DESIGN OF SOFTWARE ARCHITECTURE

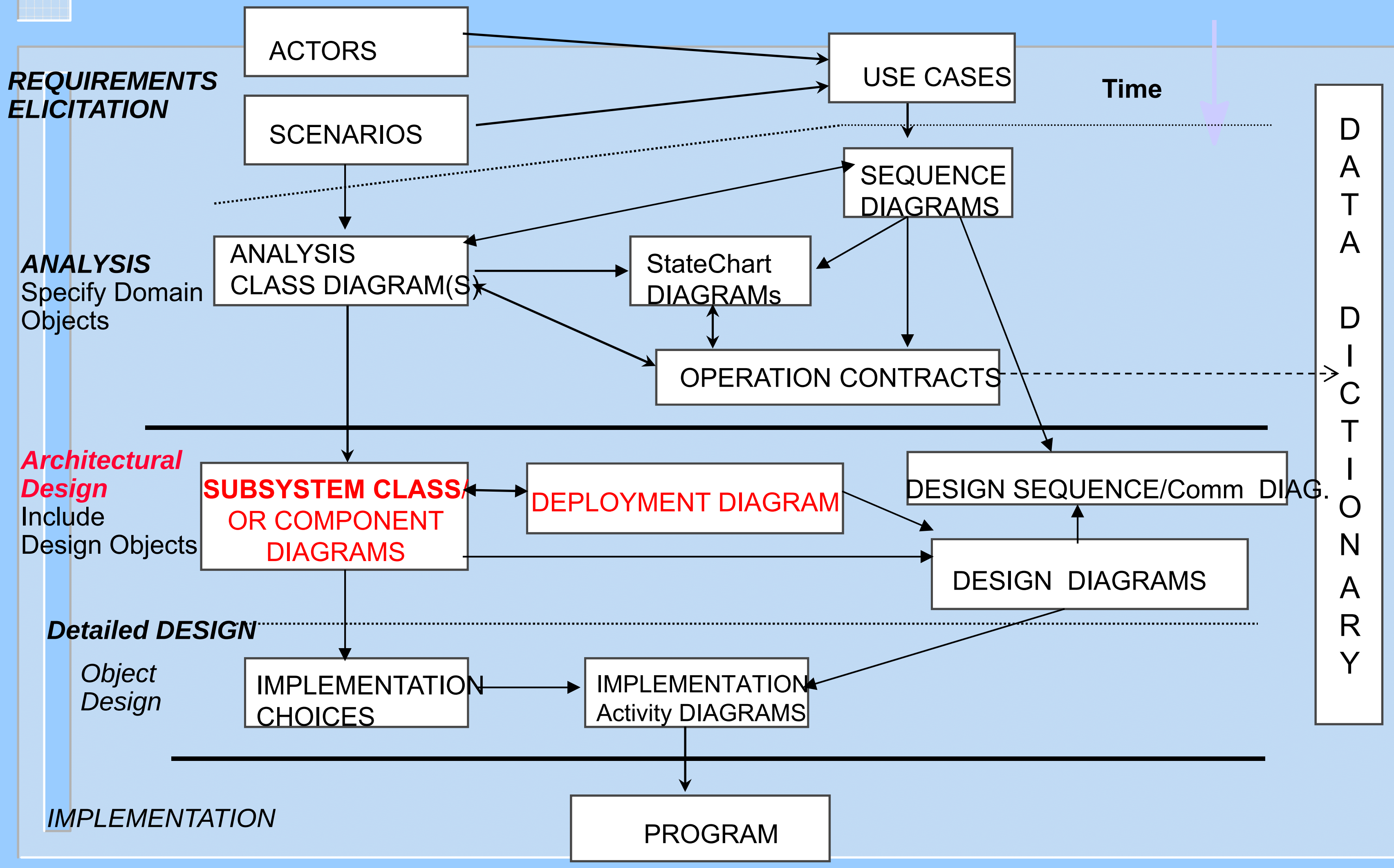
Instructor: Dr. Hany H. Ammar

Dept. of Computer Science and Electrical Engineering, WVU

Outline

- UML Development – Overview
- The Requirements, Analysis, and Design Models
- What is Software Architecture?
  - Software Architecture Elements
- Examples
- The Process of Designing Software Architectures
  - Defining Subsystems
  - Defining Subsystem Interfaces
- Design Using Architectural Styles
  - Software Architecture Styles
  - The Attribute Driven Design (ADD)

UML Development - Overview



The Requirements, Analysis, and Design Models

Requirements Elicitation Process

Functional/ Nonfunctional Requirements

Use Case Diagrams/ Sequence Diagrams (the system level)

The Analysis Process

Static Analysis
Dynamic Analysis

- Analysis Class Diagrams
- State Diagrams/ Refined Sequence Diagrams (The object level)

The Design Process

Static Architectural Design
Dynamic Design

- Design Class Diagrams and Components Diagrams
- Design Sequence/
- Collaboration Diagrams

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What is Software Architecture?

A simplified Definition

A **software architecture** is defined by a configuration of architectural elements--**components**, **connectors**, and **data**--constrained in their relationships in order to achieve a desired set of architectural properties.

Software Architecture Elements

- **A** *component* **is an abstract unit of software instructions and internal state that provides a transformation of data via its interface**

- **A** *connector* **is an abstract mechanism that mediates communication, coordination, or cooperation among components.**

Software Architecture Elements

- **A *datum* is an element of information that is transferred from a component, or received by a component, via a connector.**
- **A *configuration* is the structure of architectural relationships among components, connectors, and data during a period of system run-time.**
- *Software Architecture views:* **Architectures are described using multiple views such as the *static view*, the *dynamic view*, and *deployment view*.**
- **An *architectural style* is a coordinated set of architectural constraints that restricts the roles/features of architectural elements and the allowed relationships among those elements within any architecture that conforms to that style.**

The static view

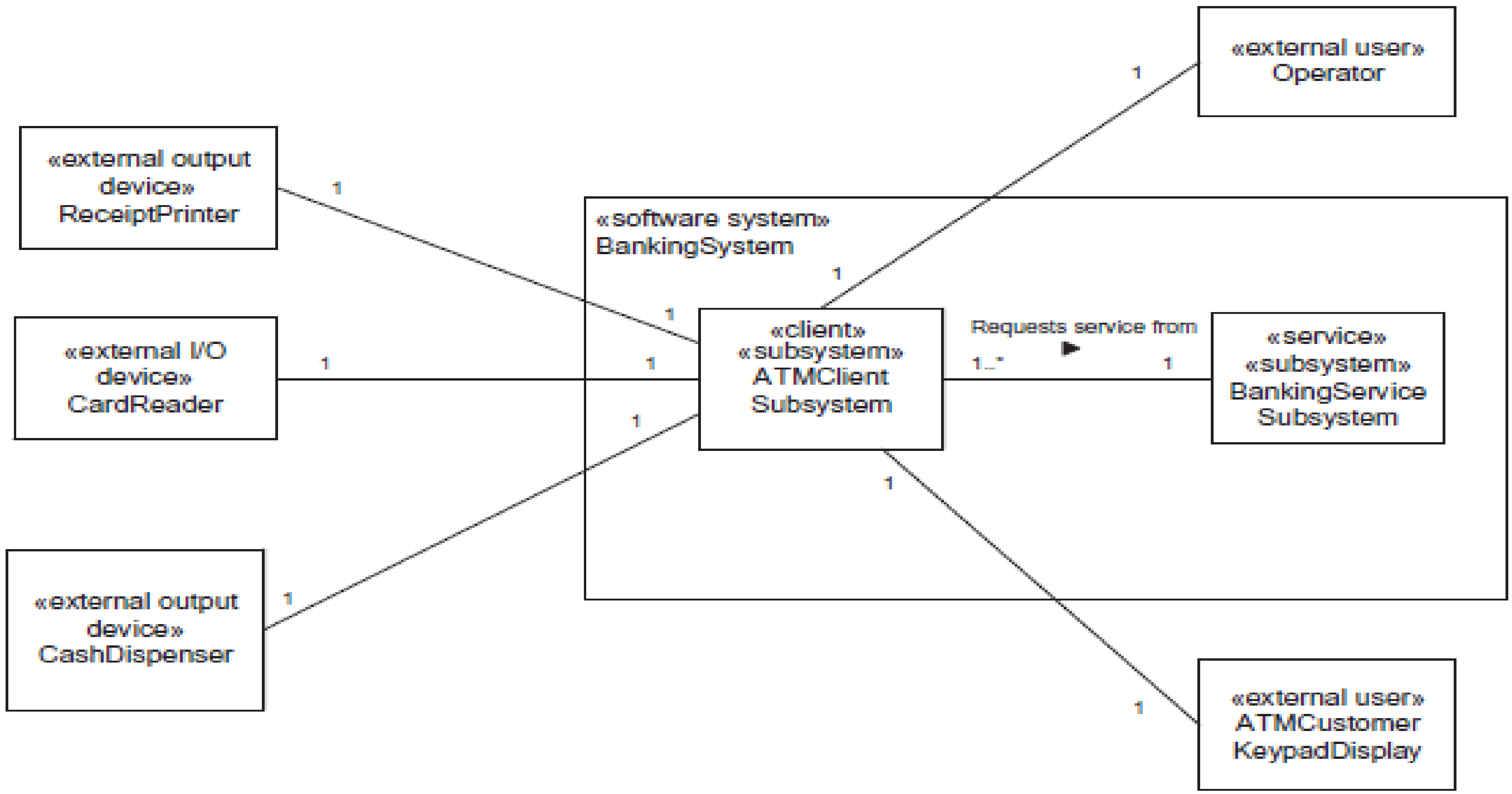


Figure 21.8. Banking System: major subsystems

The dynamic view,
a high level diagram

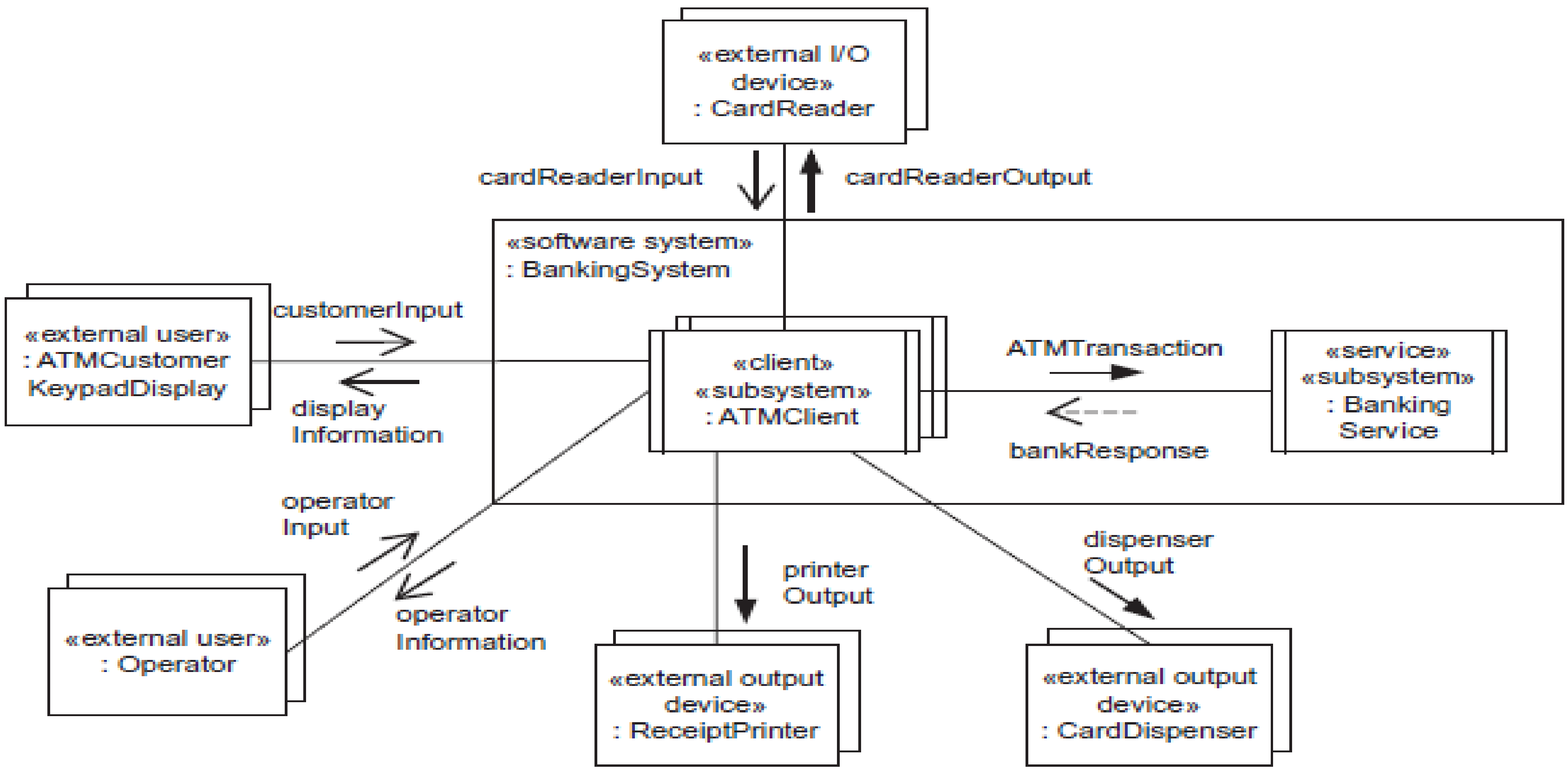


Figure 12.2. Dynamic view of client/server software architecture: high-level communication diagram for Banking System

The dynamic view of the ATMClient for a certain Use Case Scenario

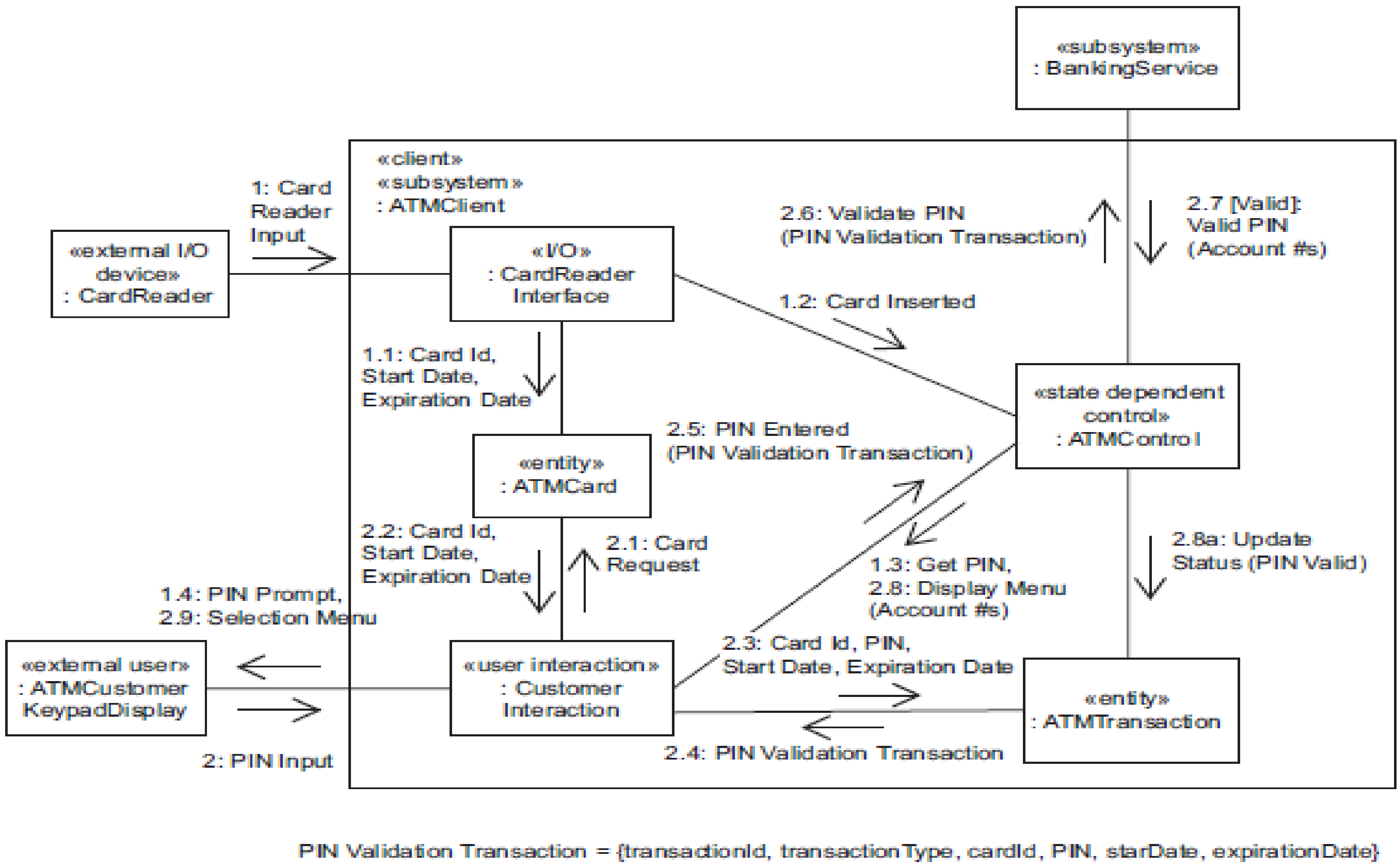


Figure 21.11. Communication diagram: ATM client Validate PIN use case

The dynamic view: another model

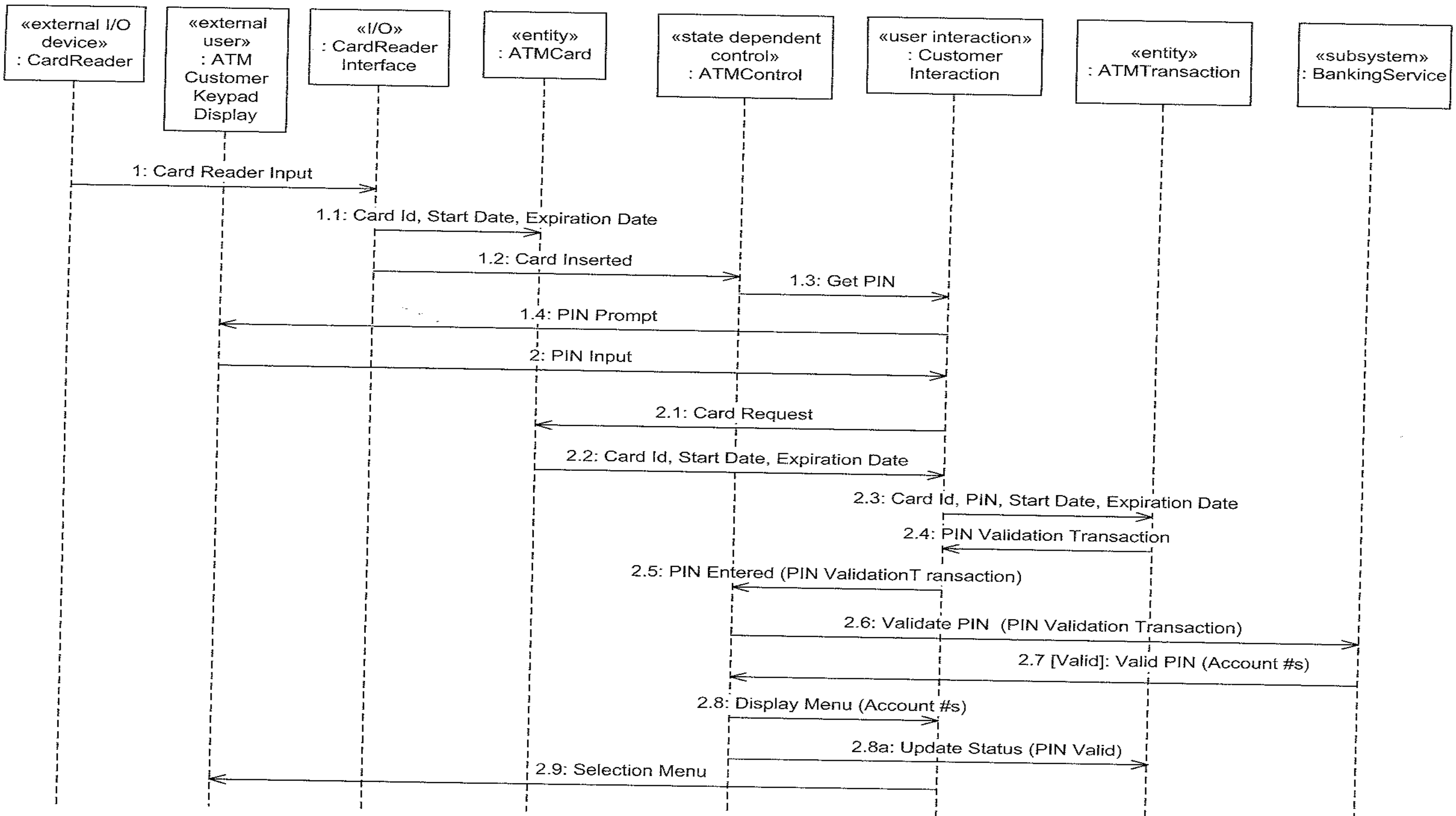


Figure 21.12. Sequence diagram: ATM client Validate PIN use case

The deployment view

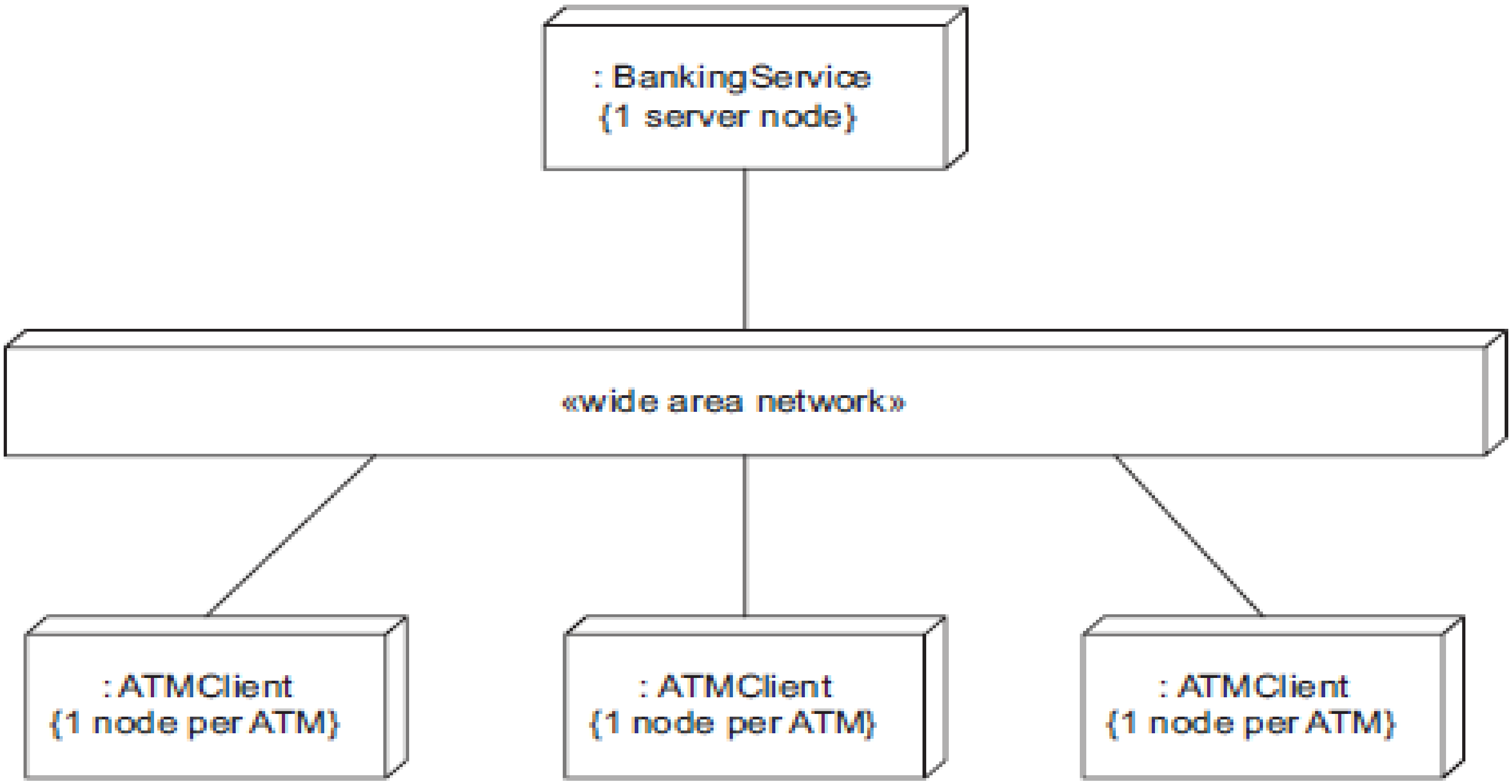


Figure 21.36. Deployment diagram for Banking System

Introducing Architecture Styles

More details on architecture styles to be discussed later

- The Layered Architecture

e.g Network

Services

Architecture

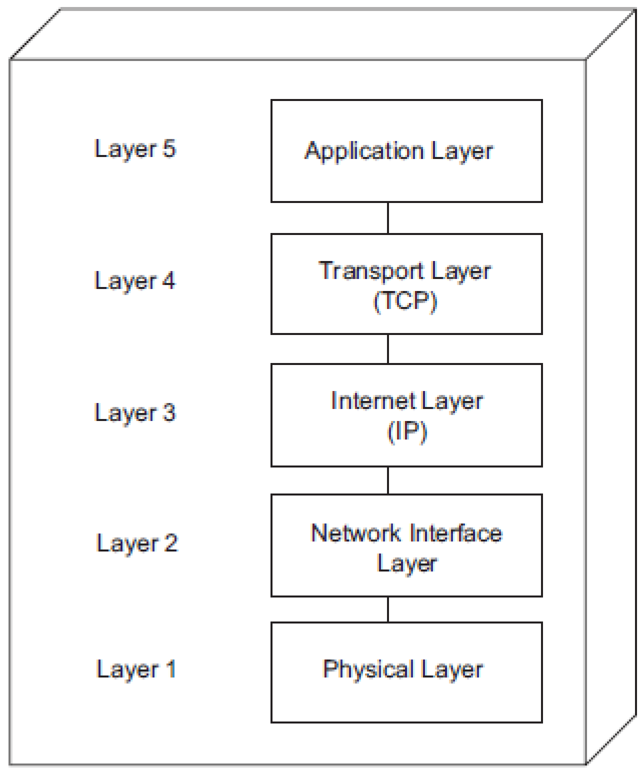


Figure 12.4. Layers of Abstraction architectural pattern: example of the Internet (TCP/IP) reference model

Network Services Architecture
Deployment view

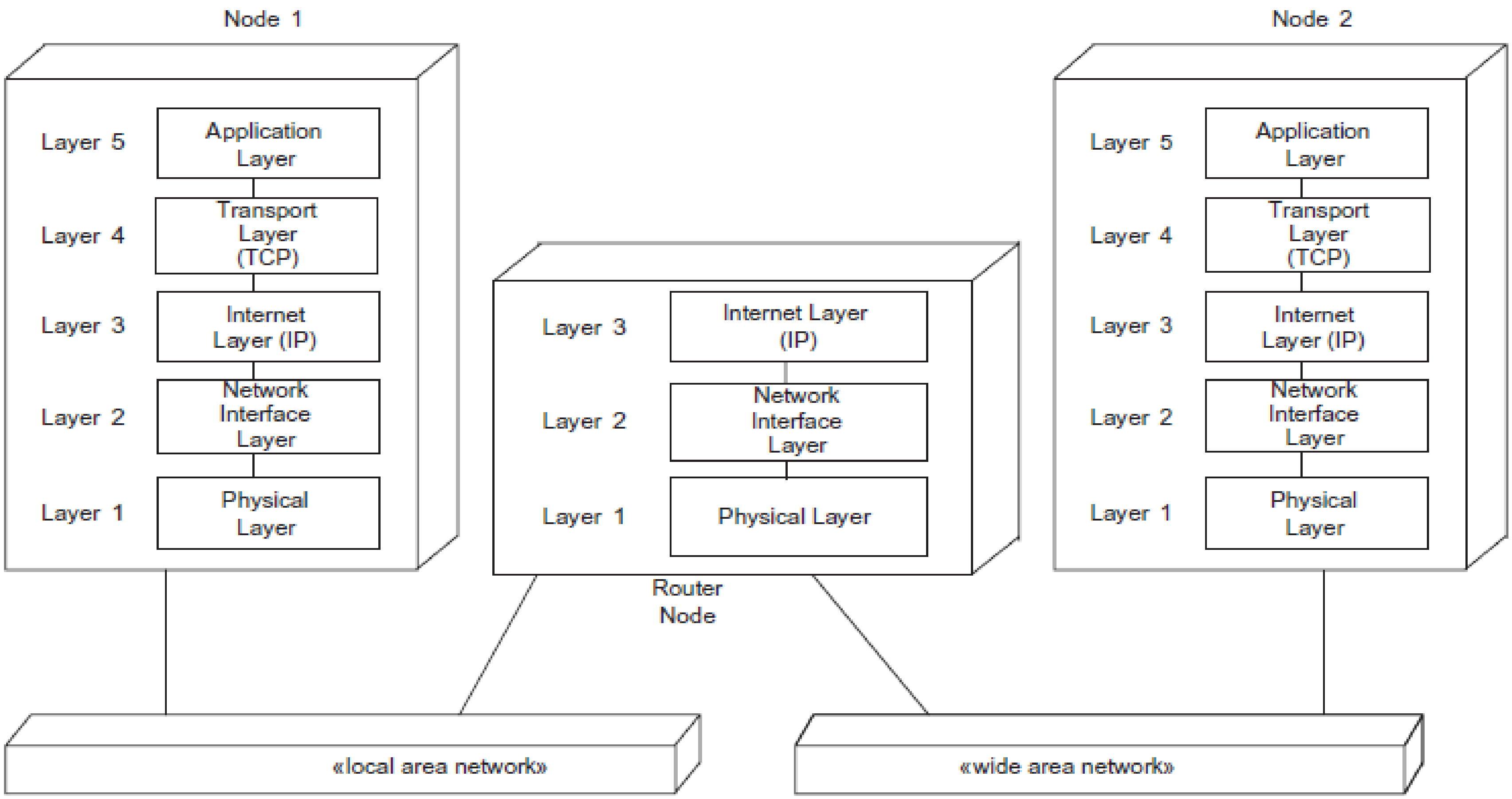
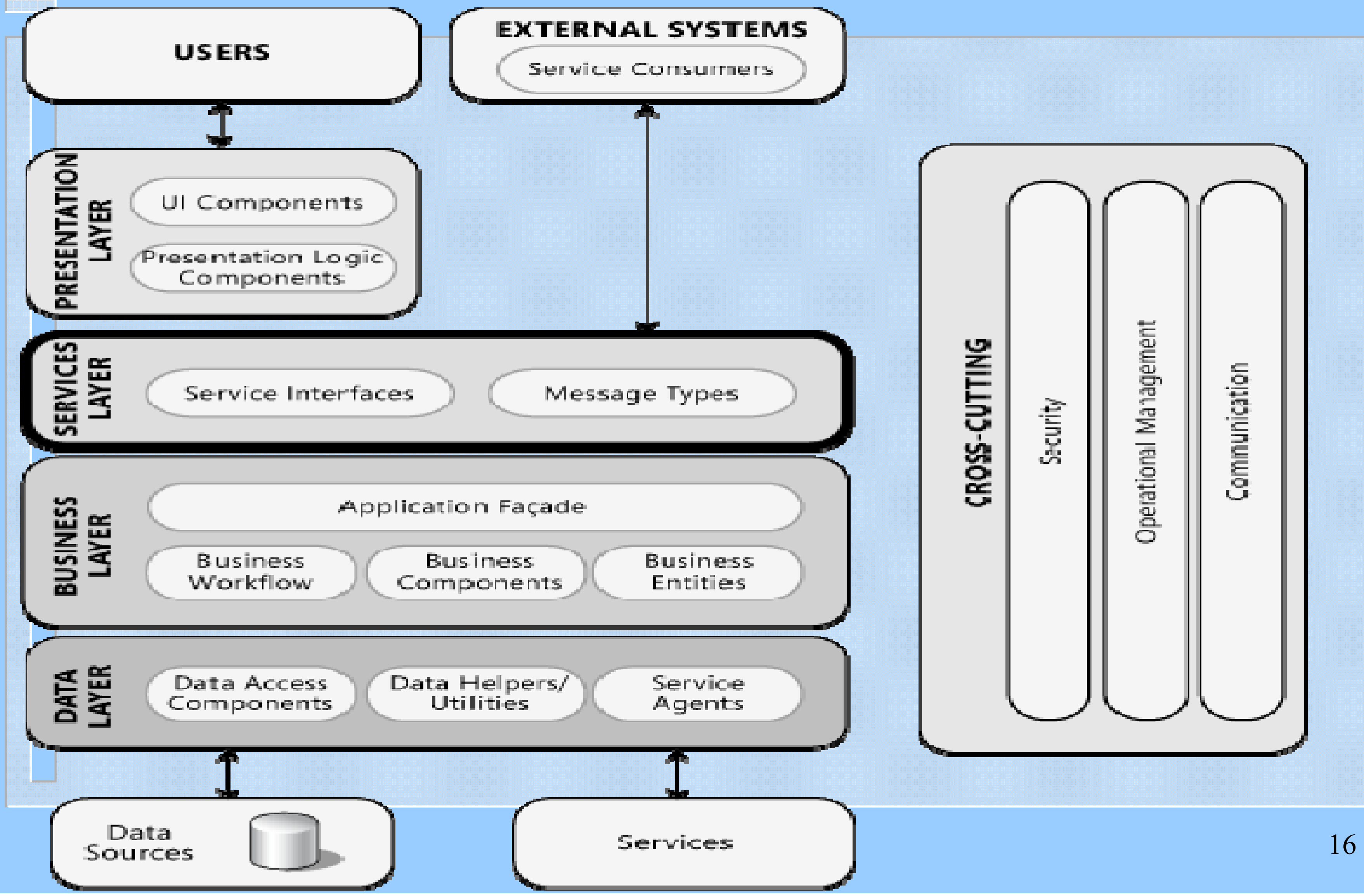
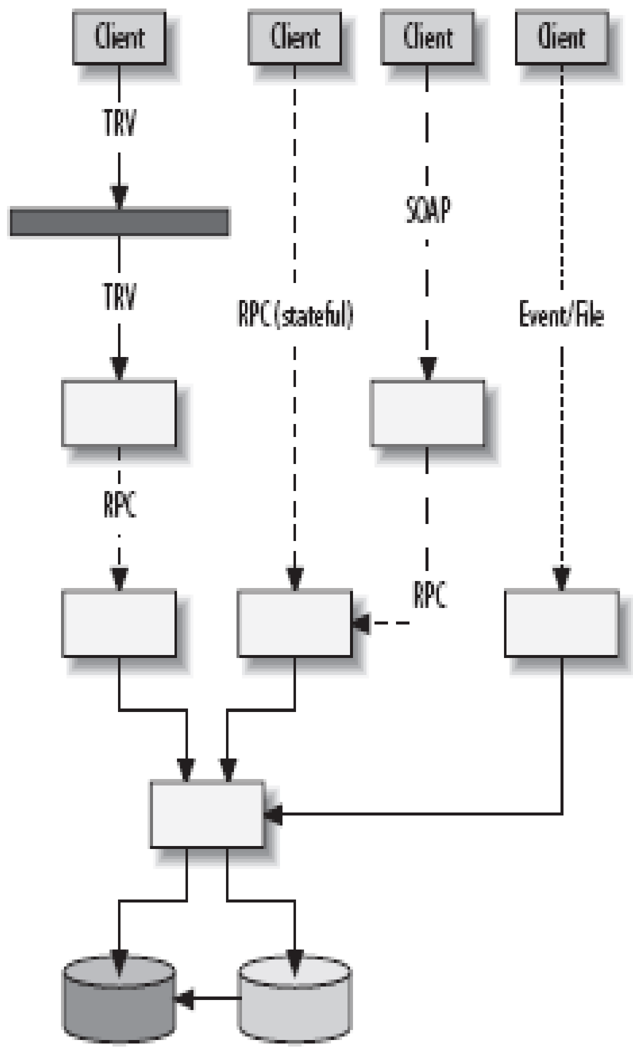


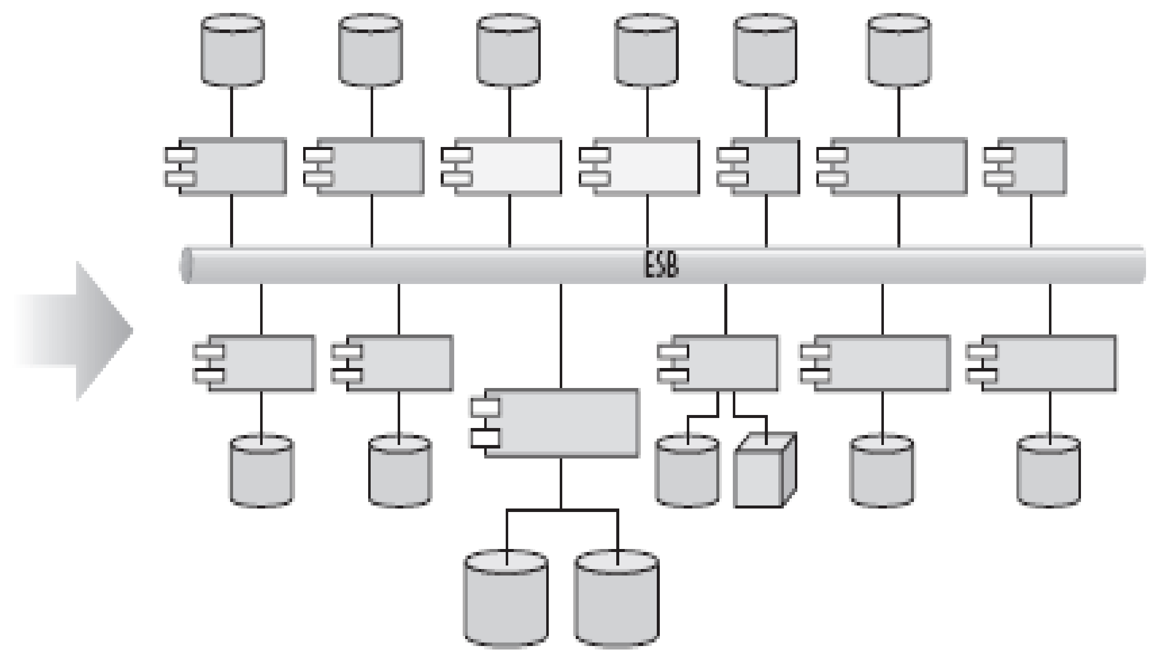
Figure 12.5. Layers of Abstraction architectural pattern: Internet communication with TCP/IP

Layered Software Architectural styles
Example of Web Applications Architecture Style



Service Oriented Architecture (SOA):
Makes use of an Enterprise Service Bus ESB
Used in web-based systems and distributed computing

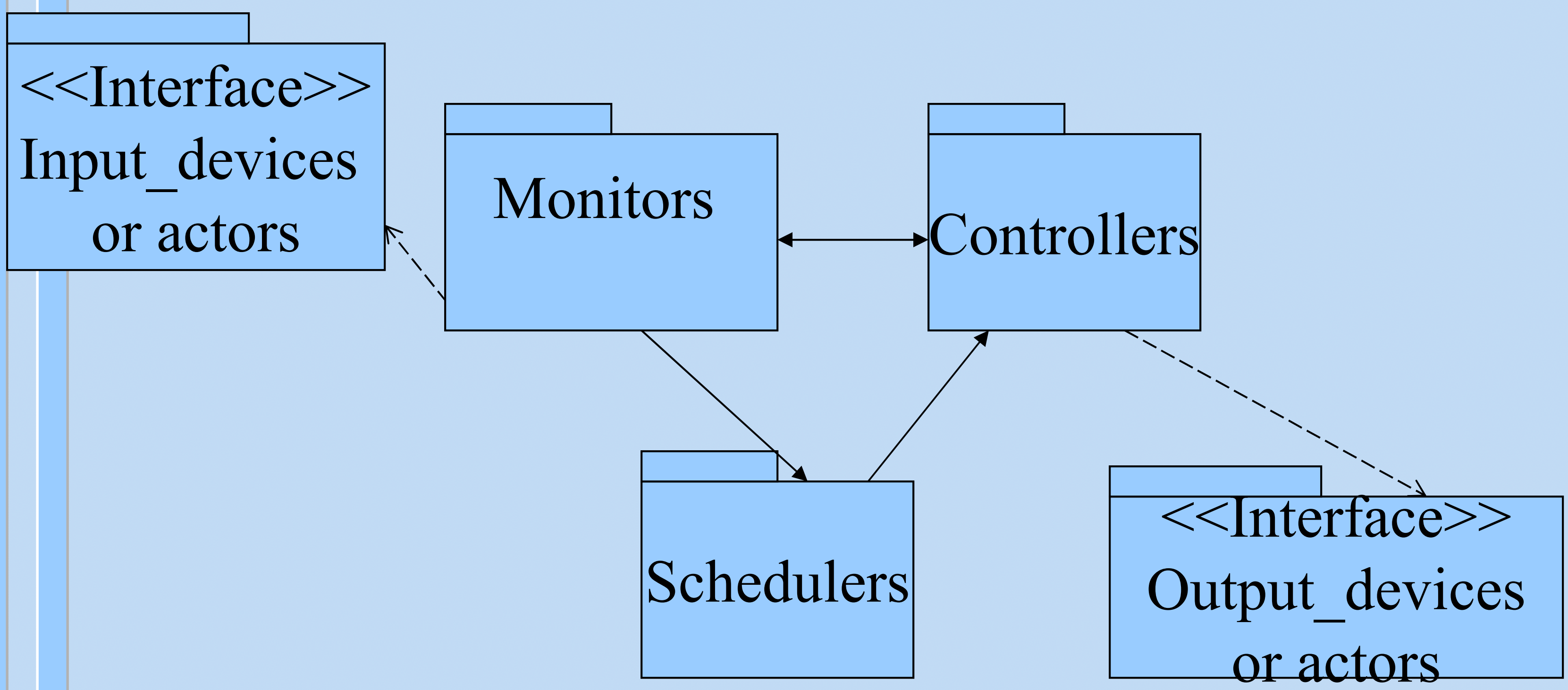




nodes on a network make resources available to other participants in the network as independent services that the participants access in a standardized way using the ESB

Examples of Architecture Styles

- Embedded Systems architecture style



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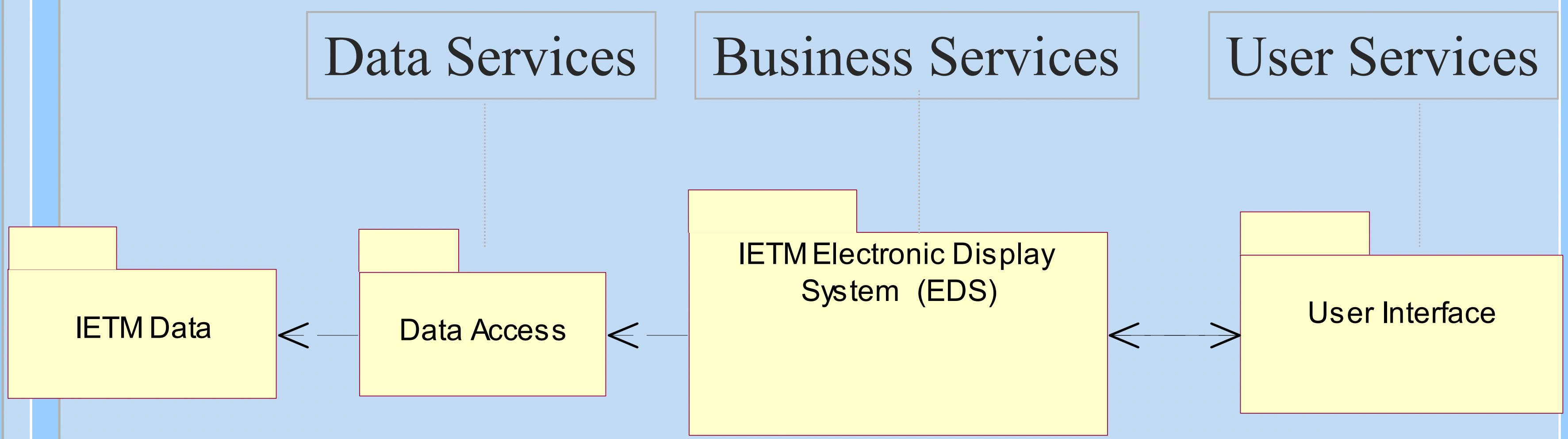
Example: Interactive Electronic Technical Manual (IETM) System

- Web Services 3-tier architecture



Recall Analysis diagram for EMS, Context Diag.

