Object-Oriented Software Engineering

Using UML, Patterns, and Java

Chapter 7
Addressing Design Goals

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.**
- 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?)

Implementing Concurrency

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

or

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

Classroom Activity – Concurrency

- Description: For your design identify the potential concurrency.
  - 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?
- Process:
  - Meet as teams
    - Choose a scribe to record design goals
  - Use questions
  - You have about 5 minutes.

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

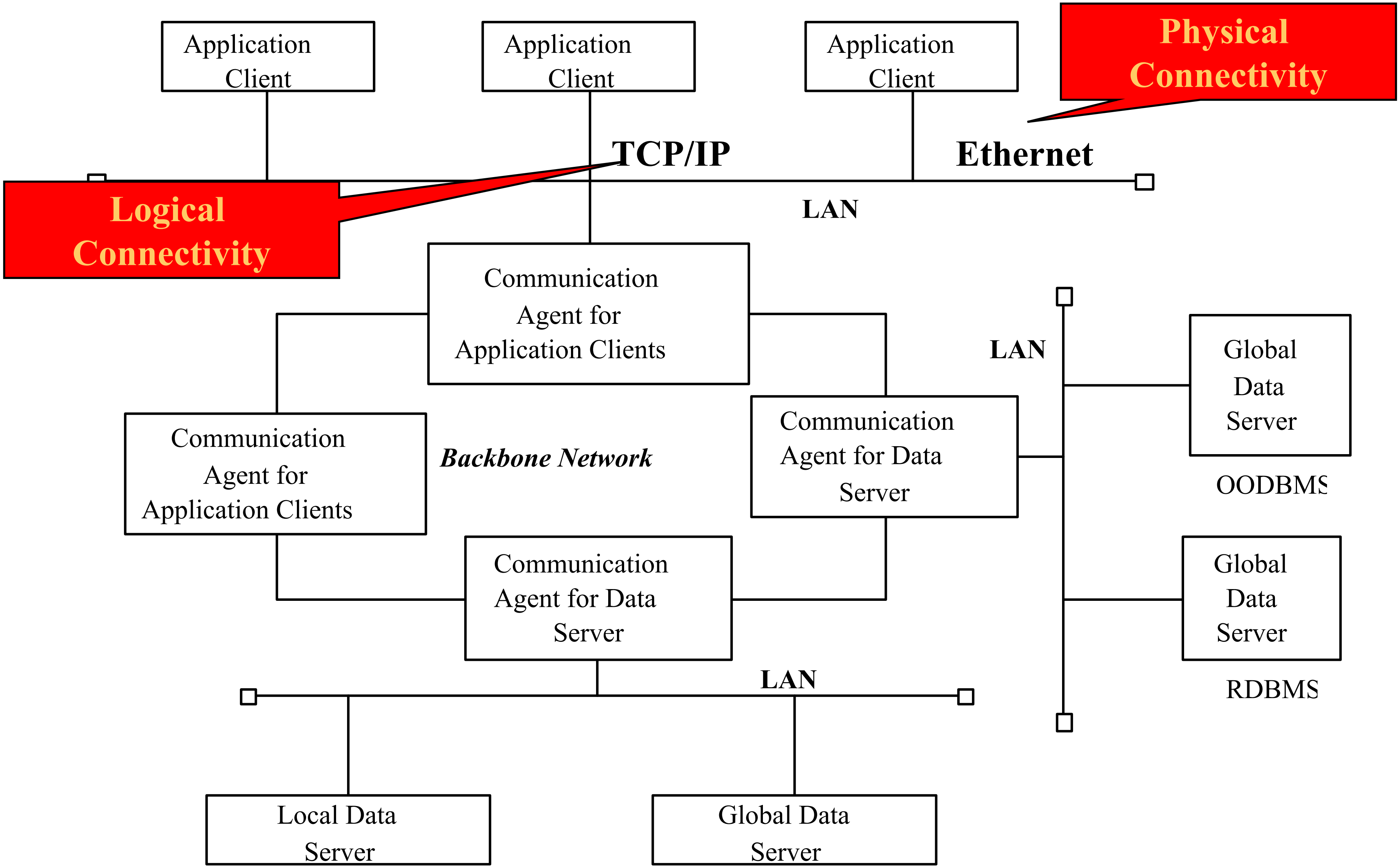
- Processor issues:
  - **Is the computation rate too demanding for a single processor?**
  - **Can we get a speedup by distributing tasks across several processors?**
  - **How many processors are required to maintain steady state load?**
- Memory issues:
  - **Is there enough memory to buffer bursts 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



