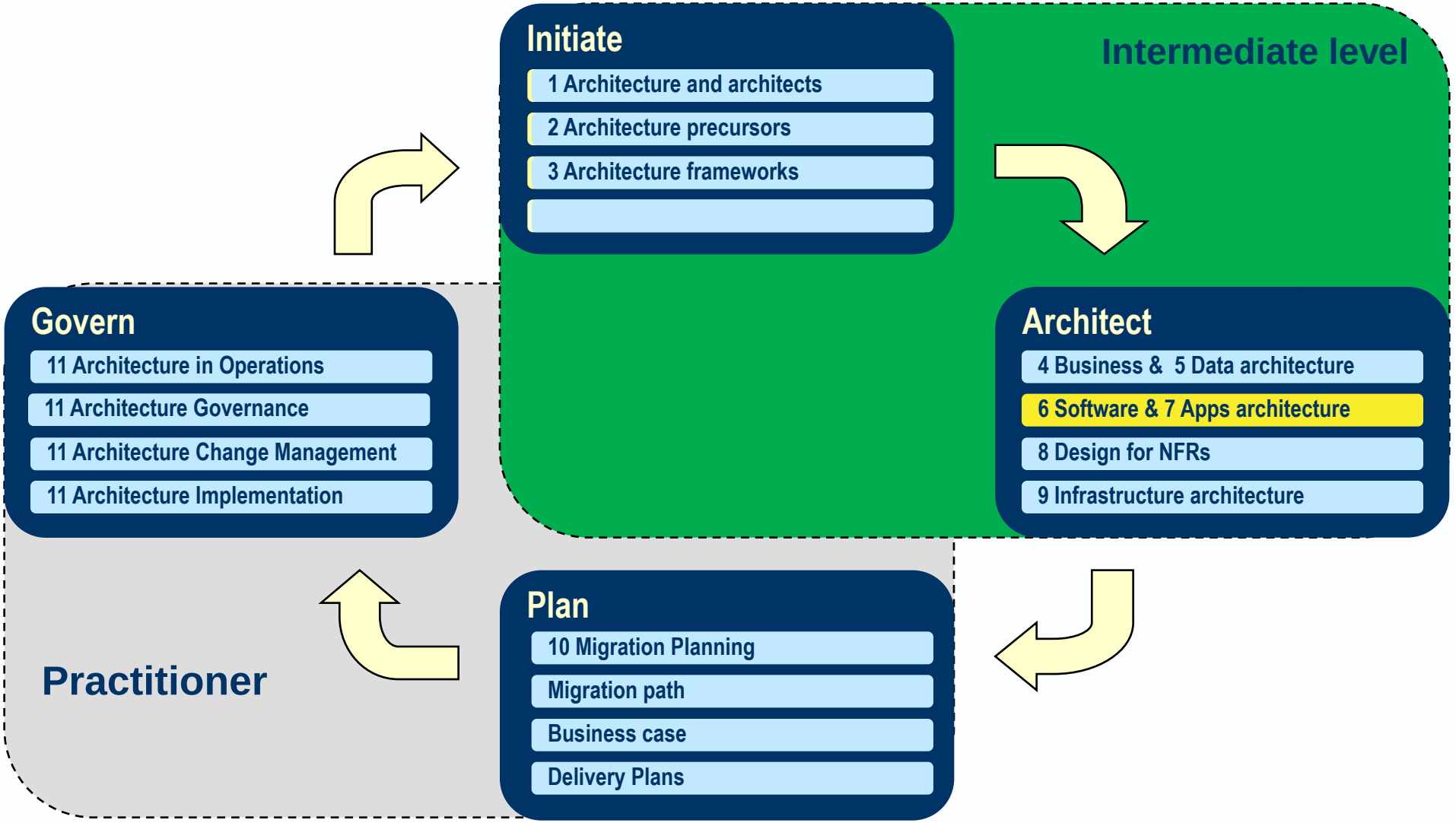
Avancier Reference Model

Software Architecture (ESA 6)

6. Software architecture

Avancier



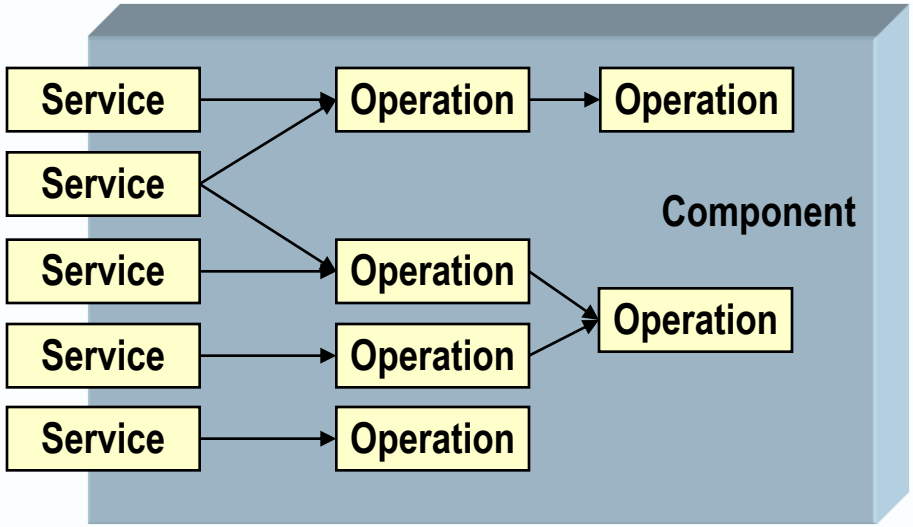
6 Software domain view

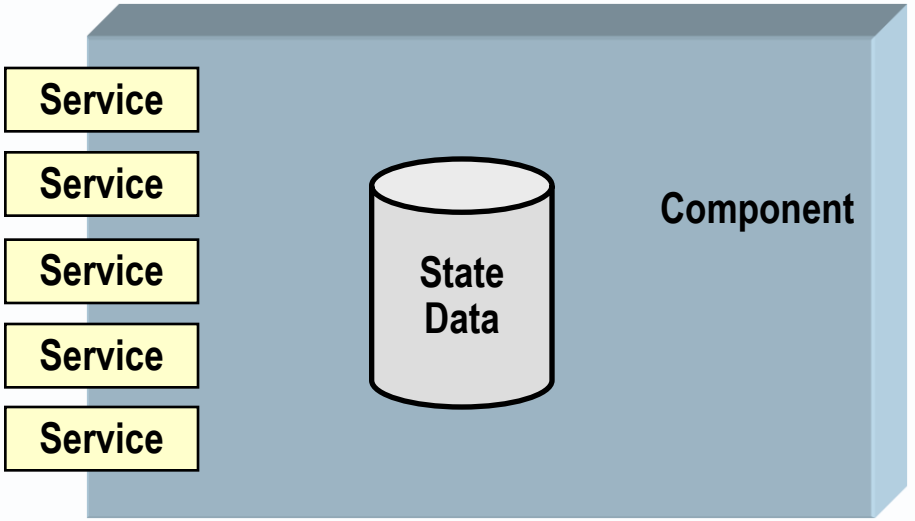
- Applications architecture (section 7) depends on the lower level design of fine-grained software components discussed in this section.

- Enterprise and solution architects should be aware of tools and techniques for modularising one application into components and integrating those components.

Encapsulation of modules

- [A technique] that defines a thing by an interface it offers.
- It hides inner workings or processes from external entities.
- It hides internal resources (notably data structures) from external entities.





API (service catalogue)

- [An interface definition] a collection of automated behaviors accessible by software clients.
- It identifies discrete services, may provide access to them, and hides what performs.

	Required behaviours	Logical structures	Physical structures
Software	Operation	API	Application component

Address Component: Interface definition
Operation: Get Address (Post Code, House Num): Address
Operation: Get Post Code (Address): Post Code

Operation (discrete service)

Avancier

- [An automated behavior] that can be requested of an application component.

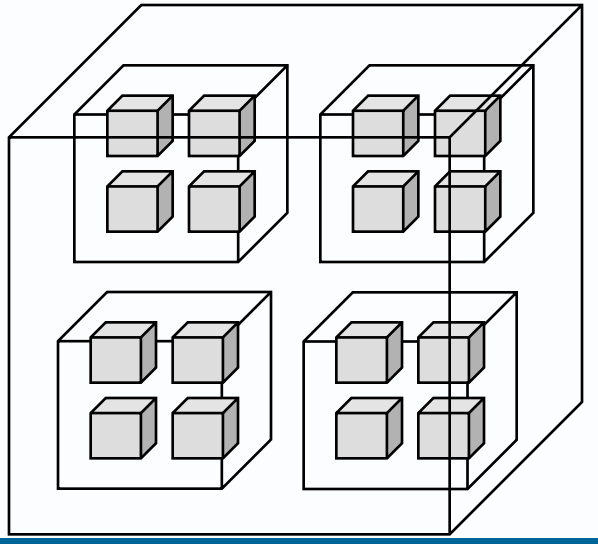
	Required behaviours	Logical structures	Physical structures
Software	Operation	API	Application component

Address Component: Interface definition
Operation: Get Address (Post Code, House Num): Address
Precondition: Post Code is properly formatted
Postcondition: Correct Address is returned
Operation: Get Post Code (Address): Post Code
Precondition: Address is properly formatted
Postcondition: Correct Post Code is returned
Non-functional characteristics – shared by services above
Response time = < 3 seconds
Throughput = 10 per second

Application component

- [A component] capable of performing automated behaviors.
- It can be a whole application or a component within one.
- It may be encapsulated behind an API, and may maintain some business data.

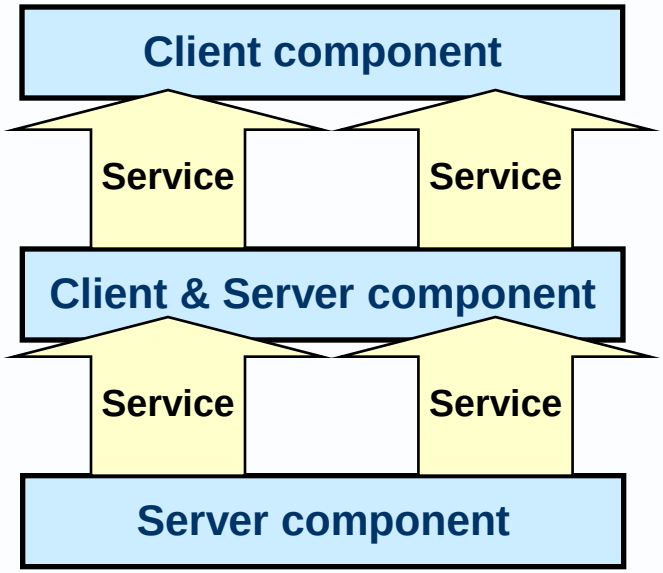
	Required behaviours	Logical structures	Physical structures
Software	Operation	API	Application component



Component-based design (software level)

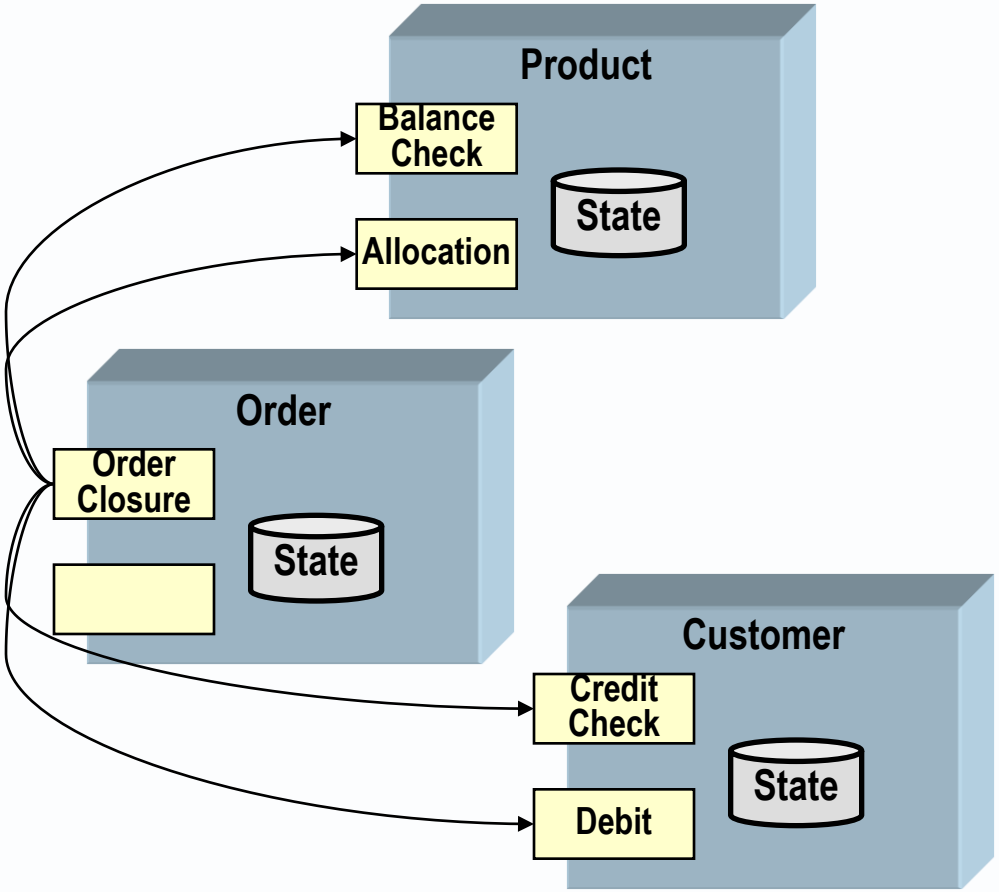
- [A technique] a modular design approach that divides a system into components.
- Components may be coded using different technologies and deployed in different locations.