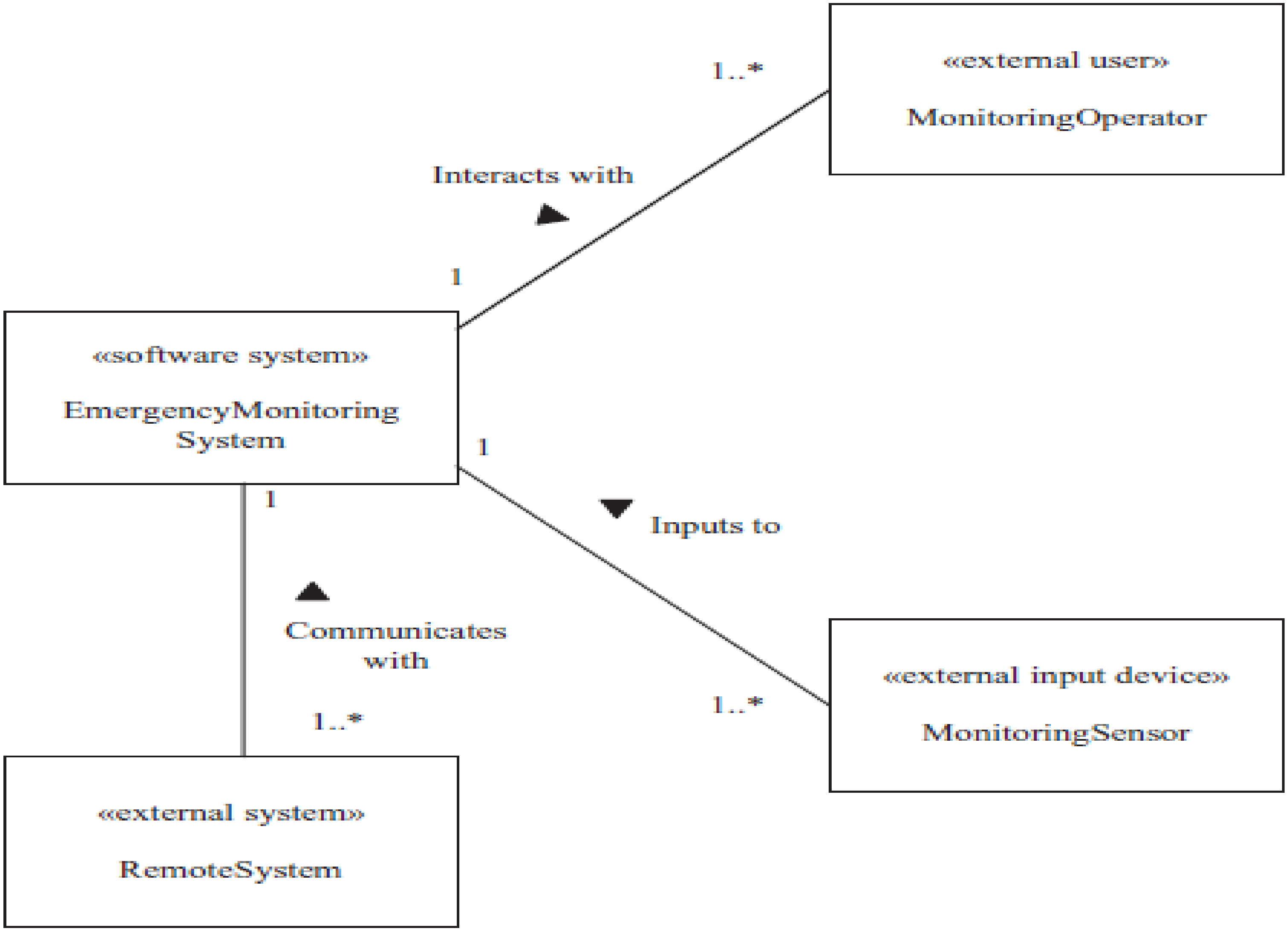


Figure 23.2. Software system context class diagram for Emergency Monitoring System

EMS Architecture

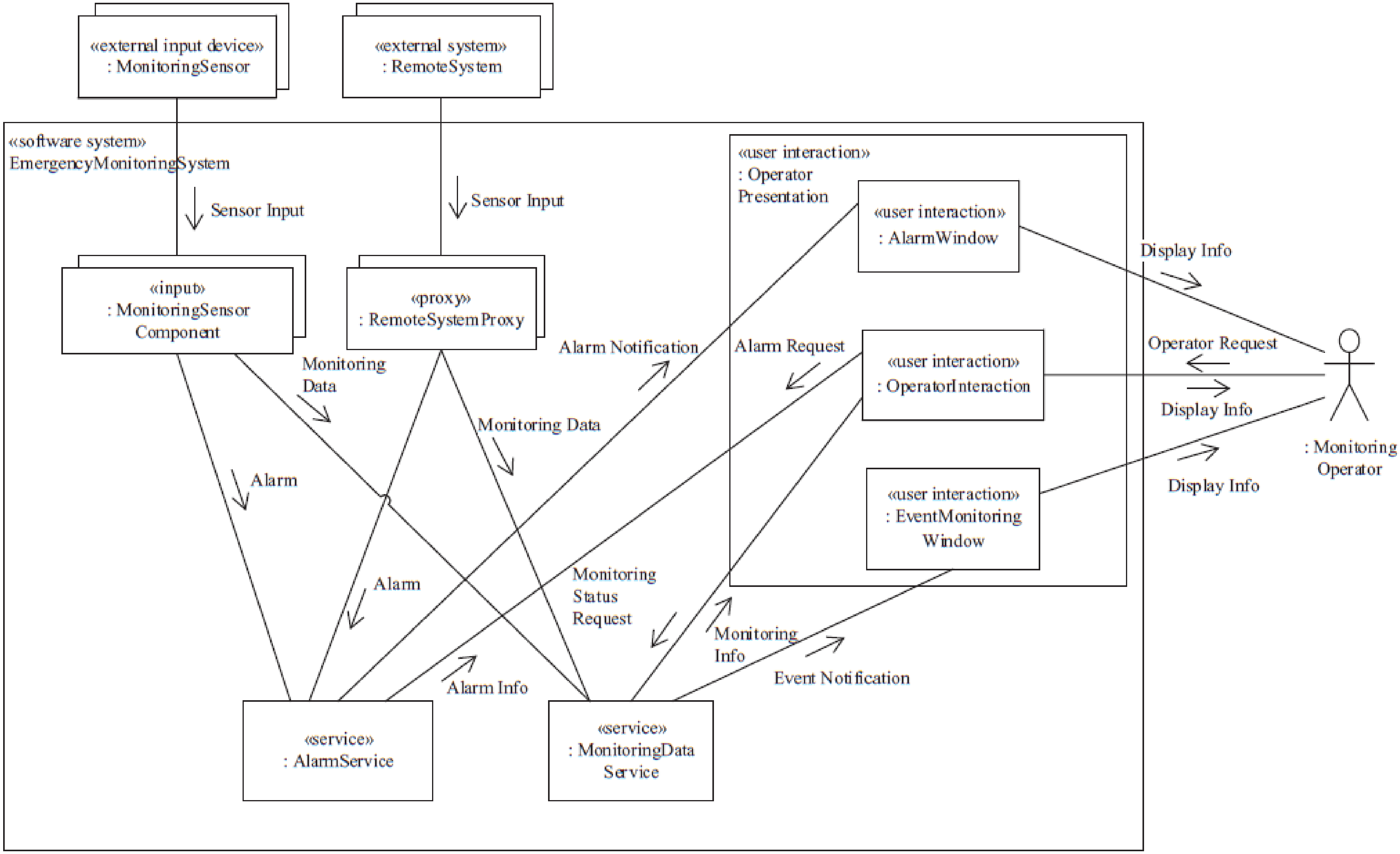


Figure 23.8. Integrated communication diagram for Emergency Monitoring System

EMS *Deployment Architecture view*

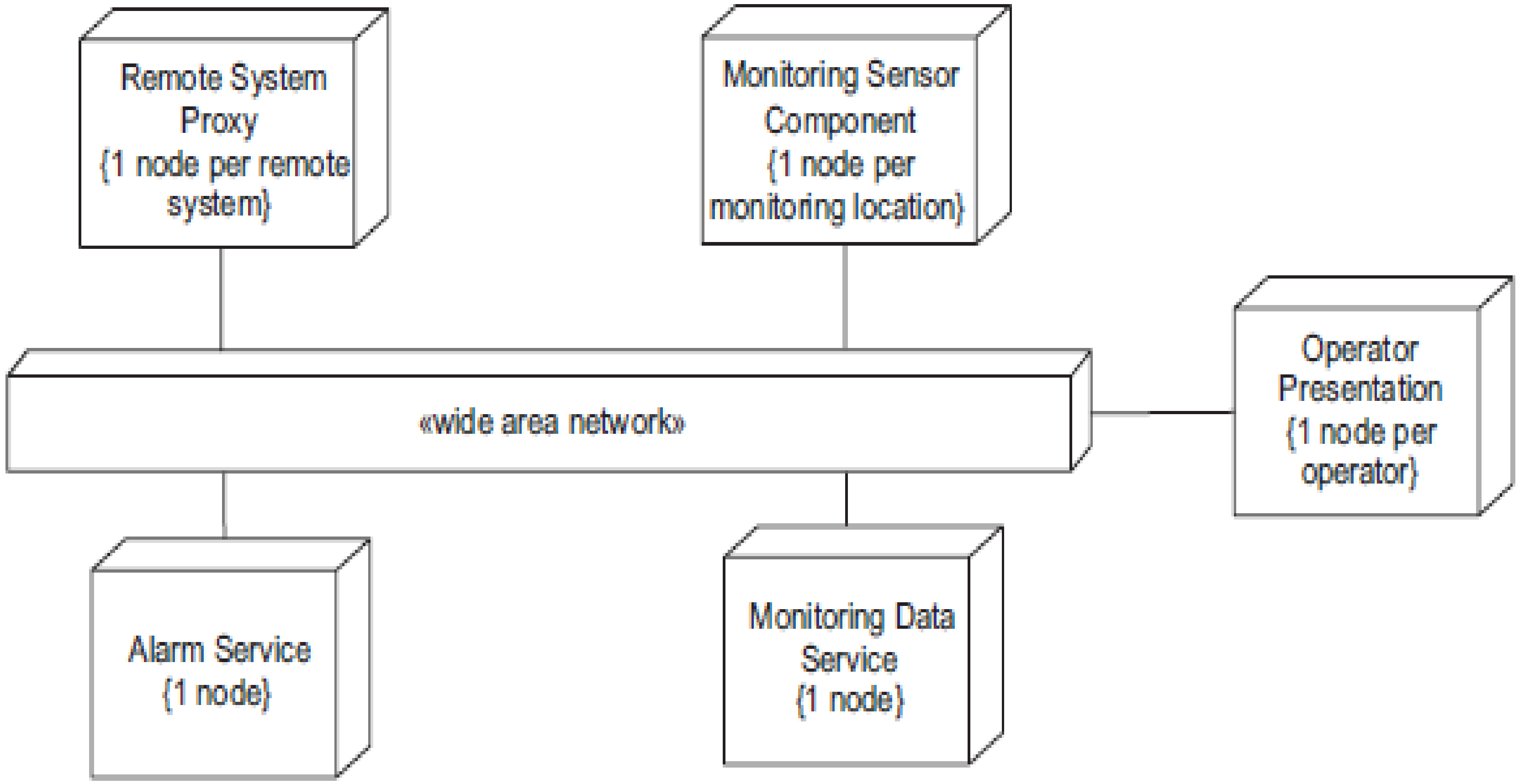
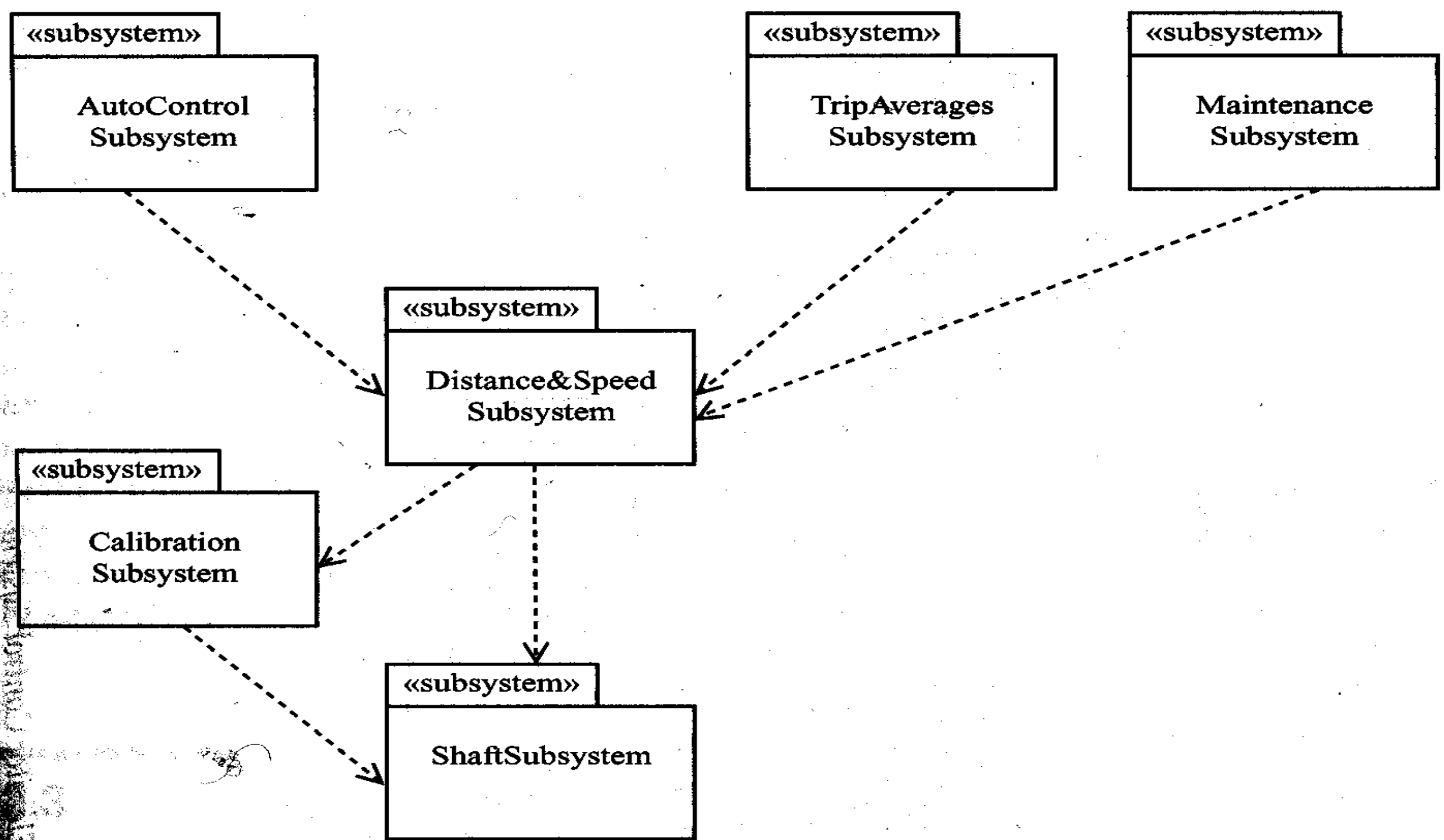


Figure 13.5. Example of geographical distribution: Emergency Monitoring System

Example of Hierarchical Architecture:
Cruise Control and Monitoring System



ure 12.3 *Example of hierarchical architecture: Cruise Control and Monitoring tem*

Example: Consolidated Collaboration Diagram of the Elevator Control System

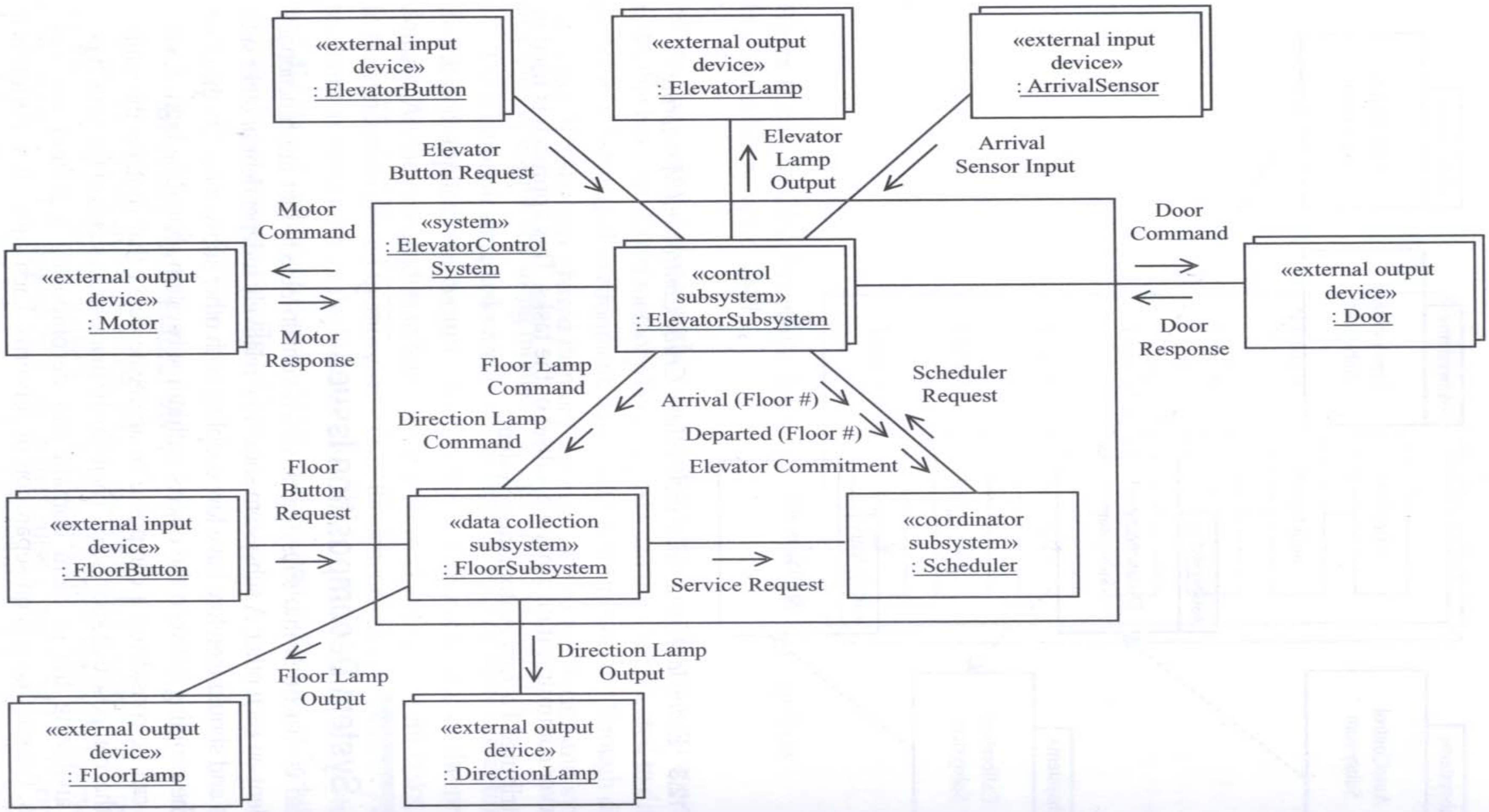


Figure 12.4 *Example of distributed software architecture: Elevator Control System*

Online Shopping System: Structured Classes with Ports

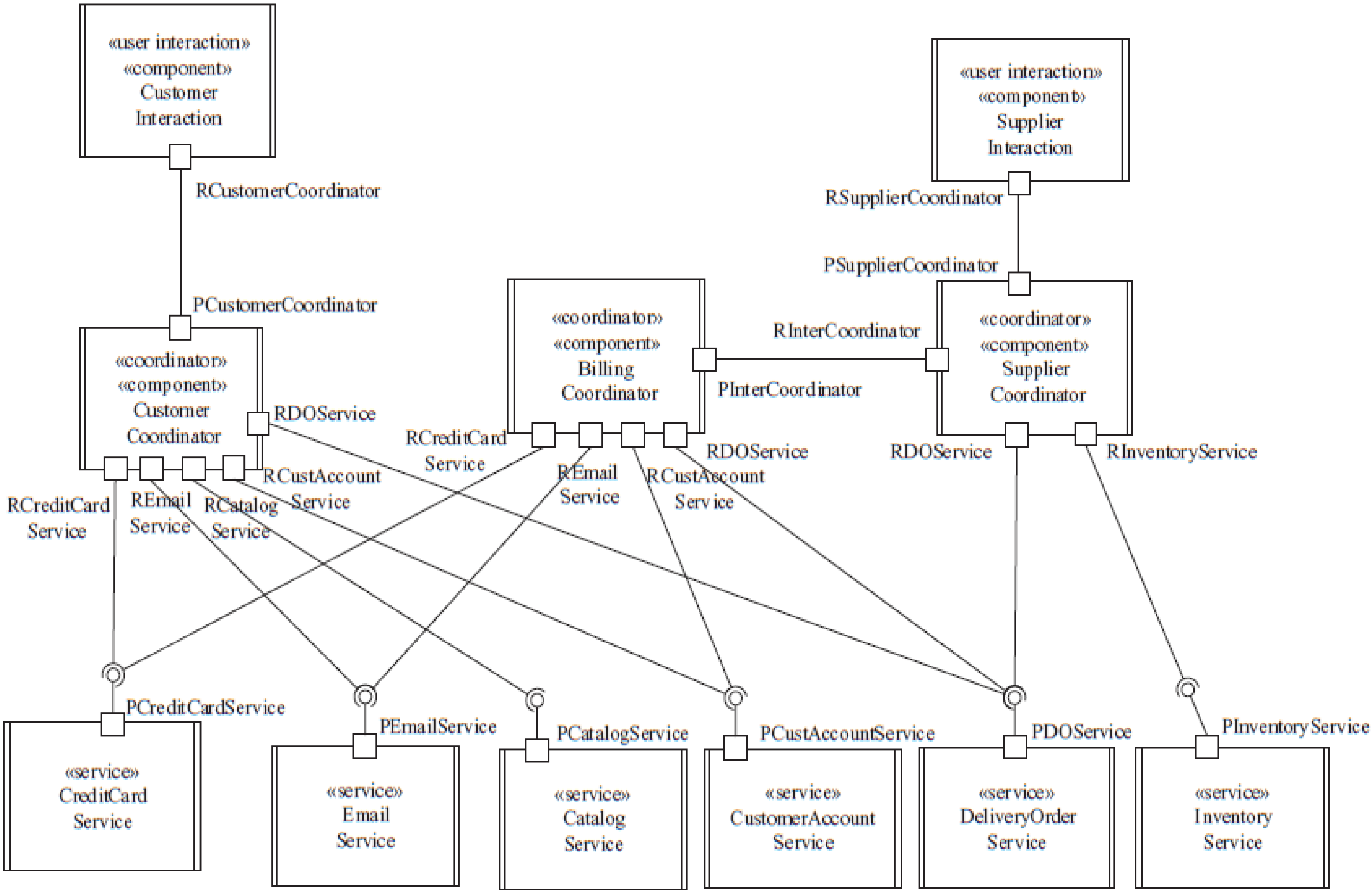


Figure 22.25. Service-oriented software architecture for the Online Shopping System

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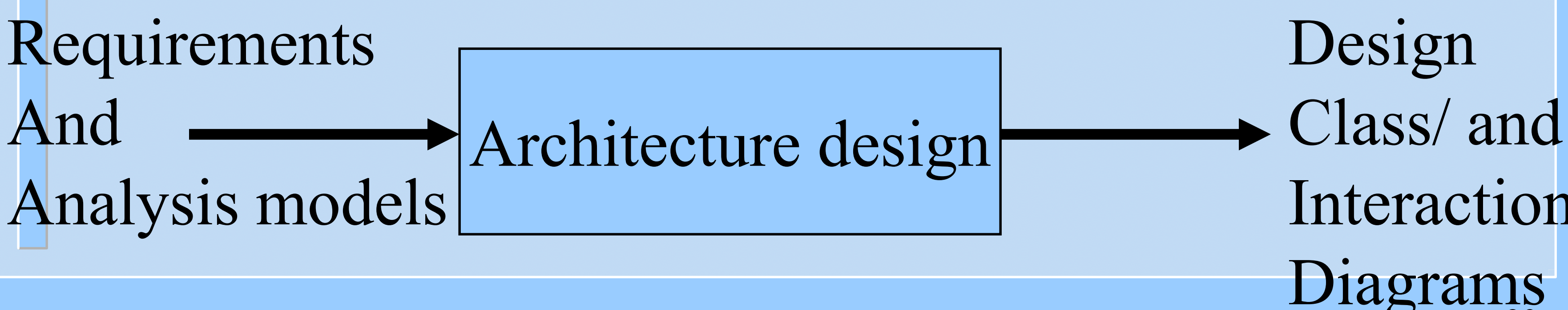
Information Available At Architectural Design

- The Requirements model
  - Use cases, Use case Diagram, system sequence diagrams
- The Analysis model
  - Analysis class diagram,
  - stateCharts for multi-modal classes, and
  - Domain Object sequence diagrams

Artifacts Developed at Architectural Design

- Subsystems + their public interfaces (APIs)
- Subsystems class diagrams. A class diagram for each subsystem
- Subsystem dependencies (interaction diagrams)



The Process of Designing Software Architectures

- Software Architecture

  Step1: Define overall structure of the system into components or subsystems, or classes

  Step 2: Define Component interfaces and interconnections separately from component internals (defined during details design)

- Each subsystem performs major service
  - Contains highly coupled objects
  - Relatively independent of other subsystems
  - May be decomposed further into smaller subsystems
  - Subsystem can be an aggregate or a composite object

Step 1 - Subsystem/Components Structuring Criteria

Decompose the system into subsystems or classes such that each performs a specific function or task to maximize cohesion and minimize coupling, the following are typical examples of subsystems or classes

- **Controllers**
  - Subsystem controls a given aspect of the system (e.g., Cruise cont. Fig. 20.45)
- **Coordinators/Schedulers**
  - Coordinates several control subsystems (e.g., Cruise cont Fig 20.45,20.46)
- **Data Collectors/Monitors**
  - Collects data from external environment (e.g., Cruise cont Fig. 20.45)•
- **Data analyzers**

  Provides reports and/or displays (e.g., Cruise cont Fig. 20.26)
- **Servers**
  - Provides service for client subsystems (e.g., MyTrip example)
- **User/Device Interface**
  - Collection of objects supporting needs of user (e.g., Cruise cont Fig. 20.26)

Control, Coordinator, Data Collection Subsystems

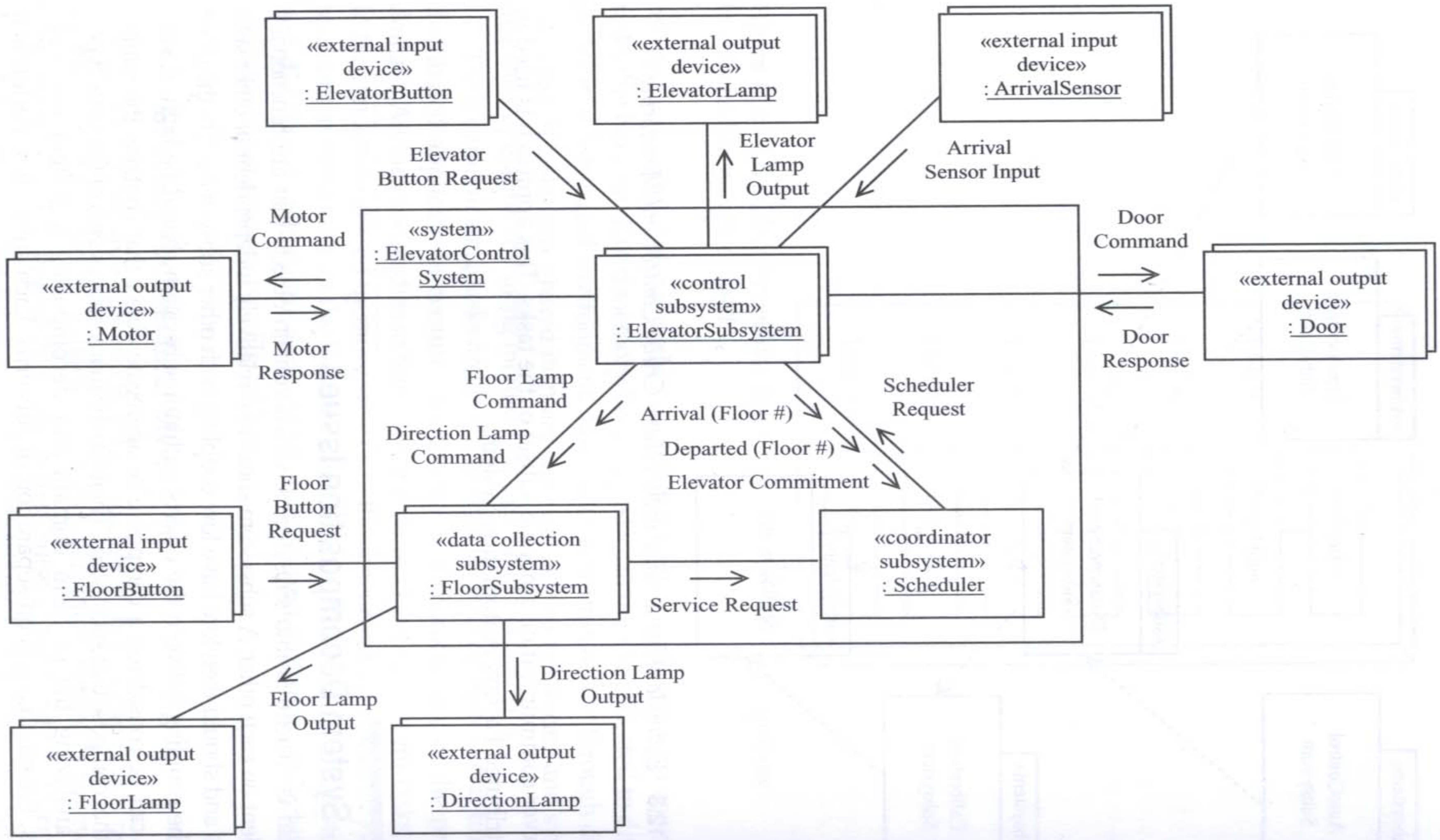


Figure 12.4 *Example of distributed software architecture: Elevator Control System*

Coordinator, Service, and User InterfaceSubsystems

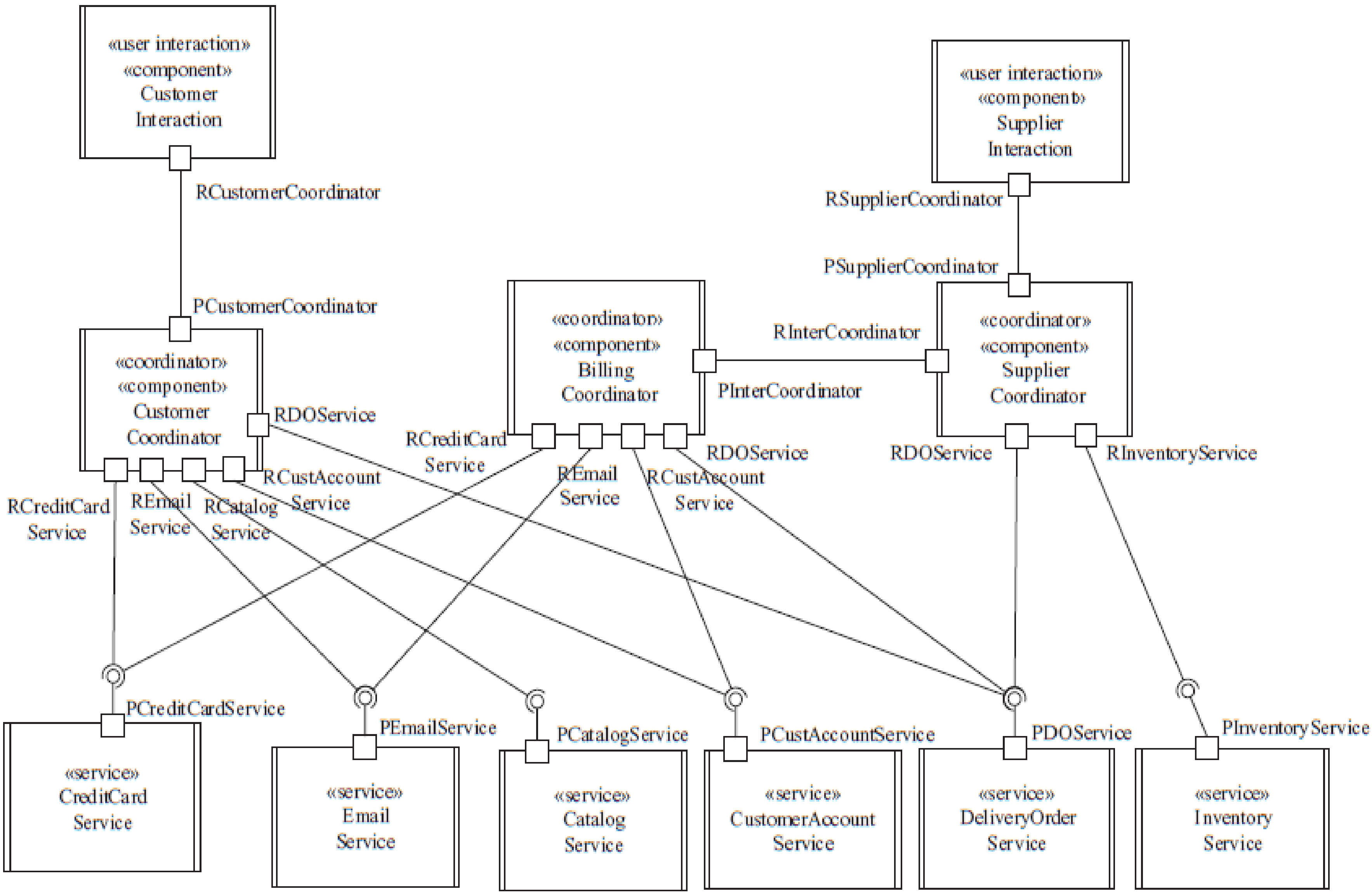


Figure 22.25. Service-oriented software architecture for the Online Shopping System

Service subsystems, Input & User Interface

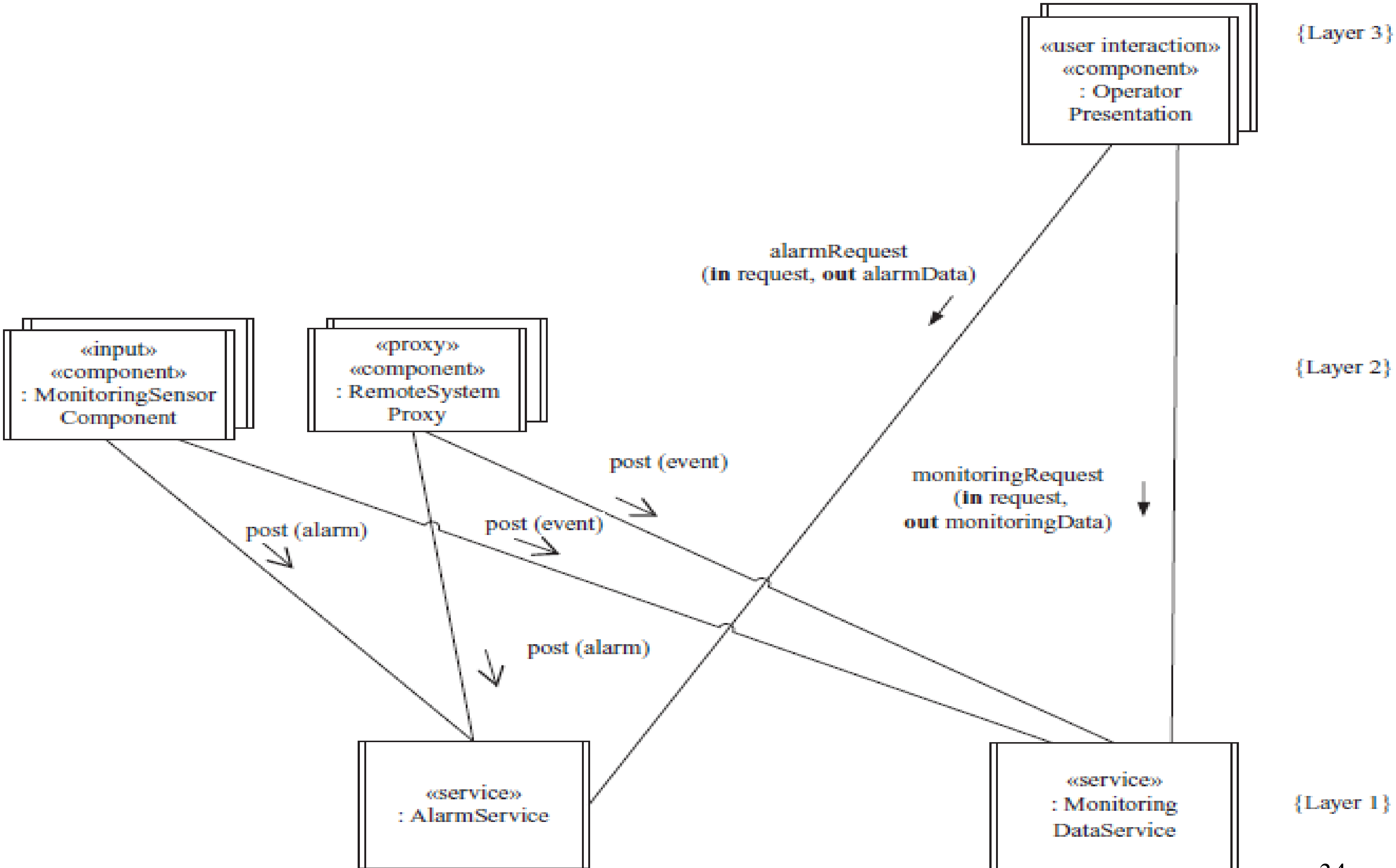


Figure 13.9. Examples of service subsystems

Coordinator, Control, and Interface

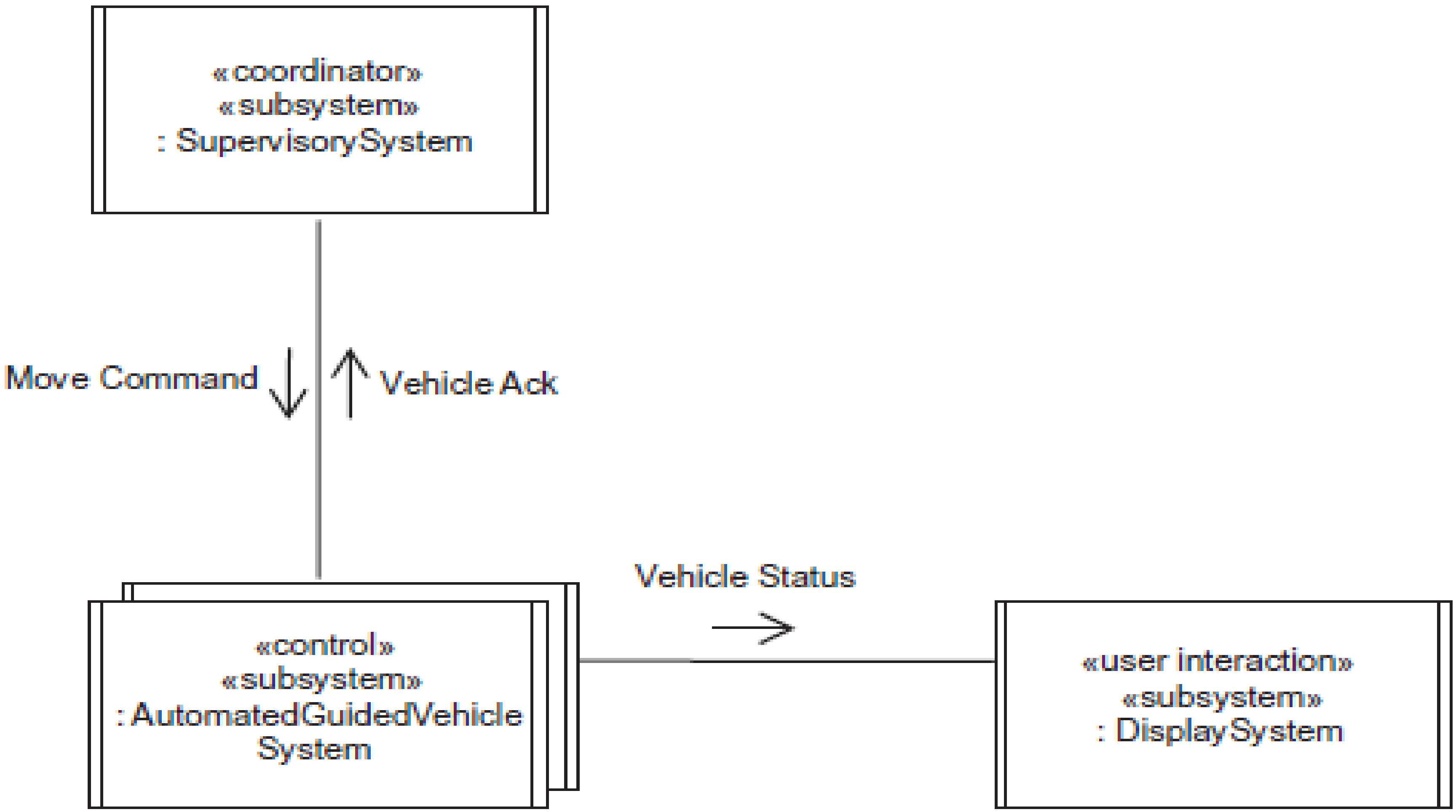


Figure 13.10. Example of control and coordinator subsystems in Factory Automation System

User Interface, Coordinator, Service

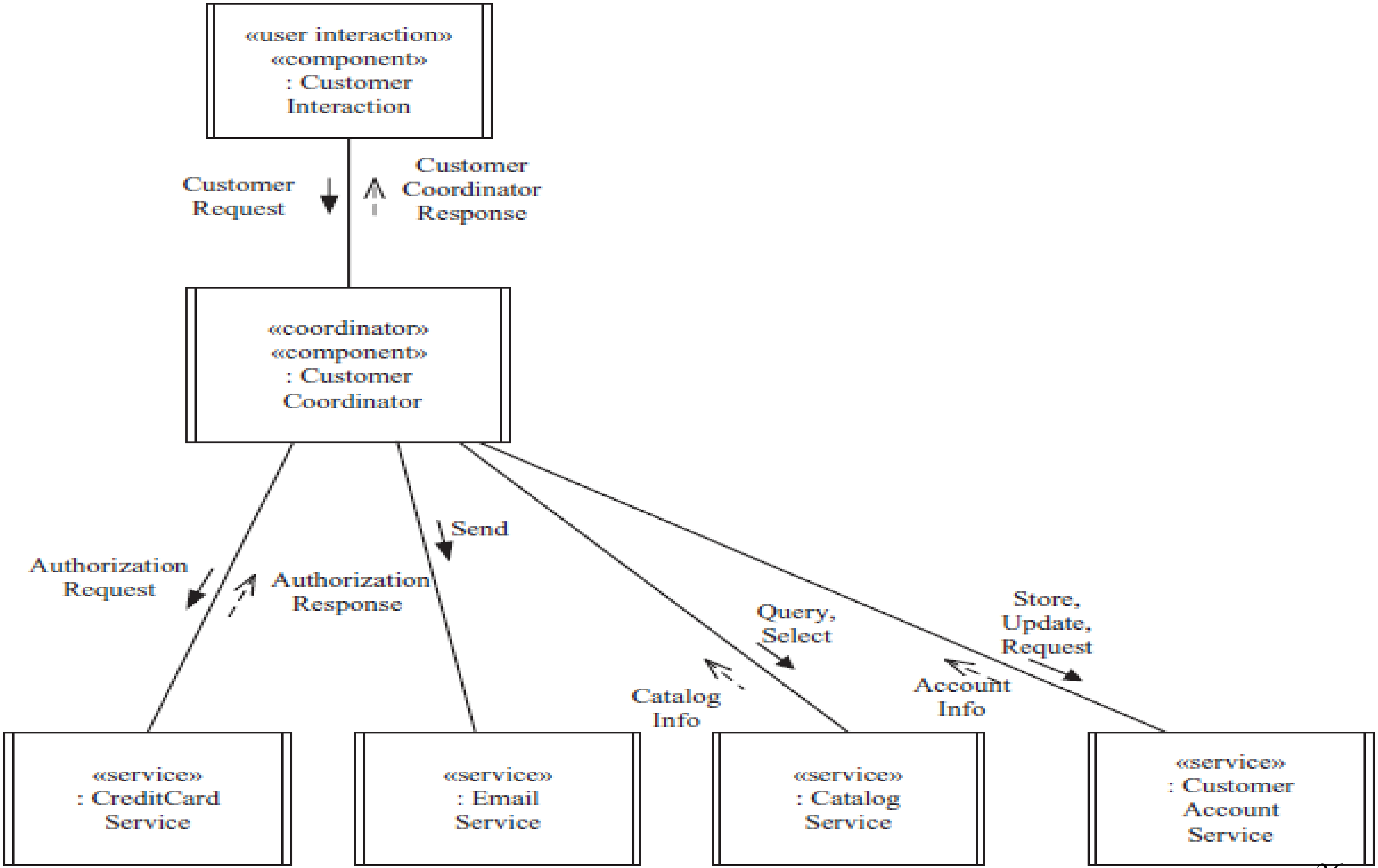


Figure 13.11. Example of coordinator subsystem in service-oriented architectures

Another way of forming subsystems

- **Aggregate** into the same subsystem
  - Objects that participate in the same use case (functional cohesion)
  - Objects that have a large volume of interactions (e,g, Control object & objects it controls) or share common data or file structures (communicational cohesion)
  - Object that execute in the same time (temporal cohesion)

User Interface Subsystem

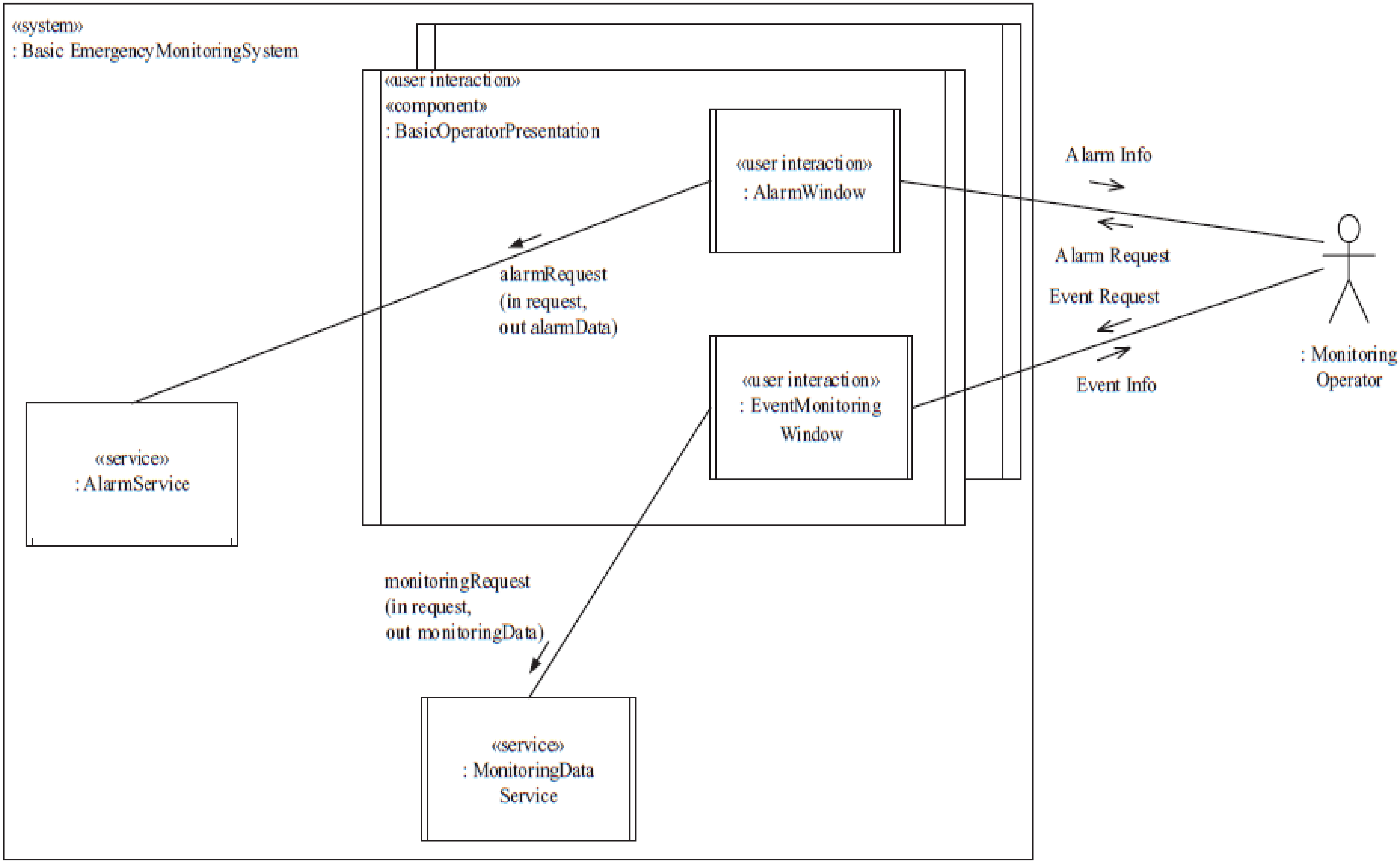


Figure 13.8. Examples of user interaction subsystem with multiple windows

Architecture

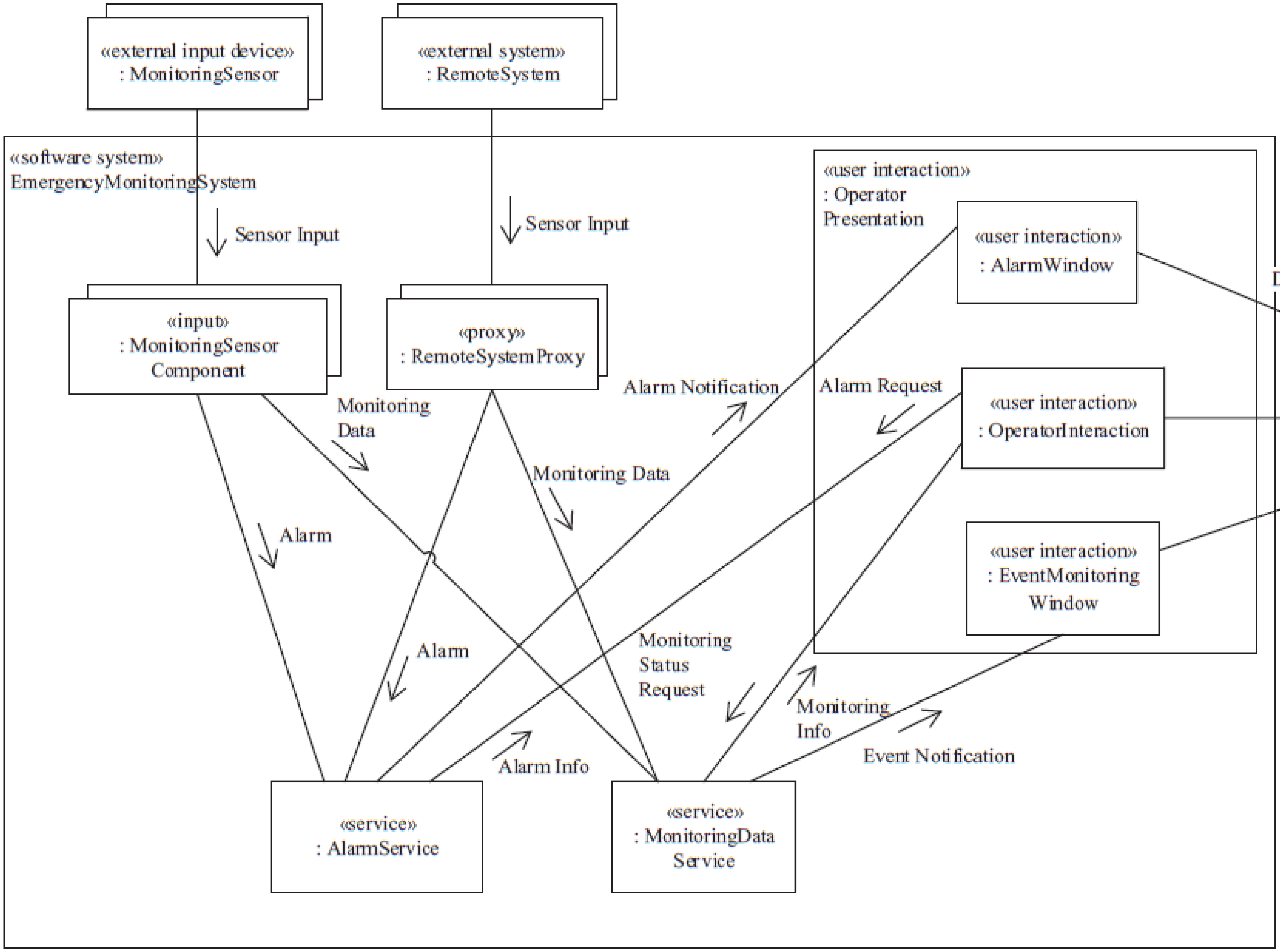


Figure 23.8. Integrated communication diagram for Emergency Monitoring System

Aggregate Control, input, and output of each distributed controller

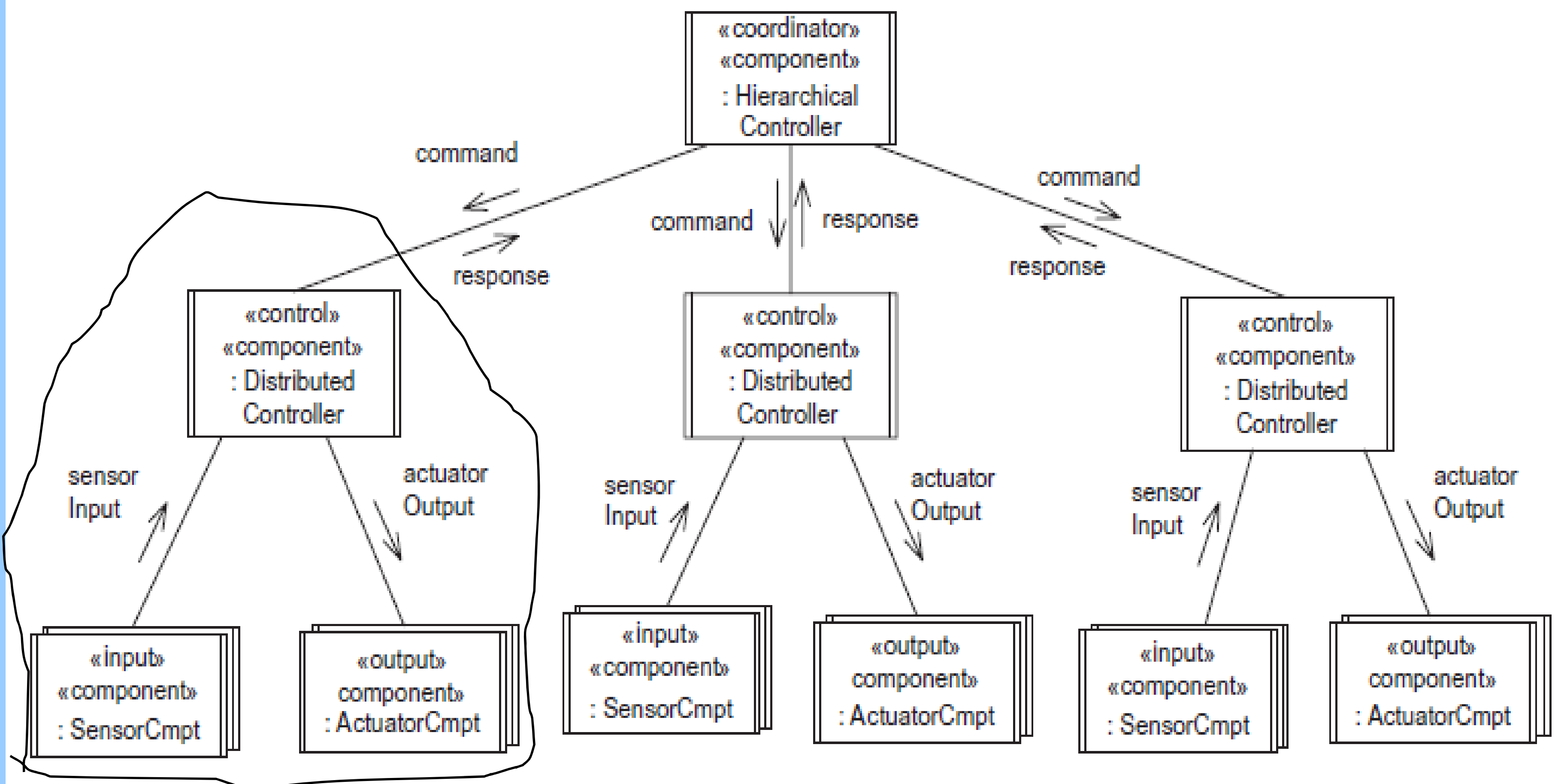
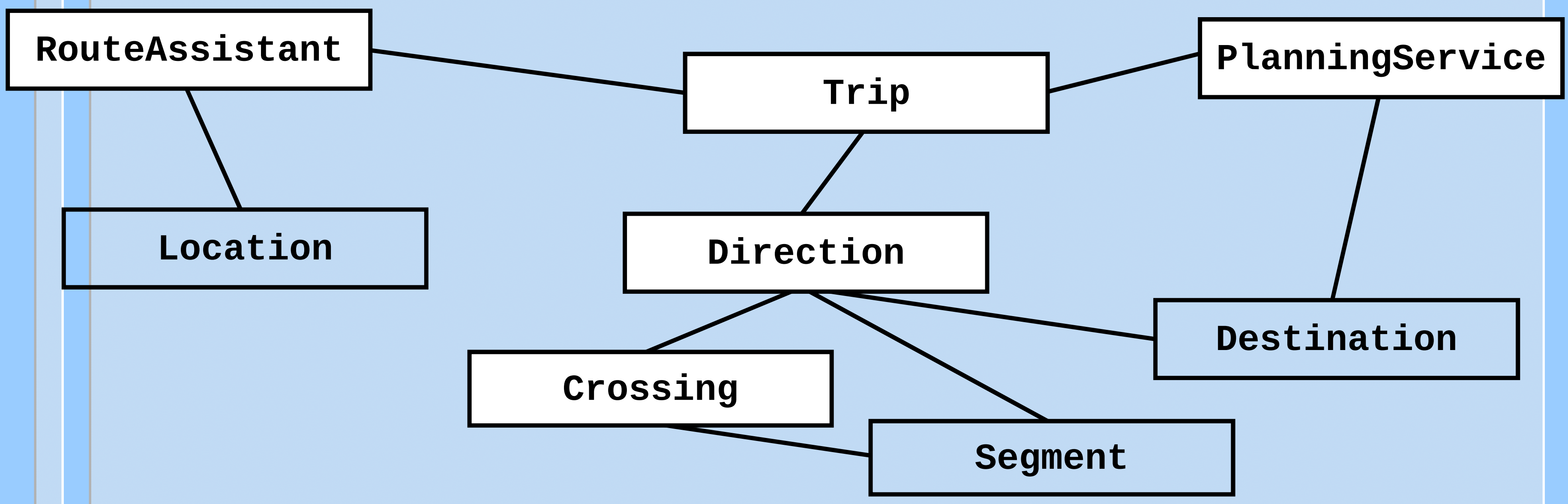


