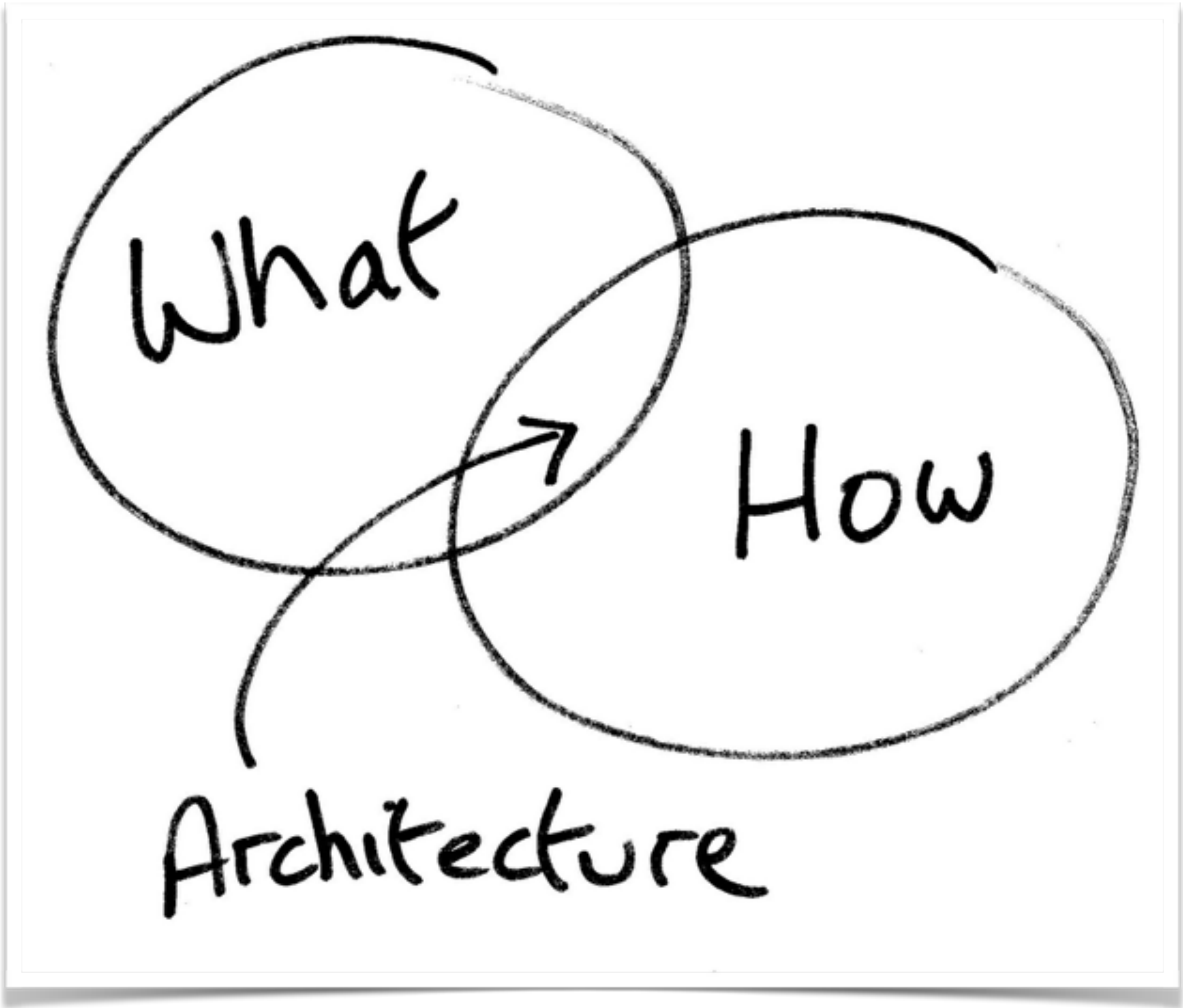
Software Architecture

Software Engineering - 2017
Alessio Gambi - Saarland University

These slides are based the slides from Cesare Pautasso and Christoph Dorn, and updated from various sources.

Architecture



Design in the Large

- Objects and methods
- Modules and components
- Large and complex systems
- Systems of systems

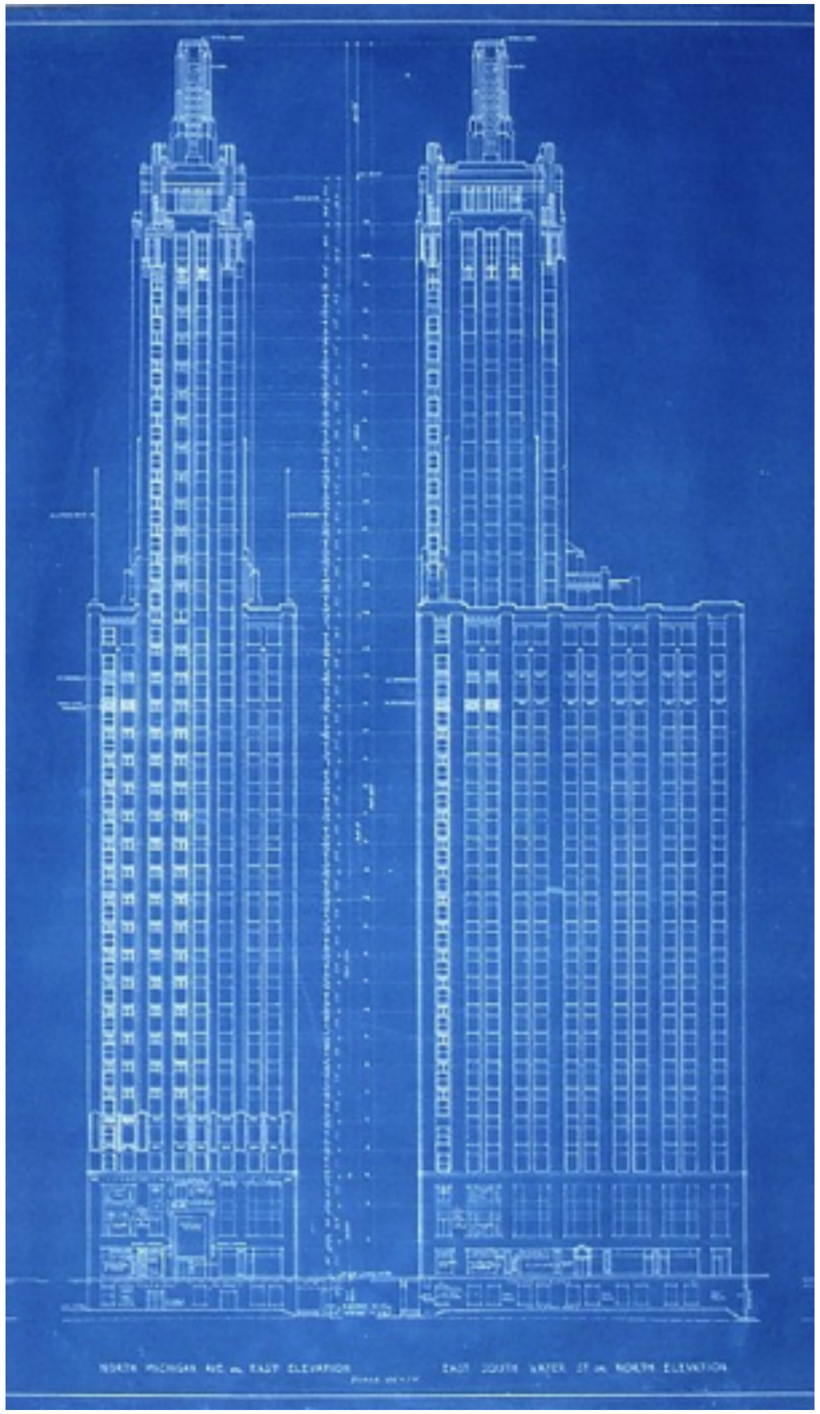
Design in the Large

- Objects and methods
- Modules and components
- Large and complex systems
- Systems of systems

- Size of the team
- Lifetime of the project
- Cost of development

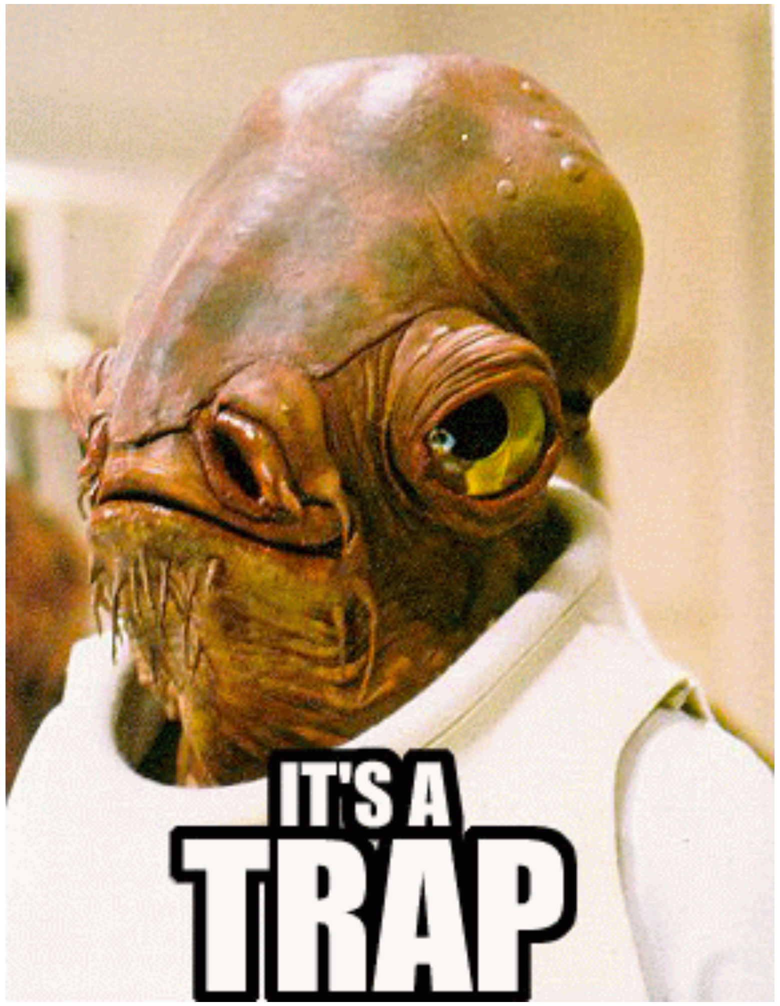
Building software as we build buildings ?

- Software is complex, so are buildings (blueprint)
- Architecture implies a systematic process for design and implementation
- Architects put together pieces and materials, they usually do not invent new materials



It’s just an analogy !

- We know a lot about buildings (2000+ years), much less about software
- Software systems do not obey to physical laws
- Software deployment has no counterpart in building architecture



Software Architecture

A software system's architecture is the set of principal design decisions made about the system.

N. Taylor et al.

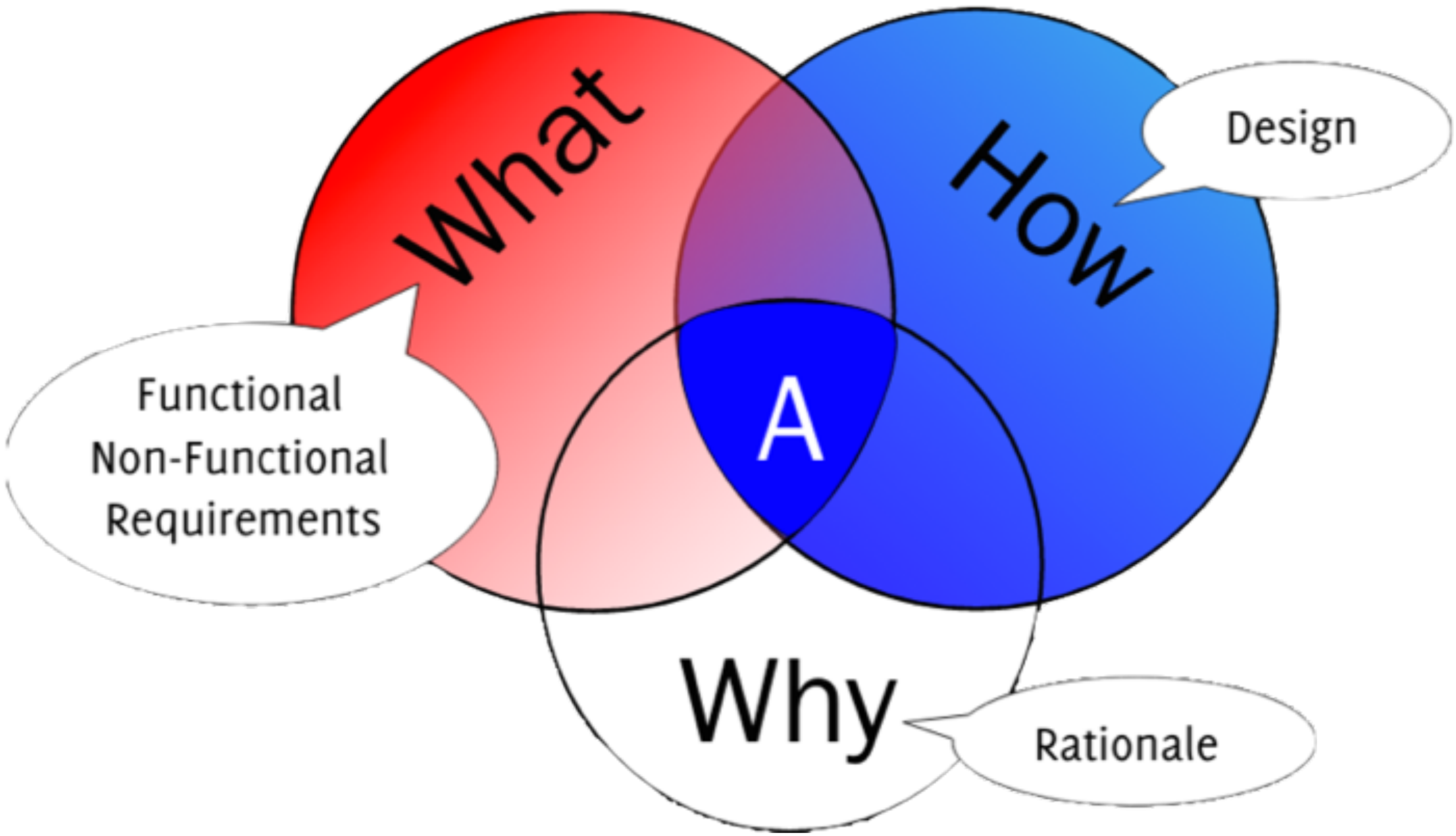
Software Architecture

A software system's architecture is the set of principal design decisions made about the system.

Where do the pillars go? VS Where do the chairs go?

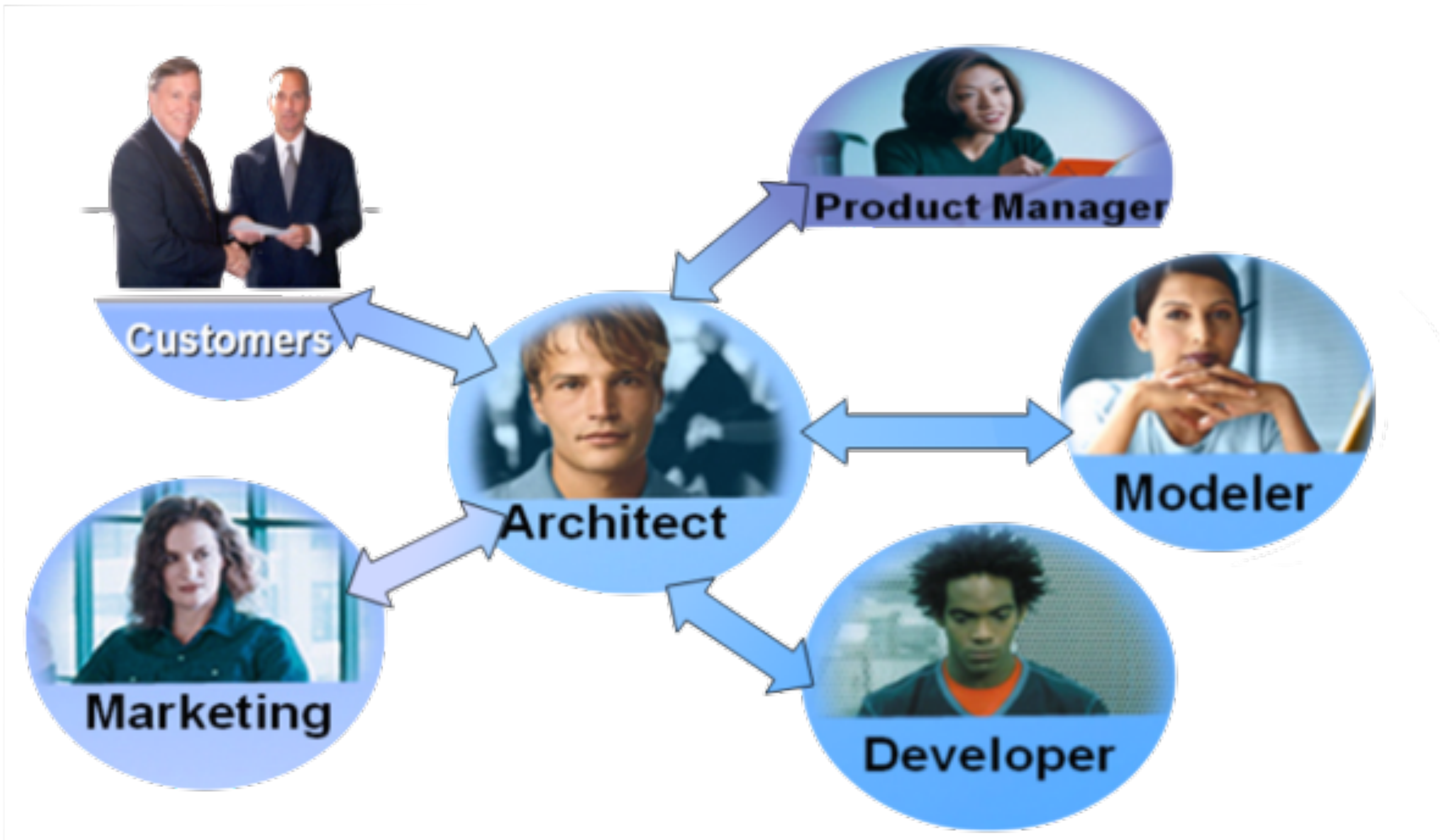
N. Taylor et al.