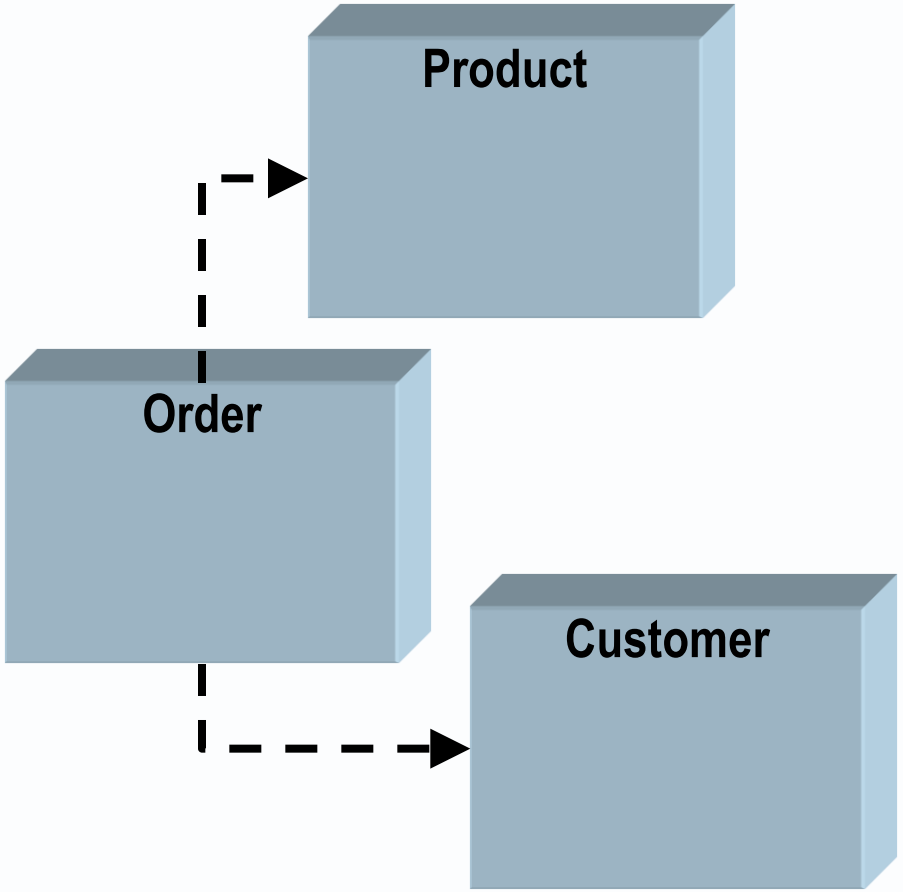
- **Delegation**
- [A process] whereby one component calls another to do the work.



Dependency

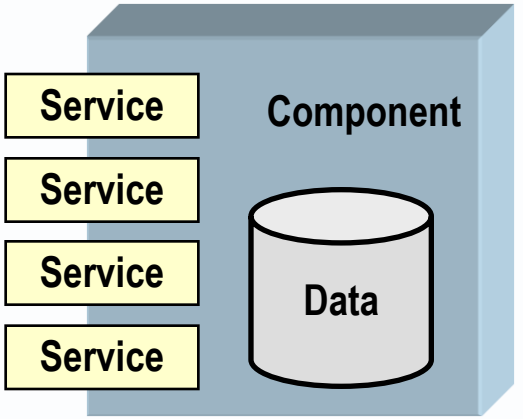
- Delegation usually implies invoking a component by passing it a message.



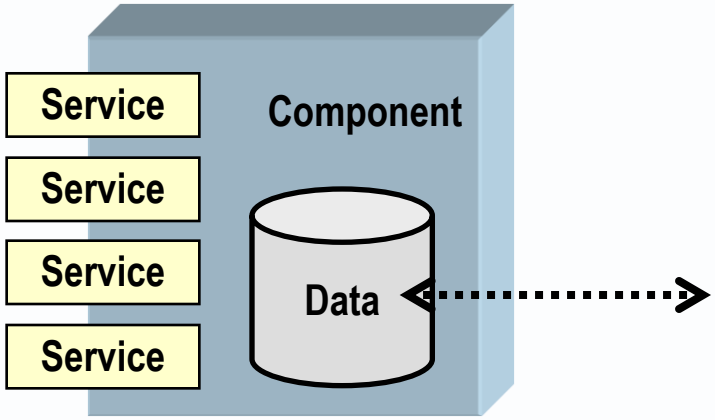


Statefulness

- **Stateful component**
- [An application component] that retains data in its local memory between invocations.
- The state is lost if the component is removed.

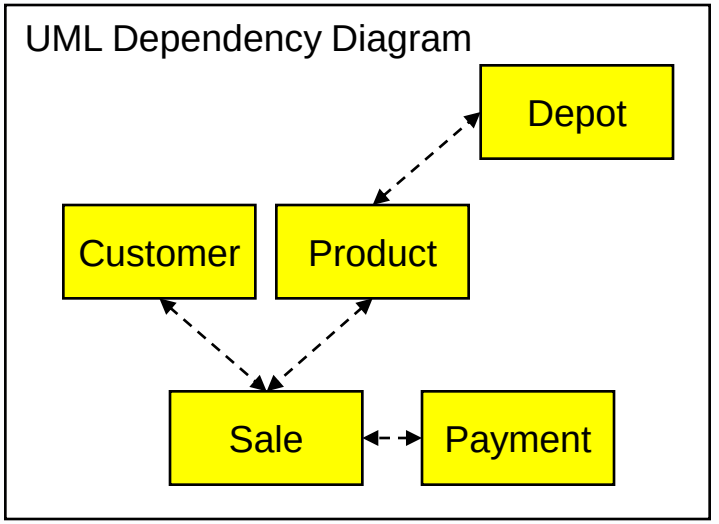


- **Stateless component**
- [An application component] that does not retain data between invocations.
- However, its transient state can be copied into a persistent data store.

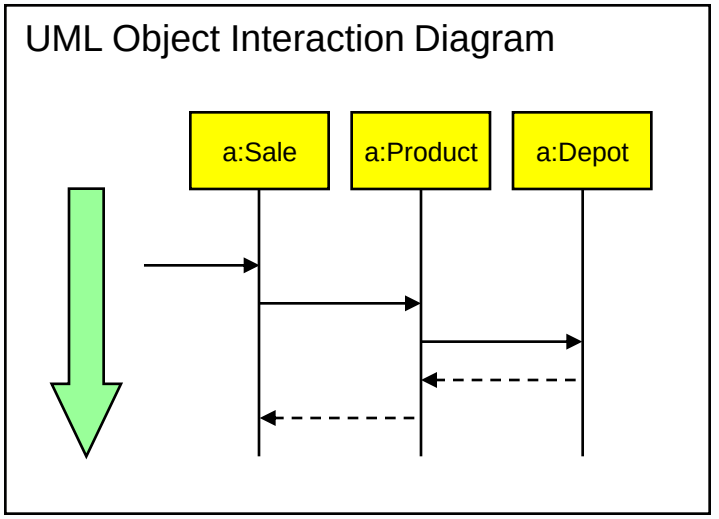


Component-based design artifacts

- **Component-dependency diagram**
- [An artifact] that shows the design-time structure of a software application.
- It shows which components depend on which other components



- **Sequence diagram**
- [An artifact] that shows how components cooperate at run-time to enable a process.
- How a design-time structure behaves at run time is critical to meeting requirements.



6.2 Component integration

- This section reflects a history of increasing distribution and integration of software systems, and the development of ways to connect loosely-coupled application components.
- However, there will always be use cases in which components are better closely coupled.

LPC *versus* RPC

- **Local Procedure Call (LPC)**
  - [A process] by which one component calls another component running on the same computer.
  - It is simpler, quicker and more secure than a remote procedure call.

- **Remote Procedure Call (RPC)**
  - [A process] by which a process on one computer calls a process on another computer.
  - It is more complex, slower and less secure than a local procedure call.
  - The term usually implies a synchronous request-reply style of interoperation.

Local Procedure Call

- Simple
- Fast
- Available
- Secure

Remote Procedure Call

- More complex
- Slower
- Less available
- Less secure

OO Design

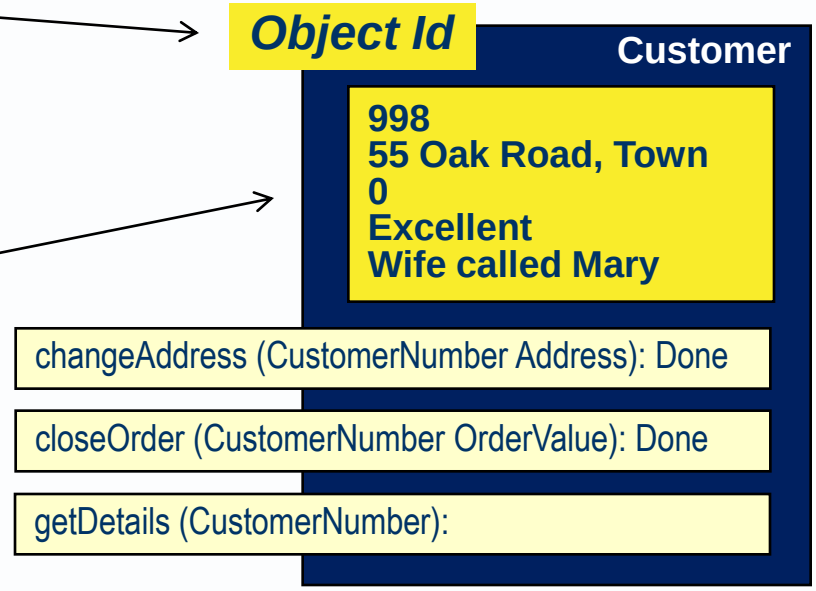
- [A technique] for modular design and integration that *initially* assumed the run-time system works like this
  - **Instantiation:** an object is an instance of a class (a component type)
  - **Identification:** an object is identified by an object identifier
  - **Co-location:** client and server objects work in the same name space
  - **Statefulness:** an object is stateful
  - **Inheritance:** a subtype object can perform the behaviors of a super type class
  - **Design pattern**: intelligent domain objects communicate to complete a process
  - **Synchronicity:** client objects make request-reply invocations to server objects
  - **Blocking:** a server object accepts only one invocation at once.