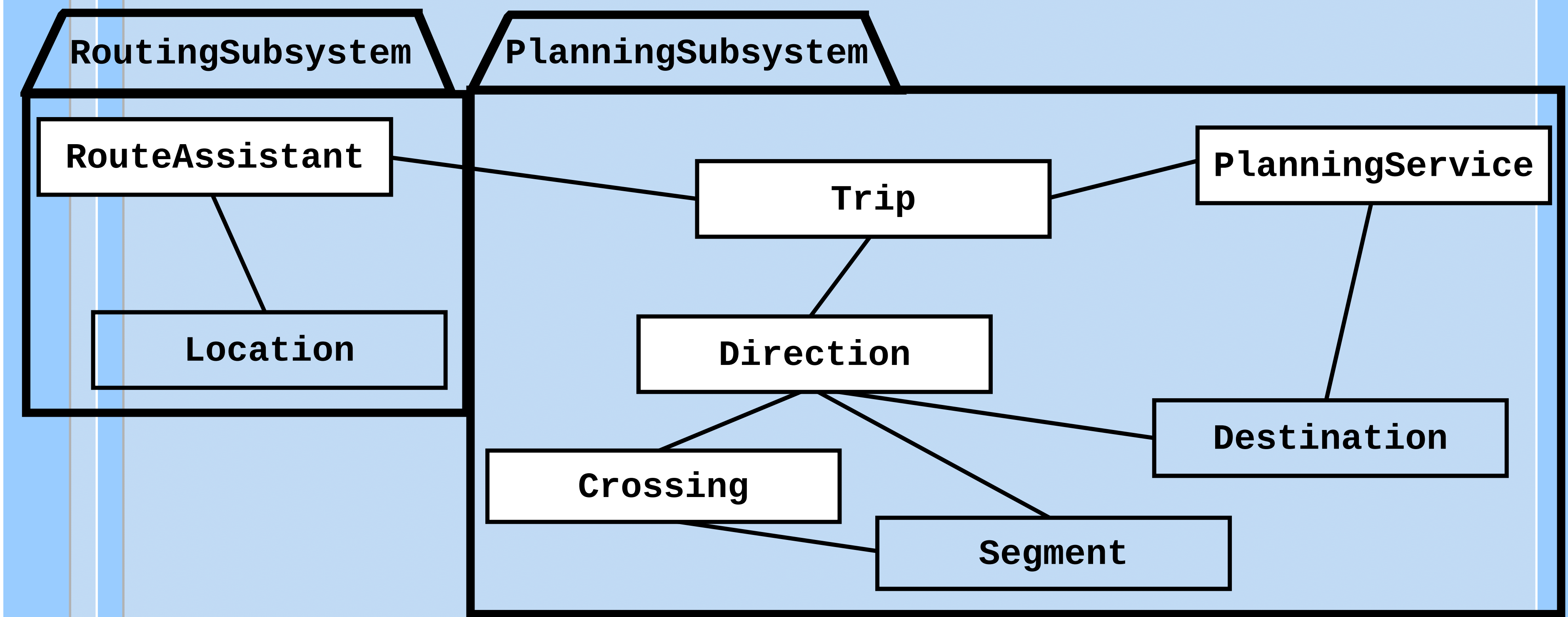
Figure A.4. Hierarchical Control pattern

Example: MyTrip System, uses a Global Positioning System to locate and coordinate a trip for a driver in an automobile software system

The Analysis Class Diagram

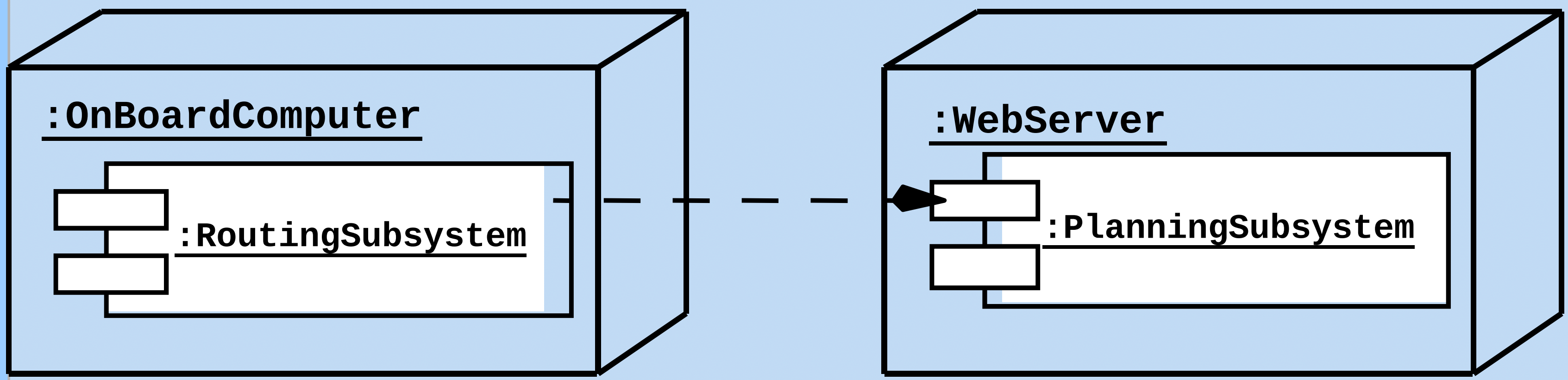


Design Class Diagram
MyTrip Subsystems

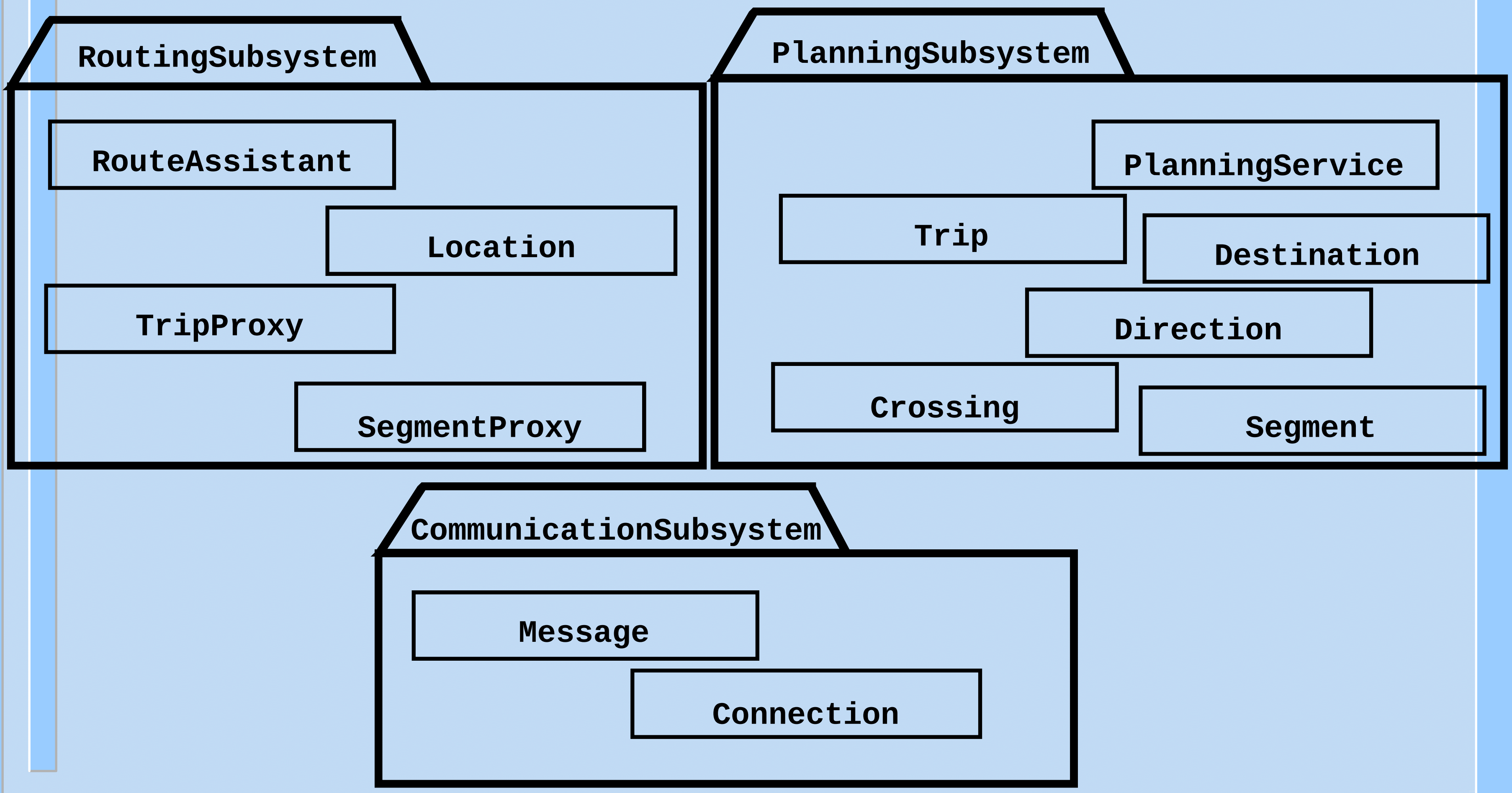


MyTrip Deployment Diagram

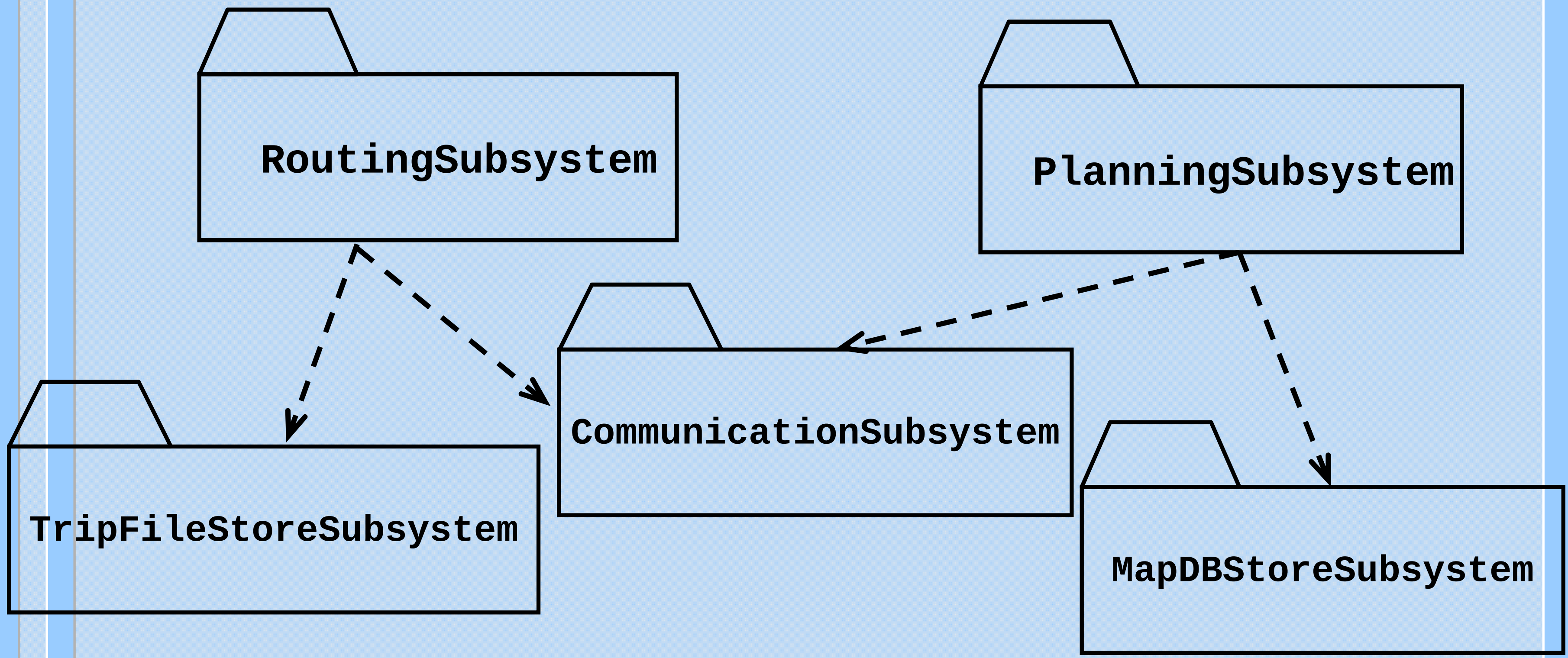
Components must be associated with a processor node in the deployment diagram



New Classes and Subsystems



MyTrip Data Storage



Example: Cruise Control and Monitoring System

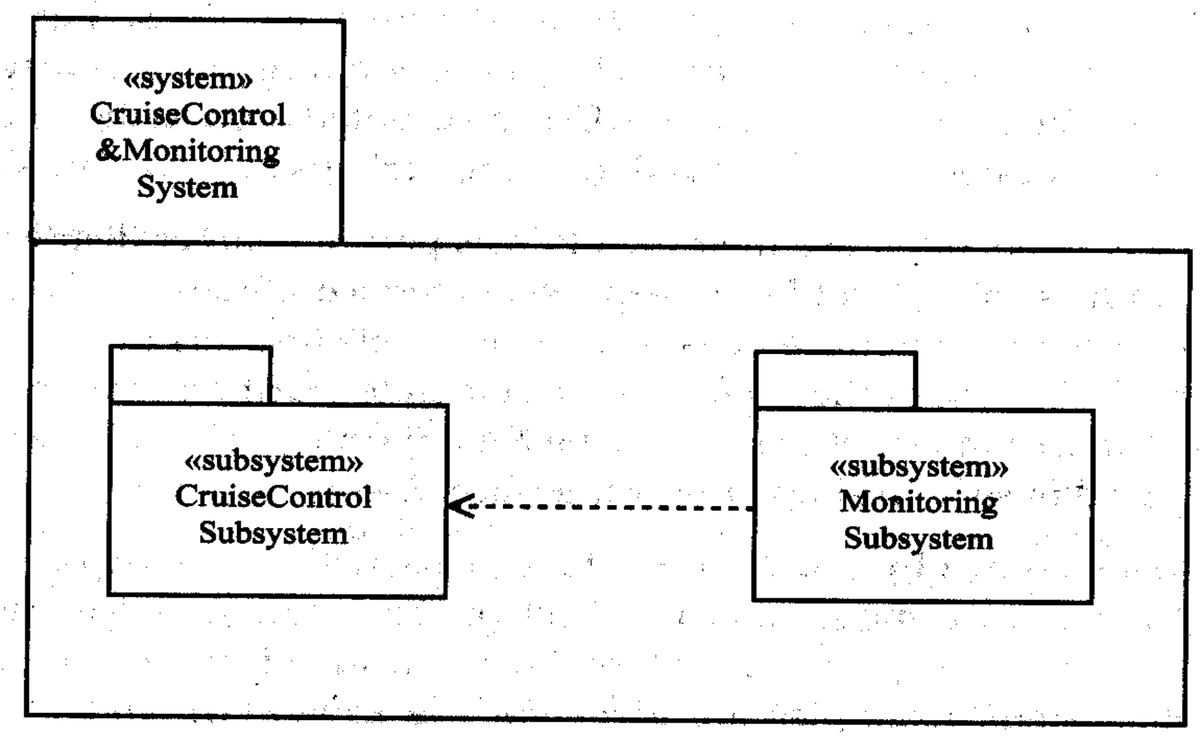


Figure 12.8 *Cruise Control and Monitoring System: major subsystems*

Example: Cruise Control And Monitoring System

Class Diagram of the Cruise Control Subsystem

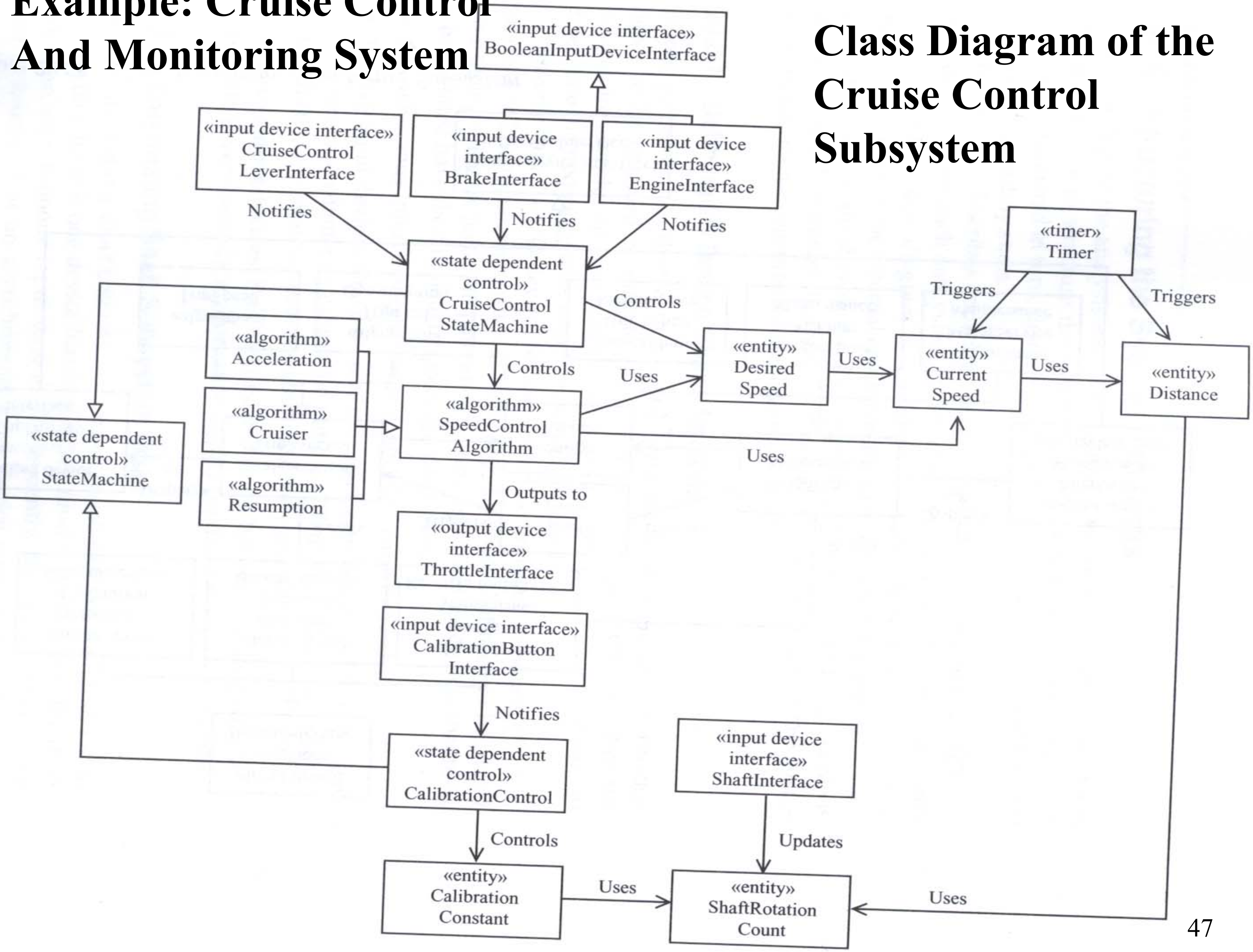


Figure 20.25 *Class diagram for Cruise Control Subsystem*

Example: Cruise Control System; The Monitoring Subsystem

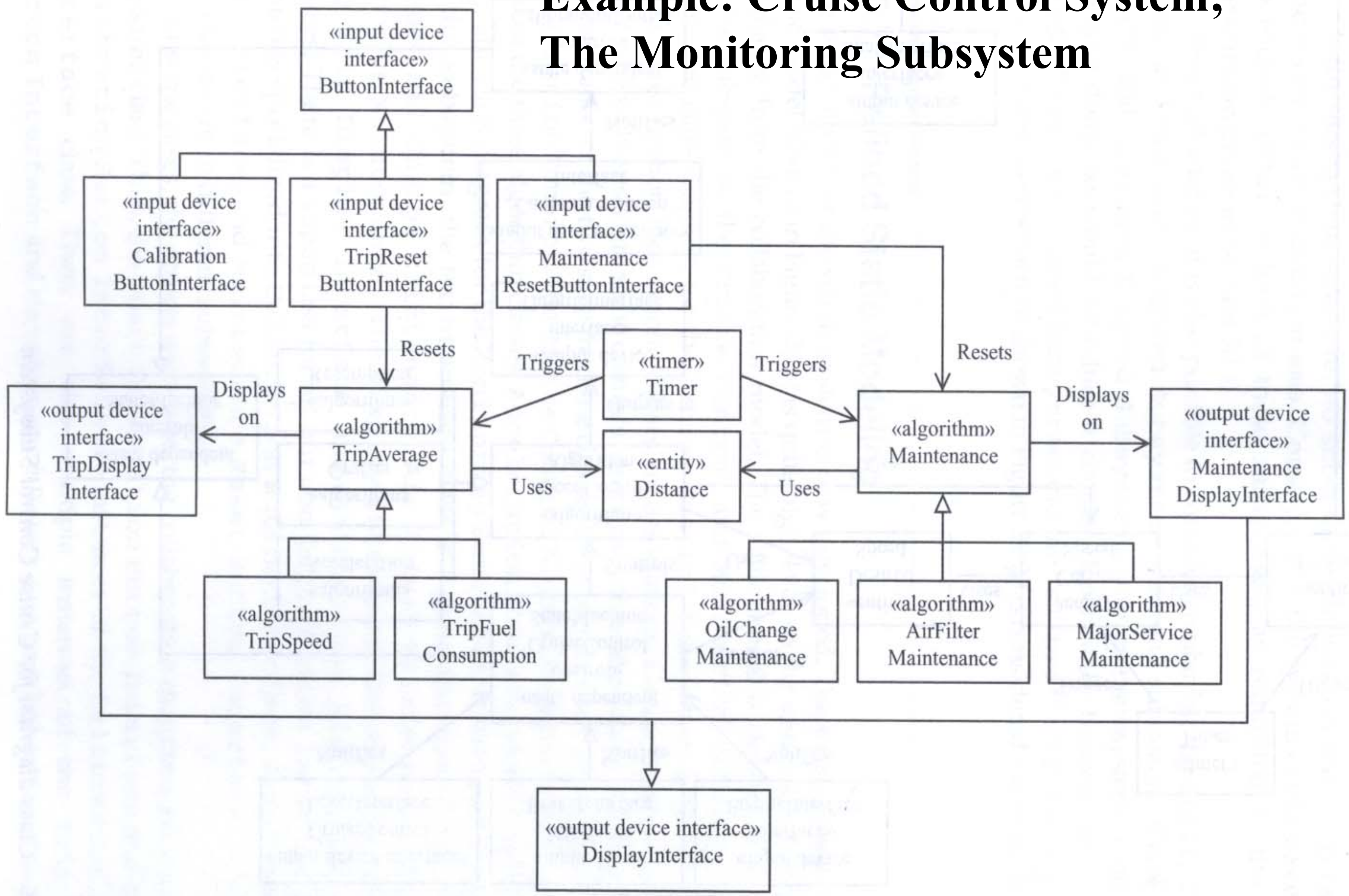


Figure 20.26 *Class diagram for Monitoring Subsystem*

Example: Aggregating classes into a subsystem using temporal cohesion

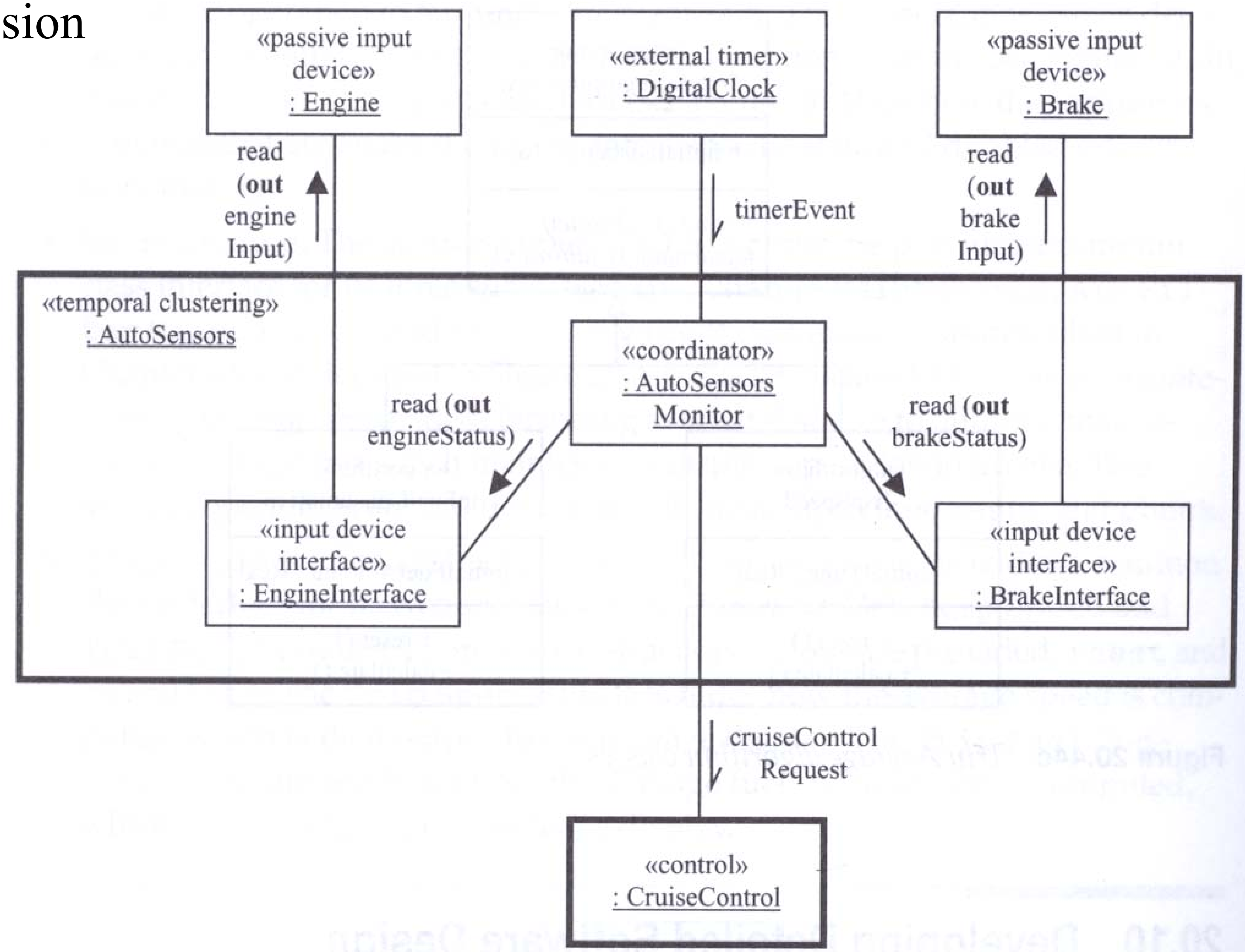


Figure 20.45 *Detailed software design of Auto Sensors task*

Example: aggregating classes
Using functional cohesion

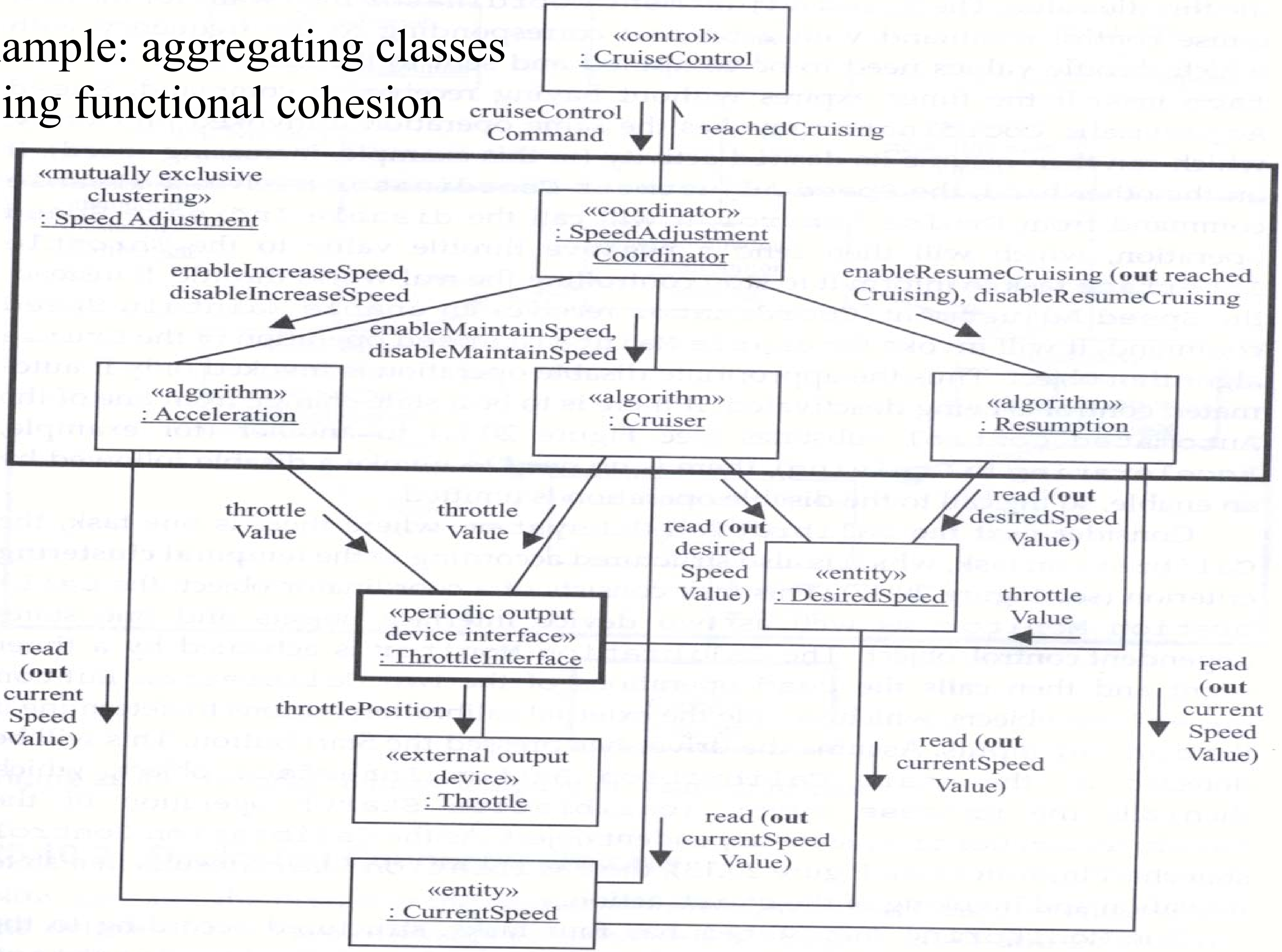


Figure 20.46 *Detailed software design of Speed Adjustment task*

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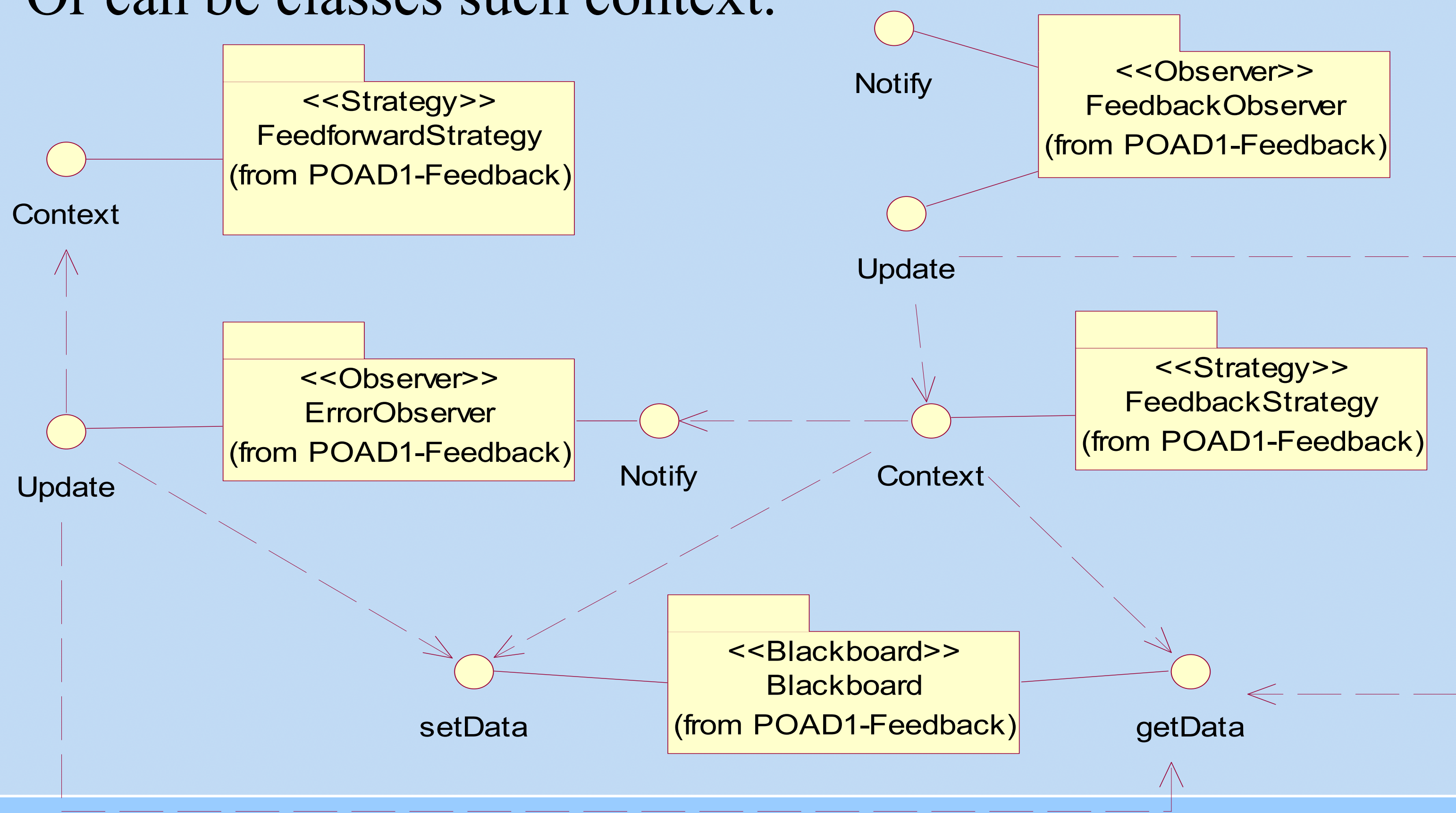
Step 2 - Define Subsystem Interfaces

- The set of public operations forms the *subsystem interface* or A*pplication Programming Interface* (API)
- Includes operations and also their parameters, types, and return values
- Operation *contracts* are also defined (pre- and post-conditions) and accounted for by client subsystems – they can be considered part of the API

Subsystem Interfaces

Interfaces can be methods such as Notify, update,
Or can be classes such context.



Internal and External Interfaces (Informal Notation)

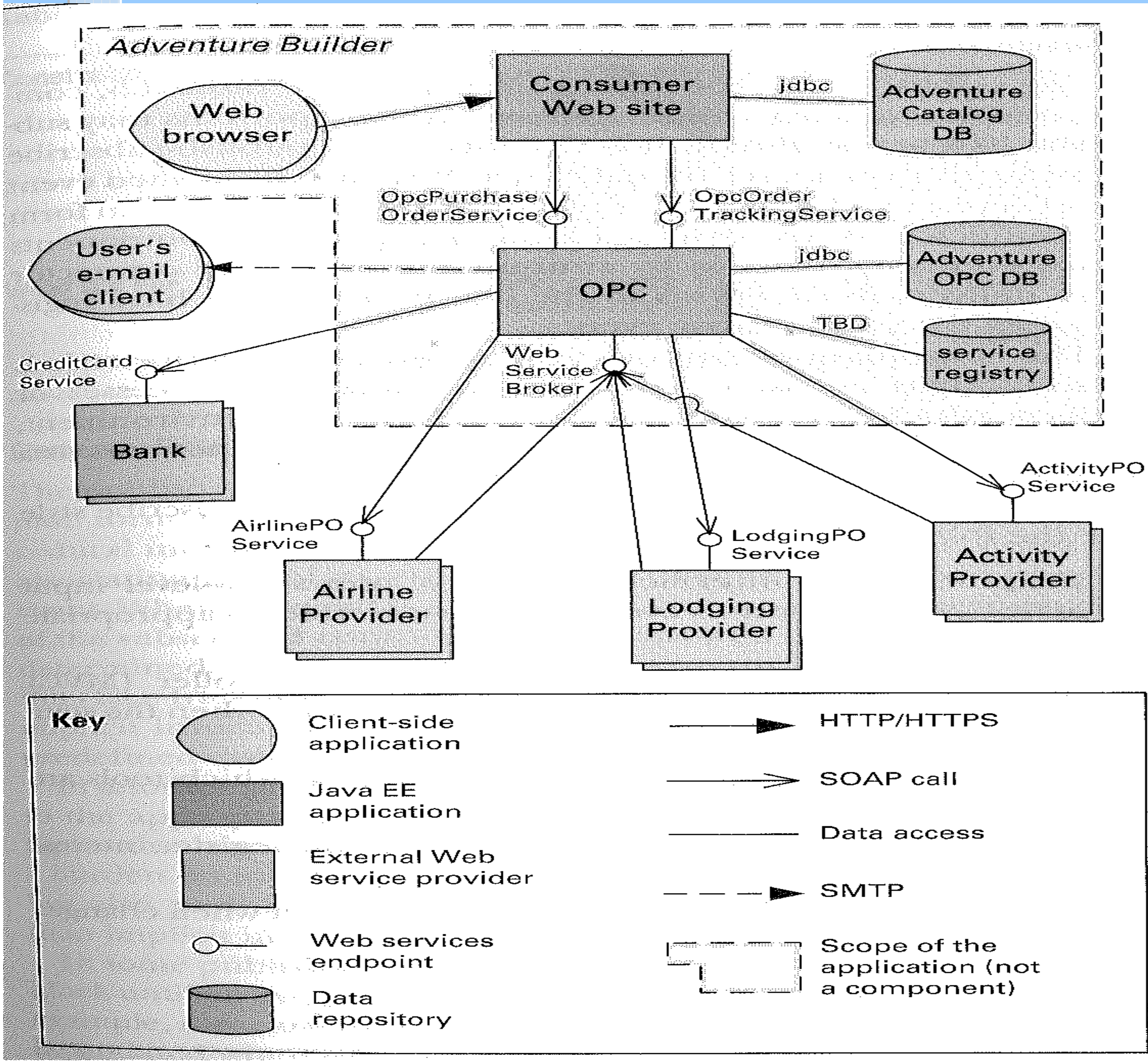


Figure 4.5
Diagram of the SOA view for the Adventure Builder system. The OPC (Order Processing Center) component coordinates the interaction with internal and external service consumers and providers

Client-Server Interfaces (Informal Notation)

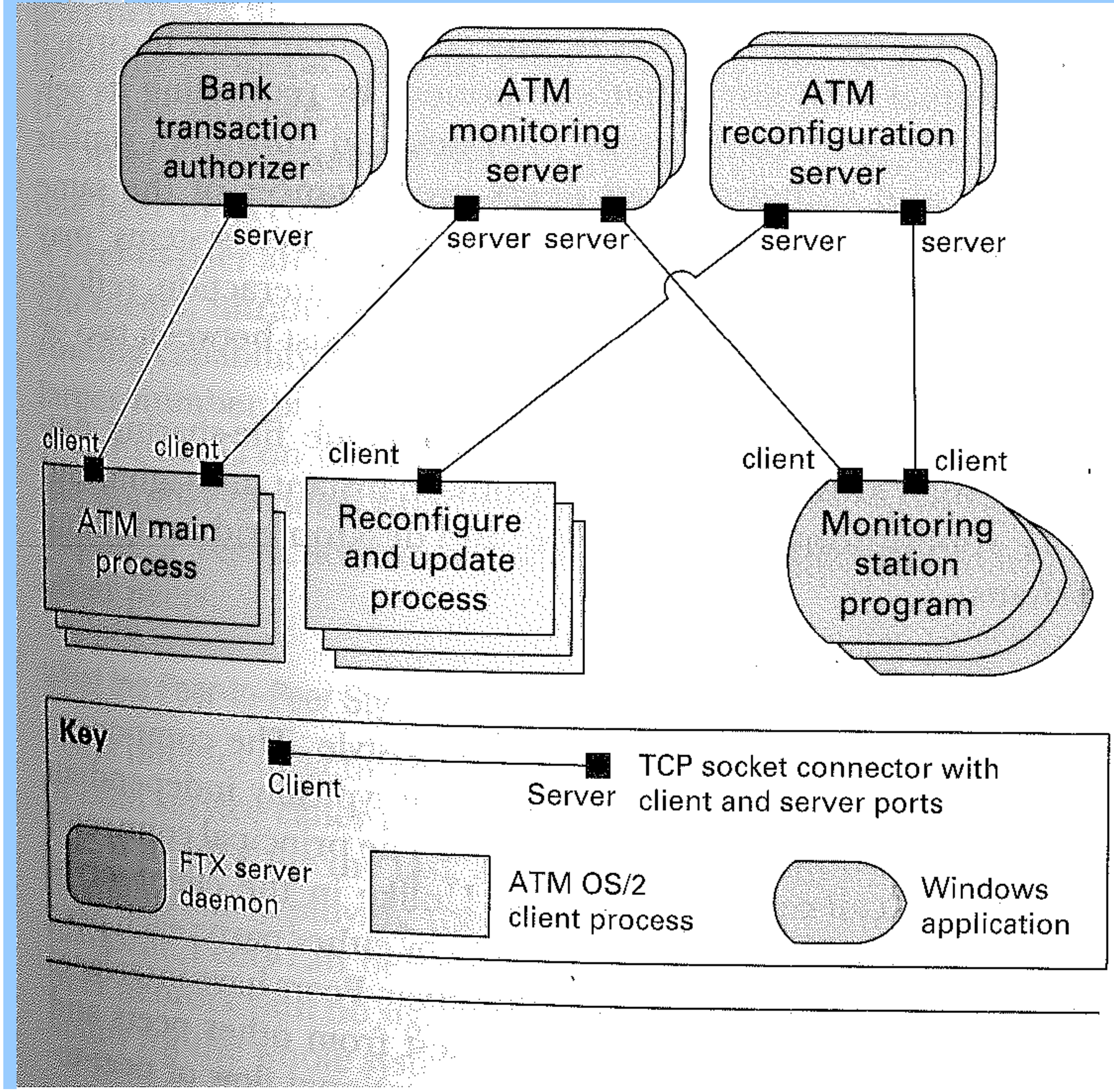


Figure 4.3
Client-server architecture of an ATM banking system. The ATM `main process` sends requests to `Bank transaction authorizer` corresponding to user operations (such as deposit, withdrawal). It also sends messages to `ATM monitoring server` informing the overall status of the ATM (devices, sensors, and supplies). The `Reconfigure and update process component` sends requests to `ATM reconfiguration server` to find out if a reconfiguration command was issued for that particular ATM. Reconfiguration of an ATM (for example, enabling or disabling a menu option) and data updates are issued by bank personnel using the `Monitoring station program`. `Monitoring station program` also sends periodic requests to `ATM monitoring server` to retrieve the status of the

Client-Server Interfaces (Informal Notation)

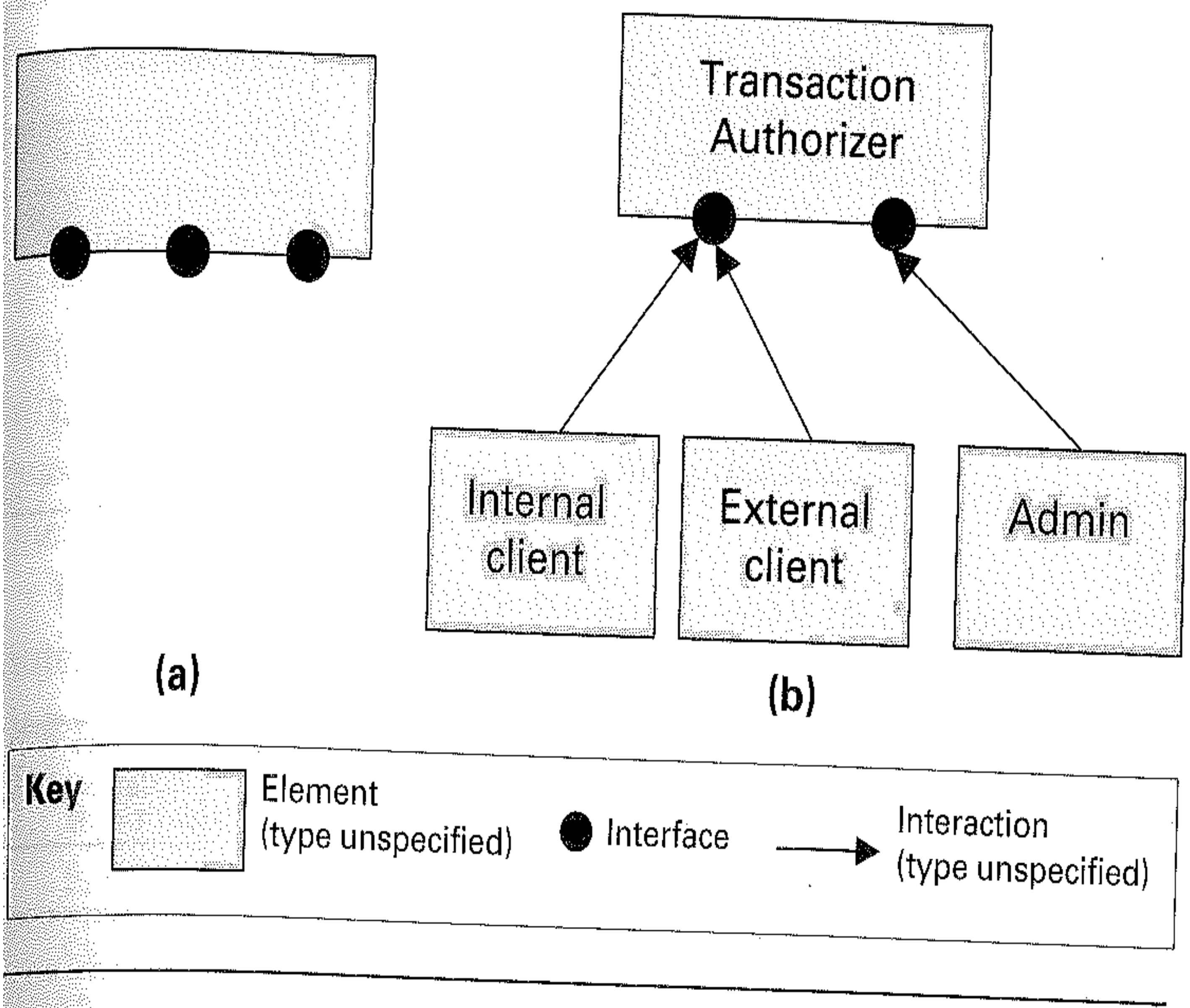
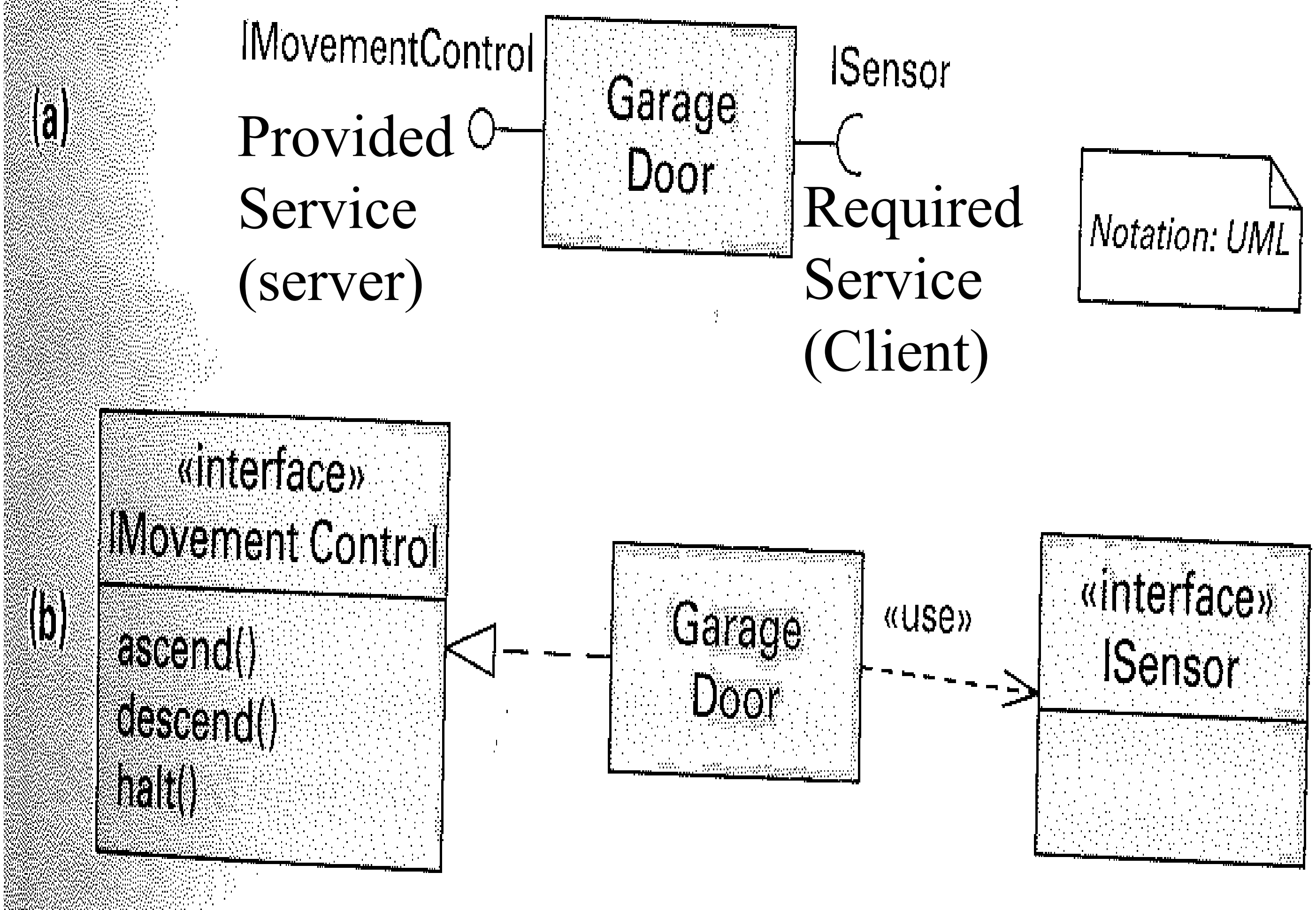


Figure 7.1
Graphical notations for interfaces typically show a symbol on the boundary of the icon for an element. Lines connecting interface symbols denote that the interface exists between the connected elements. Graphical notations like this can show only the existence of an interface, not its definition. (a) An element with multiple interfaces. For elements with a single interface, the interface symbol is often omitted. (b) Multiple actors at an interface. Internal client and External client both interact with Transaction Authorizer via the same interface. This interface is provided by Transaction Authorizer and required by both Internal client and External client.