Abstraction



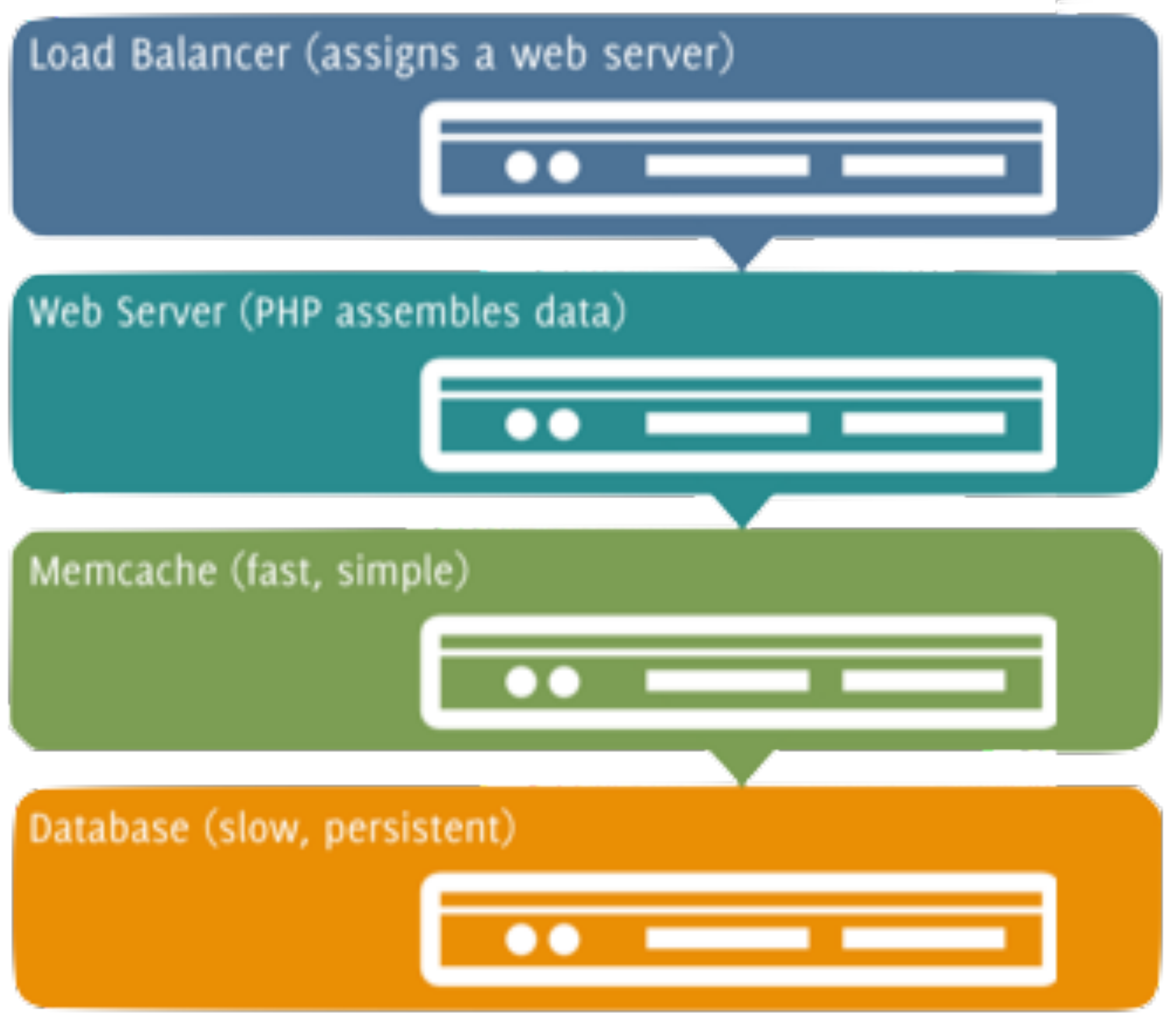
Manage complexity in the design

Communication



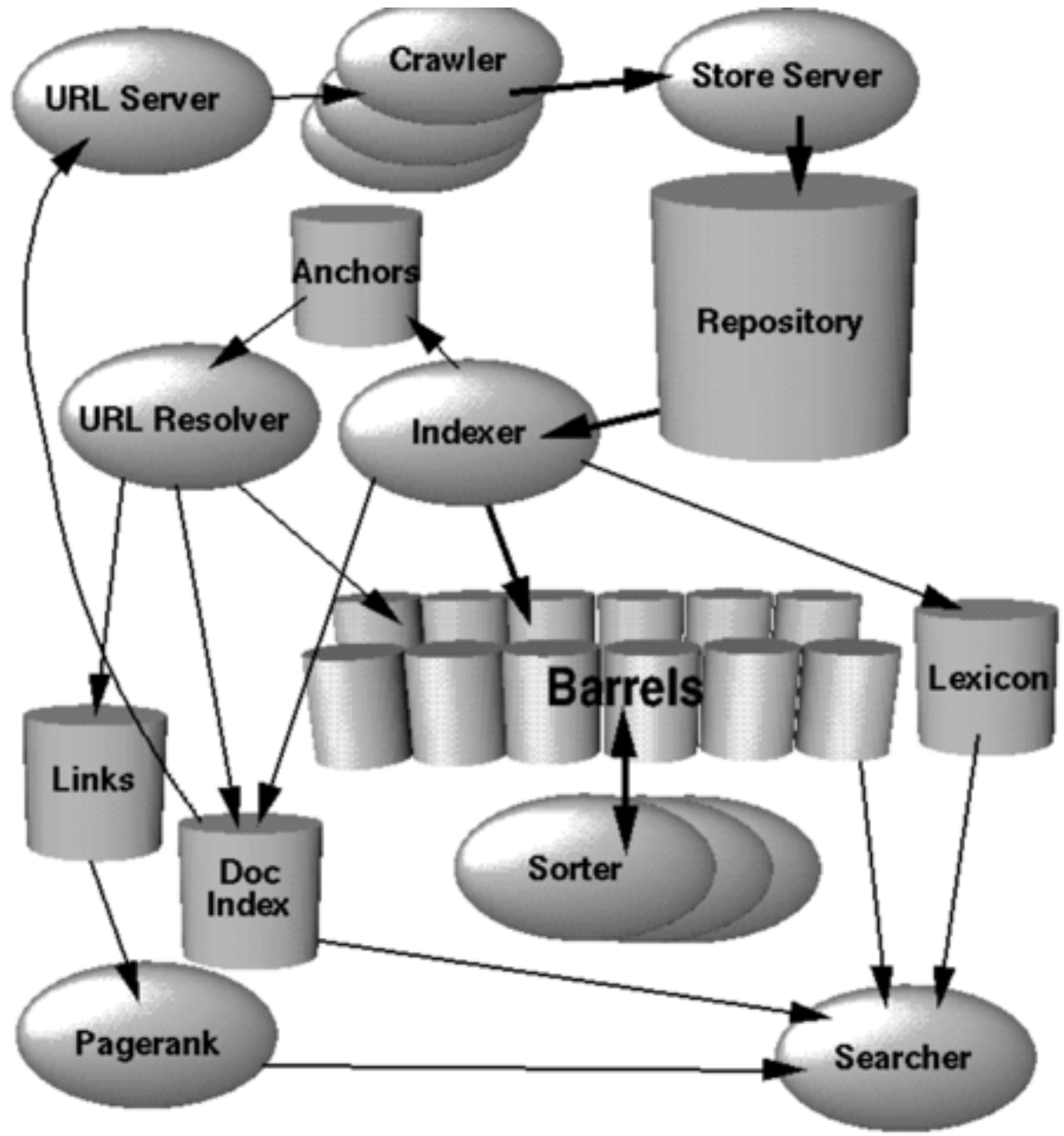
Document, remember and share design decisions among the team

Visualization



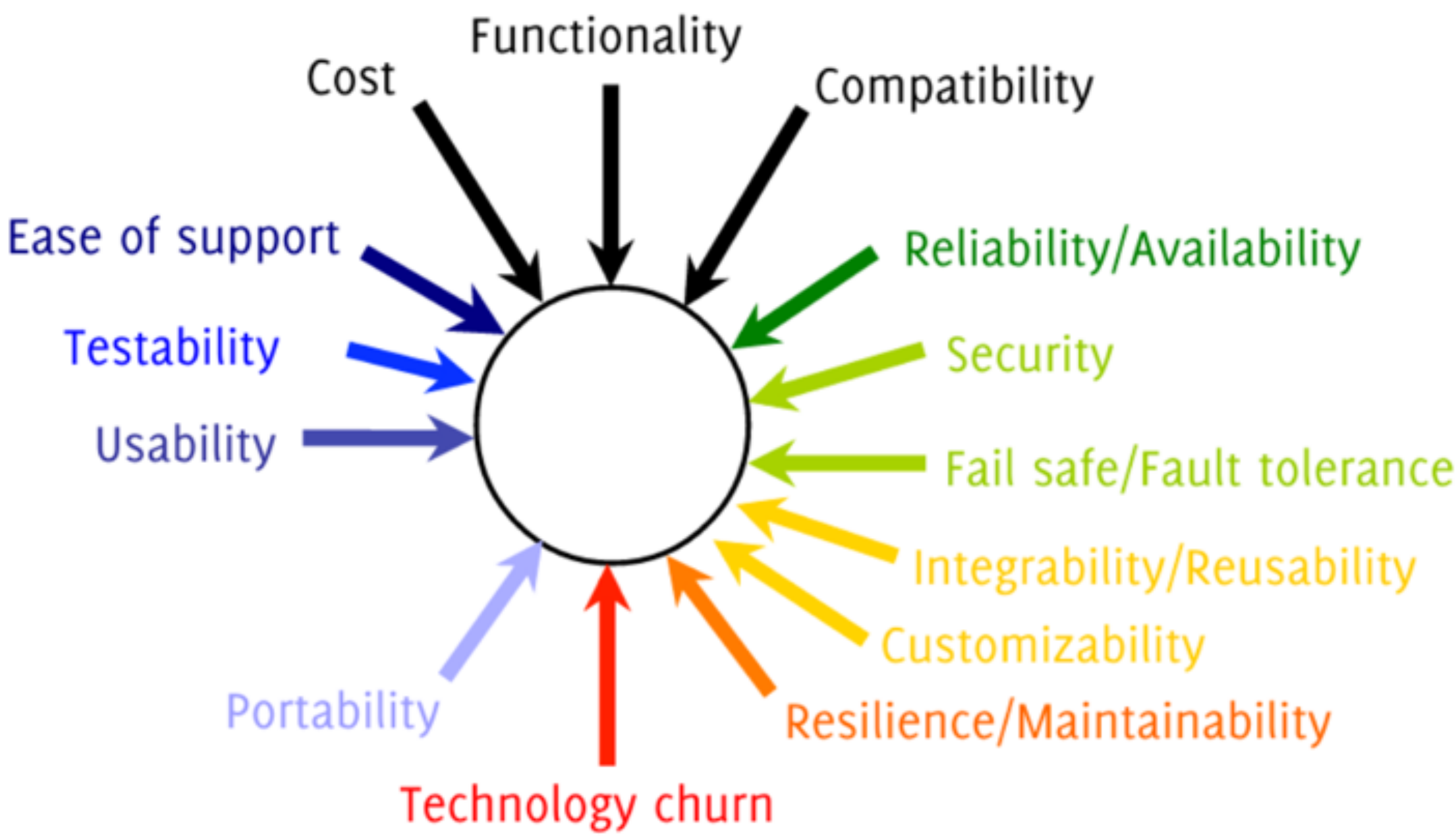
Depict and highlight important aspects

Representation



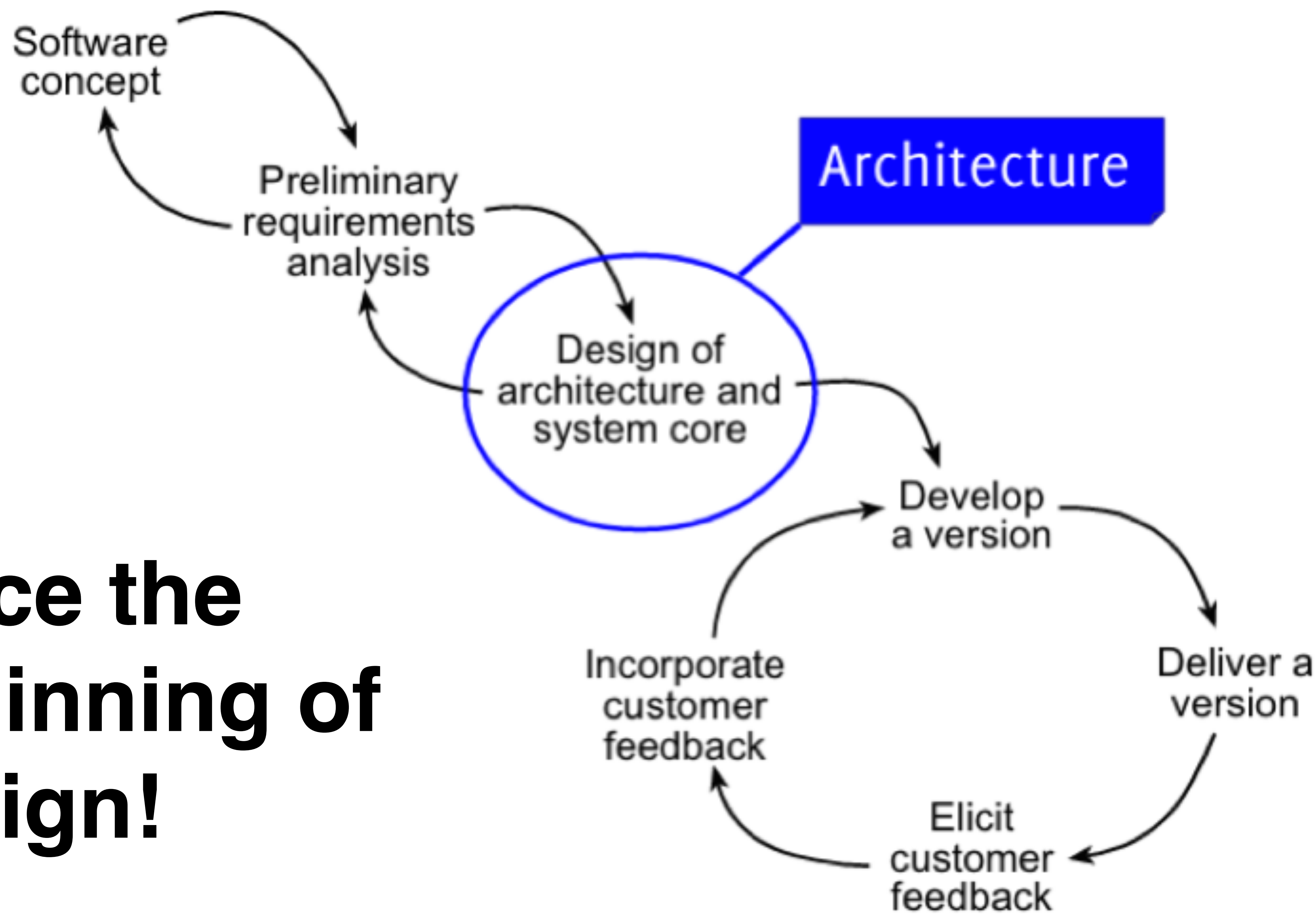
Characterize components and behaviors

Quality Analysis



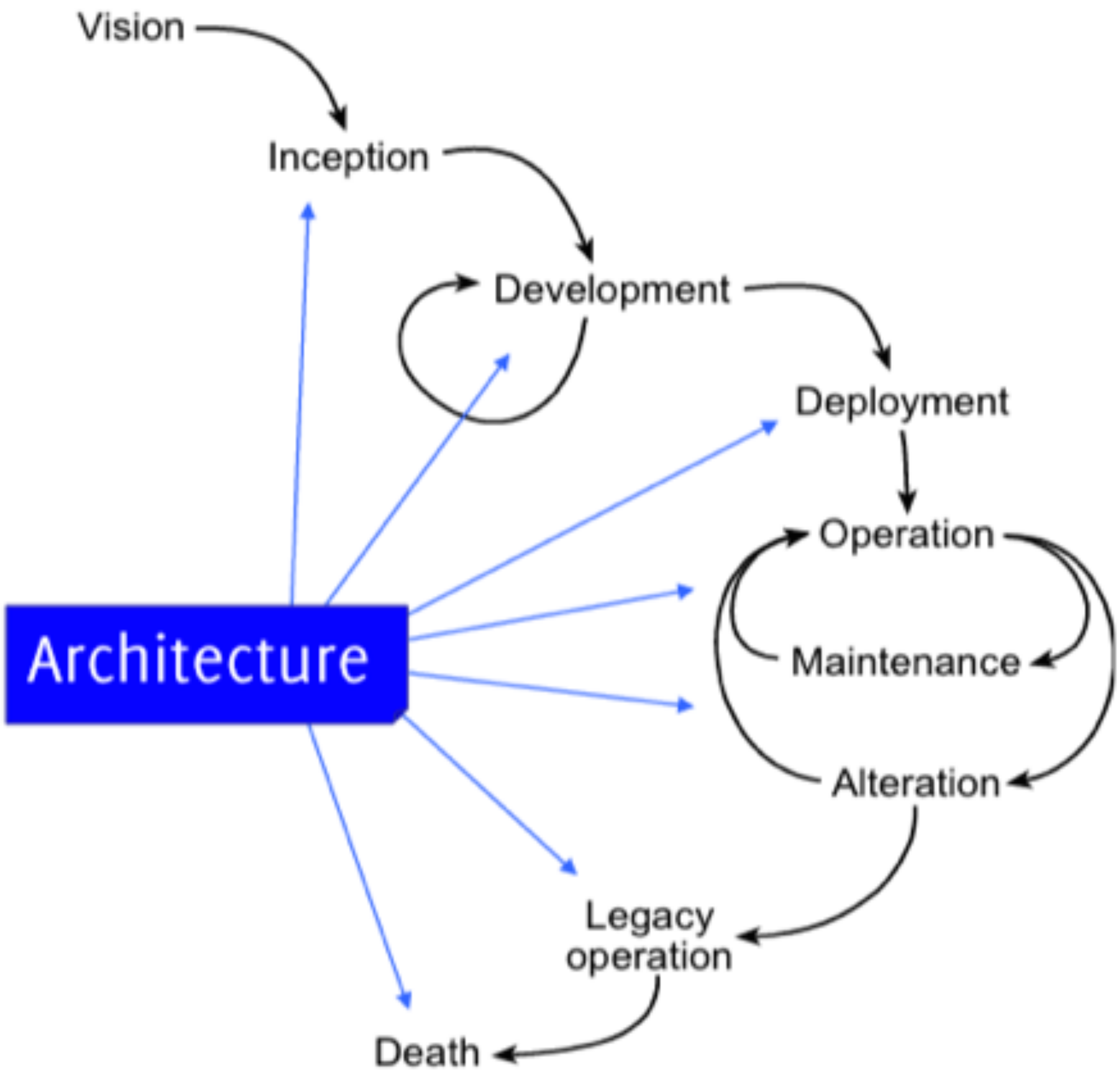
Understand, predict, and control

When SW Architecture Start ?

