Are the data voluminous (bit maps)?**
  - **Do you have lots of raw data (core dump, event trace)?**
  - **Do you need to keep the data only for a short time?**
  - **Is the information density low (archival files,history logs)?**
- When should you choose a database?
  - **Do the data require access at fine levels of details by multiple users?**
  - **Must the data be ported across multiple platforms (heterogeneous systems)?**
  - **Do multiple application programs access the data?**
  - **Does the data management require a lot of infrastructure?**

Database Management System

- ♦ Contains mechanisms for describing data, managing persistent storage and for providing a backup mechanism
- ♦ Provides concurrent access to the stored data
- ♦ Contains information about the data (“meta-data”), also called data schema.

Issues To Consider When Selecting a Database

- Storage space
  - **Database require about triple the storage space of actual data**
- Response time
  - **Mode databases are I/O or communication bound (distributed databases). Response time is also affected by CPU time, locking contention and delays from frequent screen displays**
- Locking modes
  - ***Pessimistic locking:* Lock before accessing object and release when object access is complete**
  - ***Optimistic locking:* Reads and writes may freely occur (high concurrency!) When activity has been completed, database checks if contention has occurred. If yes, all work has been lost.**
- Administration
  - **Large databases require specially trained support staff to set up security policies, manage the disk space, prepare backups, monitor performance, adjust tuning.**

Object-Oriented Databases

- Support all fundamental object modeling concepts
  - **Classes, Attributes, Methods, Associations, Inheritance**
- Mapping an object model to an OO-database
  - **Determine which objects are persistent.**
  - **Perform normal requirement analysis and object design**
  - **Create single attribute indices to reduce performance bottlenecks**
  - **Do the mapping (specific to commercially available product). Example:**
    - **In ObjectStore, implement classes and associations by preparing C++ declarations for each class and each association in the object model**

Relational Databases

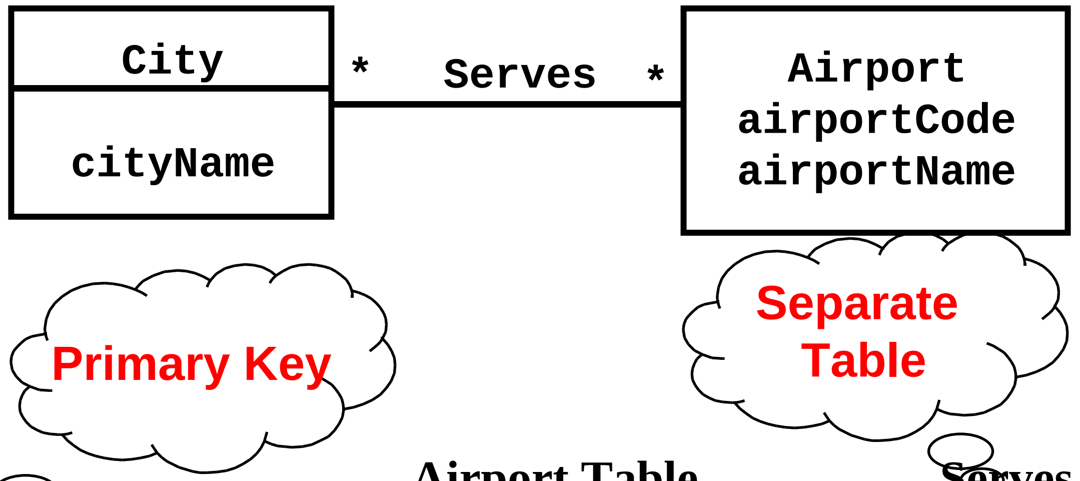
- Based on relational algebra
- Data is presented as 2-dimensional tables. Tables have a specific number of columns and and arbitrary numbers of rows
  - **Primary key: Combination of attributes that uniquely identify a row in a table. Each table should have only one primary key**
  - **Foreign key: Reference to a primary key in another table**
- SQL is the standard language defining and manipulating tables.
- Leading commercial databases support constraints.
  - **Referential integrity, for example, means that references to entries in other tables actually exist.**

Mapping an object model to a relational database

- UML object models can be mapped to relational databases:
  - **Some degradation occurs because all UML constructs must be mapped to a single relational database construct - the table.**
- UML mappings
  - **Each *class* is mapped to a table**
  - **Each class *attribute* is mapped onto a column in the table**
  - **An *instance* of a class represents a row in the table**
  - ***A many-to-many association* is mapped into its own table**
  - **A *one-to-many association* is implemented as buried foreign key**
- Methods are not mapped

