Computer Systems and Networks

a course for the Master SNE
Innopolis University – 2023

3. System architecture patterns

Agenda

Graphic notation for describing systems: UML

Layered architectures

Partitioned (tiered) architectures

Examples

Source: Richards, *Sw architecture patterns*, O'Reilly 2015

Meaning of models

A model is a *description* of a system

we can model both its structure and its behavior

A model is an *abstraction*: it captures the essential aspects of a system and ignores some details

A model is useful if it answers some questions in the same way as the system it describes

Example: Linux process tree – free graphic notation

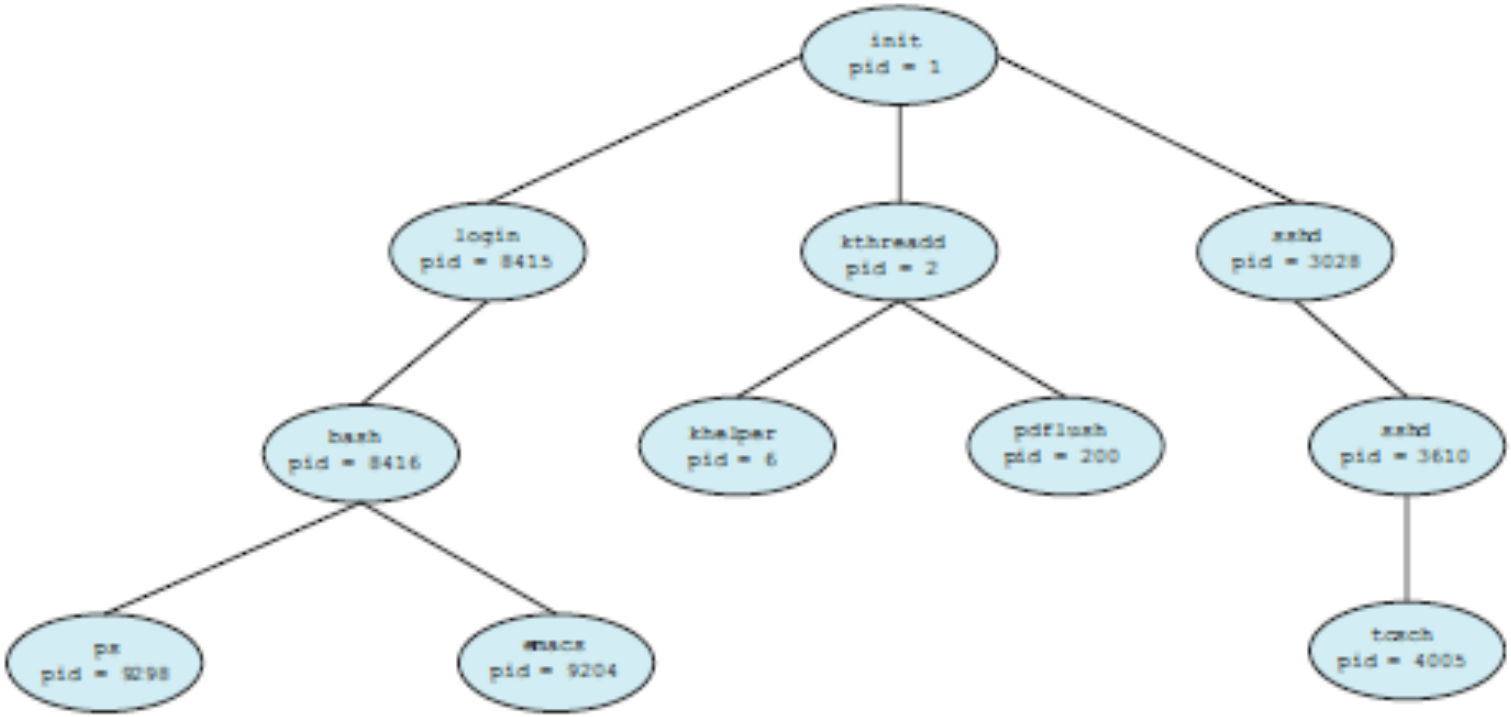
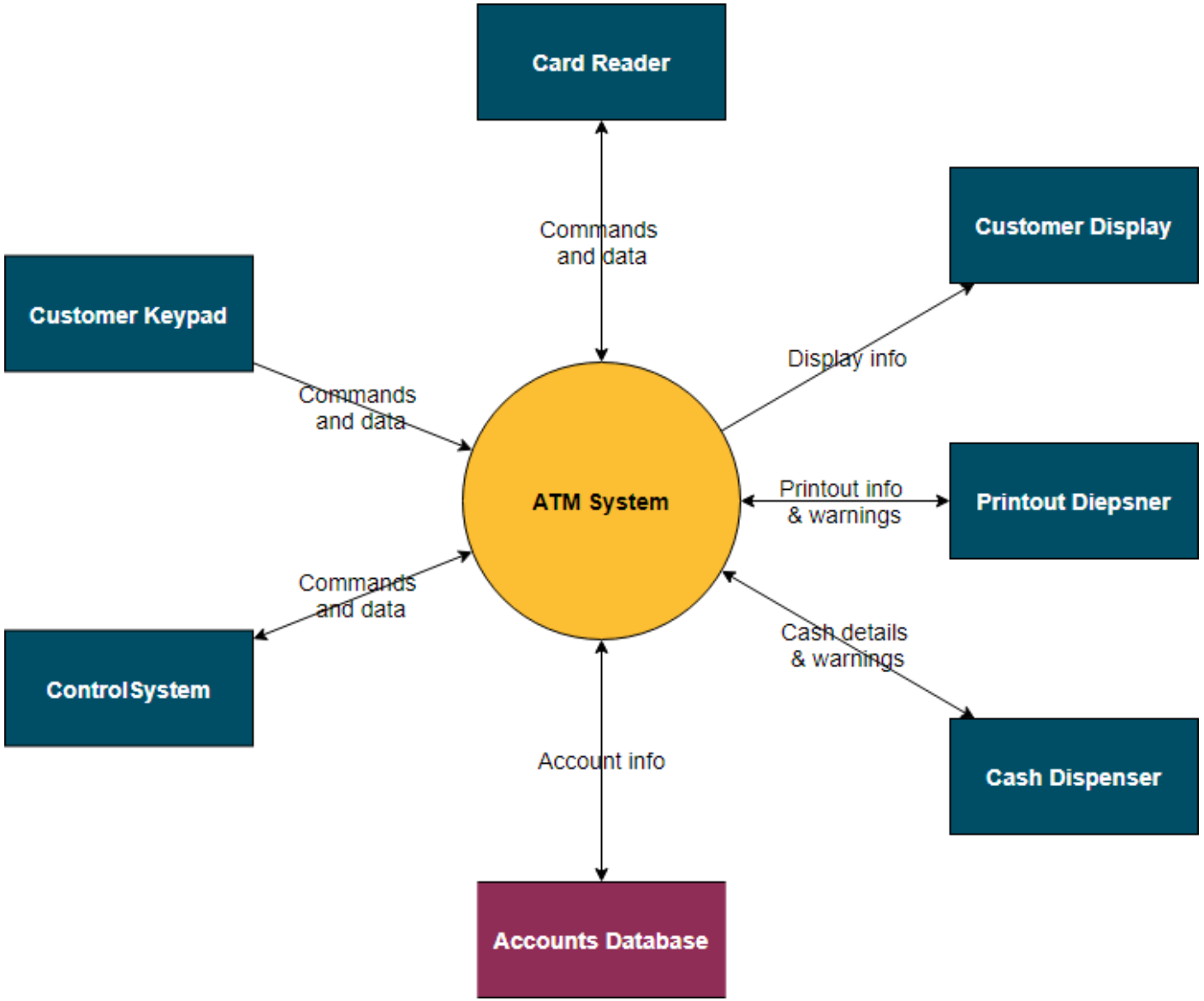


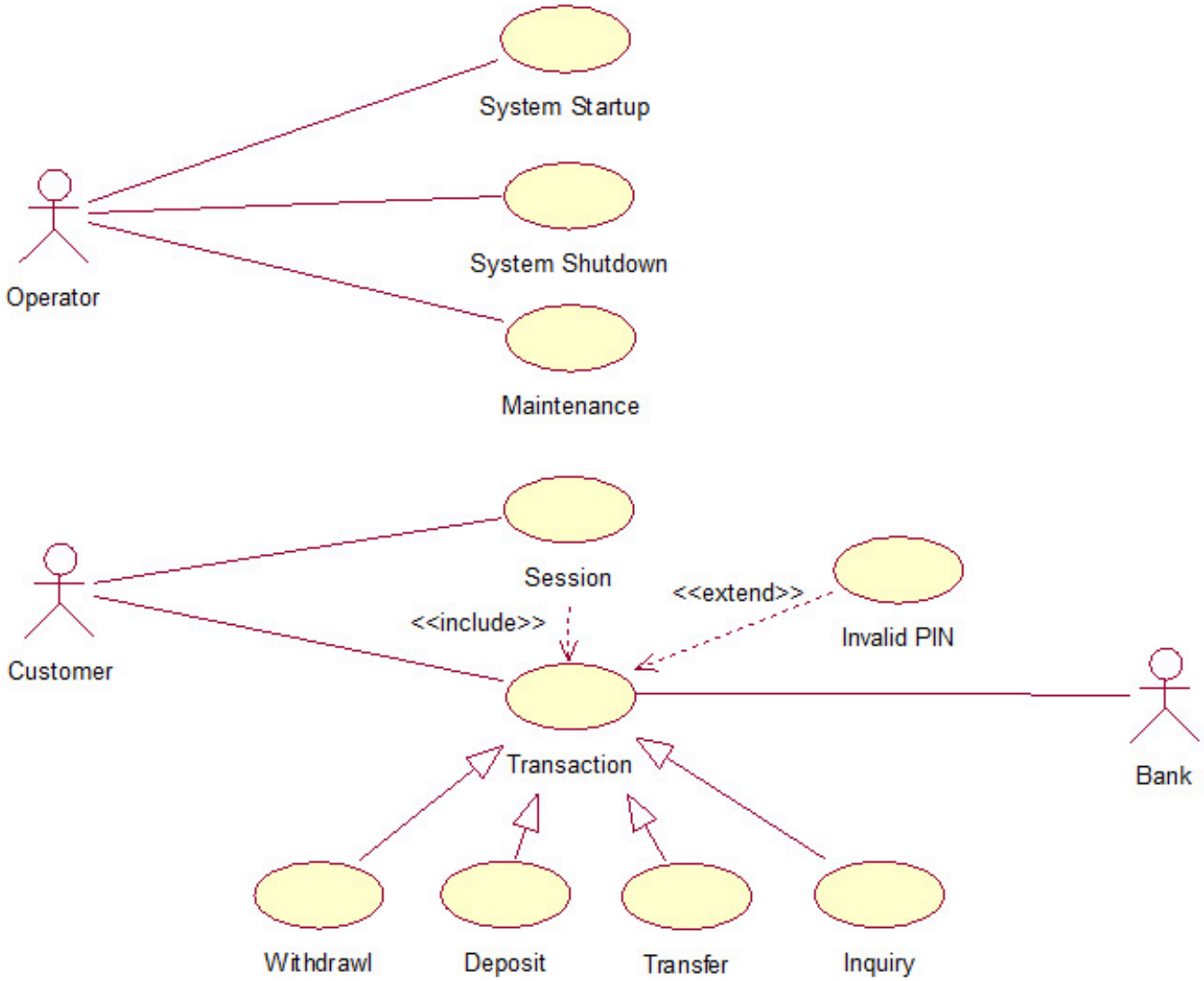
Figure 3.8 A tree of processes on a typical Linux system.

A system model – ATM example

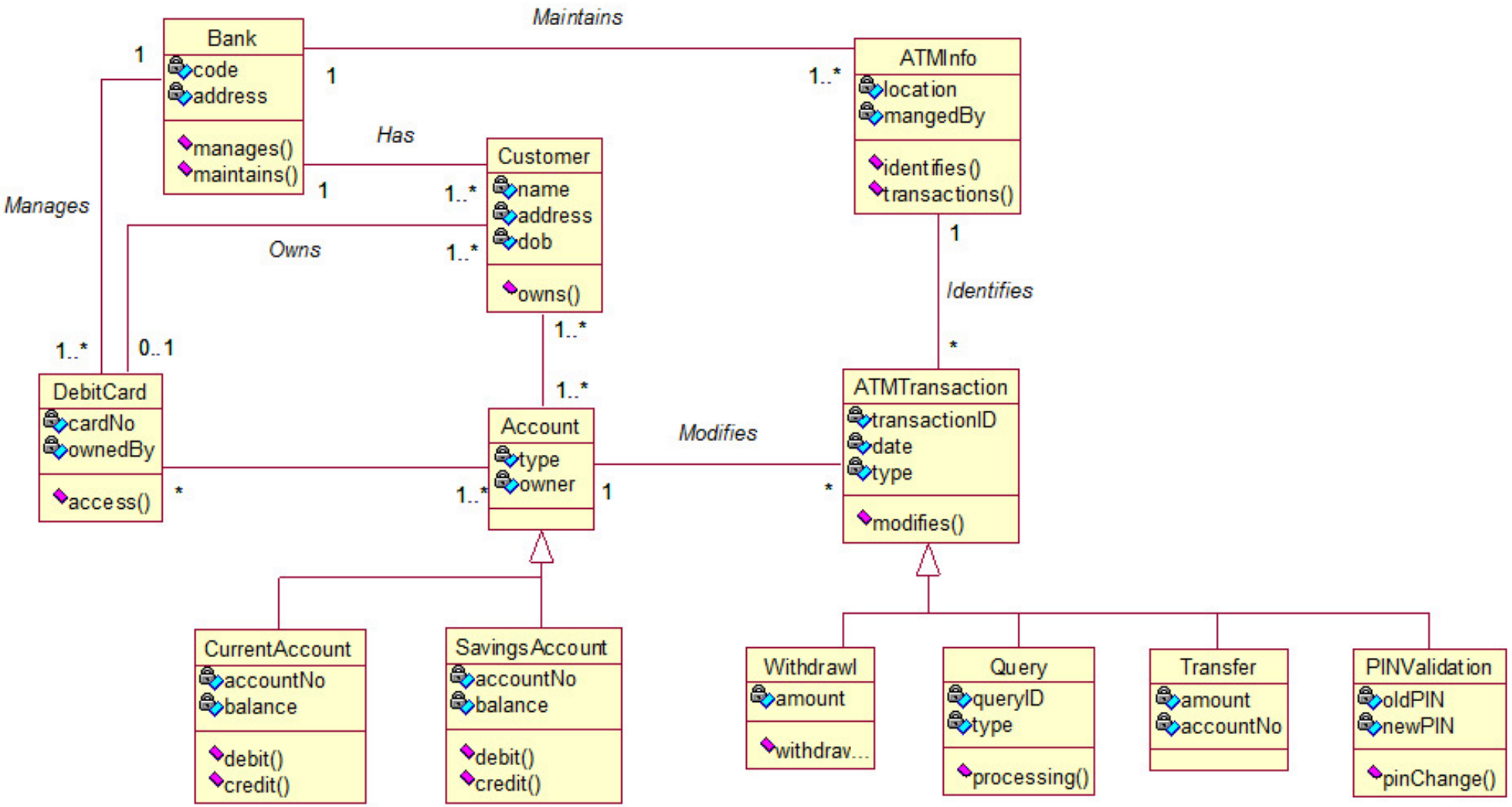


https://venngage.com/blog/context-diagram/

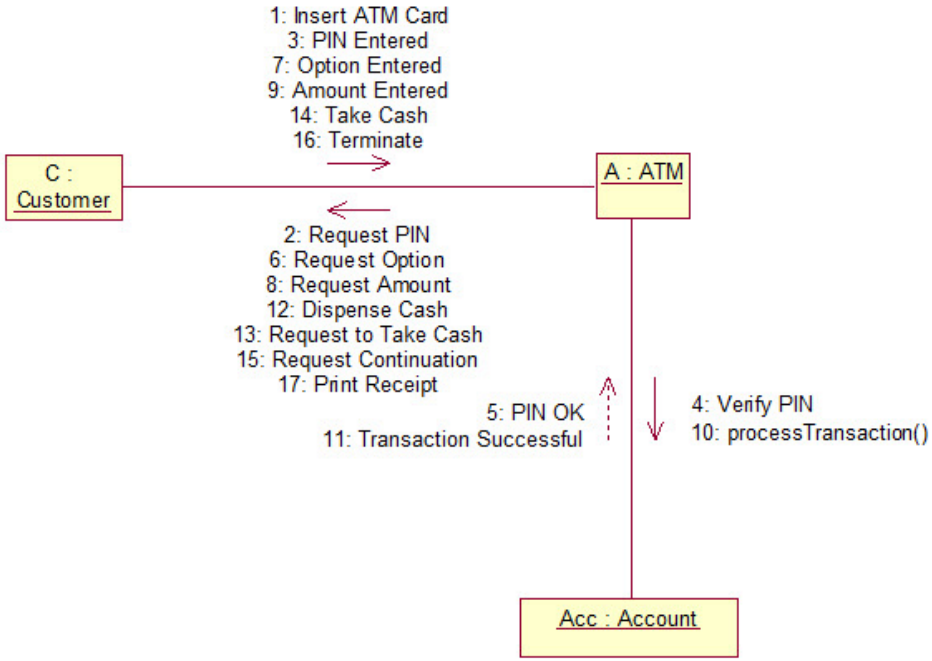
ATM Model: use case diagram (UML)



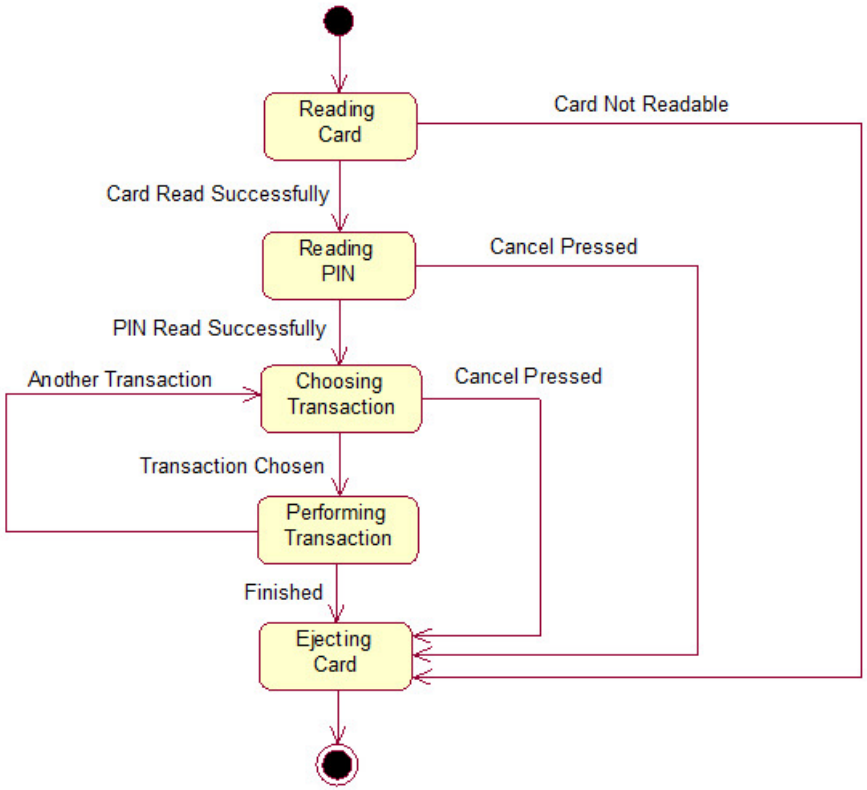
ATM model: class diagram (UML)



