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[Faculty of Science
Information and Computing Sciences]

Styles and patterns

and their relation to:
viewpoints,
perspectives
and
quality properties

A quick recap

- Views:
  - Address some concern(s) of (a) stakeholder(s)
  - Organized in viewpoints
  - Lot's of freedom!
- We already saw > 20 possible views!
  - How to choose?
  - How to organize?
  - What to put in?
- How to handle this freedom?

Chapter Outline

- What is a Pattern?
- Pattern Catalogue
  - Module patterns
  - Component and Connector Patterns
  - Allocation Patterns

A pattern

- "any regularly repeated arrangement, especially a design made from repeated lines, shapes, or colours on a surface"
- "a particular way in which something is done, is organized, or happens"
- "a drawing or shape used to show how to make something"
- "something that is used as an example, especially to copy"

Architectural patterns

An architectural pattern establishes a relationship between:

- Context: A recurring, common situation in the world that gives rise to a problem
- Problem: The problem, appropriately generalized, that arises in the given context
- Solution: A successful architectural resolution to the problem, appropriately abstracted
- Consequences: results and trade-offs of the pattern

Solutions for a pattern

- A set of element types
  - Data repositories,
  - Processes,
  - Objects
- A set of interaction mechanisms or connectors
  - method calls,
  - events,
  - message bus
- A topological layout of the components
- A set of semantic constraints covering topology, element behavior, and interaction mechanisms

Why patterns?

- Design reuse
  - Well-understood solutions applied to new problems
- Code reuse
  - Shared implementations of invariant aspects of a style
- Understandability of system organization
  - A phrase such as "client-server" conveys a lot of information
- Interoperability
  - Supported by style standardization
- Style-specific analyses
  - Enabled by the constrained design space
- Visualizations
  - Style-specific depictions matching engineers' mental models

Pattern analysis dimensions

- What is the design vocabulary?
  - Component and connector types
- What is the underlying computational model?
- What are the essential invariants of the pattern?
- What are common examples of its use?
- What are the (dis)advantages of using the pattern?
- What are the style's specializations?

Patterns vs styles

- Architectural style: fundamental structural organization schema for software systems
- Pattern: documents commonly recurring and proven structure
- Think of it as in language idiom: idiom describes the patterns of the language.

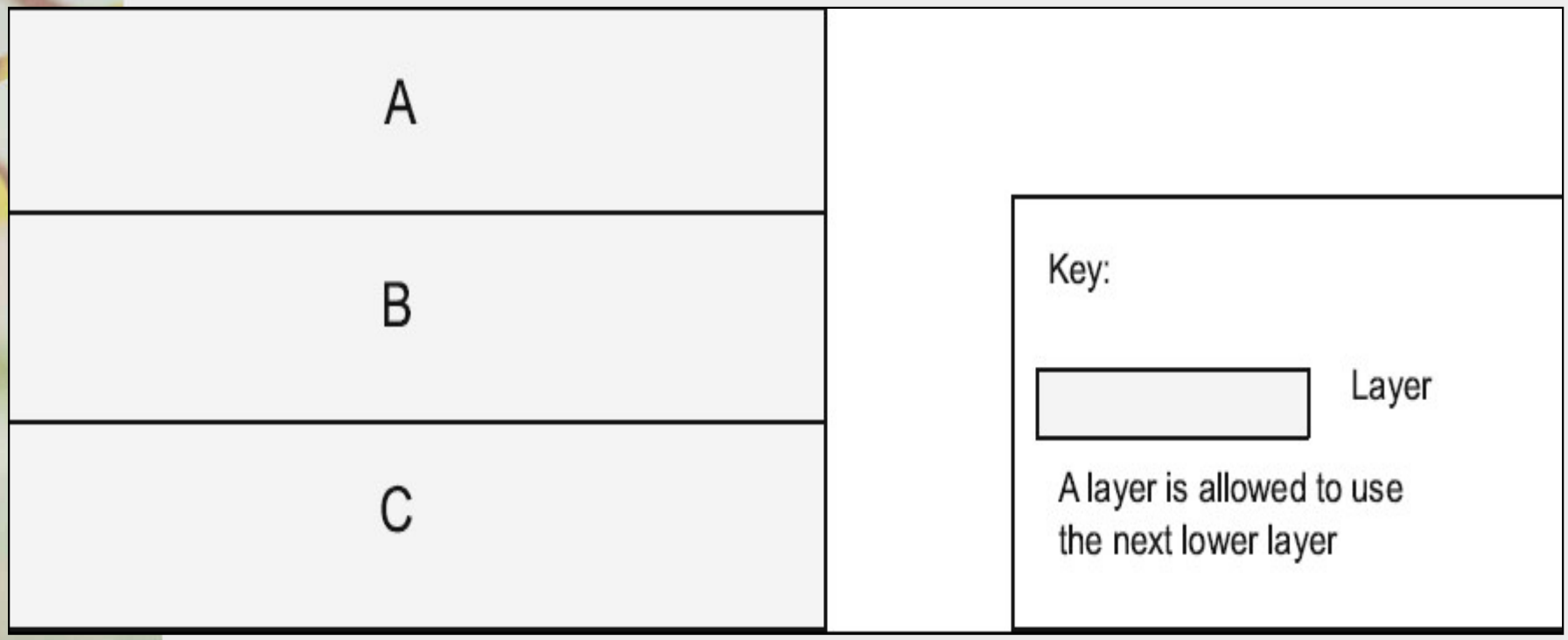
Examples of patterns

- Layer
- Broker
- Model-view-controller
- Pipe-and-filter
- Client-server
- Peer-to-peer
- Service oriented architecture
- Publish-subscribe
- Shared-data
- Multi-tier
- …

Pattern template

- Context
- Problem
- Solution
  - Element types
  - Interaction mechanisms (connectors)
  - Topological layout
  - Constraints

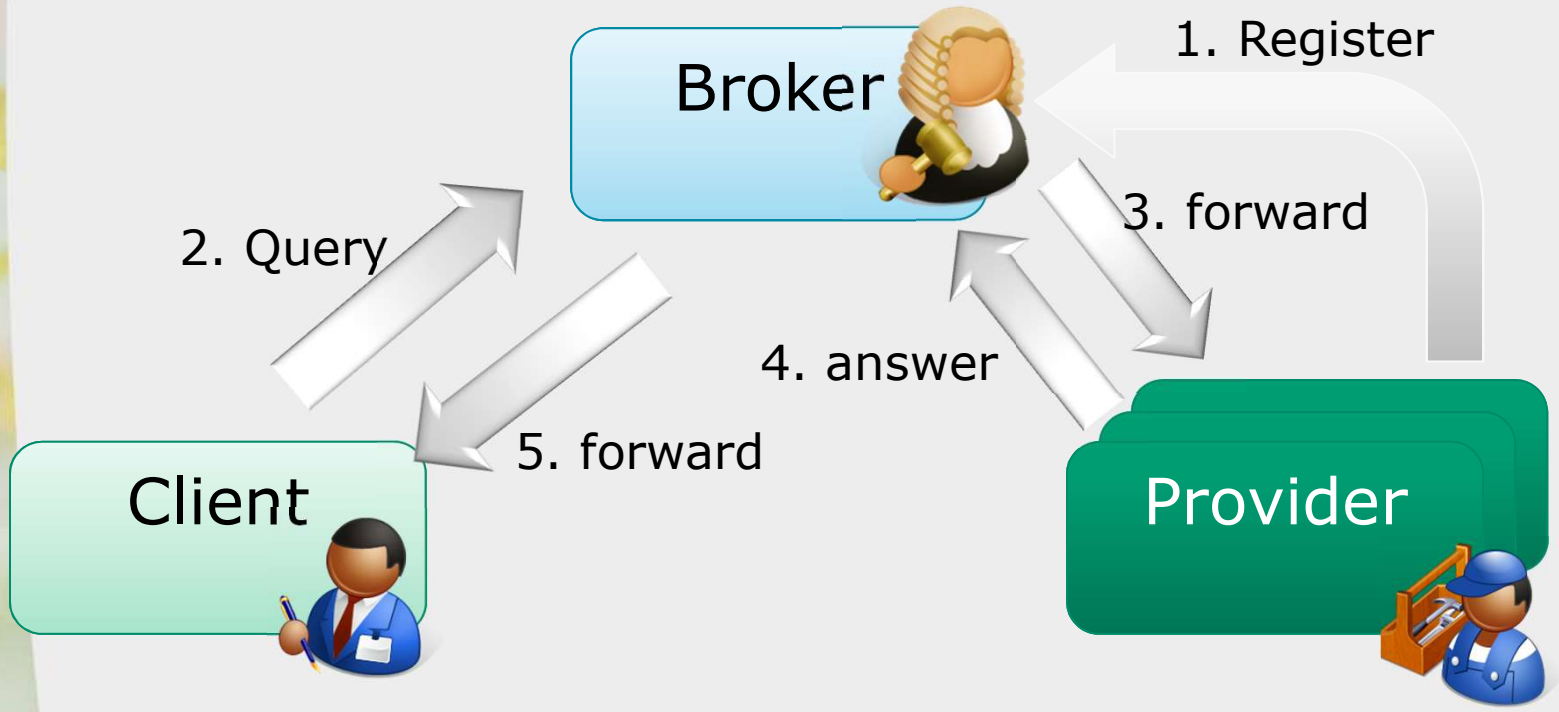
Layer pattern: topoligical layout



Layer pattern

- Context:
  - Develop and evolve portions of the system independently
  - Clear and well-documented separation of concerns
  - Modules independently developed and maintained
- Problem:
  - Segment software to be developed and evolved separately
  - Support portability, modifiability, and reuse
- Solution:
  - Element types:
    - Layer: grouping of modules that offers a cohesive set of services
  - Connectors:
    - public interface
  - Constraints:
    - unidirectional