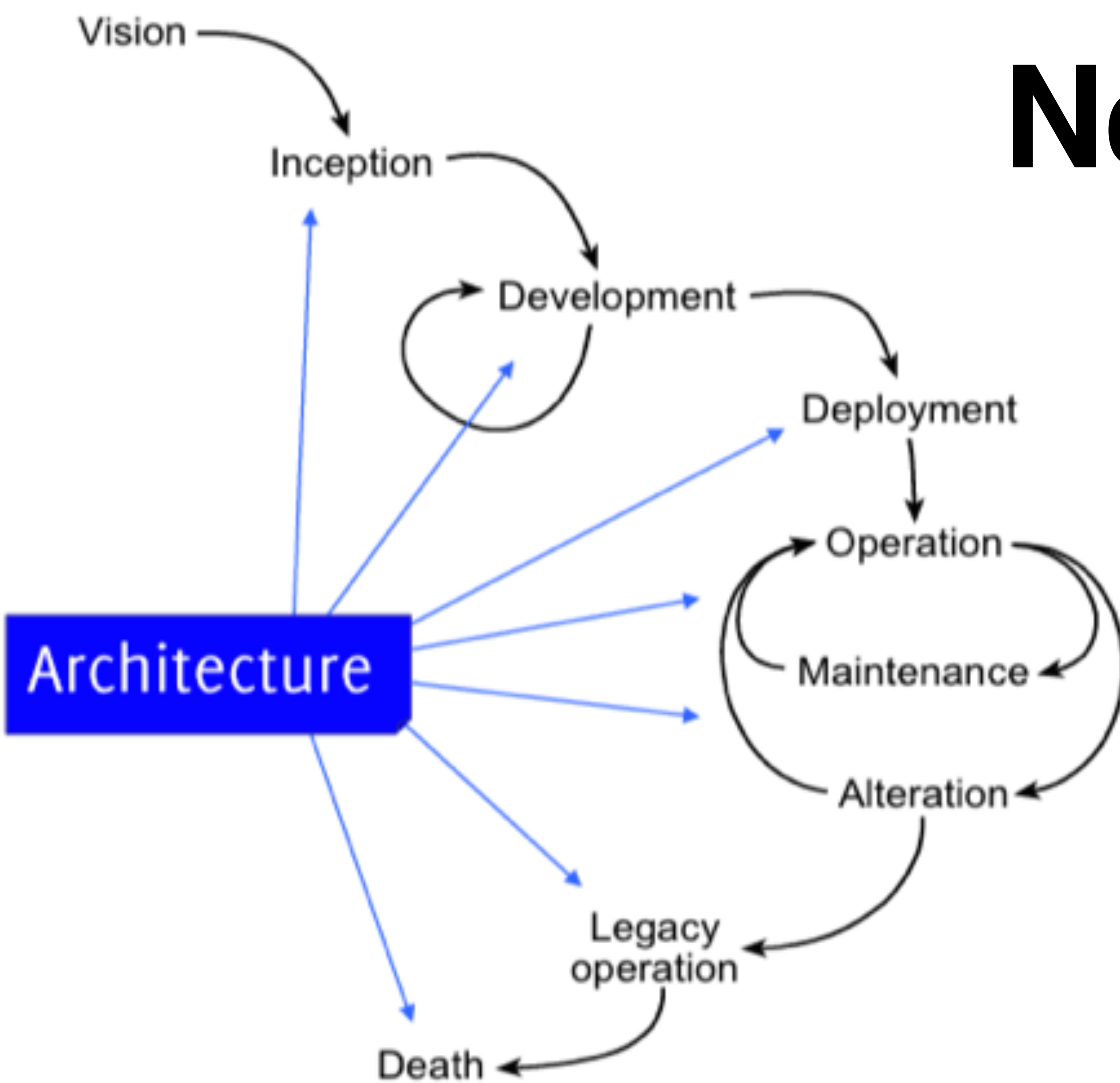


Since the beginning of design!

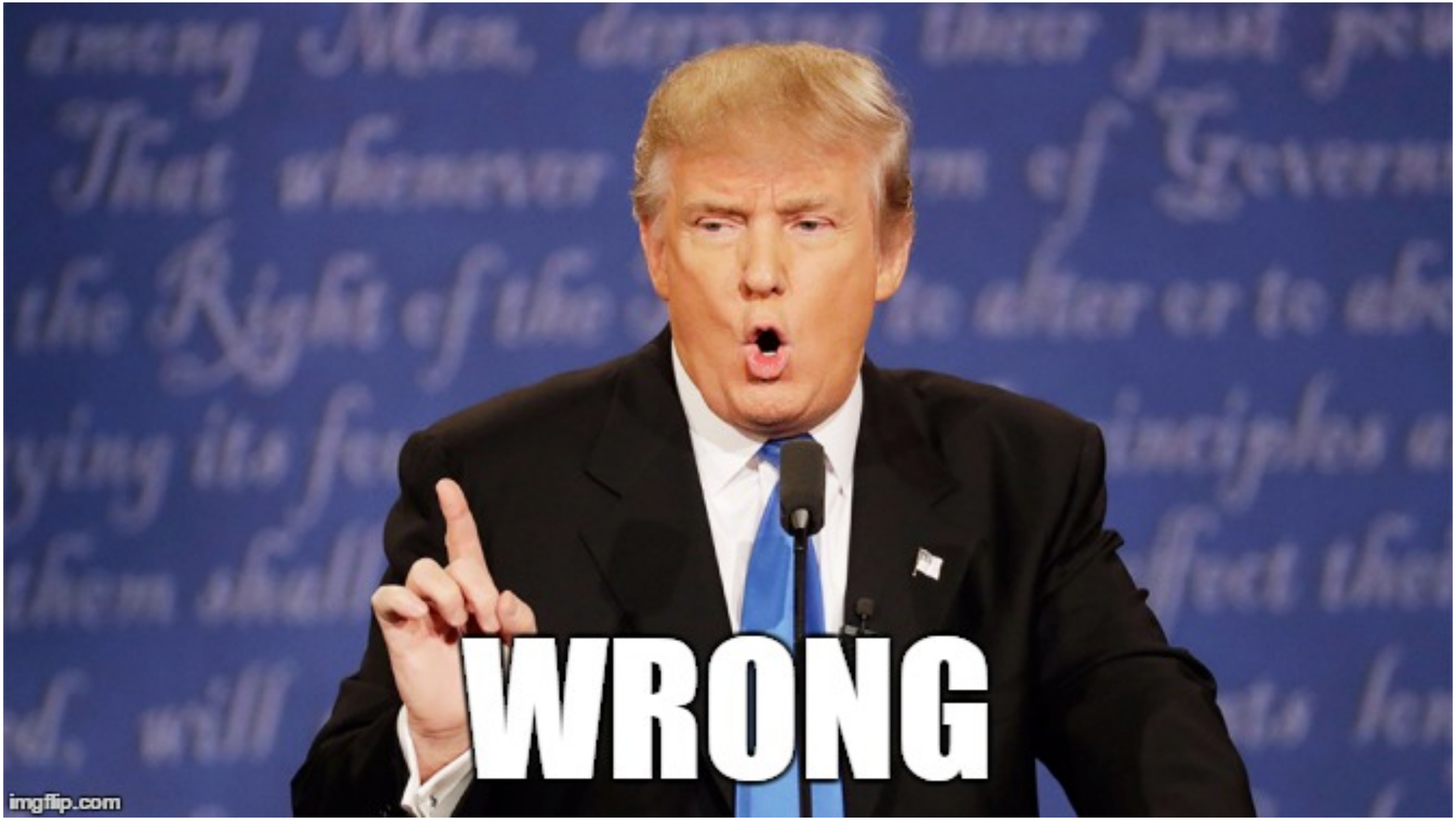
When SW Architecture Stop ?



When SW Architecture Stop ?



Never!



Architecture is NOT a development phase

Architecture is NOT only “high-level” design

Every System an Architecture has

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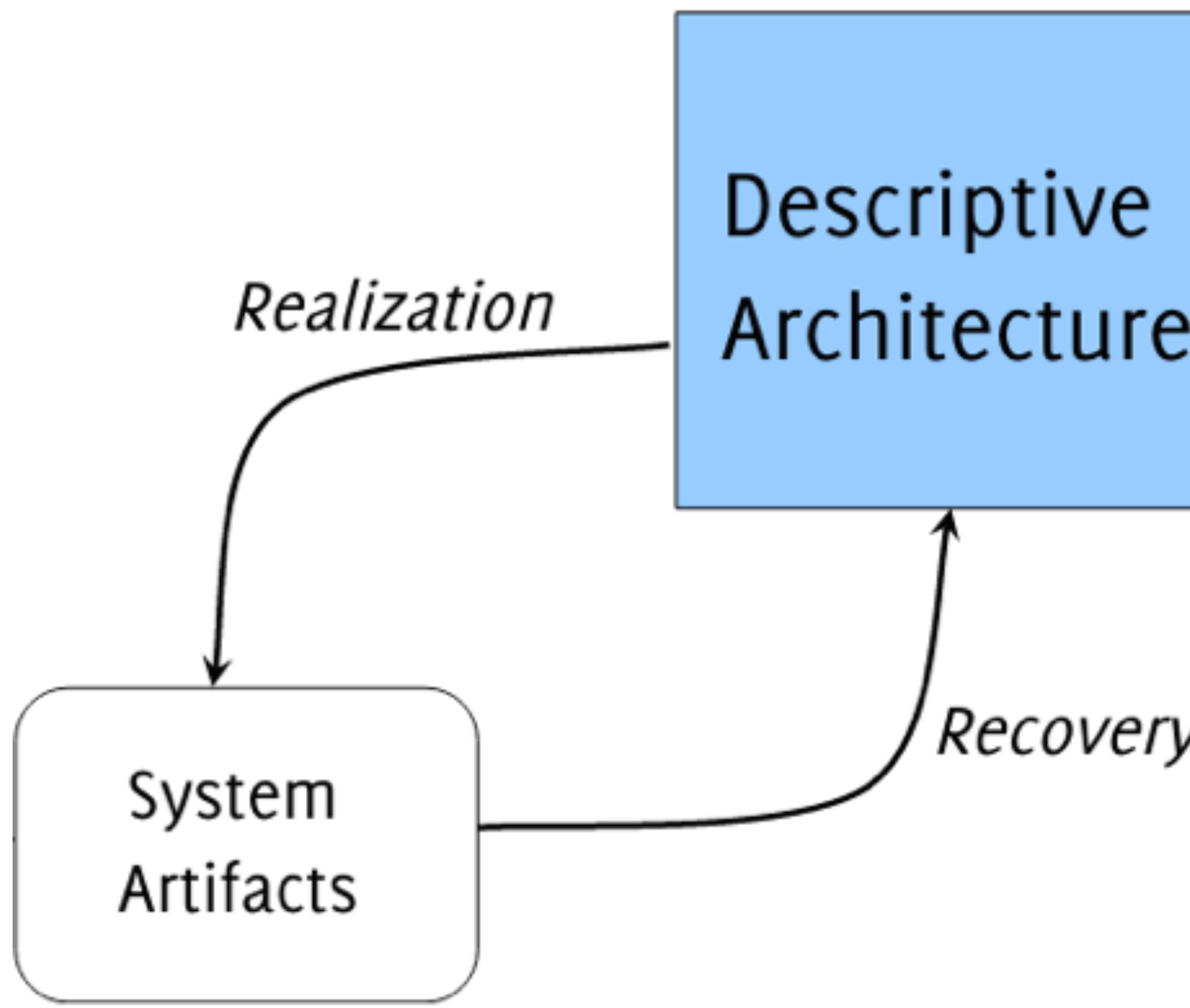
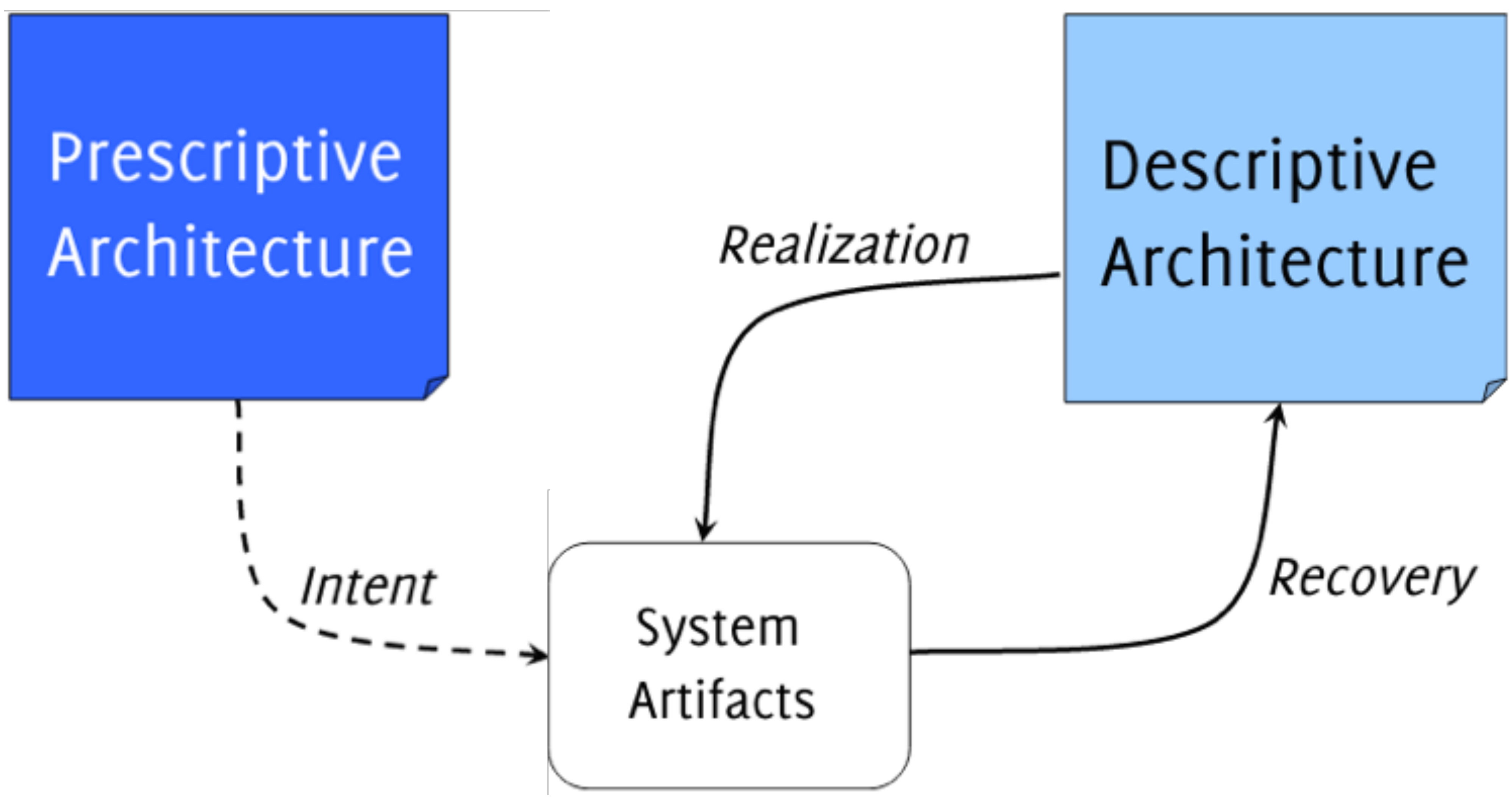