ATM model – UML behavior diagrams

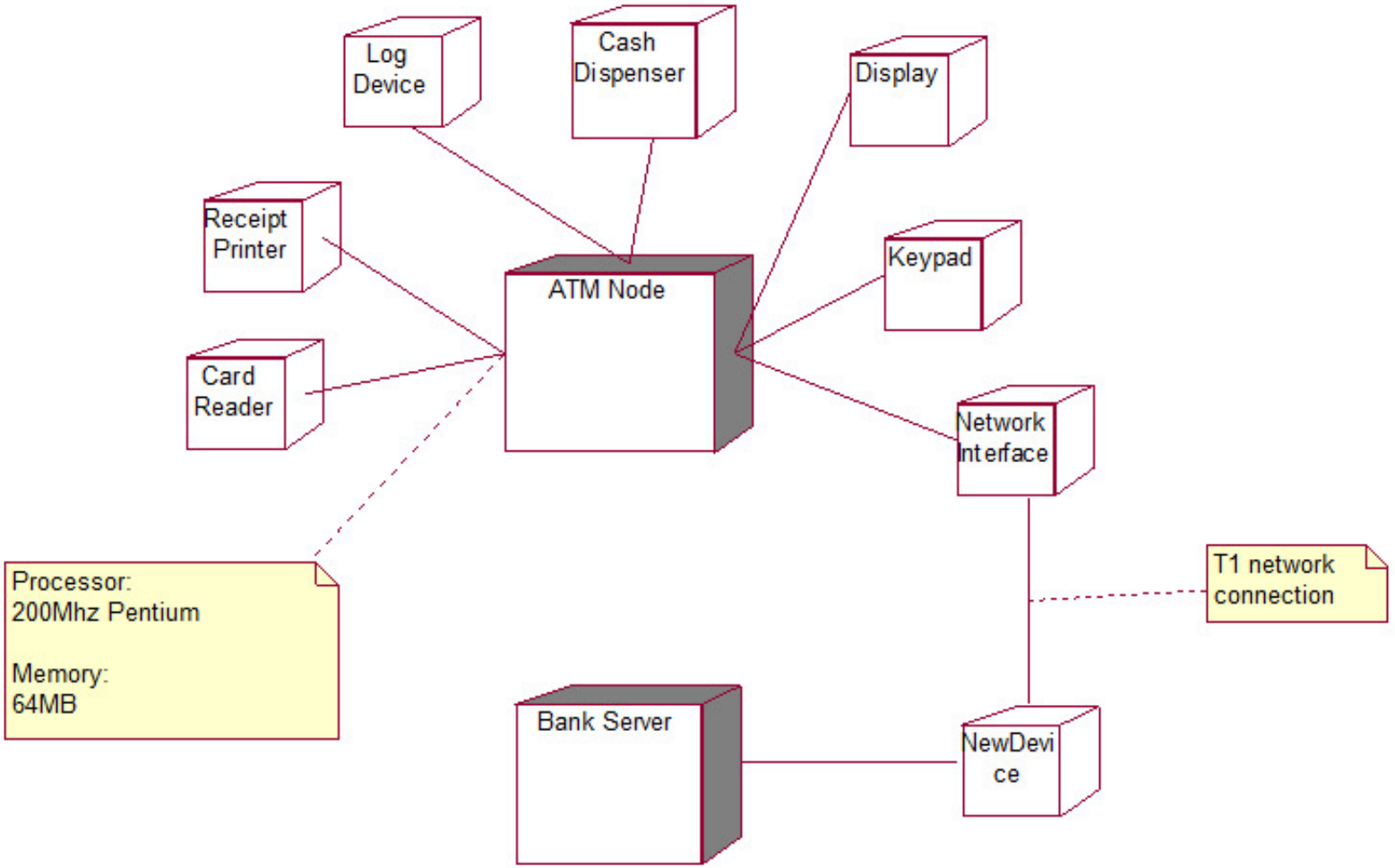


Collaboration diagram

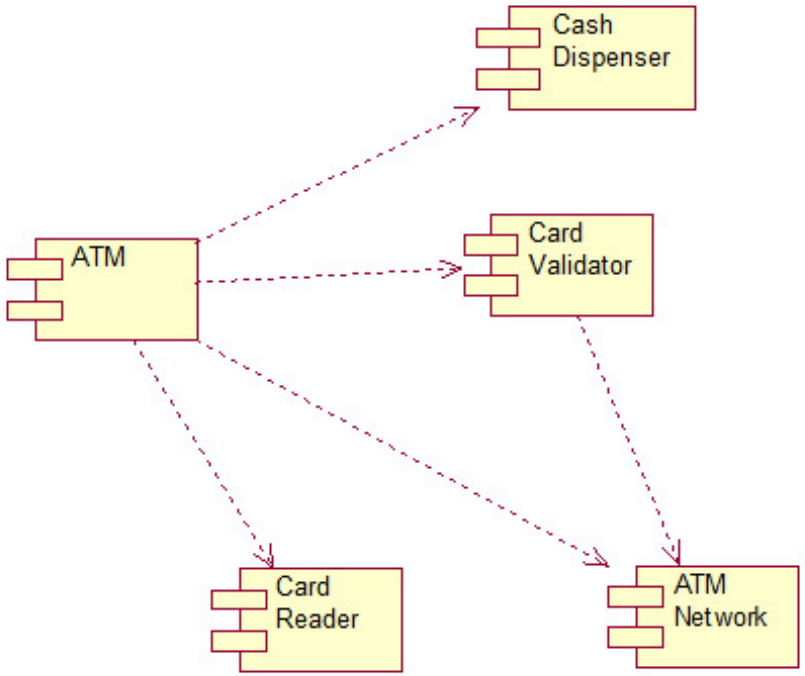


Statechart diagram

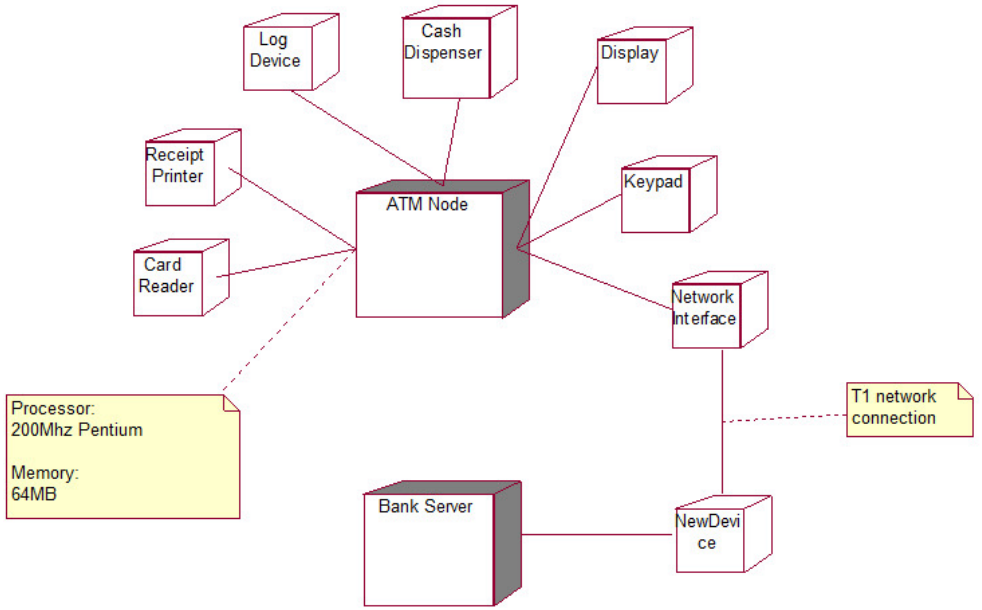
ATM model - Deployment diagram



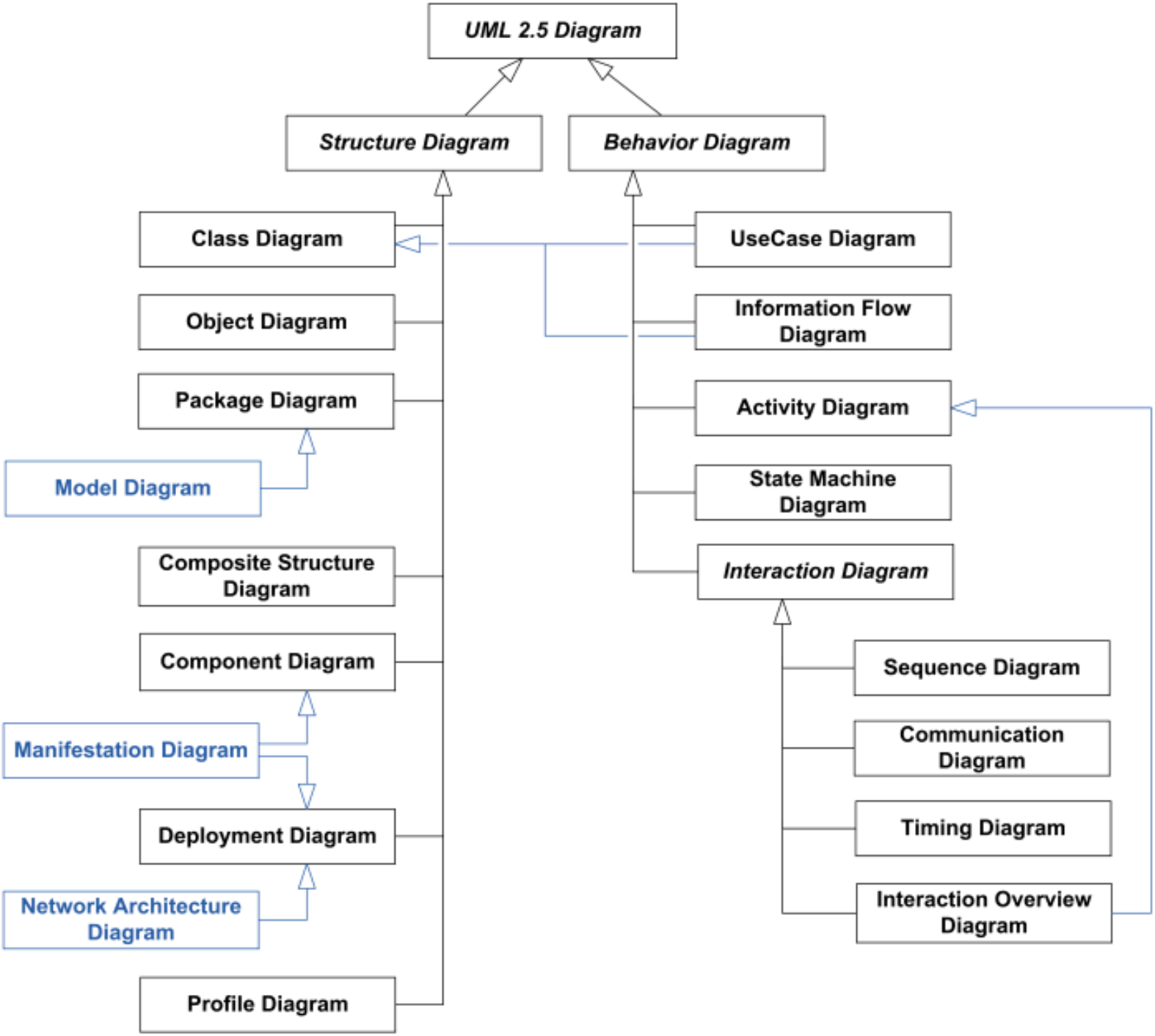
ATM model – Component + Deployment diagrams



Component diagram



Deployment diagram



UML 2.5

https://www.uml-diagrams.org/uml-25-diagrams.html

Architectural elements

Components (examples)

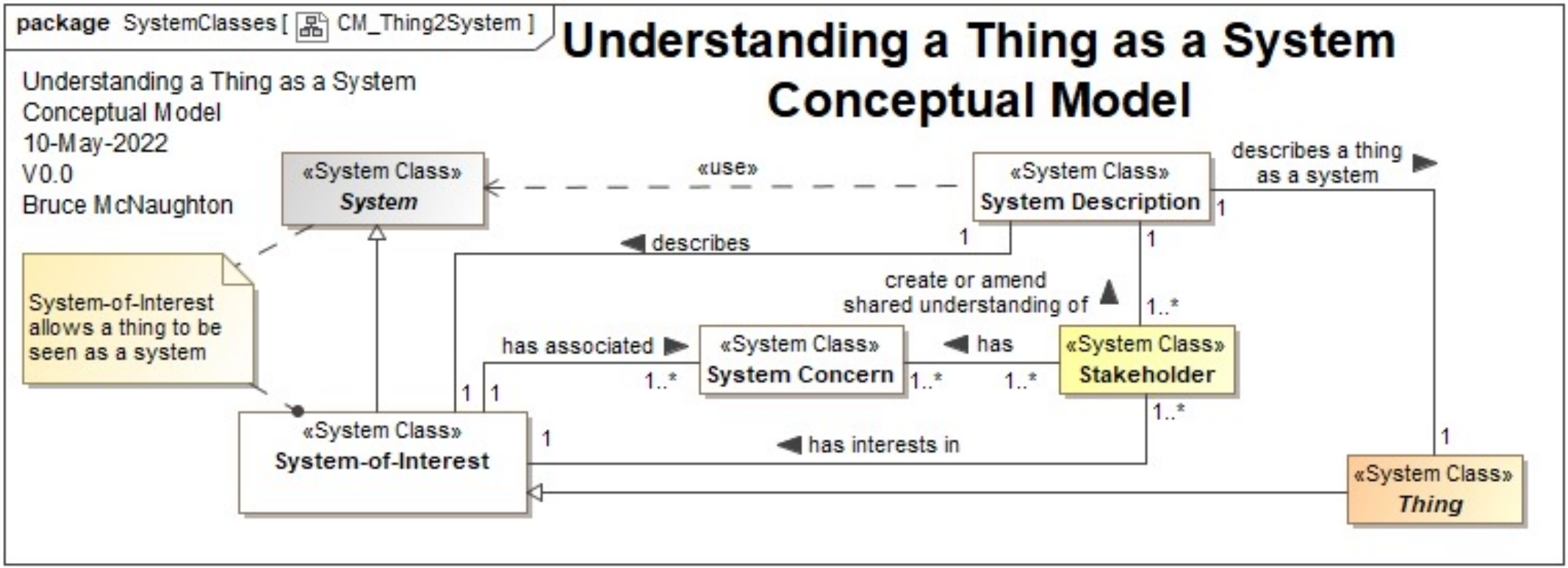
- Processes
- Objects
- Agents
- Services

Connectors (examples)

- Channels
- Protocols (middleware)
- Name systems

REMARK: We can use some UML diagrams to describe these concepts… or we can try some free graphic modeling

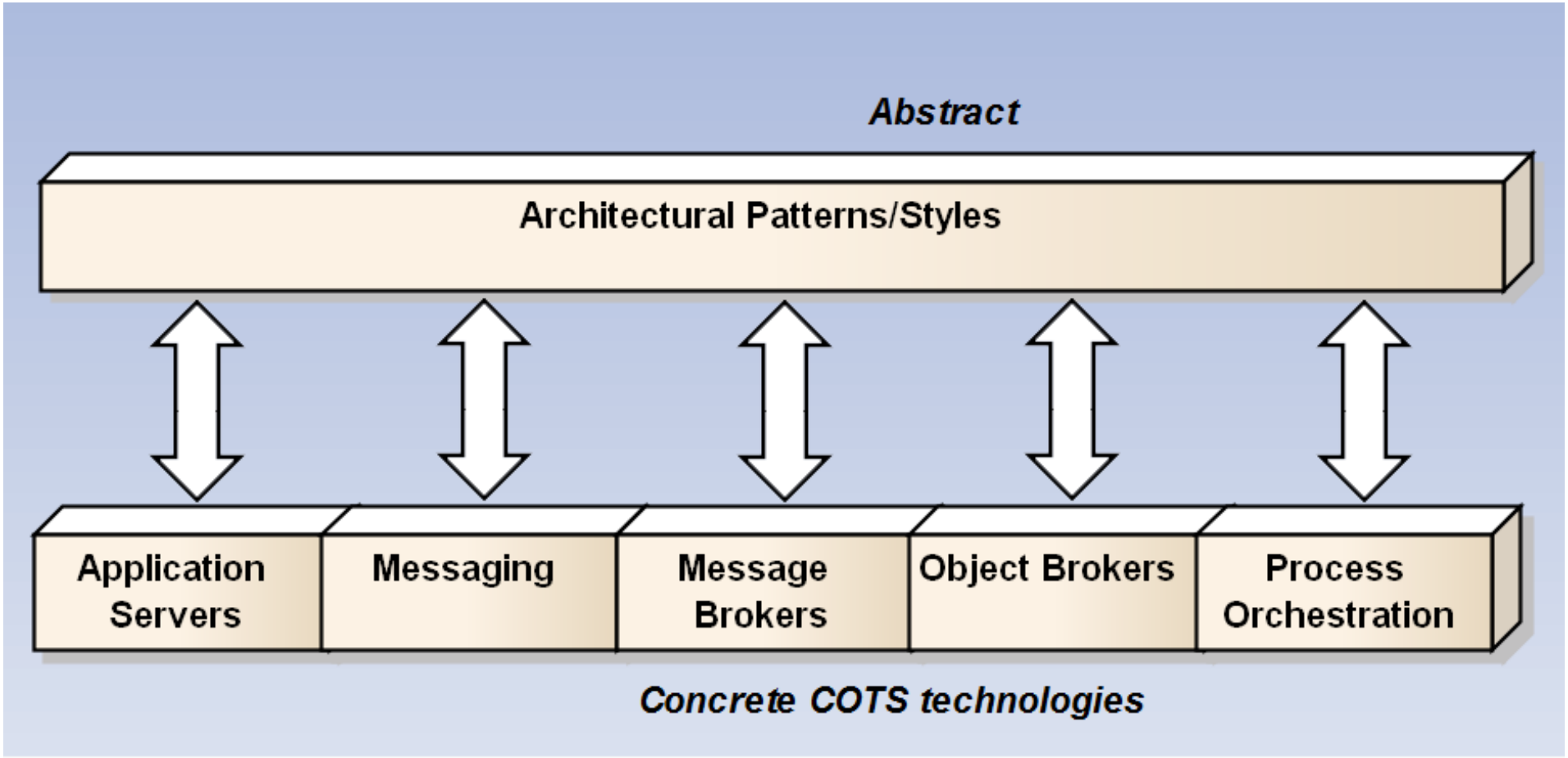
System model – using UML package diagram



A **system-of-interest** is any **thing** that a person wants to focus their attention on through the lens of a «system body of knowledge», for instance some architectural patterns used for the system description