Broker pattern



Broker pattern

- Mediates communication between clients and servers
- Elements:
  - Client requests a service
  - Server provides a service
  - Broker mediates between clients and services
- Connectors:
  - Attachment: client → broker, server → broker
- Constraints
  - No client → server or server → client

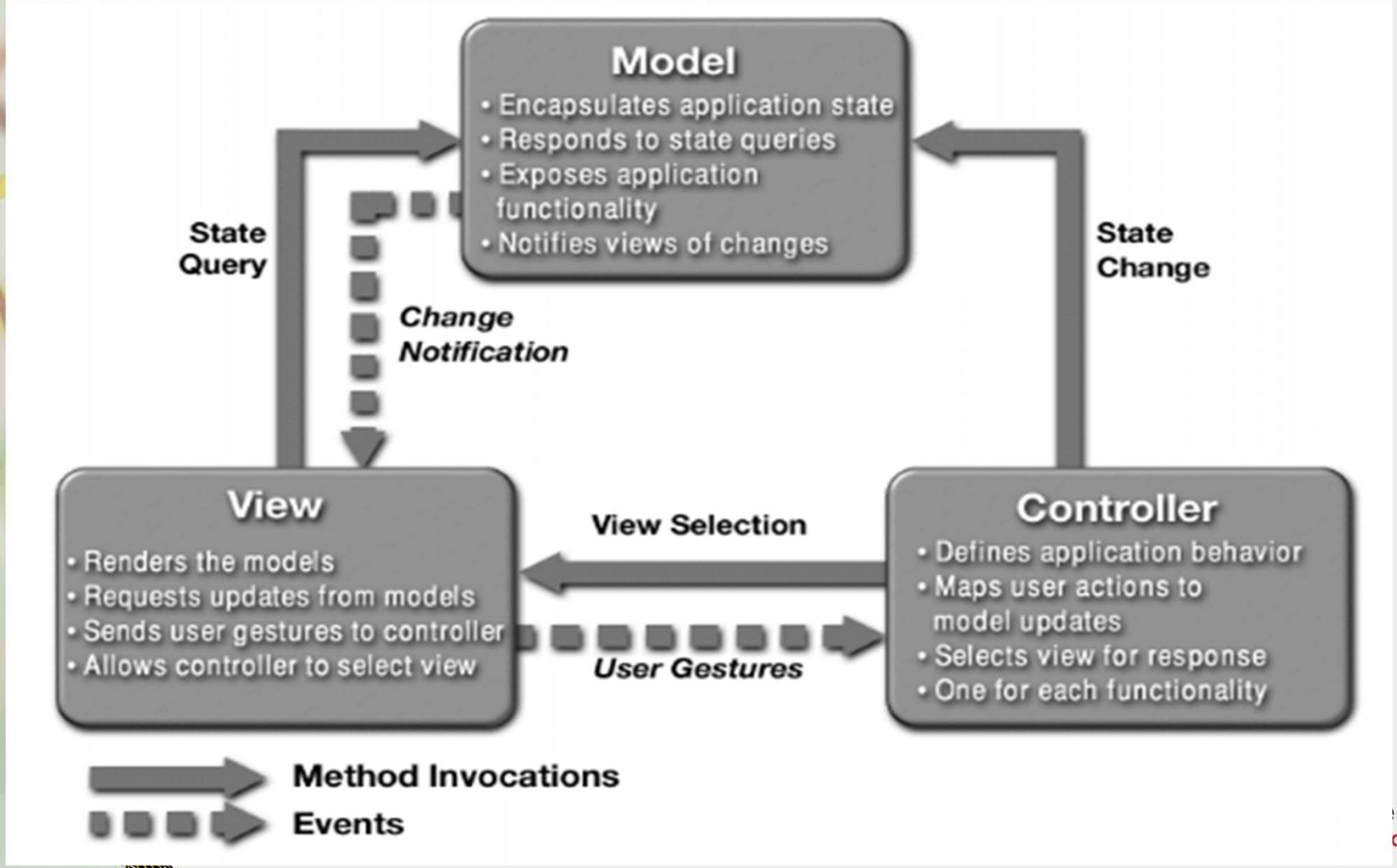
Broker pattern

- Context:
  - Collection of services distributed across multiple servers
  - Availability of these services?
  - How do they interoperate (discover, connect & exchange)?
- Problem:
  - How to structure distributed software
  - Users should not need to know nature and location of service
  - Easy to dynamically change bindings between users and providers
- Solution:
  - Element types:
    - Server, Client, Broker
  - Connectors:
    - Service interface broker
  - Constraints:
    - Only broker knows providers

Broker pattern: weaknesses

- Brokers add a layer of indirection,
  - Latency between clients and servers,
  - Broker may be a communication bottleneck
- The broker can be a single point of failure.
- Broker adds up-front complexity.
- Broker may be a target for security attacks.
- Broker may be difficult to test.

Model-View-Controller pattern



Model-View-Controller pattern

- Context:
  - User interface most frequently updated part of software
  - Data displayed from different representations
  - Representations should all reflect current state of the data
- Problem:
  - Keep UI functionality separate from application functionality
  - Keep responsive to both data changes and user input
  - Create, maintain and coordinate views of the UI consistently
- Solution:
  - Element types:
    - Model, view, controller
  - Connectors:
    - Notify
  - Constraints:
    - Model does not communicate with view directly

Model-View-Controller solution

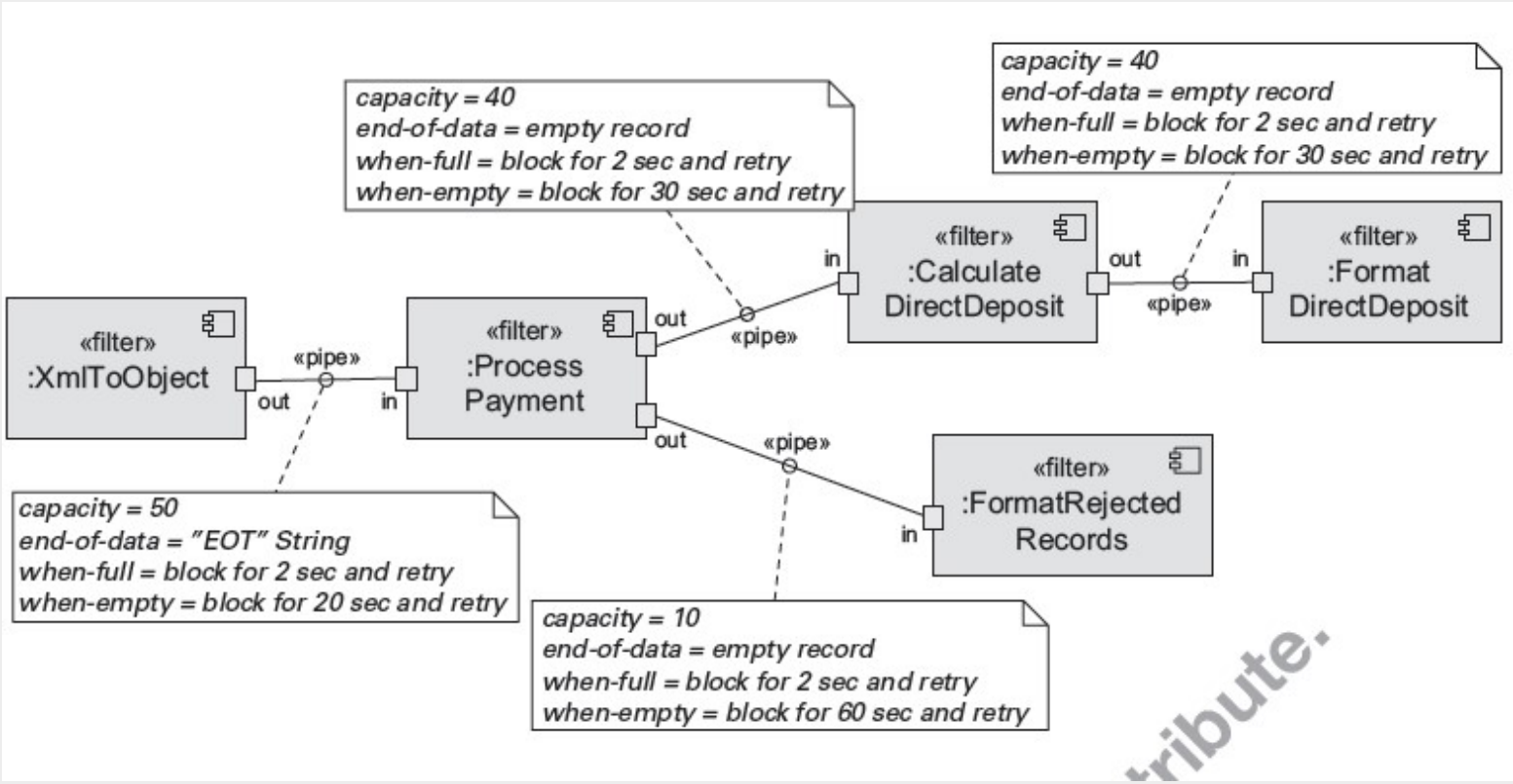
Elements:

- Model:
  - Representation of the application data or state,
  - Contains (or provides an interface to) application logic.
- View:
  - User interface component
  - Produces a representation of the model for the user
  - Allows for some form of user input
- Controller:
  - Manages all interaction between model and view
  - Translates actions into changes to the model or to the view.

Model-View-Controller solution (2)

- Constraints:
  - At least one instance of model, view, and controller
  - Model component should not interact directly with controller
- Weaknesses:
  - High complexity
  - Abstractions may not be good fits for some UI toolkits

Pipe-and-filter pattern



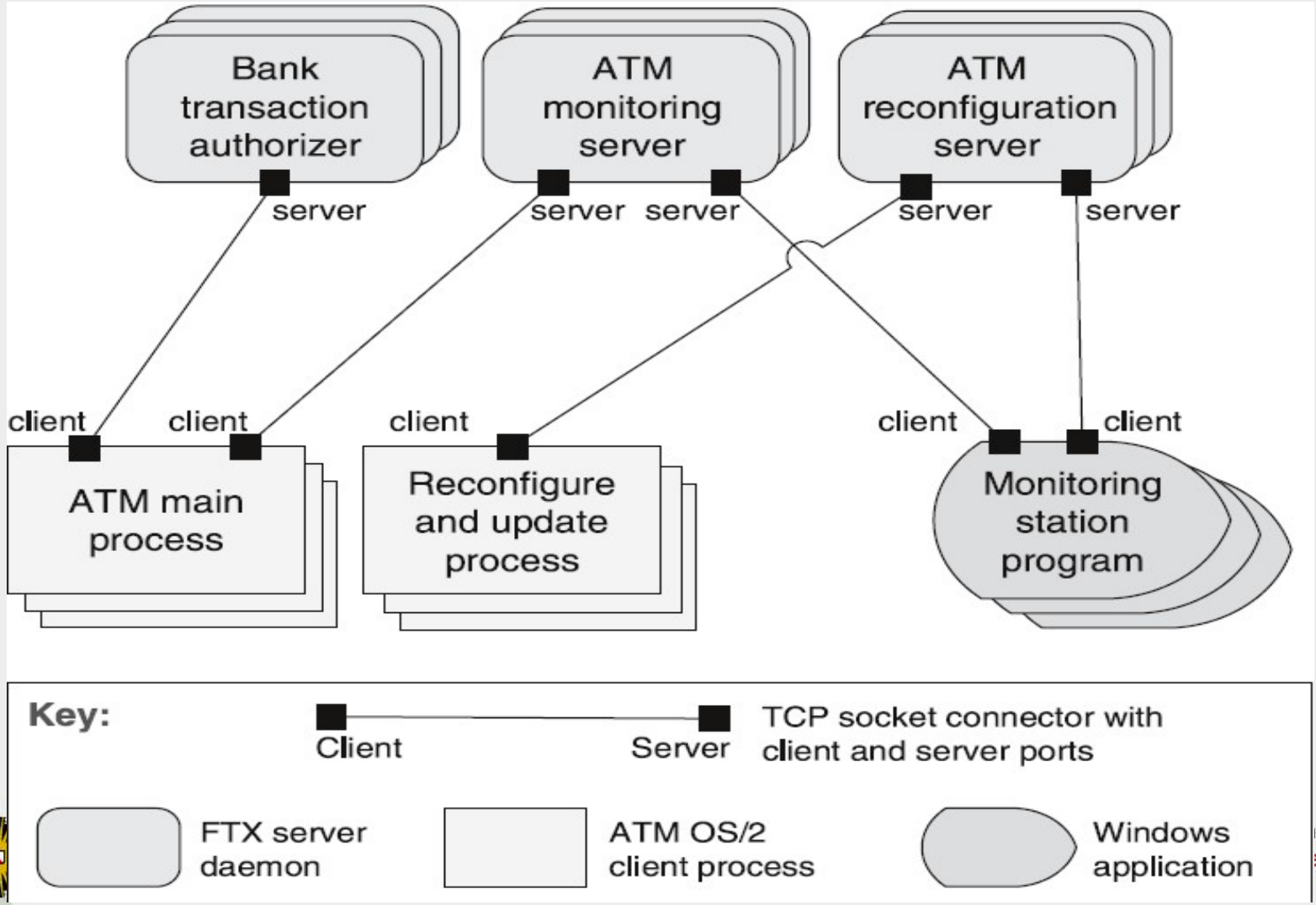
Pipe-and-filter pattern

- Context:
  - Many systems needed to transform streams of discrete data items, from input to output.
  - Transformations occur repeatedly in practice
- Problem:
  - Divide into reusable, loosely coupled components
  - Simple, generic interaction mechanisms
- Solution:
  - Element types:
    - Filter
  - Connectors:
    - Pipe, input-output interface
  - Constraints:
    - Input-output interface filters should match

Pipe-and-filter solution

- A series of transformations performed by filters connected by pipes
- Elements
  - Filter: transforms data read on input port(s) to data on its output port(s)
  - Pipe: conveys data from filter's output port to another filter's input port
- Connectors
  - Association: connect output port of filters to input port of filters
- Constraints
  - Pipes connect filter output ports to filter input ports
  - Connected filters must agree on the type of data being passed along the connecting pipe

Client-server pattern



Client-server pattern

- Context:
  - Shared resources
  - Large numbers of distributed clients,
  - Control access of clients or quality of service
- Problem:
  - Improve scalability and availability
  - Distribute resources across multiple physical servers
- Solution:
  - Element types:
    - Client, Server
  - Connectors:
    - Request/Reply
  - Constraints:

Client-server solution

Elements:

- Client:
  - Invokes services of a server component.
  - Clients have ports that describe the services they require.
- Server:
  - Provides services to clients.
  - Servers have ports that describe the services they provide.