Every System an Architecture has

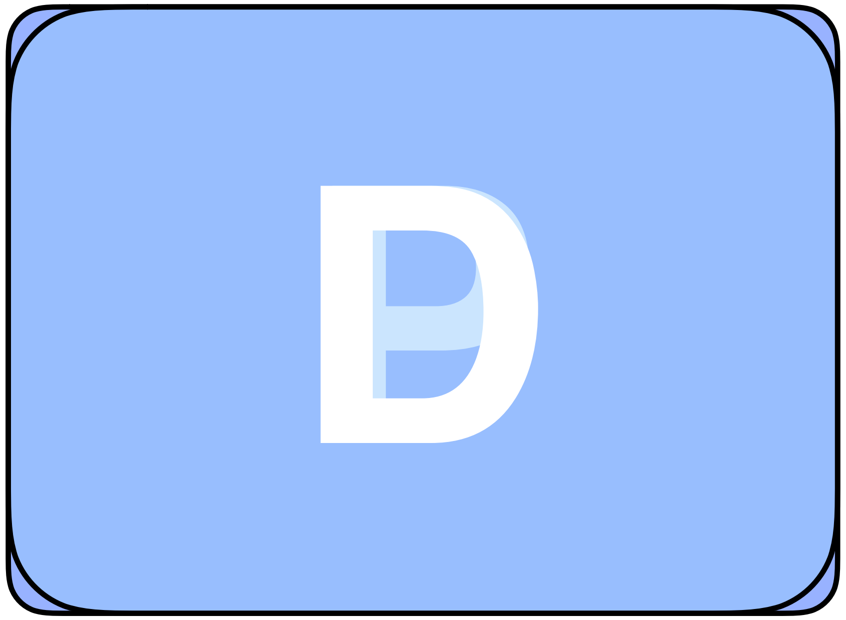


Architectural Evolution

Decisions are added and changed by multiple actors…
sometimes without knowing it

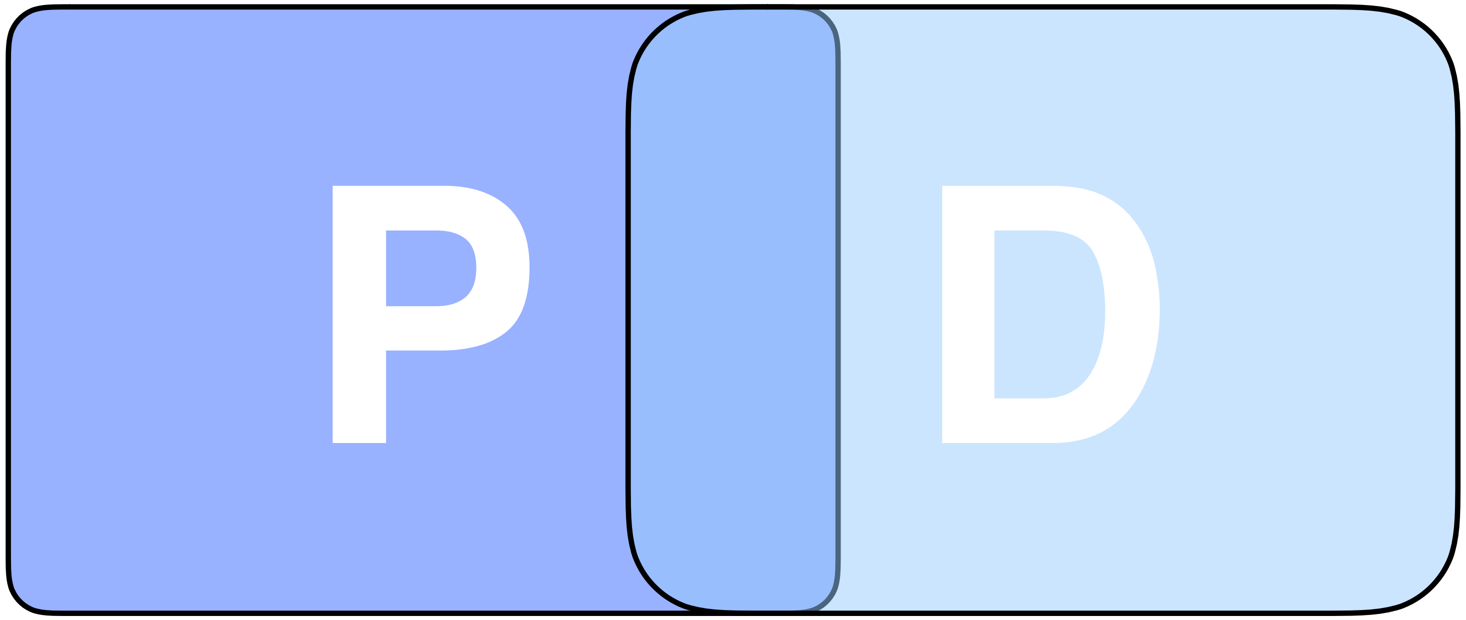
Architectural Degradation

Architectural Degradation



Ideal P=D

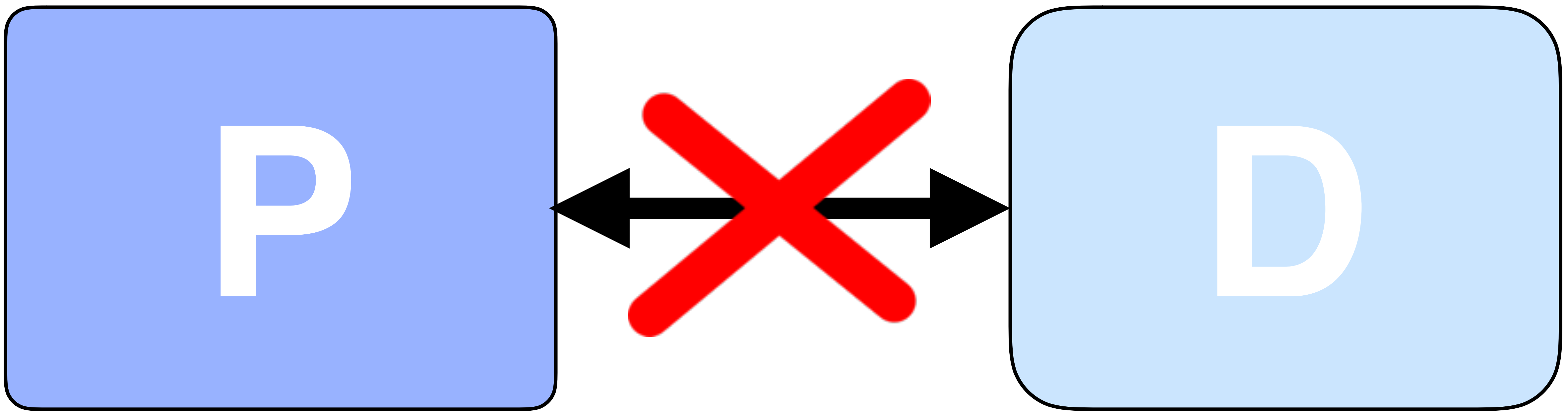
Architectural Degradation



Ideal P=D

Drift P !=D and D does not violate P

Architectural Degradation



Ideal P=D

Drift P !=D and D does not violate P

Erosion P !=D and D violates P

Summary

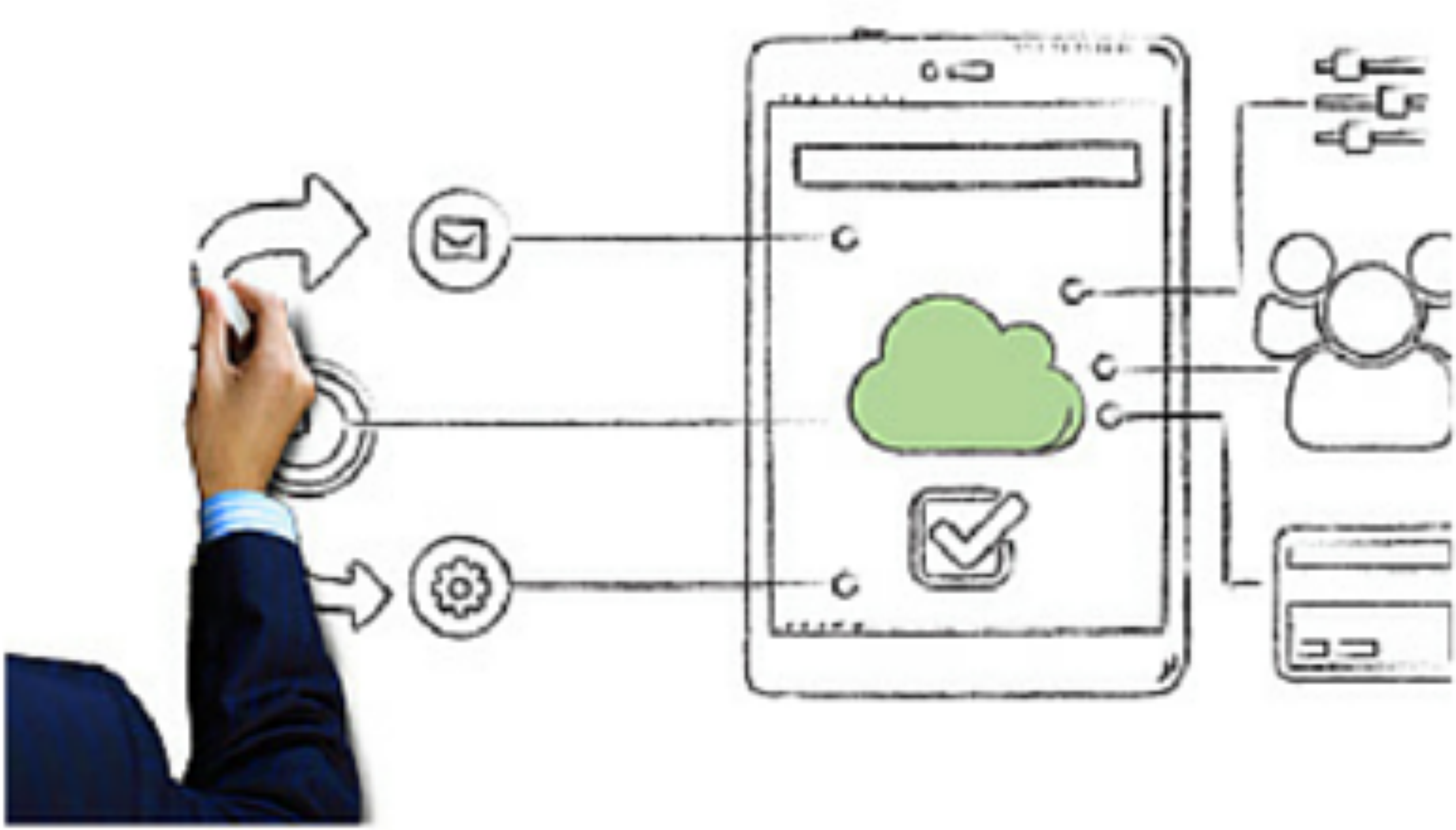
- Blueprint for construction and evolution
  abstraction • principal design decisions

- Not only about design
  communicate • visualize • represent • assess

- Every system has (an evolving) one
  descriptive • prescriptive • drift • erosion

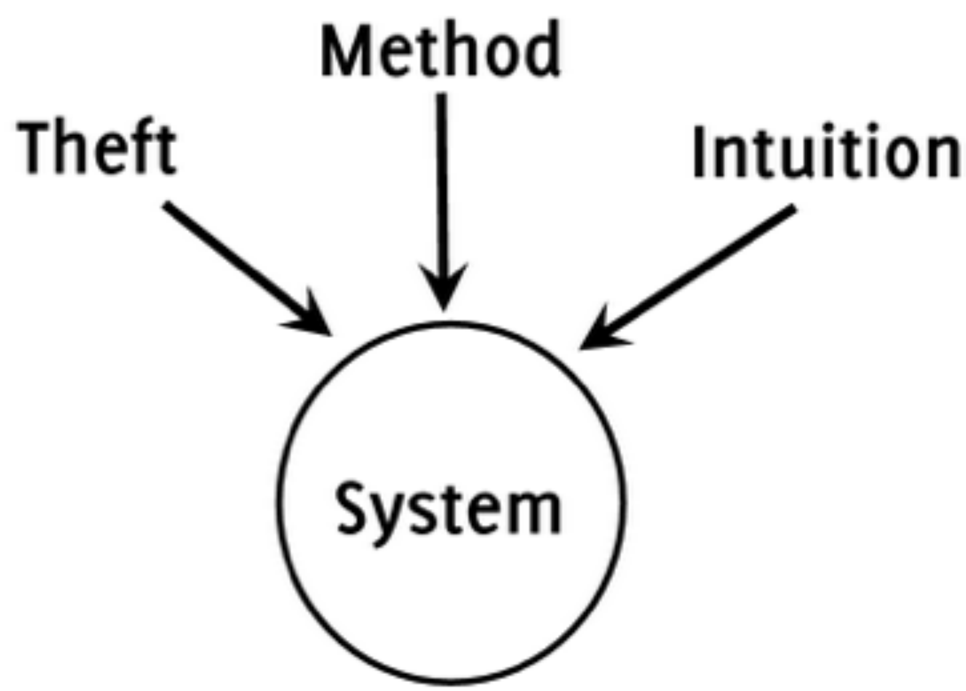
- Not a phase, not only “high-level” design

Design



How to Design

Even the best architects copy solutions that have proven themselves in practice, adapt them to the current context, improve upon their weaknesses, and then assemble them in novel ways



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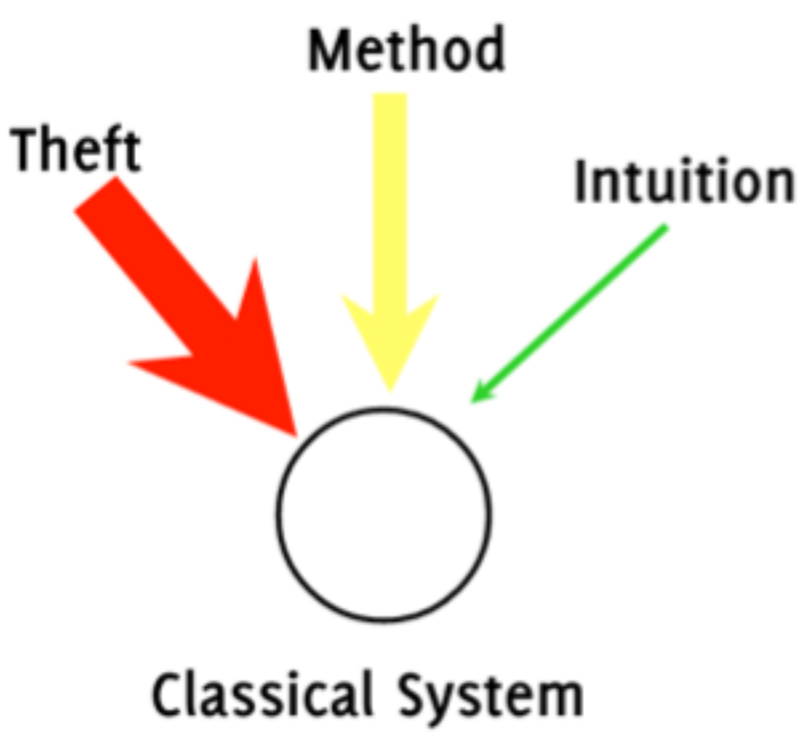

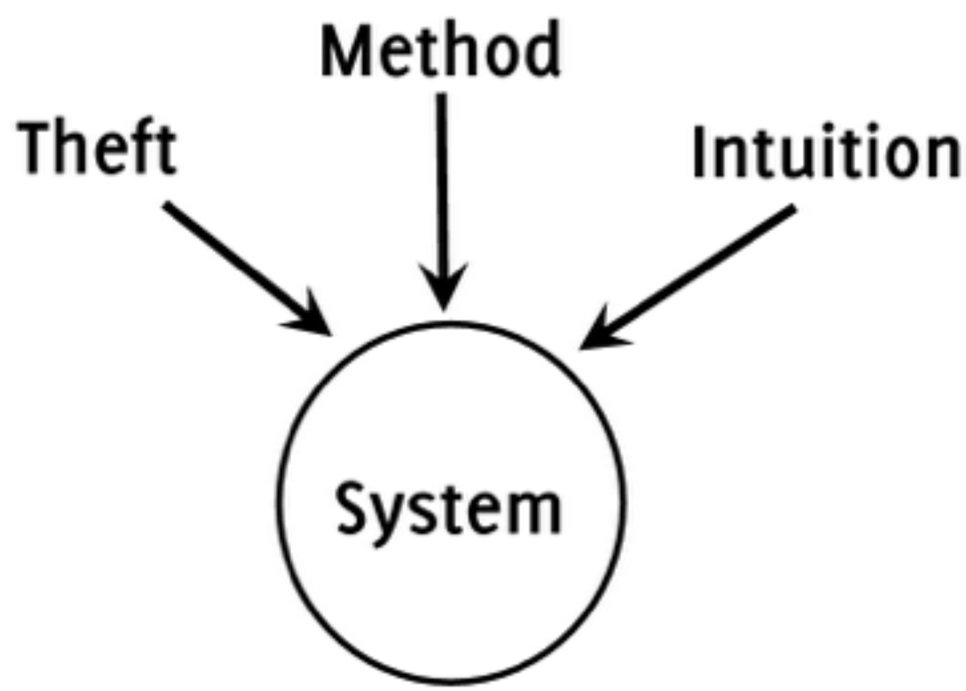

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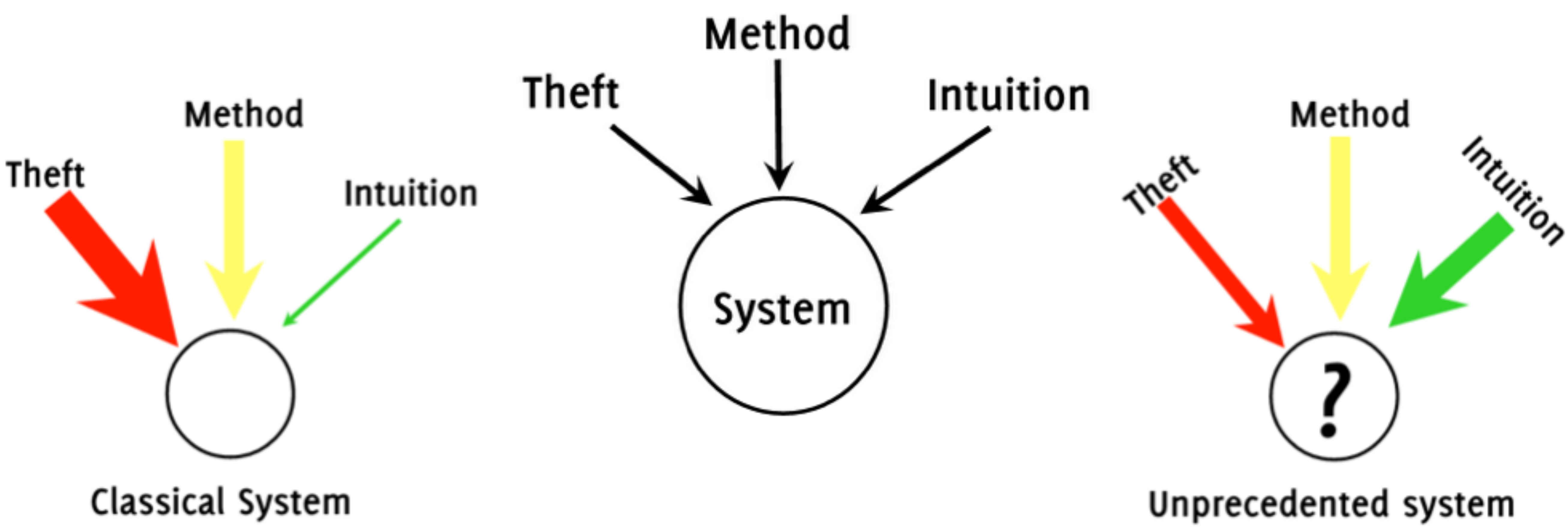

Architectural Hoisting

Design the architecture with the intent to guarantee a certain quality of the system.

George Fairbanks - http://georgefairbanks.com/blog/architectural-hoisting-original/

Architectural Hoisting

Design the architecture with the intent to guarantee a certain quality of the system.

Security	*place sensitive data behind the firewa*
Scalability	*make critical components stateless*
Persistence	*use a database*
Extensibility	*use a plug-in framework*

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What makes a “good” SW Architecture?

- No such things like perfect design and inherently good/bad architecture
- Fit to some purpose, and context-dependent

What makes a “good” SW Architecture?

- No such things like perfect design and inherently good/bad architecture
- Fit to some purpose, and context-dependent
- Principles, guidelines and the use of collective experience (*method)*

Design Principles

Architectural Patterns

Architectural Styles

Design Principles

- Abstraction
- Encapsulation - Separation of Concerns
- Modularization
- KISS (*Keep it simple, stupid*)
- DRY (*Don't repeat yourself)*

Architectural Patterns

Set of architectural design decisions that are applicable to a recurring design problem, and are parameterized to account for the development contexts in which that problem appears.

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Layered	Component
Notification	Composition

Layered Patterns

- State-Logic-Display

  separate elements with different rate of change

- Model-View-Controller

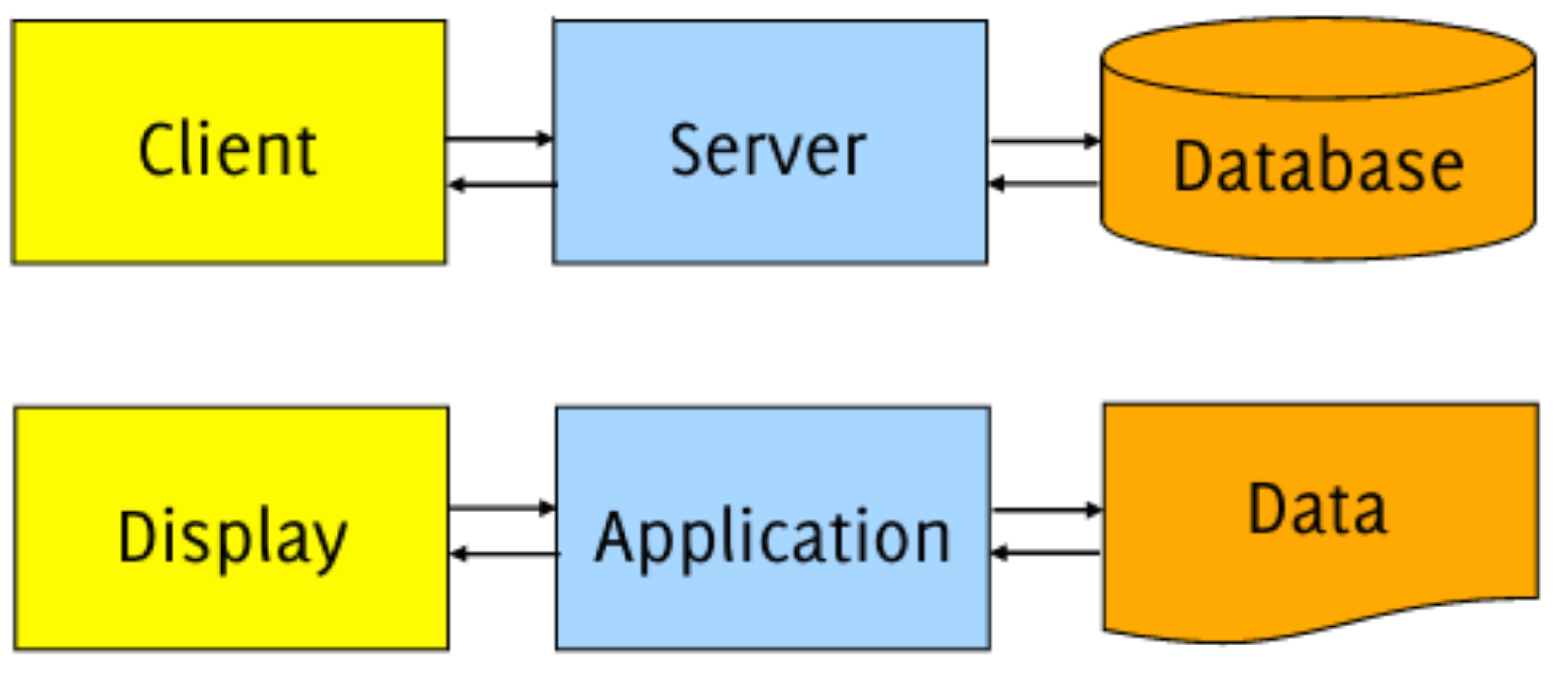
  support many interaction and display modes for the same content