DO **SOAP** **REST** **EDA**

Tightly-coupled **Loosely-coupled**

Instantiation and identification

- an object is an instance of a class (a component type)
- an object is identified by an **object identifier**

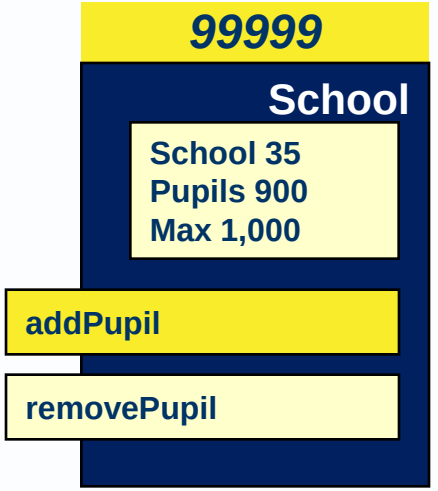


- Bertrand Meyer said classes should be abstract data types, which
  - encapsulate a **data structure**
  - define **operations** performable on that data structure.

Co-location

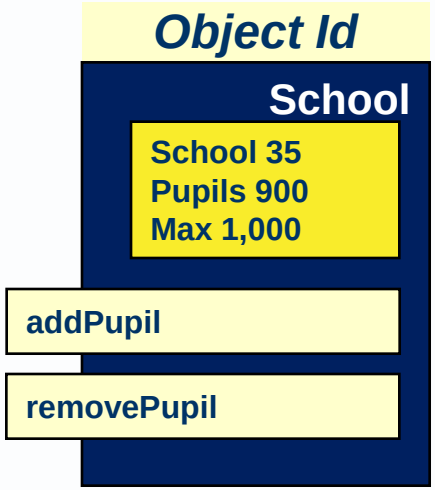
- client and server objects work in the same name space

- You call an object to do work using an
- “object/method pair”
- 99999/addPupil

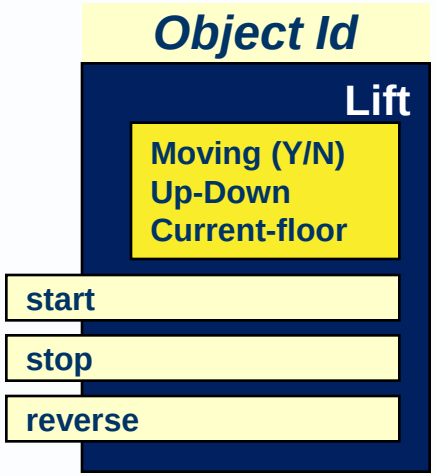


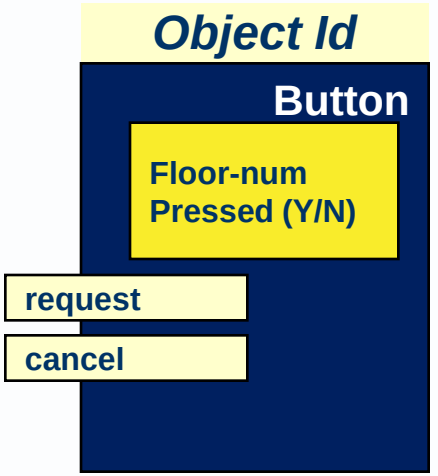
Statefulness

- an object is stateful



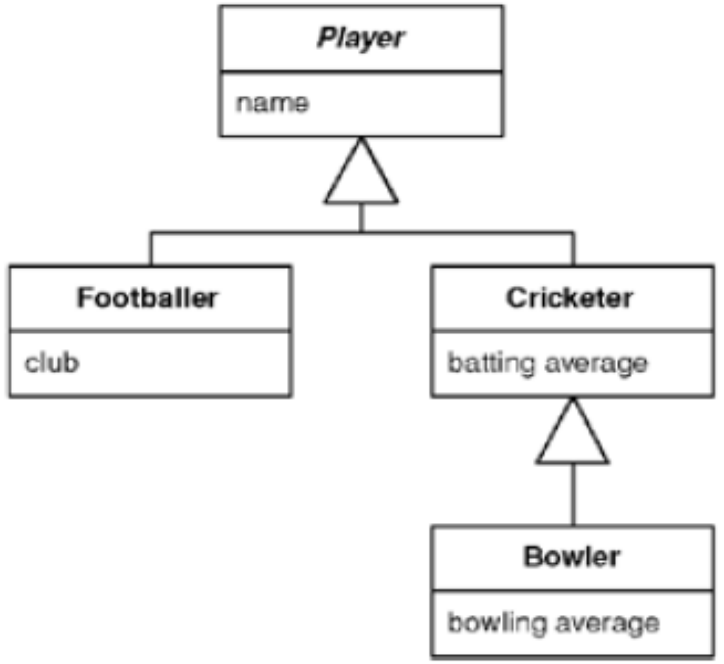
- The first OO programs handled a few small stateful objects.
- Case studies were
  - real-time process control systems – objects live forever
  - graphical user interfaces - objects deleted when the UI is closed





Inheritance

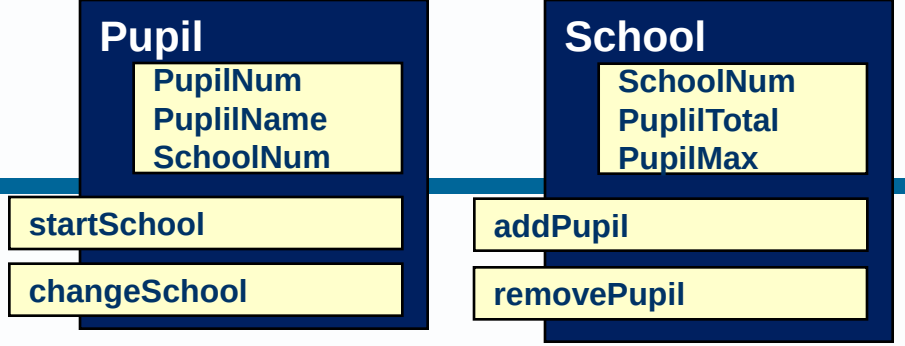
- a subtype object can perform the behaviors of a super type class



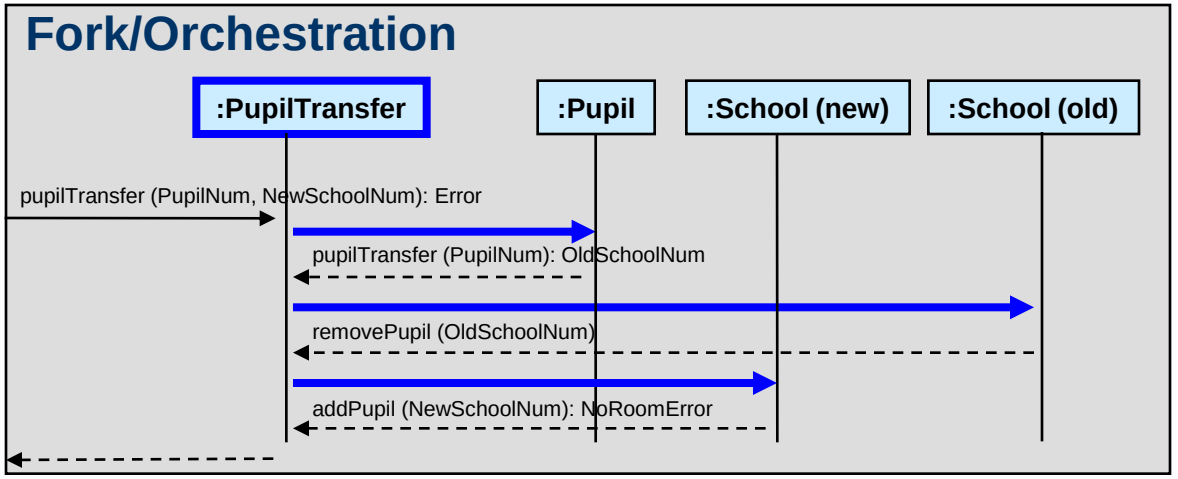
- Objects of a subclass **inherit** or **extend** the operations of a super class

- E.g. you can ask a bowler object to
  - update batting average
  - reply with the player's name

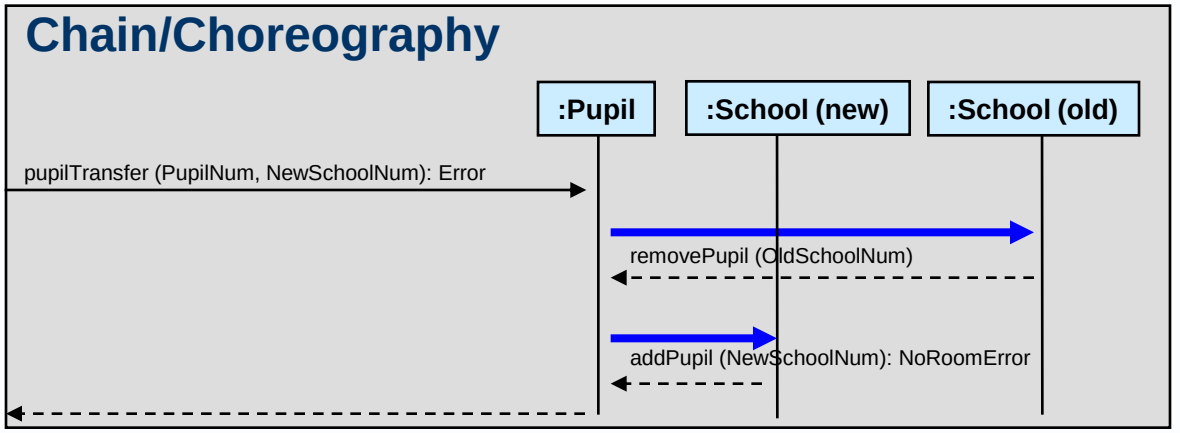
Design pattern for a process



- A controller orchestrates the domain objects
- (Betrand Meyer)

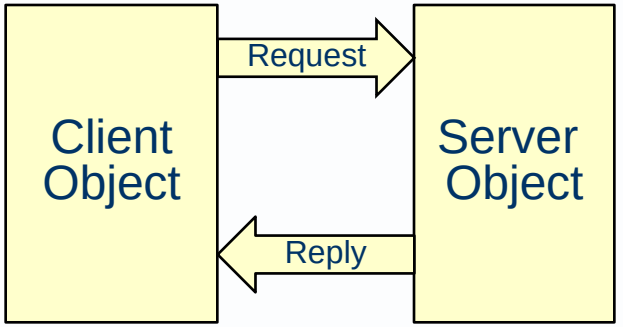


- Intelligent domain objects communicate to complete a process



Synchronicity (more later)

- client objects make request-reply invocations to server objects
  - Invokes server object
    - using an “object-method pair”
    - an object id and a method /operation name
  - Requests
    - freezes
    - holds a connection until reply
  - Receives reply
    - wakes up and carry on



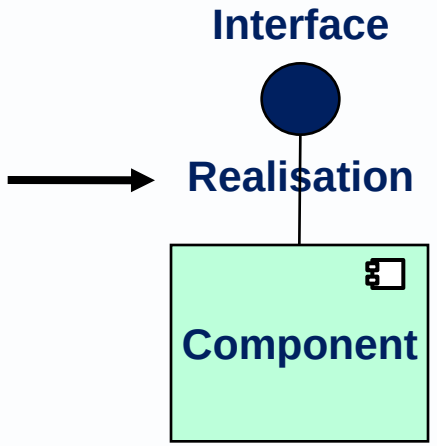
- a server object accepts only one invocation at once (so blocks others)

DO: Distributed Objects

- [A technique] for modular design and integration that employs an Object Request Broker.
- An object request broker (ORB) is RPC-like middleware that enables the objects of an OO program to be distributed.
- Software is coded as though all objects are on one computer.
- The ORB handles the distribution of objects between computers.
- So (in theory) the distributed system behaves like one OO program.
- It may provide transaction management, security and other features.

IDL: Interface Definition Language

- A language for defining an API (not the procedures of operations/services in it).
- It enables components coded in different languages and running on different operating systems to interoperate.