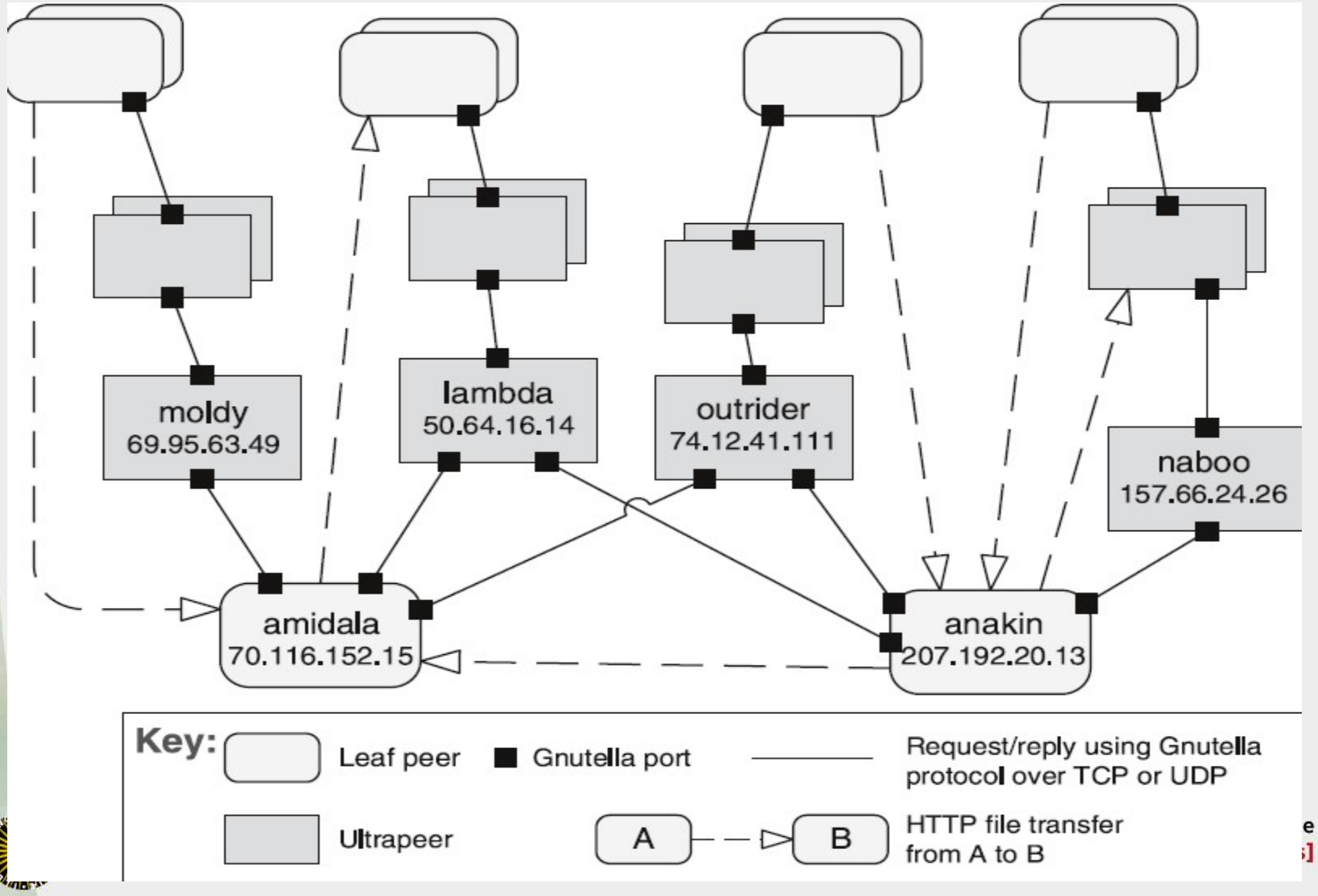
Connectors:

- Request/reply:
  - Employs a request/reply protocol
  - Calls are local or remote
  - data is encrypted or not.

Client-server solution

- Constraints:
  - Clients are connected to servers through request/reply connectors.
  - Server components can be clients to other servers
- Weaknesses:
  - Server can be a performance bottleneck.
  - Server can be a single point of failure.
  - Decisions about where to locate functionality
    - Complex
    - Costly to change after a system has been built

Peer-to-peer pattern



Peer-to-peer pattern

- Context:
  - Distributed computational, equally important entities
  - Cooperate and collaborate to provide a service to a distributed community of users.
- Problem:
  - How to connect "equal" distributed computational entities?
  - How to organize and share their services with high availability and scalability?
- Solution:
  - Element types:
    - Peer
  - Connectors:
    - Request/Reply
  - Constraints:

Peer-to-peer solution

- Computation is achieved by cooperating peers that request service from and provide services to one another across a network

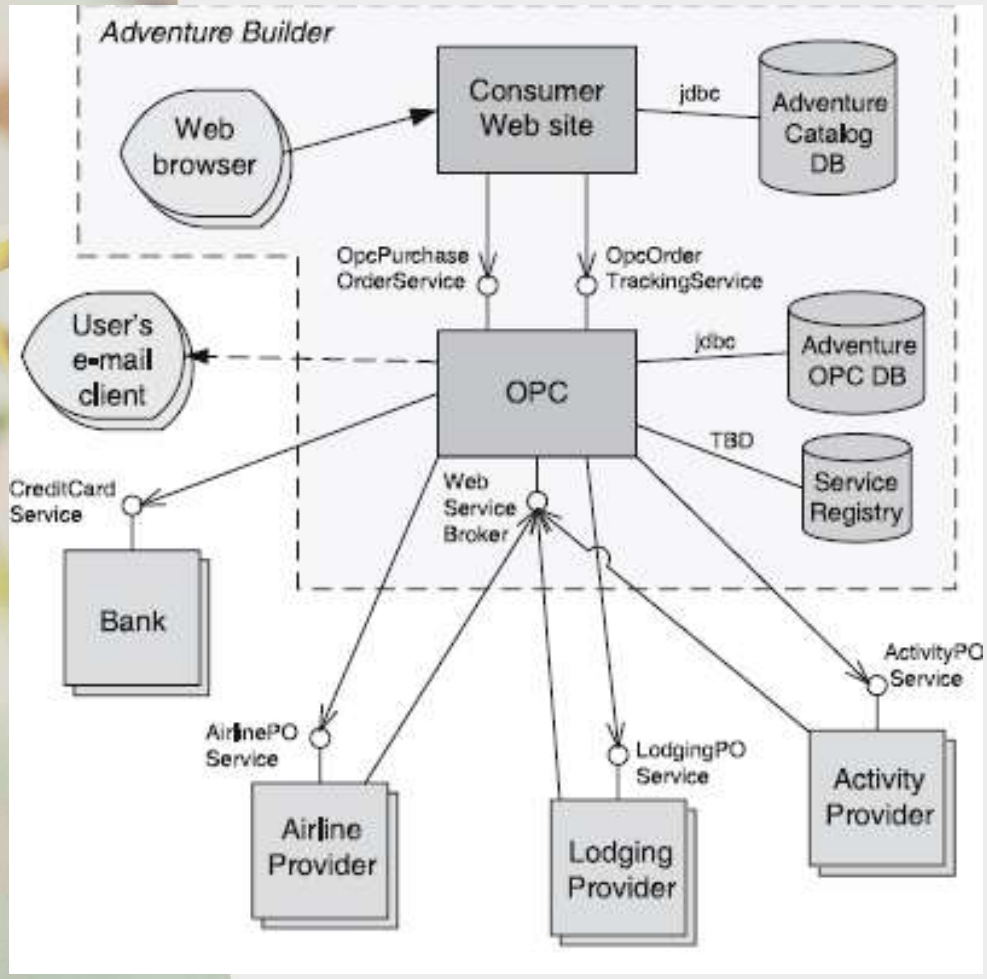
Elements:

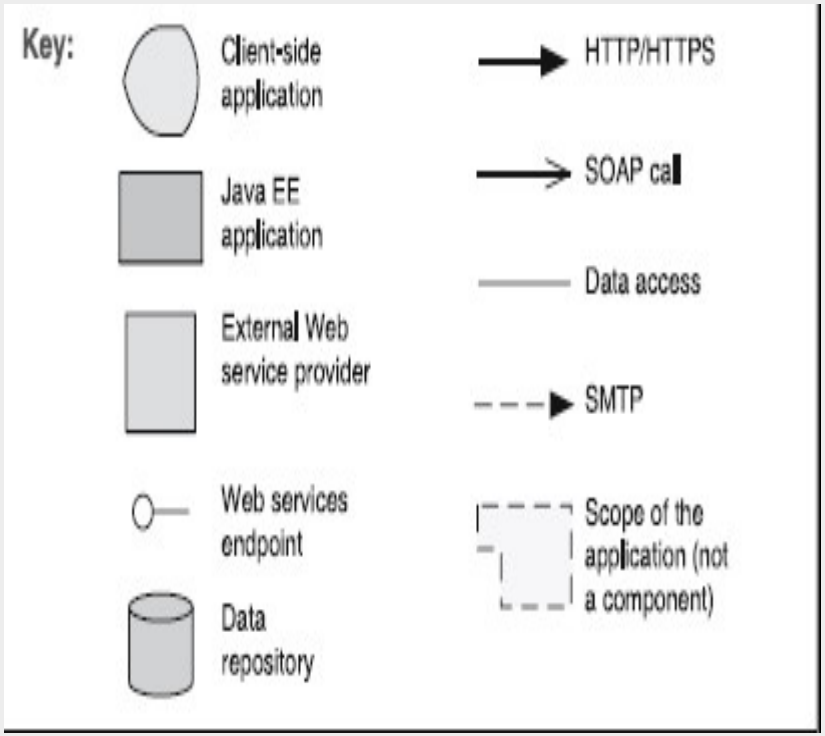
- Peer:
  - Independent component running on a network node.
  - Often provide routing, indexing, and peer search capability.
- Request/reply connector:
  - Connect to peer network
  - Search for other peers,
  - Invoke services from other peers