- Presenter-View

  keep a consistent look and feel across a complex UI

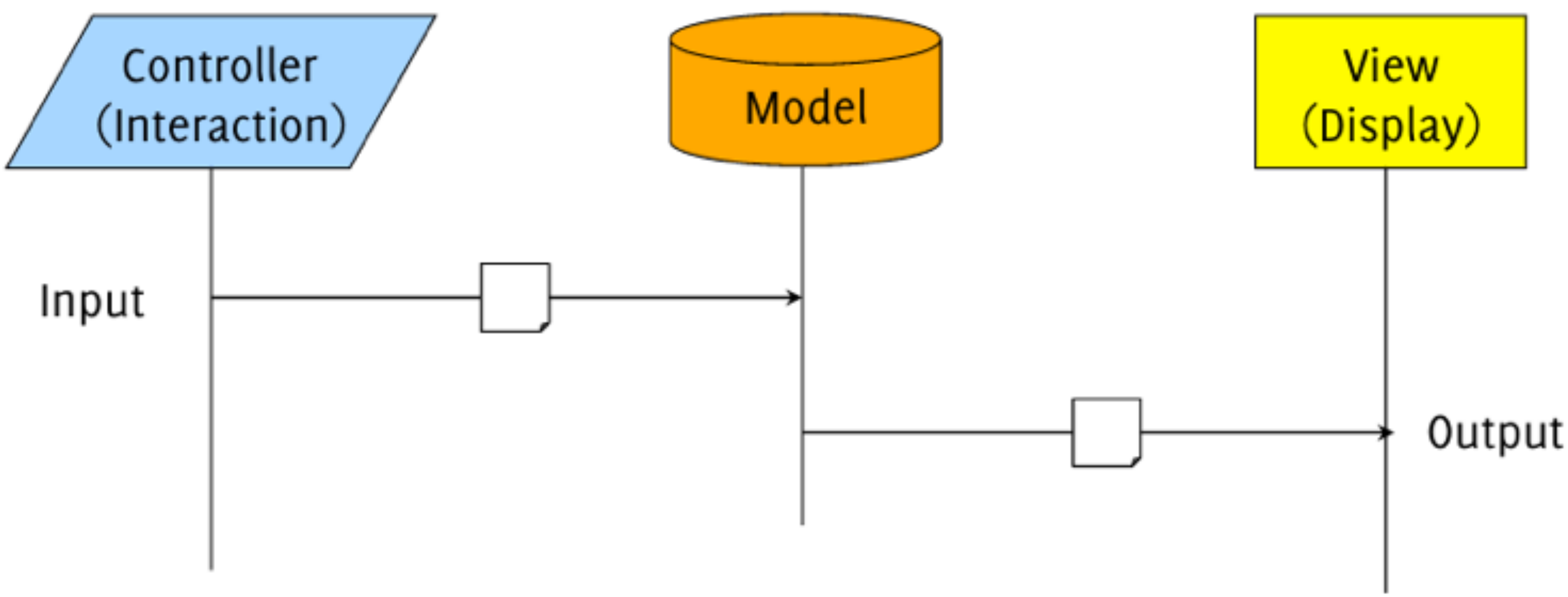
State-Logic-Display

cluster elements that change at the same rate



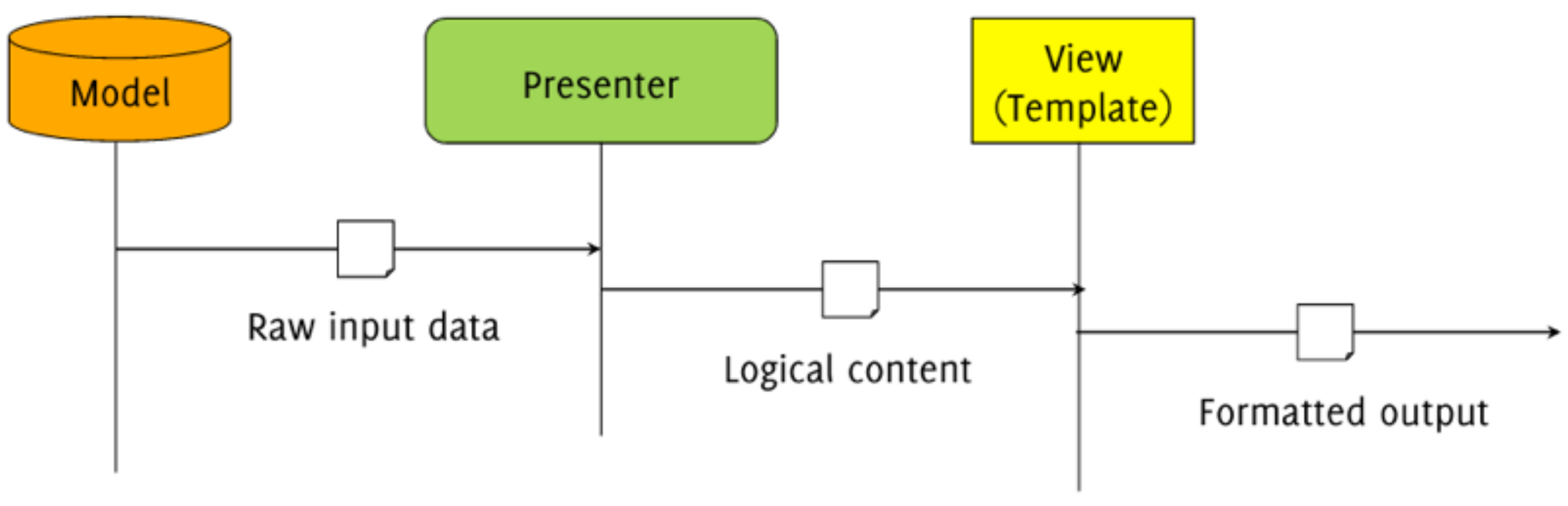
Model-View-Controller

separate content (model) from presentation (output) and interaction (input)



Presenter-View

extract the content from the model to be presented from the rendering into screens/web pages



Component Patterns

- Interoperability

  enable communication between different platforms

- Directory

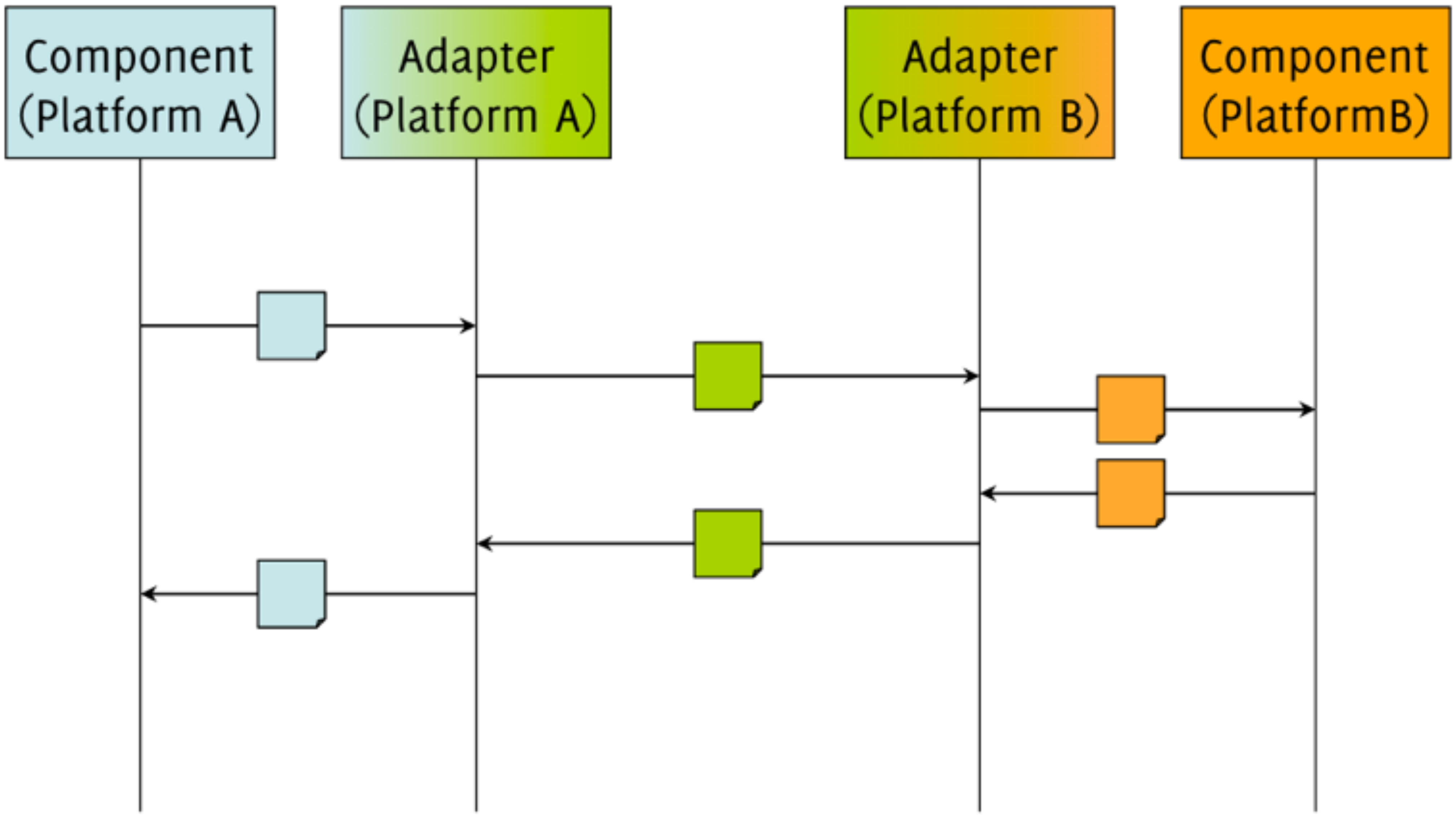
  facilitate location transparency (direct control)

- Dependency Injection

  facilitate location transparency (inversion of control)