- 1990s
  - Sun's ONC RPC
  - The Open Group's Distributed Computing Environment
  - IBM's System Object Model
  - Object Management Group's CORBA,
  - WSDL for Web services
- 2000 - 2010
  - Increasing use of WSDL
- 2010 - 2020
  - Increasing use of REST and OData

WSDL: Web Service Description Language:

- [A standard] from the W3C for an interface definition.
- A WSDL includes a signature, protocol and web address for each operation/service.
- Initially it depended on XML and SOAP.
- It is now usable with JSON and HTTP.

SOAP

- A standard application layer protocol devised by Microsoft, then adopted by the W3C.
- A protocol used to invoke operations on remote components without using an ORB.
- It allows distributed components to communicate by sending XML messages over HTTP.

DO **SOAP** **REST** **EDA**

Tightly-coupled **Loosely-coupled**

Web Service

- [A component] invoked over “the web” using an internet protocol and a published interface.
- Initially, implied the use of WSDL, XML and SOAP standards.
- No longer related to any particular IDL, data format or internet protocol.

	WSDL1	WSDL2 allows also
Data format	XML messages	JSON
Protocol	SOAP over HTTP (or perhaps SMTP)	HTTP directly

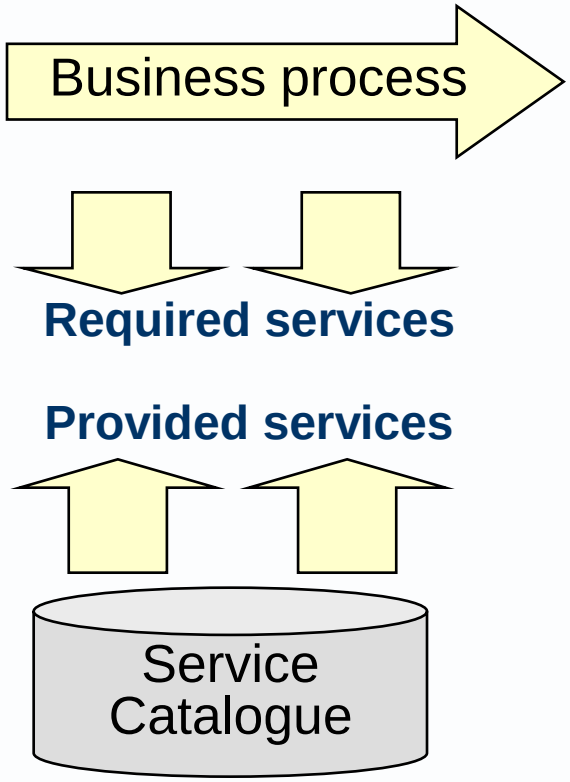
SWAGGER for JSON?
WADL (XML) for REST?

DO **SOAP** **REST** **EDA**

Tightly-coupled **WS?** **Loosely-coupled**

SOA: Service–Oriented Architecture

- [A technique] for modular design and integration that is a more loosely-coupled than Distributed Objects and facilitates the reuse of remotely accessible services.
- It is often associated with the use of Web Services, but does not have to be.



DO **SOAP** **REST** **EDA**

Tightly-coupled **SOA?** **Loosely-coupled**

REST: Representational State Transfer

- [A technique] for modular design and integration devised by Roy Fielding as a means to connect remote components using standard internet protocols.
- It decouples distributed components so that client/sender components need minimal information about server/receiver components.
- **A RESTful client**
  - invokes a remotely accessible service using a domain name and an operation type available in an internet protocol, usually HTTP.
- **A REST-compliant server**
  - is identified by a domain name and offers only one service in response to each operation type in an internet protocol, usually HTTP.

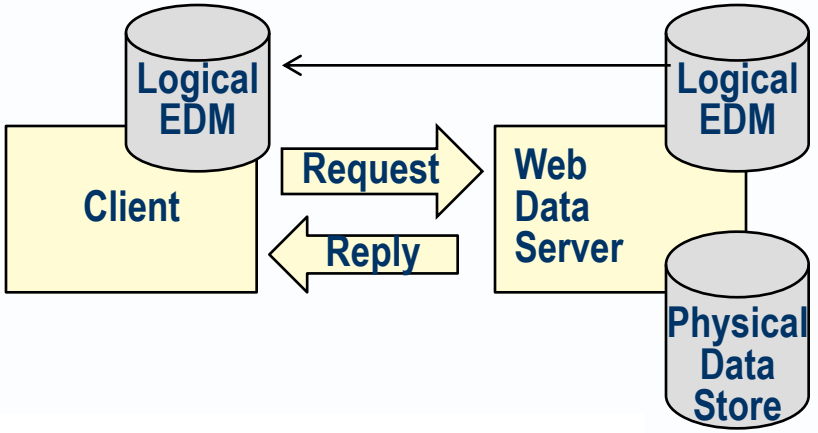
DO **SOAP** **REST** **EDA**

Tightly-coupled **Loosely-coupled**

OData *(Microsoft 2007, OASIS 2014)*

- [An IDL] an evolution of REST.
- It supports clients wanting to invoke operations on entities in a remote web data store.
- Client applications that speak OData can easily connect to data server applications that provide CRUD operations on a logical data model.

- Four parts
  - Entity Data Model (EDM) in an XML schema
  - Request and reply protocol
  - Client-side libraries
  - Server-side data servers



DO **SOAP** **REST** **EDA**

Tightly-coupled **Loosely-coupled**

EDA: Event-Driven Architecture

- [A technique] for a modular design and integration that decouples the senders of news or update events from the receivers.
- Any component can receive or read any event/message published by any other component.
- It often implies using the publish and subscribe features of a middleware technology.
- But can be implemented using a shared data space.

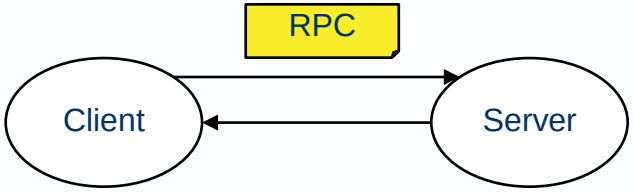
DO **SOAP** **REST** **EDA**

Tightly-coupled **Loosely-coupled**

6.3 Component coupling

Synchronous

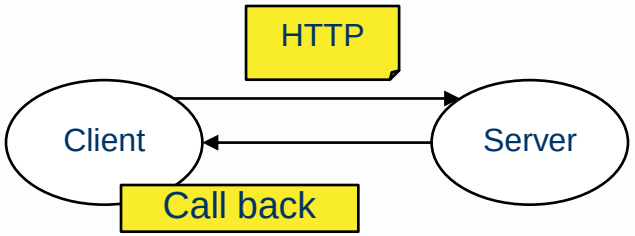
- **1: A request-reply style**
  - a client must wait for a server to reply before continuing.
  - (The usual invocation from one COBOL module or Java object to another.)



- **2: A blocking style**
  - a server serves one client at a time.
  - The caller and responder hold a channel open, blocking others from using it.
  - (The usual invocation style used by CORBA-compliant technologies.)

Asynchronous

- 1: A so-called **fire-and-forget** style in which a client does not wait for a server to reply.
- (The usual style in email conversations.)



- 2: A **non-blocking** style in which a server can accept requests from several clients before responding to the first.
- (The usual style of Web Services.)
- Typically, the server has a queue of incoming messages and releases the channel after a message is received.

Loose coupling c1990

Faster simpler

More flexible

Avancier

Factor	Tight coupling	Decoupling techniques
Naming	Clients use object identifiers One name space	Clients use domain names Multiple name spaces behind interfaces
Paradigm	Stateful objects/modules Reuse by OO inheritance Intelligent domain objects	Stateless objects/modules Reuse by delegation Intelligent process controllers
Time	Synchronous request-reply Blocking servers	Asynchronous messaging Non-blocking servers

COBOL modules and Java objects

CORBA

Web Services

Loose coupling today

Often faster and/or simpler

Often more flexible, but more complex

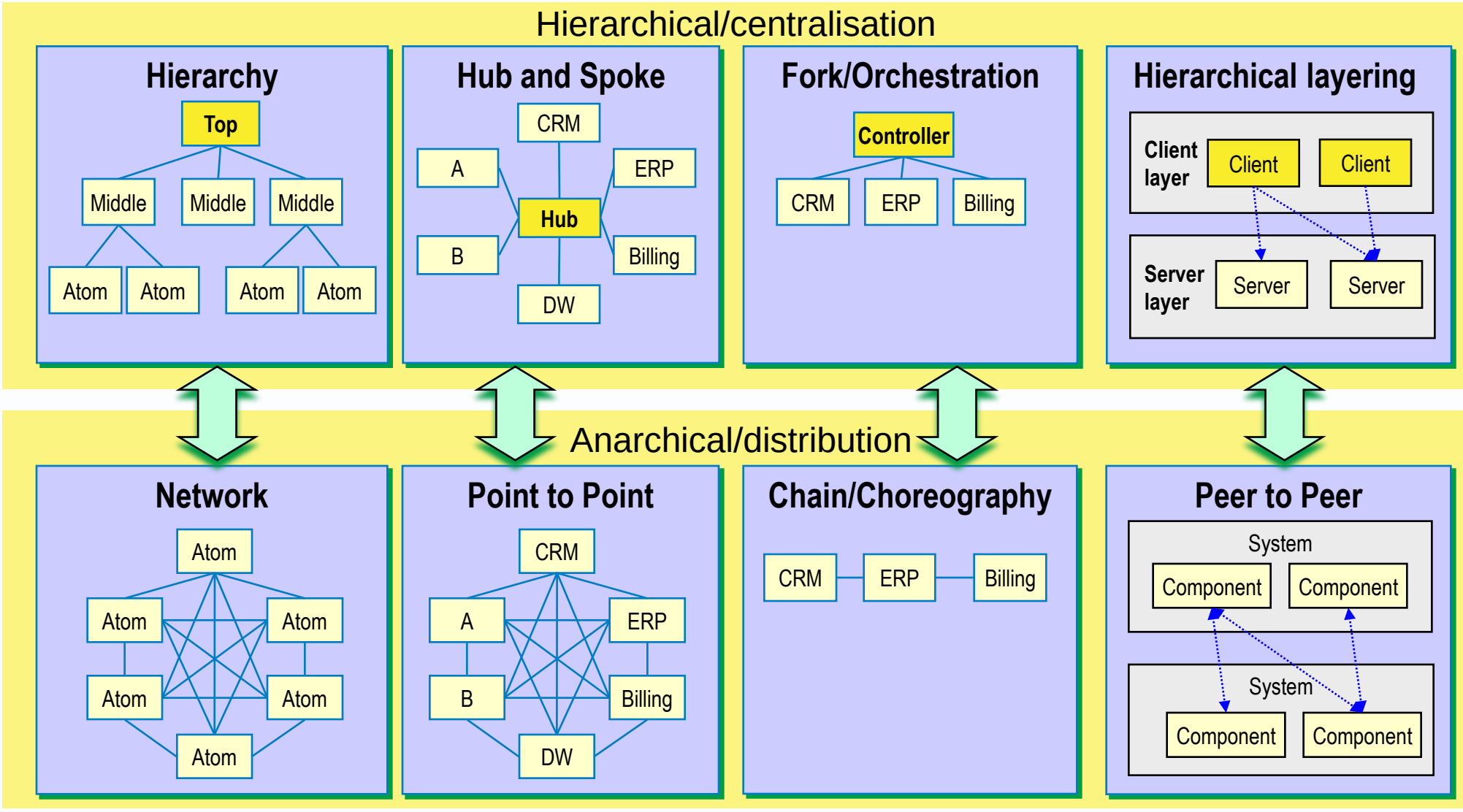
Factor	Tight coupling	Decoupling techniques
Naming	Clients use object identifiers One name space	Clients use domain names Multiple name spaces behind interfaces
Paradigm	Stateful objects/modules Reuse by OO inheritance Intelligent domain objects	Stateless objects/modules Reuse by delegation Intelligent process controllers
Time	Synchronous request-reply Blocking servers	Asynchronous messaging Non-blocking servers
Location	Remember remote addresses	Use brokers/directories/facades
Data types	Complex data types	Simple data types
Version	Version dependency	Design to avoid version dependence Apply the open-closed principle
Protocol	Protocol dependency	Design for multiple protocols
Integrity constraints	ACID transactions	BASE: compensating transactions and eventual consistency

6.4 Design patterns [not to be examined]

- **Design pattern**
- A shape or structure of elements that commonly appears in solution design.
- A tried and tested design that is tailored to address particular problems or requirements.