Interfaces in UML Notation)

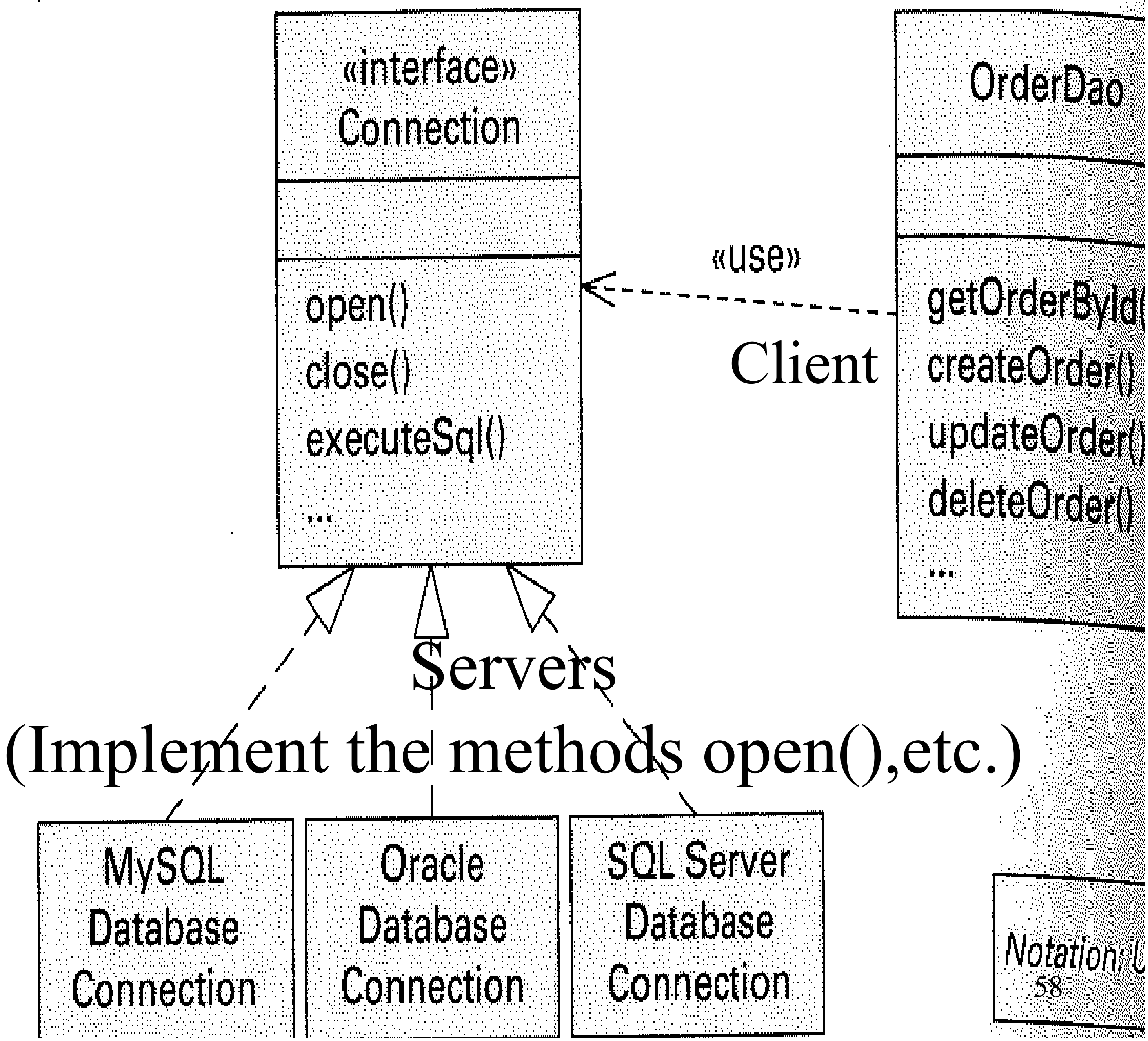


(a) And (b) are equivalent

Figure 7.2
UML uses a lollipop to denote a provided interface, which can be appended to classes, components, and packages. Required interfaces are represented with the socket symbol, which is also appended to classes and other types of elements. UML also allows a class symbol to be stereotyped as an interface; a dashed line with a closed, hollow arrowhead shows that an element realizes an interface. The operations compartment of the class symbol can be annotated with the interface's signature infor-

Figure 7.3

An interface can be shown separately from any element that realizes it, thus emphasizing the interchangeability of element implementations. `OrderDao` (and other classes not shown) require an object that implements a database connection, which is represented by the `Connection` interface. Many elements realize this interface, representing the interchangeable alternatives of database connection implementations.



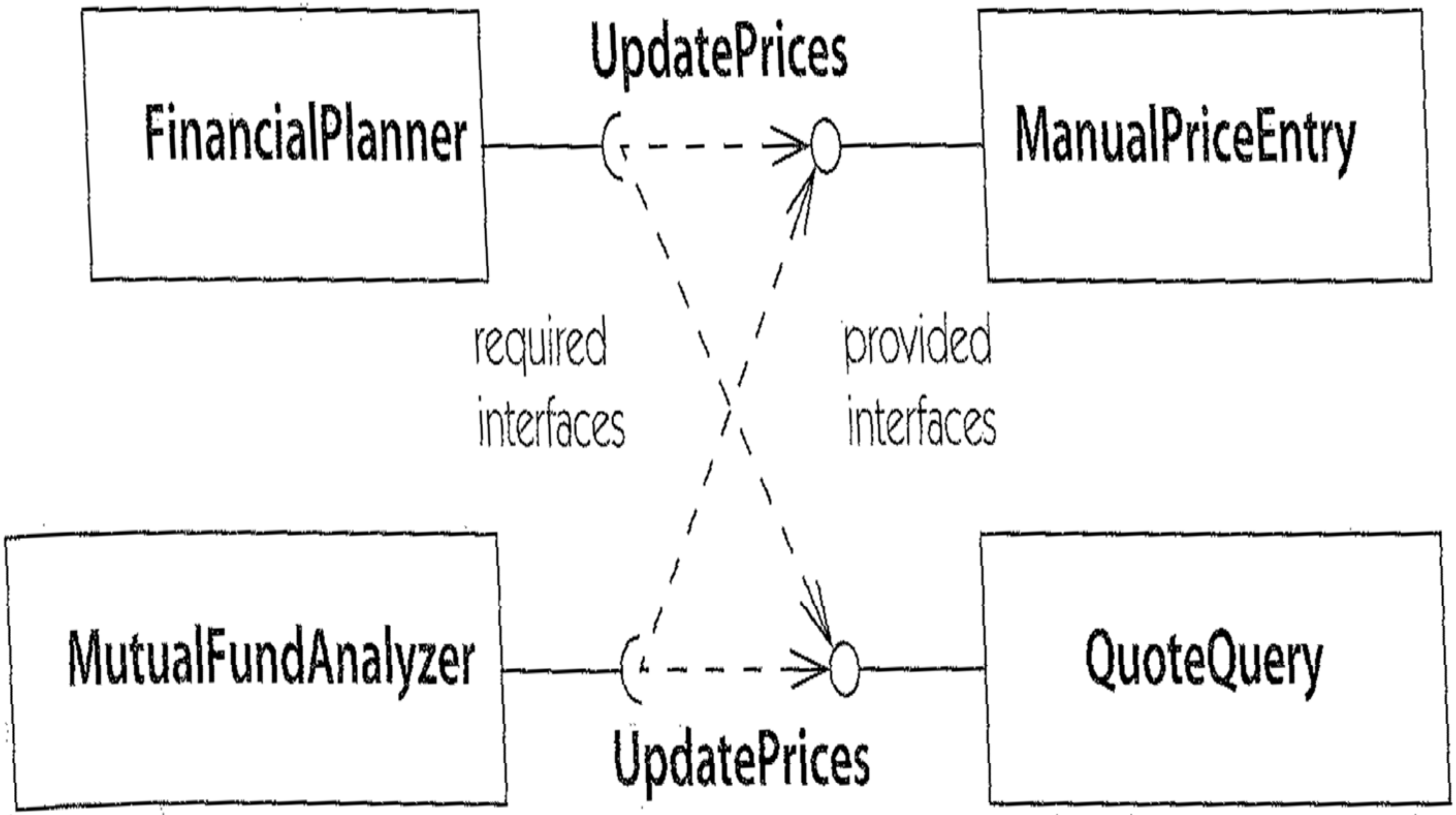
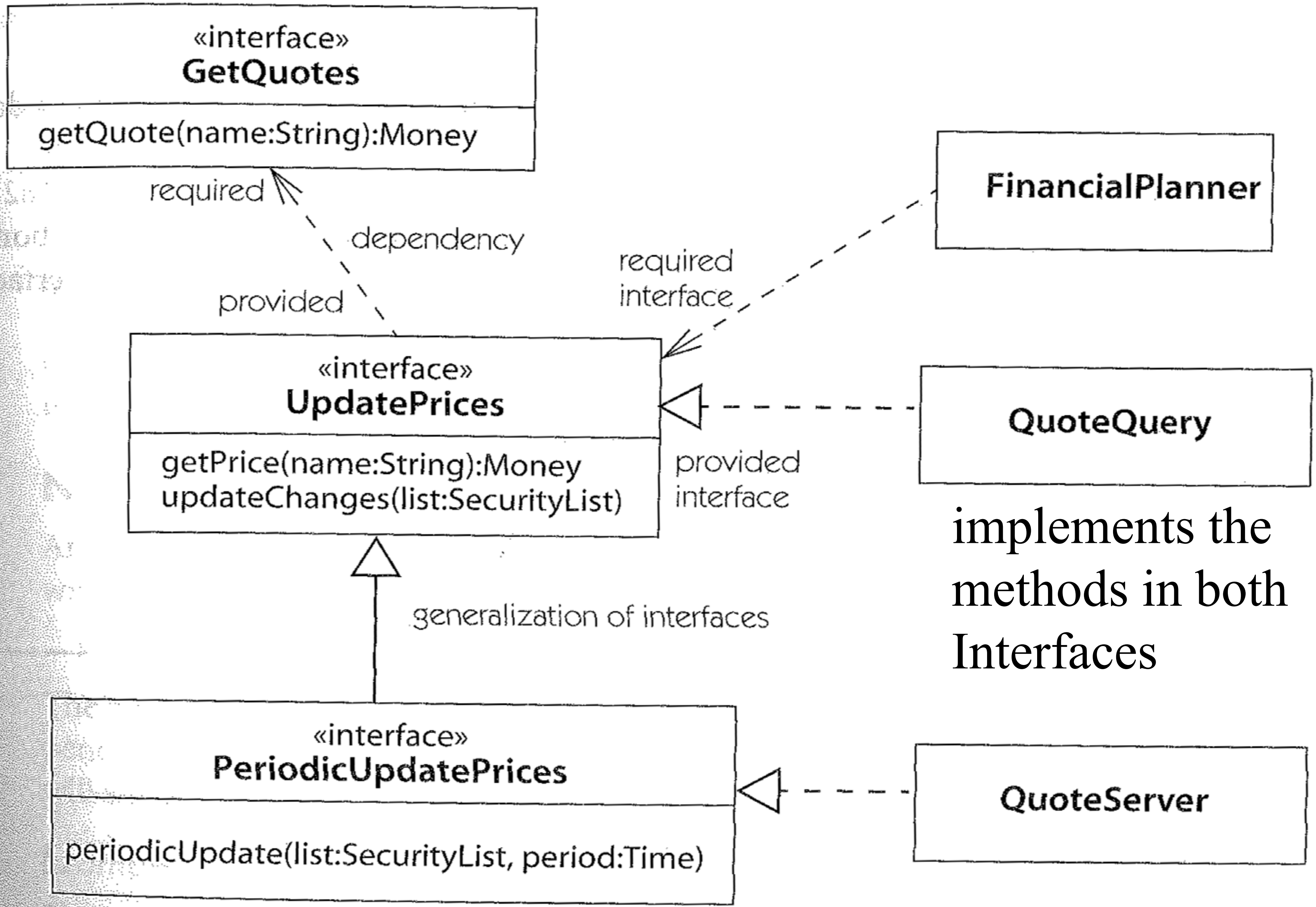


Figure 14-160. *Interface suppliers and clients*



implements the methods in both Interfaces

Figure 14-161. *Full interface notation*

Example: A Digital Sound Recorder From Requirements-to-Analysis-to-Design

- The main function of the DSR is to record and playback speech.
- The messages are recorded using a built-in microphone and they are stored in a digital memory.
- The DSR contains an alarm clock with a calendar. The user can set a daily alarm. The alarm beeps until the user presses a key, or after 60 seconds.

Digital Sound Recorder:A Complete Example From Requirements-to-Analysis-to-Design