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

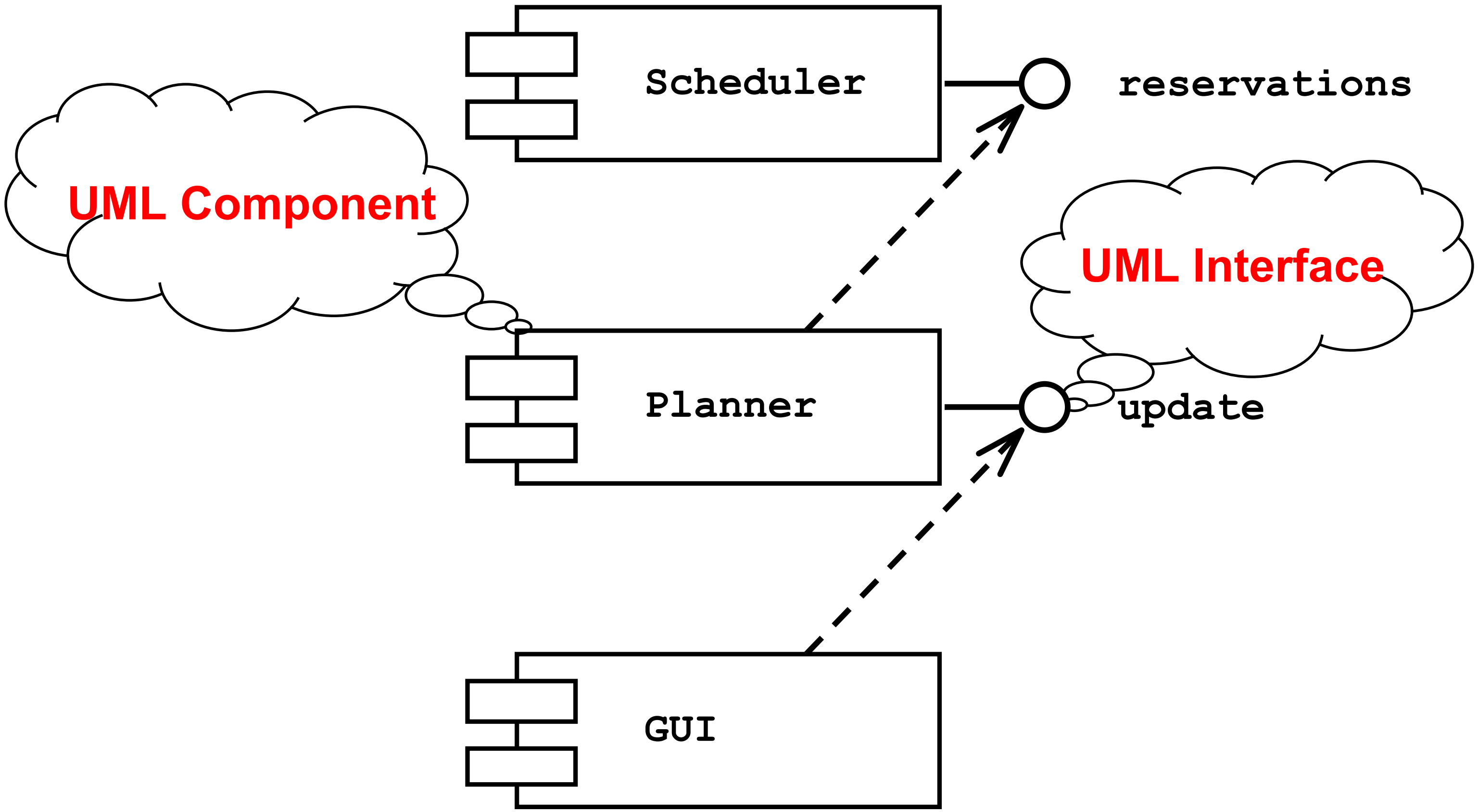
- System design must model static and dynamic structures:
  - **Component Diagrams for static structures**
    - **show the structure at design time or compilation time**
  - **Deployment Diagram for dynamic structures**
    - **show the structure of the run-time system**