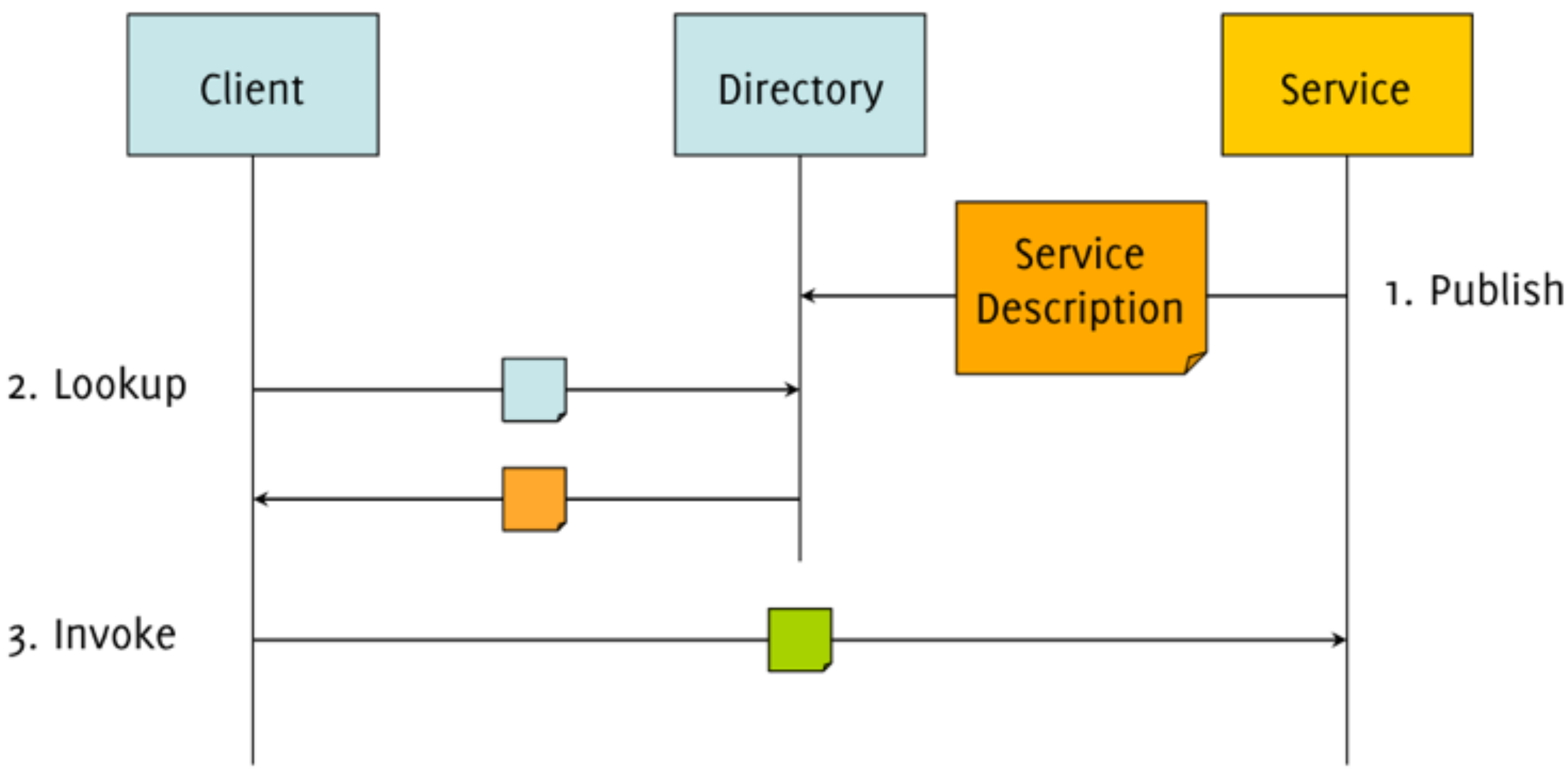
Interoperability

map to a standardized intermediate representation and communication style



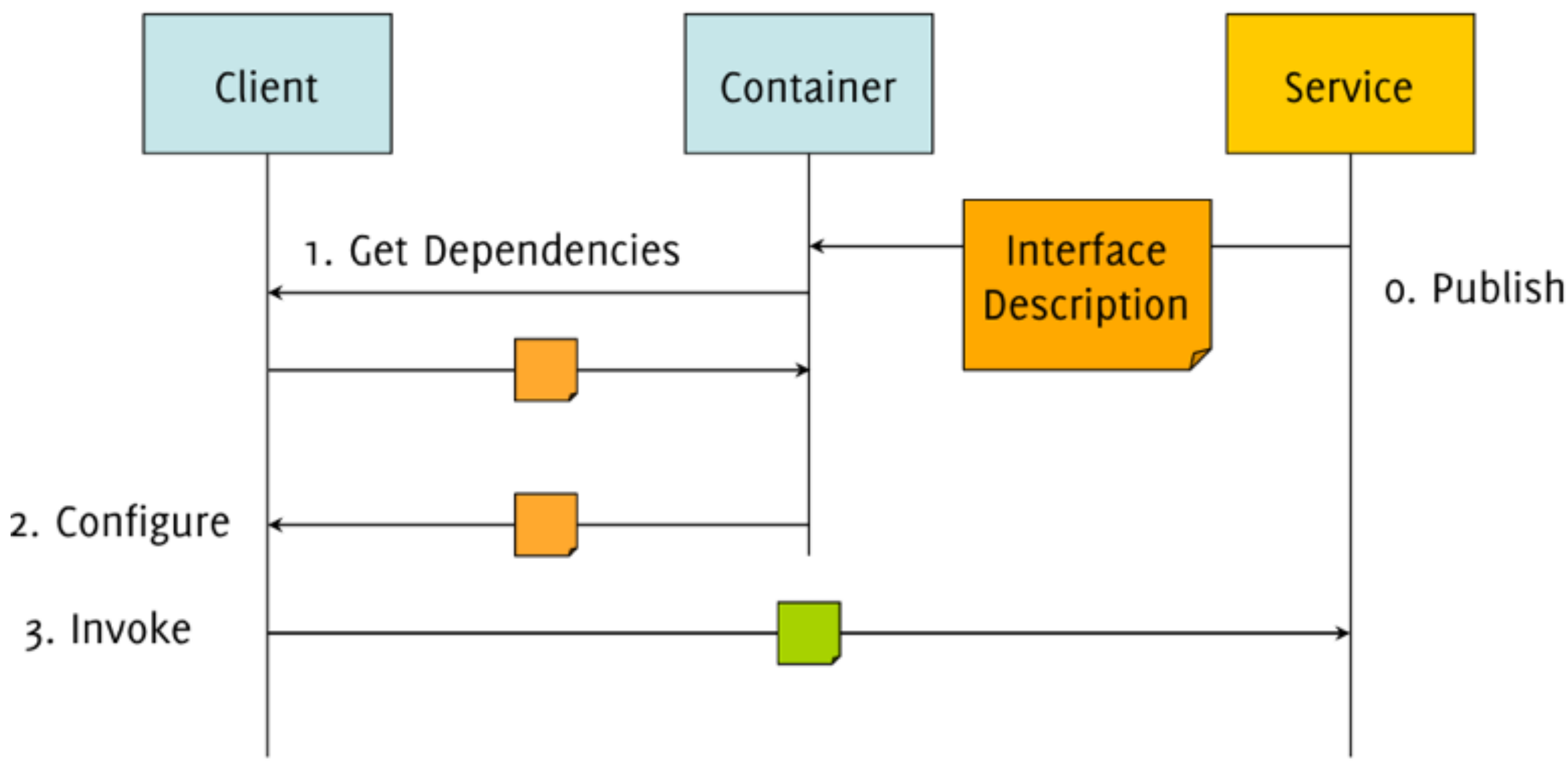
Directory

use a directory service to find service endpoints based on abstract descriptions



Dependency Injection

use a container which updates components with bindings to their dependencies



Notification Patterns

- Event Monitor

  inform clients about events happening at the service

- Observer

  promptly inform clients about state changes of a service

- Publish/Subscribe

  decouple clients from services generating events

- Messaging Bridge

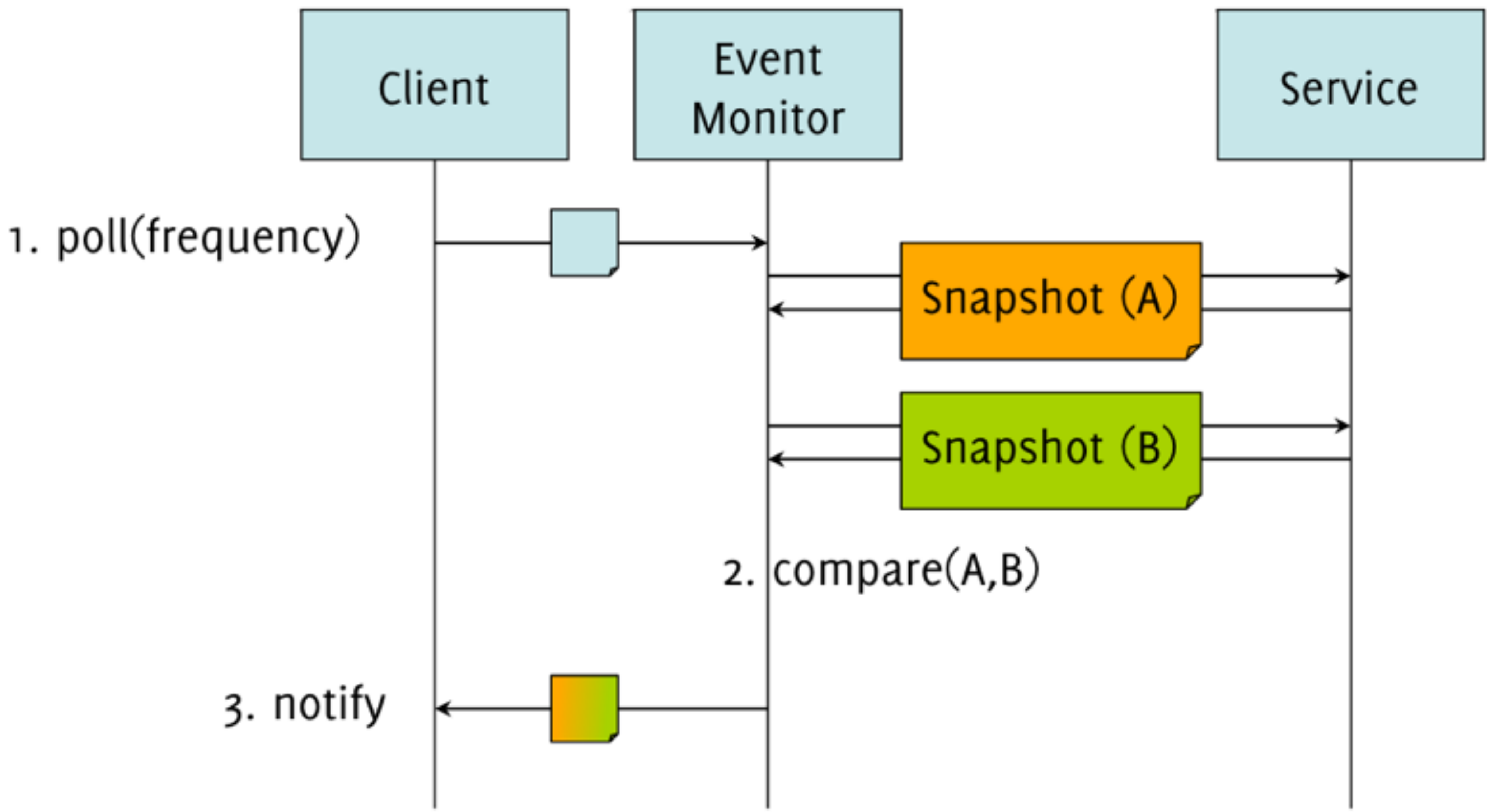
  connect multiple messaging systems

- Half Synch/Half Async

  interconnect synchronous and asynchronous components

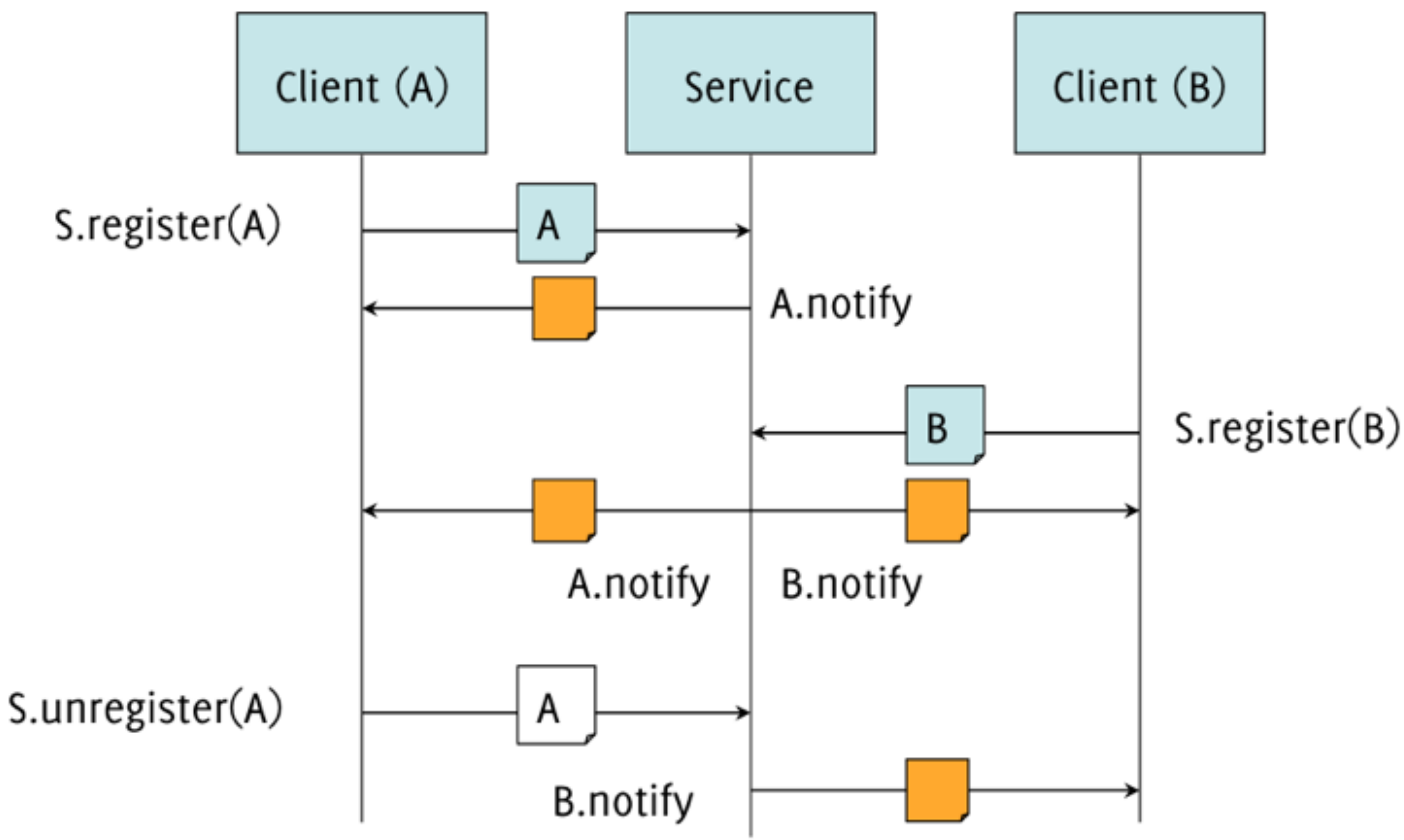
Event Monitor

poll and compare state snapshots



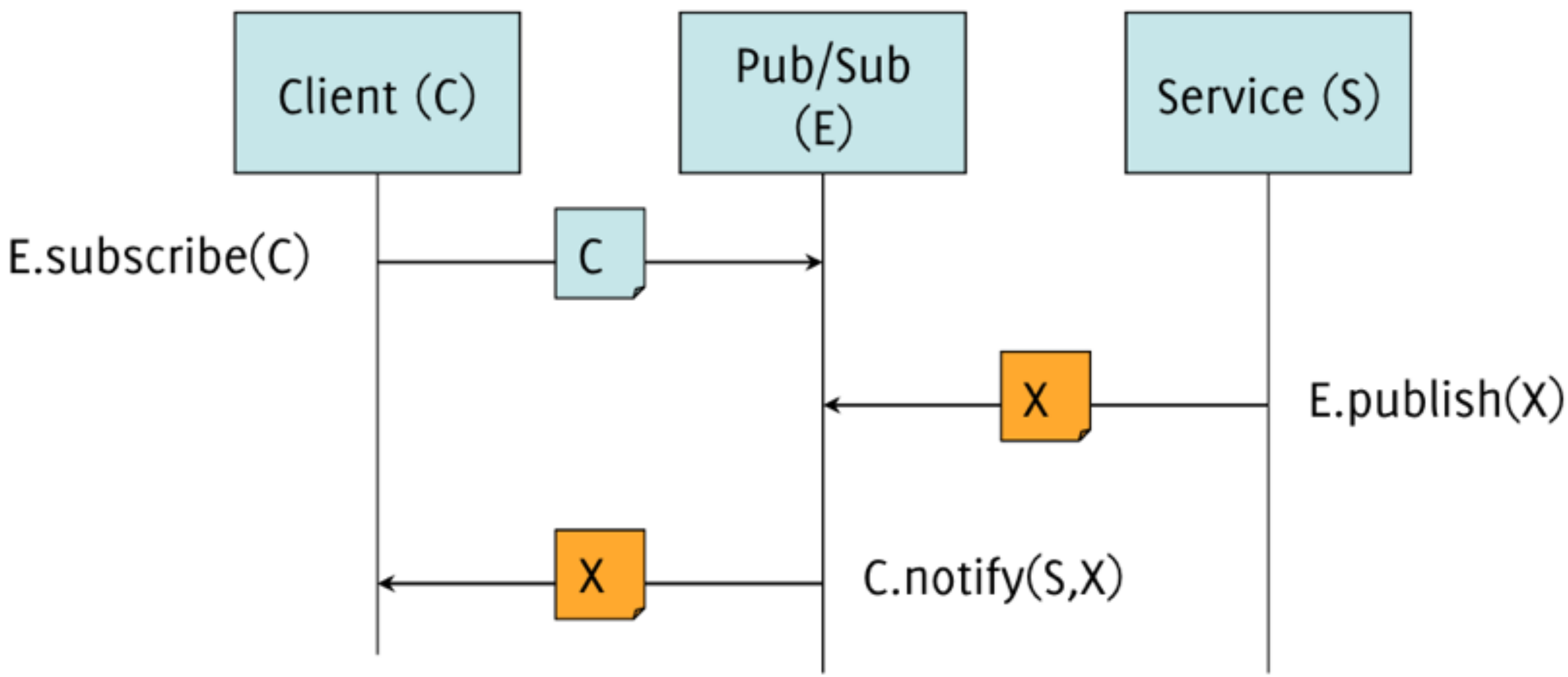
Observer

detect changes and generate events at the service



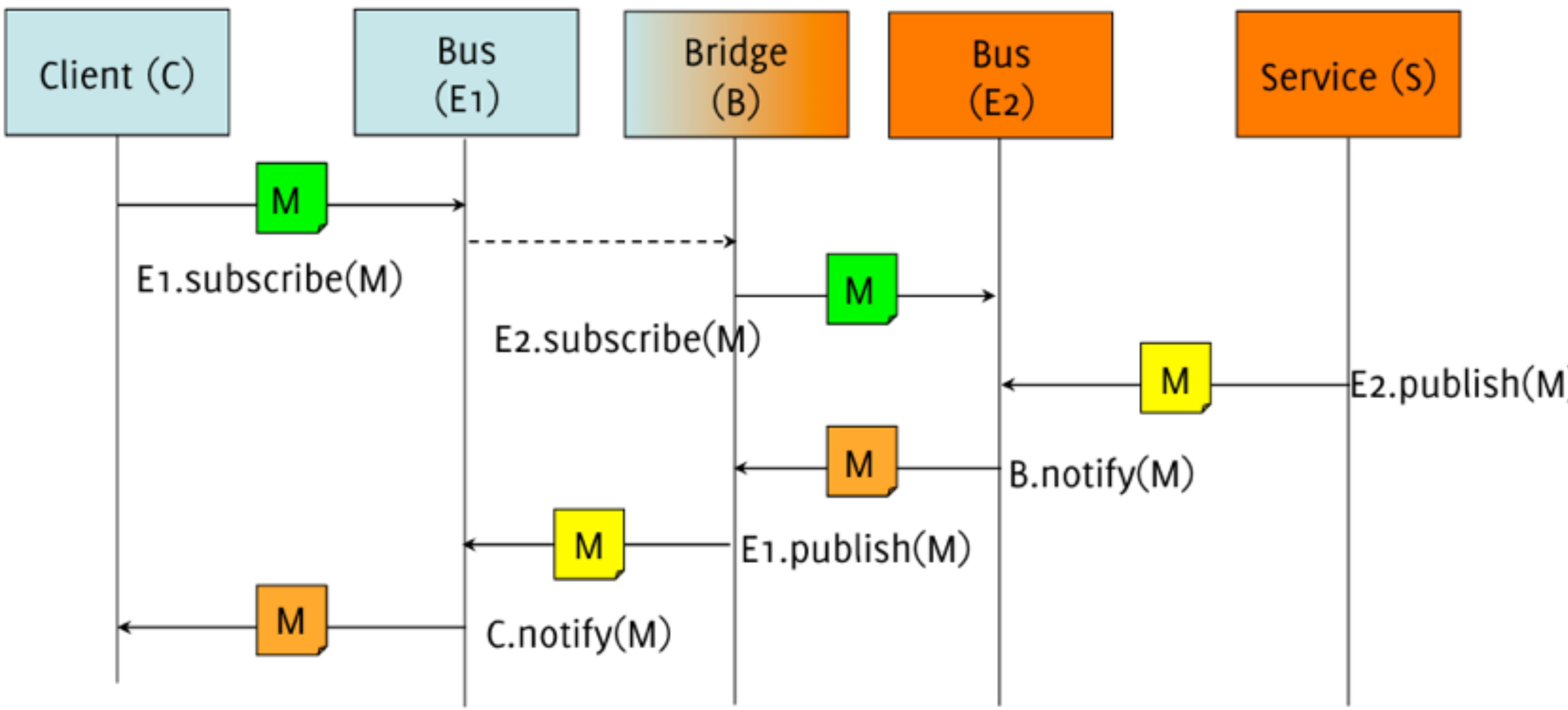
Publish/Subscribe

factor out event propagation and subscription management into a separate service



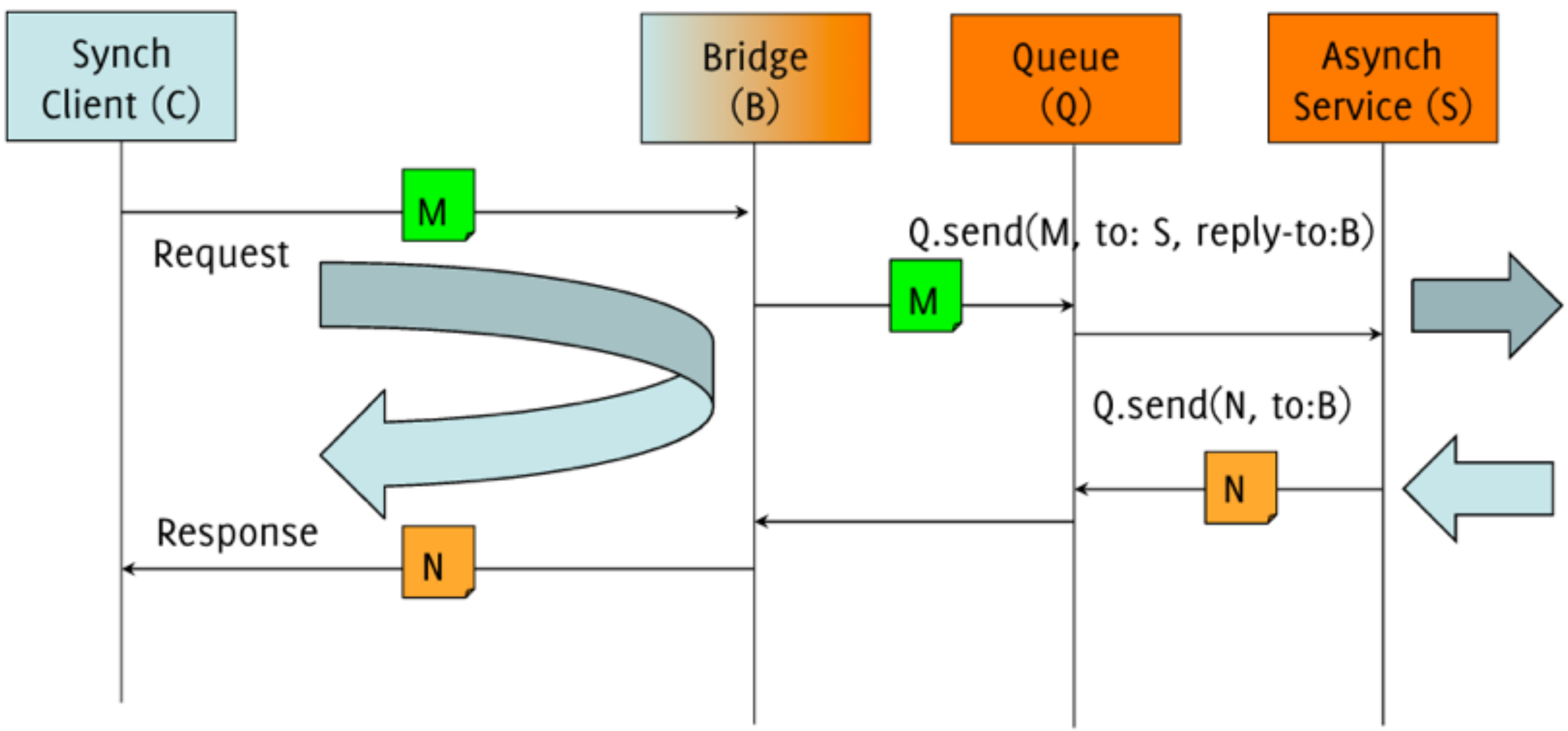
Messaging Bridge

link multiple messaging systems to make messages exchanged on one also available on the others



Half-Sync/Half-Async

Add a layer hiding asynchronous interactions behind a synchronous interface



Composition Patterns

- Scatter/Gather

  send the same message to multiple recipients which will/may reply

- Canary Call

  avoid crashing all recipients of a poisoned request

- Master/Slave

  speed up the execution of long running computations

- Load Balancing

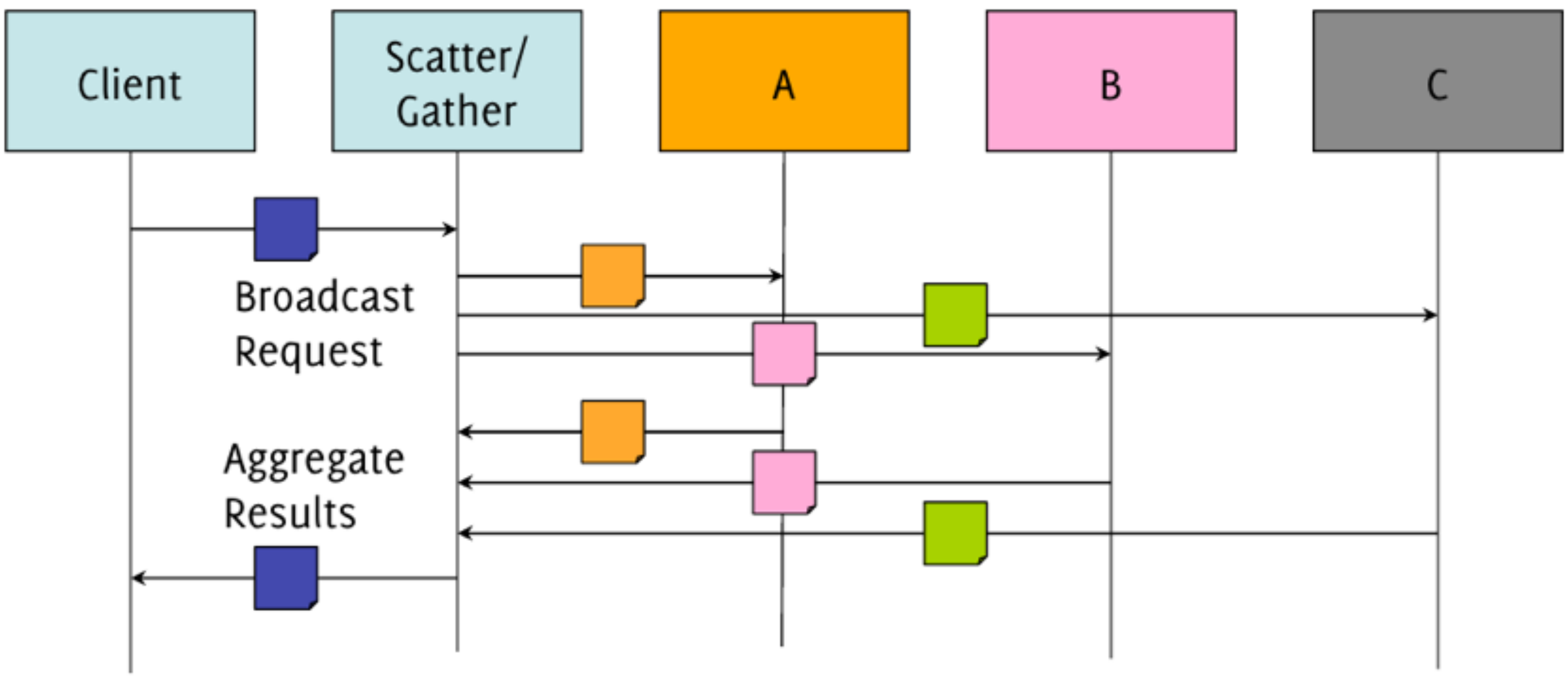
  speed up and scale up the execution of requests of many clients