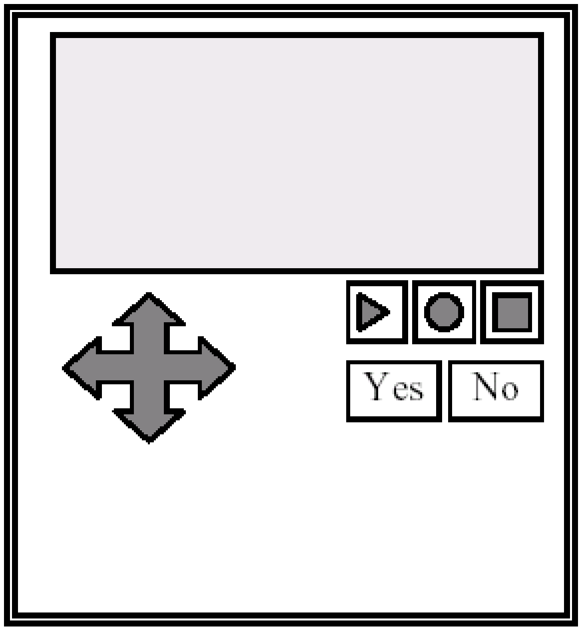


Figure 2.1: External appearance

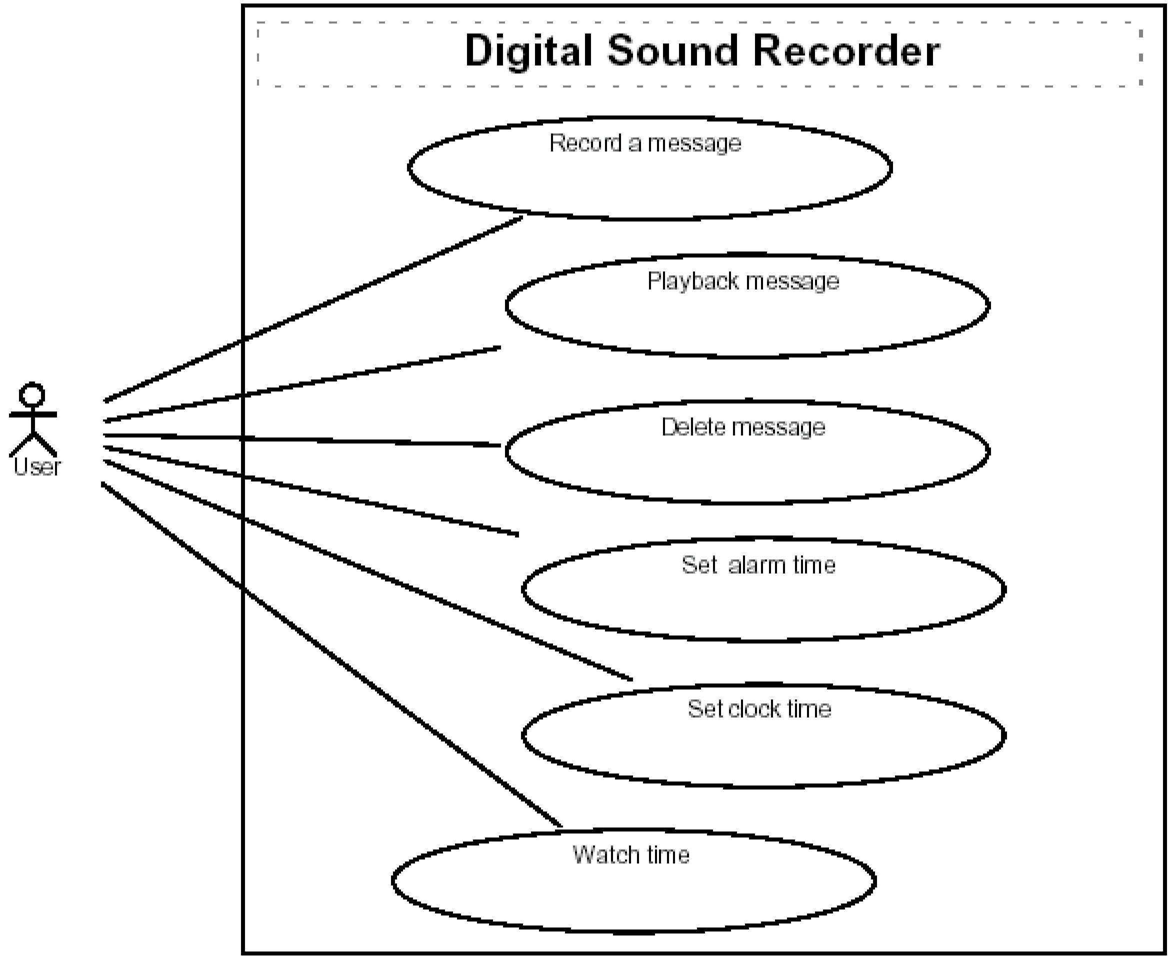


Figure 2.3: Use Case diagram

Digital Sound Recorder: A Complete Example

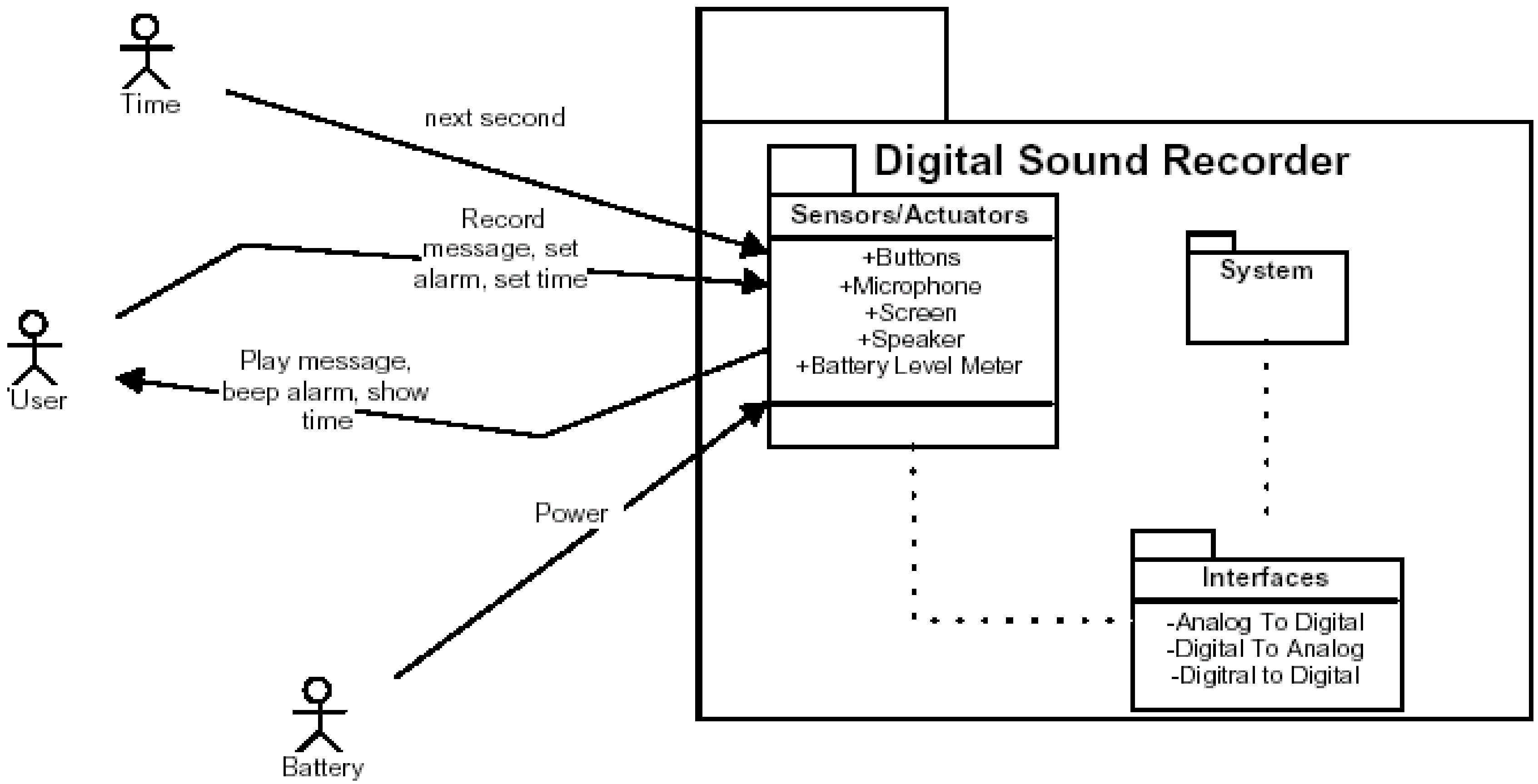


Figure 2.2: Context-Level diagram

Digital Sound Recorder: A Complete Example

System Sequence Diagram

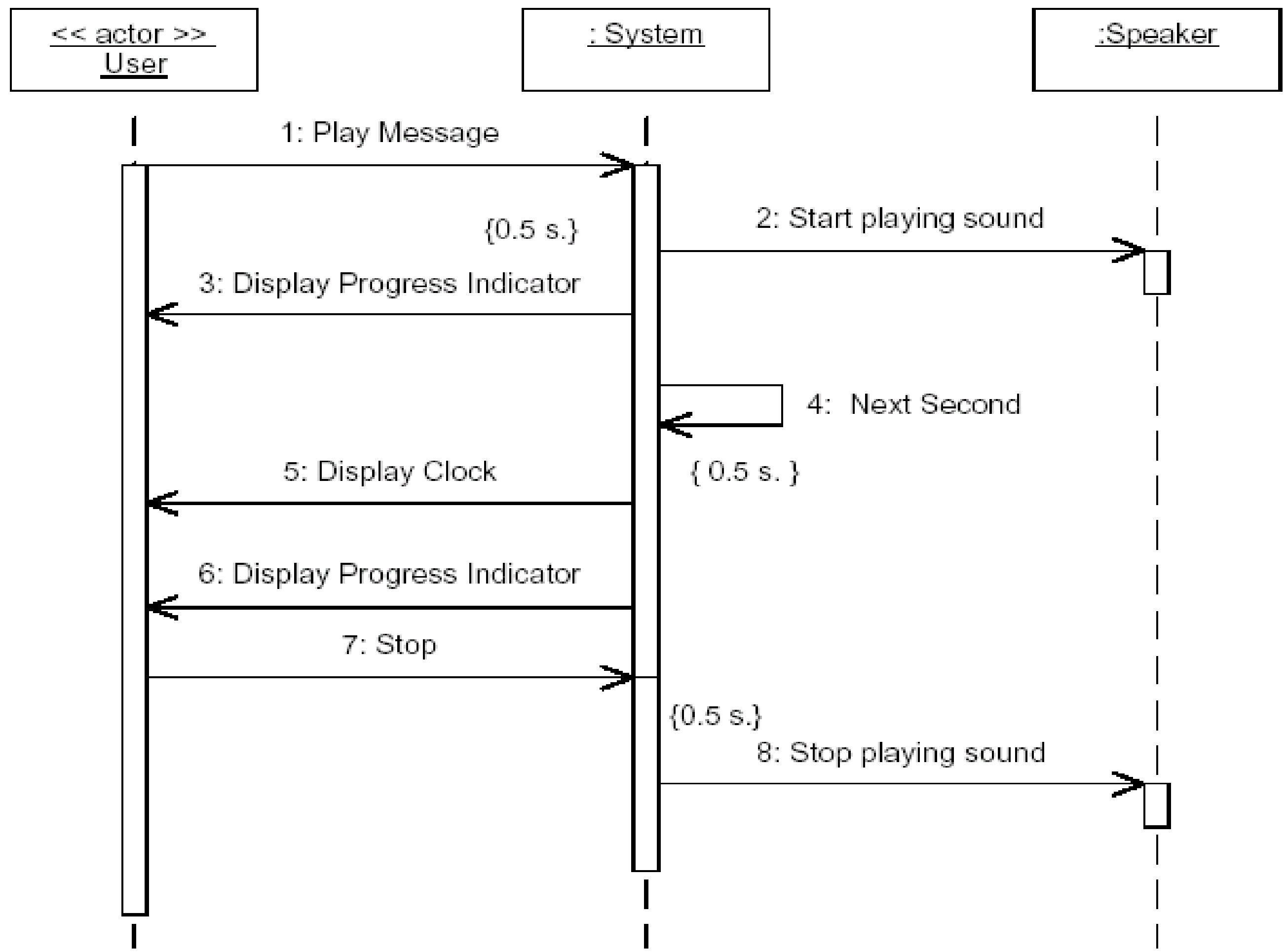


Figure 2.4: Playing message scenario

Digital Sound Recorder: A Complete Example

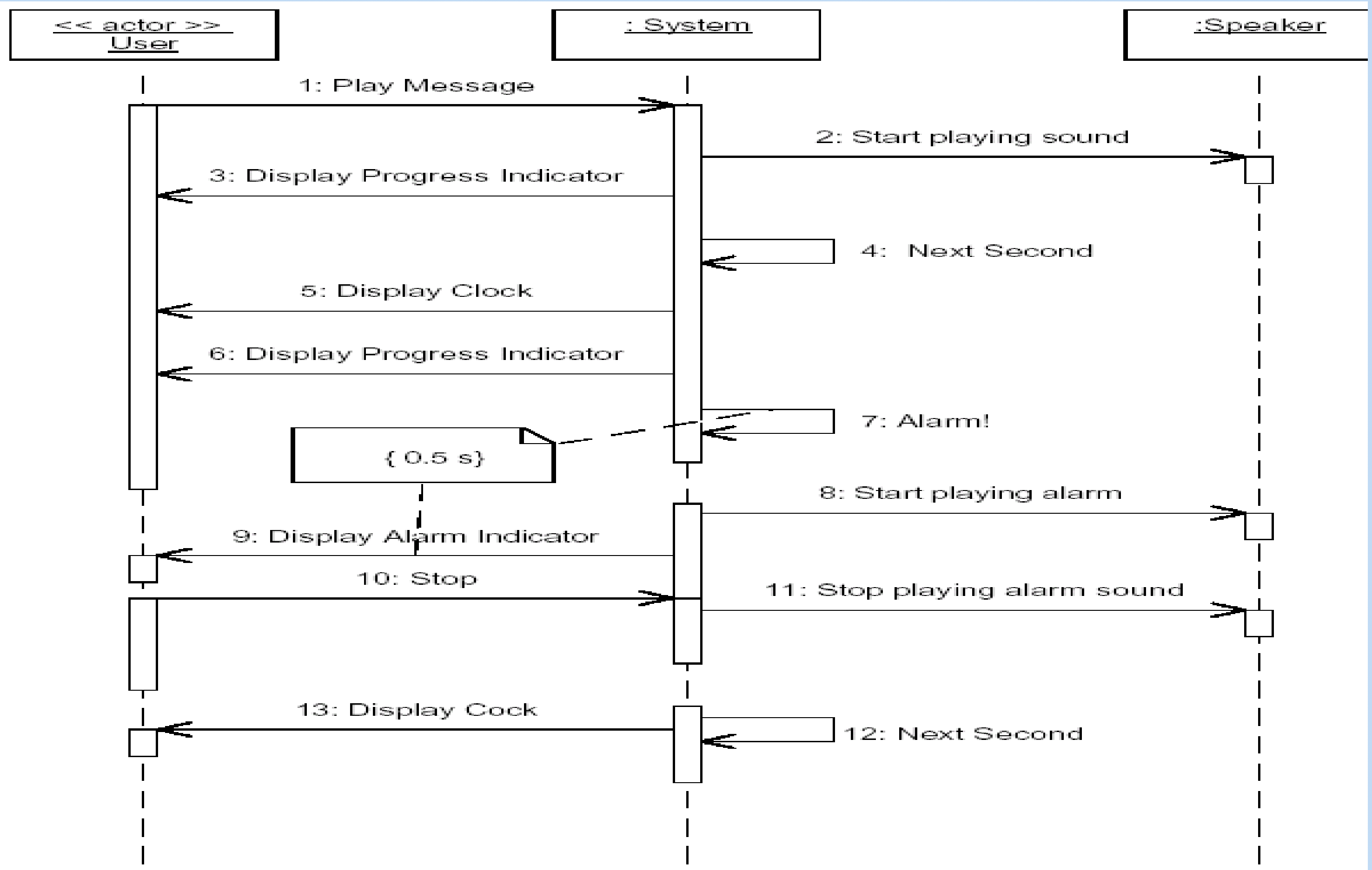


Figure 2.5: Alarm while playing scenario

Digital Sound Recorder: A Complete Example

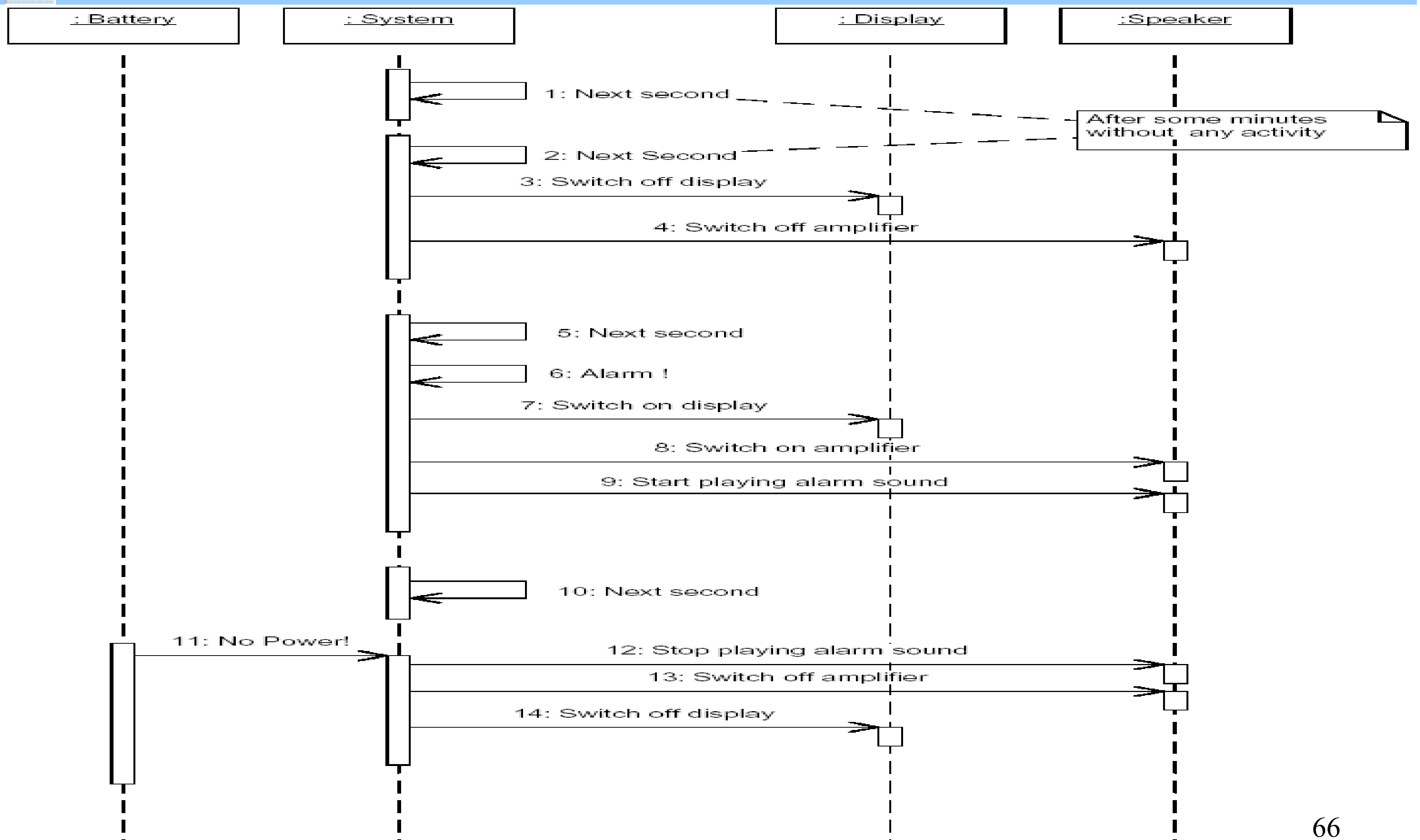


Figure 2.6: Entering and exiting stand-by mode scenario

Digital Sound Recorder: A Complete Example

Analysis
Class Diagram

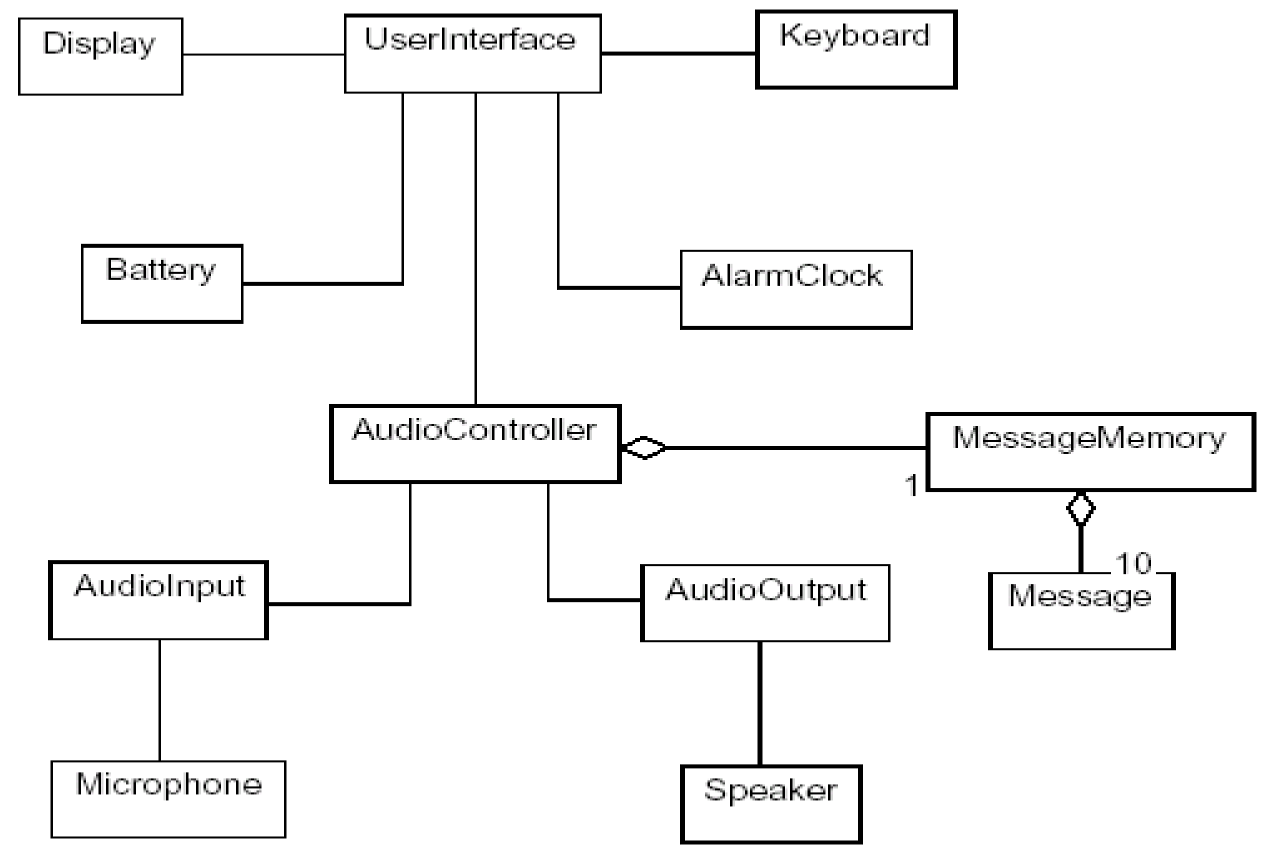


Figure 3.2: Sound Recorder class diagram

Analysis Sequence Diagram Help find operations of classes during design

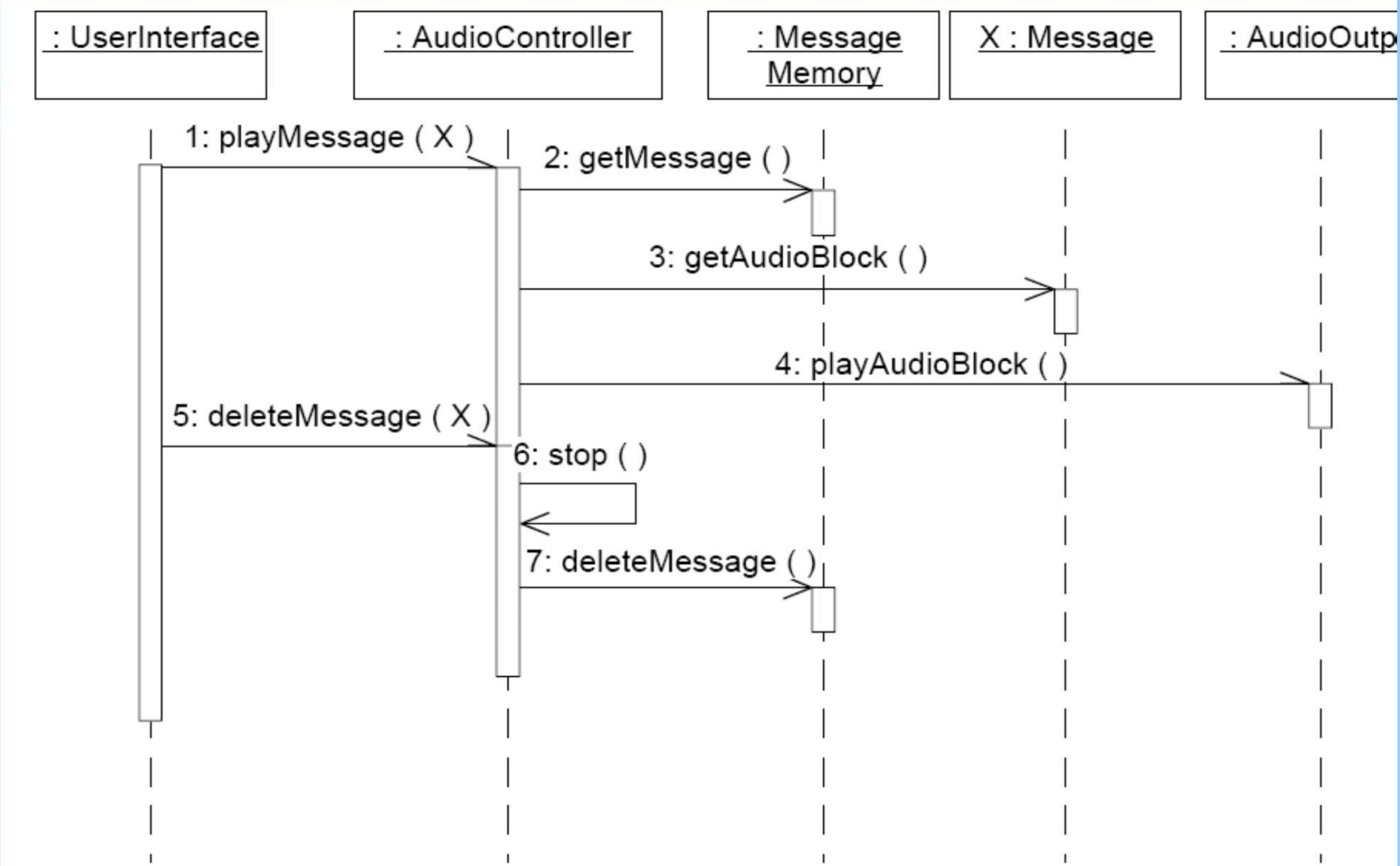


Figure 3.8: Deleting a message while playing it

Digital Sound Recorder: A Complete Example

Design Class Diagram: Designing The Subsystems,

The names of subsystems Should be improved

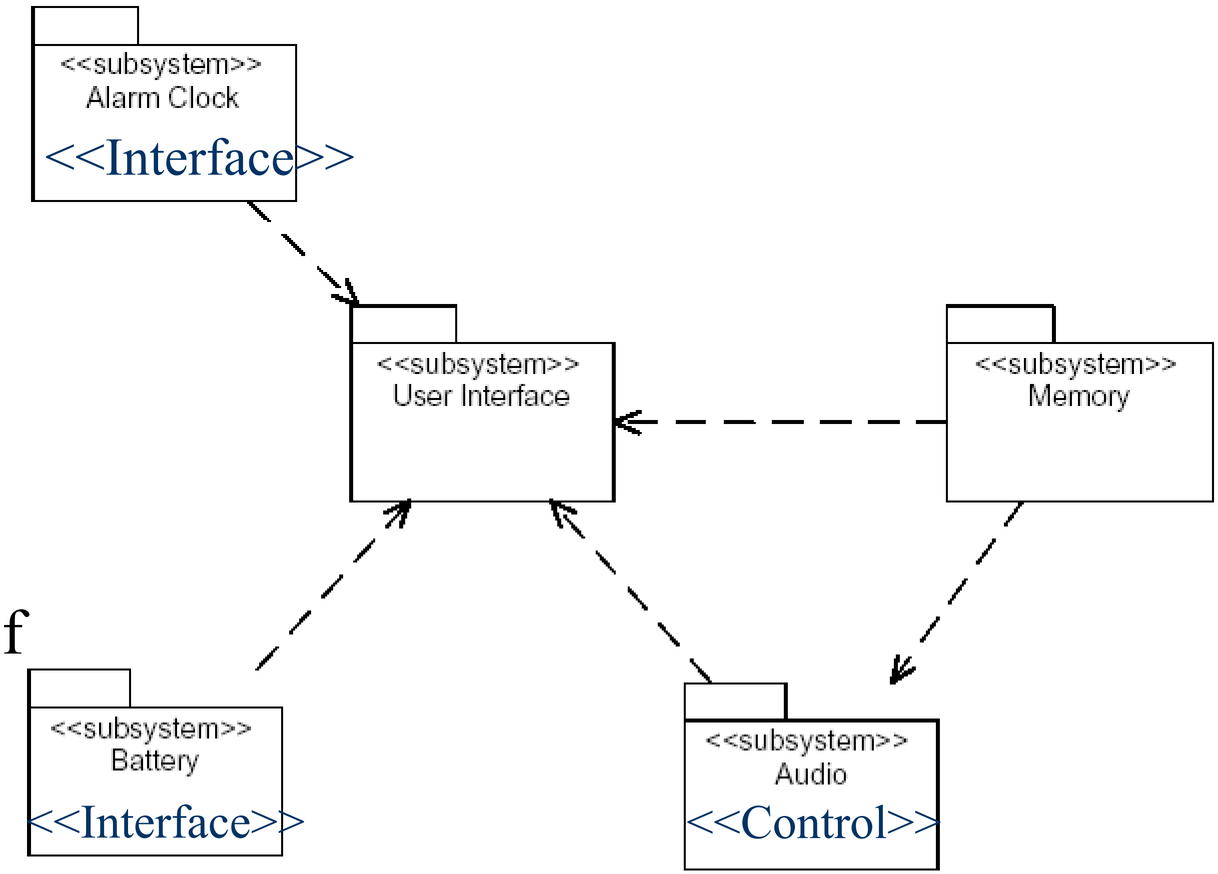


Figure 3.3: Subsystems in the sound recorder

Digital Sound Recorder: A Complete Example

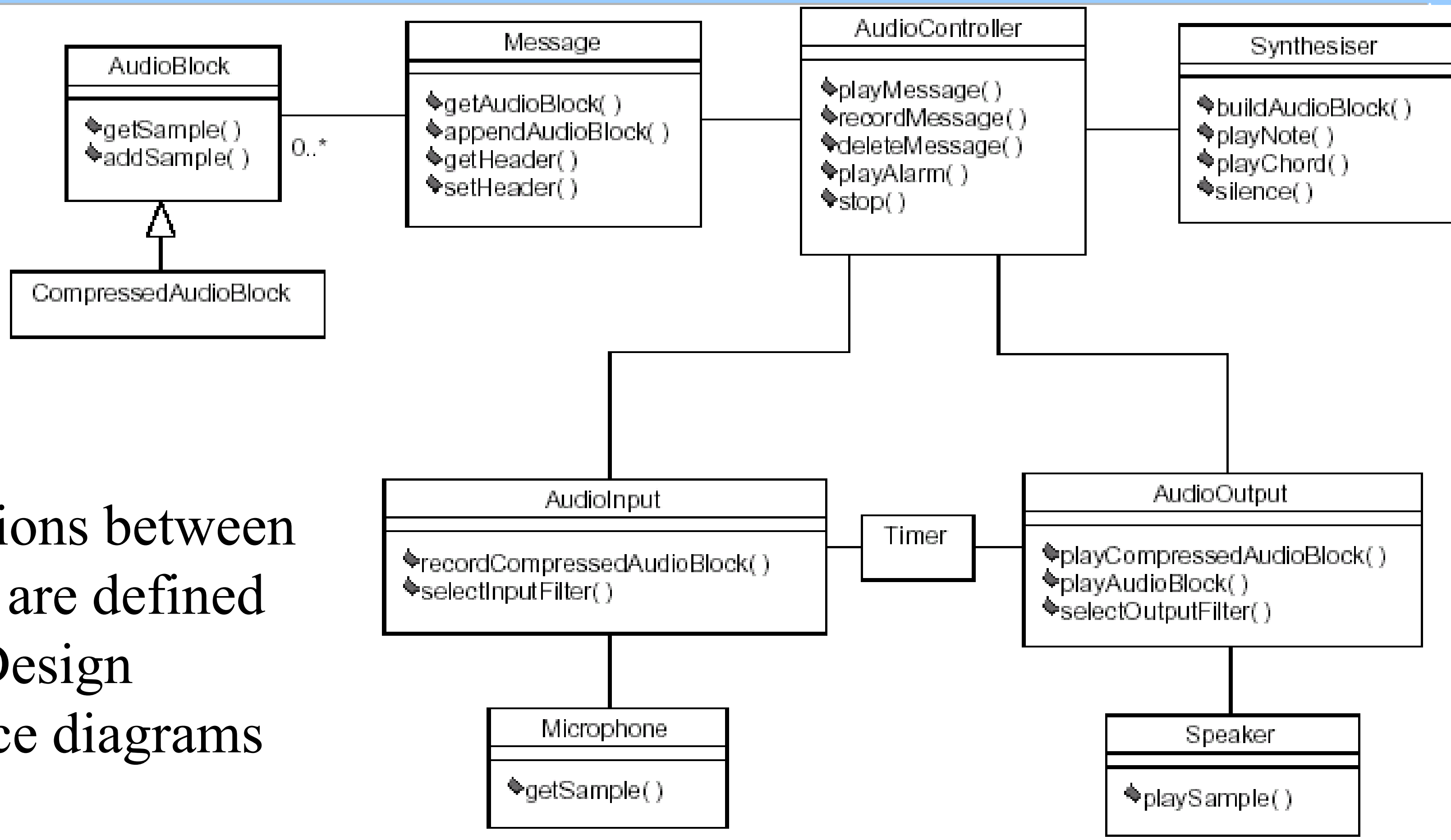


Figure 3.4: Audio subsystem class diagram

Interactions between Objects are defined Using Design Sequence diagrams

Digital Sound Recorder: A Complete Example

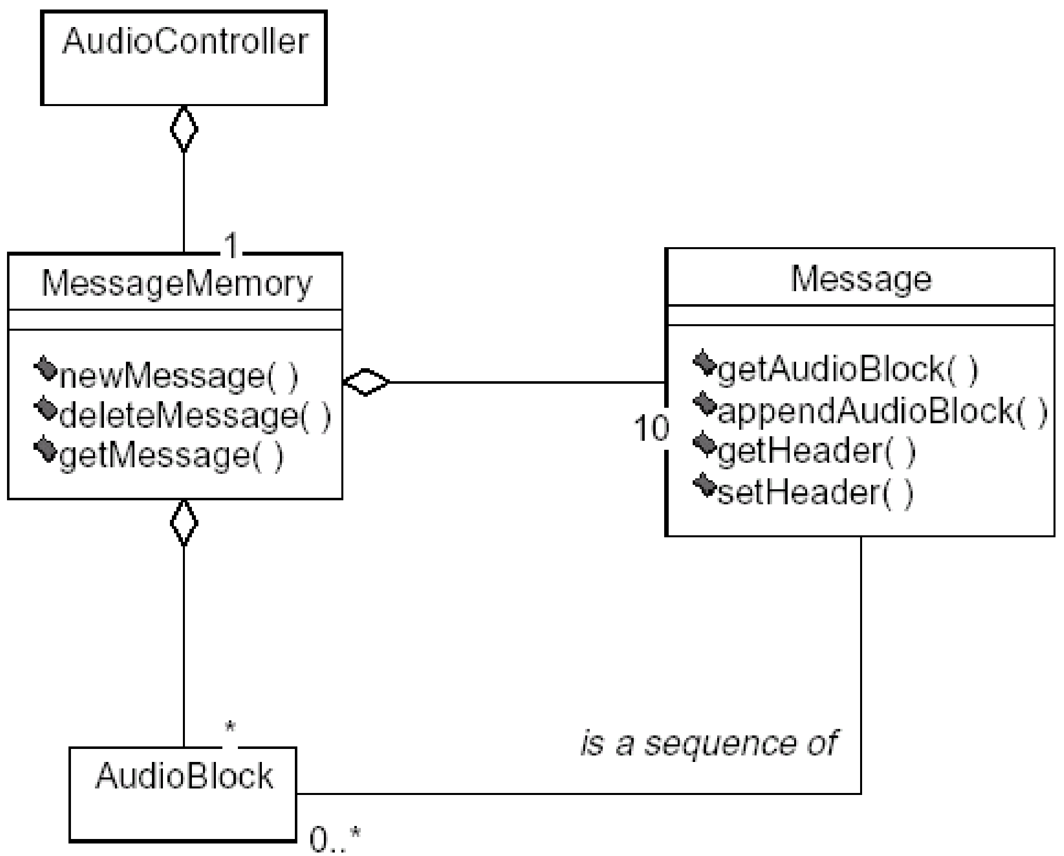


Figure 3.7: Message memory class diagram

Digital Sound Recorder: A Complete Example

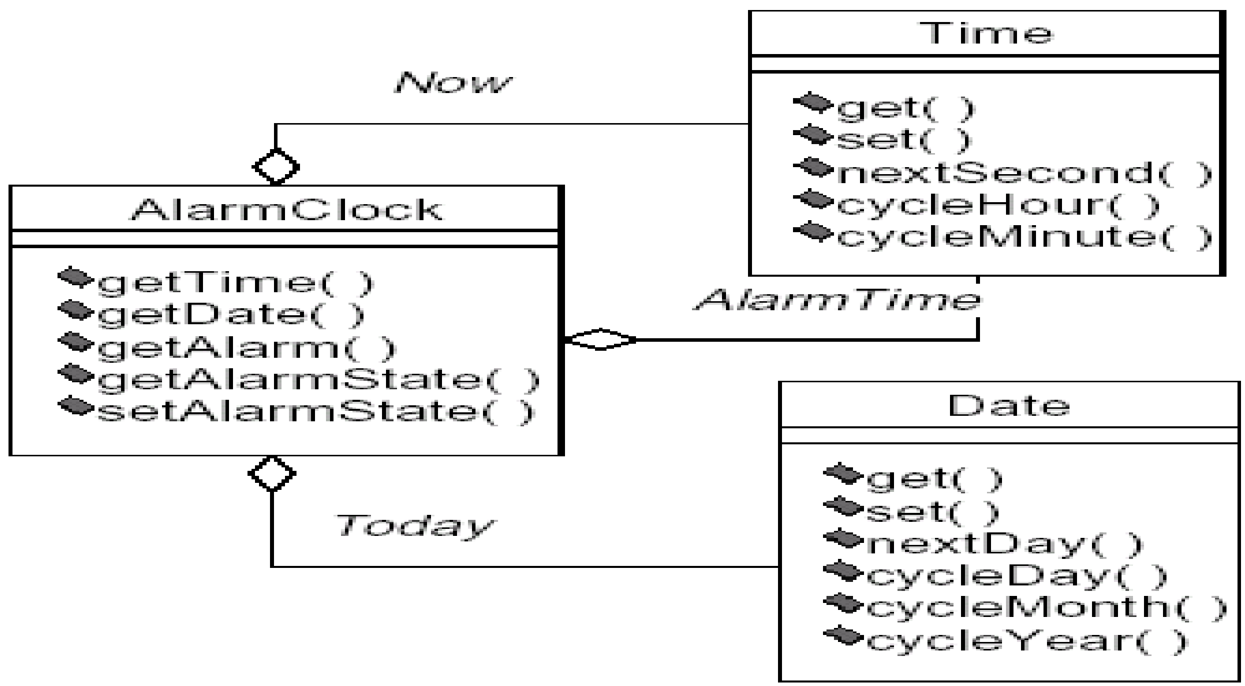


Figure 3.9: Alarm clock class diagram

Digital Sound Recorder: A Complete Example

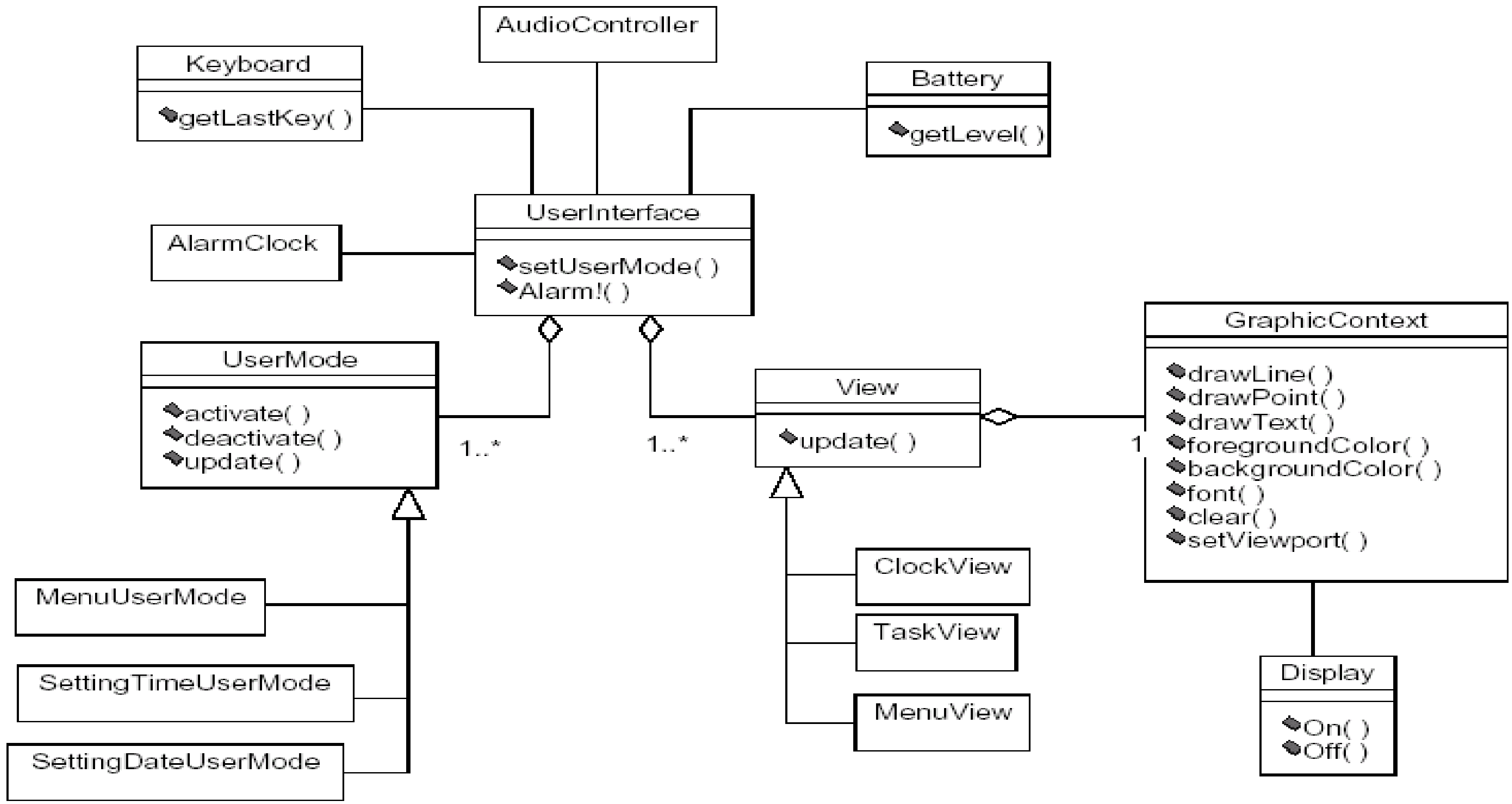


Figure 3.11: User interface subsystem class diagram

Outline

- UML Development – Overview
- The Requirements, Analysis, and Design Models
- What is Software Architecture?
  - Software Architecture Elements
- Examples
- The Process of Designing Software Architectures
  - Defining Subsystems
  - Defining Subsystem Interfaces
- Design Using Architectural Styles
  - **Software Architecture Styles**
  - The Attribute Driven Design (ADD)

OUTLINE of SW Architecture Styles

- Introduction
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- SW Systems Mix of Architecture Styles

Design Using Architectural Styles

- An architectural style is a class of architectures characterized by:
- Components types: are component classes characterized by either SW packaging properties or functional or computational roles within an application.
- Communication patterns between the components: kinds of communications between the component types.

Families of Architecture Styles

- There is a number of families of styles that has been defined and used in many software systems Notable examples are:
  1. Independent Components: Event-based Architectures
  2. Virtual Machines
  3. Data Flow: Pipes and Filters
  4. Data-Centered Systems
  5. Call-and Return Architectures

Architectural Styles Grouped Into Five Families

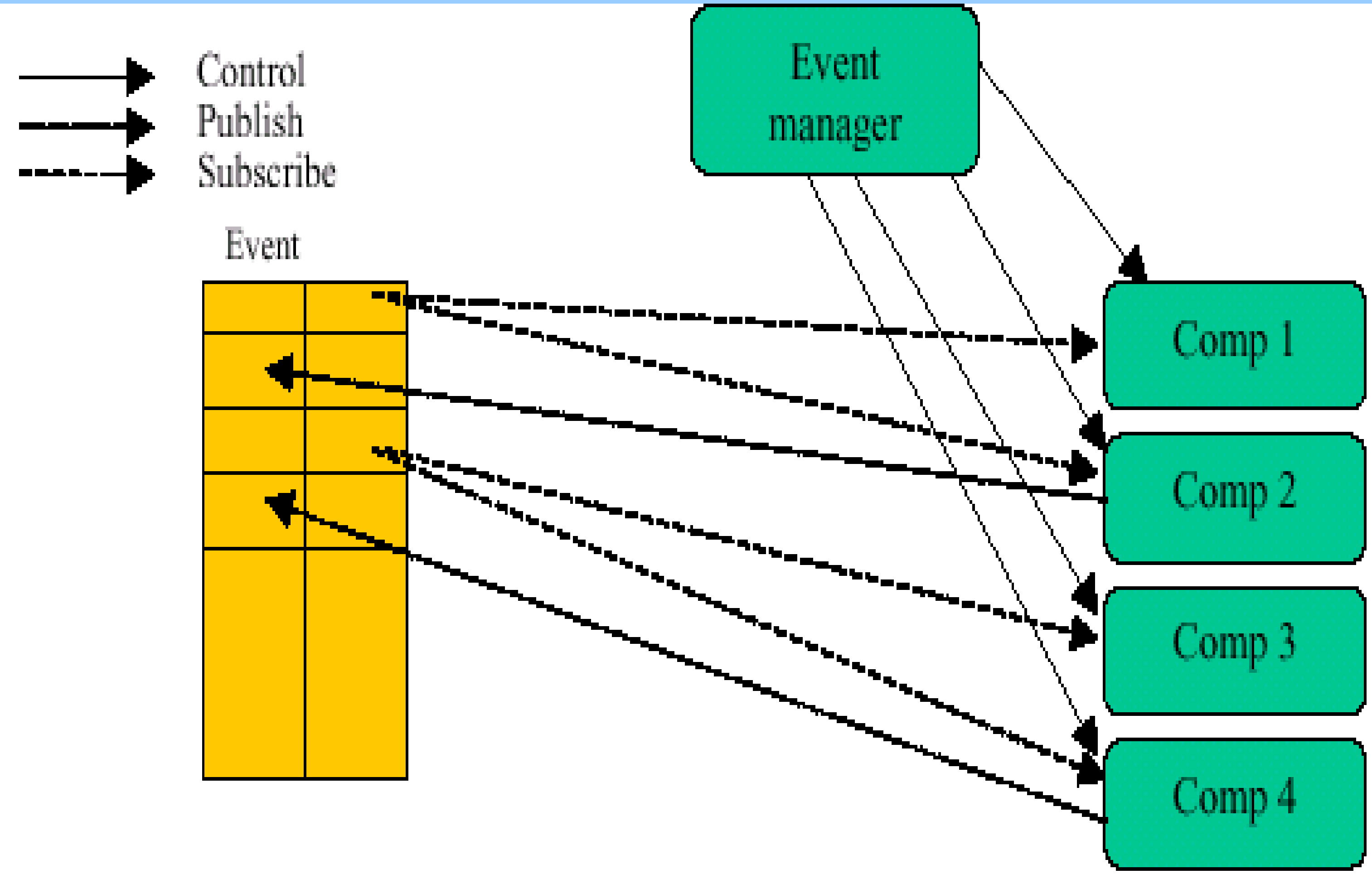
1. Independent Components. SW system is viewed a set of independent processes or objects or components that communicate through messages.

   Two subfamilies:

   - Event based systems (implicit and direct invocation style), and
   - Communicating processes family (client-server style).

Architectural styles: Event-based Architecture

Some processes post events, others express an interest in events



The publish and subscribe event-based architectural style.

Event-based Architecture

Implicit Invocation: *The Observer Pattern (to be discussed later)*

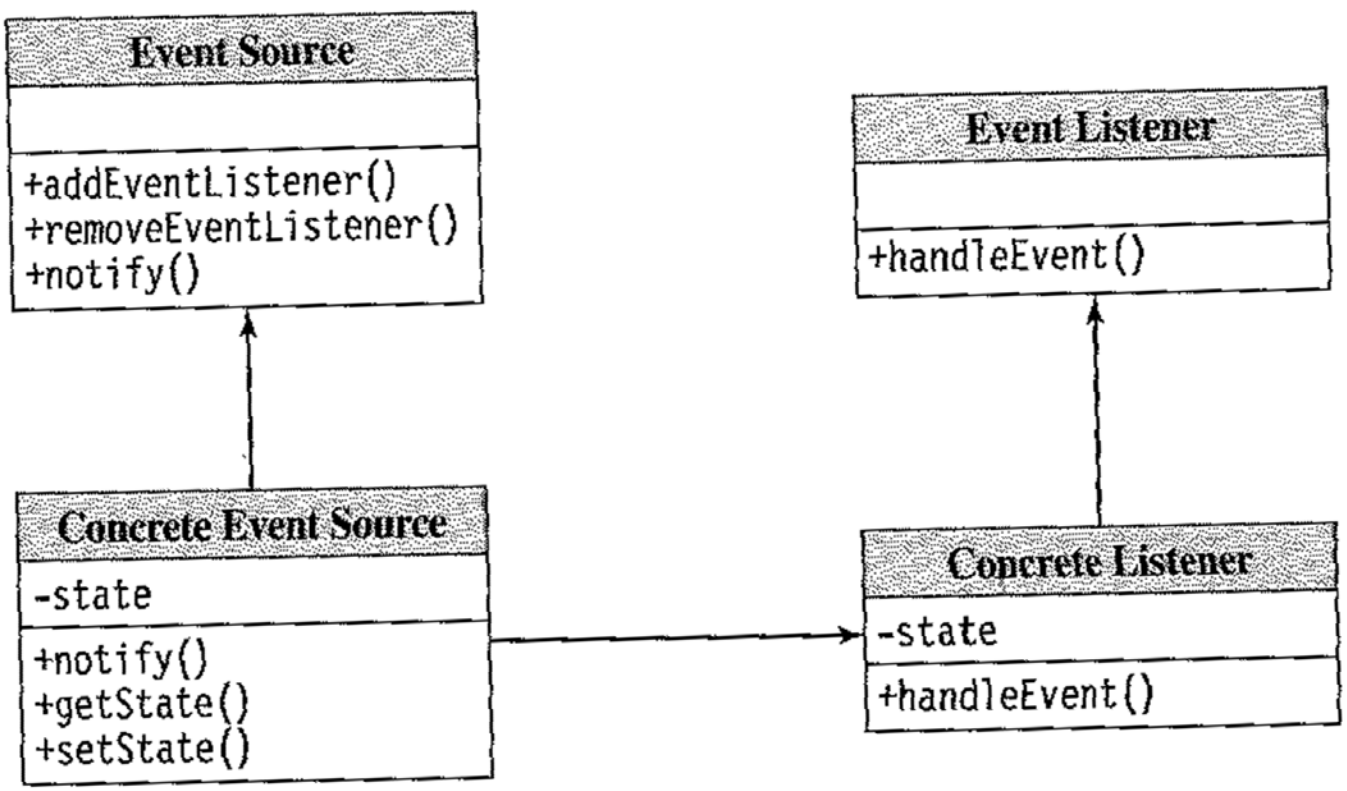
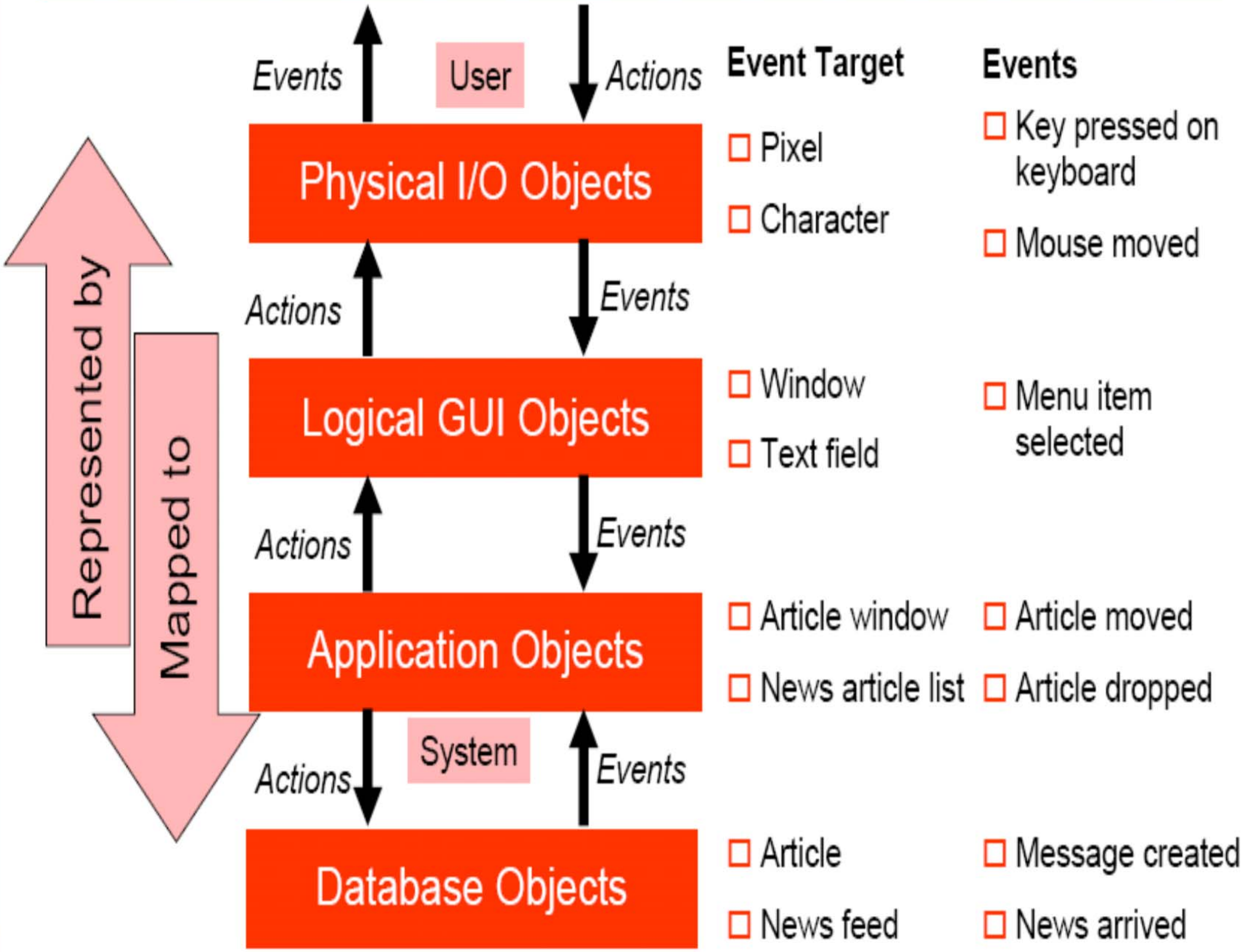


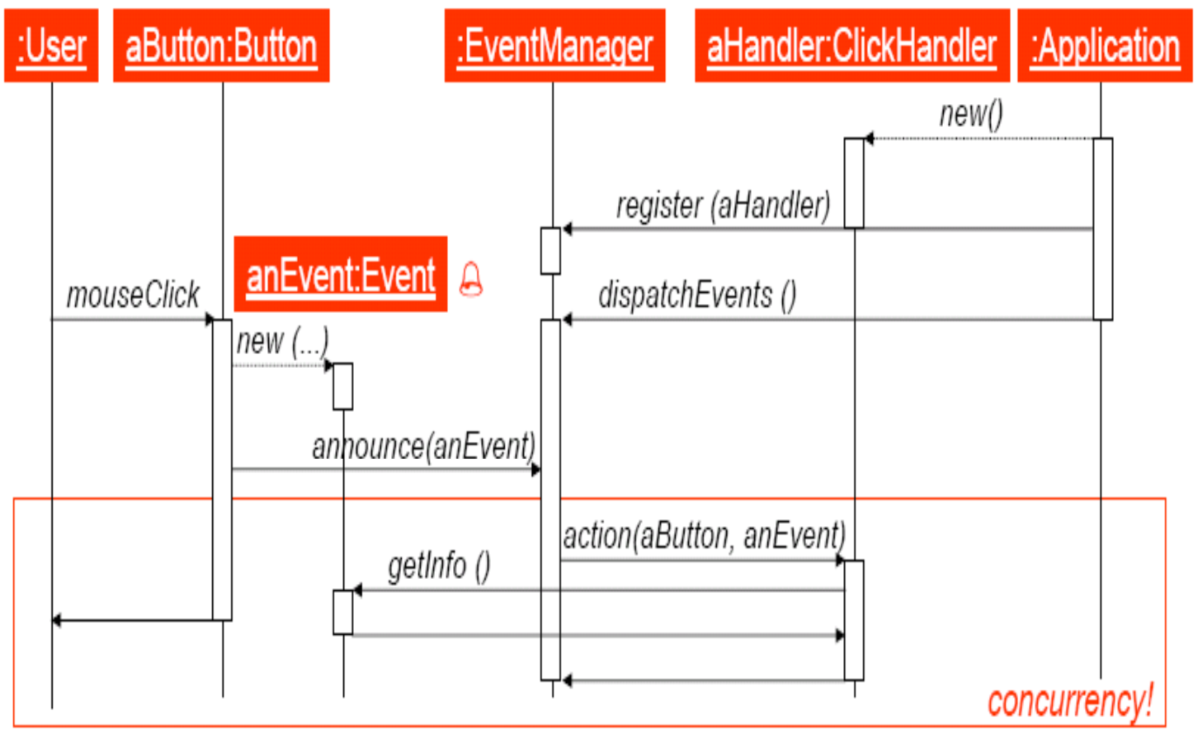
Figure 8.3
Class diagram for event-based implicit invocation architecture

Events at Different Levels of Abstraction



Example: GUI Event Processing

- **Event**: “Button” “double-clicked” “17:31:22”
- **EventSource**: Button managed by the GUI subsystem of the operating system
- **EventHandler**: Notification method in the application code
- **EventManager**: Operating system or GUI library code



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Architectural Styles: Virtual Machines

2. Virtual Machines. Originated from the concept that programs are treated as data by a virtual machine, which is an abstract machine implemented entirely in software, that runs on top of the actual hardware machine.

Architectural Styles
Java Virtual Machines

Java Virtual Machine. Java code translated to platform independent bytecodes. JVM is platform specific and interprets the bytecodes.

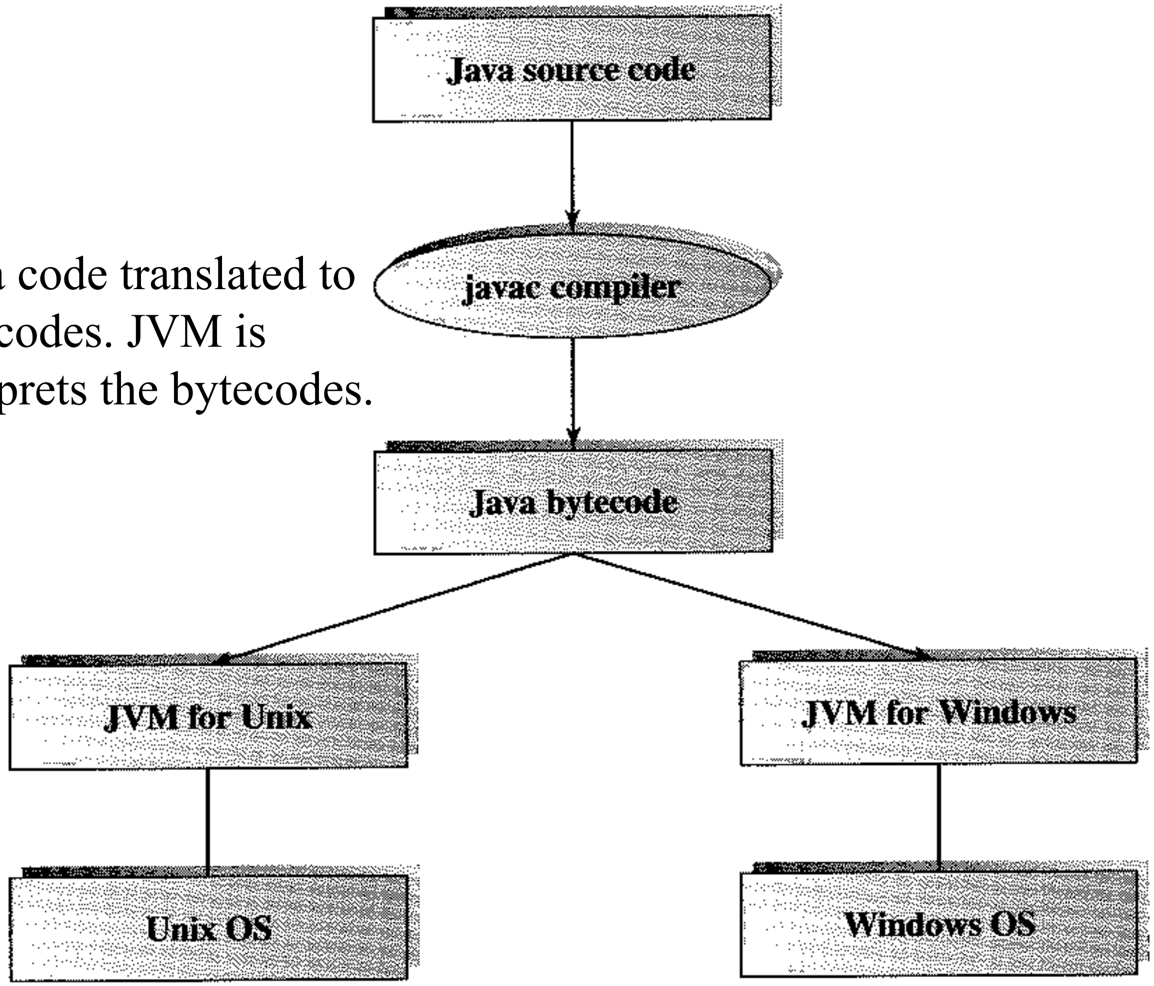
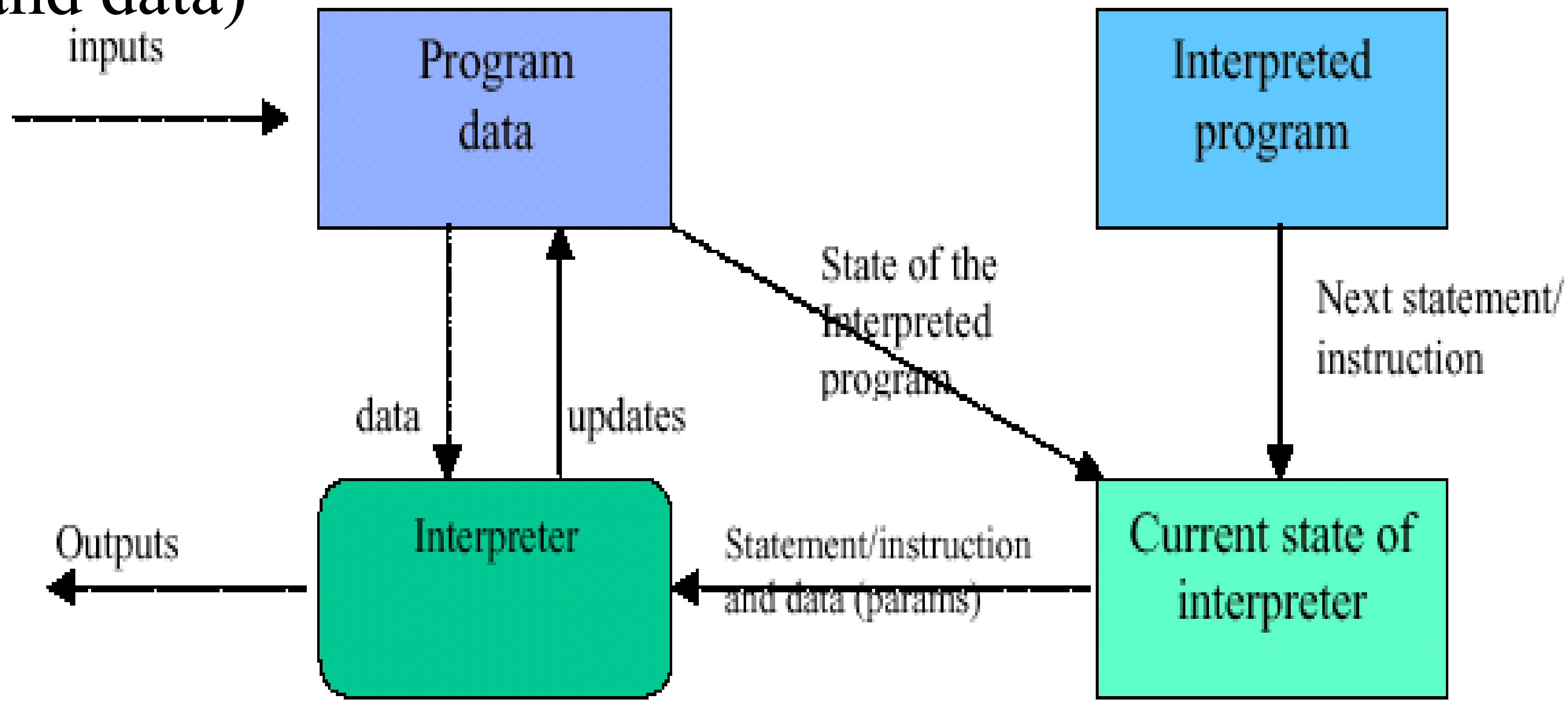


Figure 7.12
Role of Java Virtual Machine

Virtual Machines: The primary benefits are the separation between instruction and implementation, (Used when inputs are defined by a scrip or Commands, and data)



The virtual machine architectural style.

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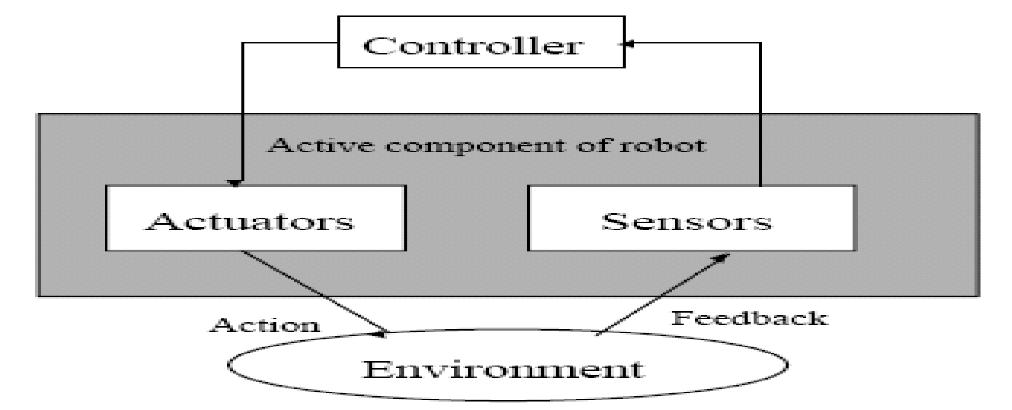
Architectural Styles: Data Flow

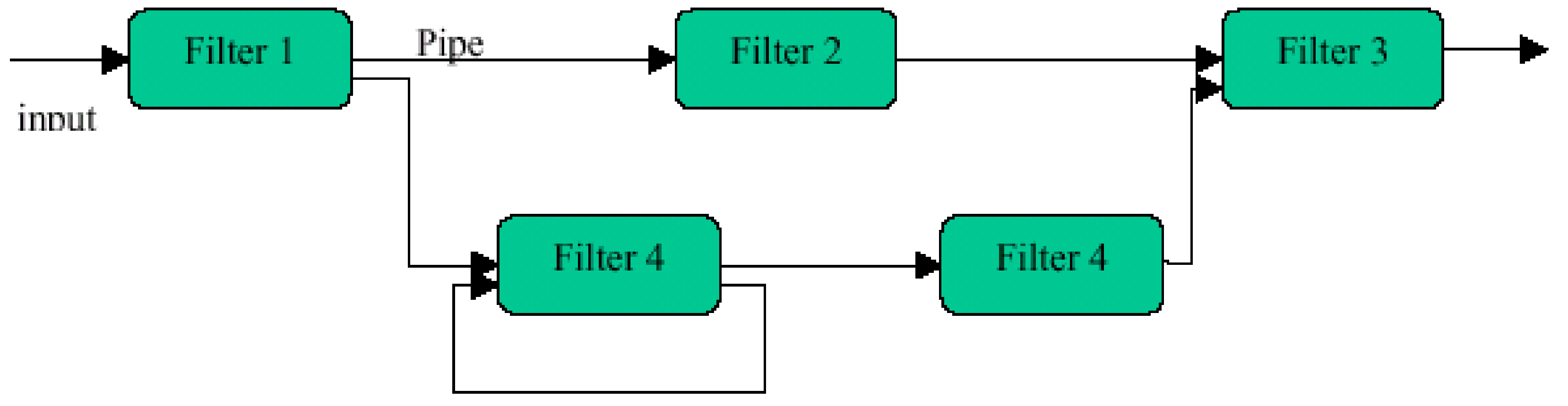
3. Data Flow. Include batch sequential systems (BSS) and pipes and filters (PF).
   - - BSS: different components take turns at processing a batch of data, each saving the result of their processing in a shared repository that the next component can access. Ex. Dynamic control of physical processes based on a feedback loop.

     - PF: A stream of data processed by a complex structure of processes (filters). Ex, UNIX.

Architectural Styles: Data Flow

Control Loop
BSS

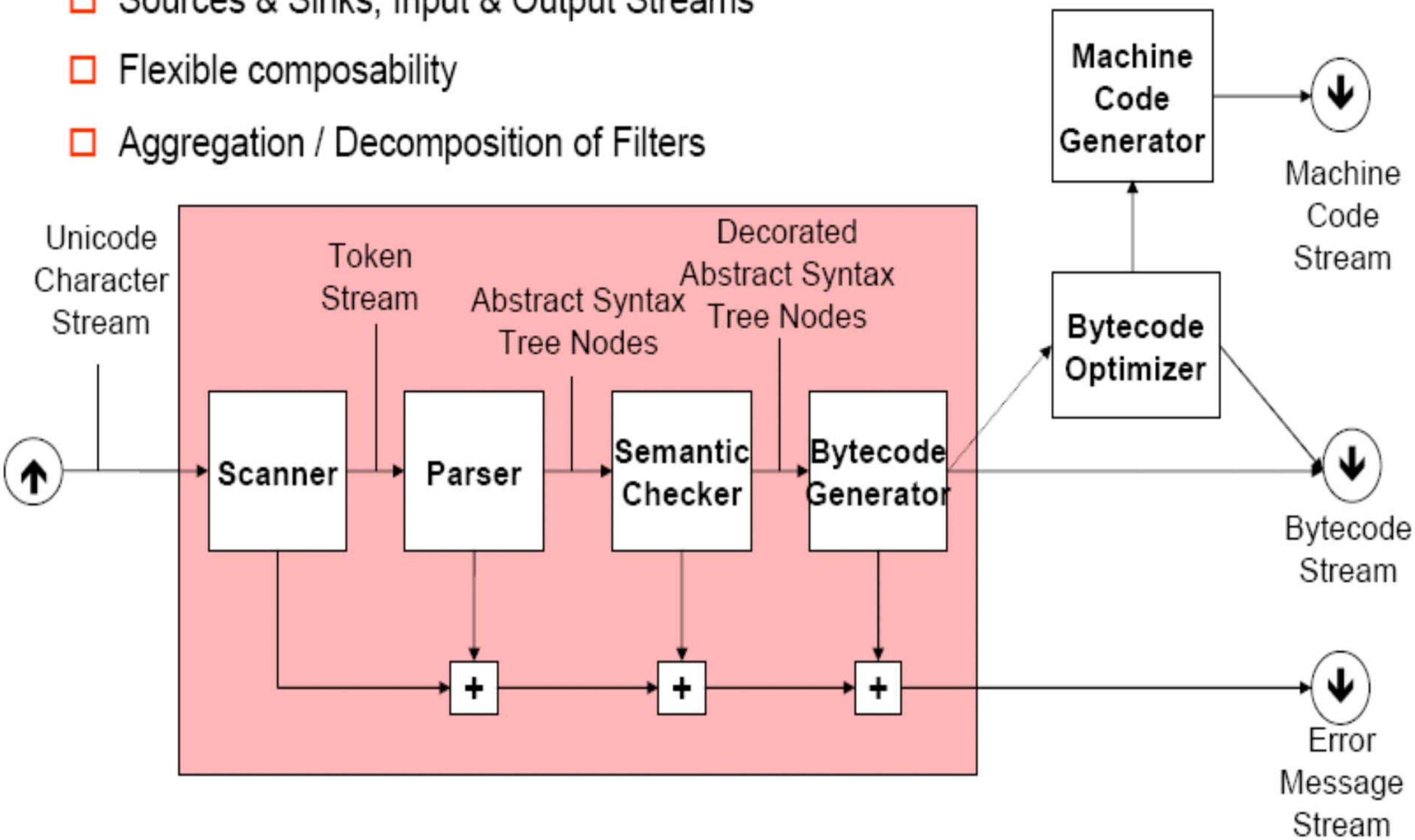




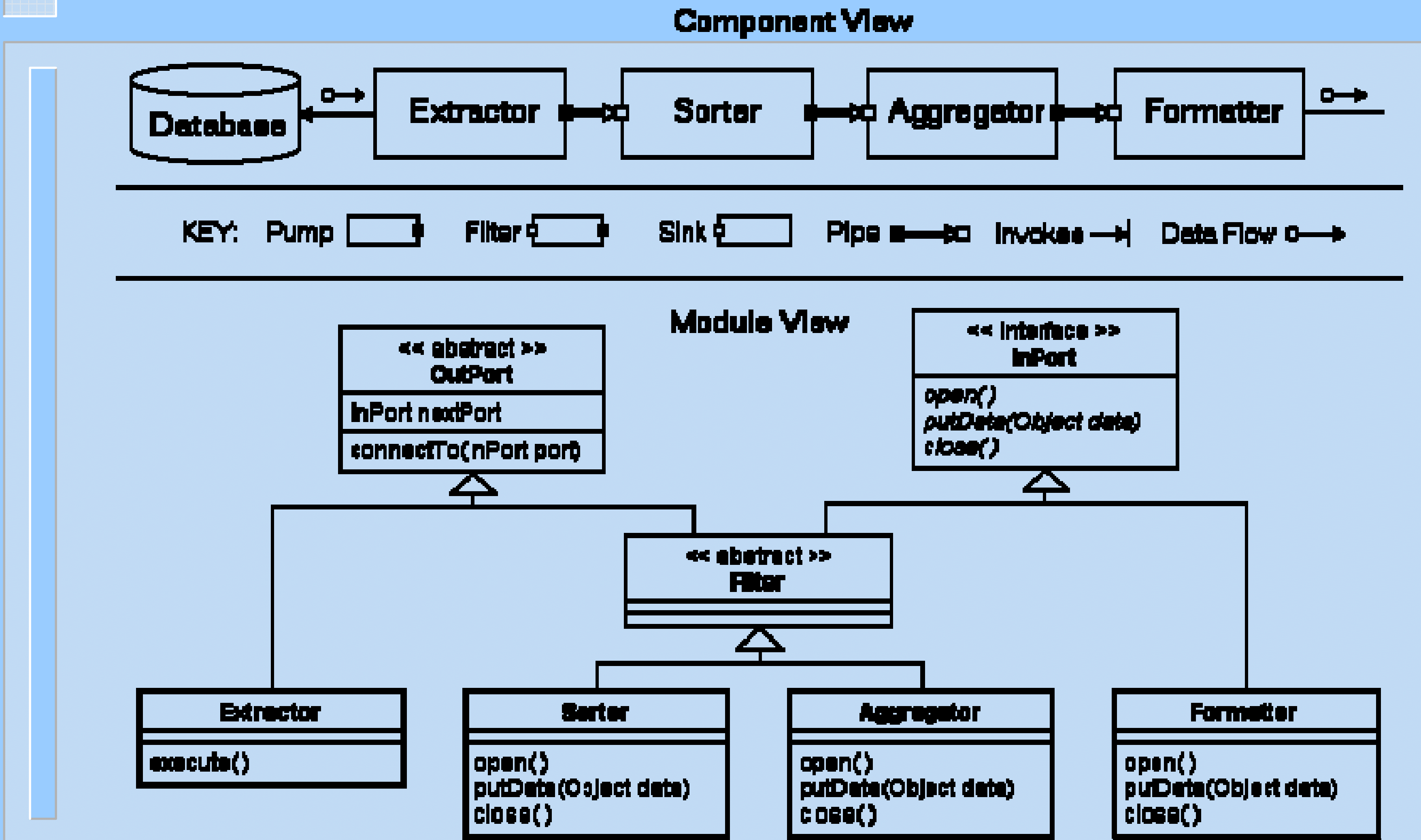
The pipes-and-filters architectural style.

Example: P&F Compiler Architecture (1)

- Sources & Sinks, Input & Output Streams
- Flexible composability
- Aggregation / Decomposition of Filters



PF Another Architecture Example:
Watch for the Two Views



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Architectural Styles

4. Data-Centered Systems. Consist of having different components communicate through shared data repositories. When data repository is an active repository that notifies registered components of changes in it then-blackboard style.

Data-Centered Architectural Styles
Repository Architecture Style

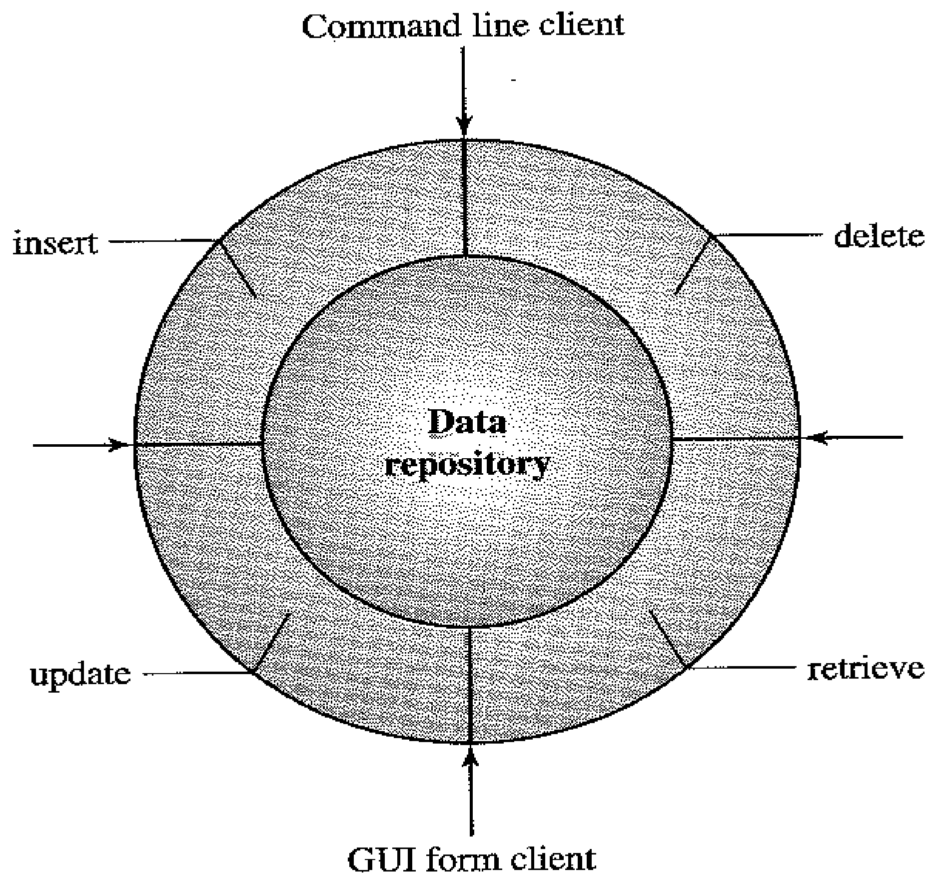
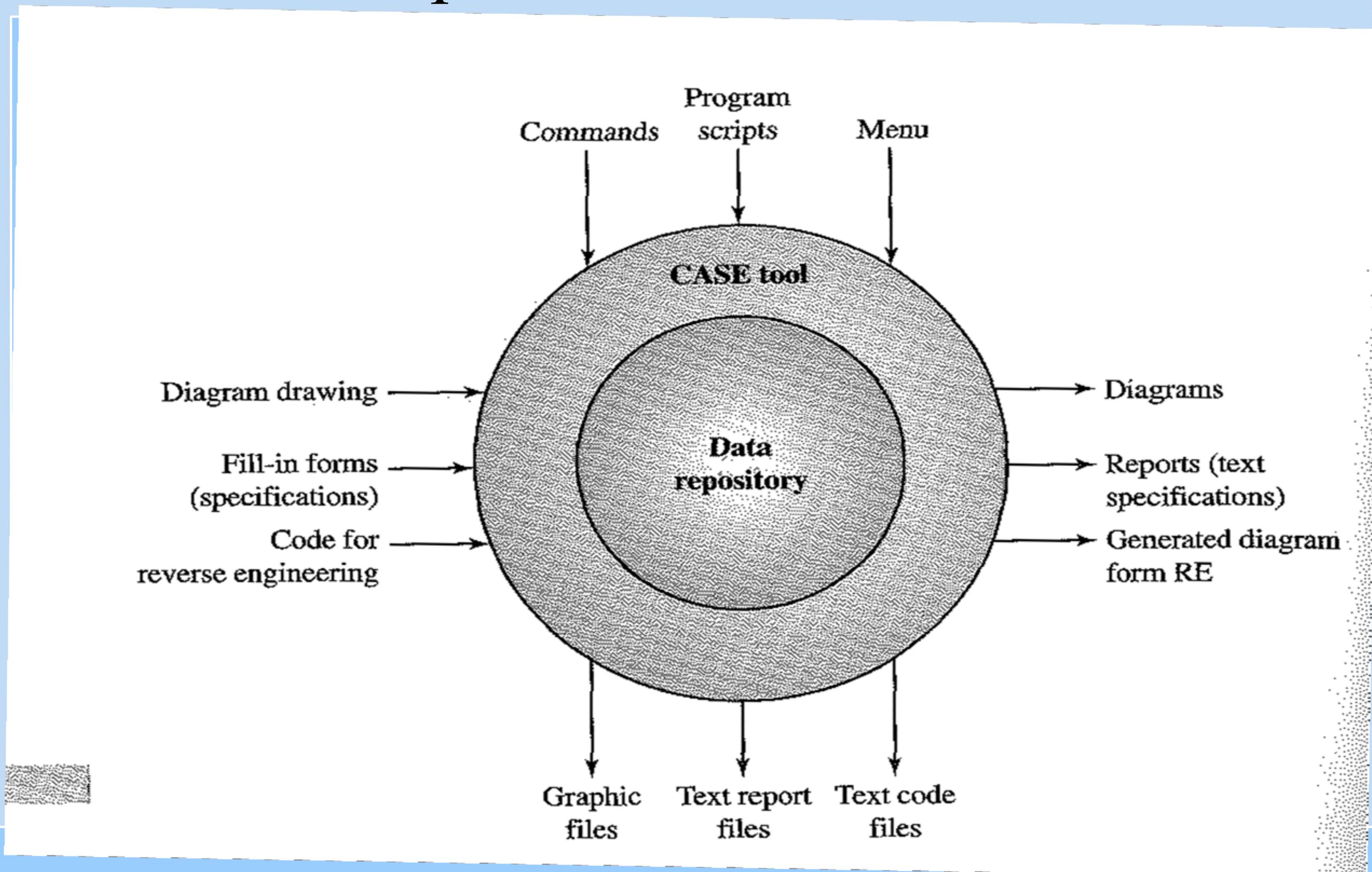


Figure 6.5
Database system

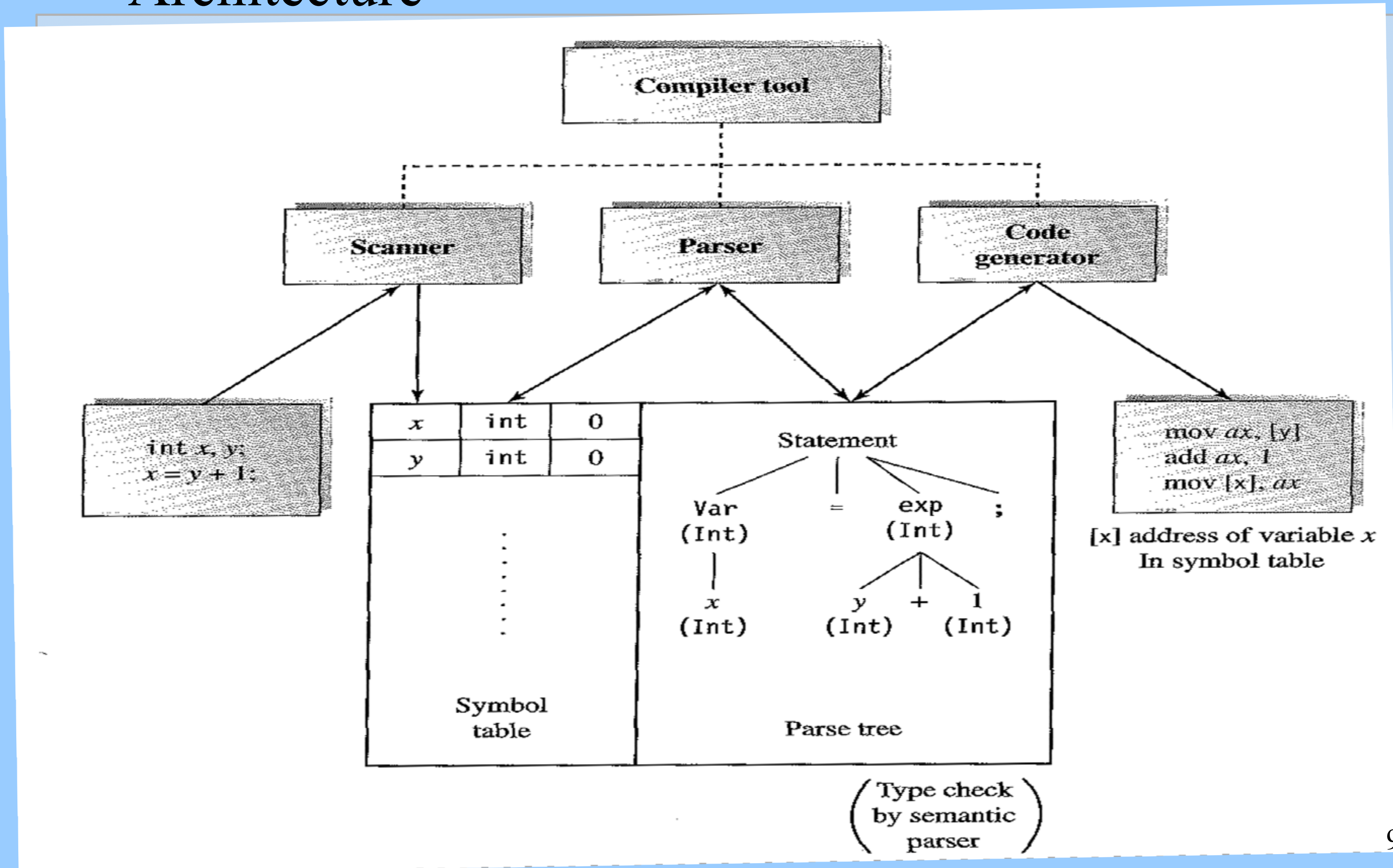
Data-Centered Architectural Styles

Repository Architecture Example: CASE Tools Example



Data-Centered Architectural Styles

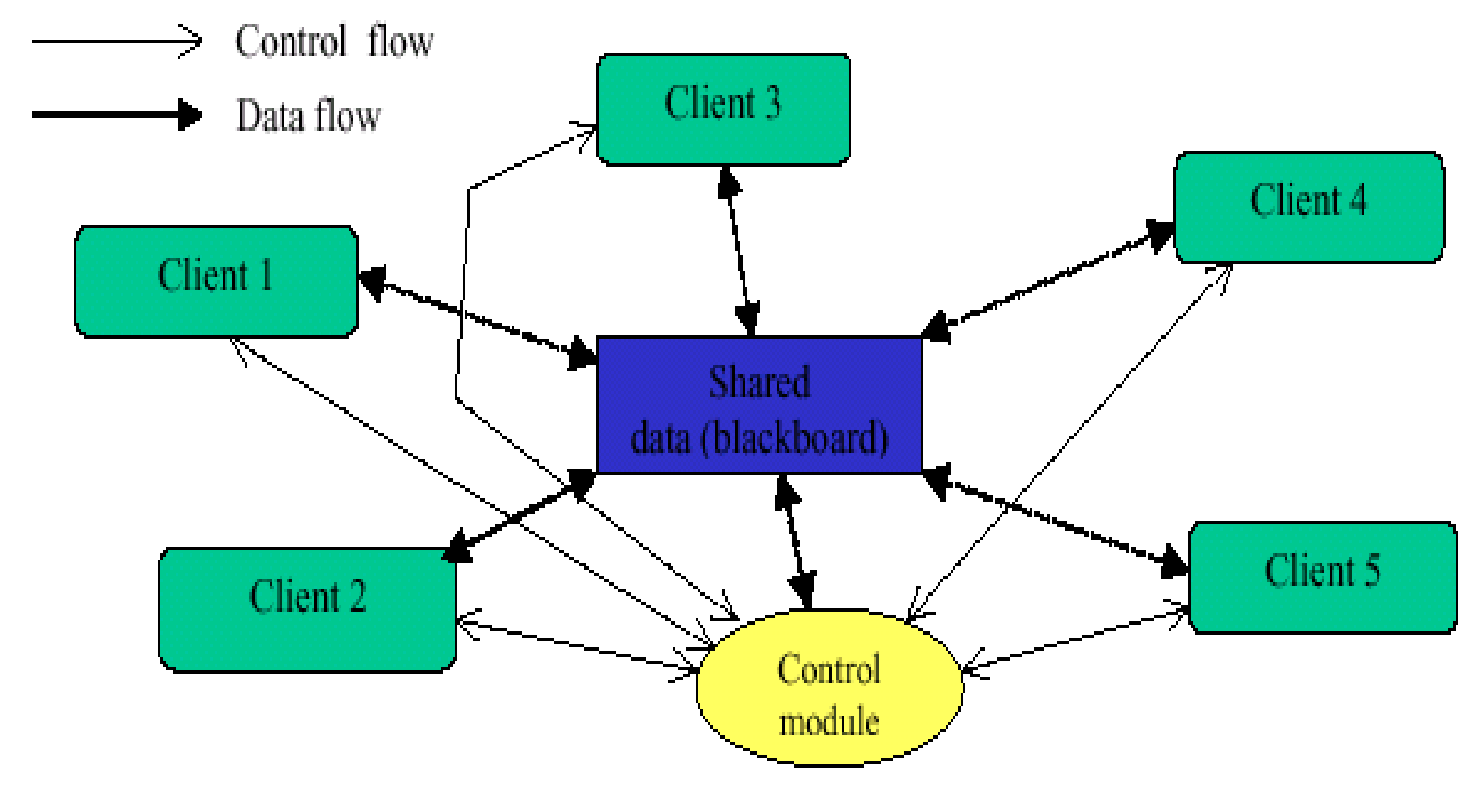
Repository Architecture Example: Compiler Architecture



Data-Centered Systems: Central data repository

Components perusing shared data, and communicating through it.