Basic design pattern pairs

Avancier



Design pattern pair

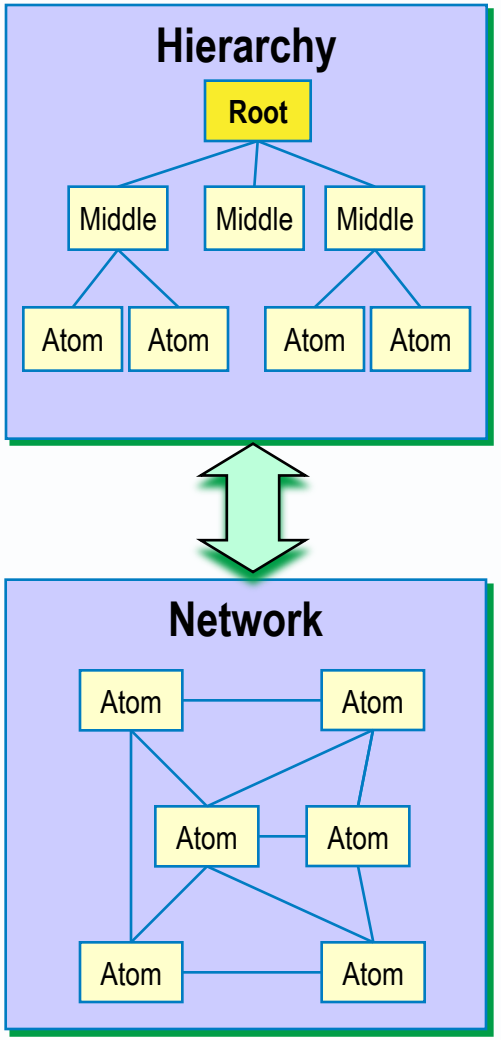
- A pair of contrasting patterns that suit different situations.
- Architects choose between alternative patterns by trading off their pros and cons.

Hierarchical or centralisation pattern	Anarchical or distribution pattern
centralises control in one place or component.	distributes control to many places or components.
Hierarchy	Anarchy or Network
Hub and Spoke	Point-to-Point or Mesh
Client-Server	Peer-to-Peer
Fork or Orchestration	Chain or Choreography

Structural patterns

- **Hierarchical structure**
  - [A design pattern] that divides a node into subordinate nodes.
  - A rule of thumb for division: divide one into about seven.
  - A rule of thumb for decomposition: stop at three or four levels.

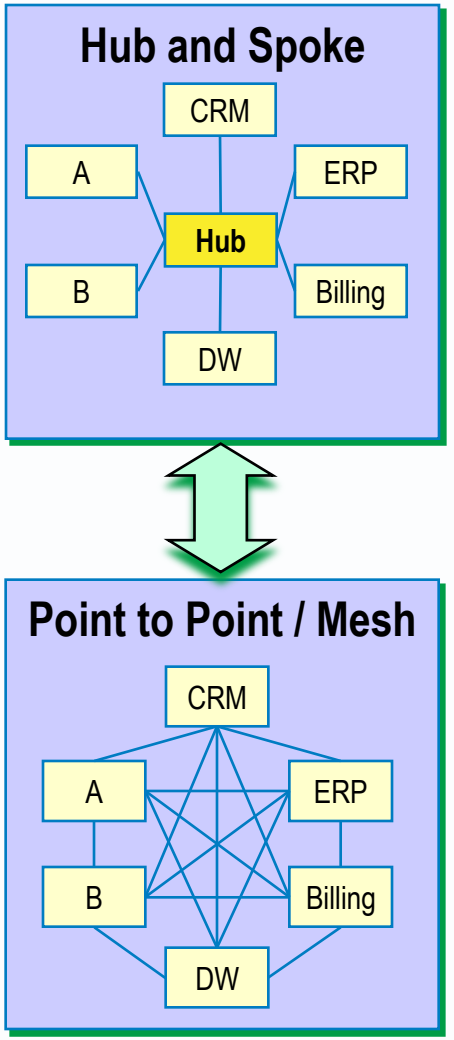
- **Network structure**
  - [A design pattern] in which a node can be connected to any other node.



Communication path patterns

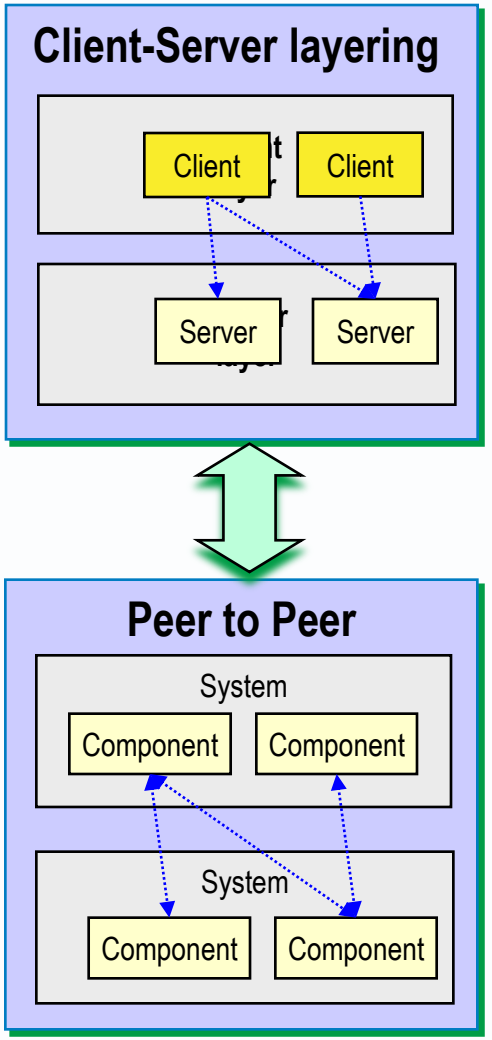
- **Hub and spoke**
  - [A design pattern] in which components communicate via a mediator.
  - It can be good where the endpoints are volatile; but can be more complex and slower.

- **Point to point**
  - [A design pattern] in which components talk to each other directly.
  - It can be faster and simpler where inter-component communication is 1 to 1 and endpoints are stable; but can hinder change.



Delegation patterns

- **Hierarchical (or layered):**
  - [A design pattern] in which higher components delegate work to lower (server) components.
  - This pattern is widely used to structure complicated systems (machines, networks, software applications and enterprise architecture).

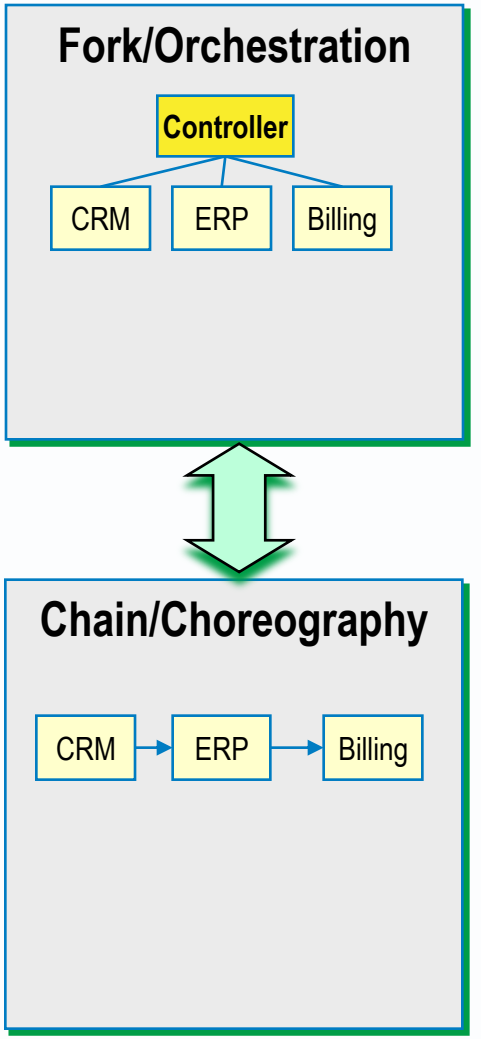


- **Peer-to-peer:**
  - [A design pattern] in which any two components can delegate to work to each other.
  - Such cyclic dependencies are said to create a fragile structure, difficult to understand and maintain, but are sometimes inevitable.

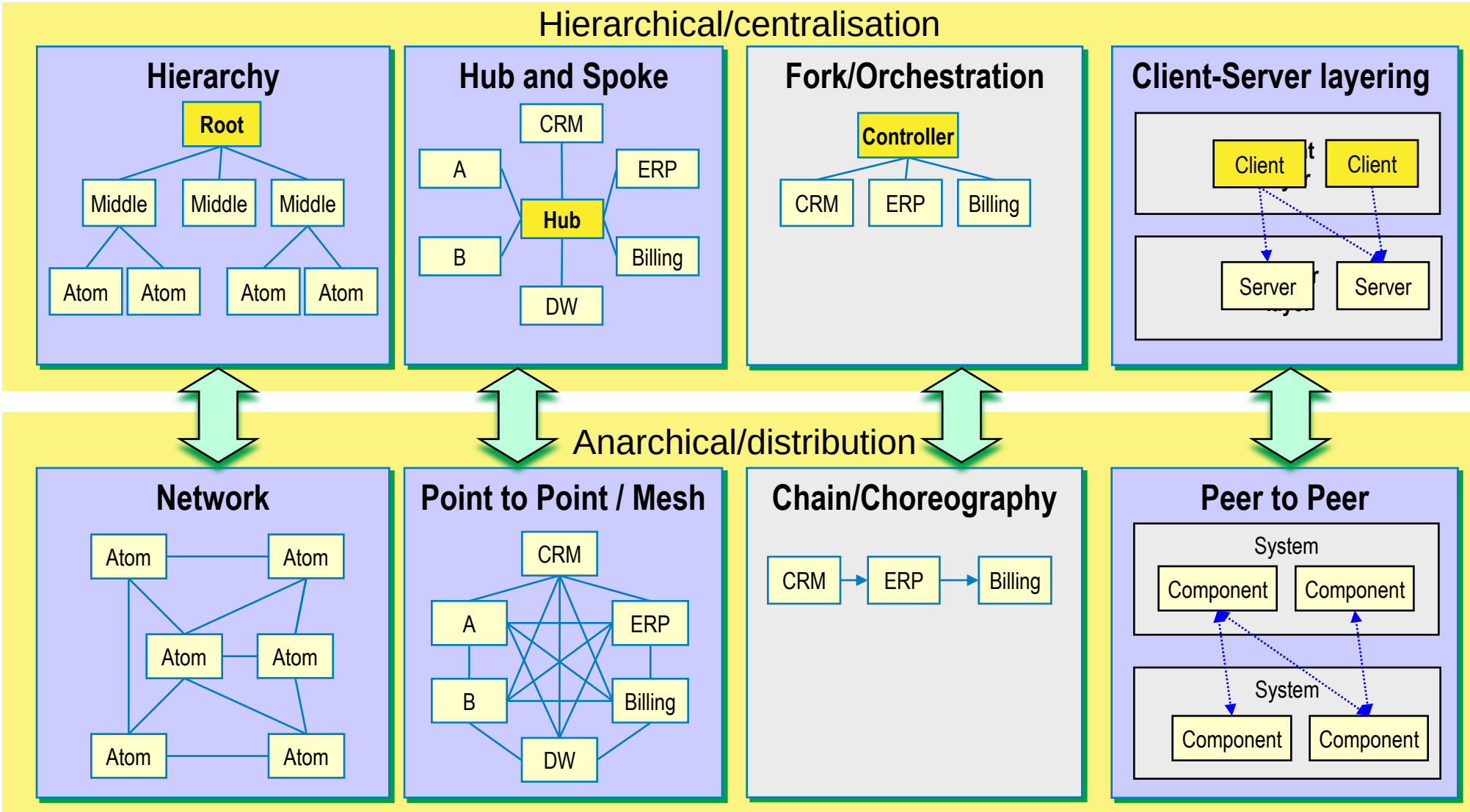
Process control patterns

- **Fork/Orchestration**
  - [A design pattern] in which one component schedules other components.
  - It centralises intelligence about the overall process or workflow.