https://sysdesc.info/Content/SysDesc/SD_Introduction.htm

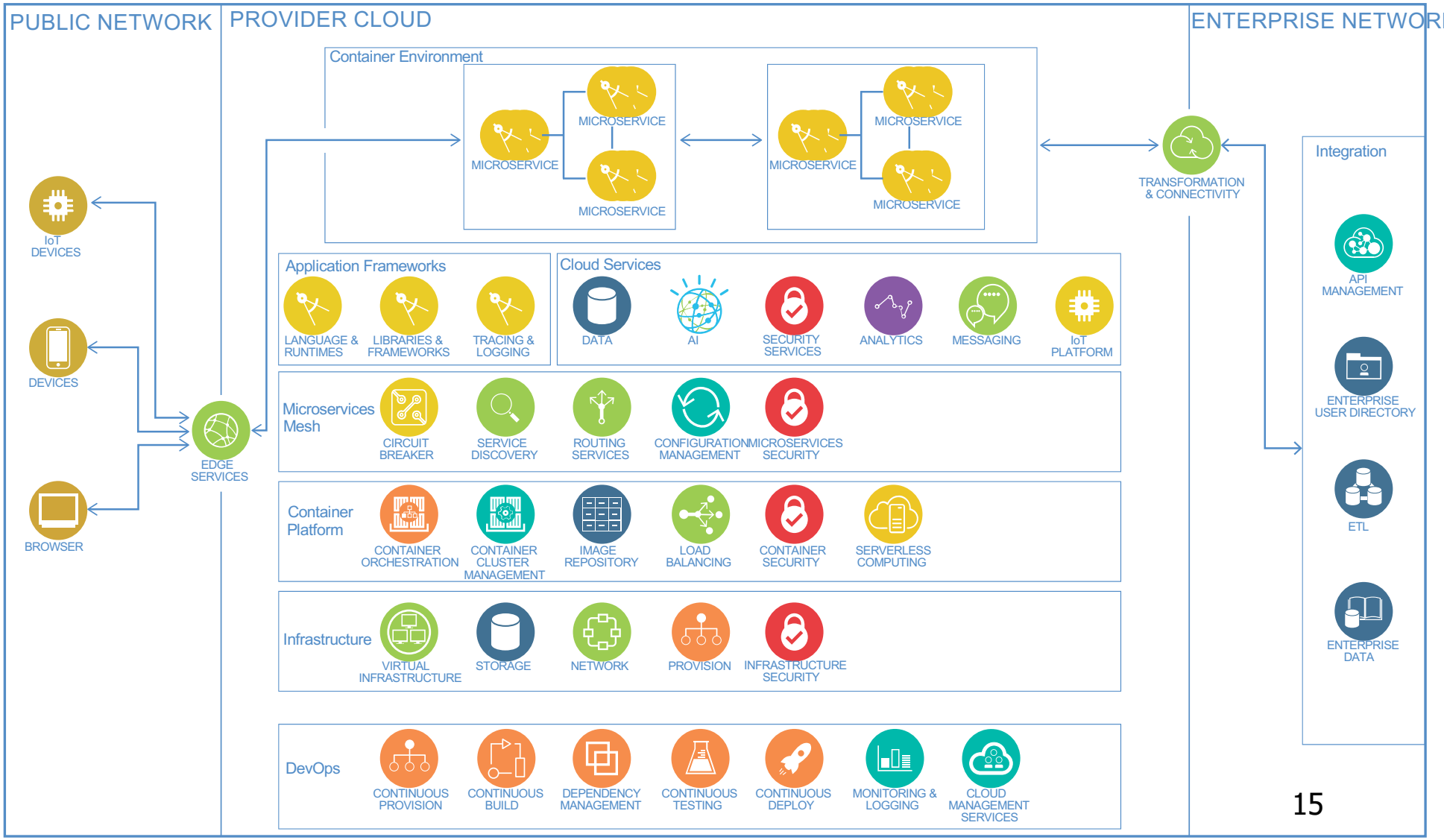
From patterns to technologies



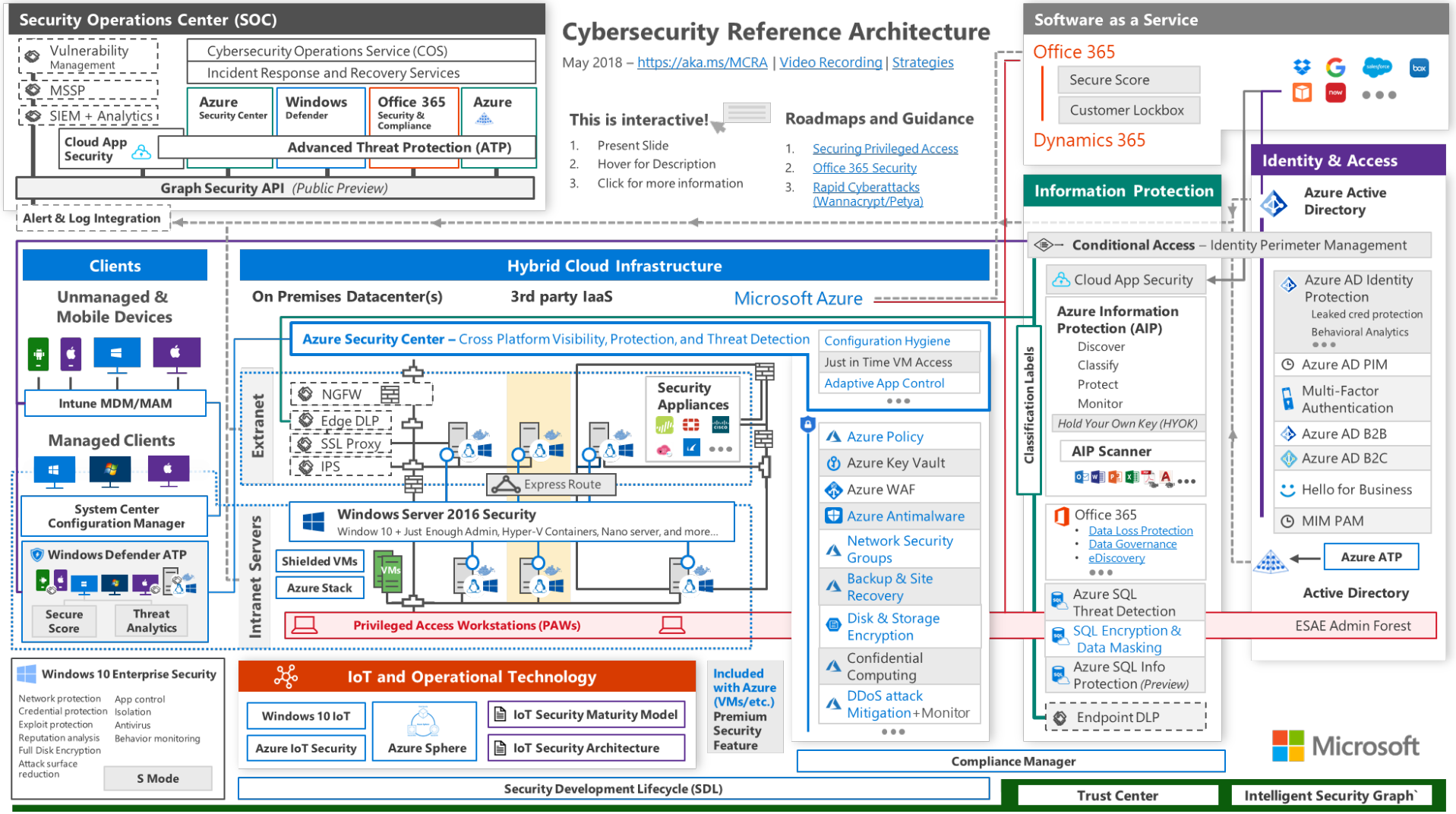
Reference architectures and patterns

A **Reference Architecture** is a set of **patterns**, partially or completely instantiated

https://www.ibm.com/cloud/architecture/architectures/microservices/reference-architecture/

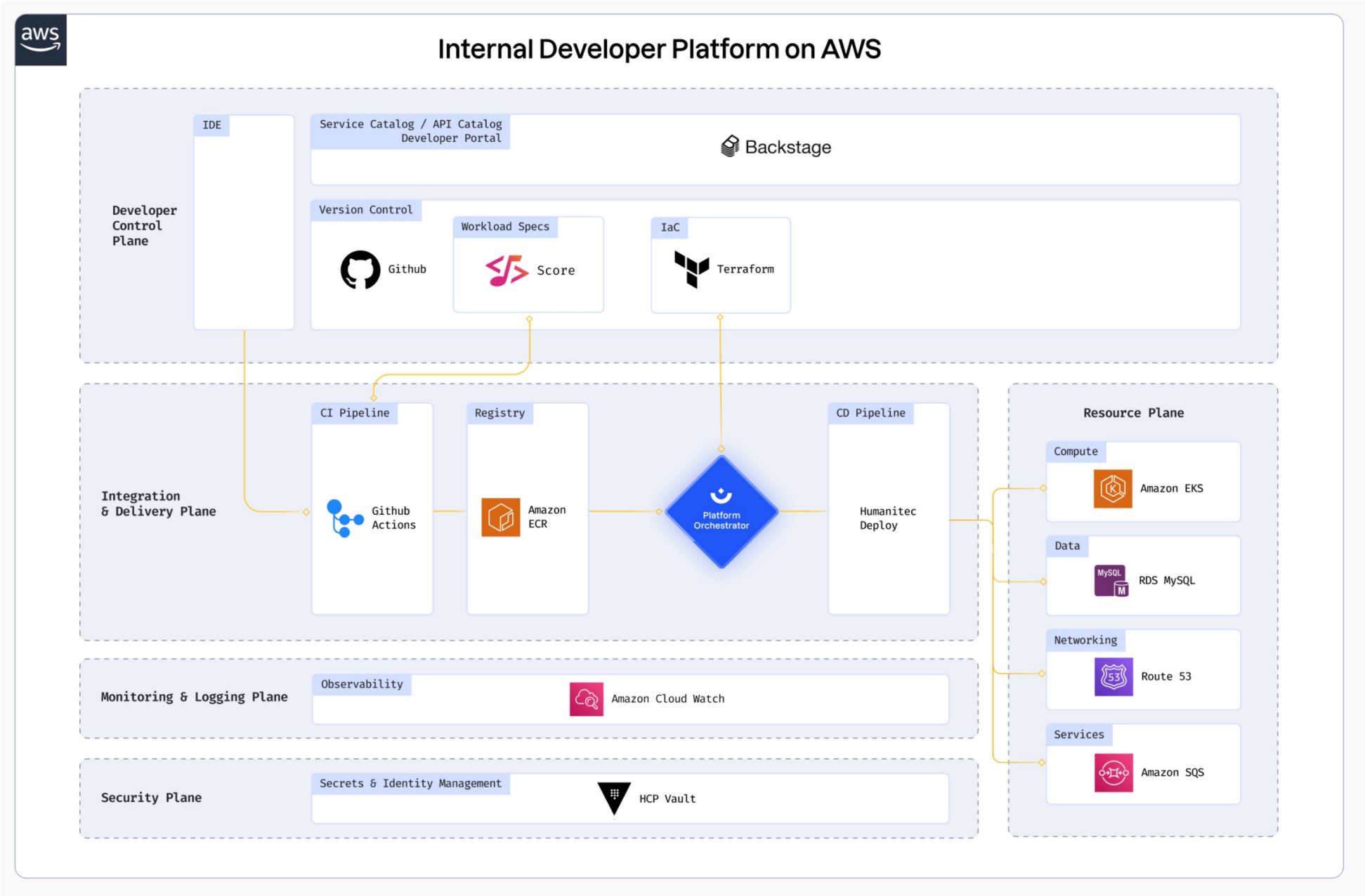


Example: Microsoft Cybersecurity Reference Architecture



https://www.microsoft.com/security/blog/2018/06/06/cybersecurity-reference-architecture-security-for-a-hybrid-enterprise/

Example: AWS platform for internal developers



What is an architectural style? (some definitions)

I. A family of systems sharing a common configuration (structure, behaviors) of their architectural elements
II. A vocabulary of components and connectors, with constraints on how they can be combined (Garlan and Shaw)
III. A set of design rules that identify the kinds of components and connectors that may be used to compose a system or subsystem, together with local or global constraints on the way the composition is done (Shaw & Clements)
IV. A set of constraints put on system development, namely a collection of design decisions applicable in a given context, specific to a particular system within that context, and choosing some beneficial qualities in each resulting system (Taylor, Medvidović and Dashofy)

Styles: Layers and tiers (1)

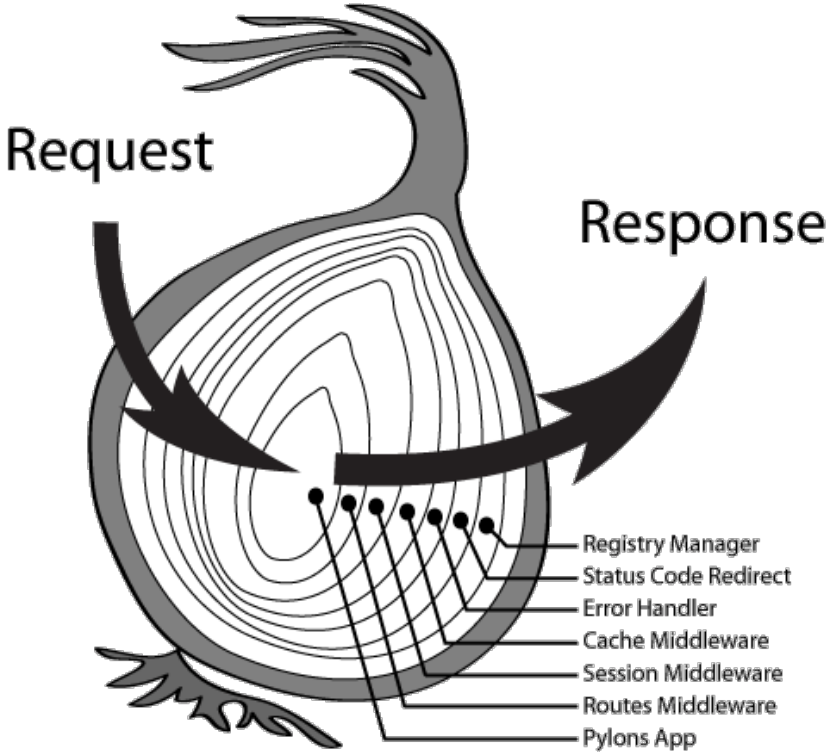
The architecture of a system is generally achieved by decomposing it into subsystems, following a ***layered*** and/or a **partition** based approach

These are orthogonal approaches:

A layer is a logical structuring mechanism for the elements that make up a software solution (e.g., a kernel is a layer)

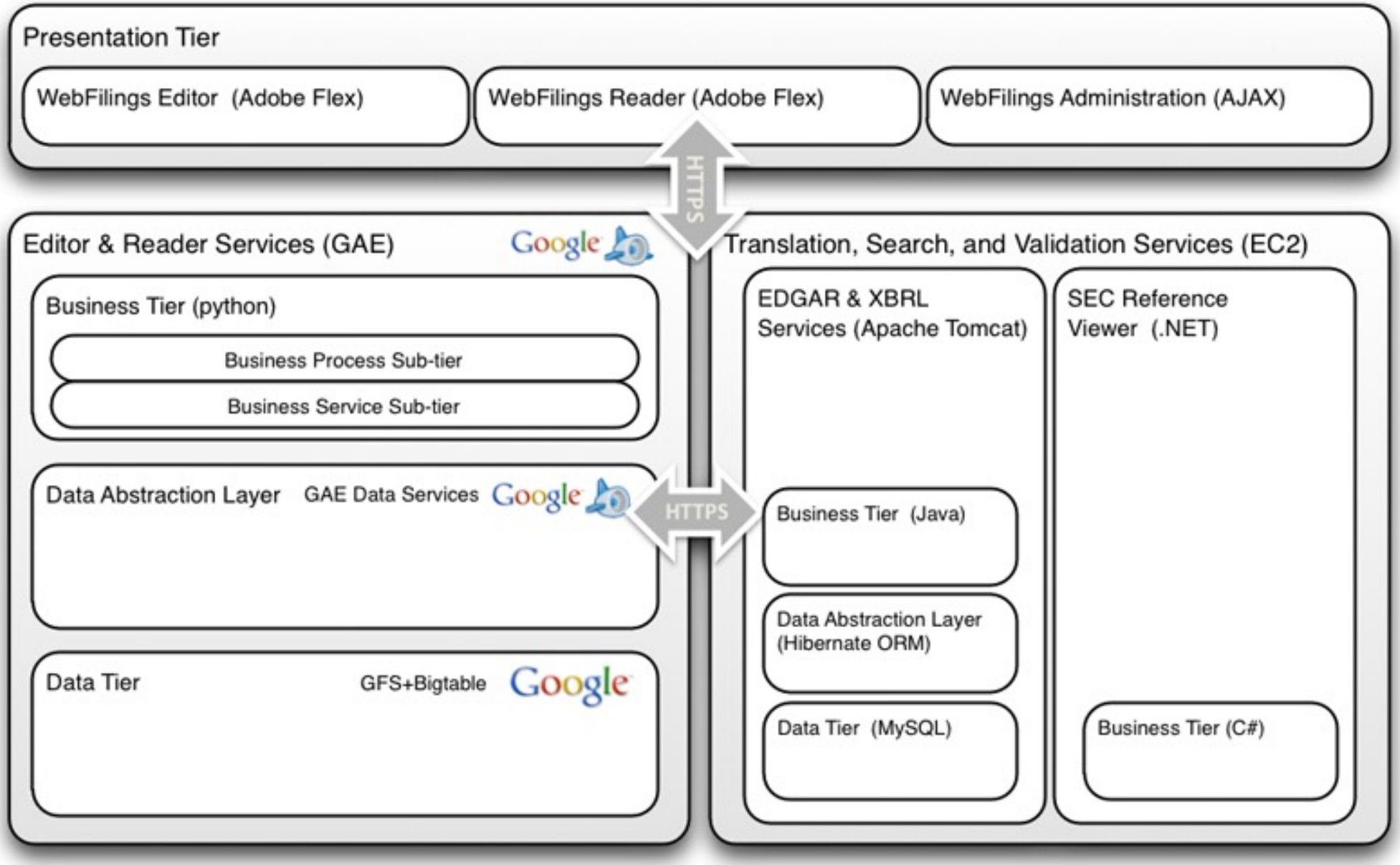
A partition (or **tier**) is a physical structuring mechanism for the system infrastructure (e.g., a user interface is a tier)

Architectural vegetables



Onion: layers

Garlic: partitions


Presentation Tier
WebFilings Editor (Adobe Flex)
WebFilings Reader (Adobe Flex)
WebFilings Administration (AJAX)
HTTPS
Editor & Reader Services (GAE)
Google
Business Tier (python)
Business Process Sub-tier
Business Service Sub-tier
Data Abstraction Layer
GAE Data Services
Google
Data Tier
GFS+Bigtable
Google
HTTPS
Translation, Search, and Validation Services (EC2)
EDGAR & XBRL Services (Apache Tomcat)
Business Tier (Java)
Data Abstraction Layer (Hibernate ORM)
Data Tier (MySQL)
SEC Reference Viewer (.NET)
Business Tier (C#)

Layers and tiers (2)

A complete decomposition of a given system comes from both layering and partitioning:

First, the system in divided into top level subsystems which are responsible for certain functionalities (*partitioning*);

Then, if necessary, each subsystem is organized into several layers, up to the definition of *simple enough* layers

Layered approach

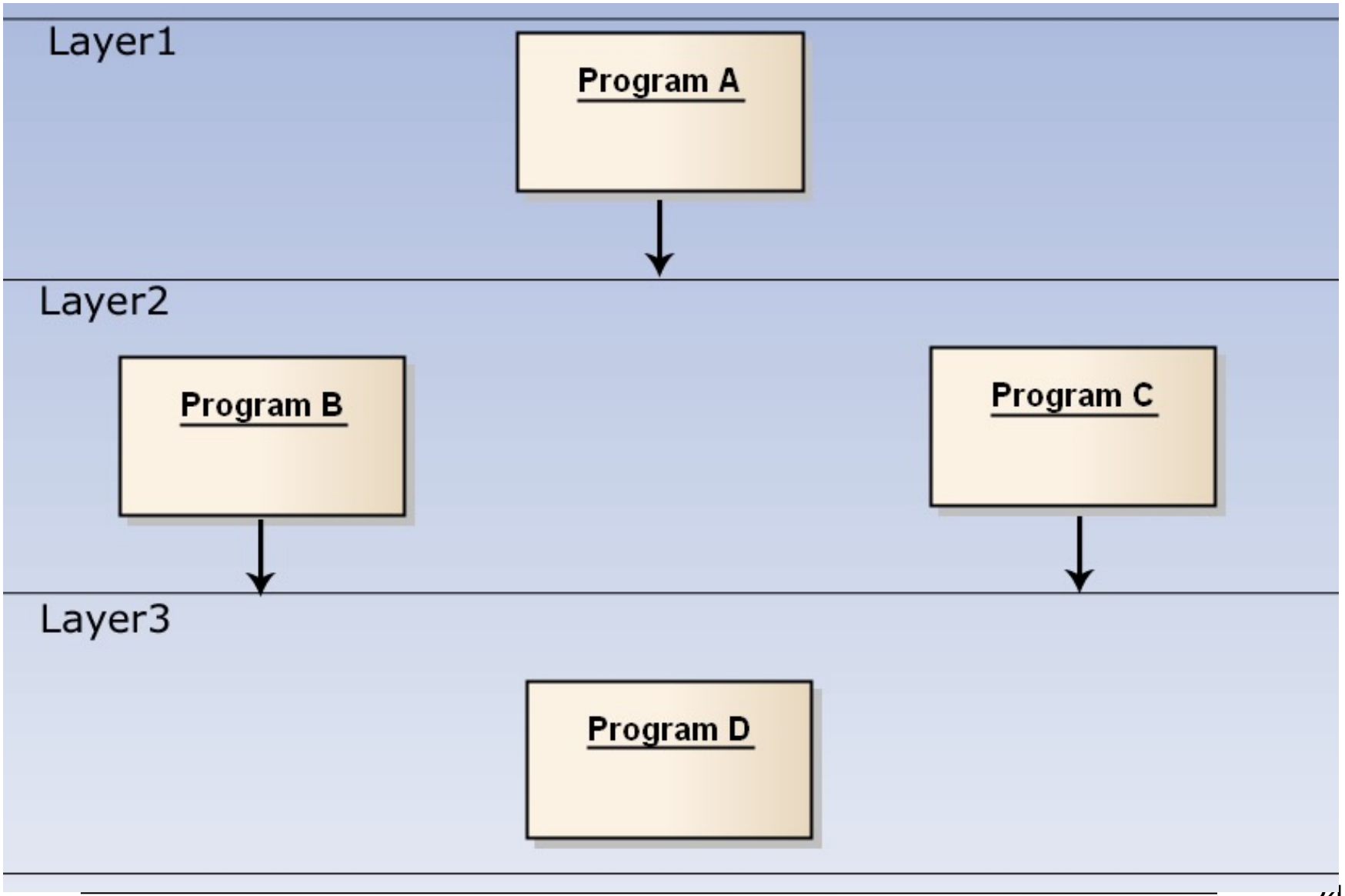
An architecture which has a hierarchical structure, consisting of an ordered set of layers, is *layered*

A **layer** is a subsystem able to provide some related services, that can be realized by exploiting services from other layers

A layer depends only from its lower layers (i.e., layers which are located at a lower level into the architecture)

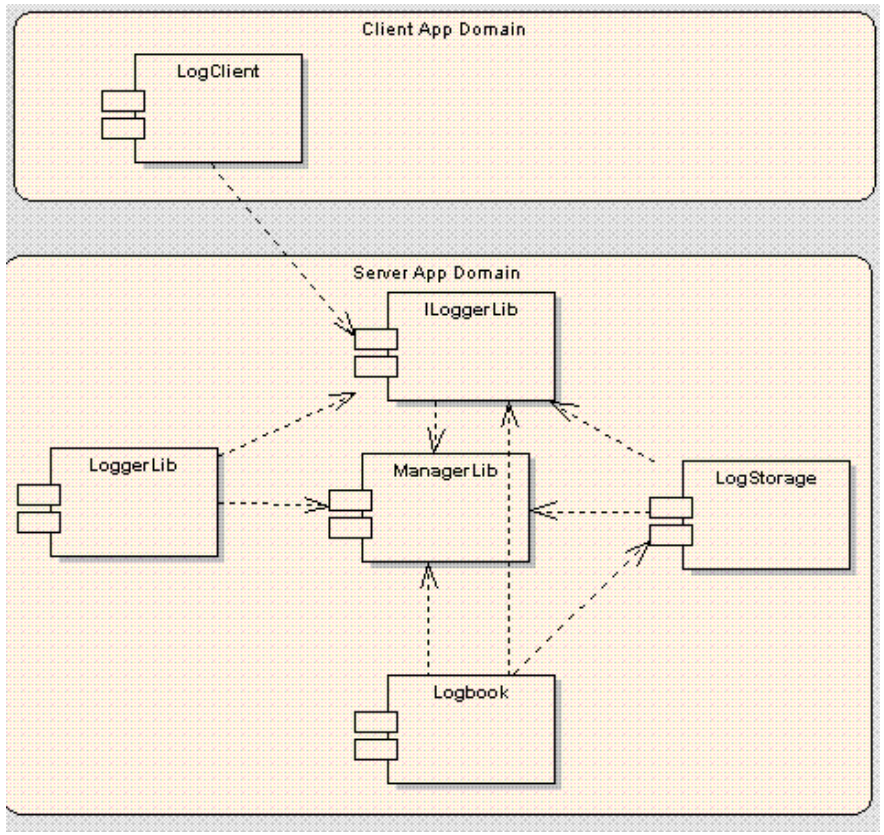
A layer is only aware of lower layers

Example: layers of Virtual Machines



Layers: component diagram

- Connectors for layered systems are often procedure calls
- Each level implements a different virtual machine with a specific input language