- Orchestration

  improve the reuse of existing applications

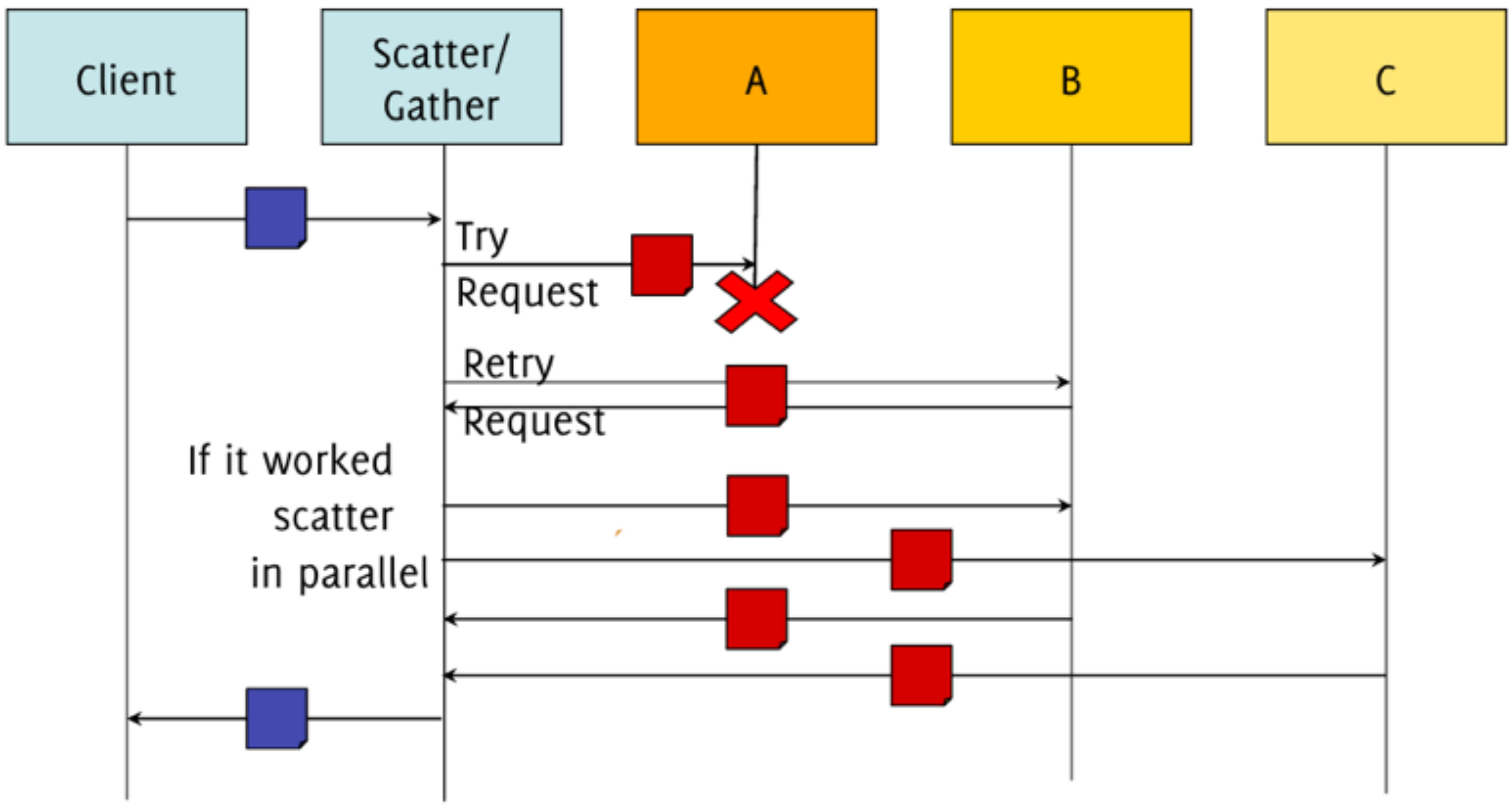
Scatter/Gather

combine the notification of the request with aggregation of replies



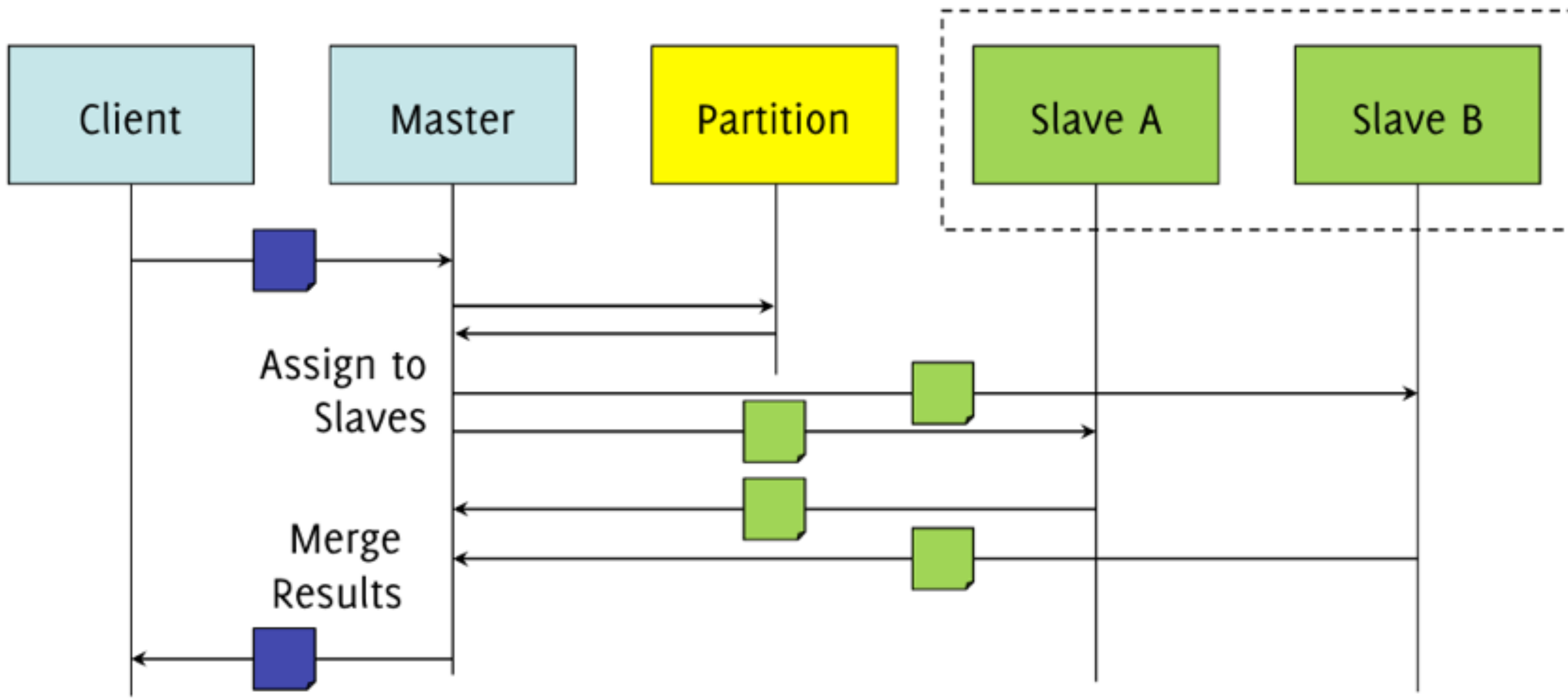
Canary Call

use an heuristic to evaluate the request



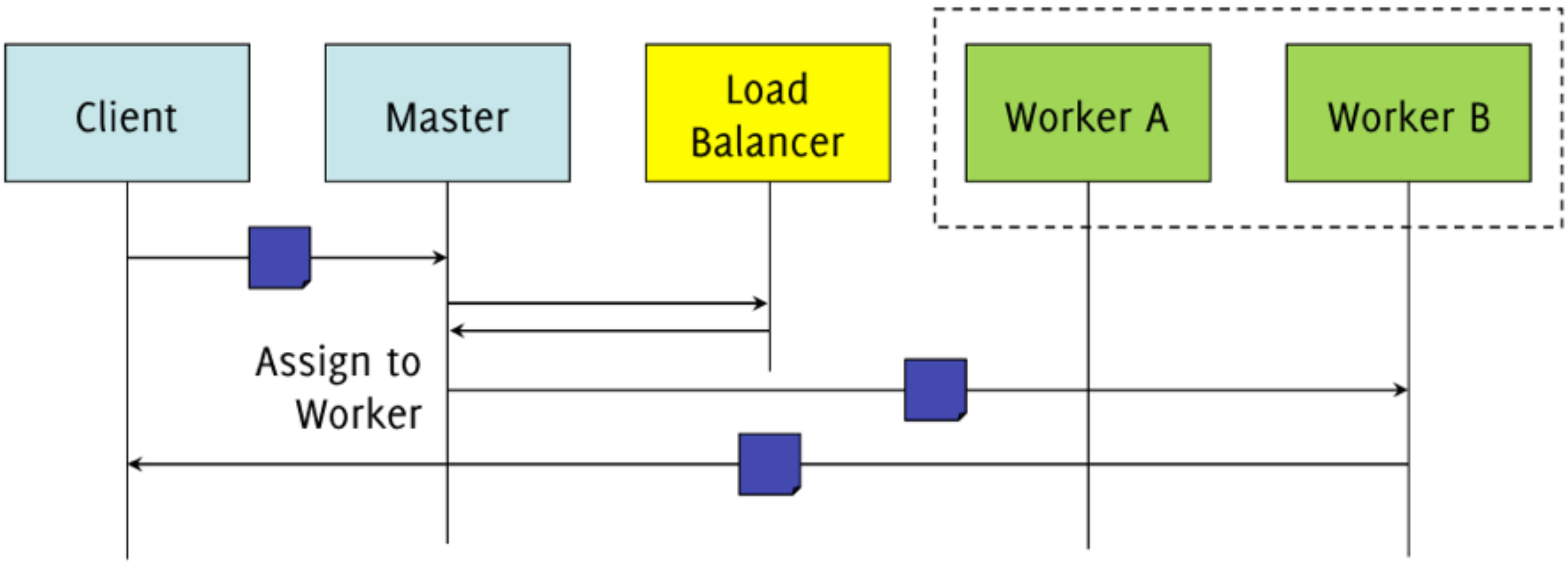
Master/Slave

split a large job into smaller independent partitions which can be processed in parallel



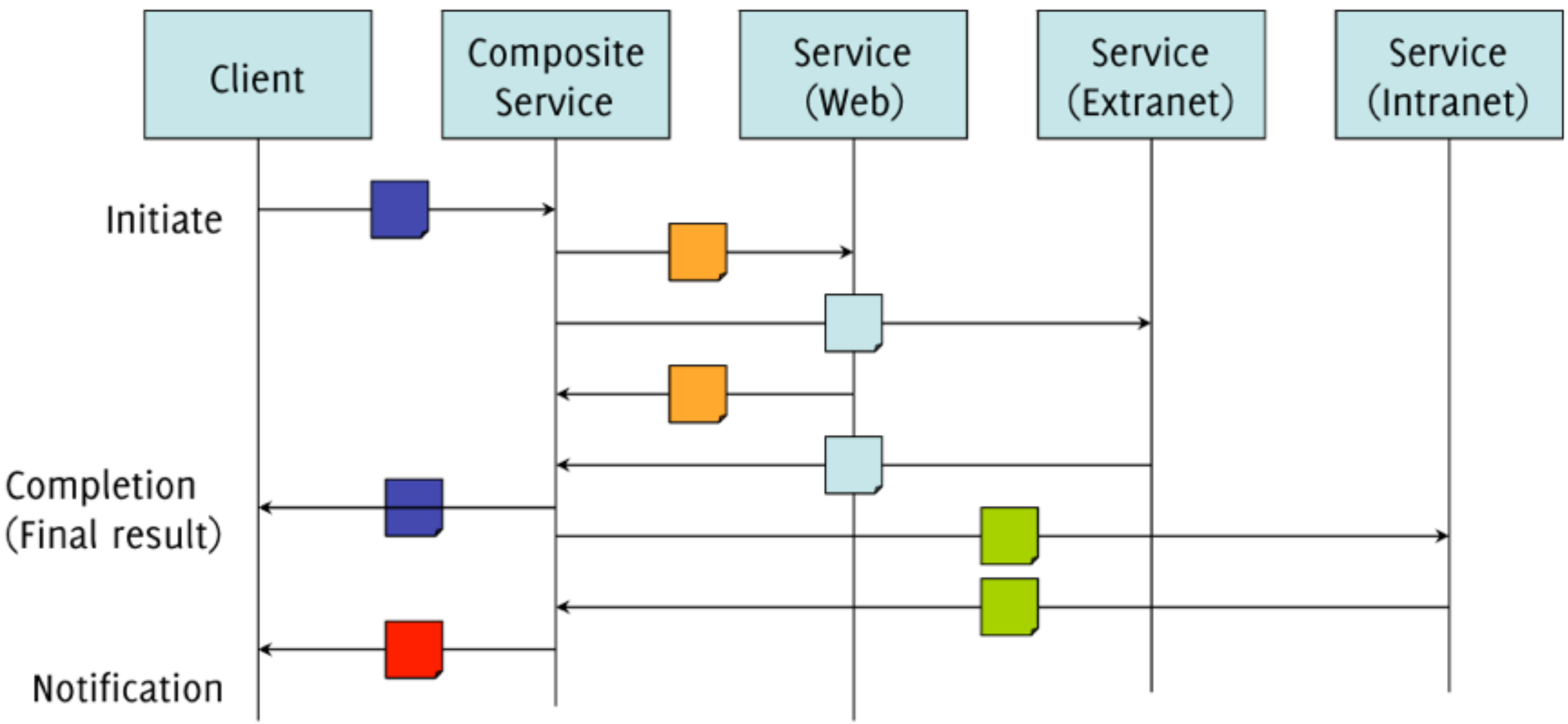
Load Balancing

deploy many replicated instances of the server on multiple machines



Composition/Orchestration

build systems out of the composition of existing ones



Patterns, Patterns, Patterns

Architectural Patterns ***not*** *Design Patterns*

Architectural

Design

Patterns, Patterns, Patterns

*Architectural Patterns **not** Design Patterns*

Express fundamental structural organizations

Specify relationships among (sub-)systems

Architectural

VS

Capture roles in solutions that occur repeatedly

Define the relationships among roles

Design

Architectural Styles

Named collections of architectural decisions and constrains for a specific development context that elicit beneficial qualities in each resulting system

Why Styles?

A common vocabulary for the design elements

improve communication by shared understanding

A predefined configuration and composition rules

known benefits and limitations

ensure quality attributes if constraints are followed

Style-specific analyses and visualizations

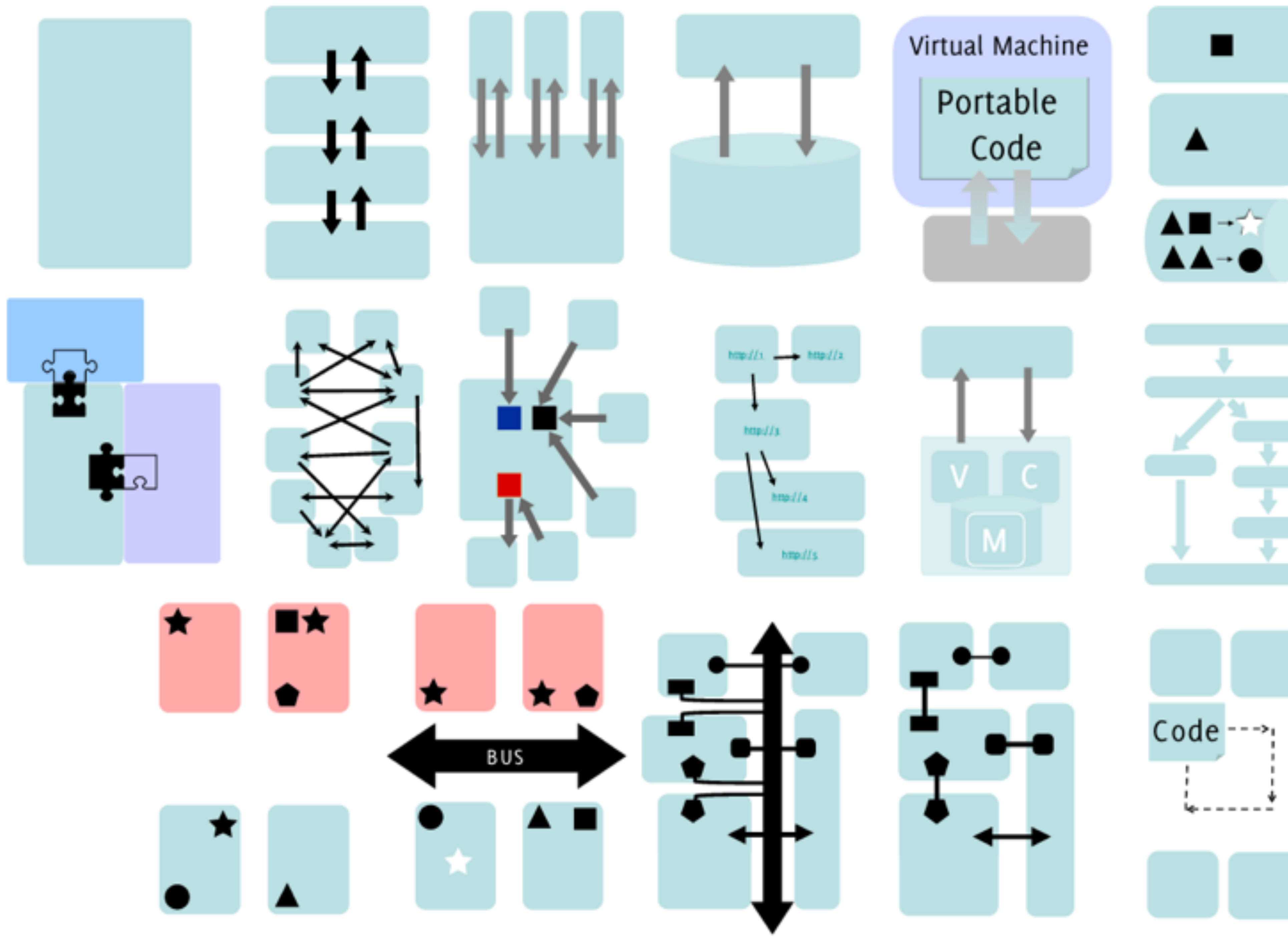
Styles and Patterns

Styles	Patterns
General constraints	Fine-grained constraints
Architecture with superior properties	Specific to recurrent problems
Styles must be refined and adapted	The same pattern can be used many times
One style is dominant	Many patterns are combined

VS

Many (and Many More)

Layered
Client/Server
Data-Centric
Virtual Machine
Rule Based
Plugin
Peer to Peer
REST
Rails
Pipe and Filter
Event-Driven
Publish/Subscribe
Service Oriented
Component Based
Mobile Code
Blackboard



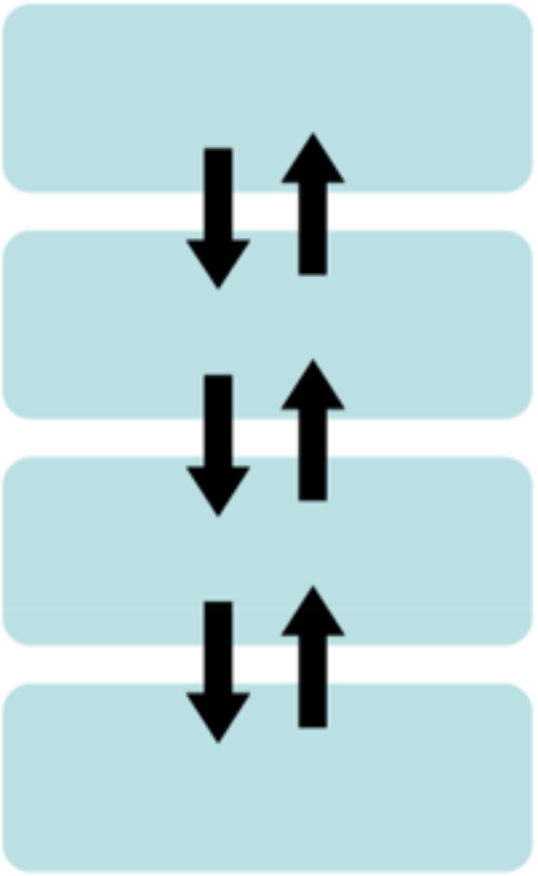
Monolithic

- Lack of structure
- No Constraints
- Poor Maintainability
- Possibly Good Performance