- **Chain/Choreography**
  - [A design pattern] in which components interact directly.
  - It distributes intelligence about the overall processes
  - Each component calls the next component.



Design pattern pairs - reminder



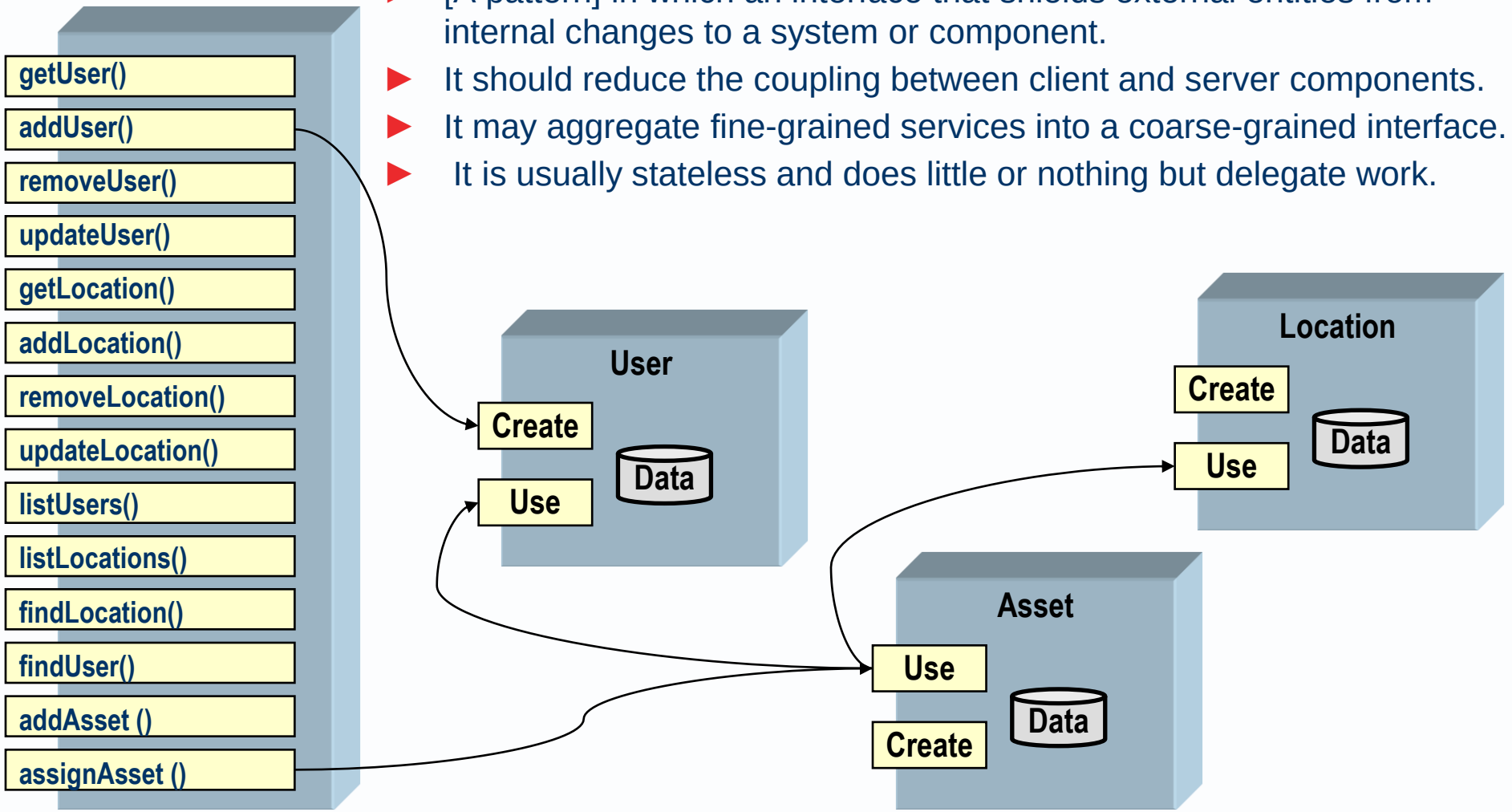
6.5 “Design Patterns: Elements of Reusable OO Software”

11 of 23 patterns

Name	Description or purpose
Façade	Consistent interface coarse-grained services that encapsulate a suibsystem
Adapter	A wrapper that converts a provided service into a required service. Facilitates the reuse of existing technologies.
Proxy	A surrogate for a distributed component. Used in distribution of code between different name spaces.
Singleton	A component (or class) with only one instance (or object).
Observer	A component that monitors the state of another component.
Composite	Enables a class to process operations on every level of a hierarchical structure, including composite and leaf nodes
Template method	Offers several variations of an algorithm.
Strategy	Adds a façade to a template method.
Manager	Often used to manage a set of objects.
Factory method	Create the right server object for the client - hiding how the server object is initialized.
Abstract object factory	Create the right factory object for the client - hiding which factory class is used.

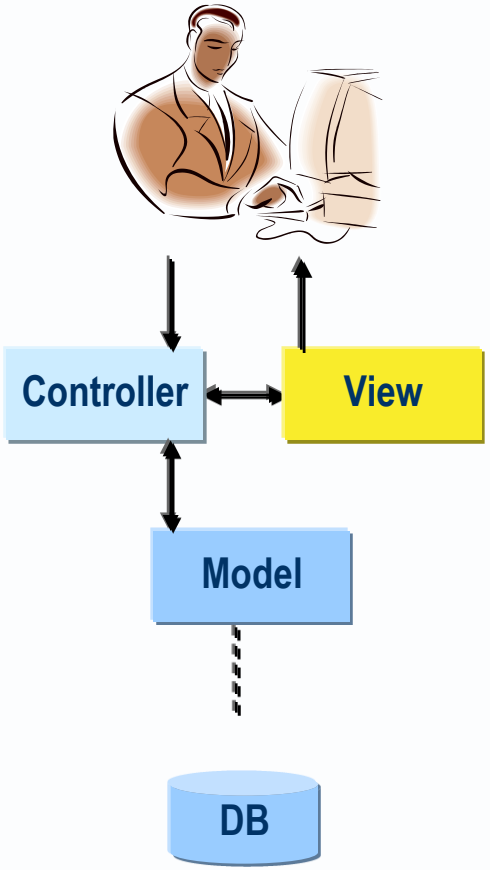
Façade

- [A pattern] in which an interface that shields external entities from internal changes to a system or component.
- It should reduce the coupling between client and server components.
- It may aggregate fine-grained services into a coarse-grained interface.
- It is usually stateless and does little or nothing but delegate work.



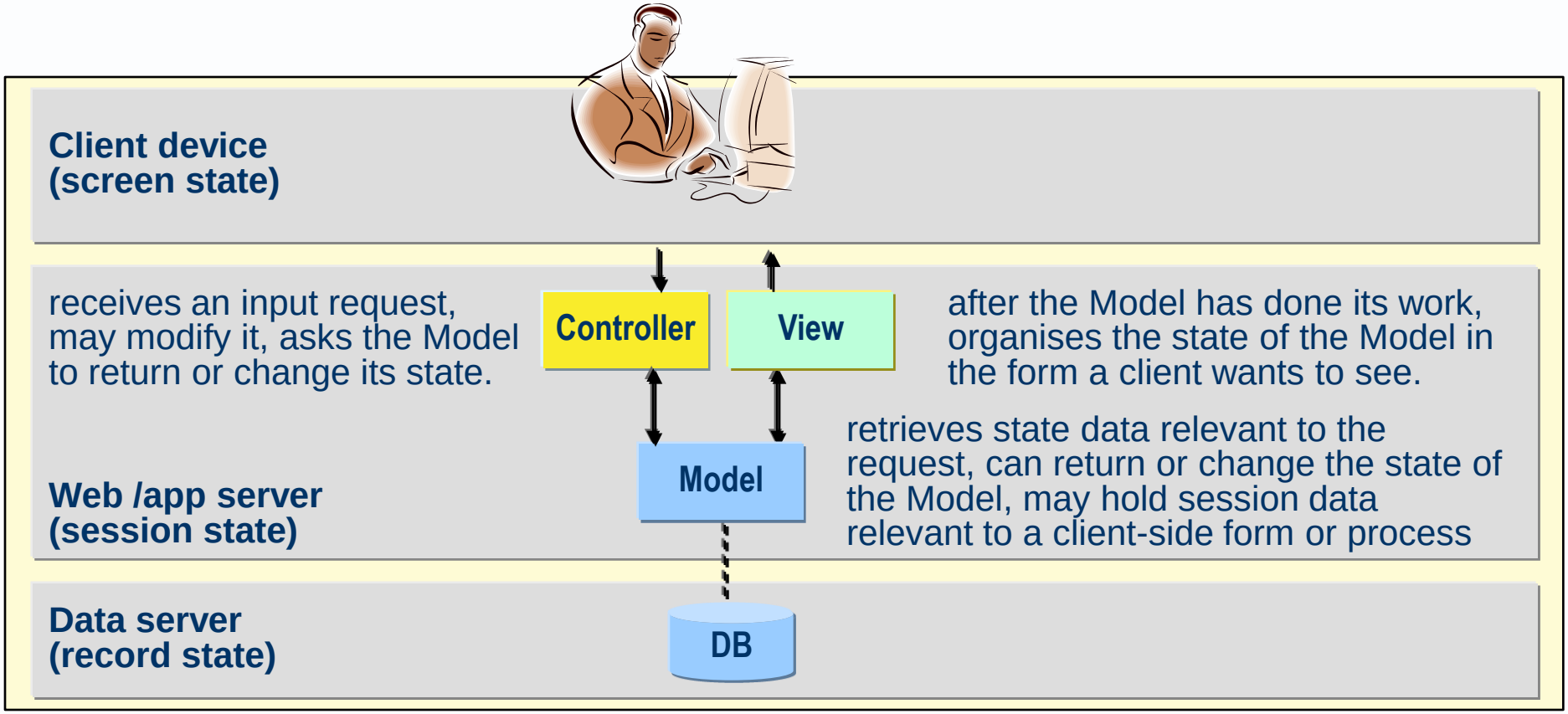
Model View Controller

- [A pattern] that separates
- the processing of an input message (controller),
- the display of a user interface (view) and
- the retrieval and processing of persistent data (model).