Closed vs. open layers

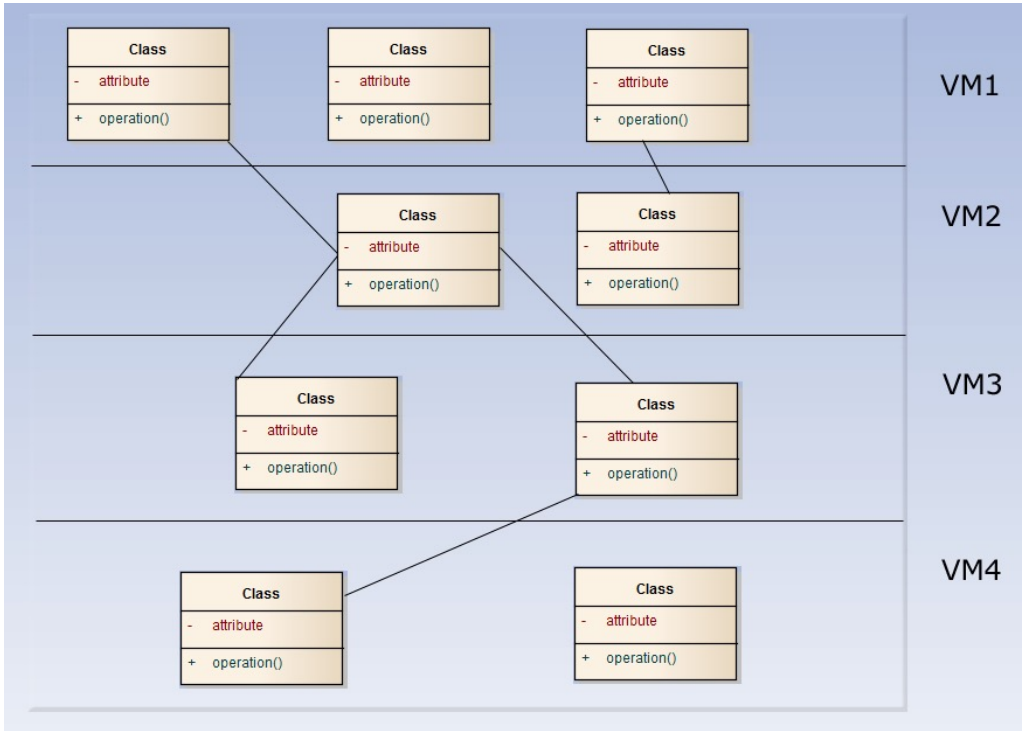
Closed Layers Architecture (CLA): the *i-th* layer can only have access to the layer *(i-1)-th*

Open Layers Architecture (OLA): the *i-th* layer can have access to all the underlying layers (i.e., the layers lower than *i*)

Closed Layers Architecture

The *i-th* layer can only invoke the services and the operations which are provided by the layer *(i-1)-th*

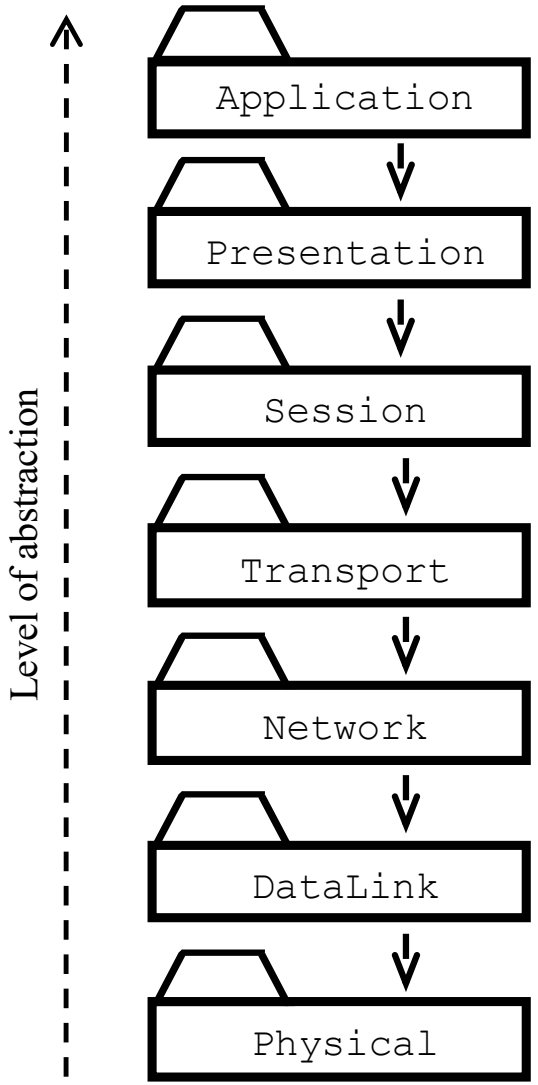
The main goals are the system maintainability and high portability (eg. Virtualization: each layer *i* defines a Virtual Machine - VM*i*)



Example of CLA: ISO/OSI stack

The ISO/OSI reference model defines 7 network layers, characterized by an increasing level of abstraction

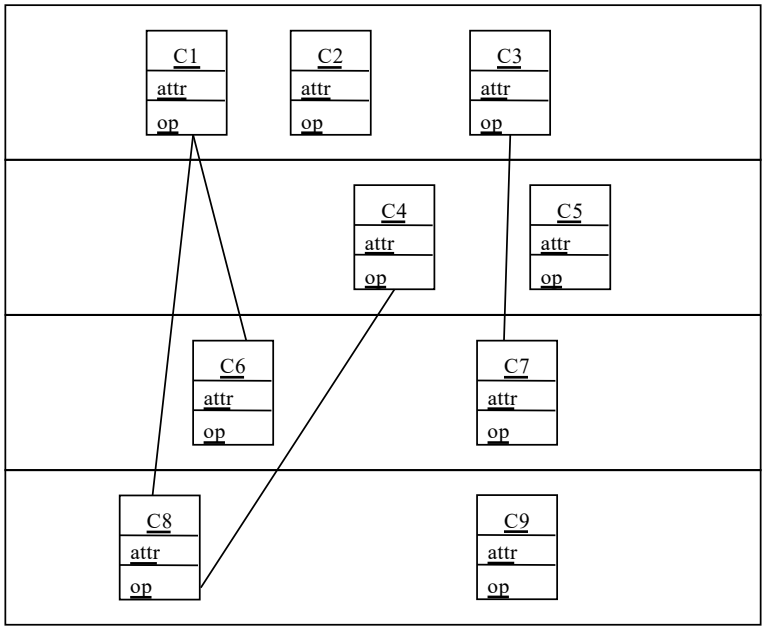
Eg: the Internet Protocol (IP) defines a VM at the network level able to identify net hosts and transmit single packets from host to host



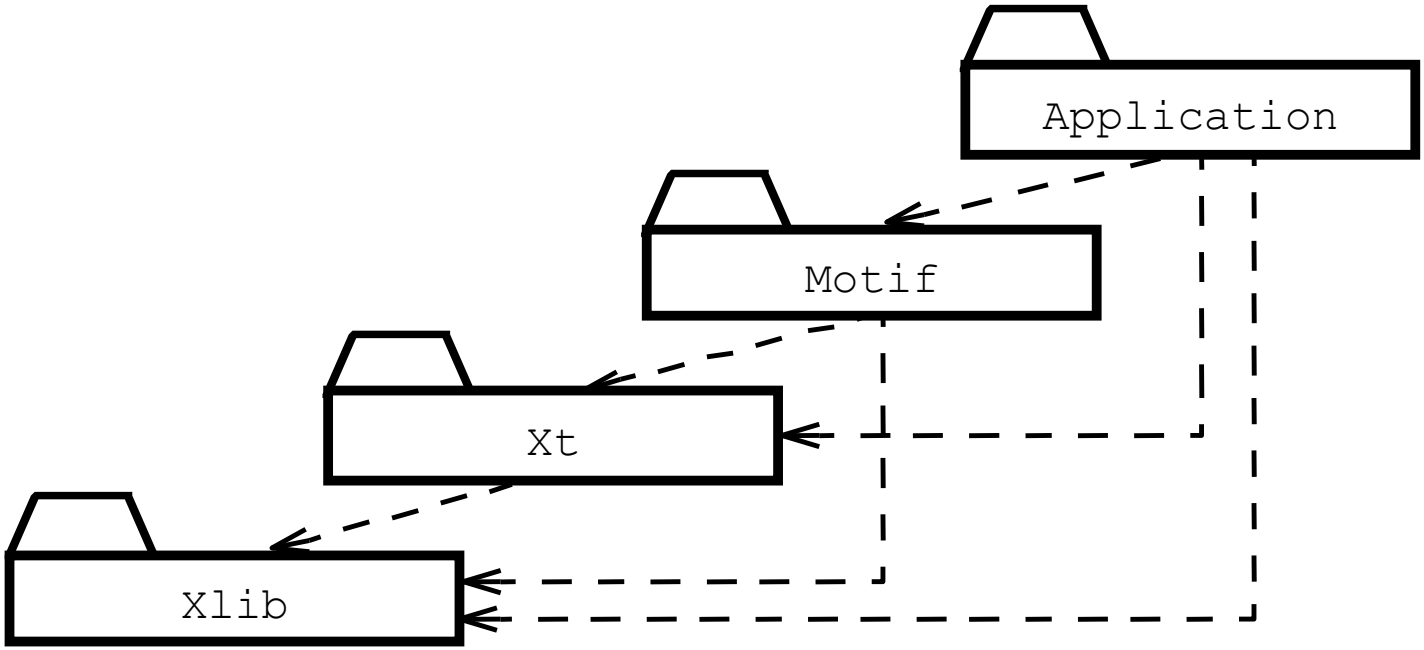
Open Layers Architecture (OLA)

The *i-th* layer can invoke the services and the operations which are provided by all the lower layers (the layers lower than *i*)

The main goals are the execution time and efficiency



Example of OLA: OSF/Motif



`Xlib:` provides low-level drawing facilities;

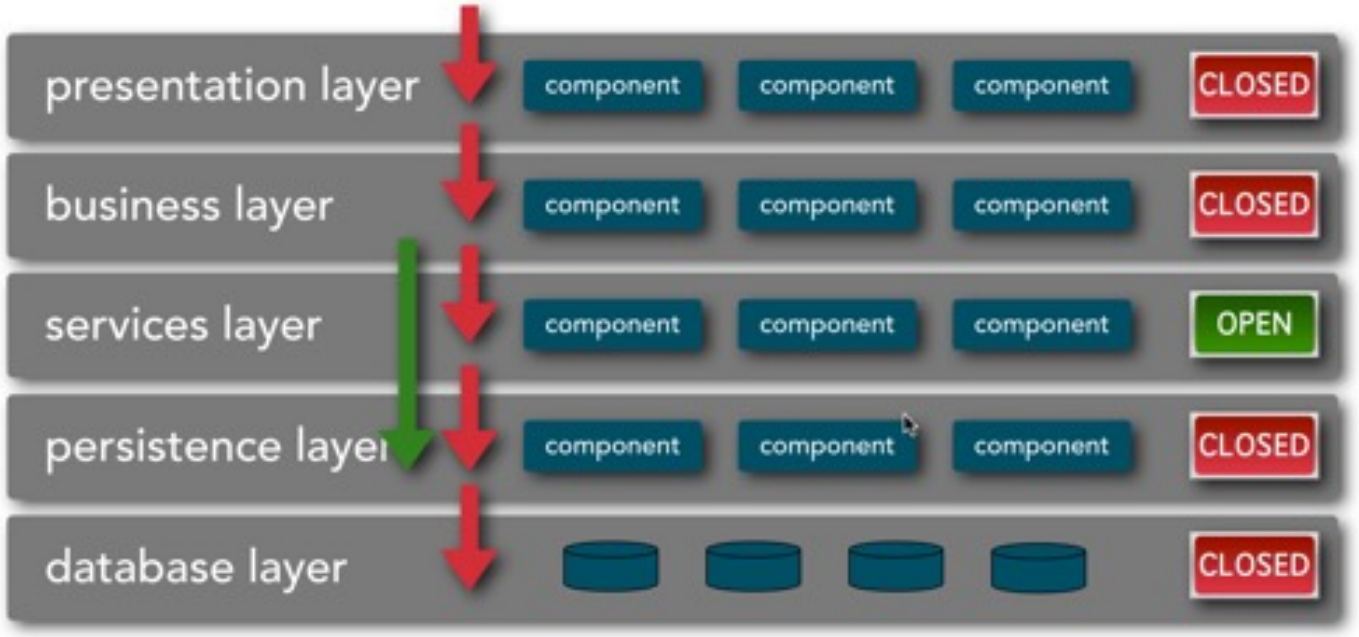
`Xt:` provides basic user interface widget management;

`Motif:` provides a large number of sophisticated widgets;

`Application:` can access each layer independently.

http://motif.ics.com

Mixed open-closed layers



https://www.oreilly.com/ideas/contrasting-architecture-patterns-with-design-patterns

Creating layers: Façade (1)

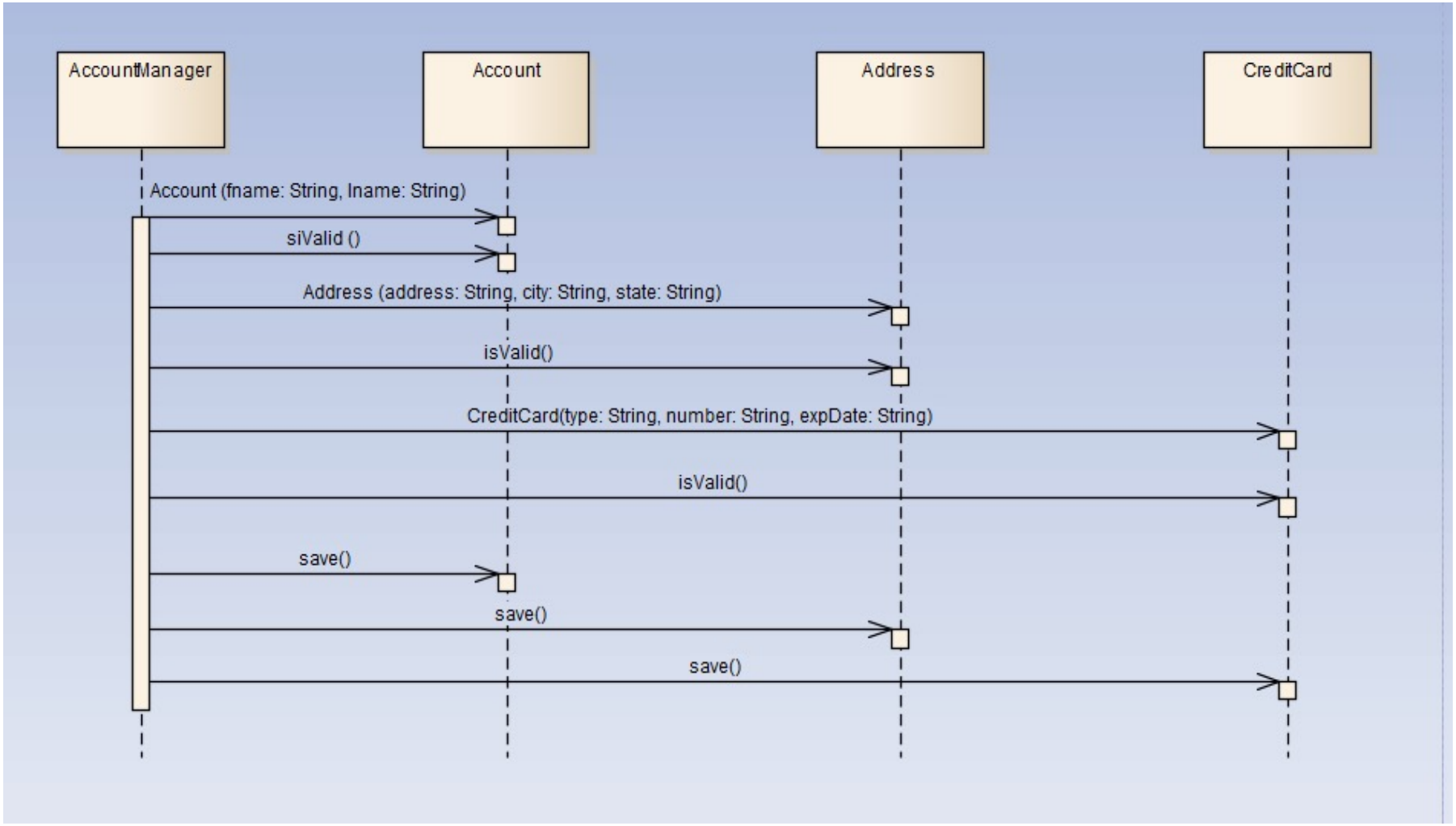


Figure 22.5 How a Client Would Normally Interact (Directly) with Subsystem Classes to Validate and Save the Customer Data

Creating layers: Façade (2)

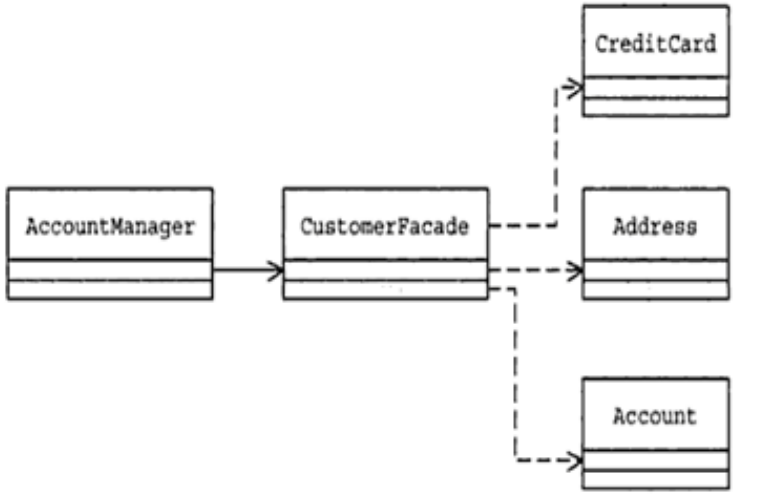


Figure 22.7 Class Association with the Façade Class in Place

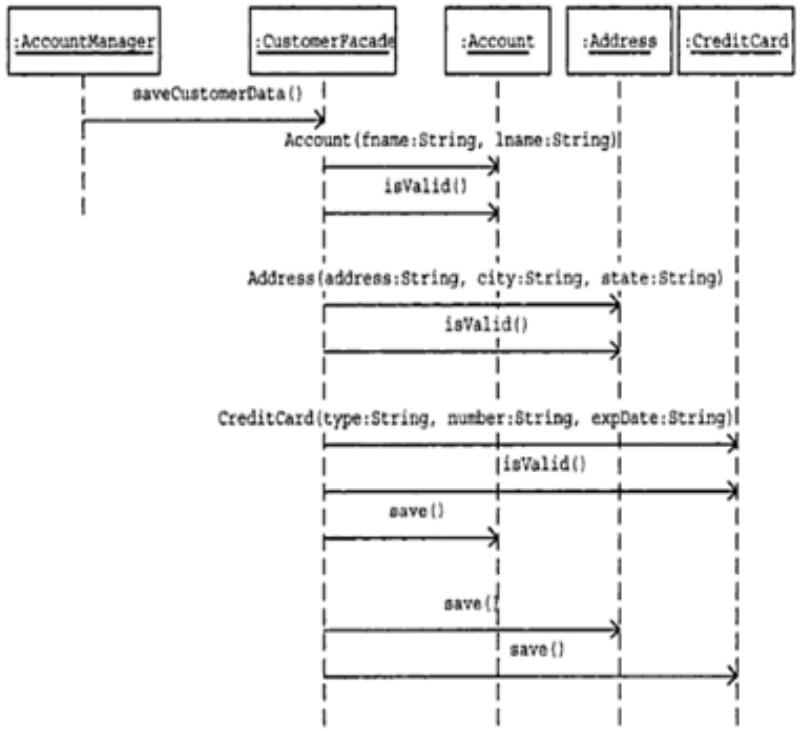


Figure 22.8 In the Revised Design, Clients Interact with the Façade Instance to Interface with the Subsystem

Tiered approach

Another approach consists of *partitioning* a system into independent sub-systems (*tiers*), which are responsible for a class of services maintained as independent modules