Used in Database intensive systems



The Blackboard architectural style.

Data-Centered Architectural Styles

Blackboard Architecture Style Example

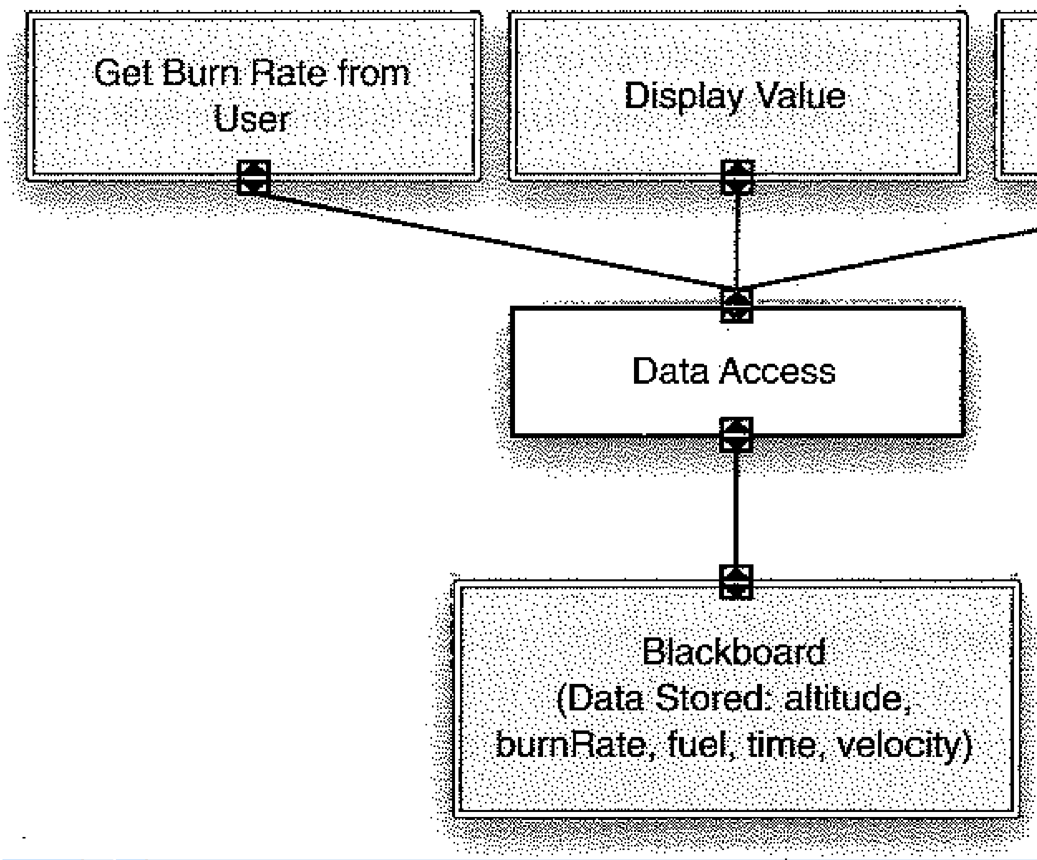


Figure 4-16.
Lunar Lander in blackboard style.

Compare with the PFs Style

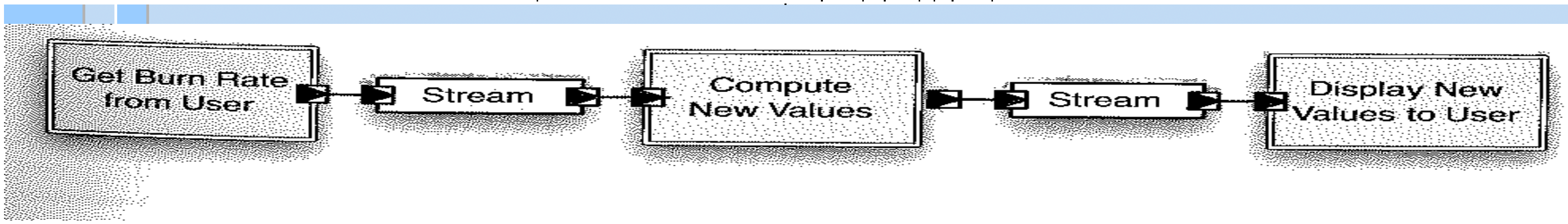


Figure 4-15.
Lunar Lander in pipe-and-filter style.

Data-Centered Architectural Styles
Blackboard Architecture Style:
Intelligent Agent Systems Example

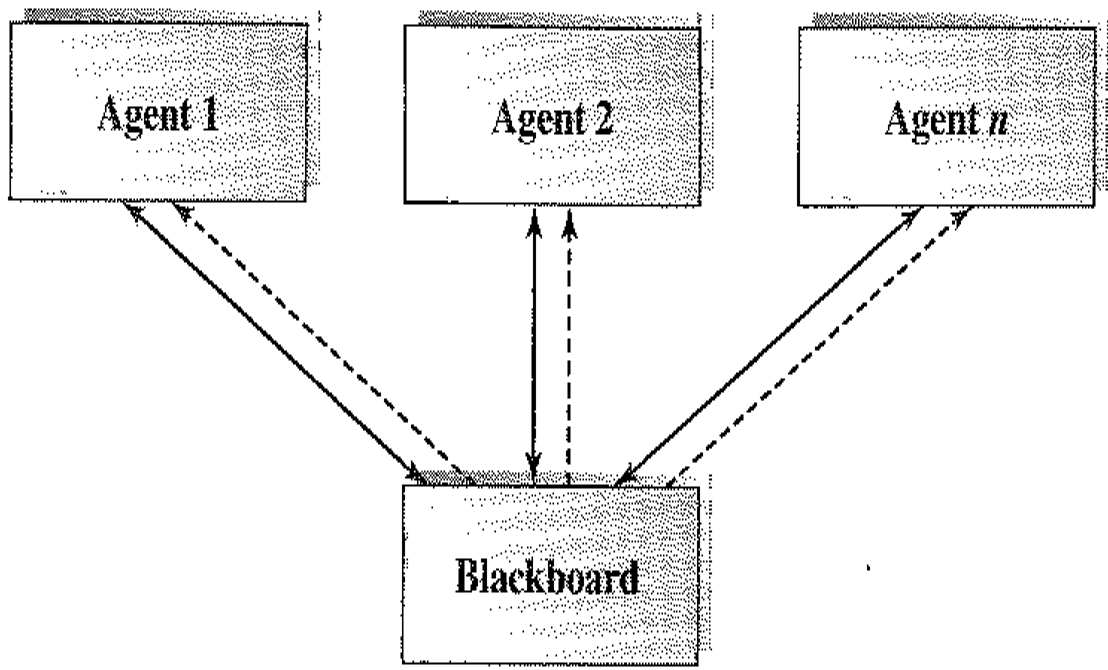


Figure 6.8
Blackboard architecture

Data-Centered Architectural Styles
Blackboard Architecture Style:
Travel Counseling System Example

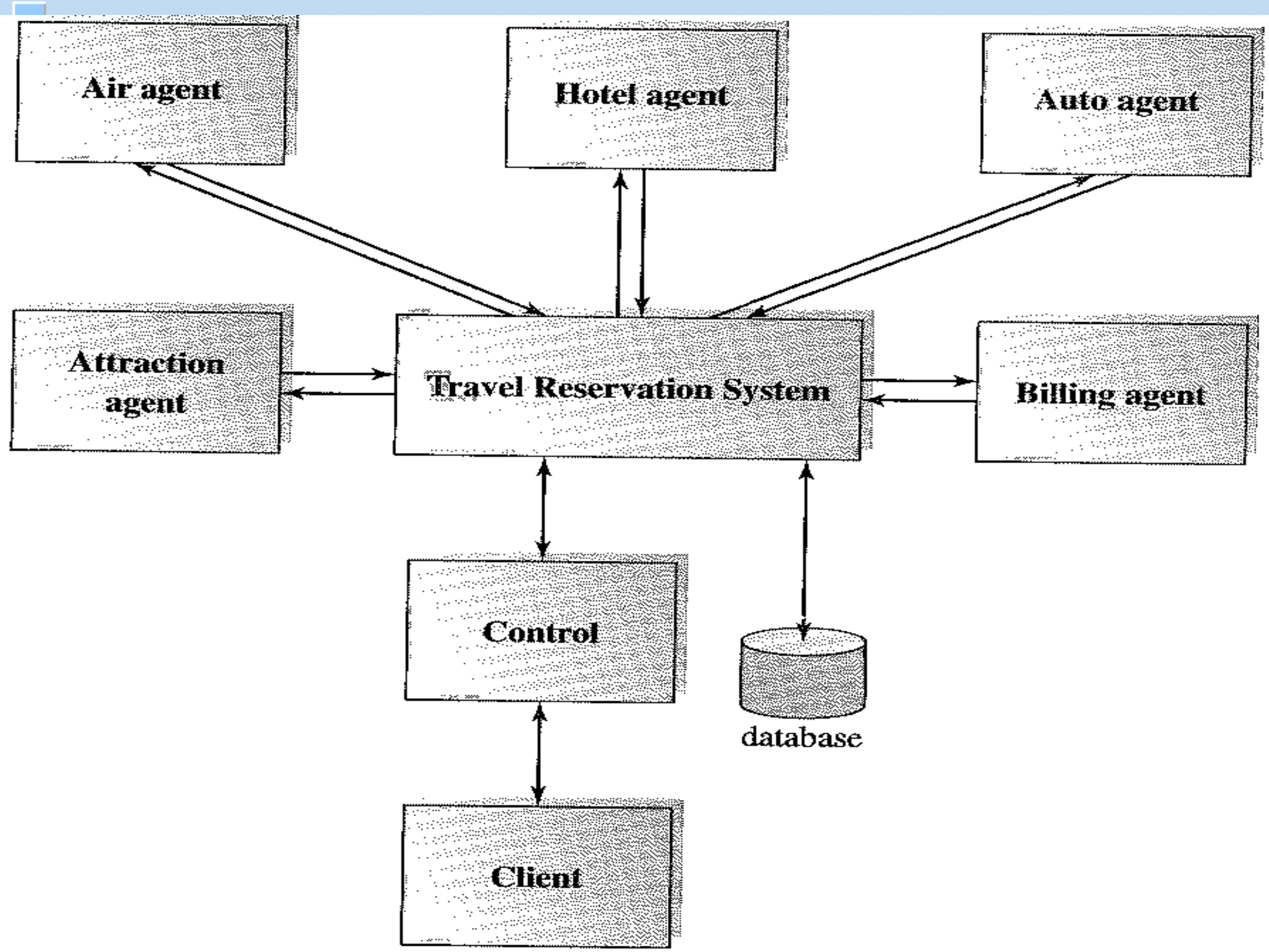


Figure 6.12
Blackboard architecture for a travel consulting system

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Architectural styles

5. Call-and Return Architectures. Due to heir simple control paradigm and component interaction mechanism , these architectures have dominated the SW landscape by the early decades of the SW Eng.

There are several styles within this family: examples are

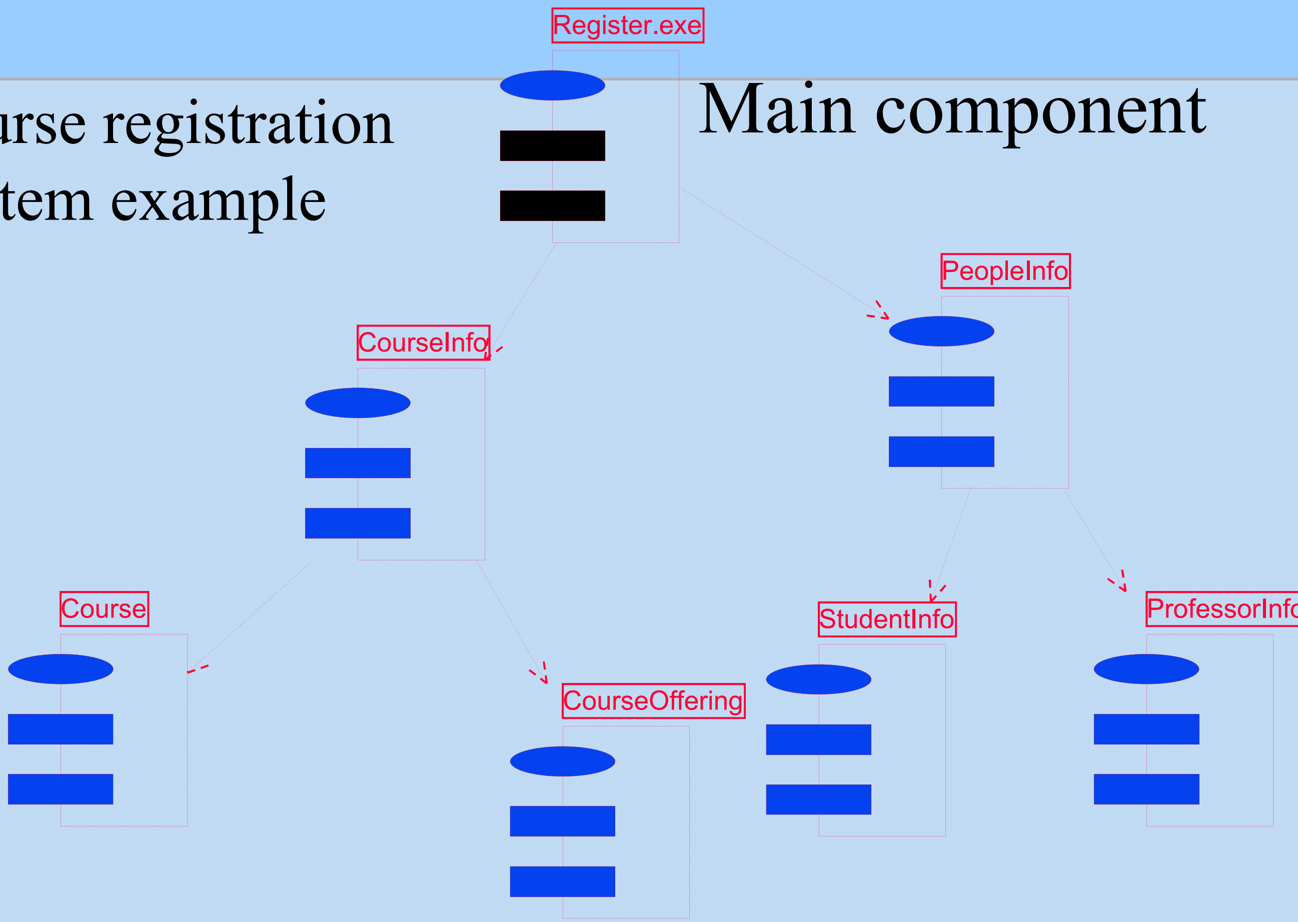
1) Main program and subroutine,

2) Layered architectures.

- Main Program and Subroutine Style. Programs are modularized based on functional decomposition, single thread of control held by the main program, which is then passed to subprograms, along with some data on which the subprograms can operate.

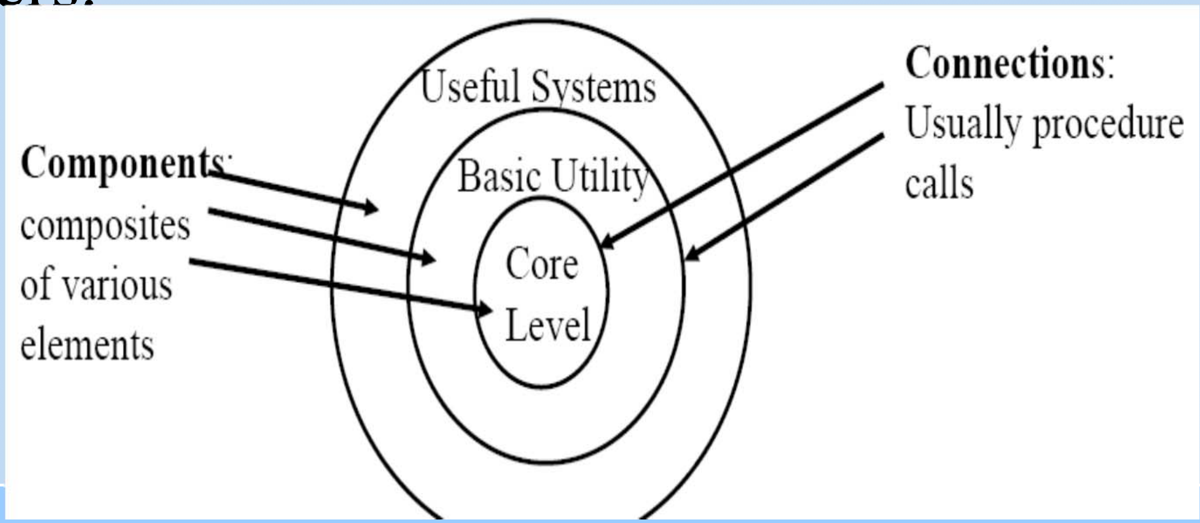
Main Program and Subroutine Style

Course registration
System example

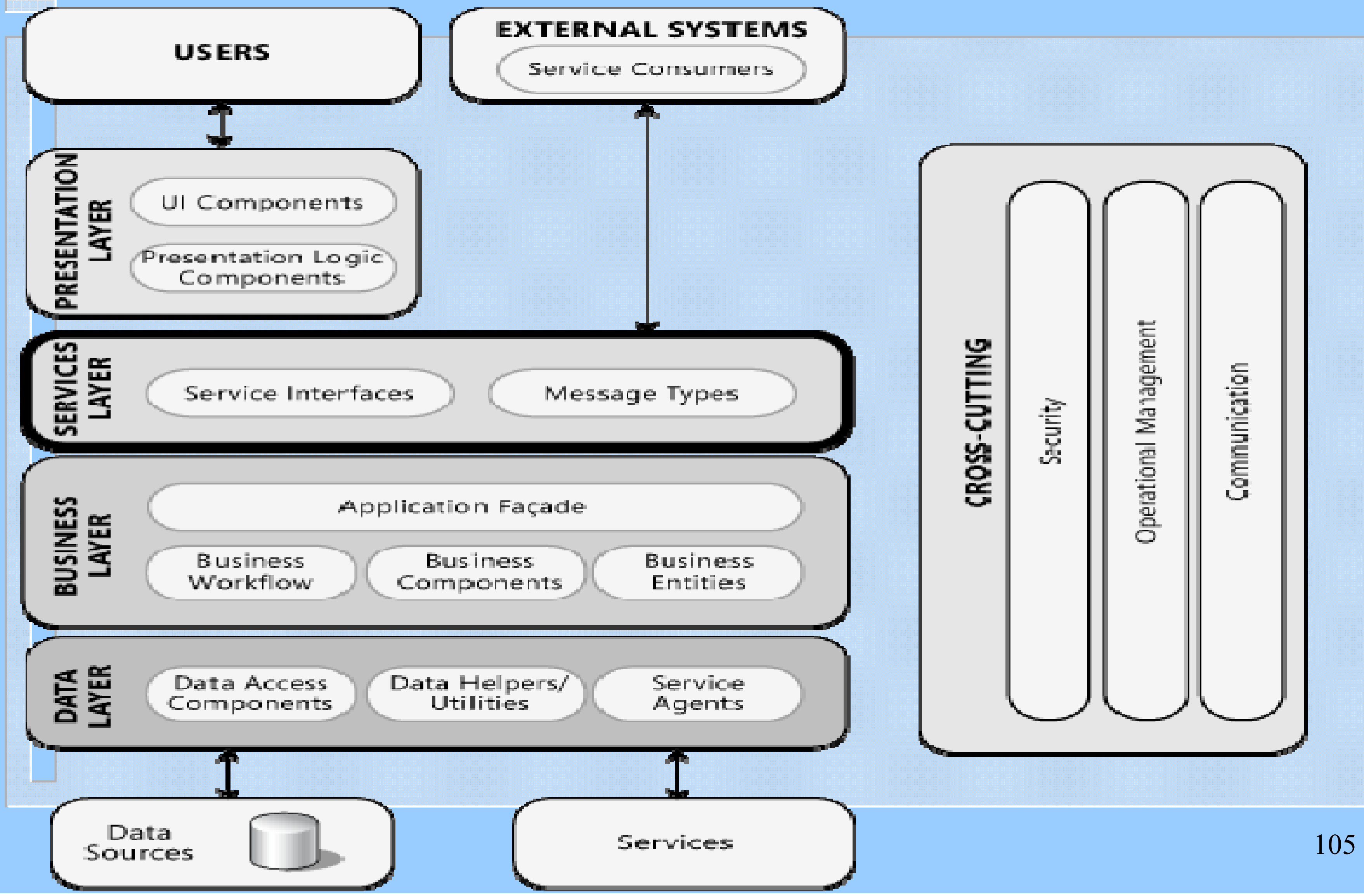


Architectural styles

-) Layered. Functionality is divided into layers of abstraction-each layer provides services to the layer(s) above it, and uses the services of layer(s) below it. In its purest form, each layer access only the layer below it, but does not depend on other lower layers.



Layered Architectural styles
Example of a Layered Application Architecture



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Model-View-Controller Architecture Style

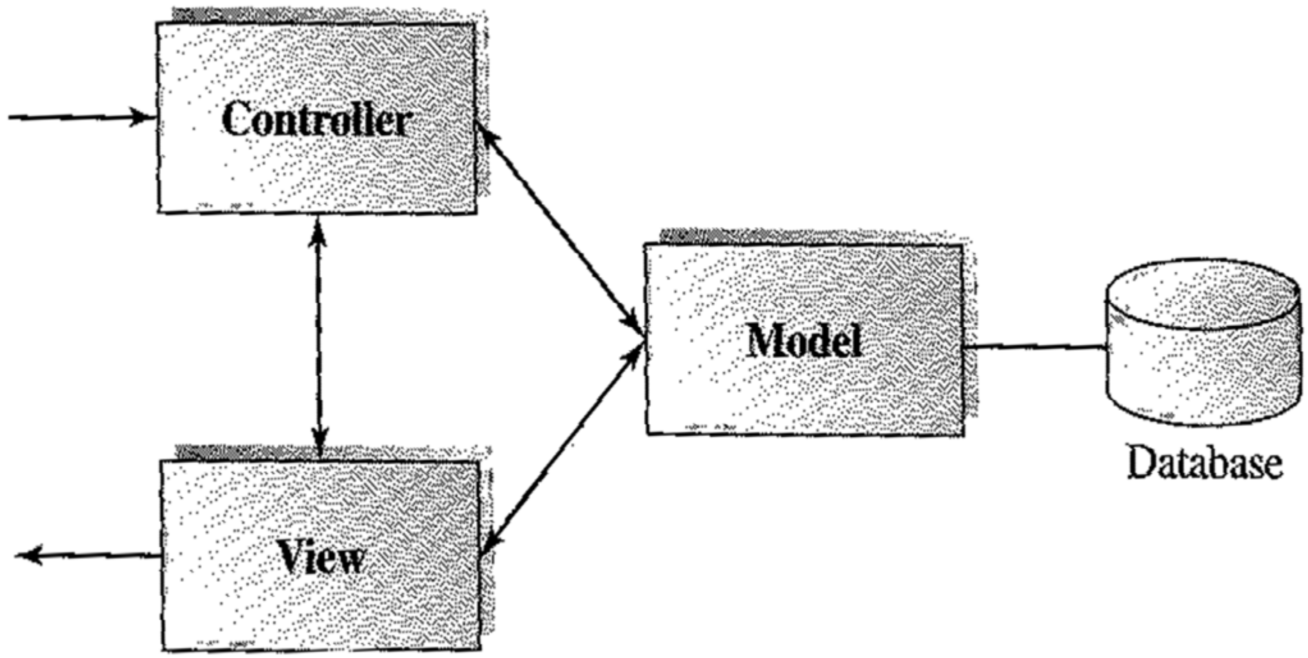


Figure 9.2
MVC-II architecture

- The Controller manipulates the data Model
- The View retrieves data from the model and displays needed information

Model-View-Controller Architecture Style

Dynamic Interactions

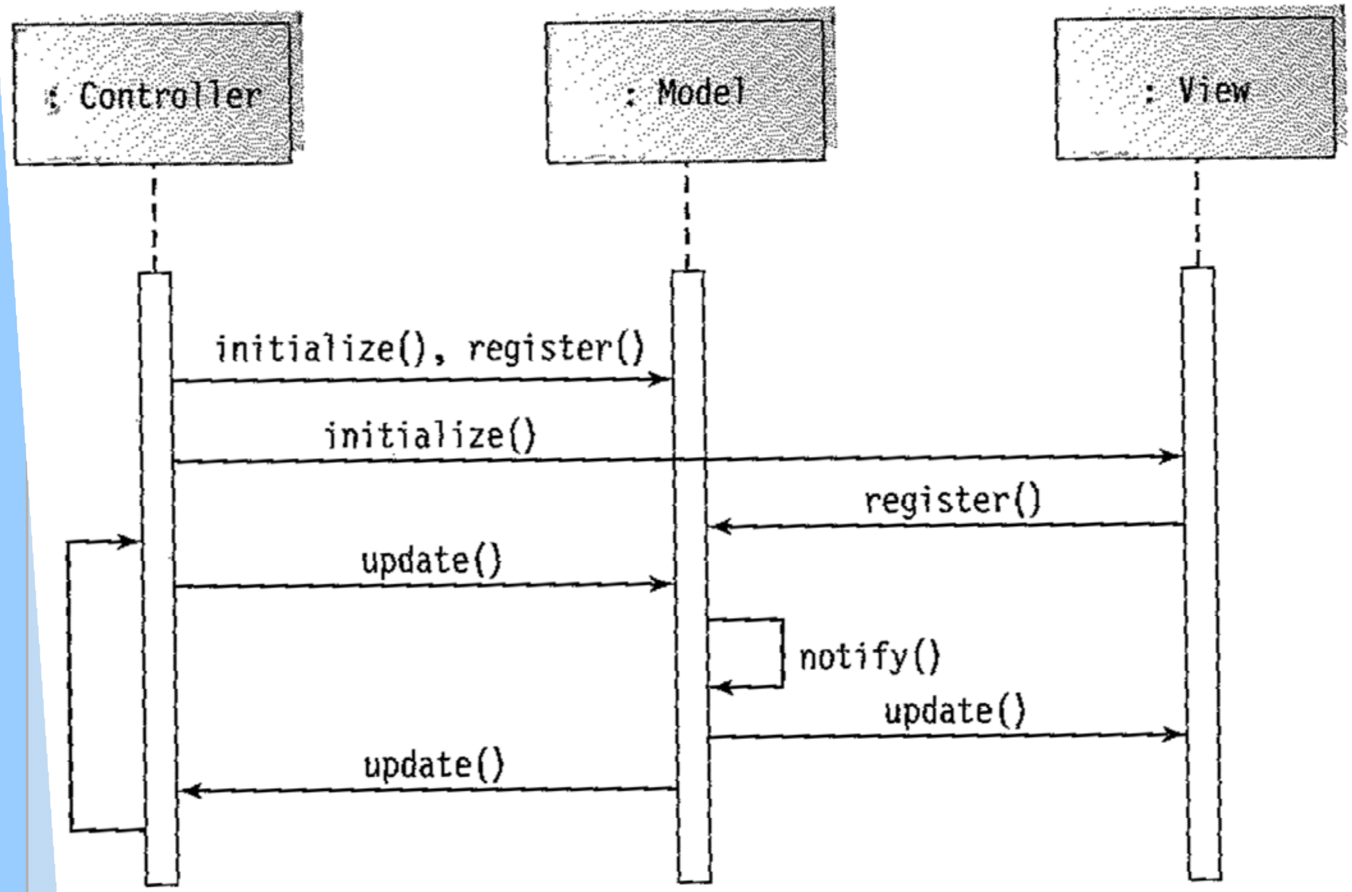
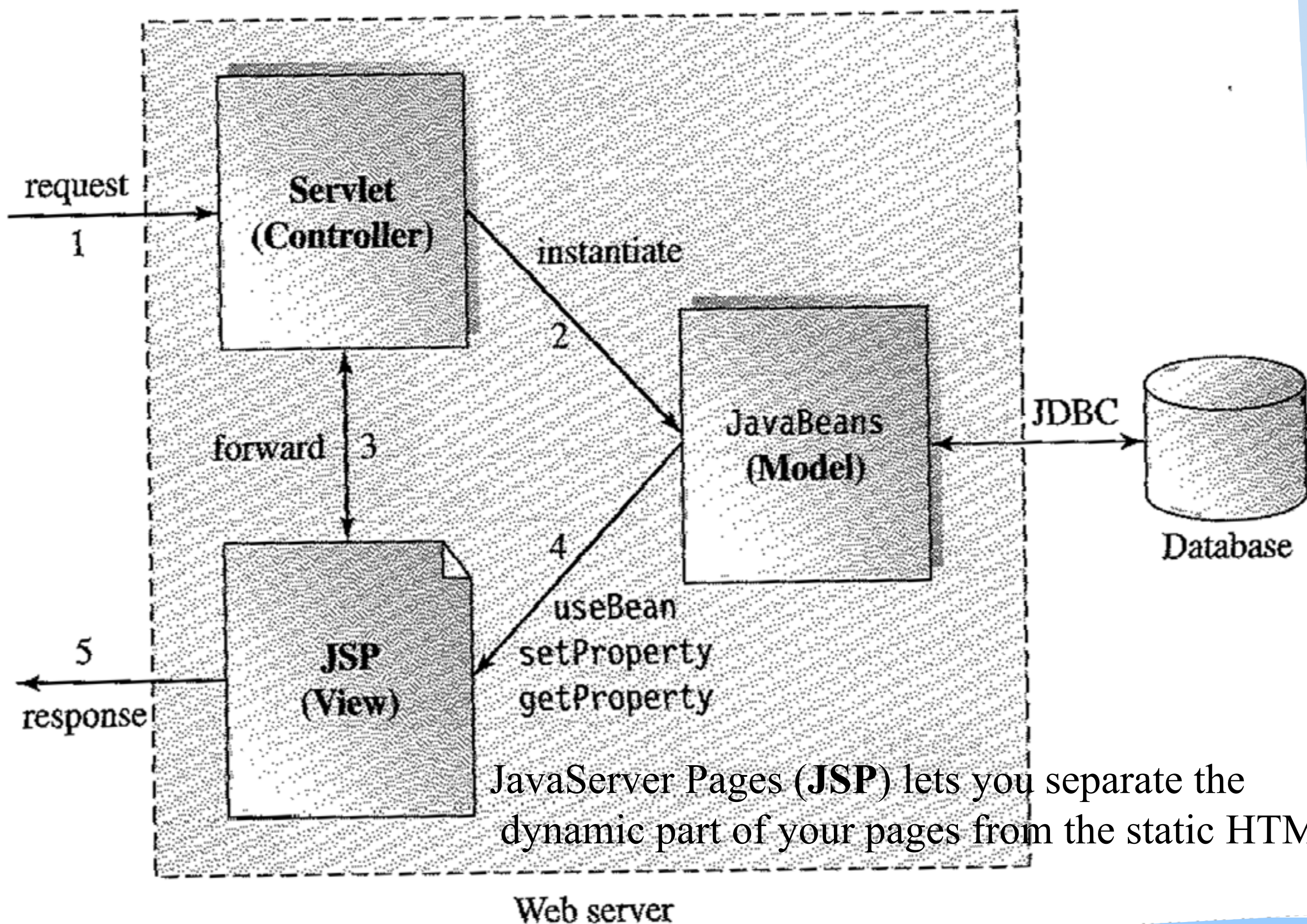


Figure 9.4

Sequence diagram for MVC architecture

Model-View-Controller Architecture Style

Web Applications Java-based Implementation Example



JavaServer Pages (**JSP**) lets you separate the dynamic part of your pages from the static HTML

Figure 9.5
MVC architecture on Java Web platform

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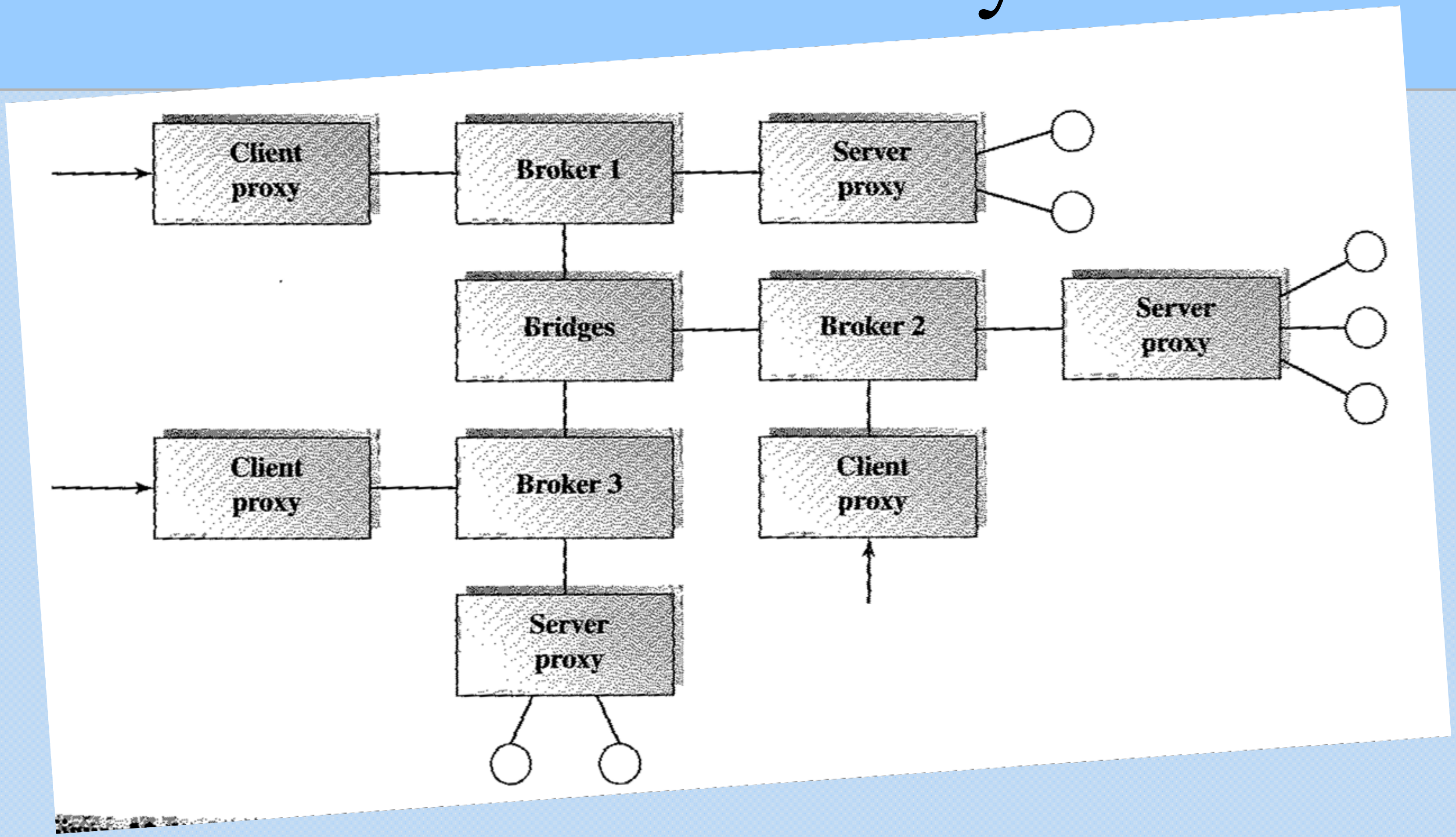
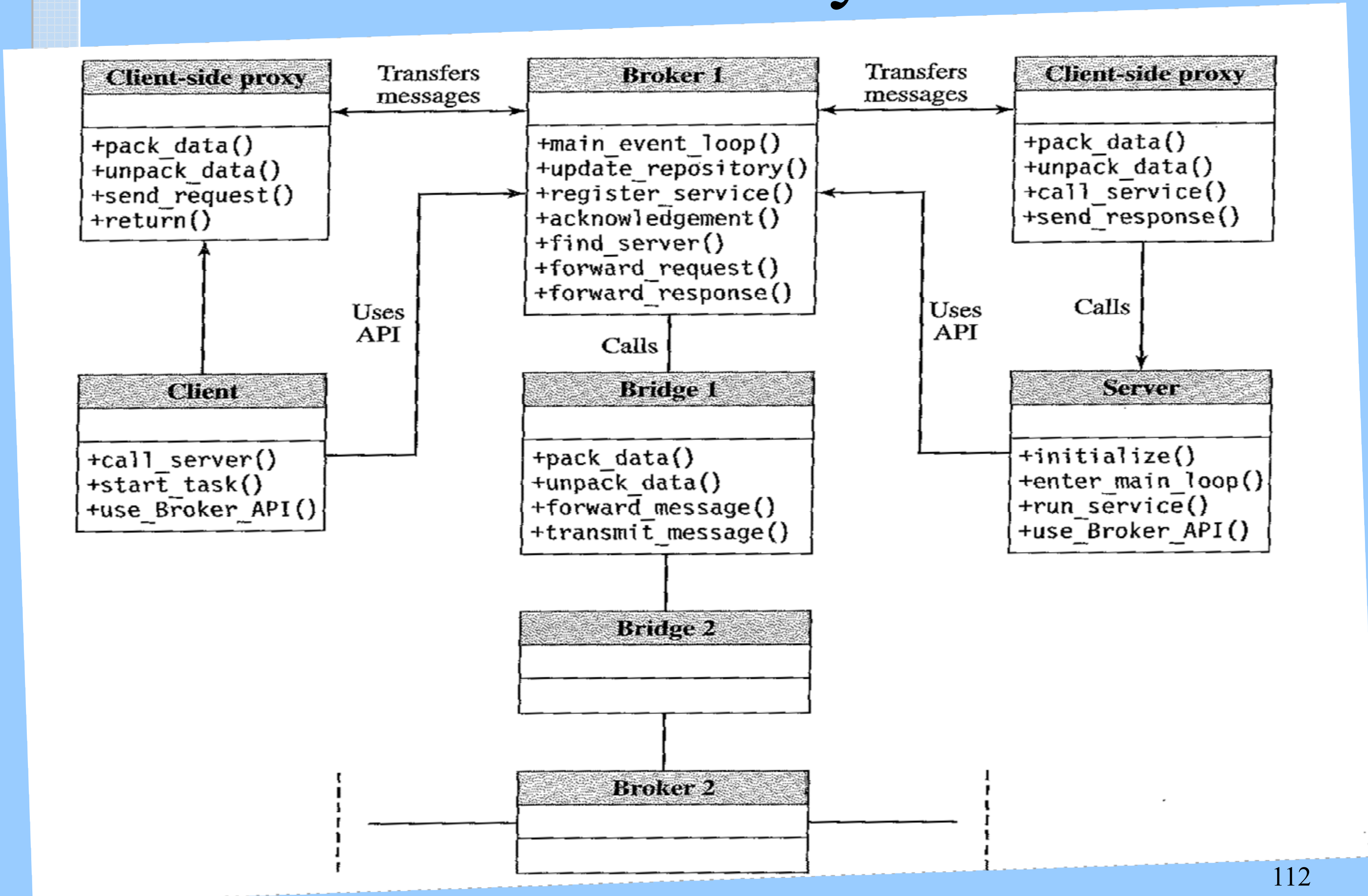
Broker Architecture Style

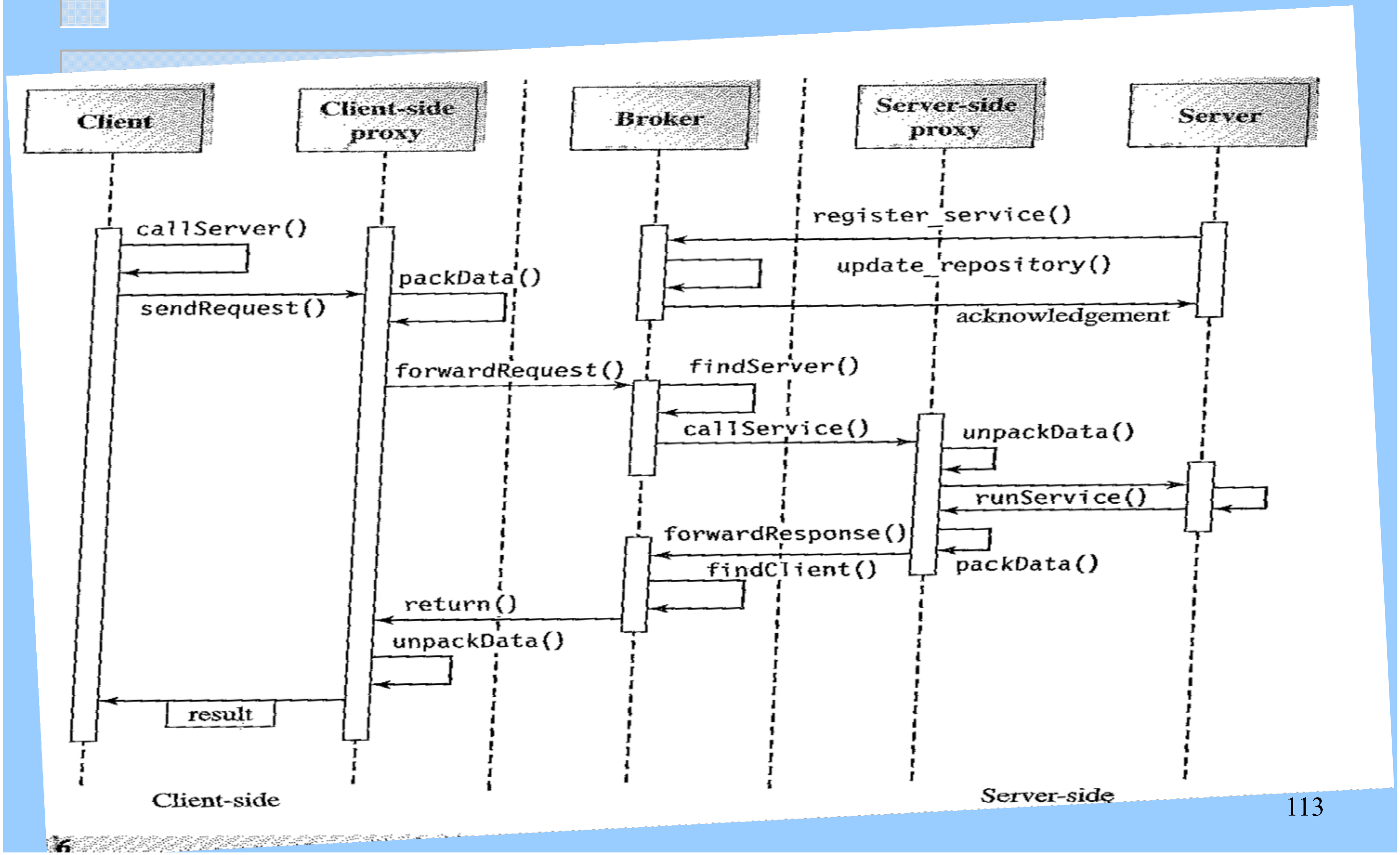


Brokers gets requests from client proxies and manages them by forwarding to server Proxies or dispatches them to other connected brokers

Broker Architecture Style



Broker Architecture Style

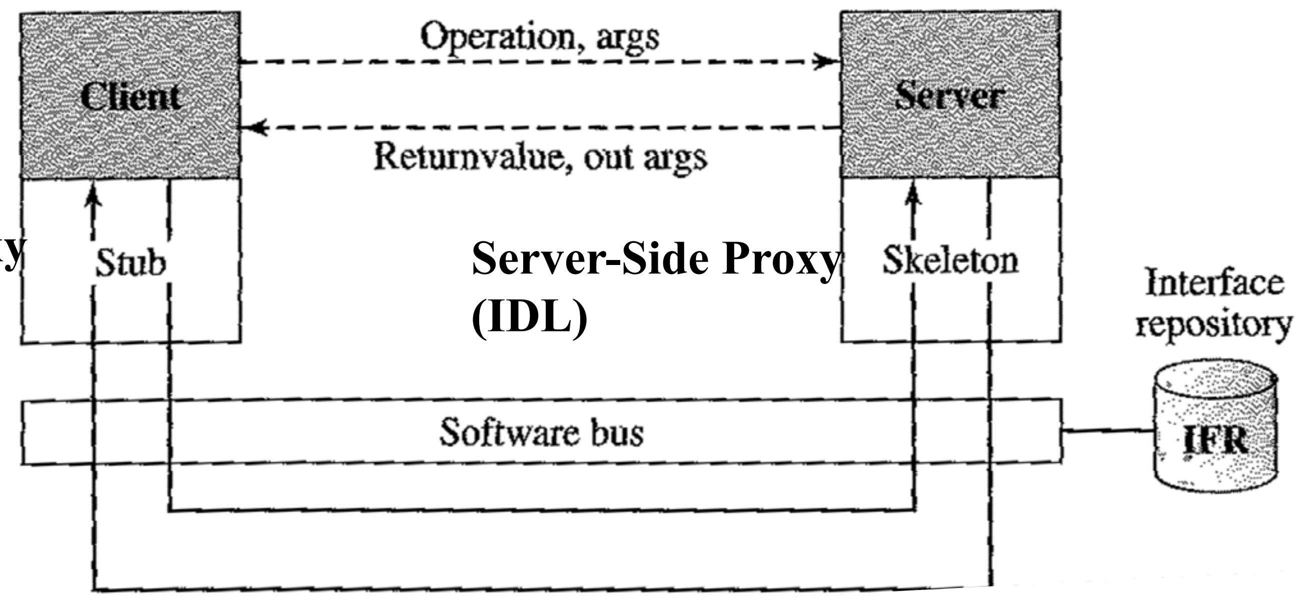


Broker Architecture Style

Advantages:

- Server component implementation and location transparency
- Changeability and extensibility
- Simplicity for clients to access server and server portability

Example: CORBA, Common Object Request Broker Architecture



Client-Side Proxy IDL

Server-Side Proxy (IDL)

Figure 10.7
CORBA architecture

The Object Request Broker (ORB) protocol provides a software bus on the network for brokering the requests from clients and the responses from servers; the protocol also supports increased interoperability with other implementations.