Peer-to-peer solution

- Relations / network:
  - Star network
  - Supernodes
  - Neighbours only
- Constraints:
  - The number of allowable attachments to any given peer
  - The number of hops used for searching for a peer
  - Which peers know about which other peers
- Weaknesses:
  - Managing security, data consistency, data/service availability, backup, and recovery are all more complex.
  - Small peer-to-peer systems may not be able to consistently achieve quality goals such as performance and availability

Service Oriented Architecture pattern





Service Oriented Architecture pattern

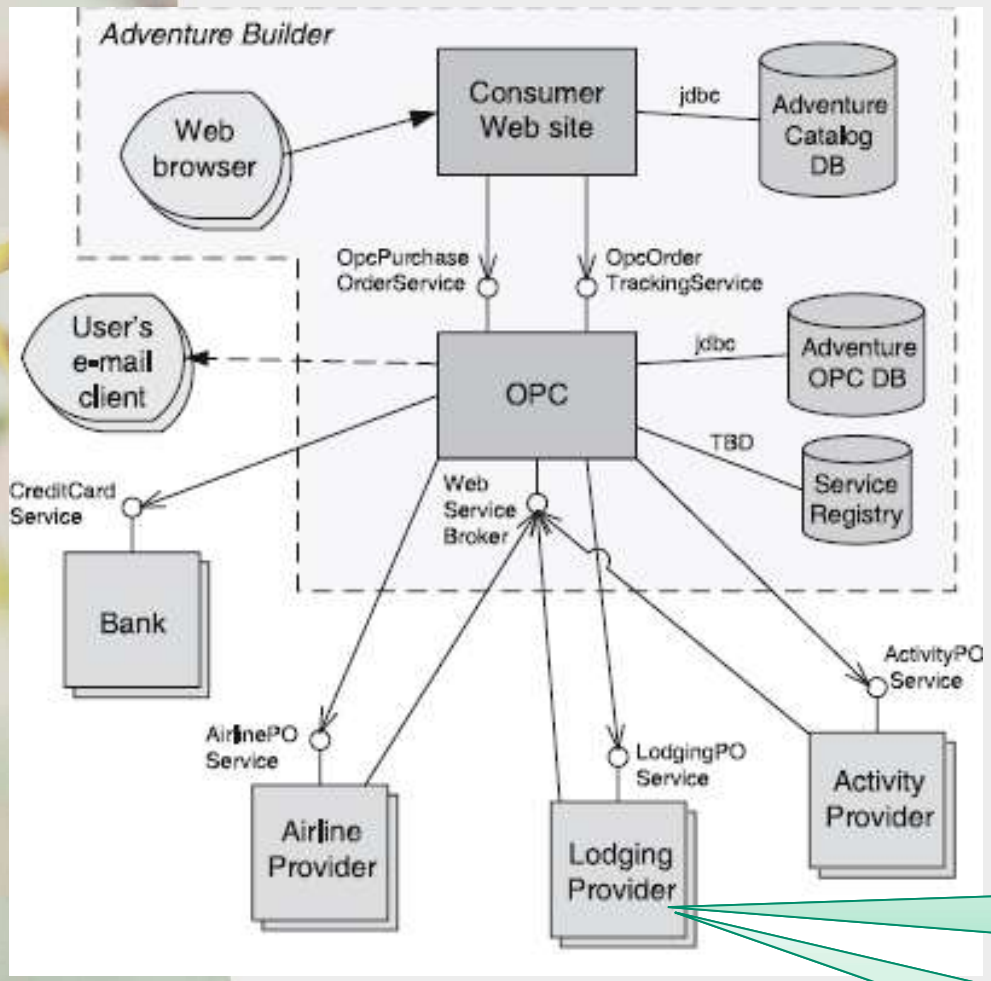
- Context:
  - Consumers need to be able to understand and use providers without any detailed knowledge of their implementation
- Problem:
  - How to support interoperability of distributed components? Provided by different organizations, distributed across Internet?
- Solution:
  - Element types:
    - Server, client
  - Connectors:
    - Interface usage / offering
  - Constraints:

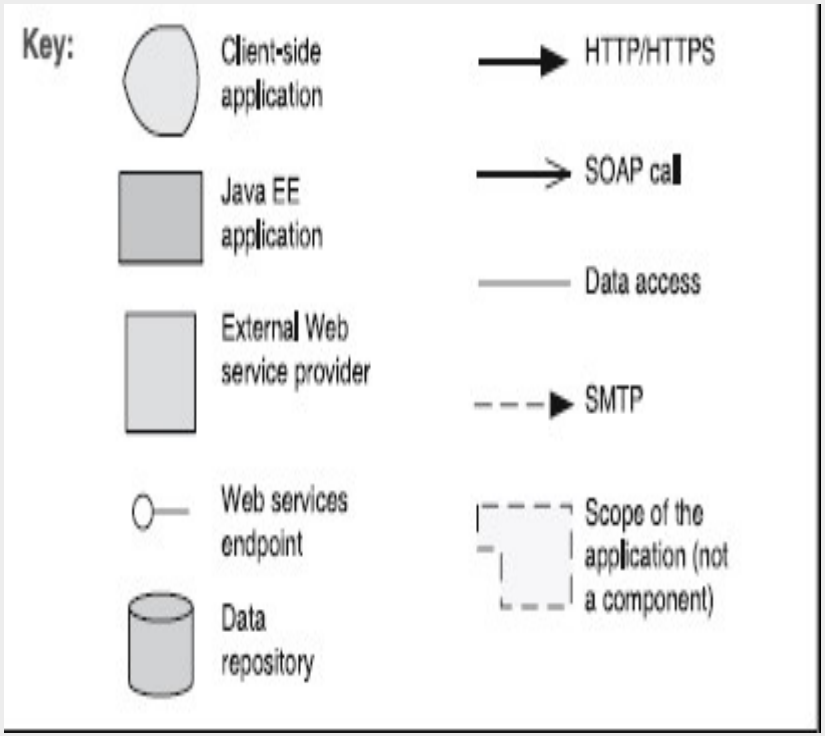
Service Oriented Architecture solution

Elements:

- Component:
  - Service provider: offers a service
  - Service consumer: invokes a service
- Enterprise Service Bus:
  - Route and transform messages between service providers and consumers
- Registry:
  - Knows the services providers offer
- Orchestrator:
  - Coordinates the interactions between service consumers and providers

Service Oriented Architecture pattern





Where are these services located?

How to find these services?