- 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

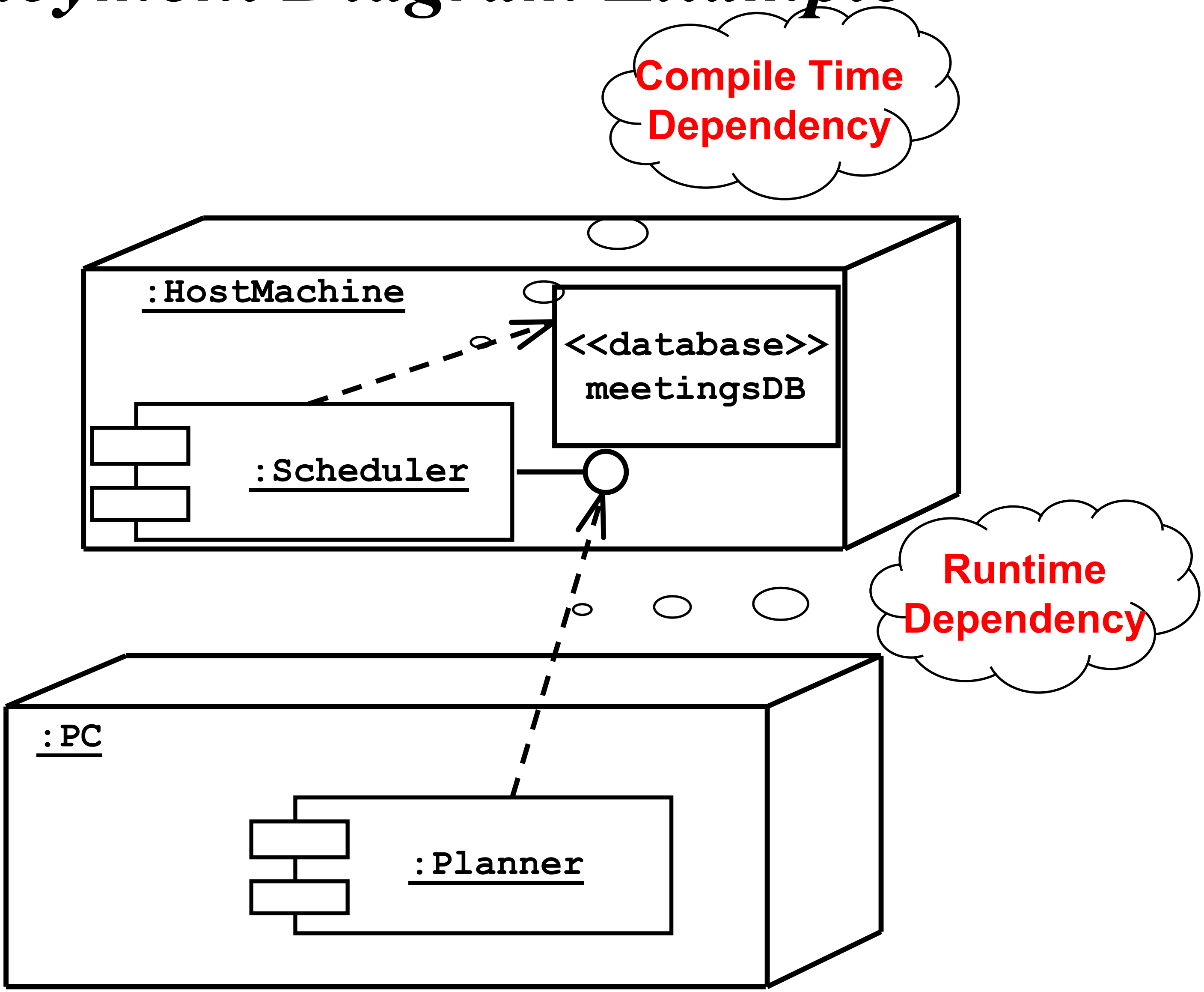


Deployment Diagram

- 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



CAT – Hardware/Software Mapping

- Description: For your design, map the software to hardware.
  - 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?
- Process:
  - Meet as teams
    - Choose a scribe to record design goals
  - Use questions
  - You have about 10 minutes.