These modules are separated from each other by physical boundaries:

machine boundaries

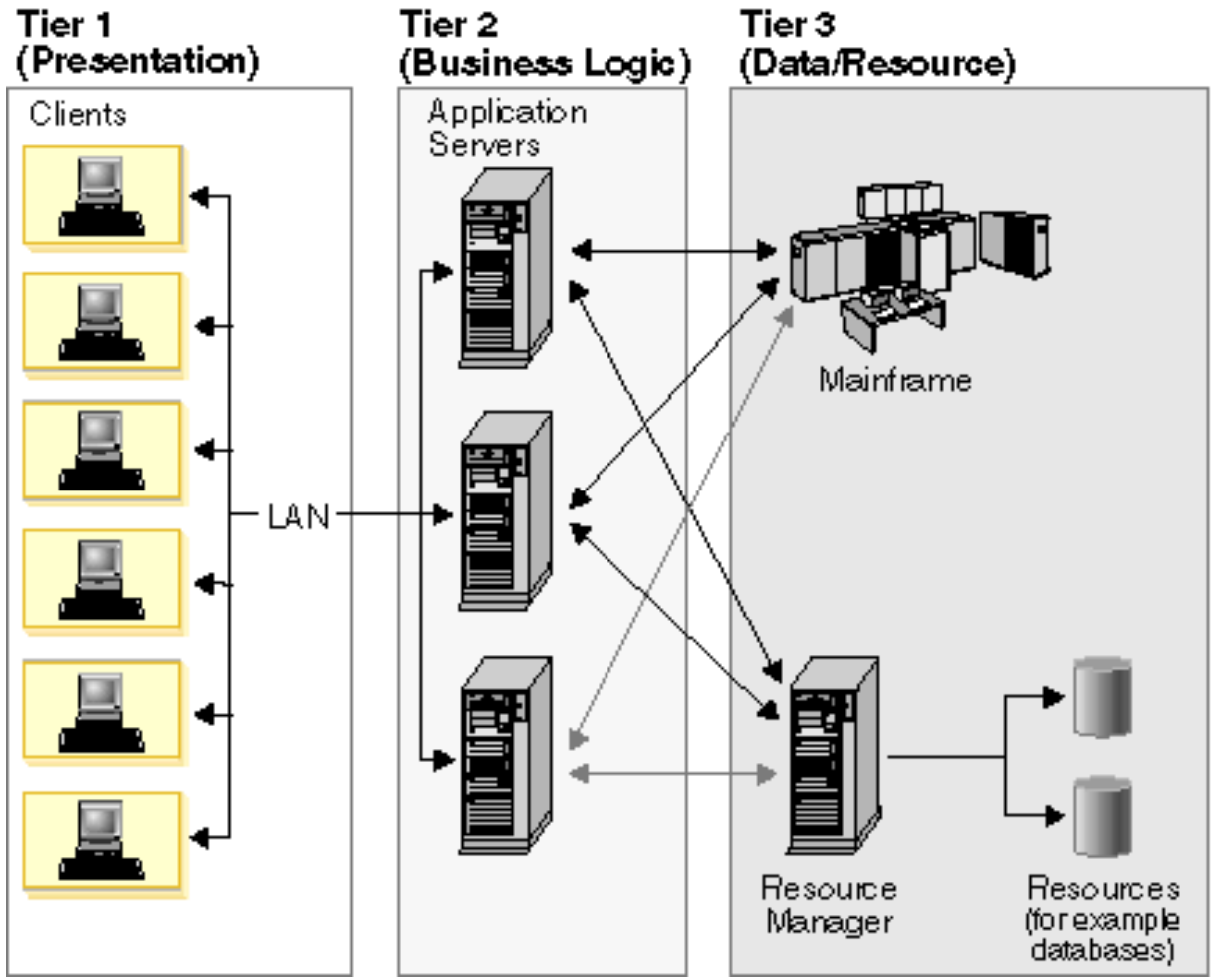
process boundaries

corporate boundaries

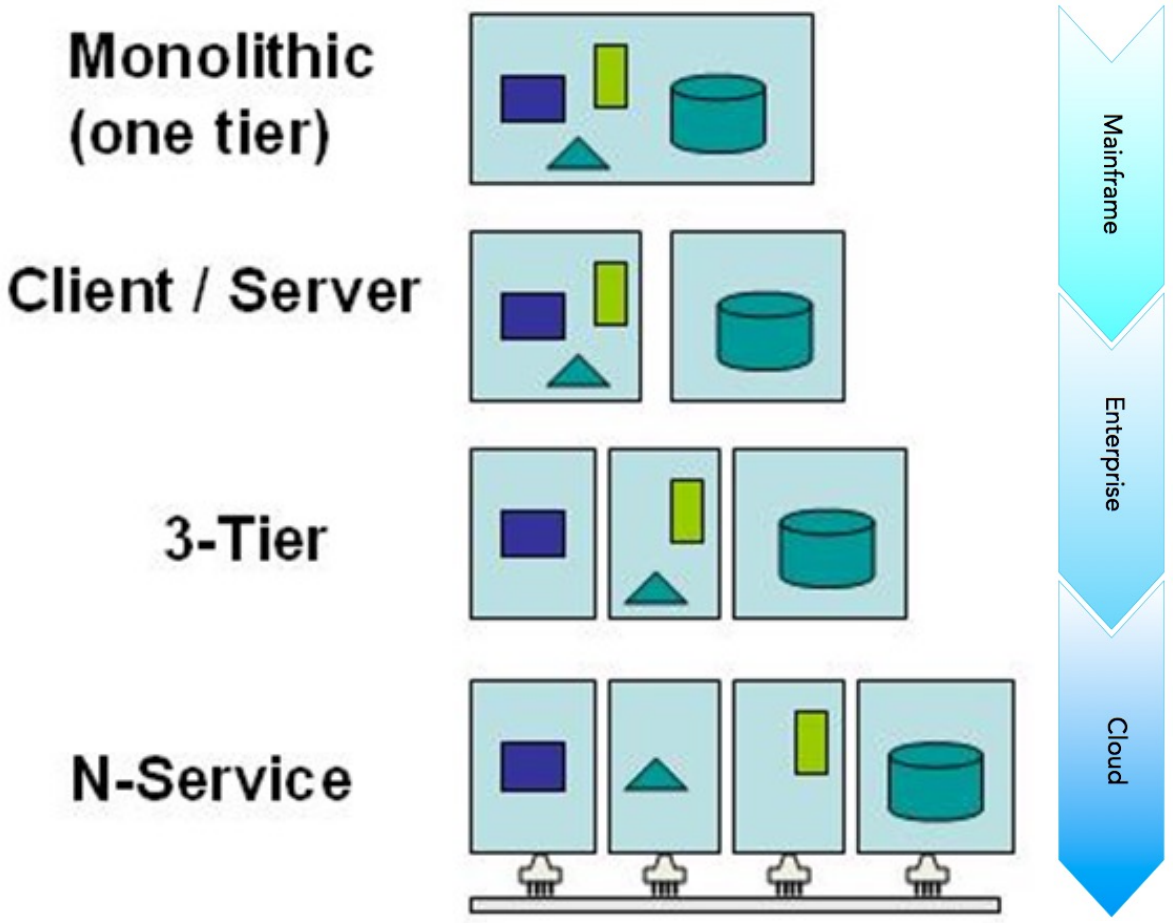
Example: tiered system

A common design of client/server systems uses three tiers:

1. A client that interacts with the user
2. An application server that contains the business logic of the application
3. A resource manager that stores data



Tiers and computing evolution



1-tier, 2-tiers, 3-tiers

A **1-tier model (monolithic)** describes a single-tiered application in which the user interface and data access code are combined into a single program from a single platform

A **2-tiers model (client/server)** represents a split monolithic model composed by a *client* tier that interacts directly with a *server* tier

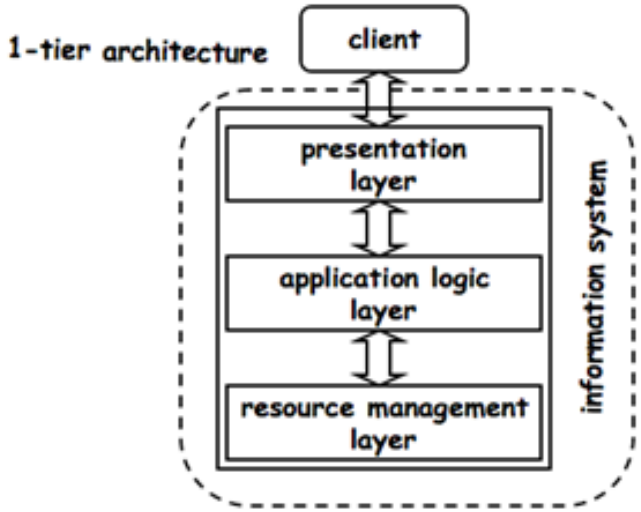
A **3-tiers model (n-tiers)** is a client/server model in which the presentation, the application processing, and the data management are logically (ad often physically) separate processes

1-tier model: Monolithic

The presentation, application logic and resource manager are built as a monolithic entity (no modularity)

Users/programs access the system through “dumb” terminals managed by an *information system*

Typical model for mainframes



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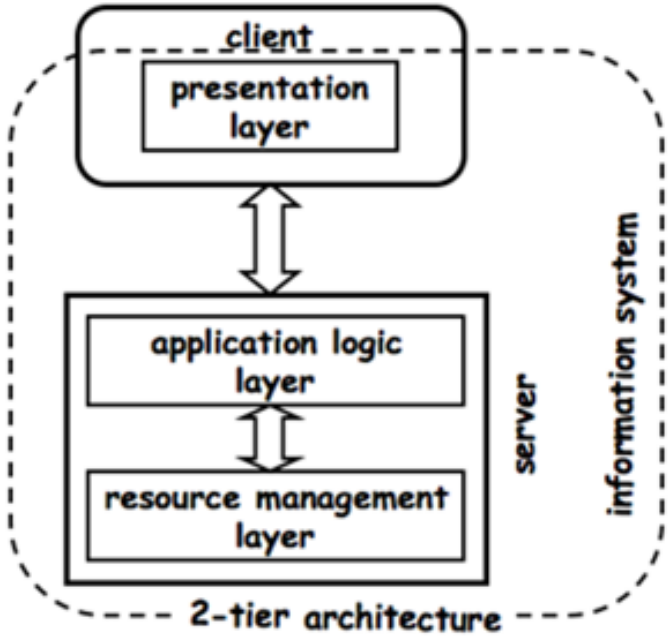
2-tiers model: Client/Server

This model allows to move the presentation tier to the client (*fat client*)

It introduces the concept of API, an interface to invoke the system from the outside



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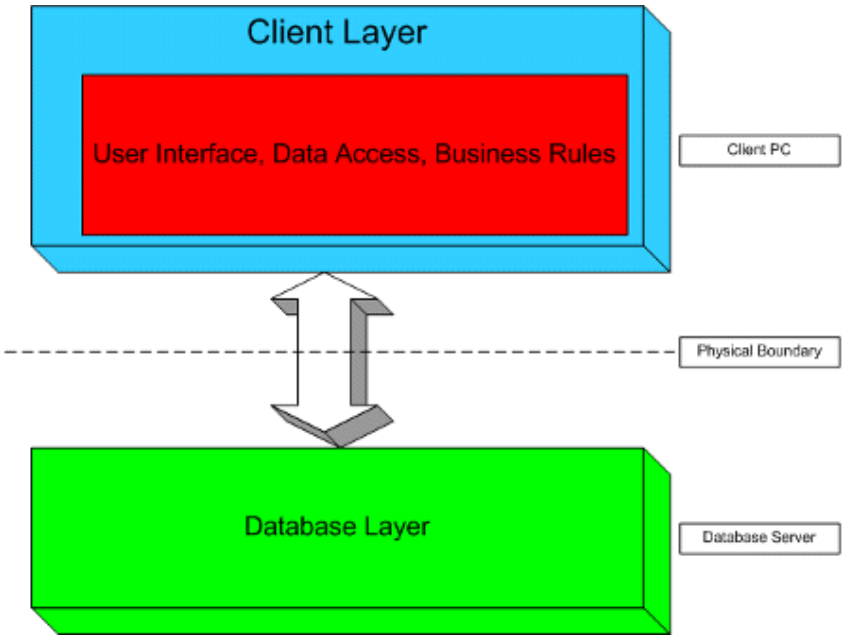

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3-tiers model: Multitiered (1)

In this approach, the user interface runs on a desktop PC or workstation and uses a standard graphical user interface (*thin client*)

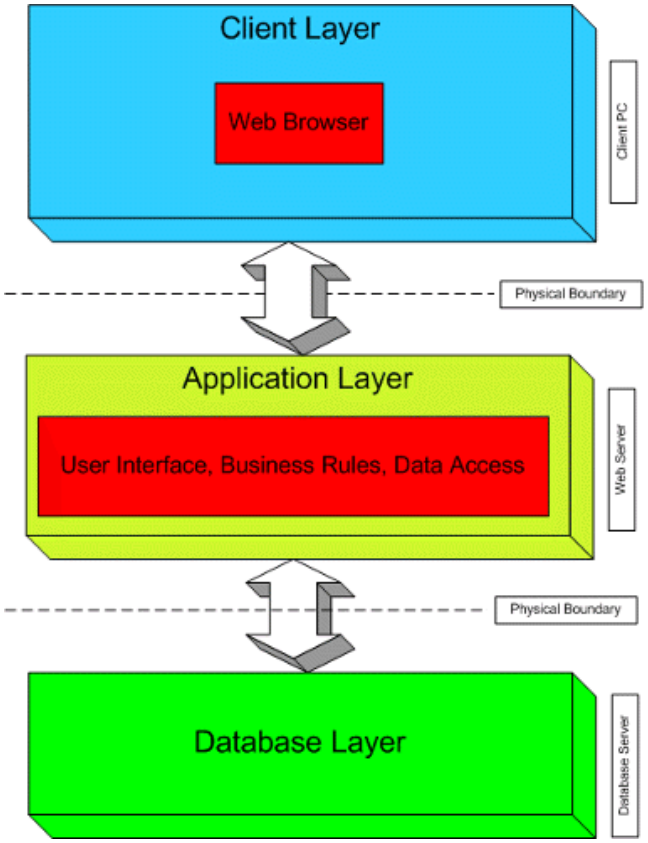
The functional process logic may consist of one or more separate modules running on a workstation or application server

An RDBMS on a database server or mainframe contains the computer data storage logic

This is a specialization (the most widespread) of the n-tiers model

3-tiers model: Multitiered (2)

Concept of *middleware,* that introduces an additional tier of business logic encompassing all the underlying systems



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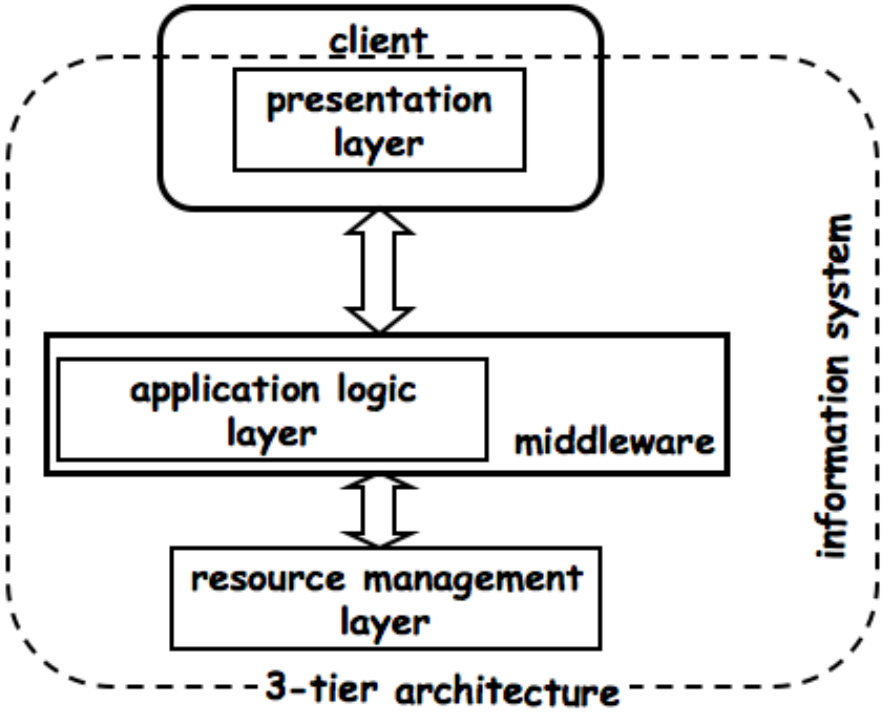

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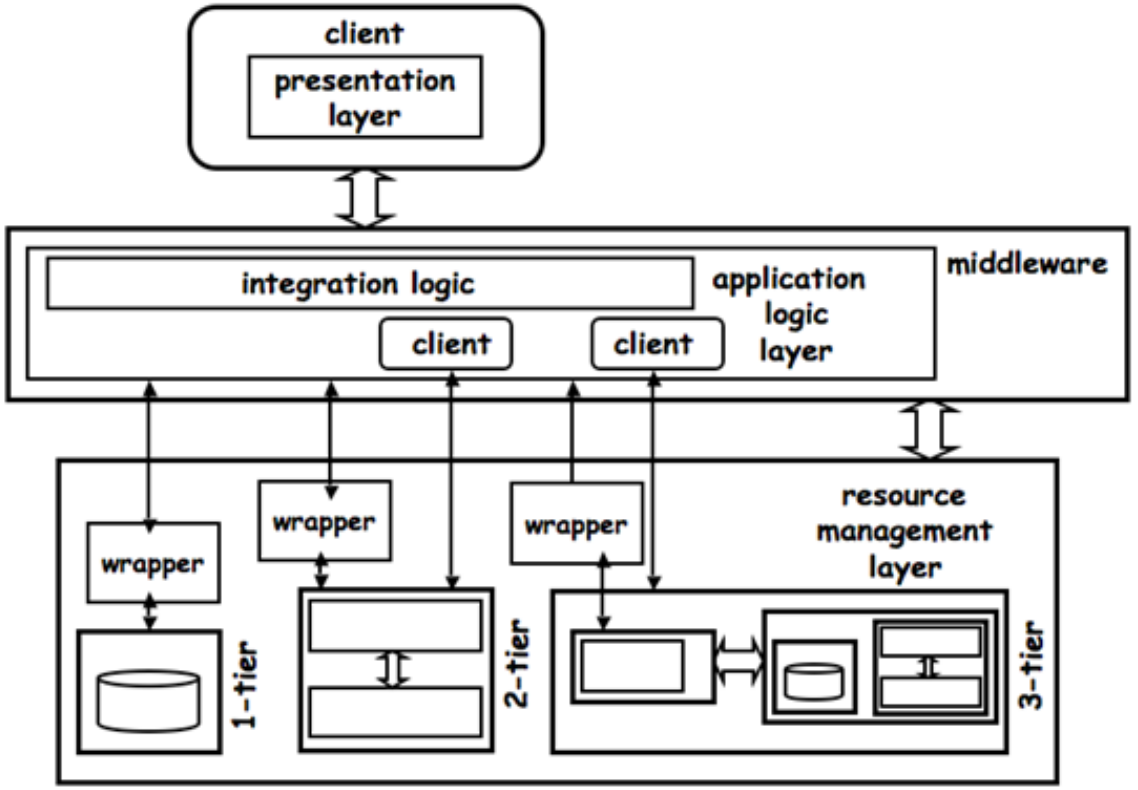
Middleware as a glue

Middleware systems also enable the integration of systems built using other architecture models



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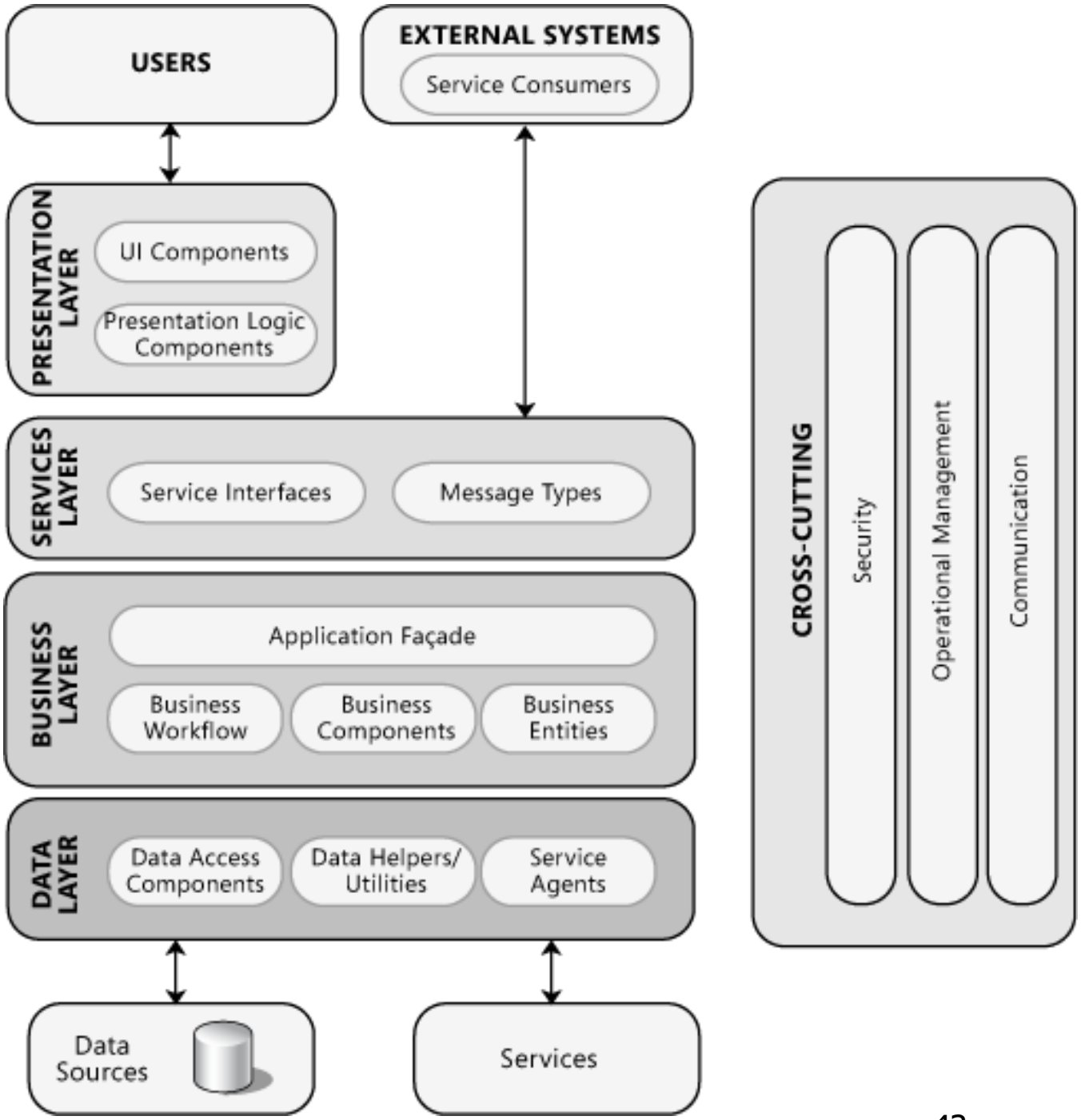
Do not confuse layers and tiers!