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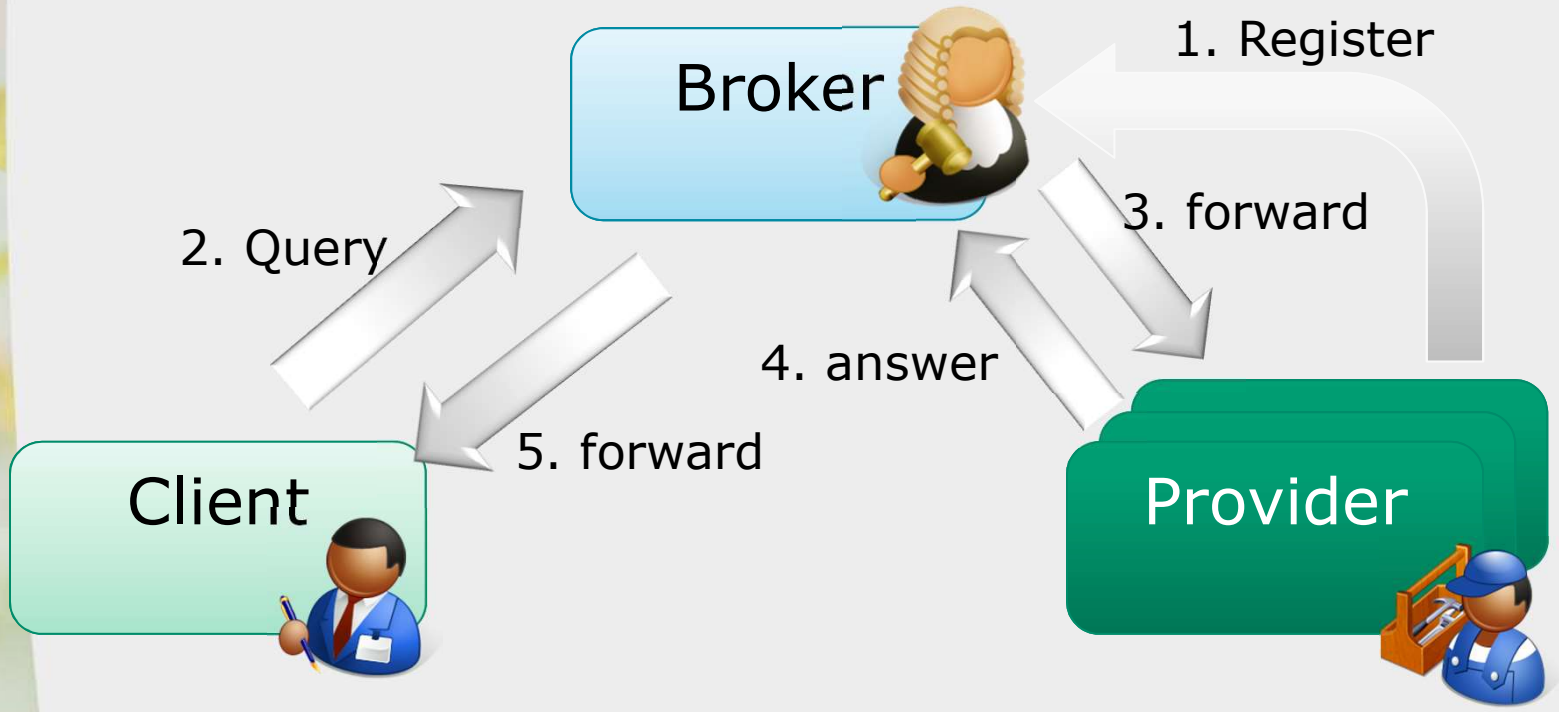
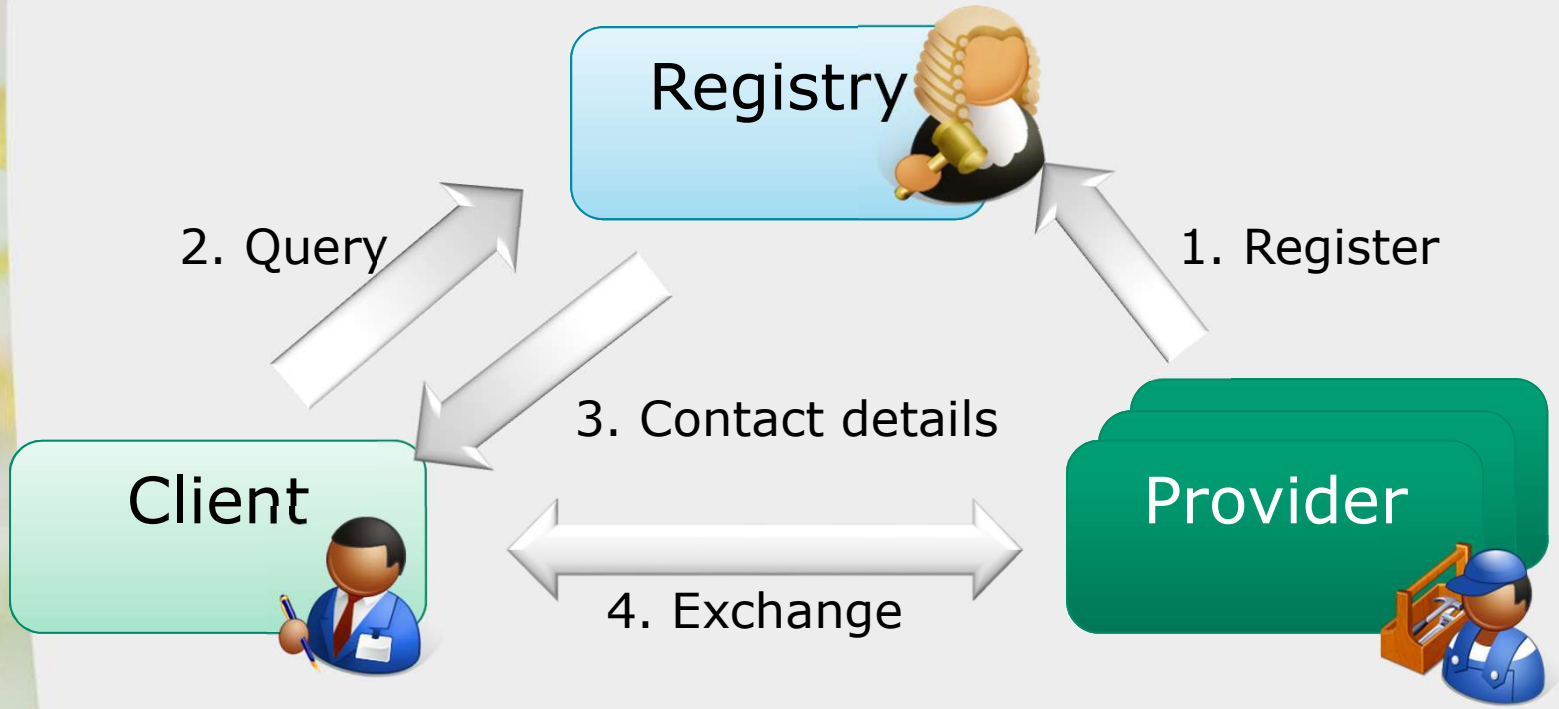
Broker pattern



Registry in SOA



Service Oriented Architecture solution

Connectors:

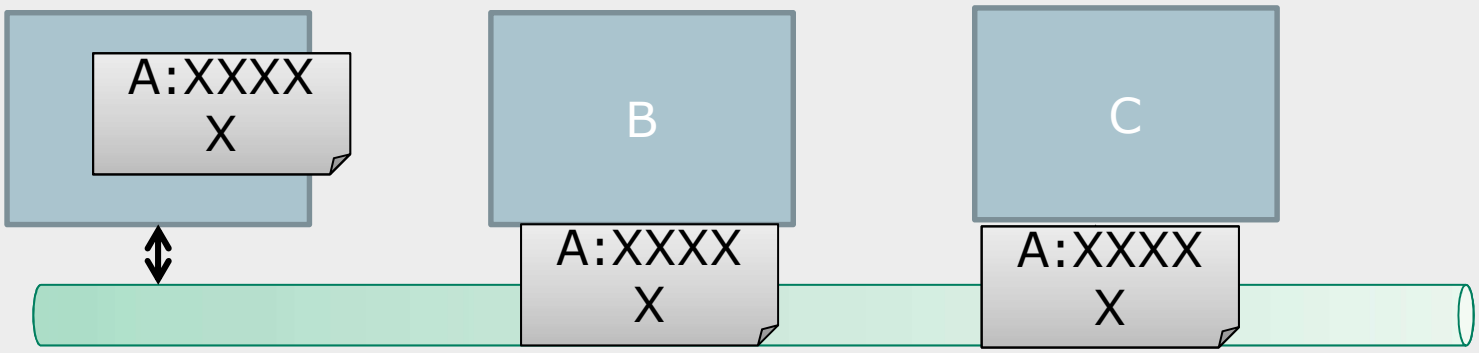
- SOAP connector
  - Uses the SOAP protocol for communication between services, can be over HTTP, SMTP, …
- REST connector
  - relies on the basic request/reply operations of the HTTP protocol.
- Asynchronous messaging connector,
  - Uses a messaging system

Service Oriented Architecture solution

- Weaknesses:
  - SOA-based systems are typically complex to build.
  - You don't control the evolution of independent services.
  - Performance overhead with middleware,
  - Services may be performance bottlenecks,
  - No performance guarantees

Publish-Subscribe solution

- Elements
  - Publisher: writes on a channel
  - Subscriber: reads from a channel
  - Channel: distributes events between publishers and subcribers