Turning Object Models into Tables I

Many-to-Many Associations: Separate Table for Association



City Table

cityName
Houston
Albany
Munich
Hamburg

Airport Table

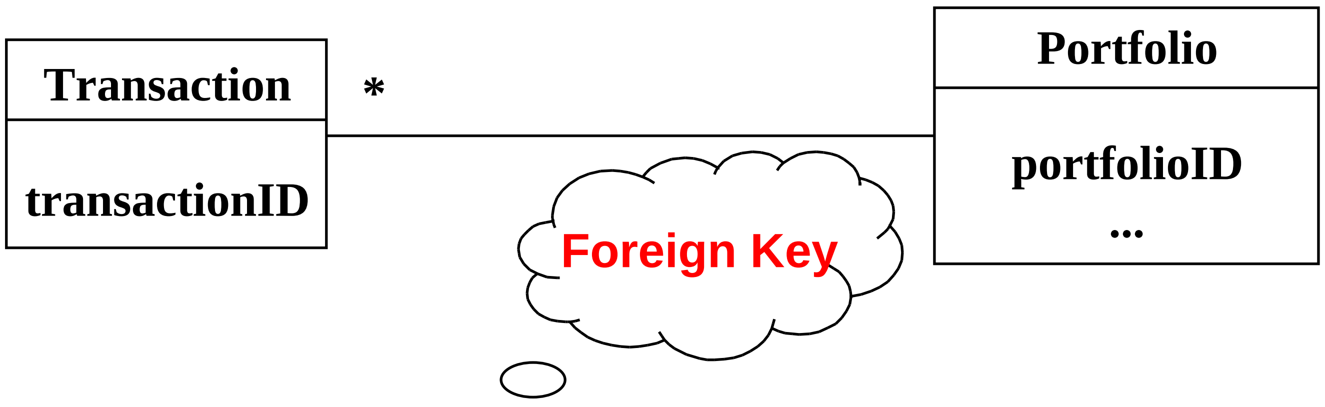
airportCode	airportName
IAH	Intercontinental
HOU	Hobby
ALB	Albany County
MUC	Munich Airport
HAM	Hamburg Airport

Serves Table

cityName	**airportCode**
Houston	IAH
Houston	HOU
Albany	ALB
Munich	MUC
Hamburg	HAM

Turning Object Models into Tables II

1-To-Many or Many-to-1 Associations: Buried Foreign Keys



Transaction Table

transactionID	portfolioID

Portfolio Table

portfolioID	...

Data Management Questions

- Should the data be distributed?
- Should the database be extensible?
- How often is the database accessed?
- What is the expected request (query) rate? In the worst case?
- What is the size of typical and worst case requests?
- Do the data need to be archived?
- Does the system design try to hide the location of the databases (location transparency)?
- Is there a need for a single interface to access the data?
- What is the query format?
- Should the database be relational or object-oriented?

6. Global Resource Handling/1/10/02

- ♦ Discusses access control
- ♦ Describes access rights for different classes of actors
- ♦ Describes how object guard against unauthorized access

Defining Access Control

- In multi-user systems different actors have access to different functionality and data.
    - During **analysis** we model these different accesses by associating different use cases with different actors.
    - During **system design** we model these different accesses by examing the object model by determining which objects are shared among actors.
        - Depending on the security requirements of the system, we also define how actors are authenticated to the system and how selected data in the system should be encrypted.

Access Matrix

- We model access on classes with an access matrix.
  - **The rows of the matrix represents the actors of the system**
  - **The column represent classes whose access we want to control.**
- **Access Right:** An entry in the access matrix. It lists the operations that can be executed on instances of the class by the actor.

Access Matrix Implementations

- **Global access table:** Represents explicitly every cell in the matrix as a (actor,class, operation) tuple.
  - Determining if an actor has access to a specific object requires looking up the corresponding tuple. If no such tuple is found, access is denied.
- **Access control list** associates a list of (actor,operation) pairs with each class to be accessed.
  - Every time an object is accessed, its access list is checked for the corresponding actor and operation.
  - Example: guest list for a party.
- A **capability** associates a (class,operation) pair with an actor.
  - A capability provides an actor to gain control access to an object of the class described in the capability.
  - Example: An invitation card for a party.
- Which is the right implementation?