msdn.microsoft.com/en-us/library/ee658124.aspx

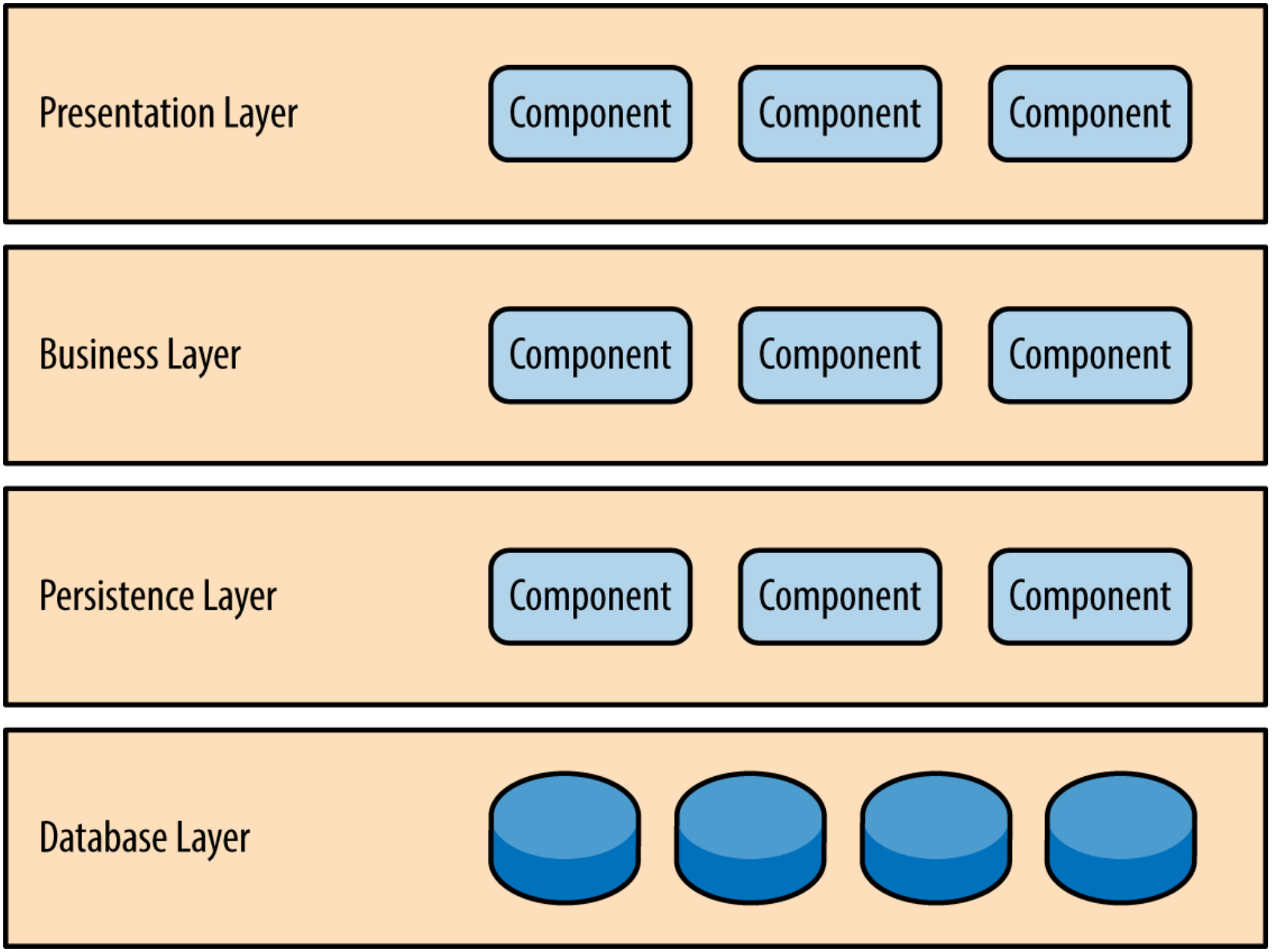
How can we describe and reuse large sw systems?

Basic questions about system deployment and maintenance are hard to answer:

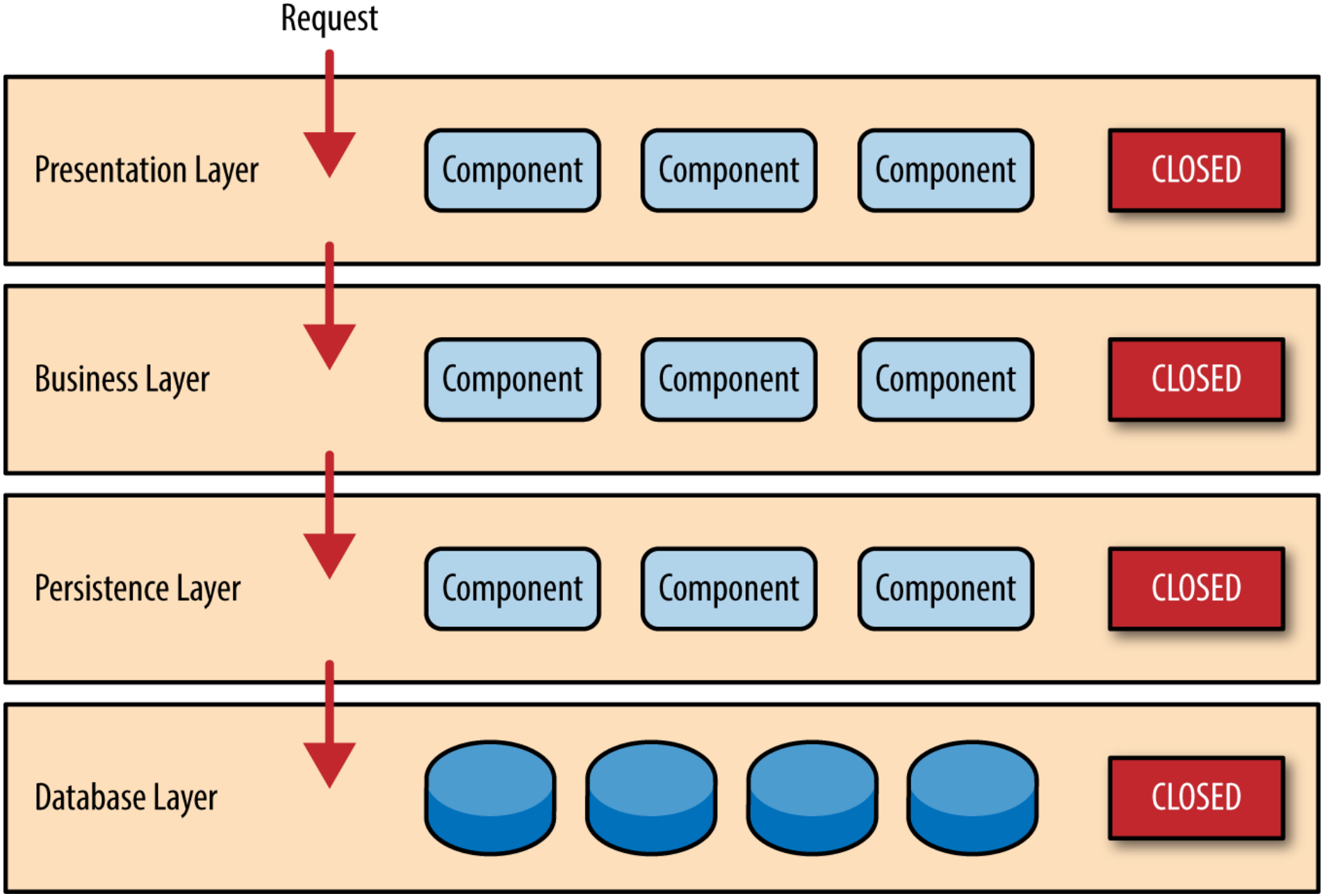
- Does the system scale?
- What are its performance characteristics ?
- How easily does the system respond to change?
- What are its deployment characteristics?
- How responsive is the system?

The main concepts useful to answer to these questions are the «software architecture patterns»