Example: CORBA, Common Object Request Broker Architecture

CORBA also supports the Dynamic Invocation Interface (DII), which allows CORBA clients to use another CORBA object without knowing its interface information until runtime. Dynamic Skeleton Interface (DSI) is used by ORB to issue requests to objects that are implemented independently and for which the ORB has no compile-time knowledge of their implementation. Although the dynamic approach of DII and DSI is more flexible, they are always slower than their static IDL counterpart. The dynamic remote invocation mode was the only invocation mode available in the early version of CORBA. In some cases the IDL is not available at compilation time and the stub and skeleton cannot be generated at compilation time. For example, if a COM client wants to make a CORBA request or a DCOM object wants to provide its services on CORBA, a bridge interface is required to do the conversion.

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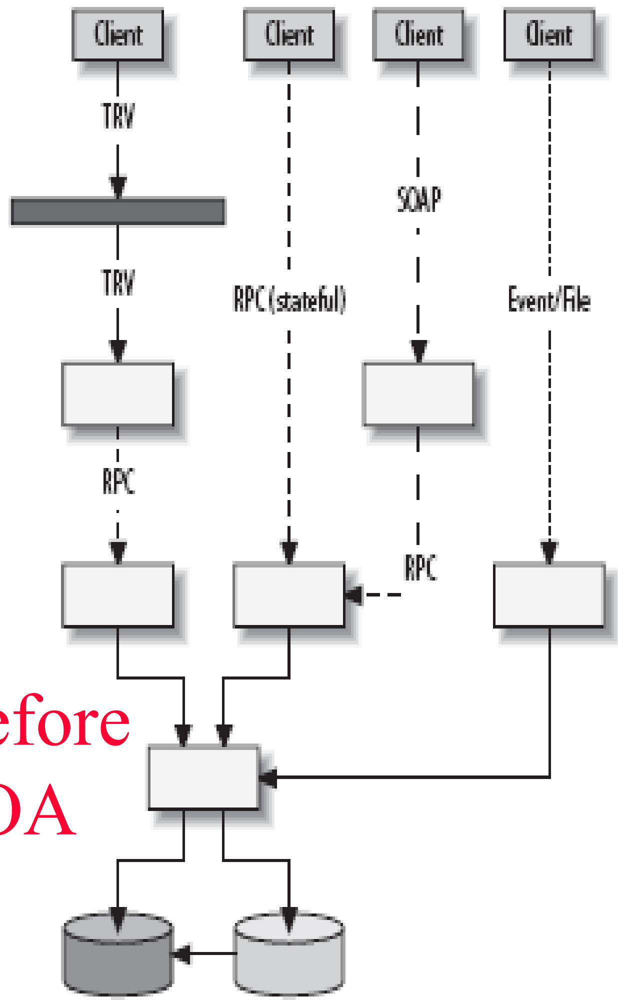
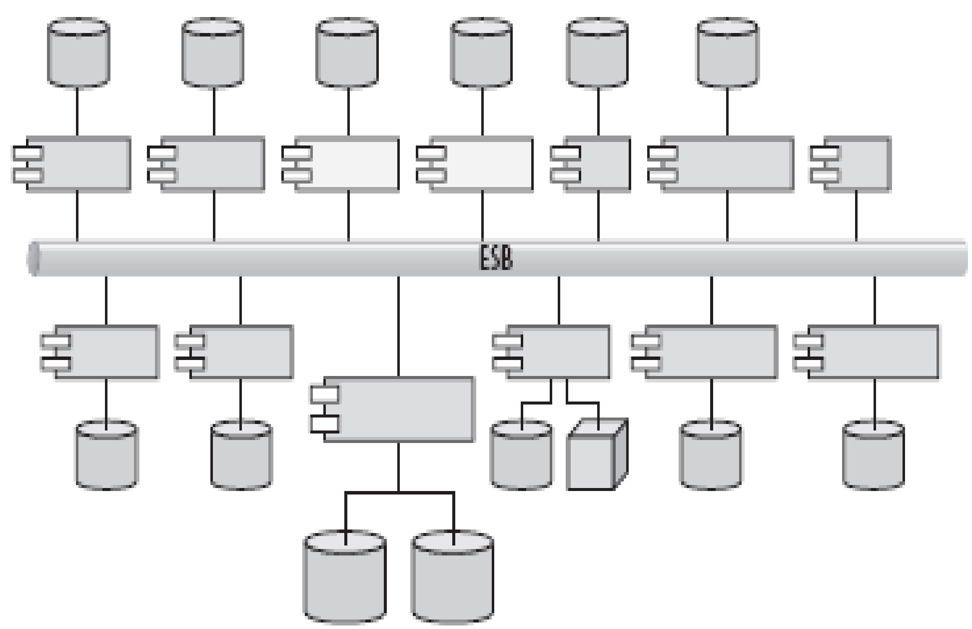
Service Oriented Architecture (SOA) Style

Makes use of an Enterprise Service Bus ESB
Used in web-based systems and distributed computing



Before SOA

The SOA Style



nodes make resources available to other participants in the system as independent services that the participants access in a standardized way using the ESB

The SP publishes/updates services using the Web Service Description Language (WSDL)
On the Universal Description Discovery and Integration (UDDI) registry.

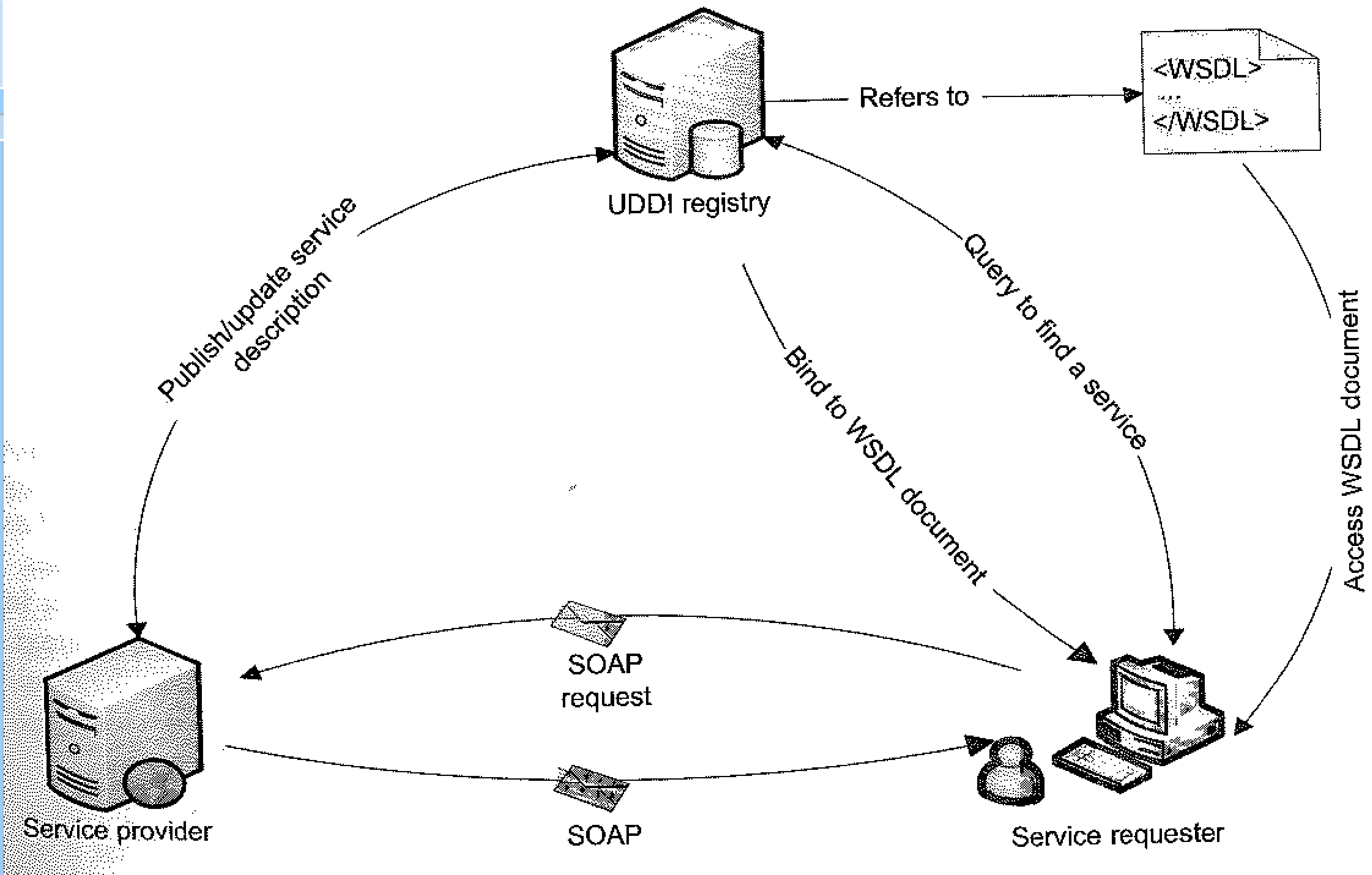
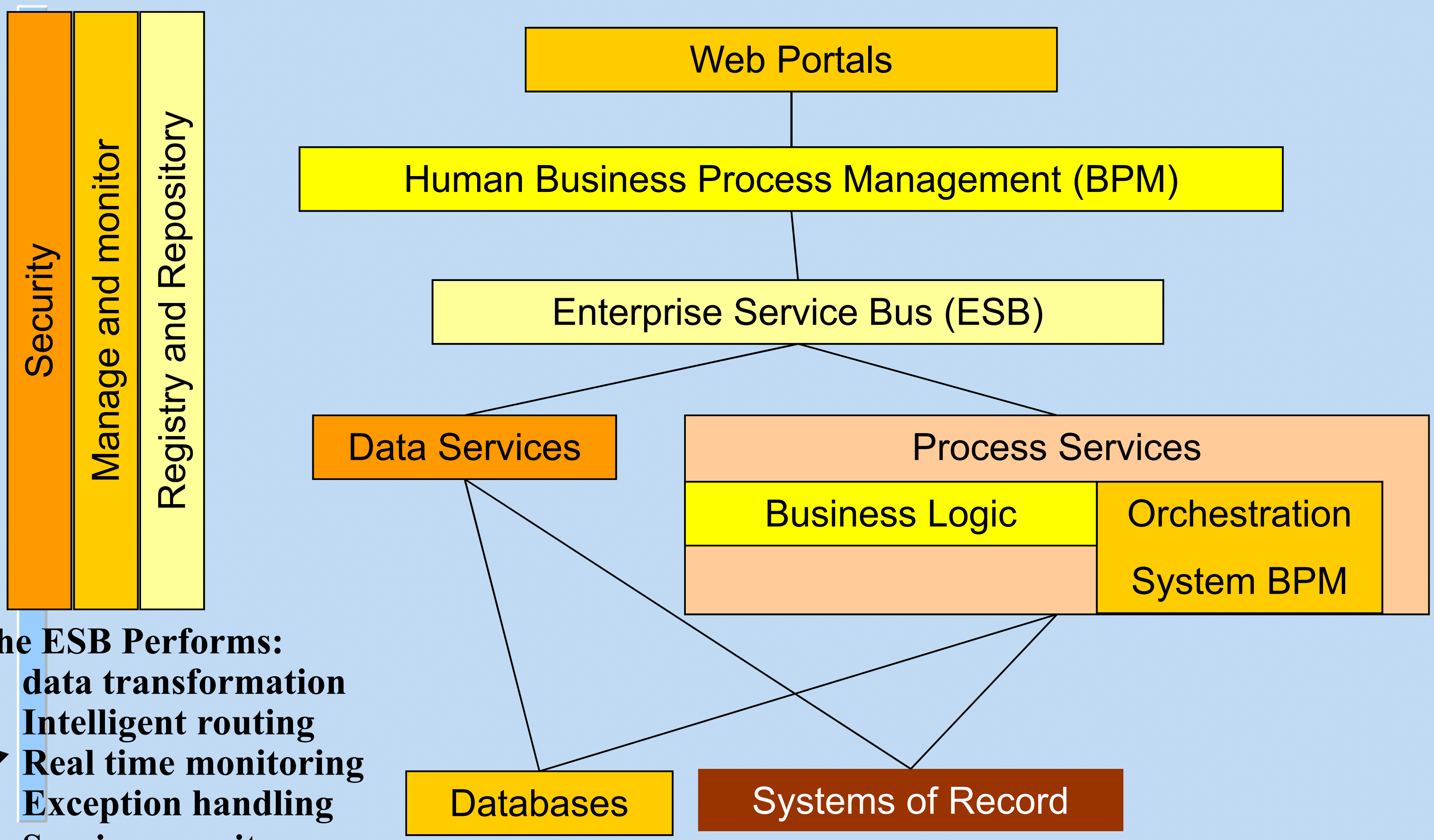


FIGURE 5.2
A simple web service interaction among provider, user, and the UDDI registry.

Service Oriented Architecture (SOA) Style: A Map of SOA Components



The ESB Performs:

- **data transformation**
- **Intelligent routing**
- **Real time monitoring**
- **Exception handling**
- **Service security**

Cloud Services Architecture

SOA supports Cloud Computing Models

The Grid of Services and Resources

Clients request the Grid Services and Resources from the Service Directory

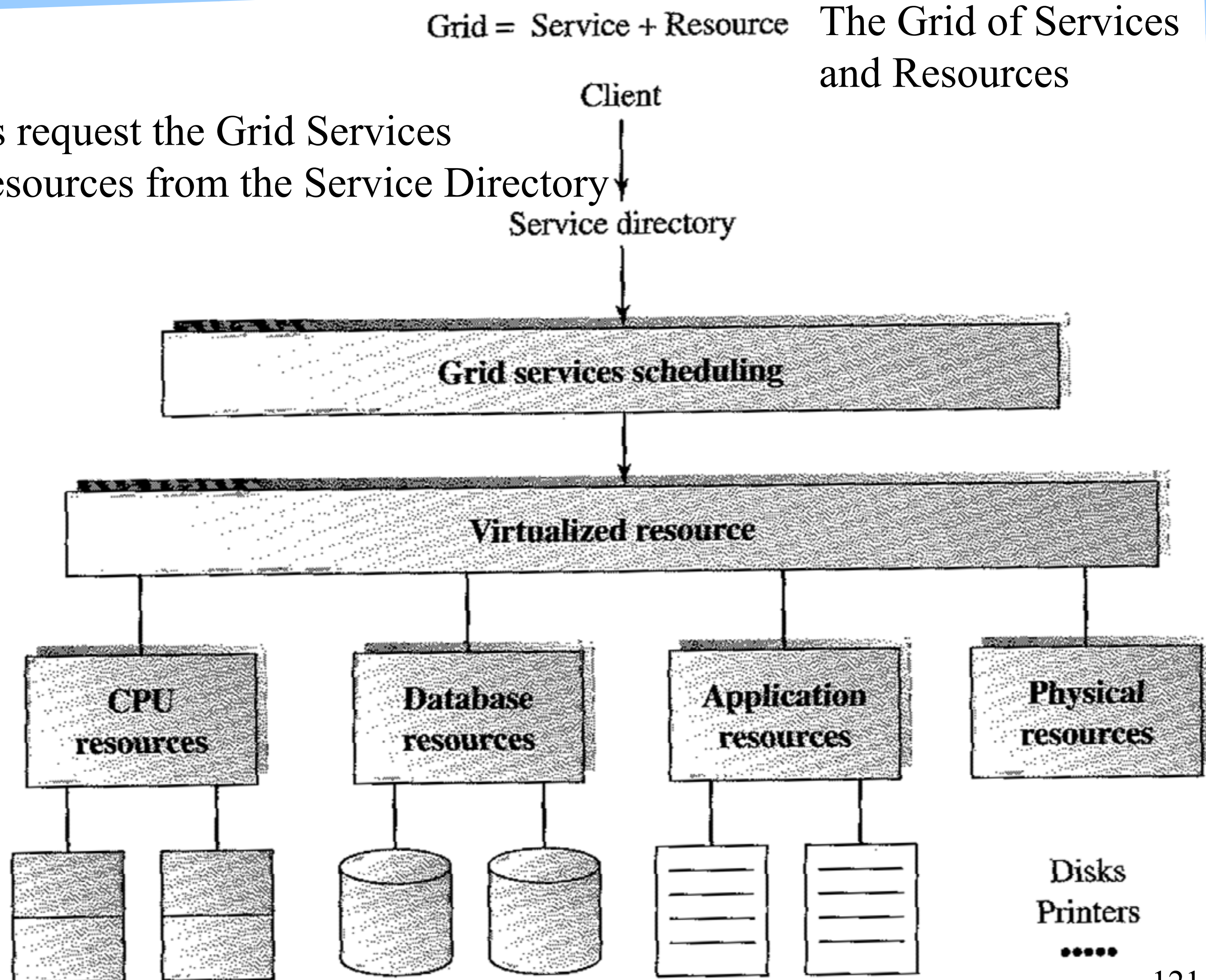
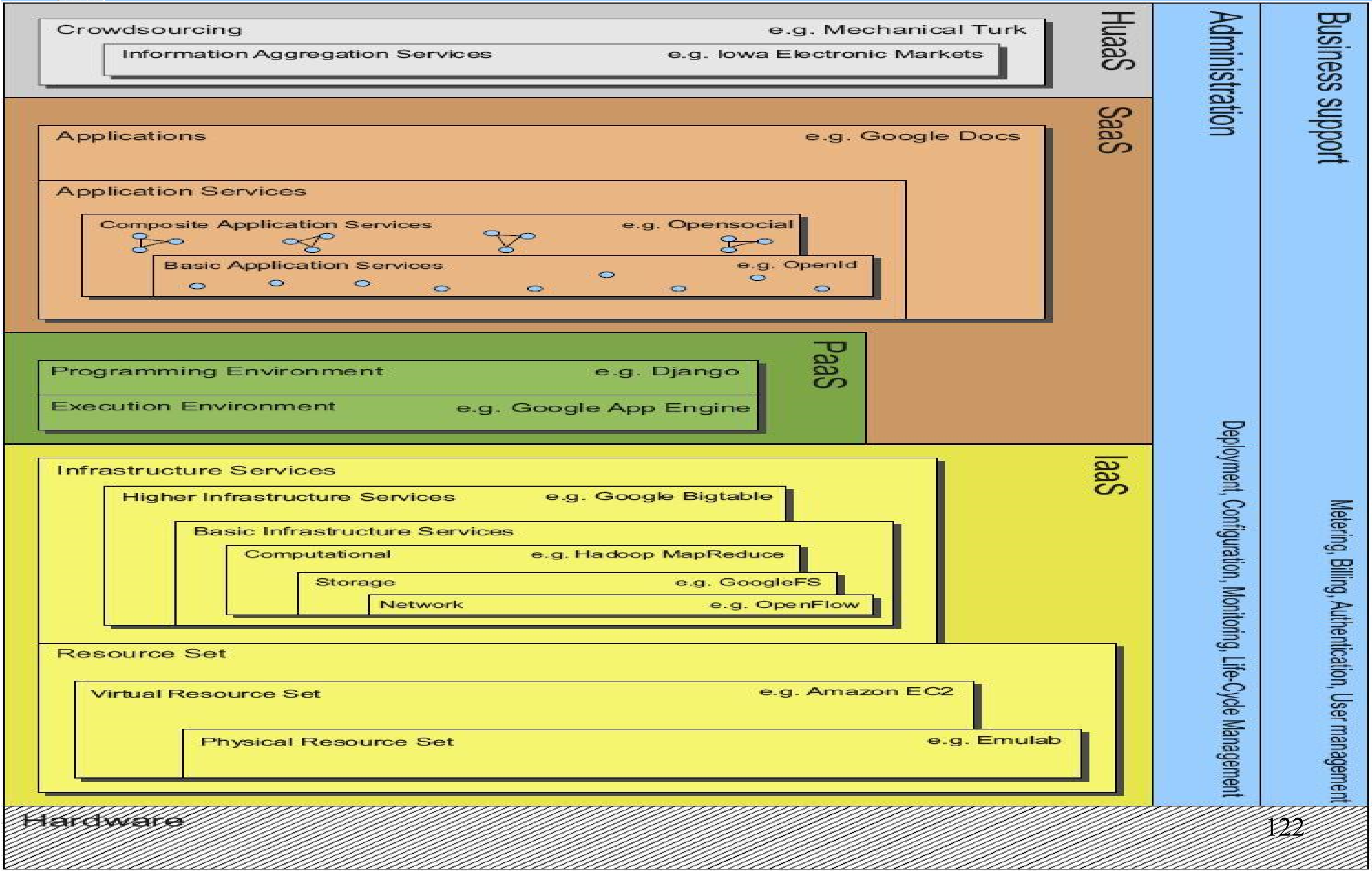


Figure 10.17

Grid service architecture

Cloud Services Architecture

Human as a service, Software as a service, Infrastructure as a service
Huaas Saas IaaS



The Internet of Things (IoT)

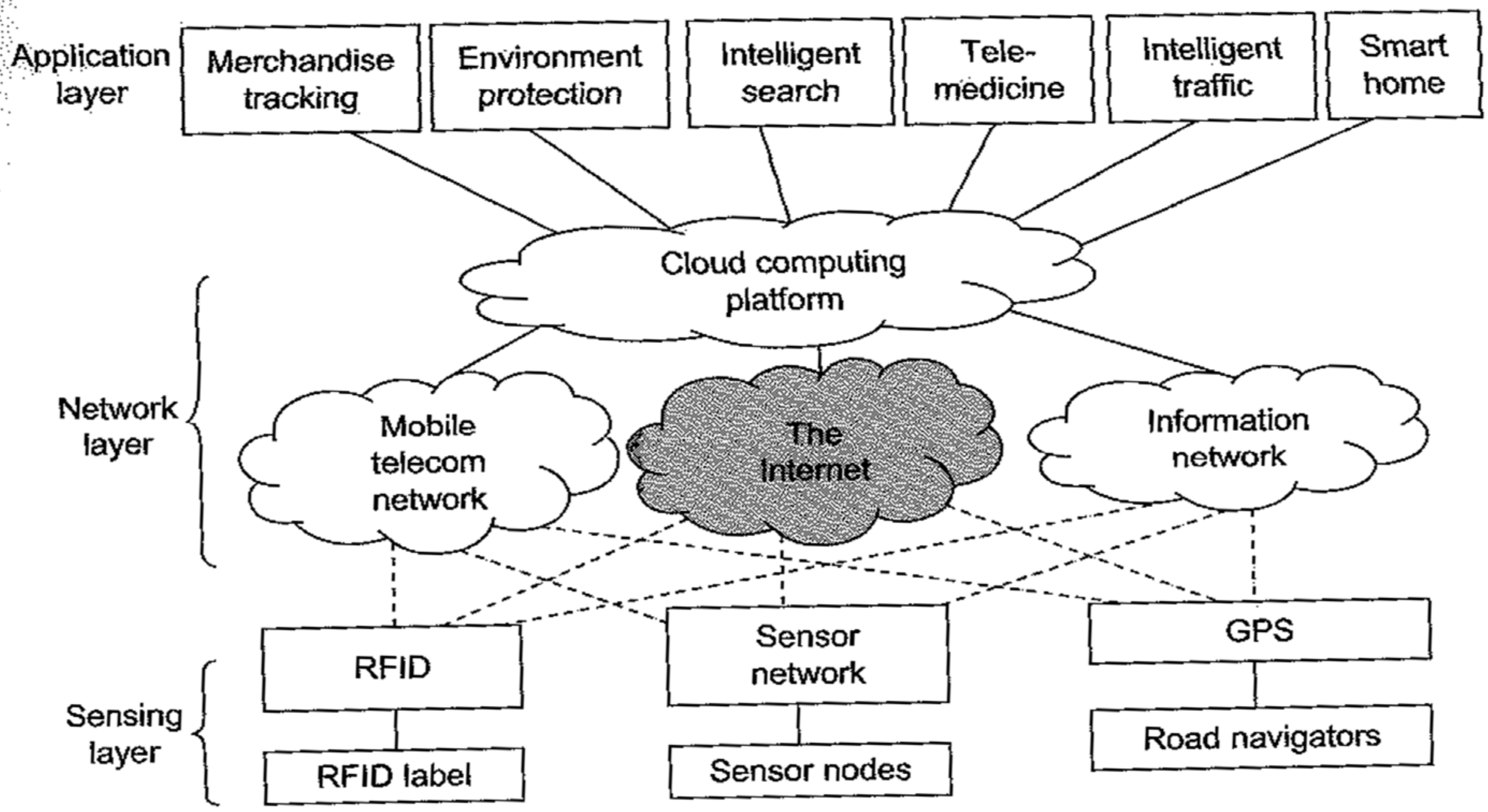


FIGURE 9.15

The architecture of an IoT consisting of sensing devices that are connected to various applications via mob networks, the Internet, and processing clouds.

Example in Telemedicine

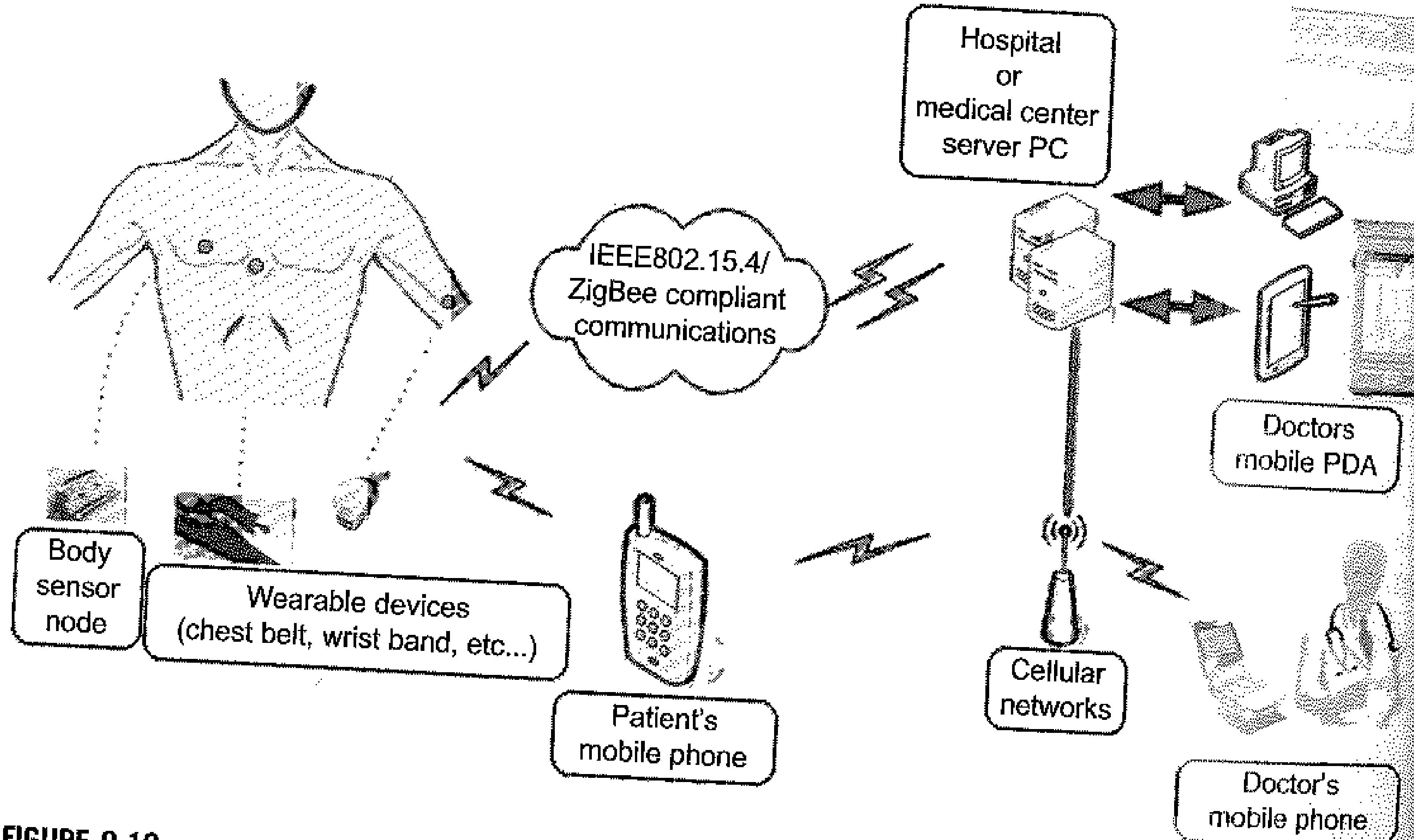


FIGURE 9.19

An example of how measured data can be transferred to doctors or medical professionals using a wireless sensor network.

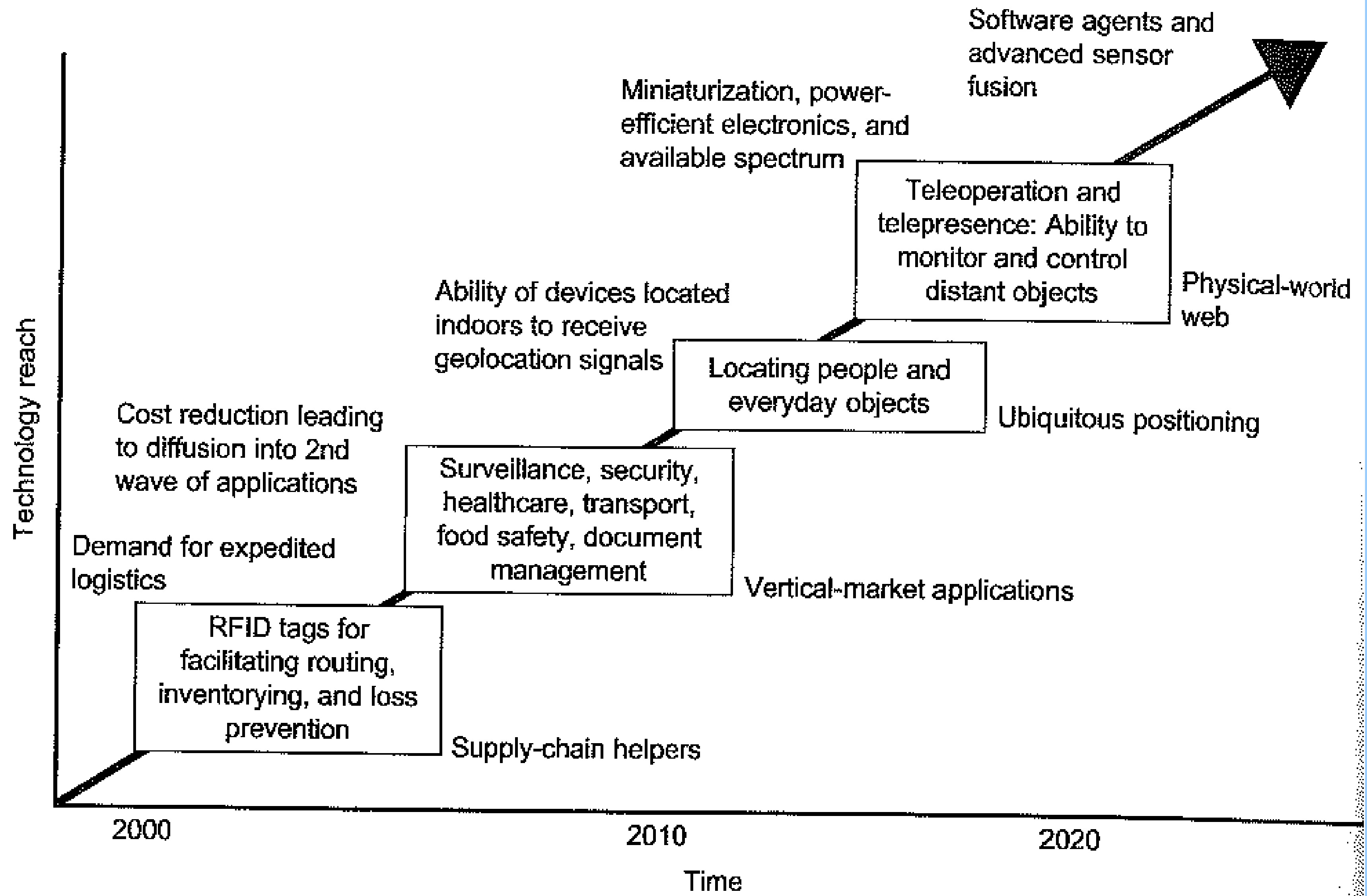


FIGURE 9.14

Technology road map of the Internet of things.

OUTLINE

- **Introduction**
- **Software Architecture Styles**
  - Independent Components
  - Virtual Machines
  - Data Flow
  - Data-Centered
  - Call-and return
  - Other Important Styles
    - Model-View-Controller
    - Broker Architecture Style
    - Service Oriented Architecture (SOA)
    - **Peer-to-Peer Architecture**

Peer-to-Peer Architecture Style

Hybrid Client-Server/Peer-to-Peer: Napster

P2P systems became part of the popular technical parlance due in large measure to the popularity of the original Napster system that appeared in 1999. Napster was designed to facilitate the sharing of digital recordings in the form of MP3 files. Napster was not, however, a true P2P system. Its design choices, however, are instructive.

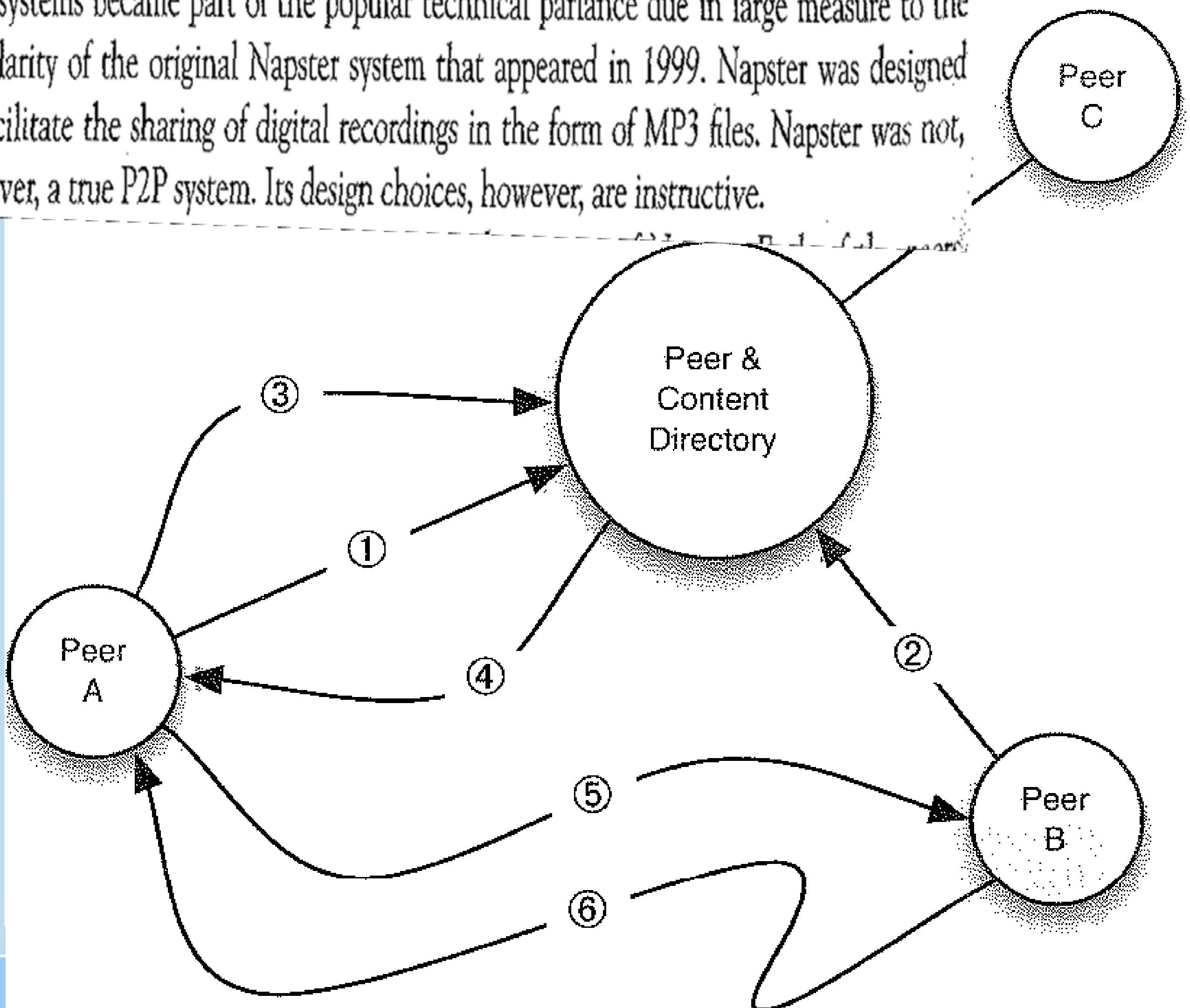
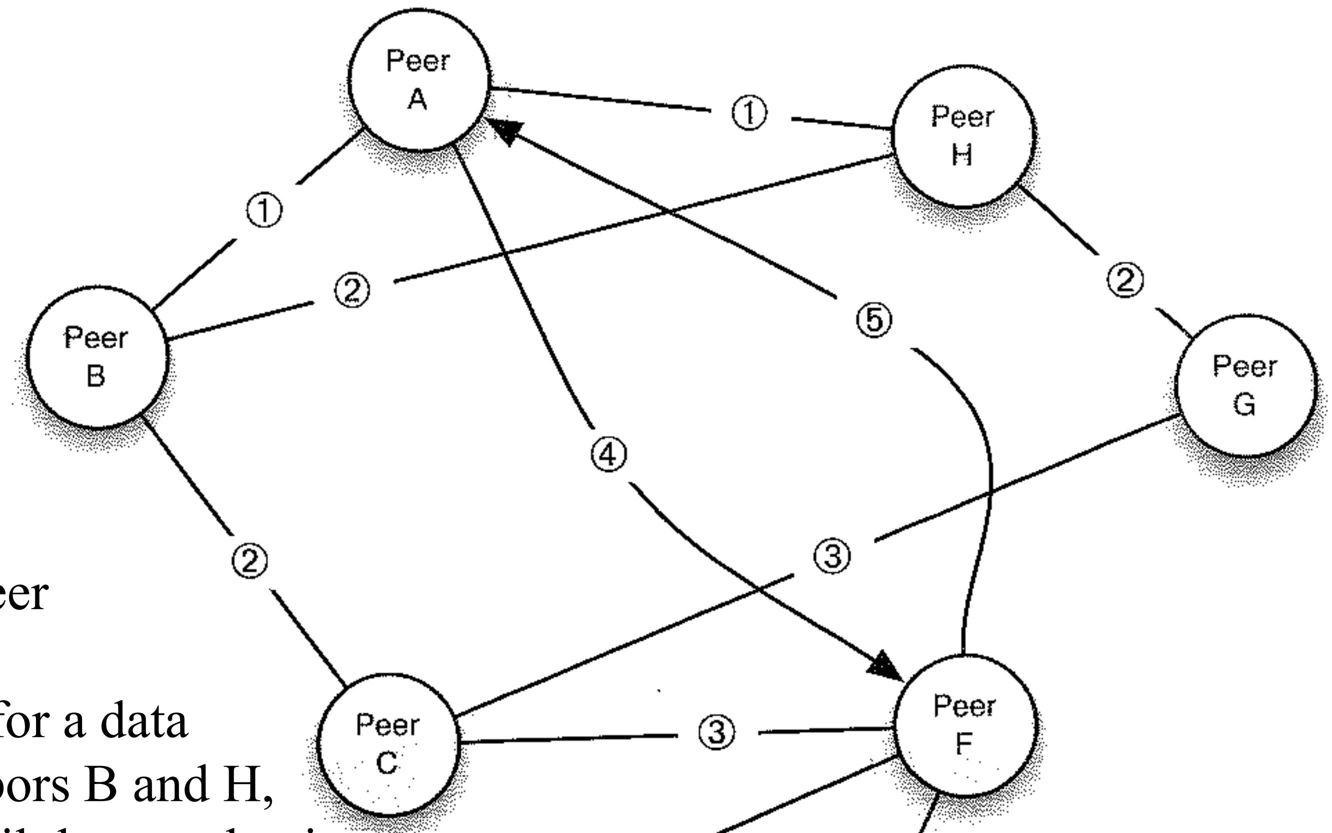


Figure 11-4. *Notional view of the operation of Napster. In steps 1 and 2, Peers A and B log in with the server. In step 3, Peer A queries the server where it can find Rondo Veneziano's "Masquerade." The location of Peer B is returned to A (step 4). In step 5, A asks B for the song, which is then transferred to A (step 6).*

Peer-to-Peer Architecture Style
The Gnutella Example

Figure 11-5.
Notional interactions between peers using the original Gnutella protocol.



- Pure Peer-to-Peer Architecture
- A sends query for a data resource to neighbors B and H, they pass it on until the peer having the resource is found or until a certain threshold of hops is reached

Peer-to-Peer Architecture Style
The Gnutella Example

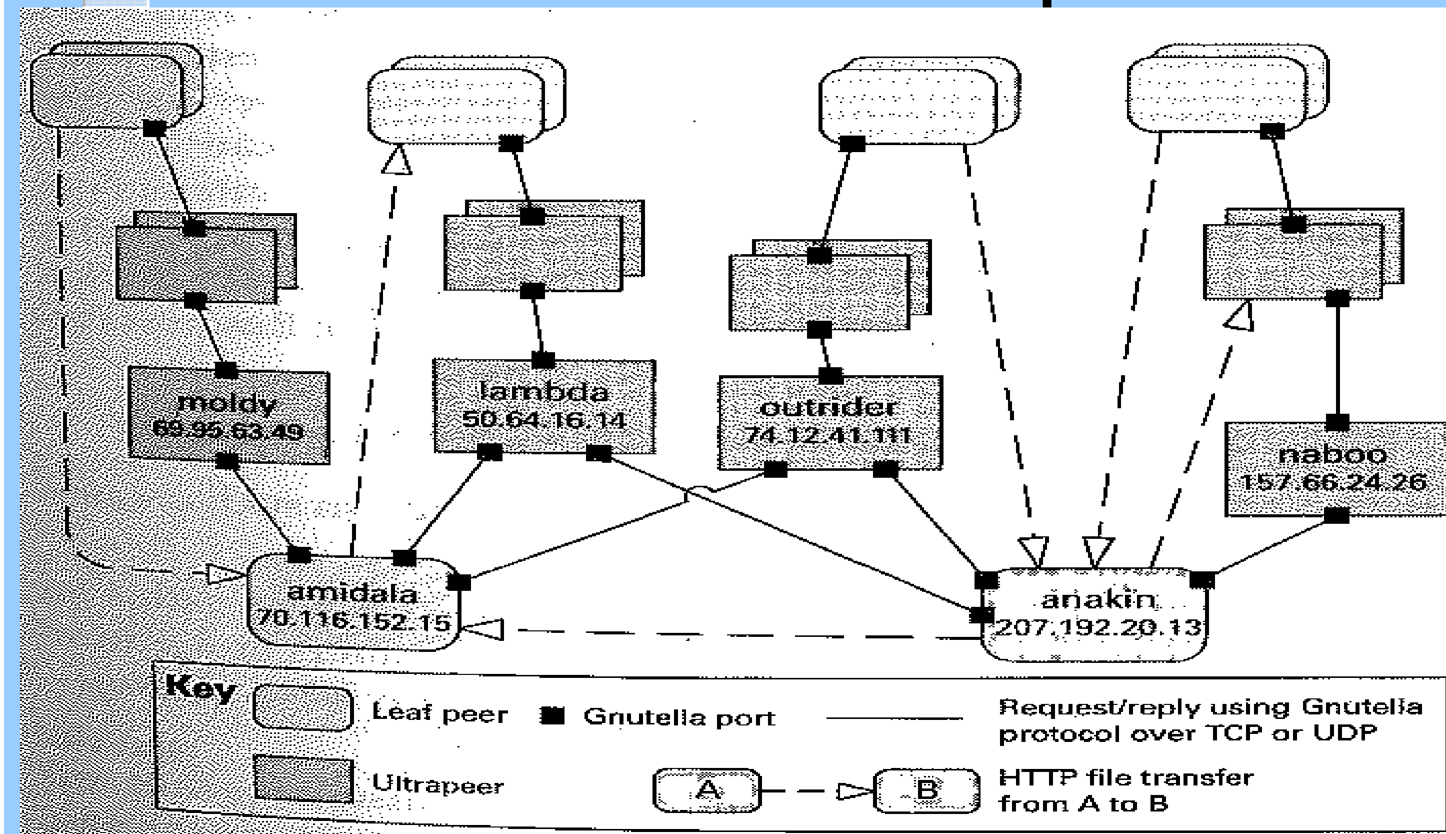
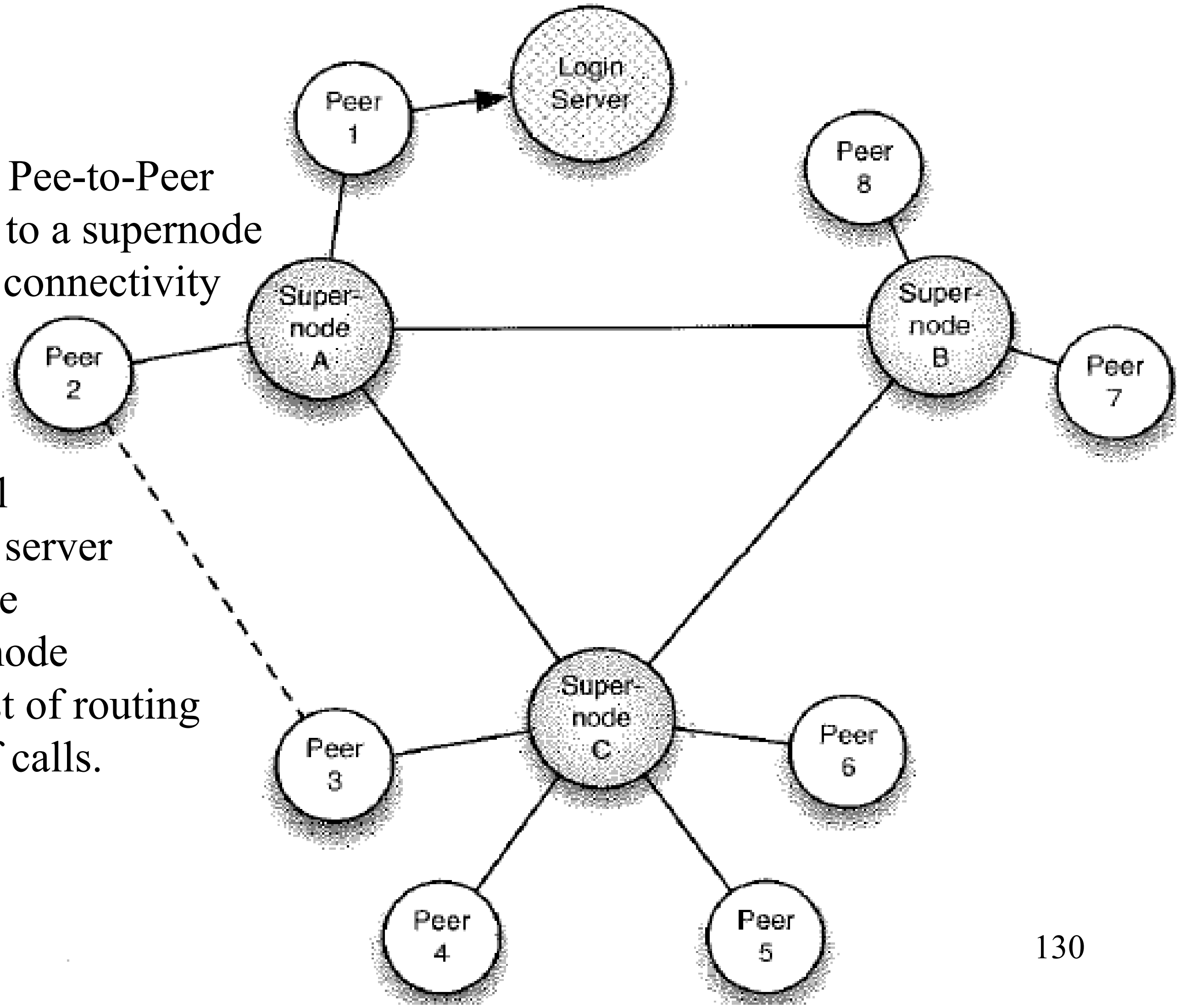


Figure 4.4
A C&C diagram of a Gnutella network, using informal notation

Recent Versions of Gnutella supports two types of peers Ultra peers and Leaf peers
Ultra peers runs in systems with fast internet connects and are responsible for request routing and responses, they are connected to a large number of other Ultra peers and leaf peers, while the leaf peers are connected to a small number of Ultra peers

Peer-to-Peer Architecture Style The Skype Example

Figure 11-6.
Notional instance of the Skype architecture.



- A mixed client-Server and Pee-to-Peer
- Skype Peers get promoted to a supernode status based on their network connectivity And machine performance
- Supernodes perform the Communication and routing of massages to establish a call
- When a user logs in to the server he is connected to a supernode
- If a peer becomes a supernode he unknowingly bears the cost of routing a potentially large number of calls.

Peer-to-Peer Architecture Style
The Skype Example

Several aspects of this architecture are noteworthy:

- A mixed client-server and peer-to-peer architecture addresses the discovery problem. The network is not flooded with requests in attempts to locate a buddy, such as would happen with the original Gnutella.
- Replication and distribution of the directories, in the form of supernodes, addresses the scalability and robustness problems encountered in Napster.

Conclusions

- An architectural style is a coordinated set of architectural constraints that restricts the roles/features of architectural elements and the allowed relationships among those elements
- Choosing a style to implement a particular system depends on several factors based on stakeholders concerns and quality attributes
- Most SW systems use a mix of architecture styles

SW Systems-Mix of Architecture Styles

- Most SW systems use a mix of architecture styles. Ex, personnel management system with a scheduling component, implemented using the independent component style, and a payroll component, using the batch sequential style.
- Choosing a style to implement a particular system depends on several factors. The technical factors concern the level of quality attributes that each style enables us to attain. EX, event-based systems-achieve very high level of evolvability, at the expense of performance and complexity. Virtual-machine style-achieve very high level of portability, at expense of performance and perhaps even testability.