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.**

Classroom Activity – Data Management

- Description: Design the data management for your system.
  - 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?
- Process:
  - Meet as teams
    - Choose a scribe to record design goals
  - Use questions
  - You have about 10 minutes.

6. Global Resource Handling

- 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**

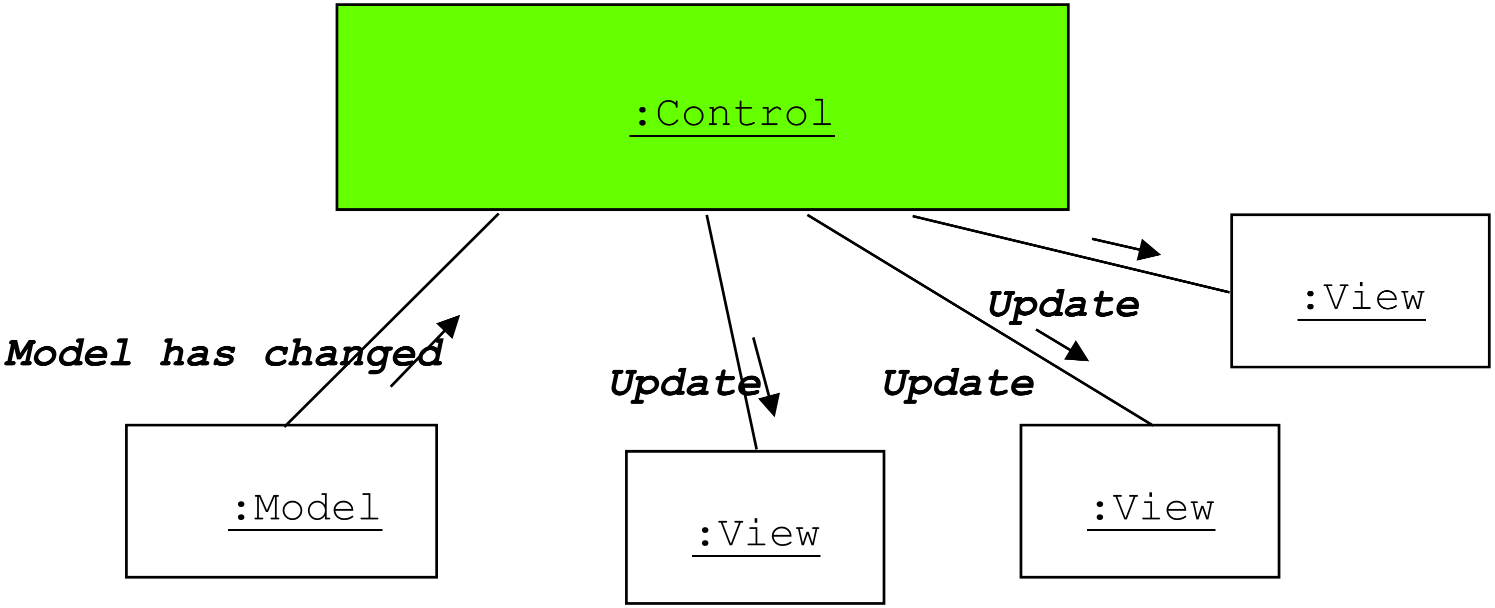
Choose explicit control (procedural languages): Centralized or decentralized

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**

Classroom Activity – Control

- Description: Select the type of software control for your system and justify your selection.
  - **Procedural**
  - **Event-driven**
  - **Threads**
- Process:
  - Meet as teams
    - Choose a scribe to record design goals
  - You have about 10 minutes.