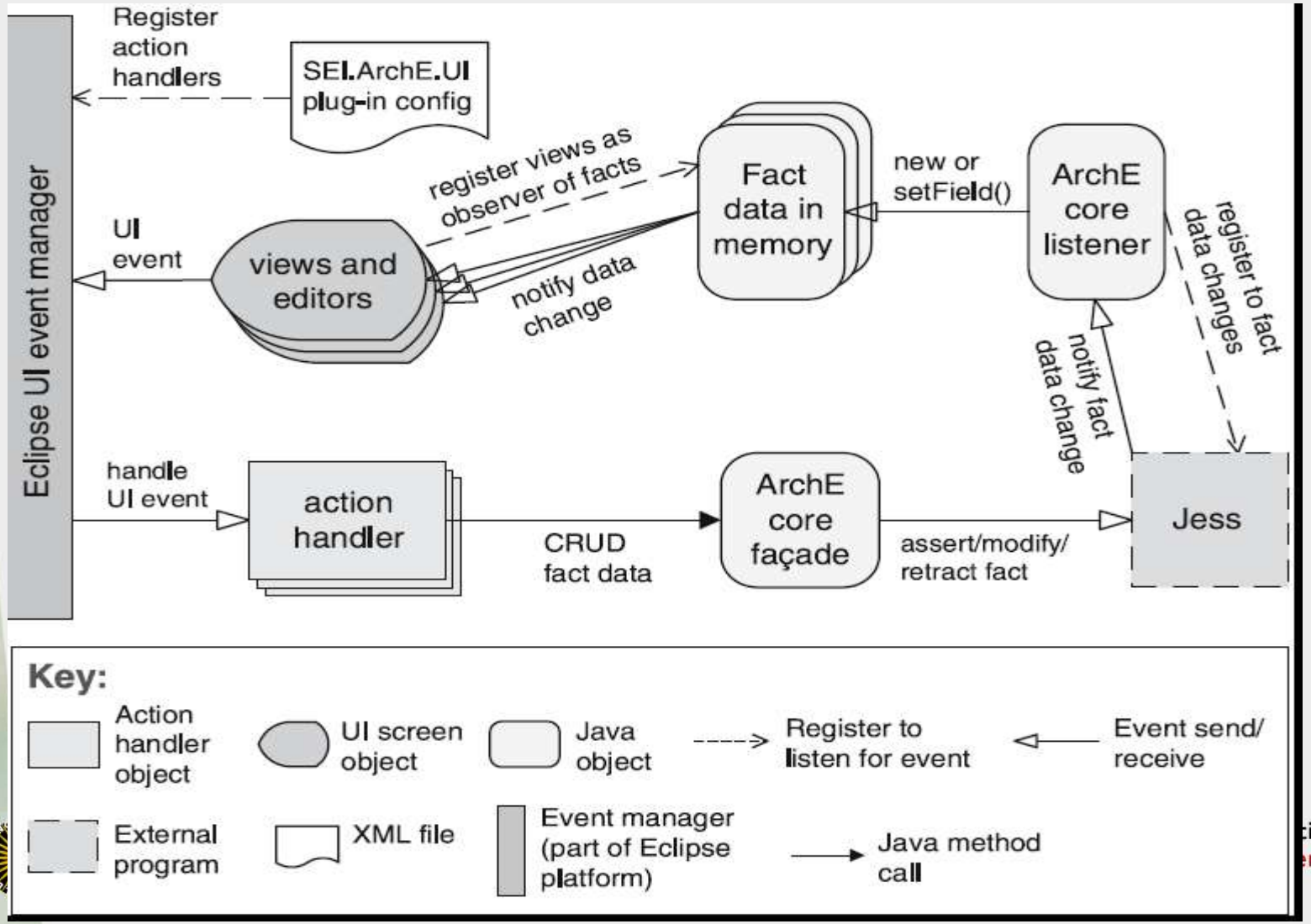
Publish-Subscribe pattern

- Context:
  - Independent producers and consumers of data must interact
  - Nature of data not predetermined or fixed
- Problem:
  - Integration mechanisms that support the ability to transmit messages between producers and consumers that are unaware of each other
- Solution:
  - Element types:
    - Publisher, Subcriber, Blackboard, Event
  - Connectors:
    - Channel
  - Constraints:

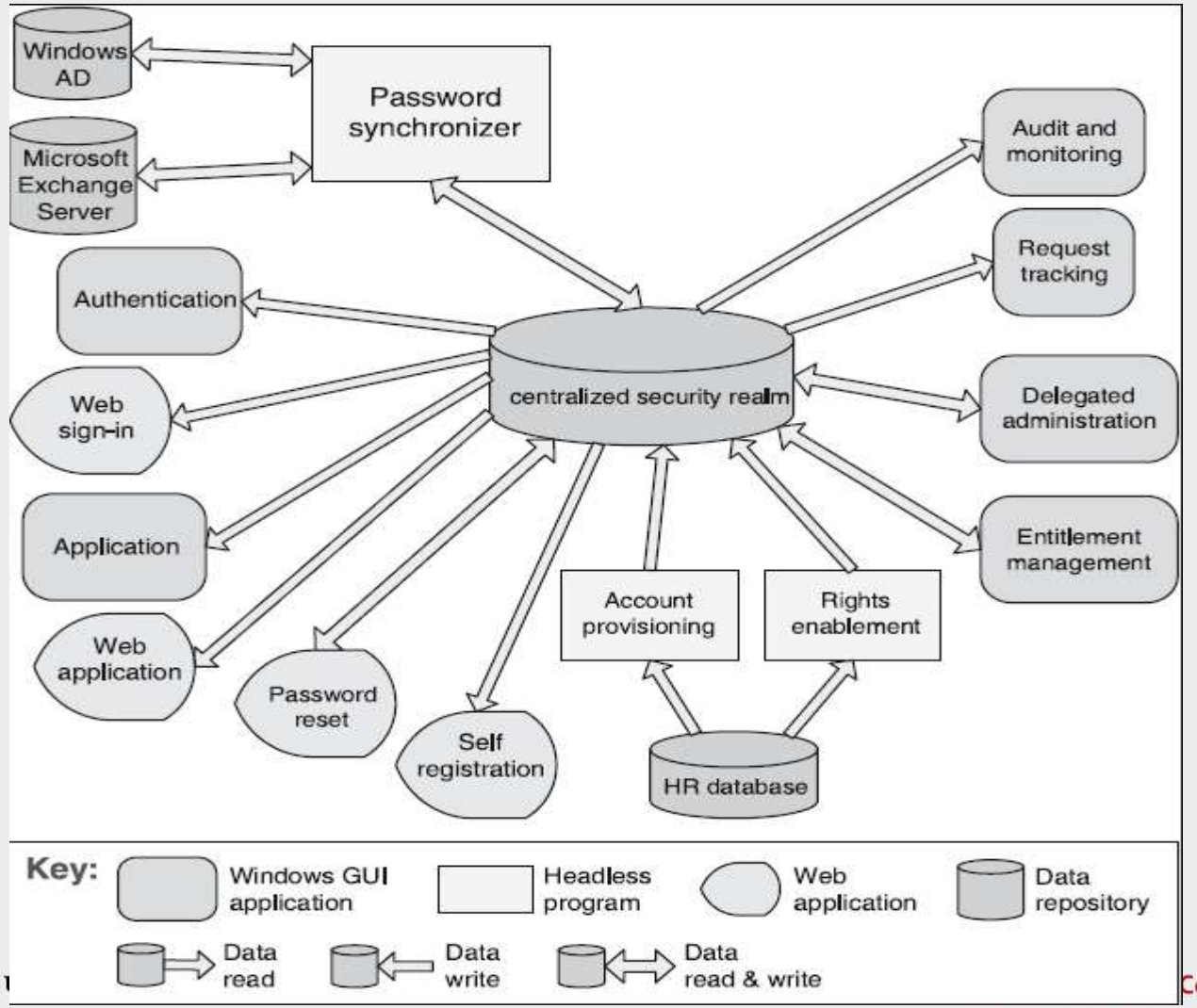
Publish-Subscribe solution

- Constraints:
  - All components are connected to an event distributor
- Weaknesses:
  - Increases latency
  - Negative effect on scalability
  - Negative effect on predictability of message delivery time
  - Less control over ordering of messages
  - Delivery of messages is not guaranteed