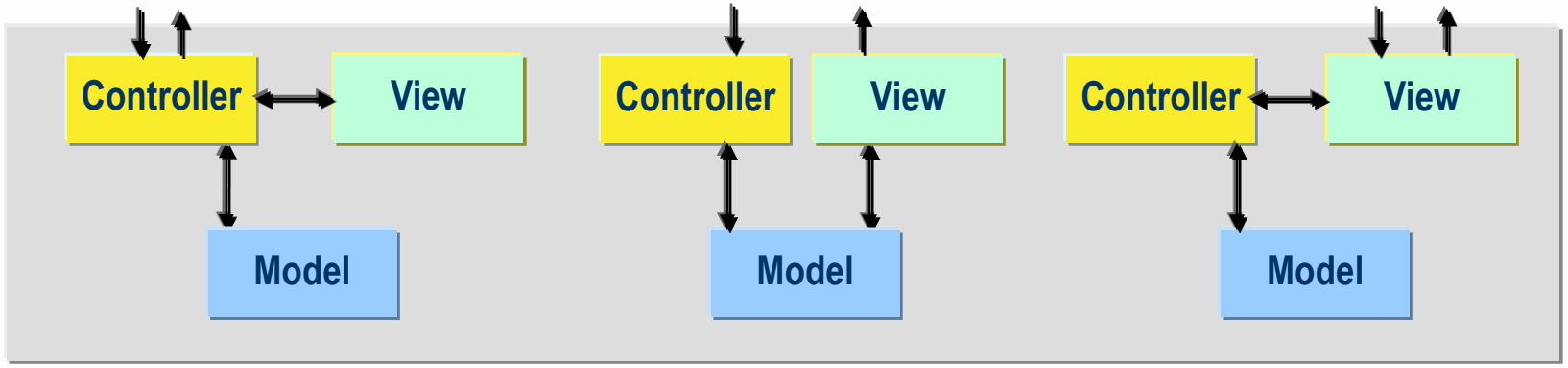
How the MVC pattern may be used in enterprise applications

- Separates modules that handle client-side data structures from modules that handle server-side data structures



Variations of the MVC pattern

- Three variations



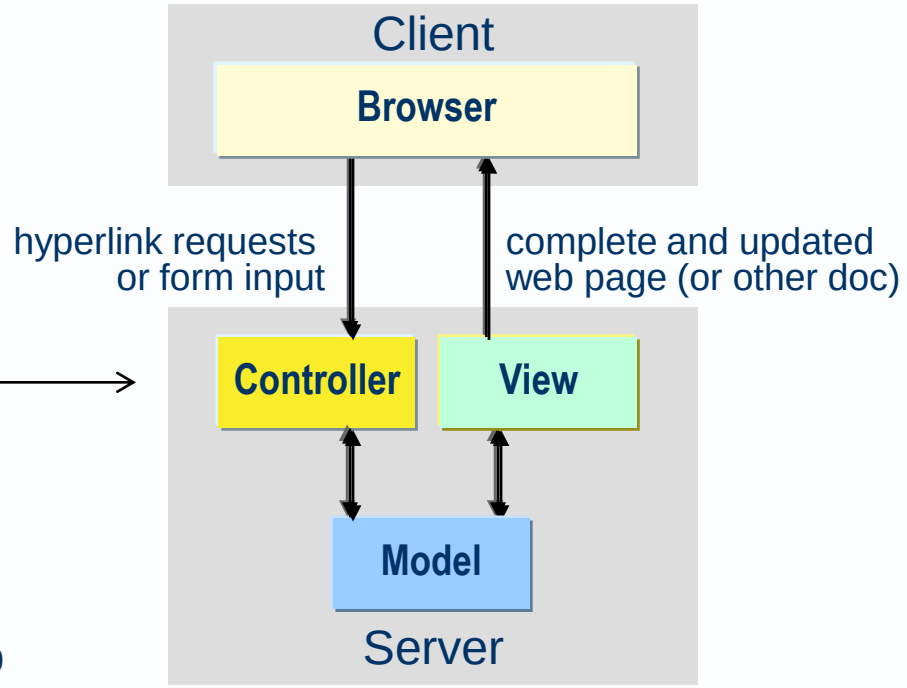
- Other MVC variants include
  - hierarchical model–view–controller (HMVC),
  - model–view–adapter (MVA)
  - model–view–presenter (MVP),
  - model–view–viewmodel (MVVM)

MVC in web frameworks (after Wikipedia)

- Web frameworks divide MVC differently between client and server tiers.

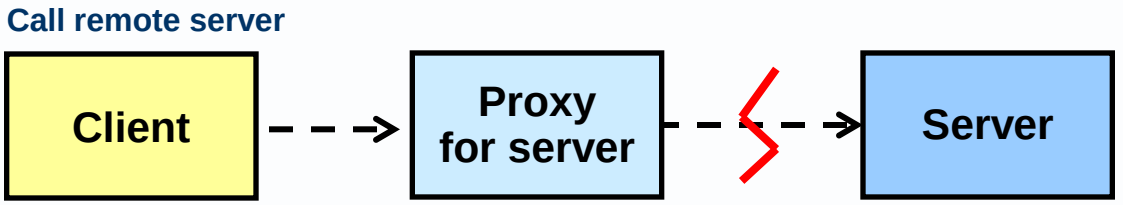
- Early web frameworks mostly put MVC components **on the server**.
  - Ruby on Rails,
  - Django,
  - ASP.NET MVC and
  - Express

- Other frameworks allow MVC components to execute partly **on the client**
  - AngularJS,
  - EmberJS,
  - JavaScriptMVC and B
  - ackbone (also see Ajax).



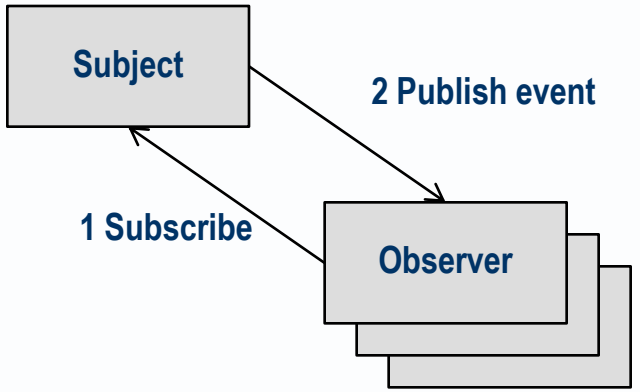
Proxy

- [A pattern] in which proxy components act as surrogates for remote components.
- It is used in distribution of code between different name spaces, as in “Distributed Objects”



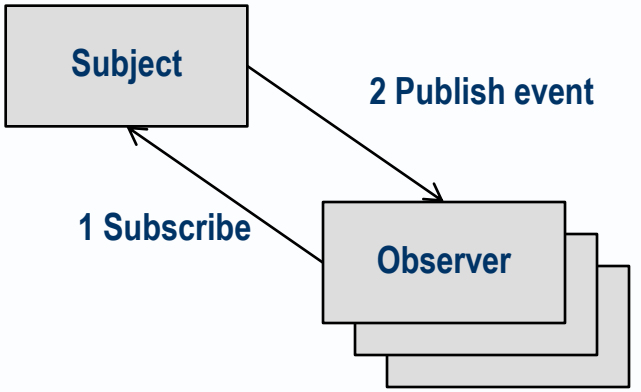
Observer

- [A pattern] in which observer components monitor the state of a subject component.
- A primitive kind of “Event-Driven Architecture”

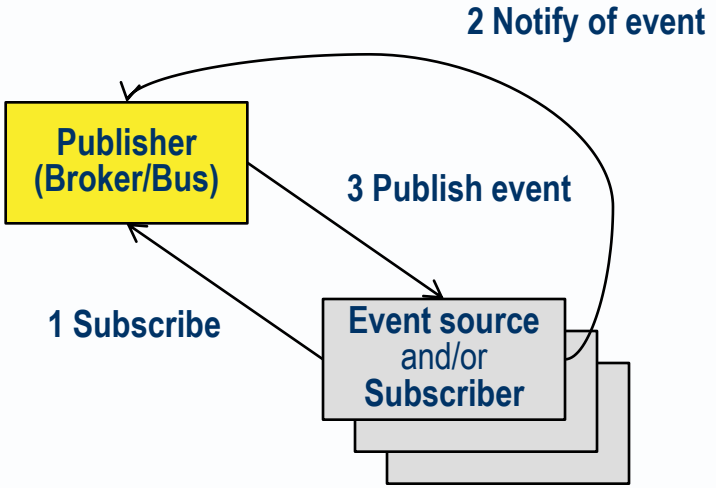


Moving notification into a separate publisher

- **Observer**
  - A subject
    - notifies observers of changes to its state
  - Observers
    - register with the subject to be notified of changes.
    - unregister when no longer interested



- **Event-Driven Architecture (EDA)**
  - Inserts a publisher (broker) between Subjects and Observers, and so decouples



Singleton

- [A pattern] in which a component (or class) has only one instance (or object).

- We only need one copy of:
  - Global variables – e.g. current date and time
  - A commonly required table – e.g. exchange rates
  - A façade – e.g. a stateless controller
- So, a single-object class can hold the data or do the job

In Java, static fields (aka class variables) exist independently of any instances of the class and one copy is shared among all instances

Utility class = a stateless singleton?

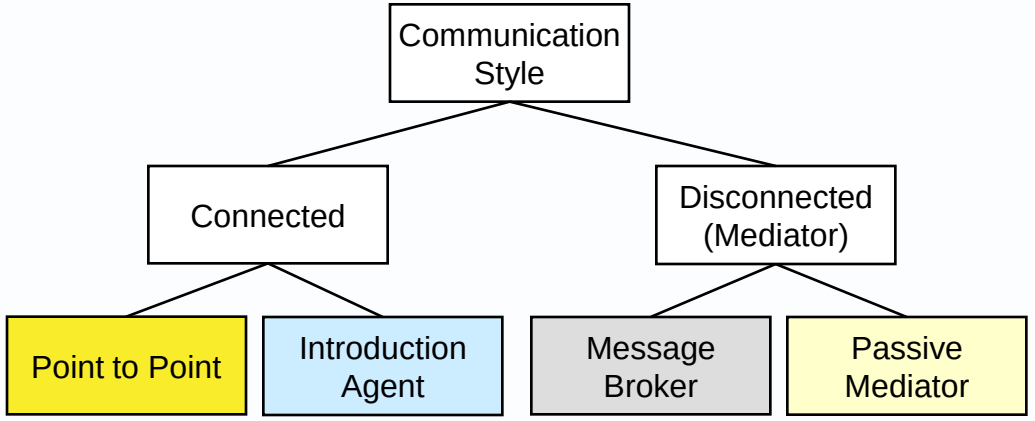
Commonly required mathematical functions

Length, weight and temperature conversions

Circumference, area and volume calculations

6.6 Communication Patterns

- **Communication pattern** [a pattern] in which a client/sender application (or other actor) connects to a server/receiver application (or other actor).
- Two broad communication styles, each subdivided into two narrower styles, are listed below.
- There are other subcategories, not listed here.