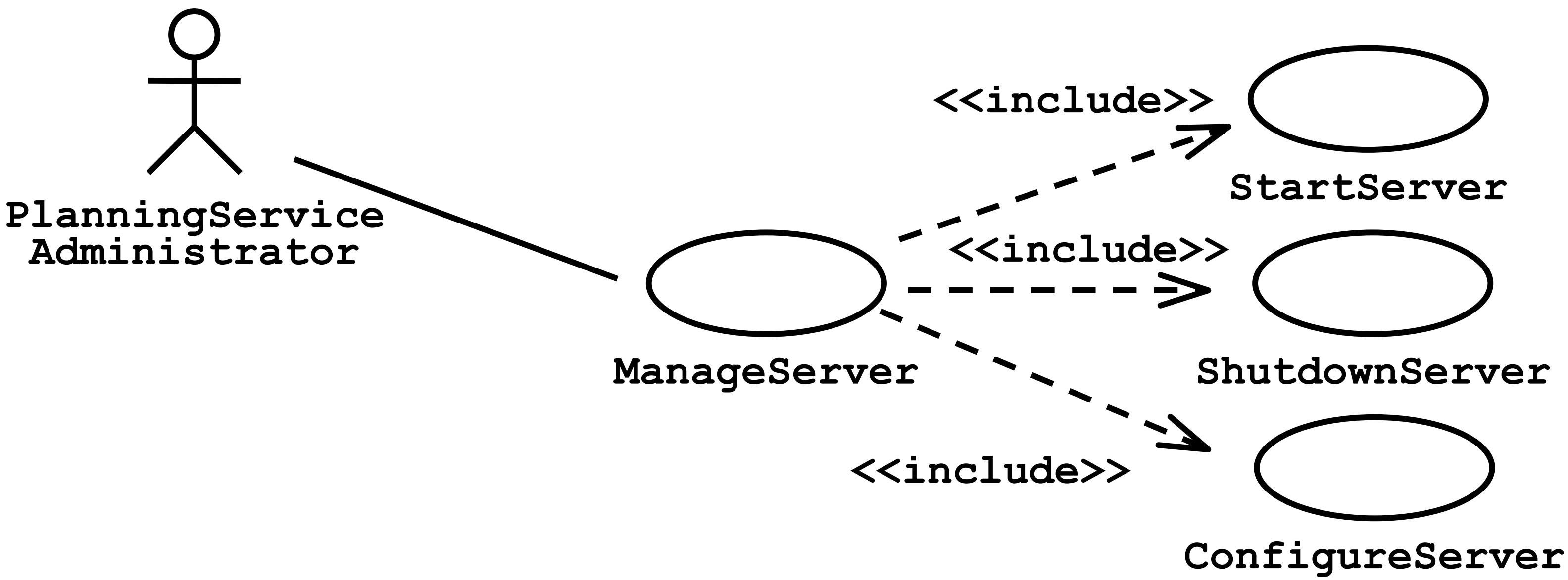
8. Boundary Conditions

- 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

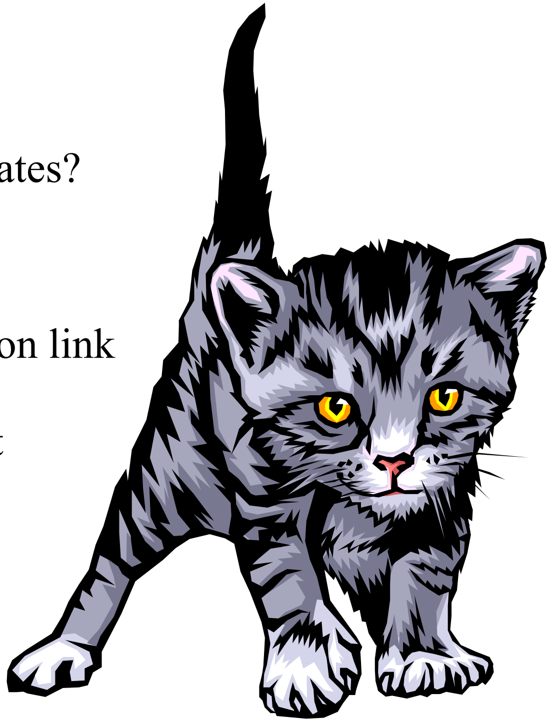


Modeling Boundary Conditions

- 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.**

Classroom Activity – Partitioning

- Description: Partition you system into subsystems using the ideas of coupling and cohesion.
  - 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?
  - Termination
    - Are single subsystems allowed to terminate?
    - Are other subsystems notified if a single subsystem terminates?
    - How are local updates communicated to the database?
  - 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?
- Process:
  - Meet as teams, Use questions, You have about 10 minutes.



Summary

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.