Publish-Subscribe pattern



Shared-data pattern



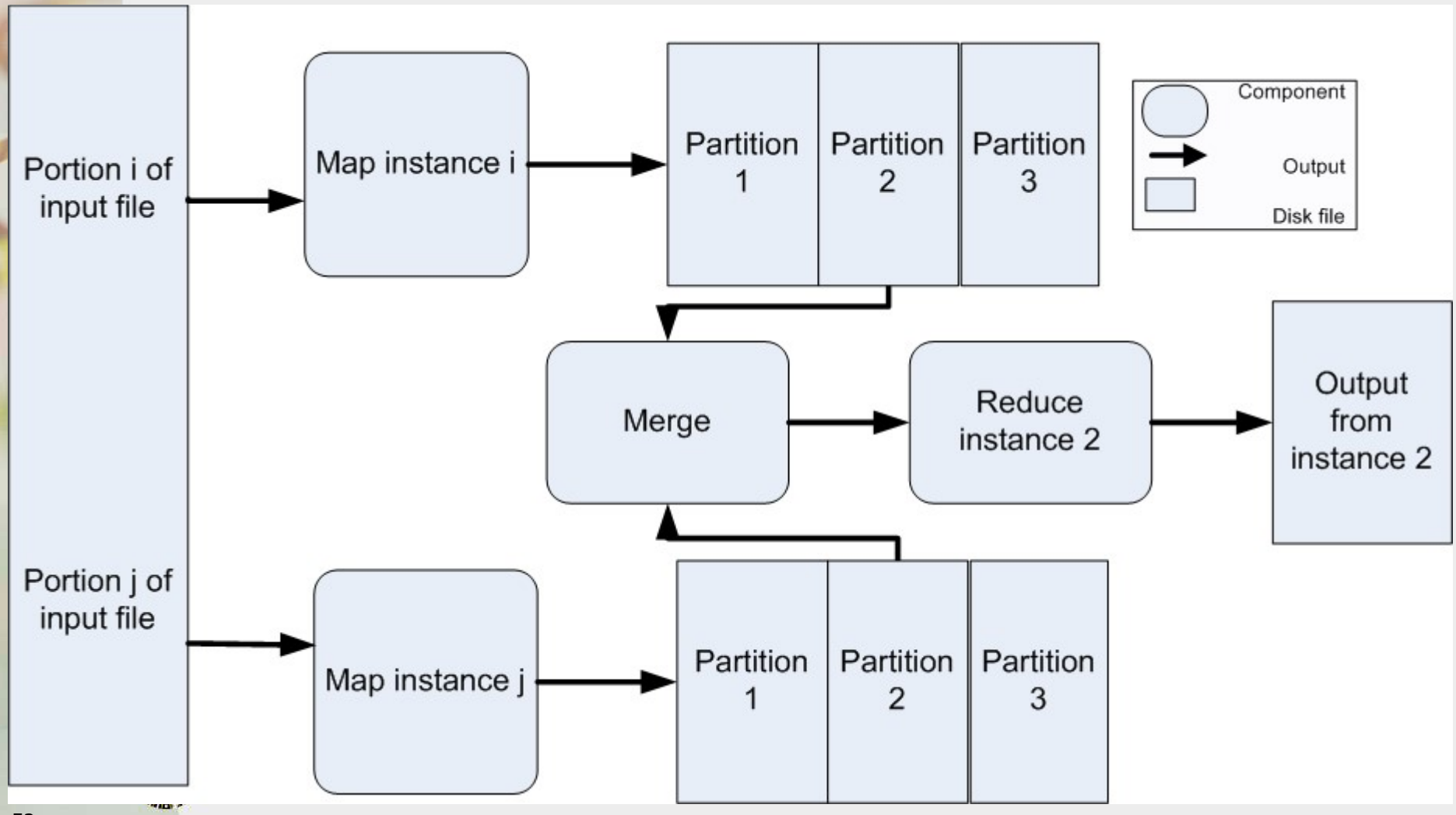
Shared-data pattern

- Context:
  - Components share and manipulate large amounts of data
  - No component owner of the data
- Problem:
  - How can systems store and manipulate persistent data that is accessed by multiple independent components?
- Solution:
  - Element types:
    - Accessor, Shated data store
  - Connectors:
    - Data accessor
  - Constraints:

Shared-data solution

- Elements:
  - Shared data store: manages access control and data persistency
  - Accessor:
- Weaknesses:
  - Shared-data store may be a performance bottleneck
  - Shared-data store may be a single point of failure
  - Producers and consumers of data may be tightly coupled

Map-Reduce pattern



Map-Reduce pattern

- Context:
  - Quickly analyze enormous volumes of data
- Problem:
  - Ultra-large data sets
  - Efficiently perform a distributed and parallel sort
- Solution:
  - A specialized infrastructure takes care of allocating software to the hardware nodes in a massively parallel computing environment and handles sorting the data as needed
  - A programmer specified component called the map which filters the data to retrieve those items to be combined
  - A programmer specified component called reduce which combines the results of the map

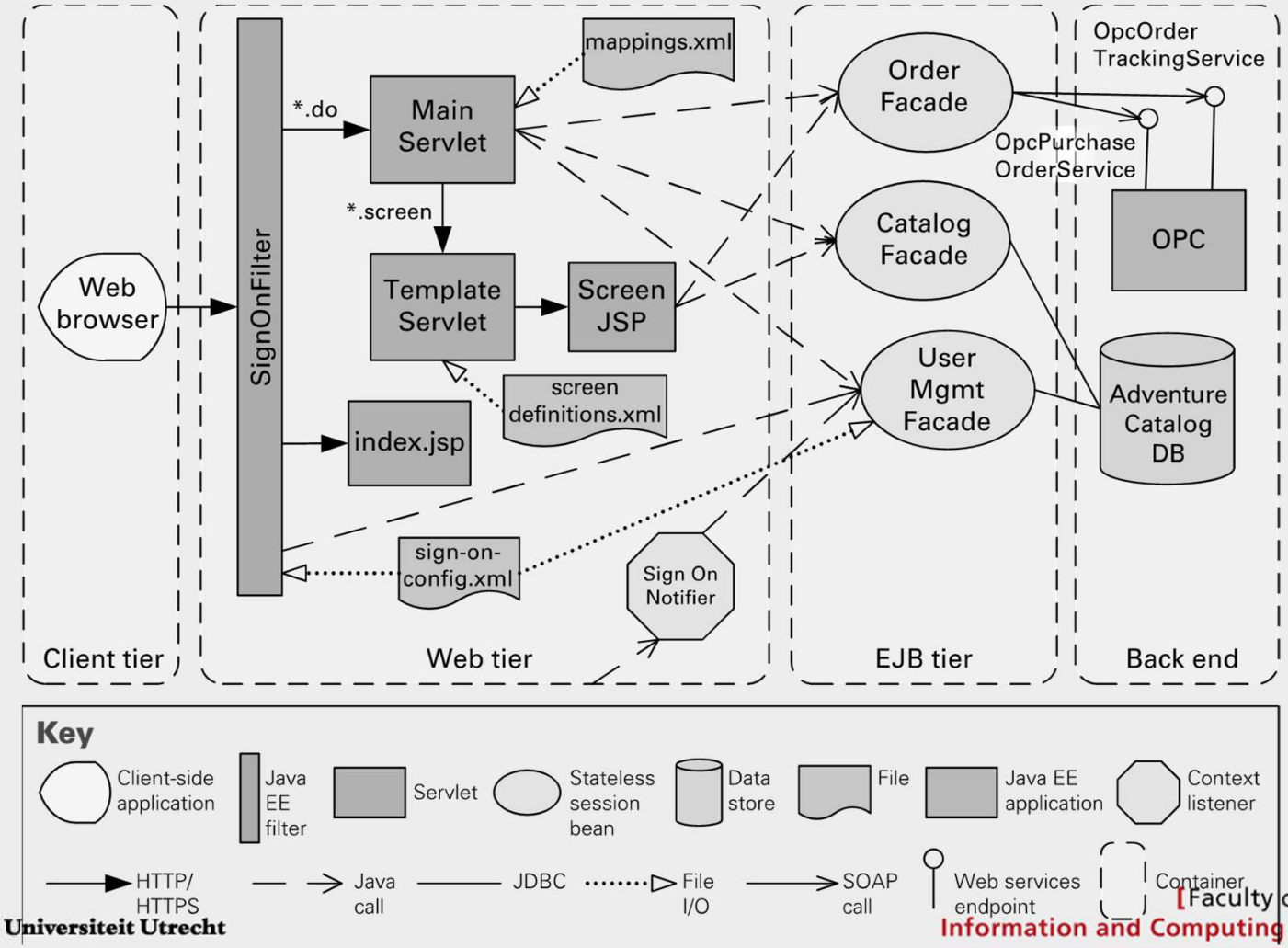
Map-Reduce pattern

- Elements:
  - Map is a function with multiple instances deployed across multiple processors that performs the extract and transformation portions of the analysis.
  - Reduce is a function that may be deployed as a single instance or as multiple instances across processors to perform the load portion of extract-transform-load.
  - The infrastructure is the framework responsible for deploying map and reduce instances, shepherding the data between them, and detecting and recovering from failure

Map-Reduce solution

- Relations:
  - Deploy: relation between map or reduce function and processor
  - Instantiate, monitor, and control
- Constraints:
  - The data to be analyzed must exist as a set of files
  - Map functions are stateless and do not communicate
  - The only communication between map reduce instances is the data emitted from the map instances as <key, value> pairs.
- Weaknesses:
  - If you do not have large data sets, the overhead of map-reduce is not justified.
  - If you cannot divide your data set into similar sized subsets, the advantages of parallelism are lost.
  - Operations requiring multiple reduces are complex to orchestrate

Multi-Tier pattern



Multi-Tier pattern

- Context:
  - Distribute a system's infrastructure into distinct subsets
- Problem:
  - Split system in computationally independent execution structures
- Solution:
  - Element types:
    - Tier: logical grouping of components
  - Connectors:
    - Part of, communicates-with, allocated-to
  - Constraints:
    - Communication only with tier above and below
- Weakness:
  - Substantial up-front cost and complexity

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To summarize

To summarize

- Many patterns exist
  - Context – what is the environment of our problem
  - Problem – what do I want to achieve? Can I generalize?
  - Solution – what is a possible solution?
- Solution:
  - Element types
  - Interaction mechanisms
  - Topological layout
  - Constraints
- Patterns are one of the first design decisions you will make!
- Which one suits better?
  - Use rationale to weight pros and cons