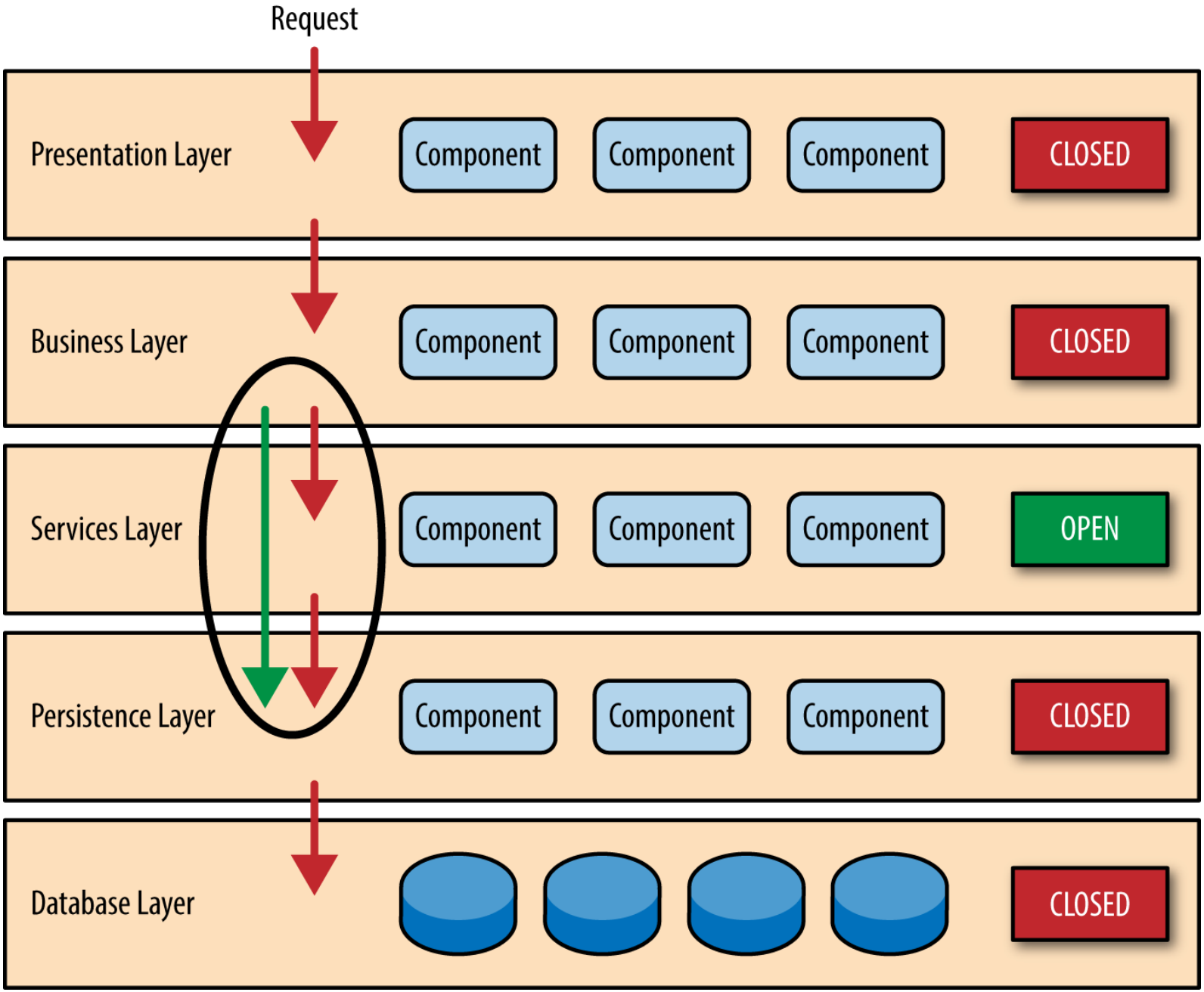
Summary: Layered architecture



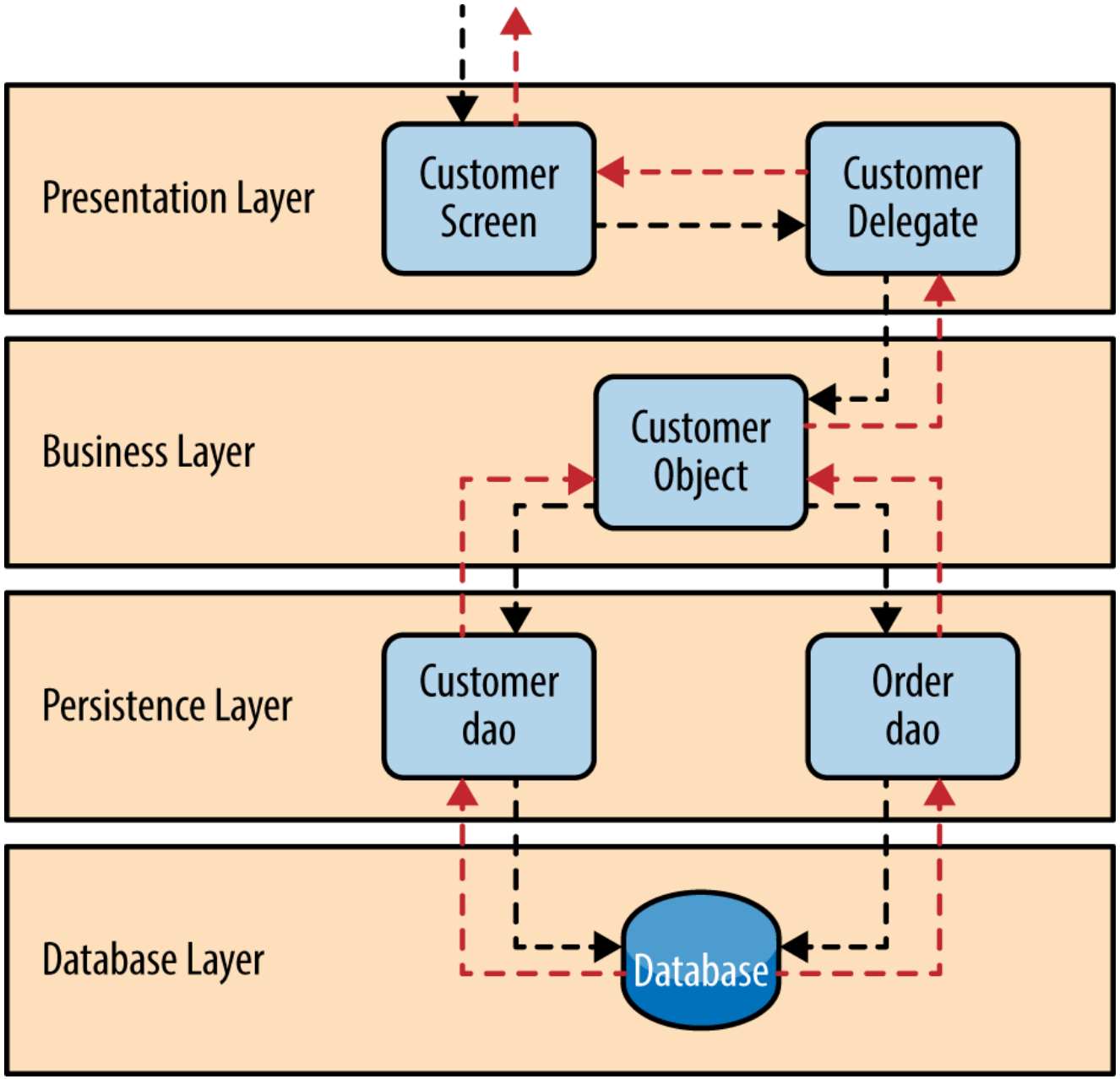
Summary: Closed layers



Summary: Open layers

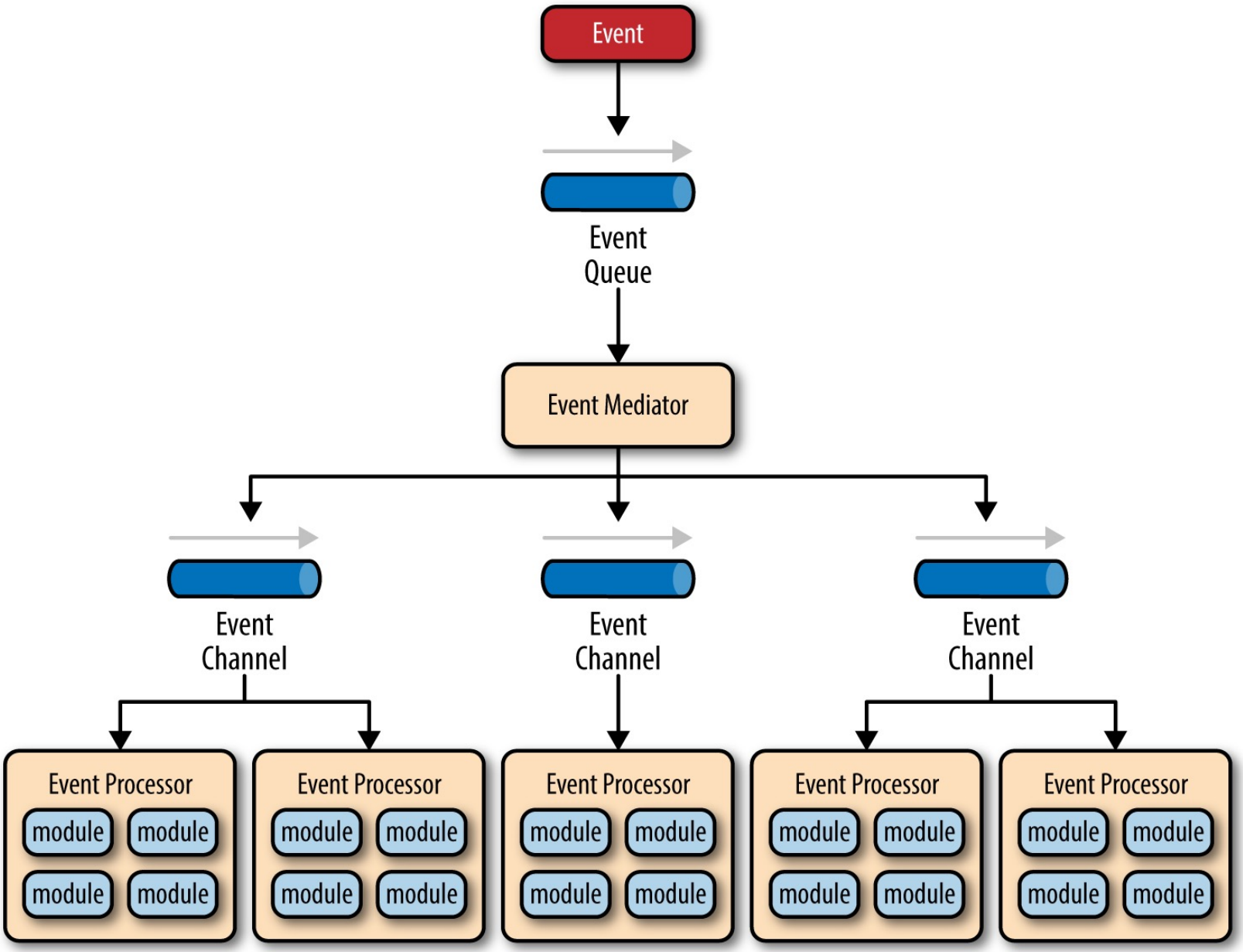


Layered architecture example

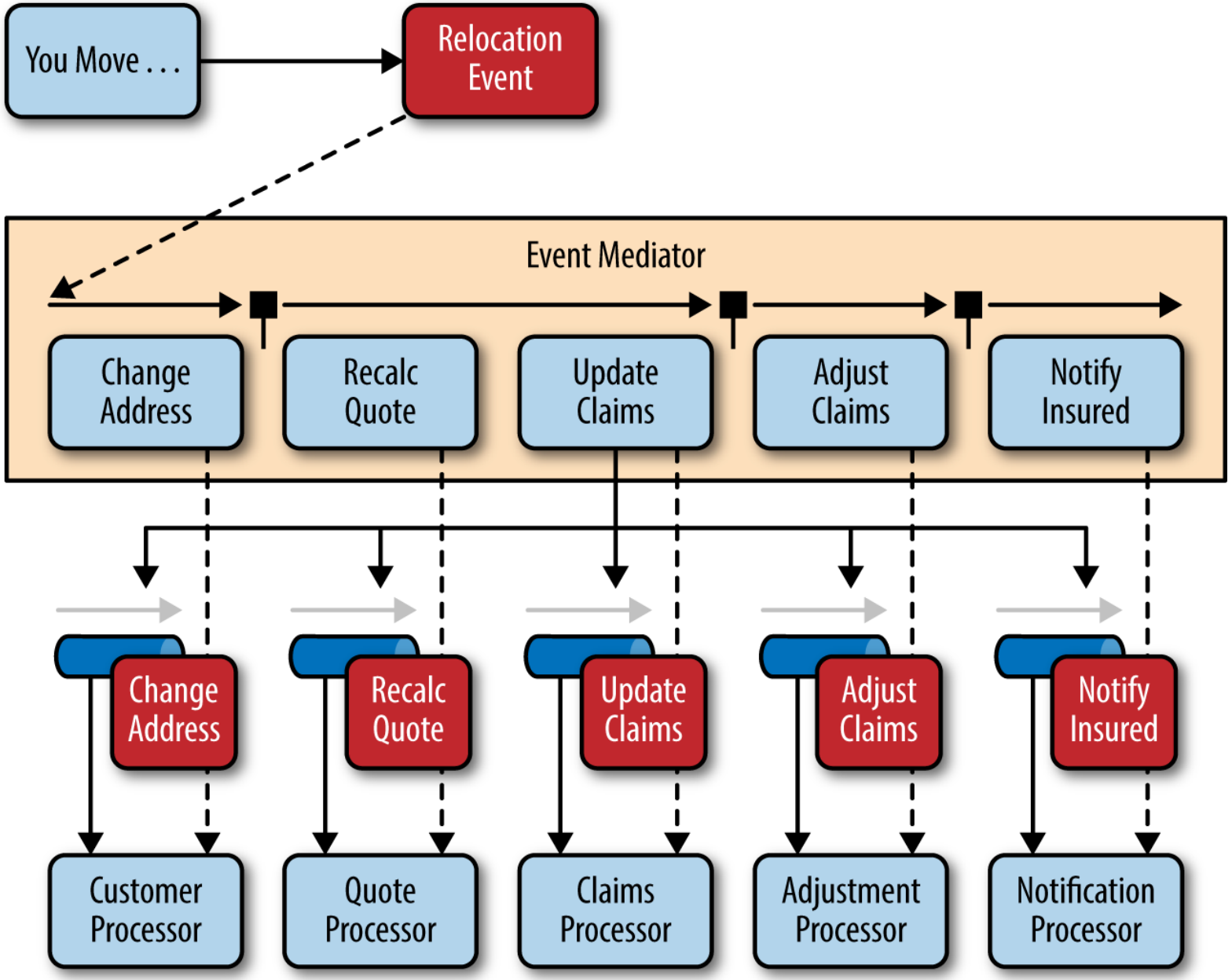


The black arrows show the user request flowing down to the database to retrieve the customer data, and the red arrows show the response flowing back up to the screen to display the data.