Global Resource Questions

- Does the system need authentication?
- If yes, what is the authentication scheme?
  - **User name and password? Access control list**
  - **Tickets? Capability-based**
- What is the user interface for authentication?
- Does the system need a network-wide name server?
- How is a service known to the rest of the system?
  - **At runtime? At compile time?**
  - **By Port?**
  - **By Name?**

7. Decide on Software Control

Choose implicit control (non-procedural, declarative languages)

- **Rule-based systems**
- **Logic programming**

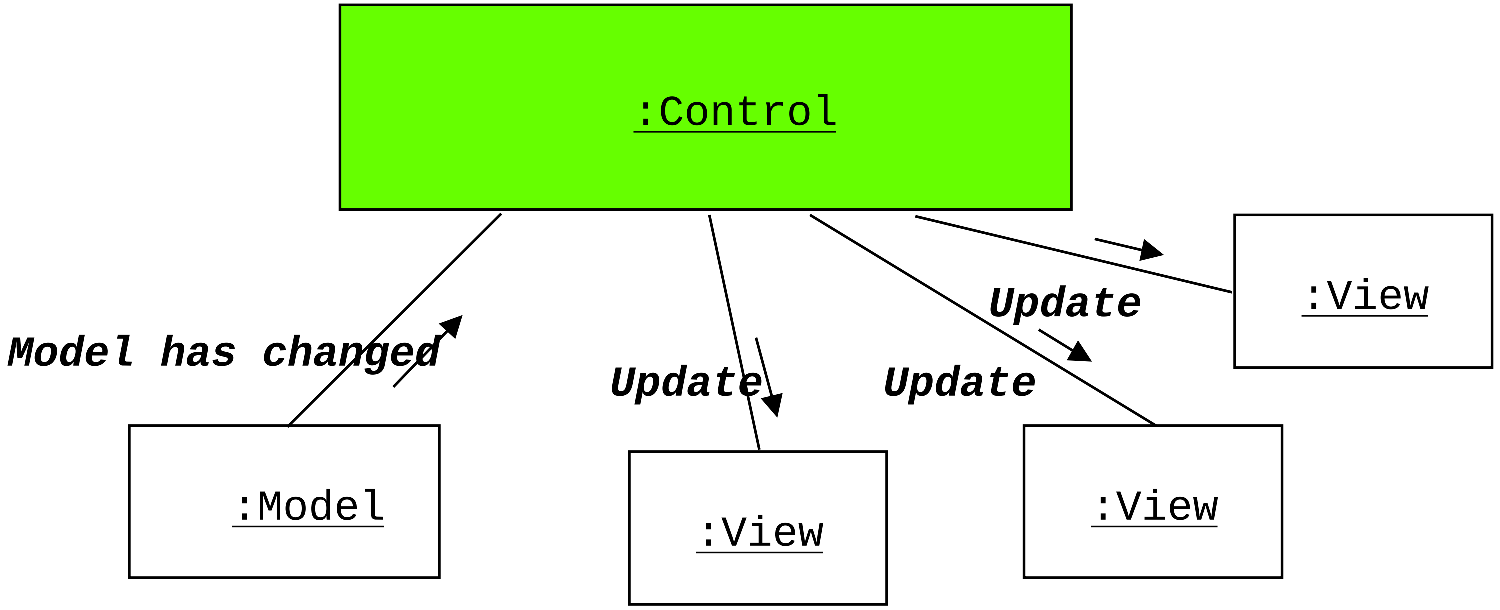
Choose explicit control (procedural languages): Centralized or decentralized

Centralized control: Procedure-driven or event-driven

- Procedure-driven control
  - **Control resides within program code. Example: Main program calling procedures of subsystems.**
  - **Simple, easy to build, hard to maintain (high recompilation costs)**
- Event-driven control
  - **Control resides within a dispatcher calling functions via callbacks.**
  - **Very flexible, good for the design of graphical user interfaces, easy to extend**

Event-Driven Control Example: MVC

- Model-View-Controller Paradigm (Adele Goldberg, Smalltalk 80)



Software Control (continued)

- **Decentralized control**
  - **Control resides in several independent objects.**
  - **Possible speedup by mapping the objects on different processors, increased communication overhead.**
  - **Example: Message based system.**

Centralized vs. Decentralized Designs

- Should you use a centralized or decentralized design?
  - **Take the sequence diagrams and control objects from the analysis model**
  - **Check the participation of the control objects in the sequence diagrams**
    - **If sequence diagram looks more like a fork: Centralized design**
    - **The sequence diagram looks more like a stair: Decentralized design**
- Centralized Design
  - **One control object or subsystem ("spider") controls everything**
    - **Pro: Change in the control structure is very easy**
    - **Con: The single conctrol ojbect is a possible performance bottleneck**
- Decentralized Design
  - **Not a single object is in control, control is distributed, That means, there is more than one control object**
    - **Con: The responsibility is spread out**
    - **Pro: Fits nicely into object-oriented development**