SW Systems-Mix of Architecture Styles
Components of each Layer use different architecture styles

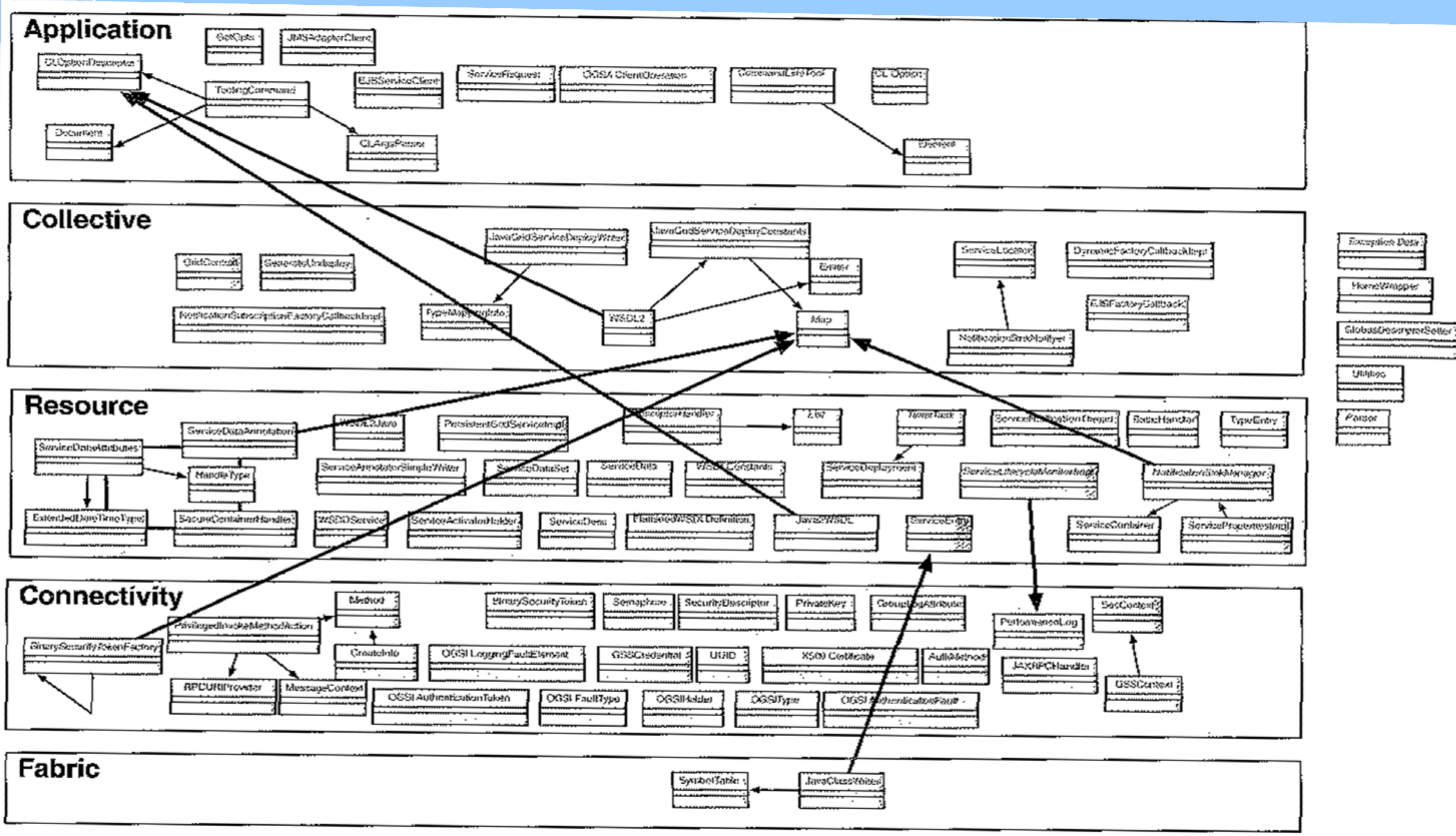


Figure 11-3. *Architecture of Globus Grid technology (recovered). (Mattmann, Medvidović et al. 2005).*

SW Systems-Mix of Architecture Styles

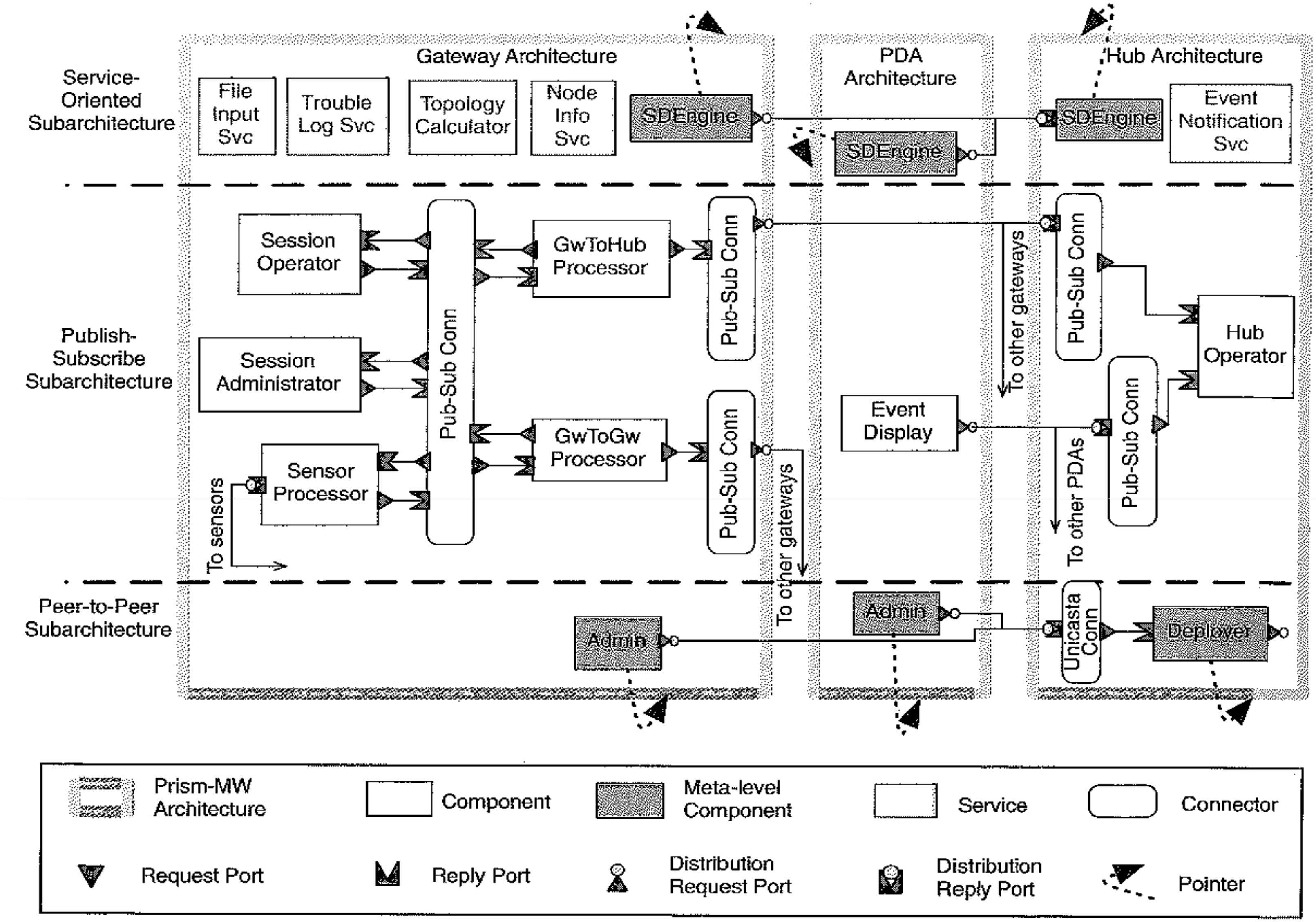


Figure 11-12. *The MIDAS wireless sensor network architecture. Diagram adapted from (Malek et al. 2007) © IEEE 2007.*

Outline

- UML Development – Overview
- The Requirements, Analysis, and Design Models
- What is Software Architecture?
  - Software Architecture Elements
- Examples
- The Process of Designing Software Architectures
  - Defining Subsystems
  - Defining Subsystem Interfaces
- Design Using Architectural Styles
  - Software Architecture Styles
  - The Attribute Driven Design (ADD)

Designing Architectures Using Styles

- One method of designing an architecture to achieve quality and functional needs is called Attribute Driven Design (ADD).
  - In ADD, architecture design is developed by taking sets of quality attribute scenario inputs and using knowledge of relationship between quality attributes and architecture styles.
  - **http://www.sei.cmu.edu/architecture/tools/define/add.cfm**
  - **http://www.sei.cmu.edu/reports/07tr005.pdf**

Attribute-Driven Design (ADD)

- A Method for producing software architecture based on process decomposition, stepwise refinement and fulfillment of attribute qualities.
- It is a recursive process where at each repetition, tactics and an architecture style or a pattern is chosen to fulfill quality attribute needs.

Attribute-Driven Design (ADD): Overview

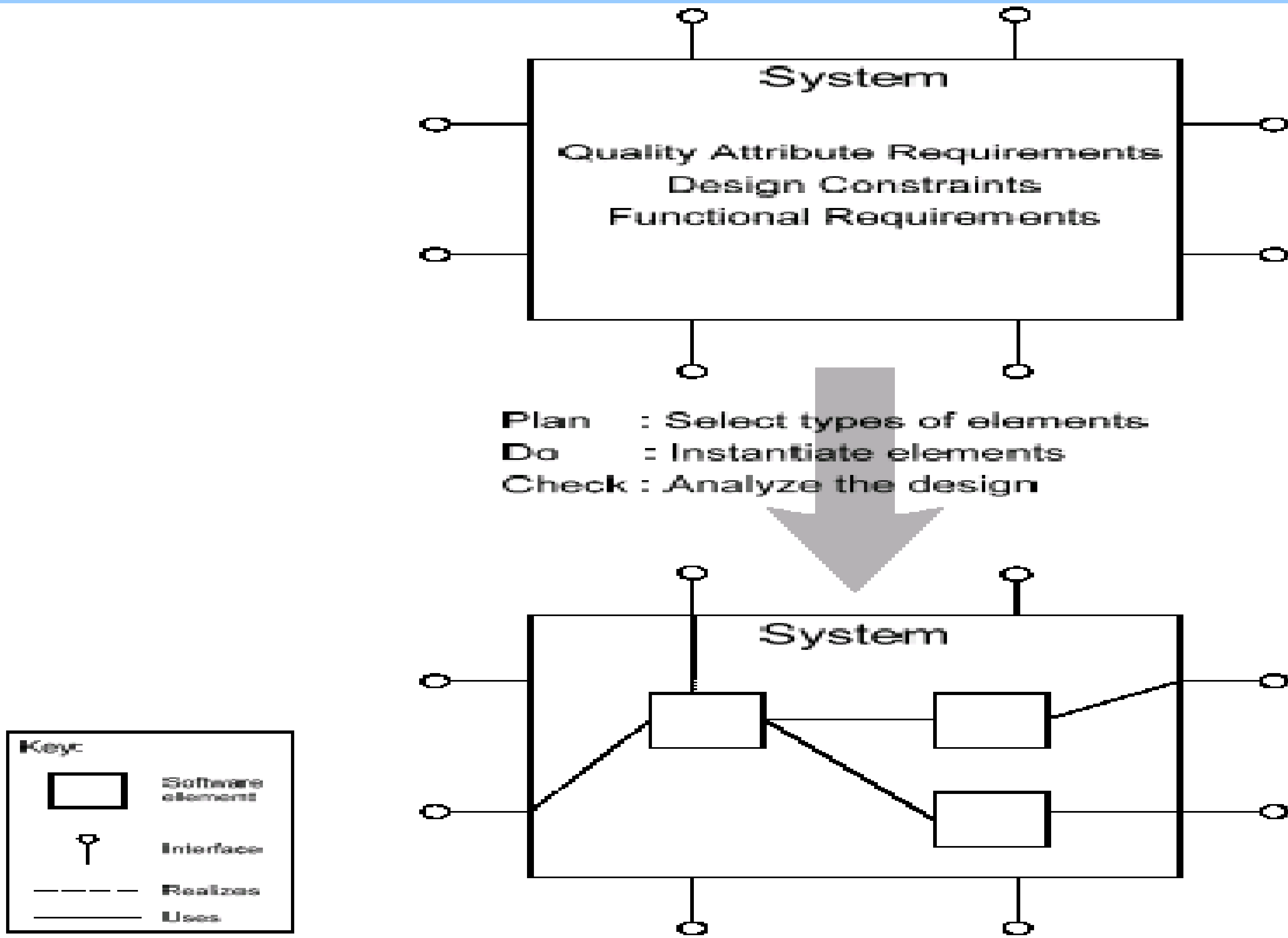


Figure 1: The ADD Plan, Do, and Check Cycle

Design the Software Architecture Using the Attribute-Driven Design (ADD) Method	
Purpose: The Attribute-Driven Design (ADD) Method is an approach to defining software architectures by basing the design process on the architecture's quality attribute requirements. It follows a recursive decomposition process where, at each stage in the decomposition, architectural tactics and patterns are chosen to satisfy a set of quality attribute scenarios.	
Role: Software architect [Software architect]	
Frequency: This activity is optional in the Inception Phase. It should occur in the first iteration of the Elaboration Phase and can recur in later iterations if substantial changes or additions to the software architecture need to be explored.	

Steps:
1. Choose the module to decompose.
2. Refine the module according to these steps:
    a. Choose the architectural drivers.
    b. Choose an architectural pattern that satisfies the architectural drivers.
    c. Instantiate modules and allocate functionality from the use cases. Represent the results using multiple views.
    d. Define interfaces of the child modules.
    e. Verify and refine the use cases and quality scenarios and make them constraints for the child modules.
3. Repeat the above steps for the next module.	

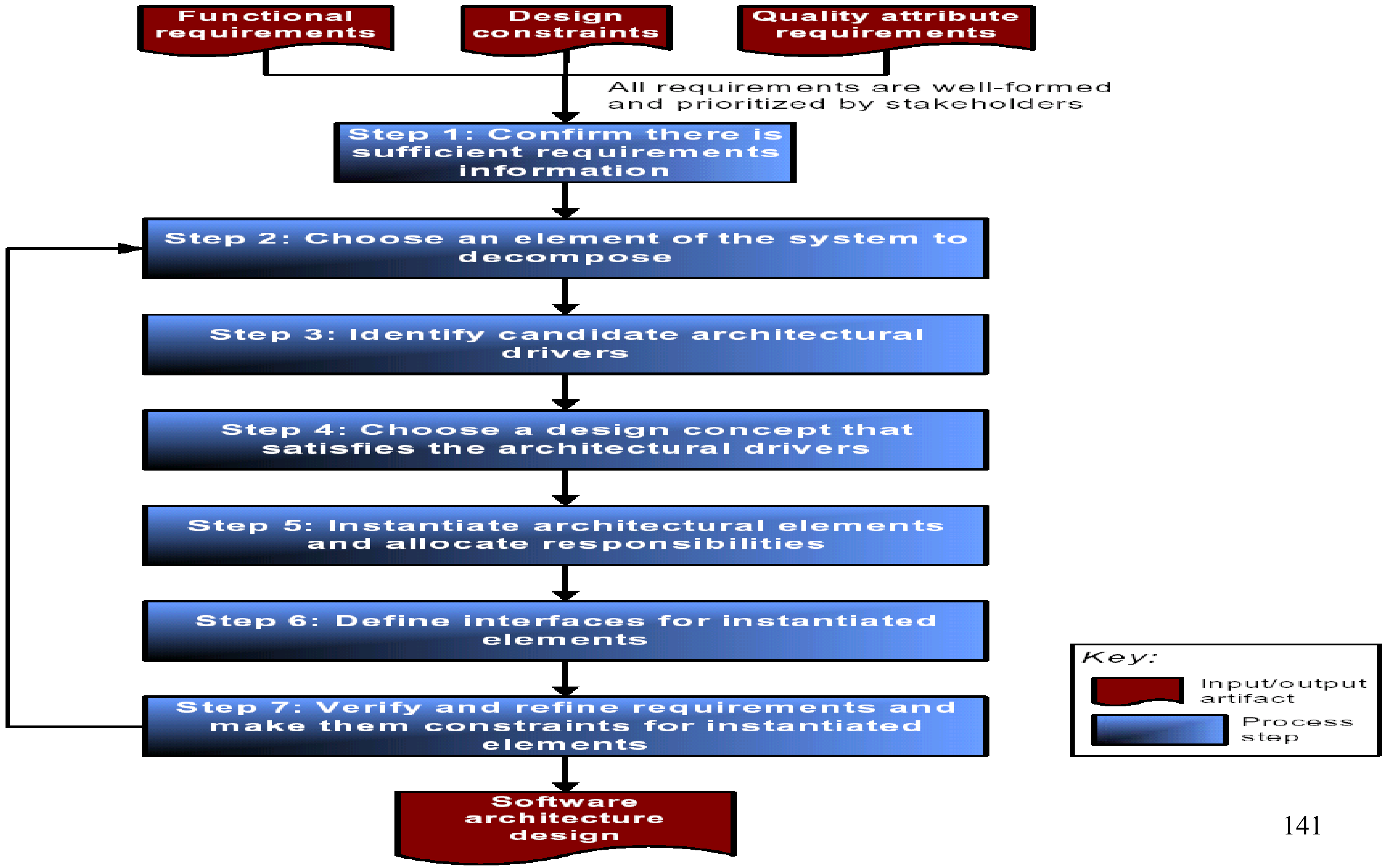
Input Artifacts: • vision [constraints] • architectural proof-of-concept [constraints] • use case model [functional requirements, quality requirements] • supplementary specifications [quality requirements]	**Resulting Artifacts:** • software architecture document [decomposition of the architecture expressed in module, concurrency, and deployment views]
Tool Mentors: None	
More Information: [Bass 03]	

Workflow Details:
• Analysis and Design
    • Define a Candidate Architecture
    • Perform Architectural Synthesis	

Figure 9: The ADD Method as a RUP Activity[6]

Updated ADD Steps

http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA460414



Step 1: Confirm There Is Sufficient Requirements Information

WHAT DOES STEP 1 INVOLVE?

1. Make sure that the system's stakeholders have prioritized the requirements according to business and mission goals.
2. You should also confirm that there is sufficient information about the quality attribute requirements to proceed.

Step 2: Choose an Element of the System to Decompose

In this second step, you choose which element of the system will be the design focus in subsequent steps. You can arrive at this step in one of two ways:

1. You reach Step 2 for the first time. The only element you can decompose is the system itself. By default, all requirements are assigned to that system.
2. You are refining a partially designed system and have visited Step 2 before.4 In this case, the system has been partitioned into two or more elements, and requirements have been assigned to those elements. You must choose one of these elements as the focus of subsequent steps.

Step 3: Identify Candidate Architectural Drivers

WHAT DOES STEP 3 INVOLVE?

At this point, you have chosen an element of the system to decompose, and stakeholders have prioritized any requirements that affect that element.

During this step, you'll rank these same requirements a second time based on their relative impact on the architecture.

This second ranking can be as simple as assigning "high impact," "medium impact," or "low impact" to each requirement.

Given that the stakeholders ranked the requirements initially, the second ranking based on architecture impact has the effect of partially ordering the requirements into a number of groups. If you use simple high/medium/low rankings, the groups would be (H,H) (H,M) (H,L) (M,H) (M,M) (M,L) (L,H) (L,M) (L,L)

The first letter in each group indicates the importance of requirements to stakeholders, the second letter in each group indicates the potential impact of requirements on the architecture.

From these pairs, you should choose several (five or six) high-priority requirements as the focus for subsequent steps in the design process.

Step 4: Choose a Design Concept that Satisfies the Architectural Drivers

- In Step 4, you should choose the major types of elements that will appear in the architecture and the types of relationships among them.
- Design constraints and quality attribute requirements (which are candidate architectural drivers) are used to determine the types of elements, relationships, and their interactions.
- The process uses architecture patterns or styles

Step 4: Choose a Design Concept that Satisfies the Architectural Drivers (cont.)

- Choose architecture patterns or styles that together come closest to satisfying the architectural drivers

Table 1: Structure of Matrix to Evaluate Candidate Patterns

	Pattern 1		Pattern 2		. . .	Pattern n	
	Pros	Cons	Pros	Cons		Pros	Cons
Architectural driver 1							
Architectural driver 2							
. . .							
Architectural driver n							

Step 4: Example

Mobile Robots example (to be discussed at the end)

Architecture	Control Loop	Layers	Blackboard
Drivers			
Task coordination	+-	-	+
Dealing with uncertainty	-	+-	+
Fault tolerance	+-	+-	+-
Safety	+-	+-	+
Performance	+-	-	+
Flexibility	-	-	+

Step 4: Major Design Decisions

- Decide on an overall design concept that includes the major types of elements that will appear in the architecture and the types of relationships among them.
- Identify some of the functionality associated with the different types of elements
- Decide on the nature and type of communications (synchronous/asynchronous) among the various types of elements (both internal software elements and external entities)

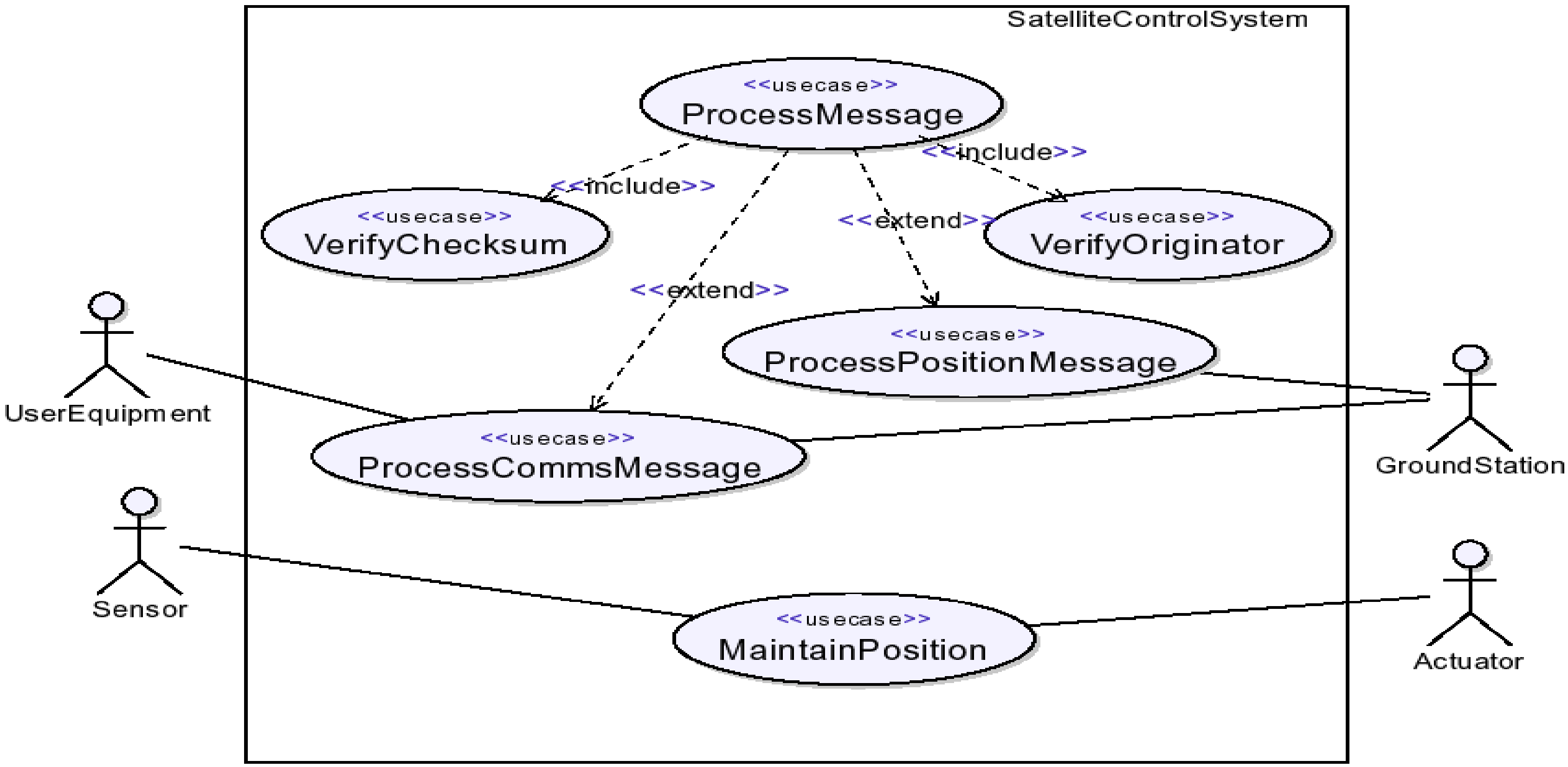
Step 5: Instantiate Architectural Elements and Allocate Responsibilities

- In Step 5, you instantiate the various types of software elements you chose in the previous step. Instantiated elements are assigned responsibilities from the functional requirements (captured in use-cases) according to their types
- At the end of Step 5, every functional requirement (in every use-case) associated with the parent element must be represented by a sequence of responsibilities within the child elements.
- This exercise might reveal new responsibilities (e.g., resource management). In addition, you might discover new element types and wish to create new instances of them.

A Simple Example of Software Architecture Using UML2

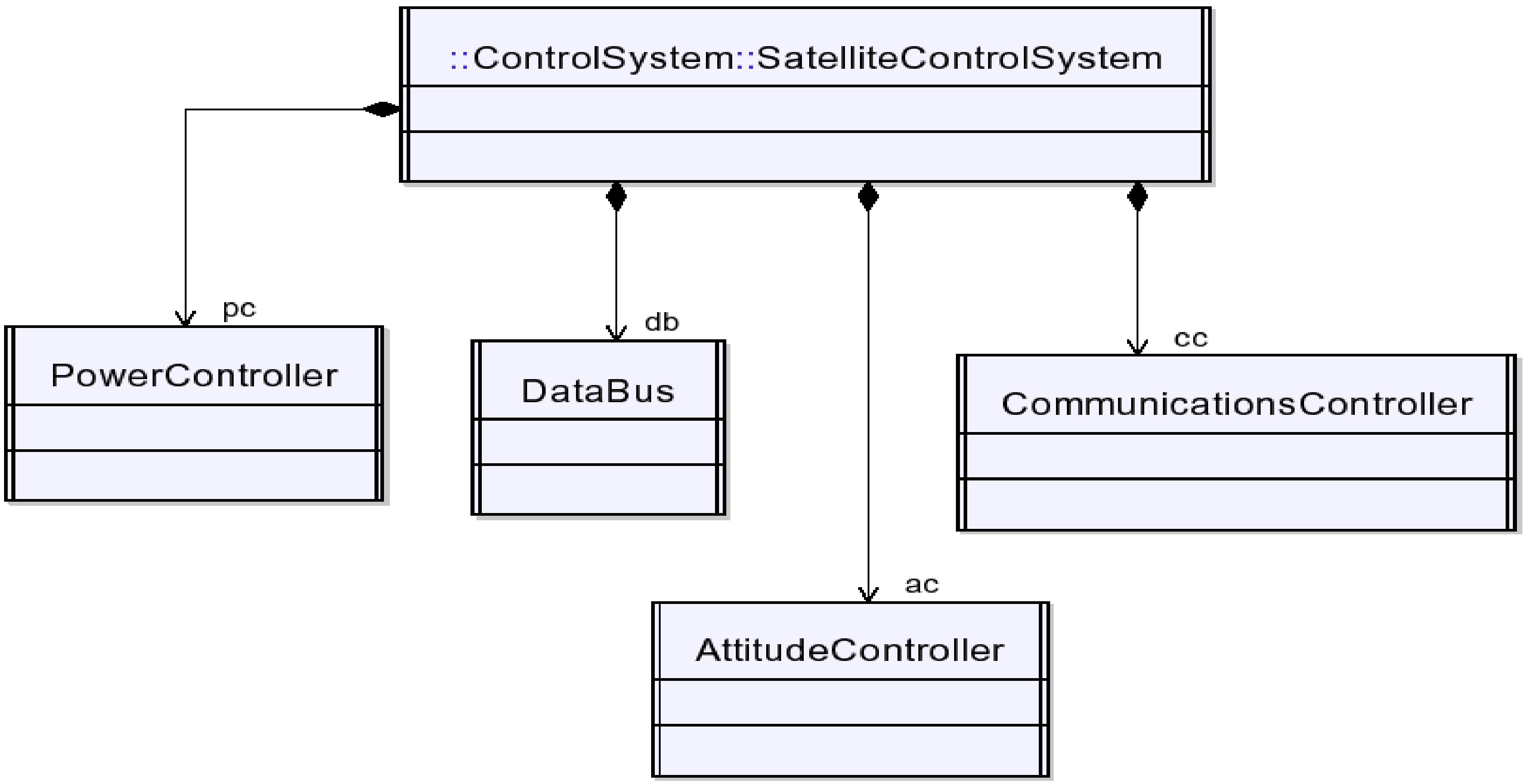
EXAMPLE: SATELLITE CONTROL SYSTEM

Use-Case Diagram



A Simple Example of Software Architecture Using UML2

SATELLITE CONTROL SYSTEM Architecture composition



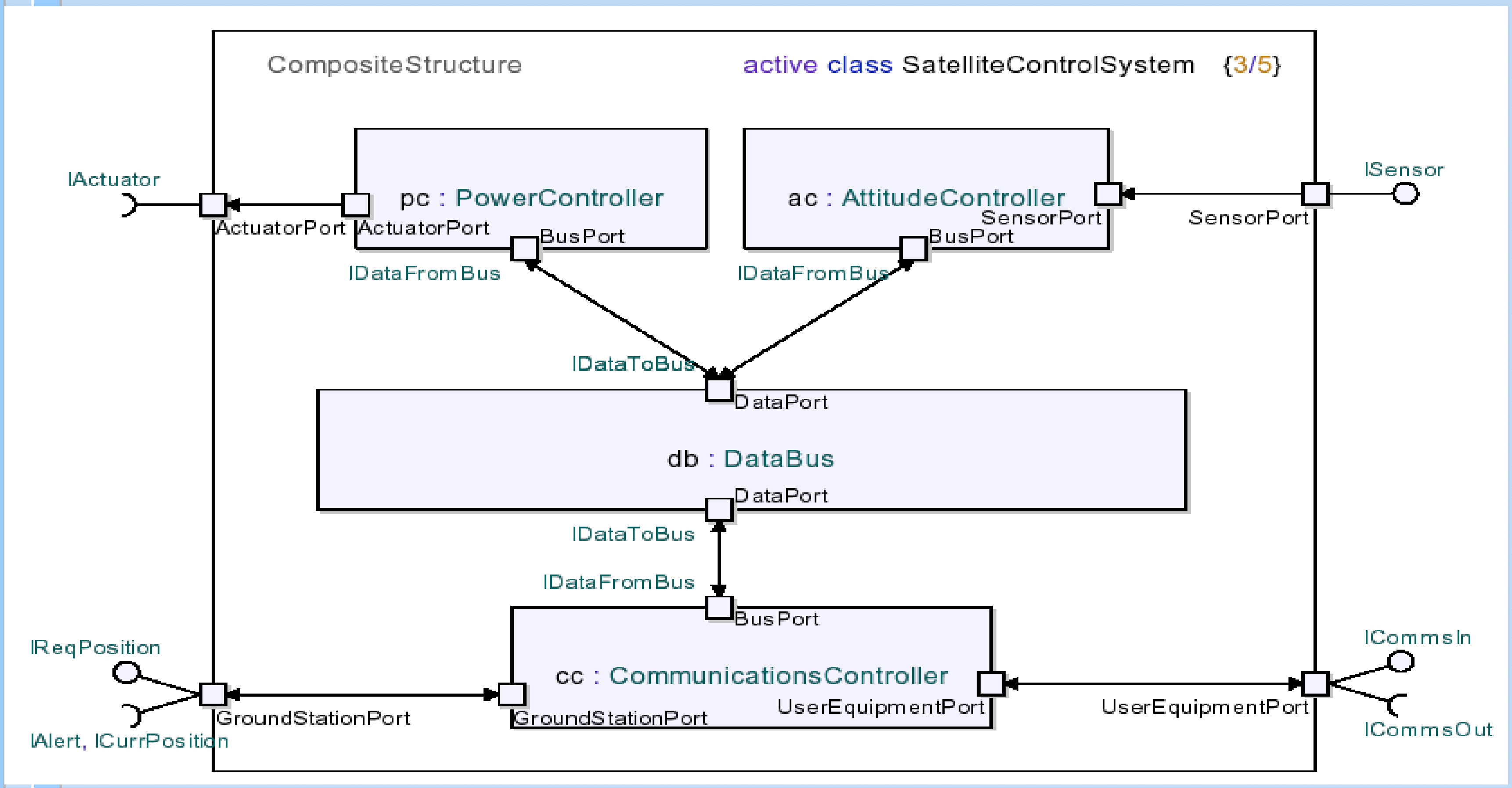
Step 6: Define Interfaces for Instantiated Elements

WHAT DOES STEP 6 INVOLVE?

- In step 6, you define the services and properties required and provided by the software elements in our design. In ADD, these services and properties are referred to as the element's interface.
- Interfaces describe the *PROVIDES* and *REQUIRES* assumptions that software elements make about one another.

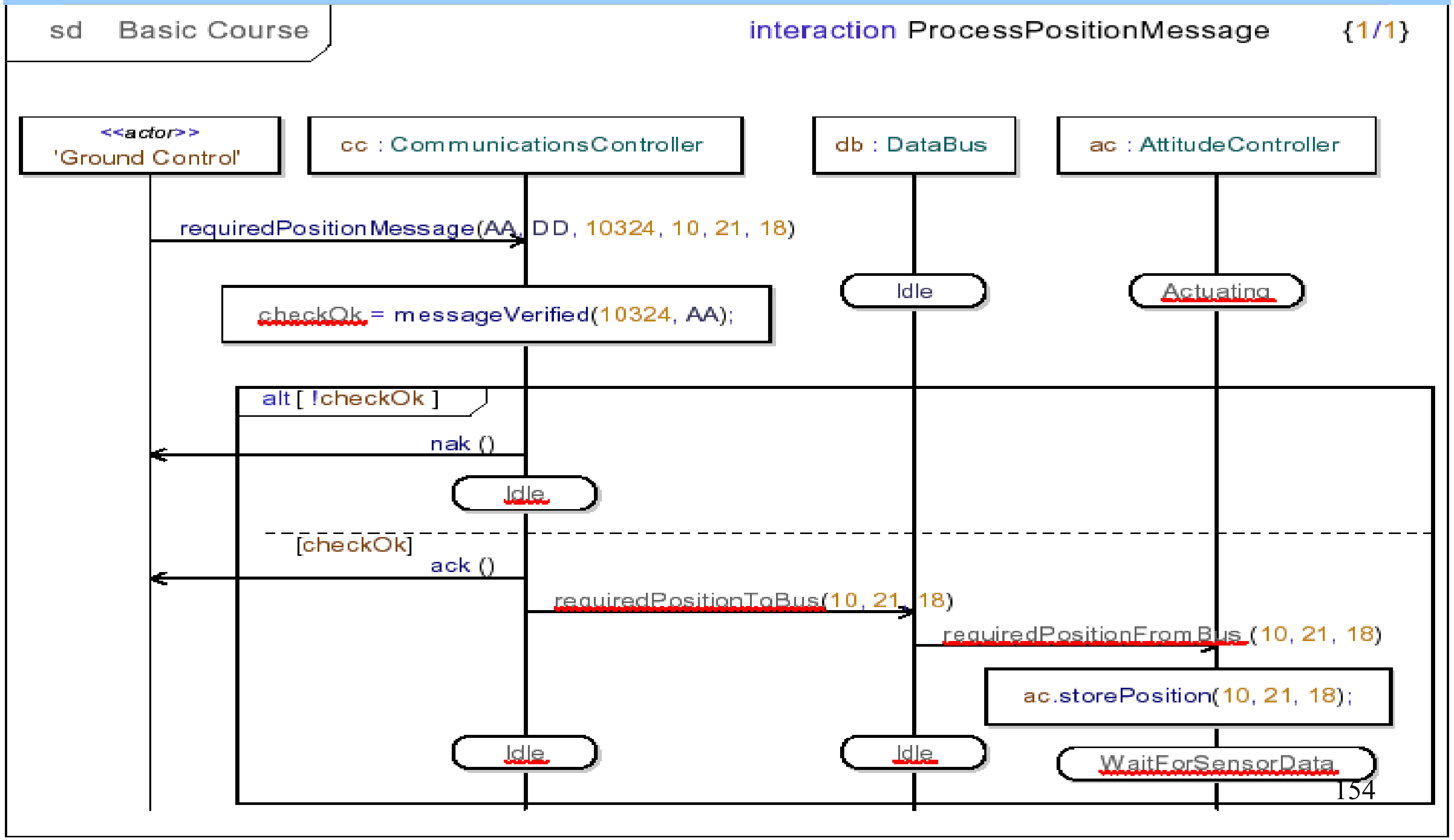
A Simple Example of Software Architecture Using UML2

SATELLITE CONTROL SYSTEM Architecture Structure



A Simple Example of Software Architecture Using UML2

SATELLITE CONTROL SYSTEM Architectural Behavior



Step 6: Major Design Decisions

Decisions will likely involve several of the following:

- The external interfaces to the system
- The interfaces between high-level system partitions, or subsystems
- The interfaces between applications within high-level system partitions
- The interfaces to the infrastructure (reusable components or elements, middleware, run-time environment, etc.)

Step 7: Verify and Refine Requirements and Make Them Constraints for Instantiated Elements

WHAT DOES STEP 7 INVOLVE?

- In Step 7, you verify that the element decomposition thus far meets functional requirements, quality attribute requirements, and design constraints. You also prepare child elements for further decomposition.
- Refine quality attribute requirements for individual child elements as necessary (e.g., child elements that must have fault-tolerance, high performance, high security, etc.)

Example 1 Mobile Robotics System

Overview

– controls manned, partially-manned, or unmanned vehicle--car, submarine, space vehicle, etc.

– System performs tasks that involve planning and dealing with obstacles and other external factors.

– System has sensors and actuators and real-time performance constraints.

Mobile Robotics System Requirements (Candidate Architecture Drivers)

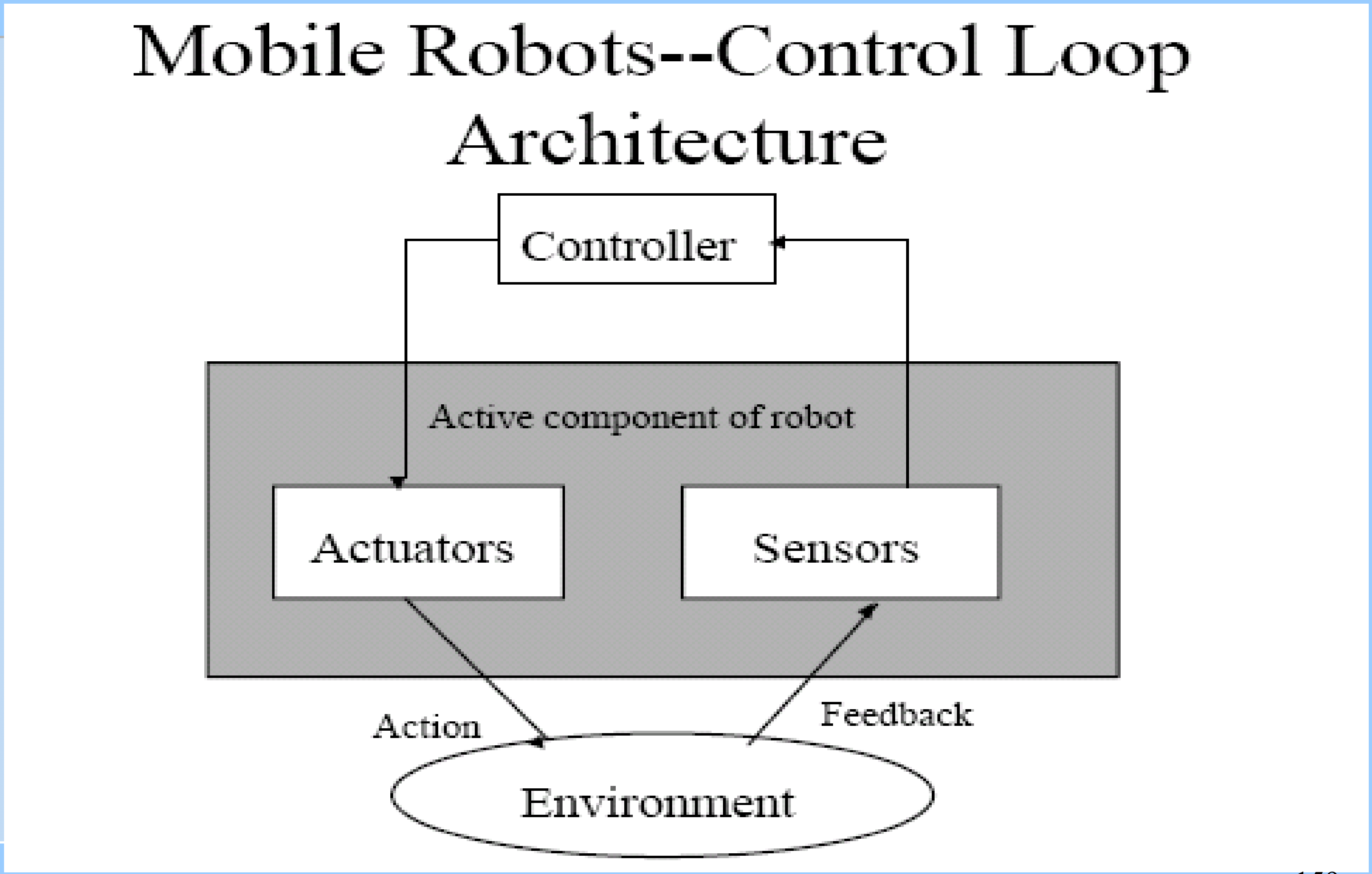
Req 1: System must provide both *deliberative* and *reactive* behavior.

Req 2: System must deal with *uncertainty*.

Req. 3 System must deal with *dangers* in robot’s operation and environment.

Req. 4: System must be *flexible* with respect to experimentation and reconfiguration of robot and modification of tasks.

Choose an architecture style



Control Loop Architecture

Evaluate Control Loop Architecture--Strengths and Weaknesses w.r.t candidate architecture drivers

- Req 1--deliberative and reactive behavior
  - advantage-simplicity
  - drawback-dealing with unpredictability
    - feedback loops assumes continuous changes in environment and continuous reaction
    - robots are often confronted with disparate, discrete events that require very different modes of reactive behavior.
  - drawback-architecture provides no leverage for decomposing complex tasks into cooperating components.

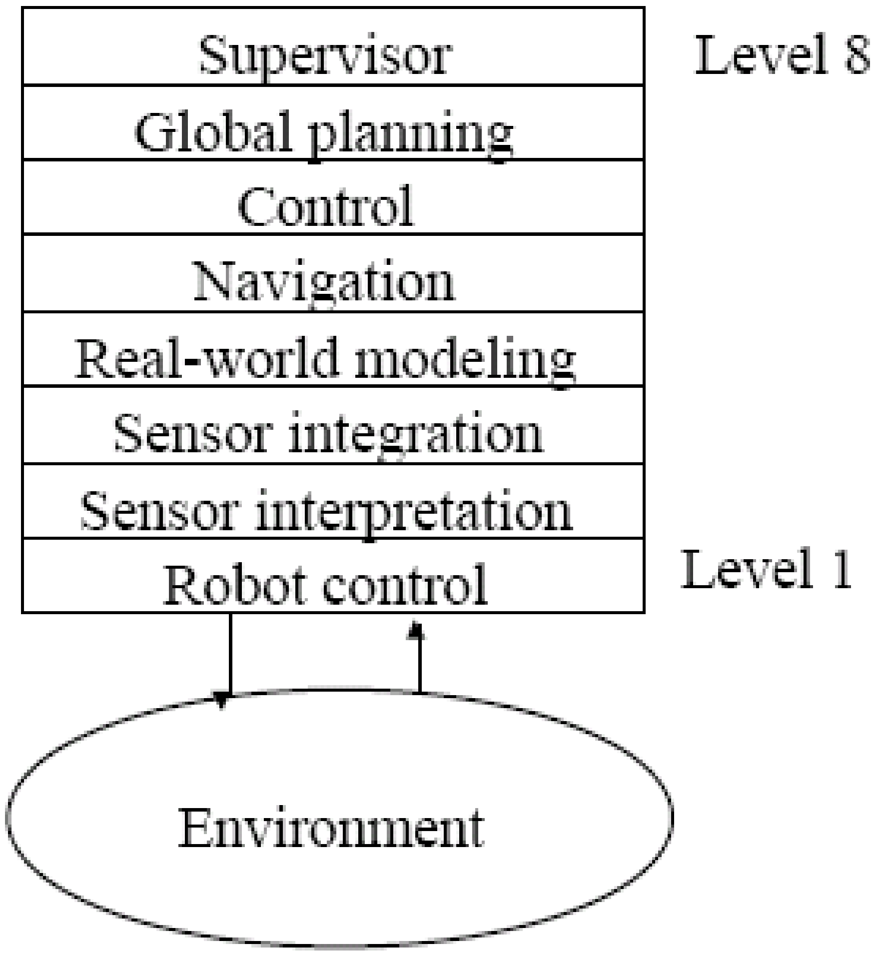
Control Loop Architecture

Control Loop Architecture--Continued

- Req 2--dealing with uncertainty
  - disadvantage-biased toward one way of dealing with uncertainty, namely iteration via closed loop feedback.
- Req 3--safety and fault-tolerance
  - advantage-simplicity
  - advantage-easy to implement duplication (redundancy).
  - disadvantage-reaction to sudden, discrete events.
- Req 4--flexibility
  - drawback--architecture does not exhibit a modular component structure
- Overall Assessment: architecture may be appropriate for
  - simple systems
  - small number of external events
  - tasks that do not require complex decomposition,

Choose another architecture style

Mobile Robots--Layered Architecture



Layered Architecture

Evaluate Layered Architecture--Strengths and Weaknesses

- Req 1--deliberative and reactive behavior
  - advantage-architecture defines clear abstraction levels to guide design
  - drawback-architectural structure does not reflect actual data and control-flow patterns
  - drawback-data hierarchy and control hierarchy are not separated.

Layered Architecture

Layered Architecture--Continued

- Req 2--dealing with uncertainty
  - advantage-layers of abstraction should provide a good basis for resolving uncertainties.

- Req 3--safety and fault-tolerance
  - advantage-layers of abstraction should also help (security and fault-tolerance elements in each layer)
  - drawback-emergency behavior may require short-circuiting of strict layering for faster recovery when failures occur.

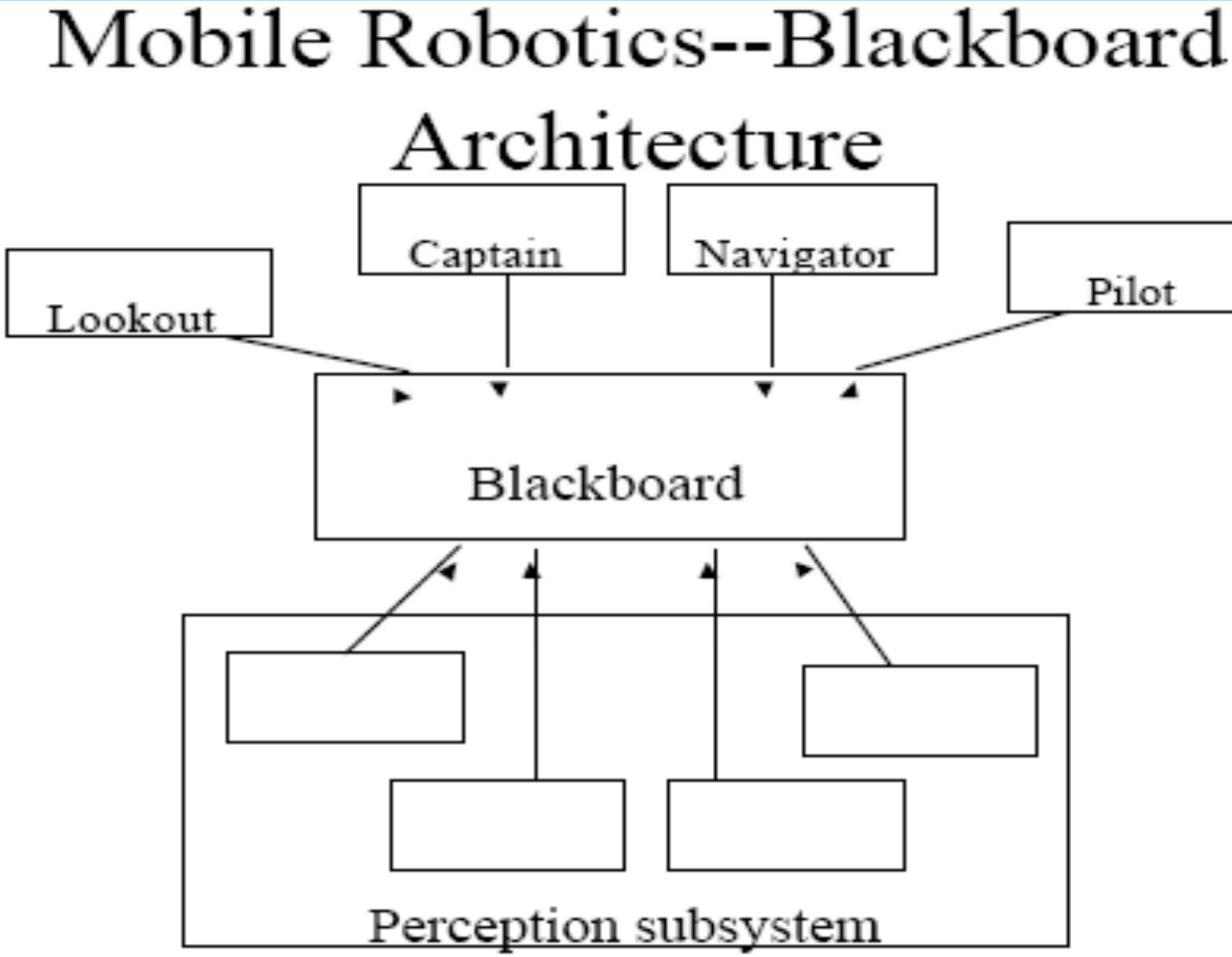
Layered Architecture

Layered Architecture--Continued

- Req 4--flexibility
  - drawback-changes to configuration and/or behavior may involve several or all layers

- Overall Assessment
  - layered model is useful for understanding and organizing system functionality
  - strict layered architecture may break down with respect to implementation and flexibility.

Blackboard Architecture



Blackboard Architecture

Evaluate Blackboard Architecture--Strengths and Weaknesses

- Req1-- Deliberative and reactive behavior
  - advantage: Easy to integrate disparate, autonomous subsystems
  - drawback: blackboard may be cumbersome in circumstances where direct interaction among components would be more natural.
- Req 2--Dealing with uncertainty
  - advantage: blackboard is well-suited for resolving conflicts and uncertainties.

Blackboard Architecture

Blackboard Strengths and Weaknesses--Continued

- Req3--safety and fault-tolerance
  - advantage: subsystems can monitor blackboard for potential trouble conditions
  - disadvantage: blackboard is critical resource (this can be addressed using a back up)
- Req4--flexibility
  - advantage: blackboard is inherently flexible since subsystems retain autonomy.

Architecture Comparison

Mobile Robotics--Summary of

Architectural Tradeoffs	Control Loop	Layers	Blackboard
Task coordination	+-	-	+
Dealing with uncertainty	-	+-	+
Fault tolerance	+-	+-	+-
Safety	+-	+-	+
Performance	+-	-	+
Flexibility	-	-	+