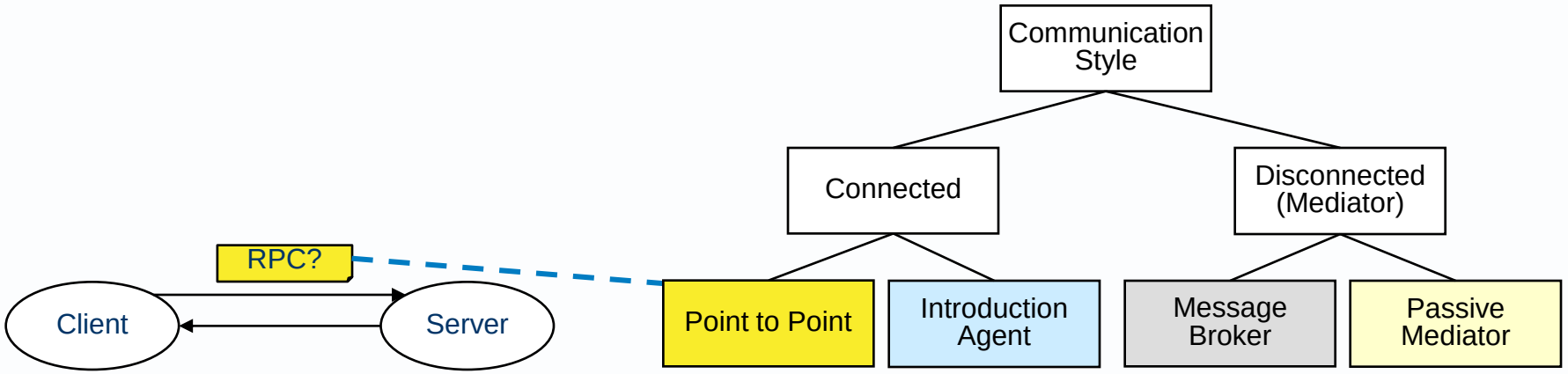


Tightly-coupled

Loosely-coupled

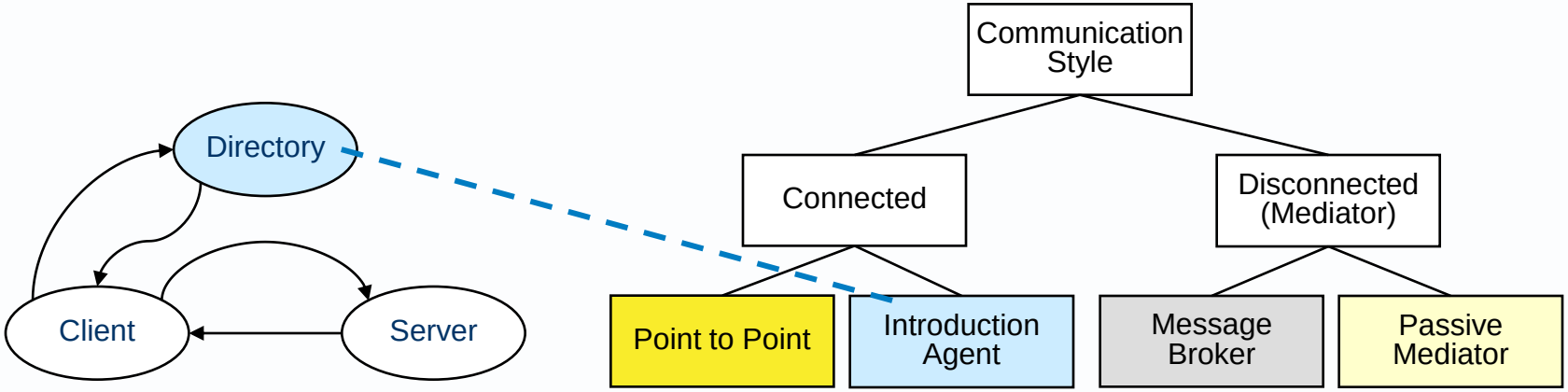
Direct connection: point to point

- **Point-to-point connection** [a pattern] in which a message sent by one client/sender is received by one server/receiver.
- The client/sender knows the location of the receiver.
- The client knows what protocols and data formats the server/receiver understands.
- Strengths: simple and fast.
- Weaknesses: potential duplication of data transformation and routing code, reconfiguration costs on receiver address changes.



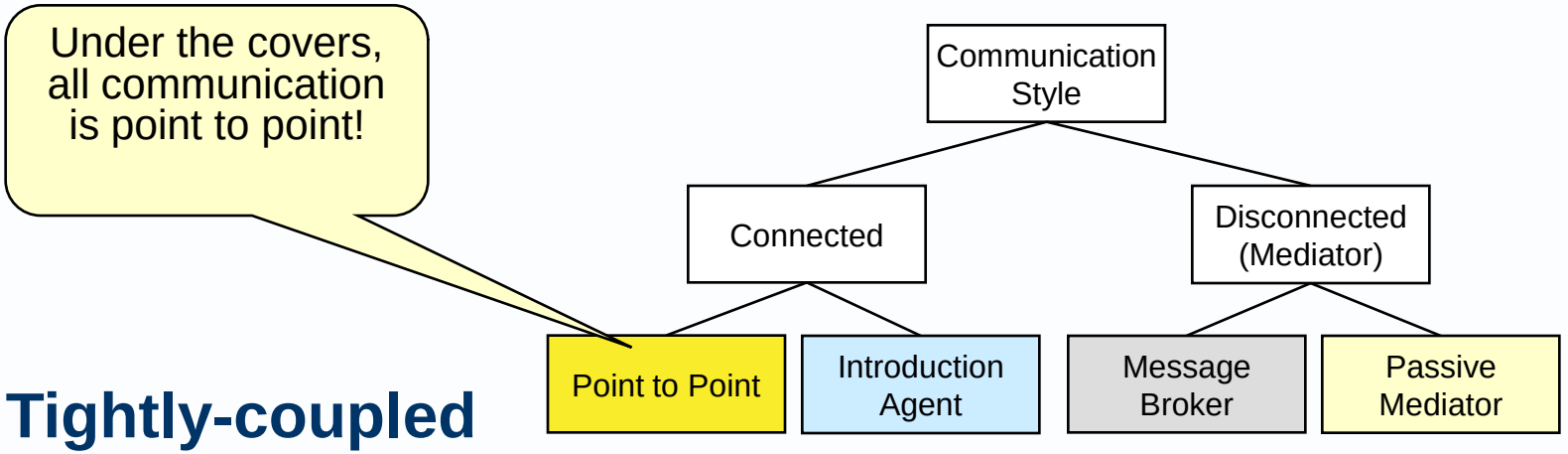
Direct connection: direct broker

- **Direct broker connection** [a pattern] in which parties willing to communicate are registered (with end point locations) in a directory.
- When a client/sender wants to send a message to a server/receiver, the broker makes the introduction, and may establish client-side and server-side proxies.
- From then on, the parties talk directly or through proxies, as though using point-to-point connection.
- Not so simple and fast, but decouples clients/senders from server/receiver locations.



Indirect communication

- [a pattern] in which clients/senders never talk directly to servers/receivers, they talk only through a mediator or shared resource. There are two subcategories.

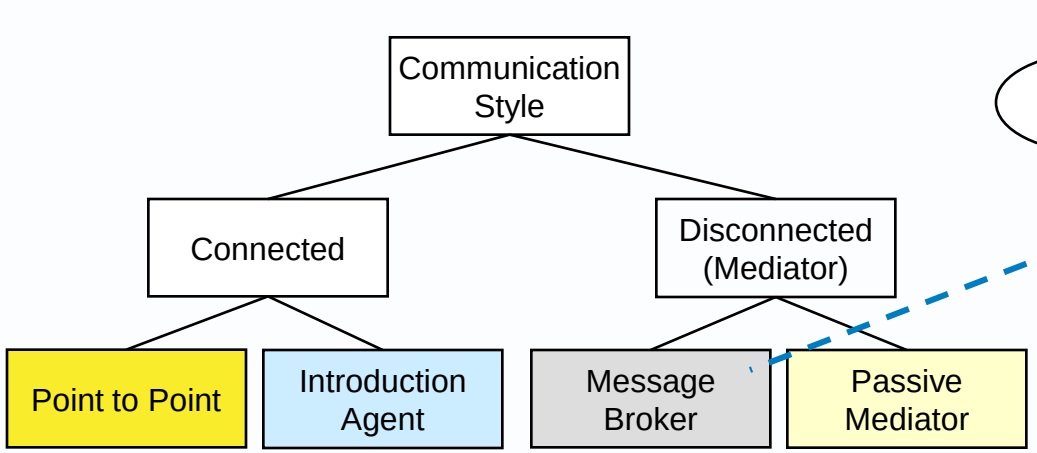


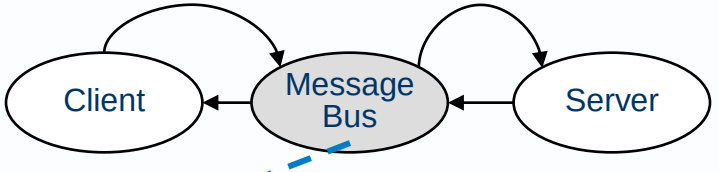
Tightly-coupled

Loosely-coupled

Mediated communication

- [a pattern] in which an **indirect broker** decouples communicating parties; it adds a layer of indirection between clients/senders and servers/receivers.
- This can enable communicating parties to work at different places and different times (asynchronously).
- It can shield one party from the effects of some changes to the other party.
- Mediator technologies include message brokers, message routers, message buses and publish-subscribe middleware.

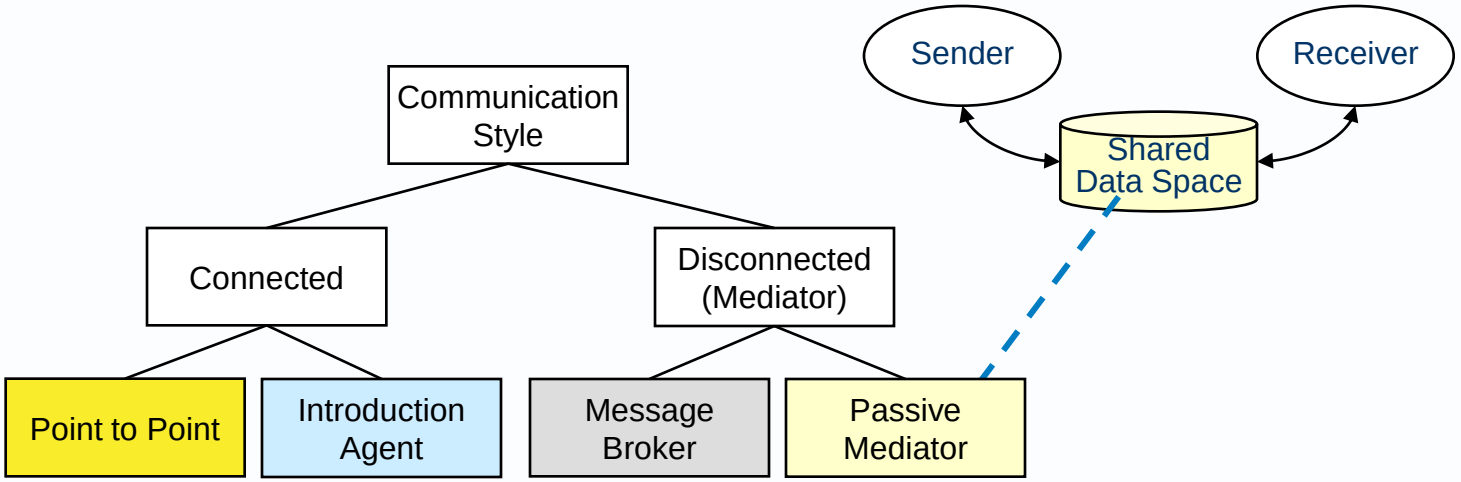




- Message bus = message broker + schema-based distribution

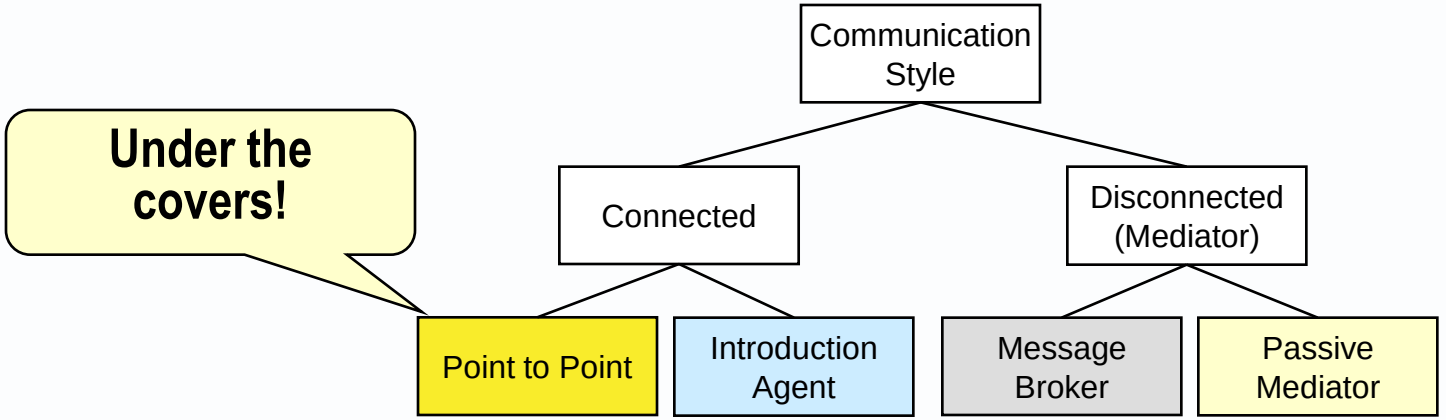
Shared data space communication

- [a pattern] in which parties communicate indirectly by reading and writing messages in a common data store, which might be shared memory, a message queue, a serial file or a database.
- Aka “shared memory”, “space-based architecture” or “blackboard design pattern” or “passive mediator”.



Aside

- Different communication styles may be used at different levels of a communication stack.
- Under the covers is always some point-to-point communication.



Communication patterns – summary overview