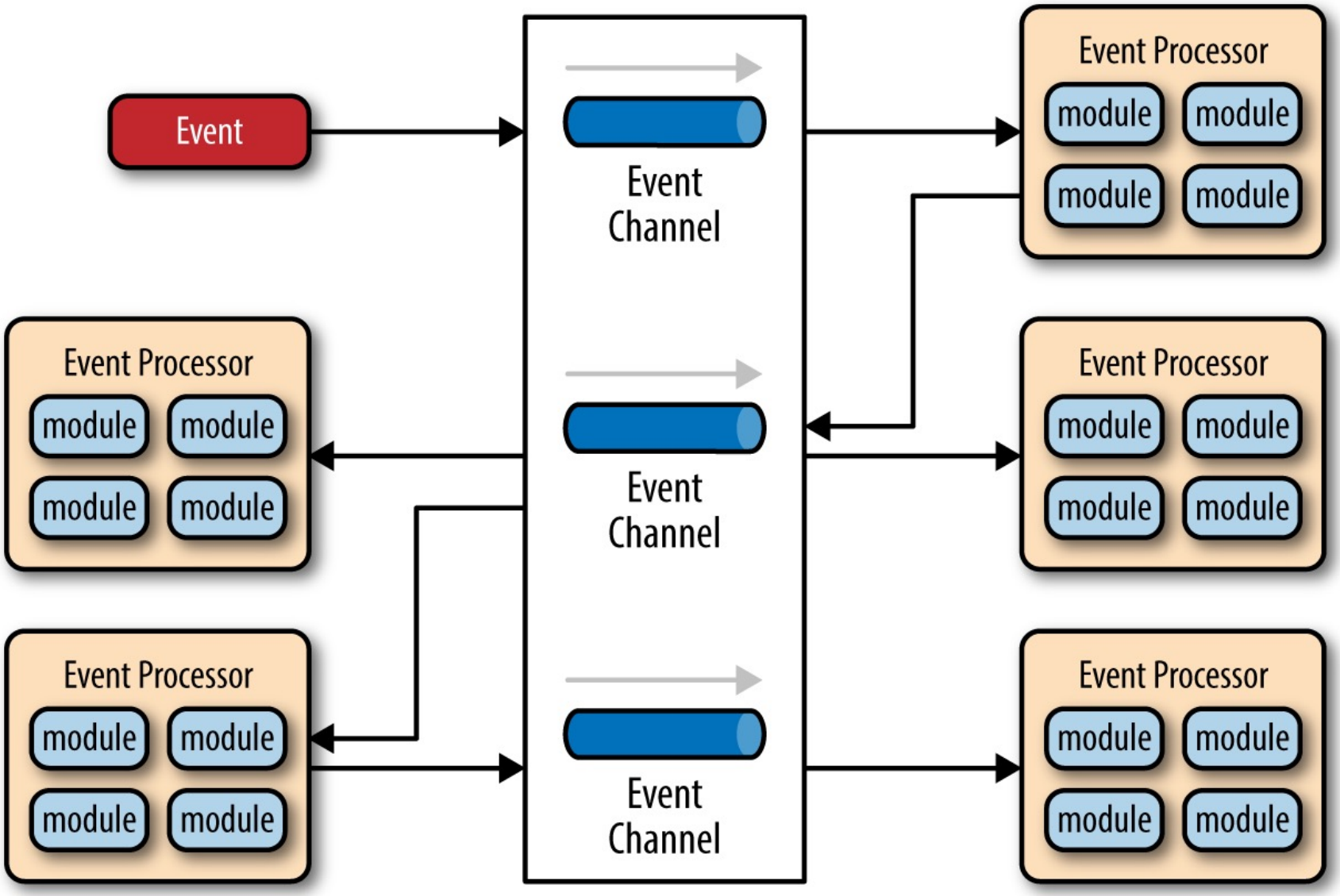
Event driven mediator topology



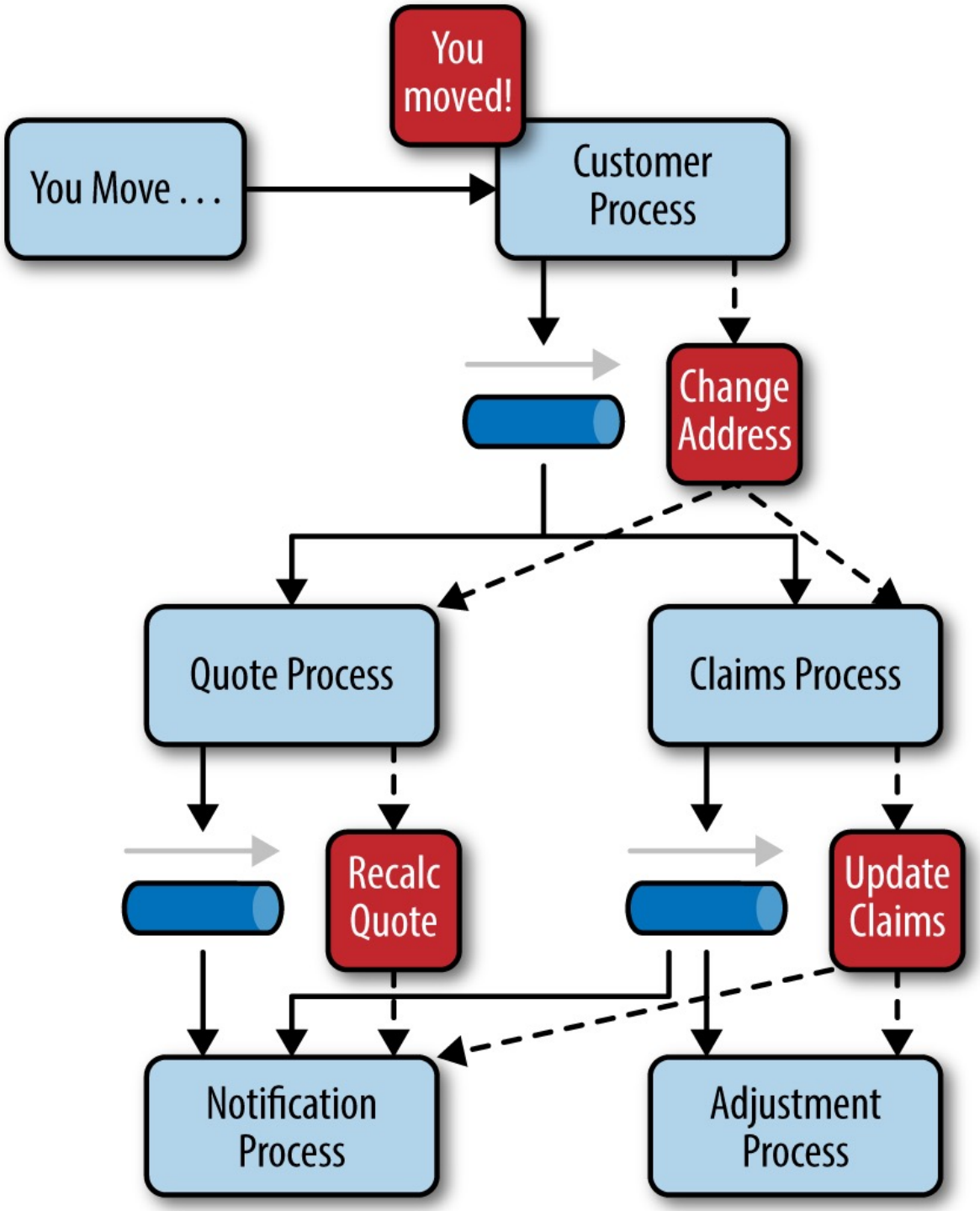
Mediator topology example



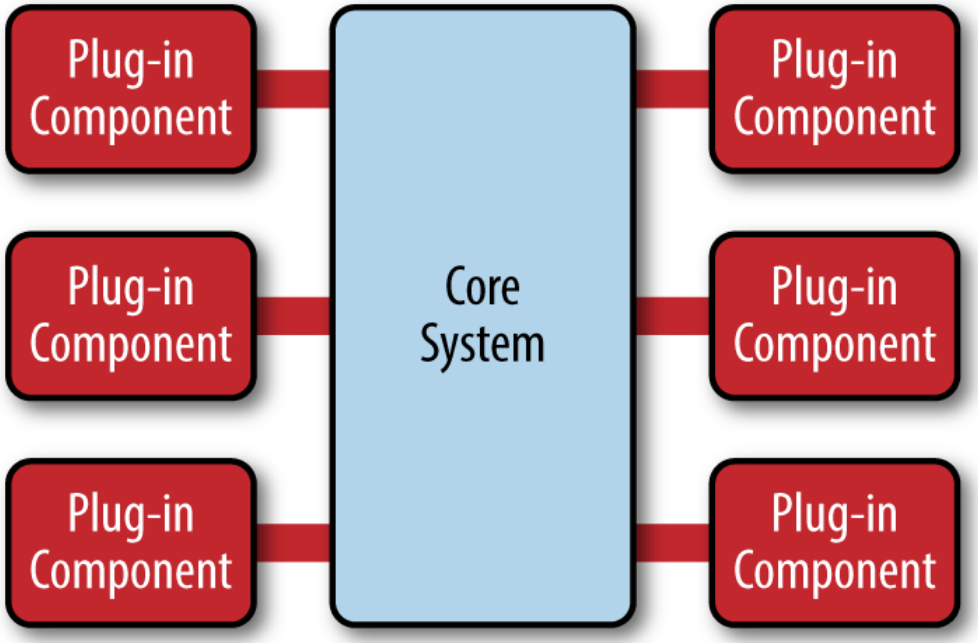
Event driven broker topology

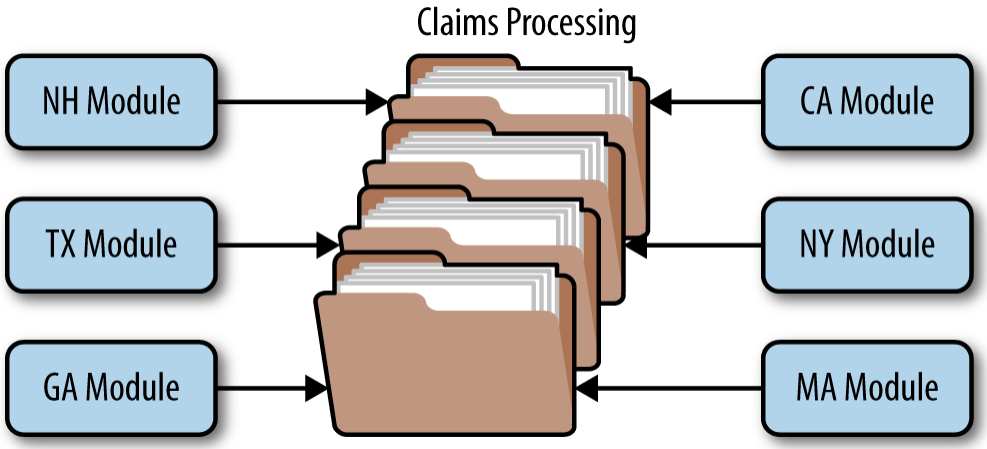


Broker topology example

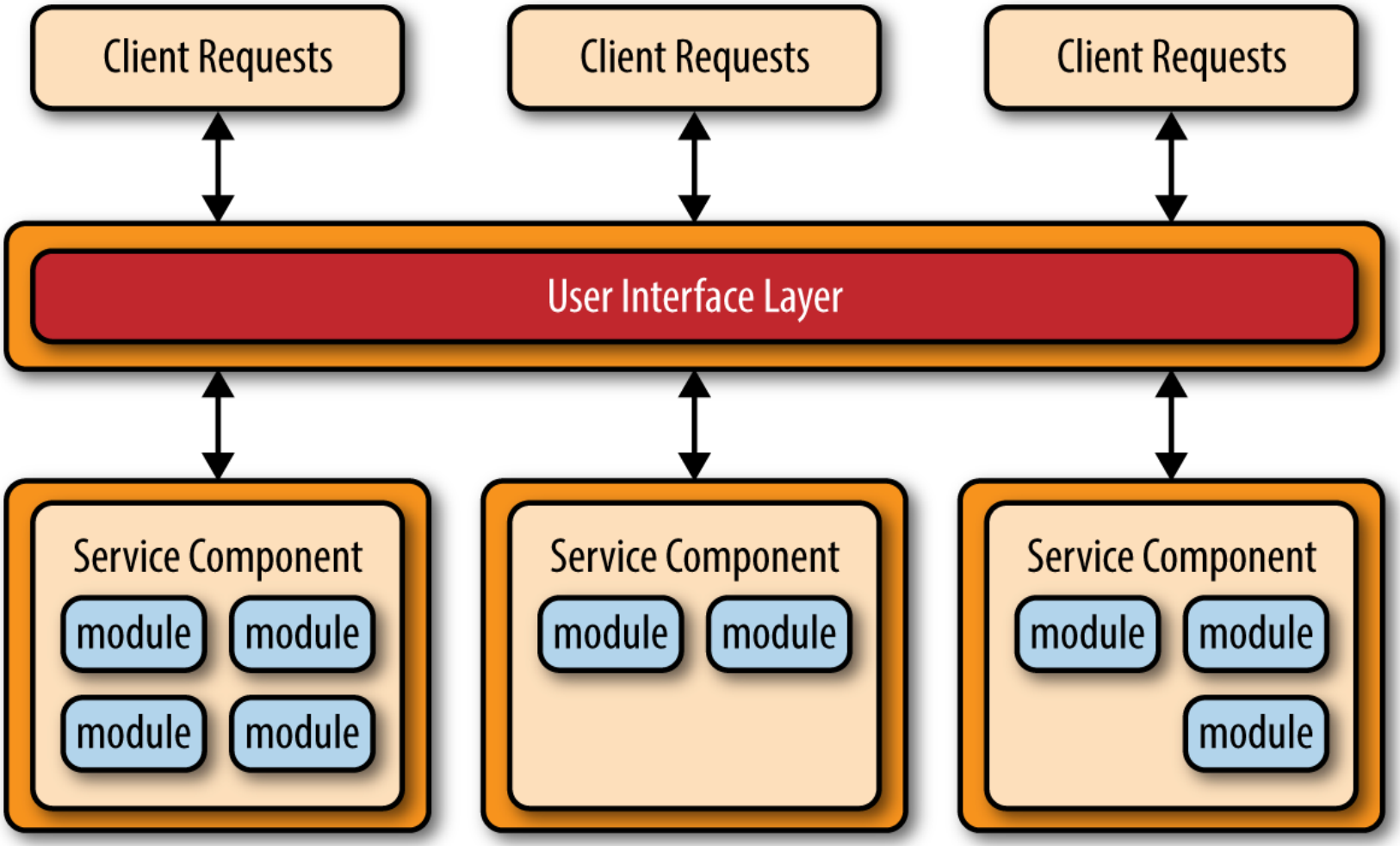


Microkernel pattern and example

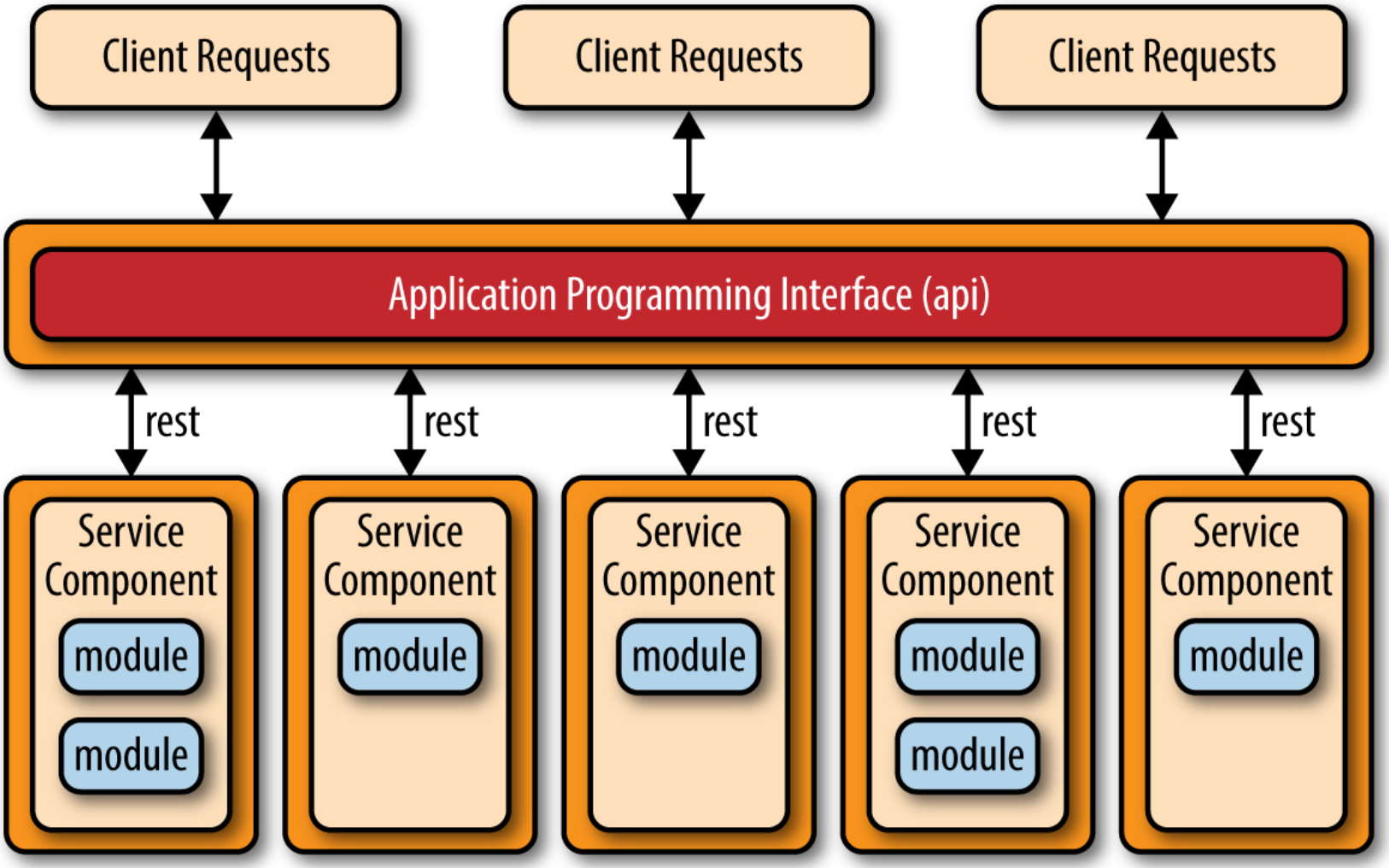




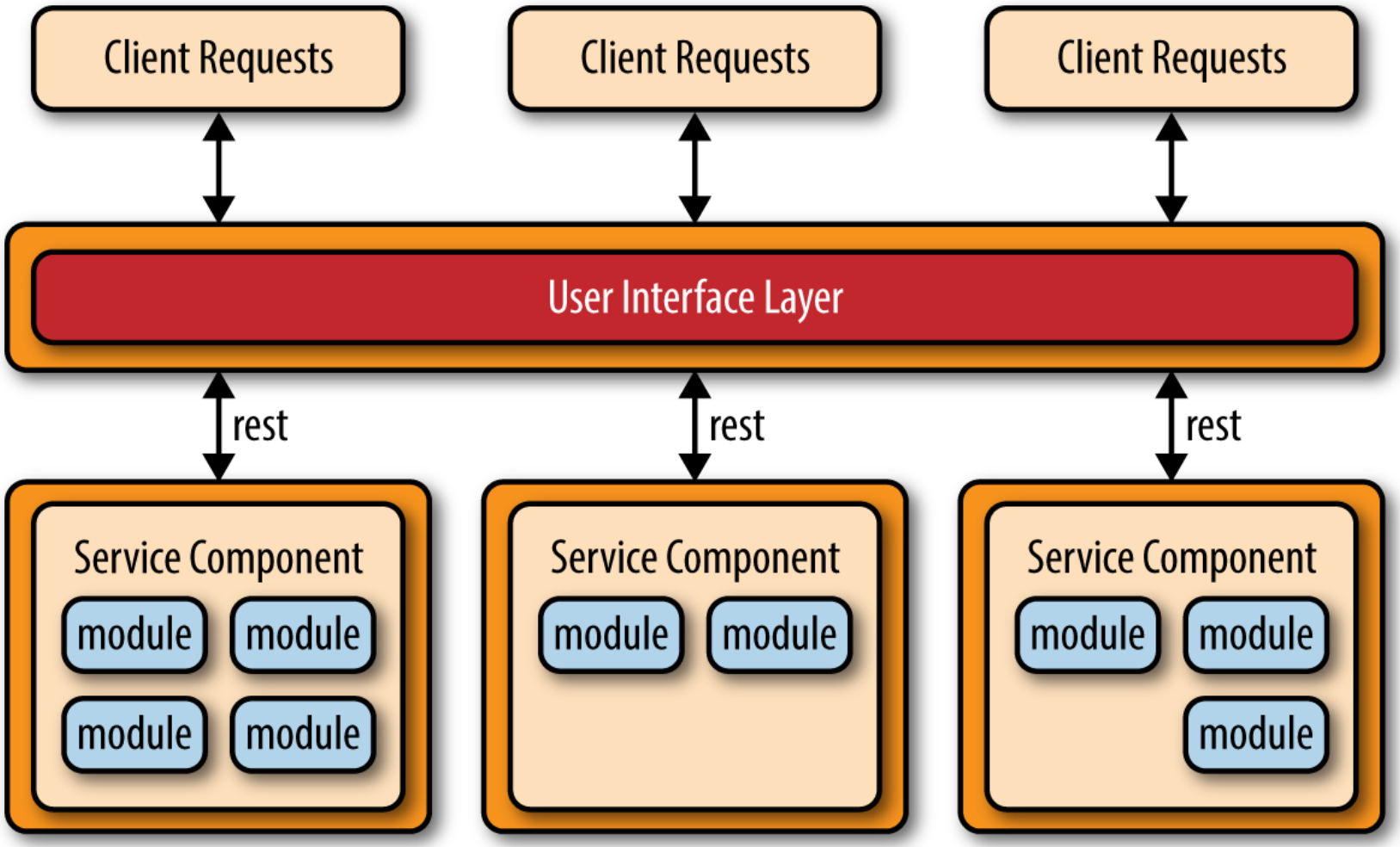
Basic microservice architecture pattern



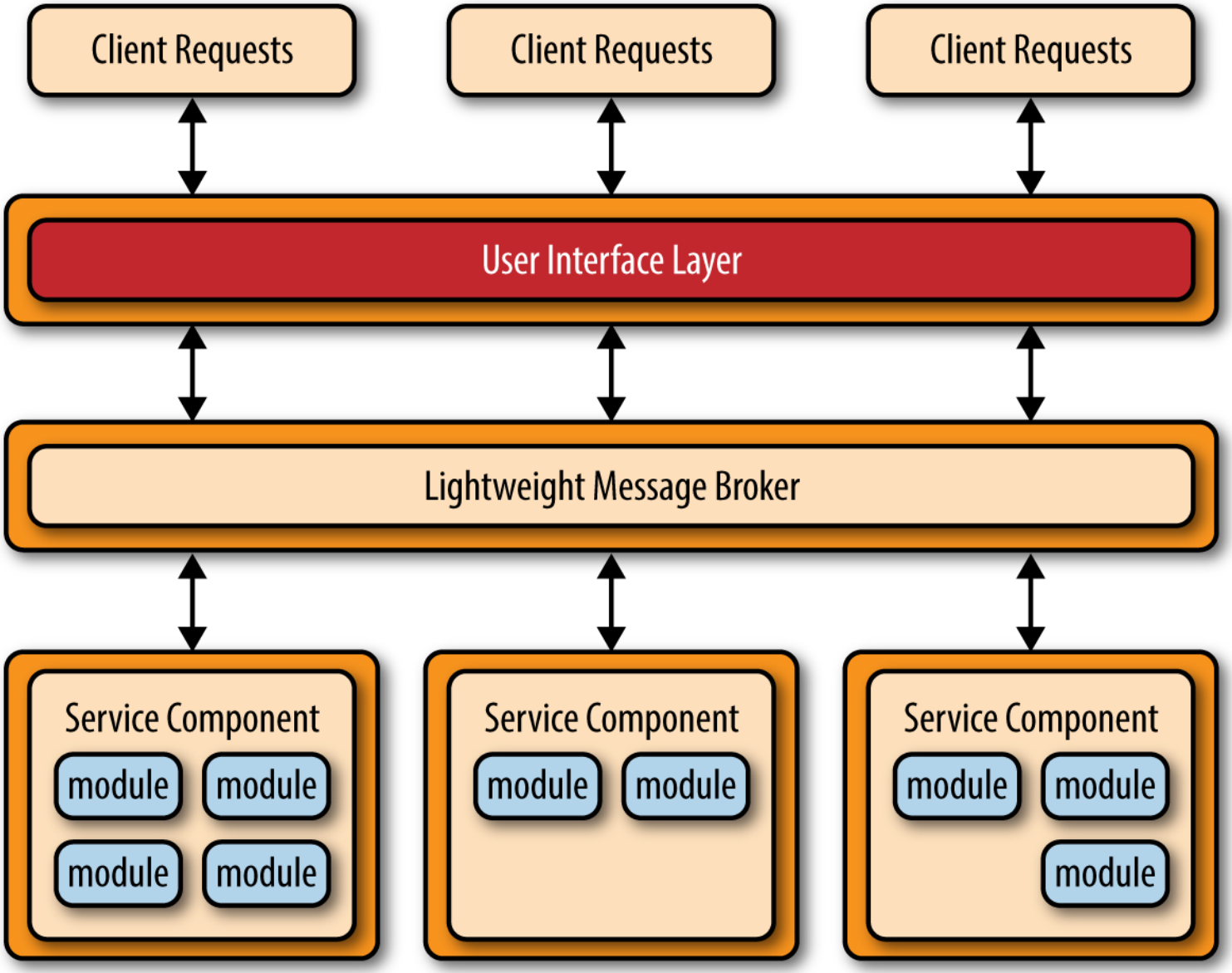
API REST-based topology



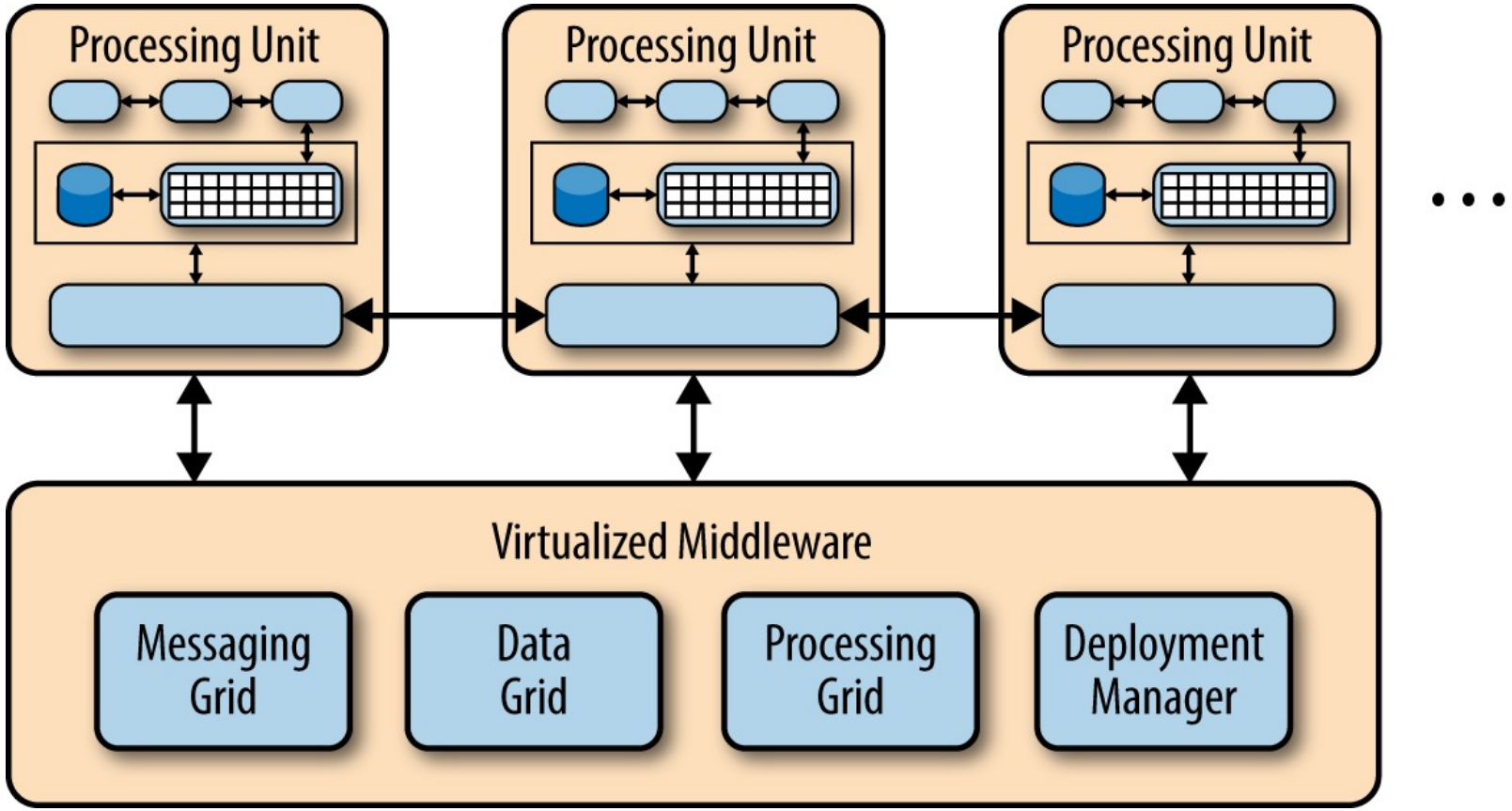
Application REST-based topology

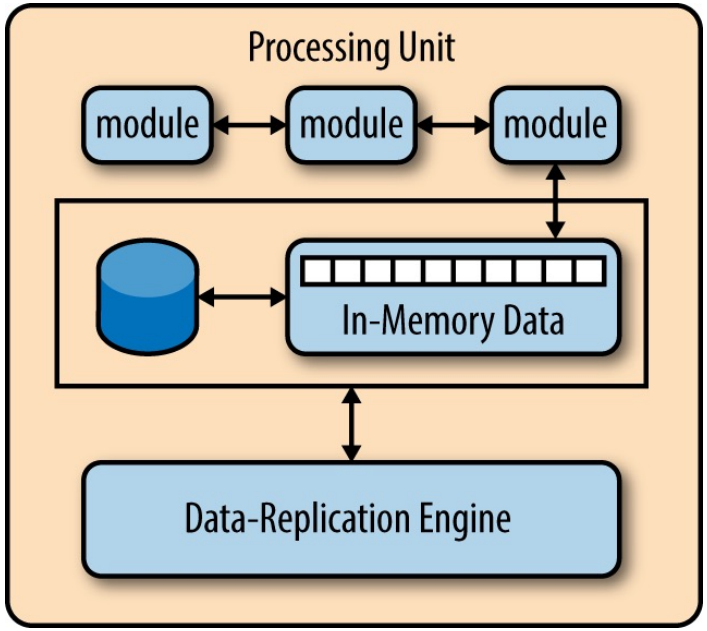


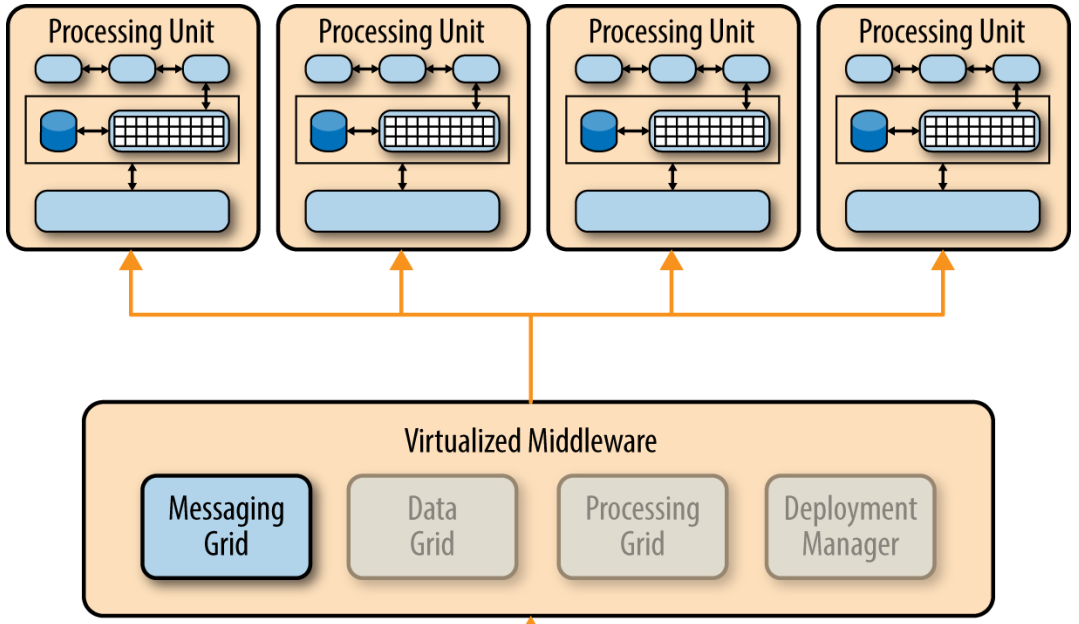
Centralized messaging (SOA-like) topology



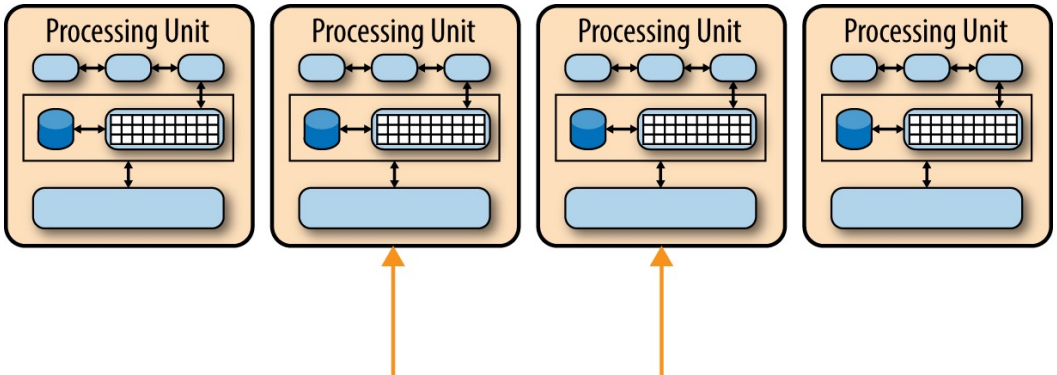
Space-based architecture pattern (cloud-like)



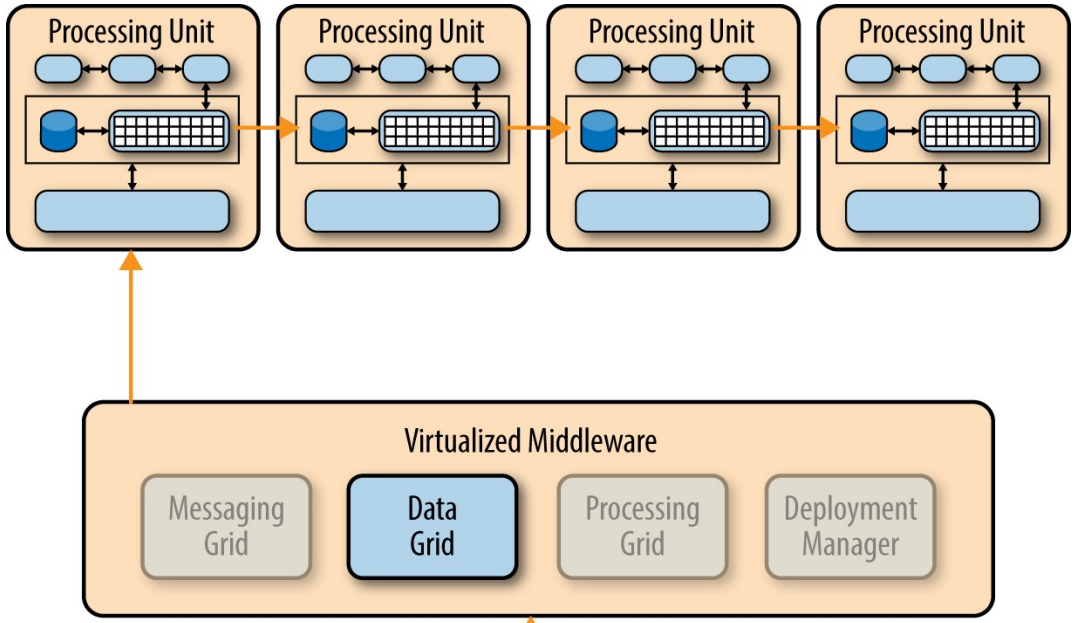




Messaging-grid component



Processing-grid component

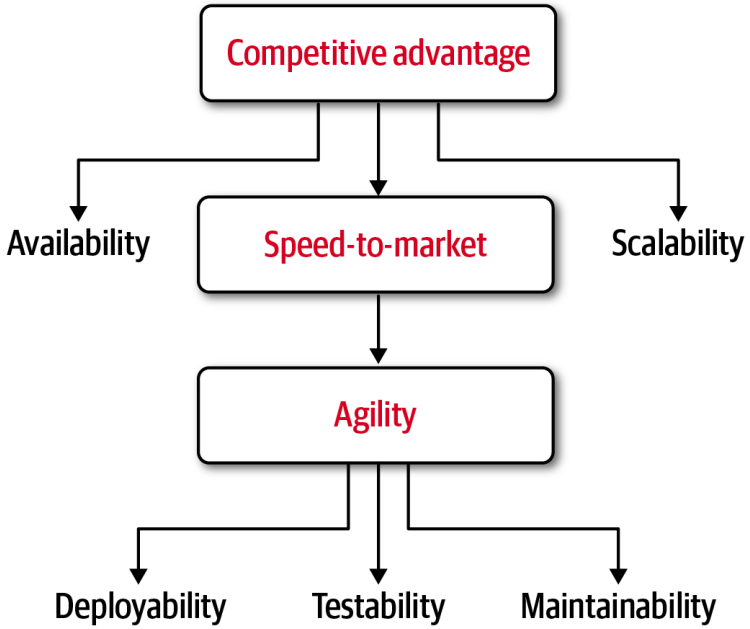


Data-grid component

Pattern analysis comparison summary

	Layered	Event-driven	Microkernel	Microservices	Space-based
Overall Agility	↓	↑	↑	↑	↑
Deployment	↓	↑	↑	↑	↑
Testability	↑	↓	↑	↑	↓
Performance	↓	↑	↑	↓	↑
Scalability	↓	↑	↓	↑	↑
Development	↑	↓	↓	↑	↓

Overall agility is the ability to respond quickly to a constantly changing environment



Conclusions

Describing system architectures is important to understand how systems are designed, built and maintained

Reference architecture, architectural styles, and patterns help in understanding, building and maintaining complex computer systems

Questions