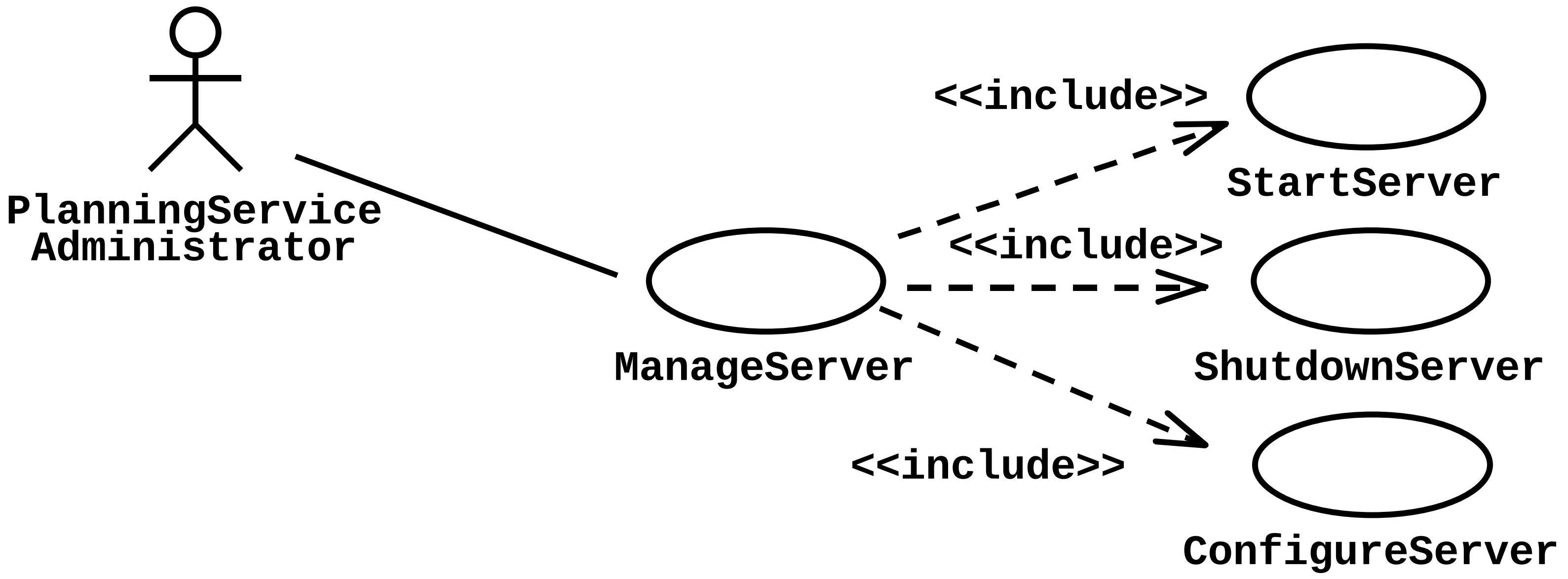
8. Boundary Conditions

- Most of the system design effort is concerned with steady-state behavior.
- However, the system design phase must also address the initiation and finalization of the system. This is addressed by a set of new uses cases called administration use cases
  - **Initialization**
    - **Describes how the system is brought from an non initialized state to steady-state ("startup use cases”).**
  - **Termination**
    - **Describes what resources are cleaned up and which systems are notified upon termination ("termination use cases").**
  - **Failure**
    - **Many possible causes: Bugs, errors, external problems (power supply).**
    - **Good system design foresees fatal failures (“failure use cases”).**

Example: Administrative Use cases for MyTrip

- Administration use cases for MyTrip (UML use case diagram).
- An additional subsystems that was found during system design is the server. For this new subsystem we need to define use cases.
- `ManageServer` includes all the functions necessary to start up and shutdown the server.

ManageServer Use Case



Boundary Condition Questions

- 8.1 Initialization
  - **How does the system start up?**
    - **What data need to be accessed at startup time?**
    - **What services have to registered?**
  - **What does the user interface do at start up time?**
    - **How does it present itself to the user?**
- 8.2 Termination
  - **Are single subsystems allowed to terminate?**
  - **Are other subsystems notified if a single subsystem terminates?**
  - **How are local updates communicated to the database?**
- 8.3 Failure
  - **How does the system behave when a node or communication link fails? Are there backup communication links?**
  - **How does the system recover from failure? Is this different from initialization?**

Modeling Boundary Conditions

- Boundary conditions are best modeled as use cases with actors and objects.
- Actor: often the system administrator
- Interesting use cases:
  - **Start up of a subsystem**
  - **Start up of the full system**
  - **Termination of a subsystem**
  - **Error in a subystem or component, failure of a subsystem or component**
- Task:
  - **Model the startup of the ARENA system as a set of use cases.**

Summary

In this lecture, we reviewed the activities of system design :

- ♦ Concurrency identification
- ♦ Hardware/Software mapping
- ♦ Persistent data management
- ♦ Global resource handling
- ♦ Software control selection
- ♦ Boundary conditions

Each of these activities revises the subsystem decomposition to address a specific issue. Once these activities are completed, the interface of the subsystems can be defined.