Mainframe COBOL programs · powerpoint · many games

Layered

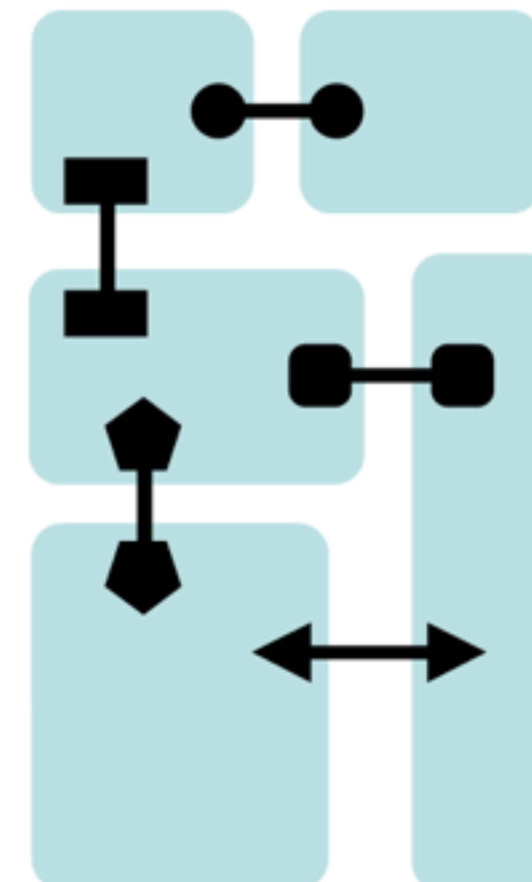
- Communications 1 layer up/down
- Information hiding, no circular deps
- Possibly bad performance
- Good evolvability



Network protocol stacks · Web applications · Virtual Machines

Component Based

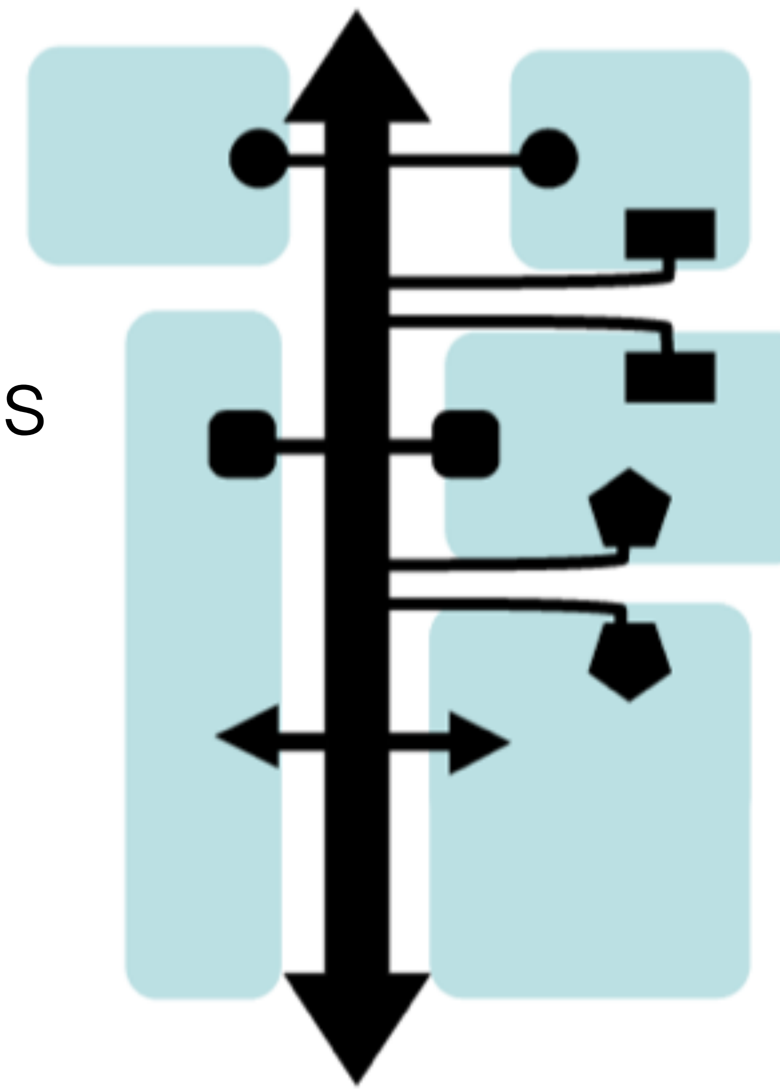
- Encapsulation
- Information hiding
- Components compatibility problem
- Good reuse, independent development



CORBA · Enterprise JavaBean · OSGi

Service Oriented

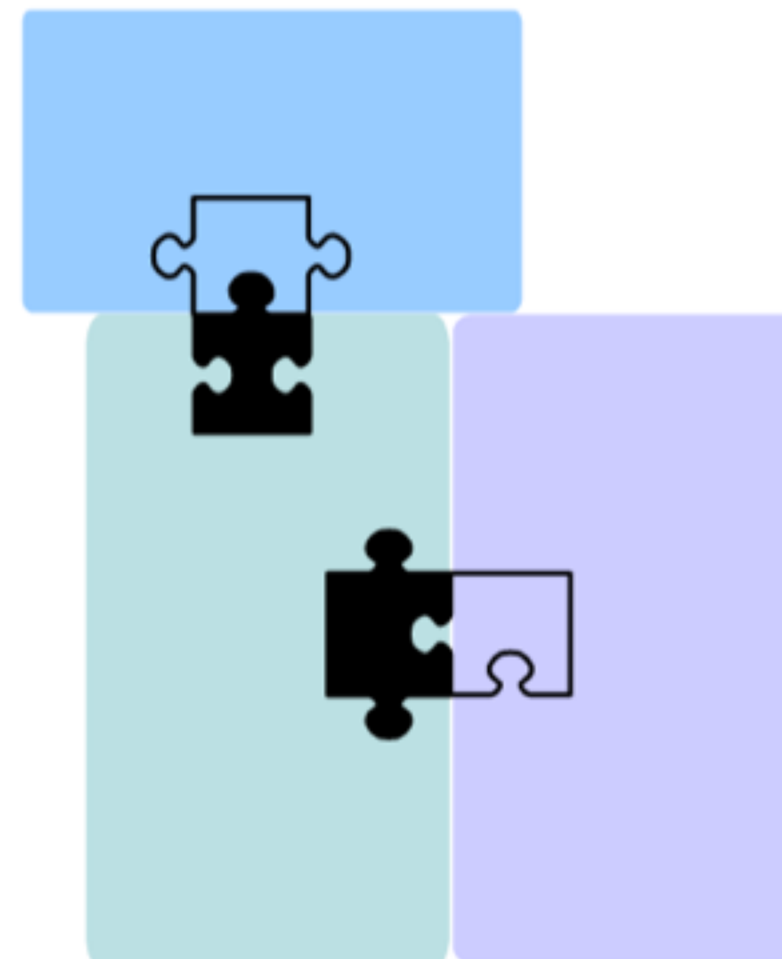
- Components might be outside control
- Standard connectors, precise interfaces
- Interface compatibility problem
- Loose coupling, reuse



Web Services (WS-) · Cloud Computing*

Plugin

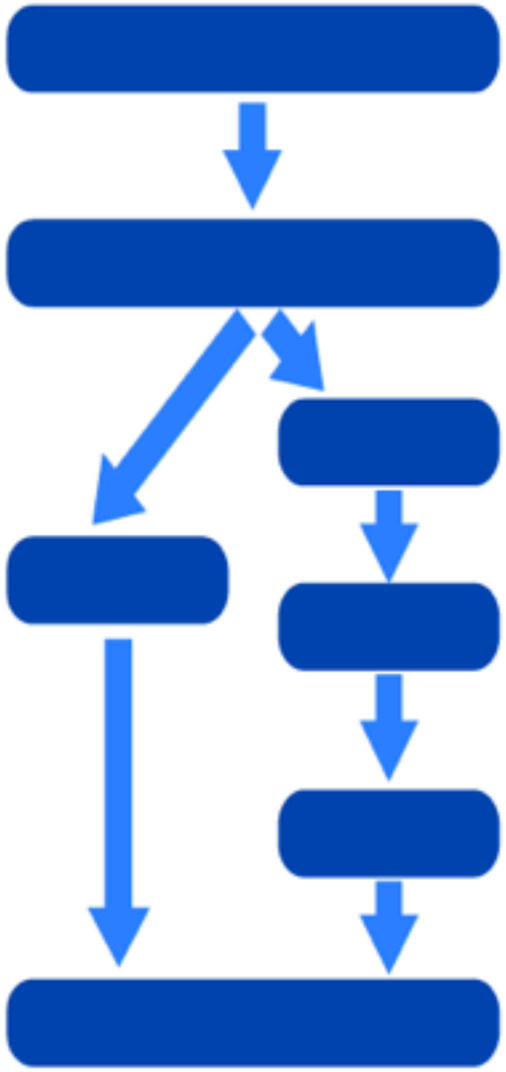
- Explicit extension points
- Static/Dynamic composition
- Low security (3rd party code)
- Extensibility and customizability



Eclipse · Photoshop · Browsers' extensions

Pipe & Filter

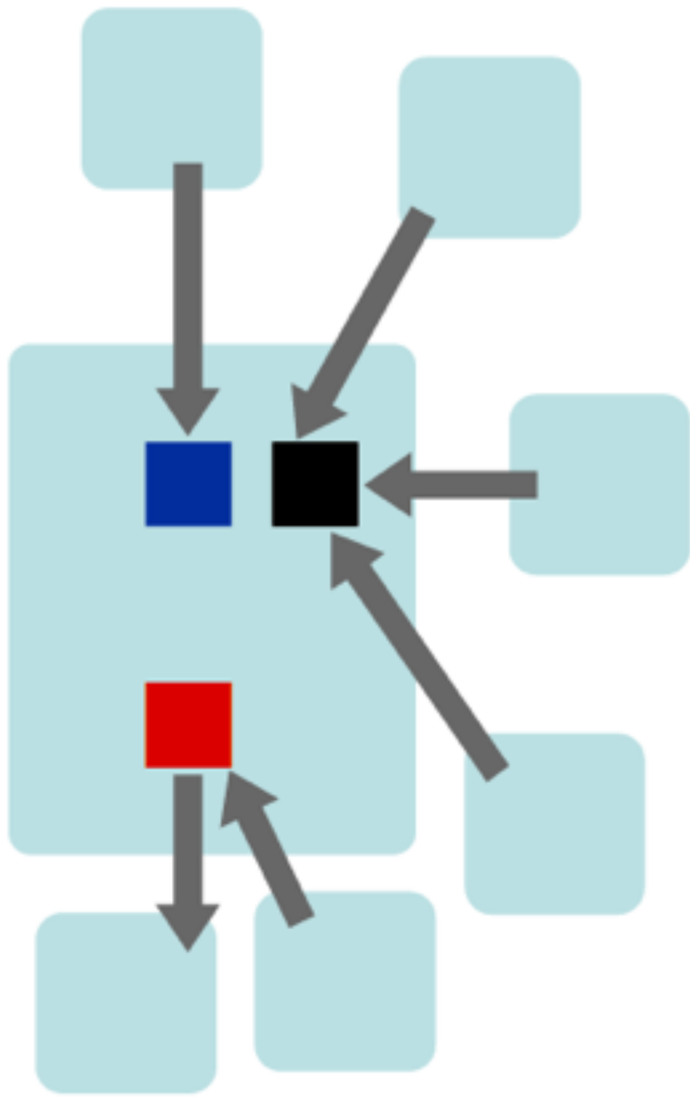
- Clean separation: filter process, pipe transport
- Heterogeneity and distribution
- Only batch processing, serializable data
- Composability, Reuse



UNIX shell · Compiler · Graphics Rendering

Black Board

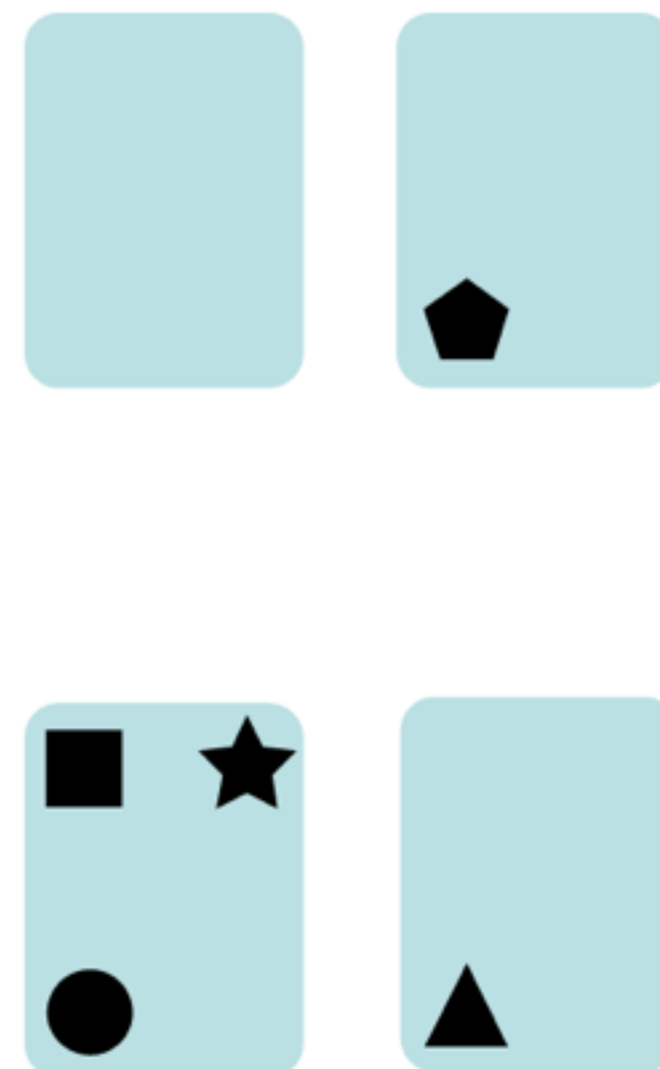
- Collective problem solving via shared data
- Asynchronous components interactions
- Requires common data format
- Loose coupling, implicit data flow



Database · Tuple space · Expert systems (AI)

Event Driven

- Produce/React to events
- Asynchronous signals/messages
- Difficult guarantee performance
- Loose coupling, scalable



Sensor Monitoring · Complex Event Processing

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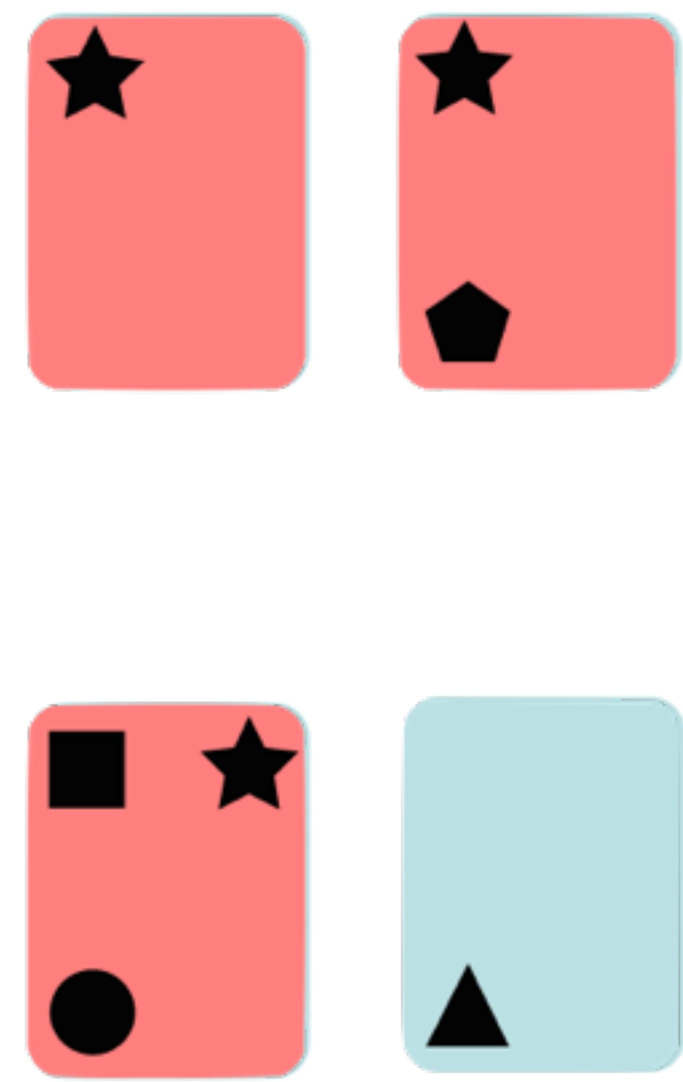

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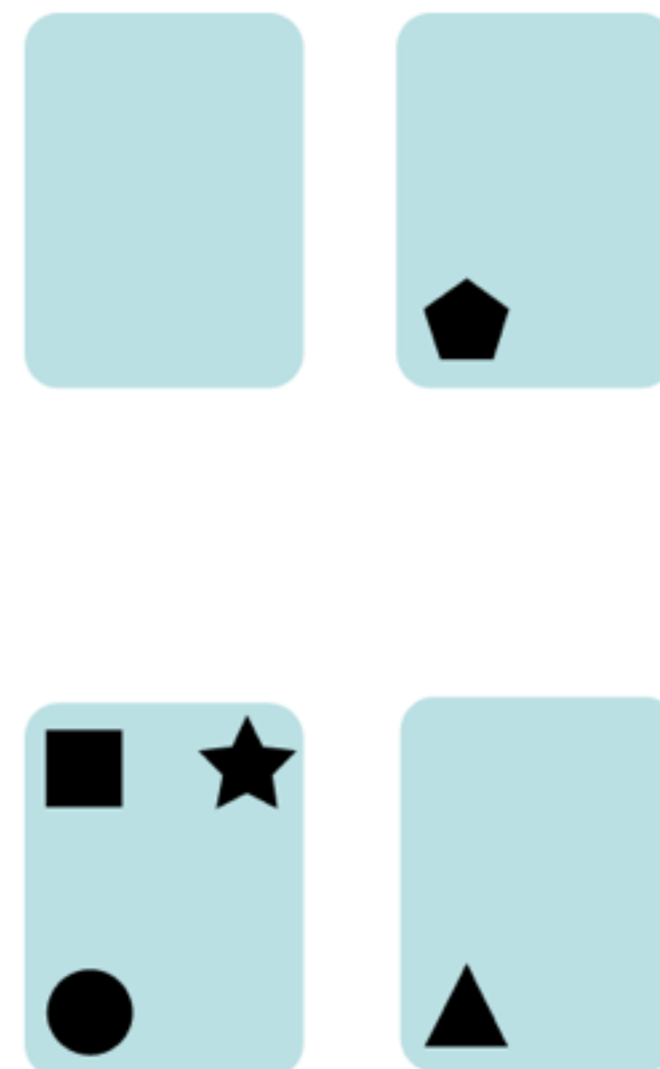
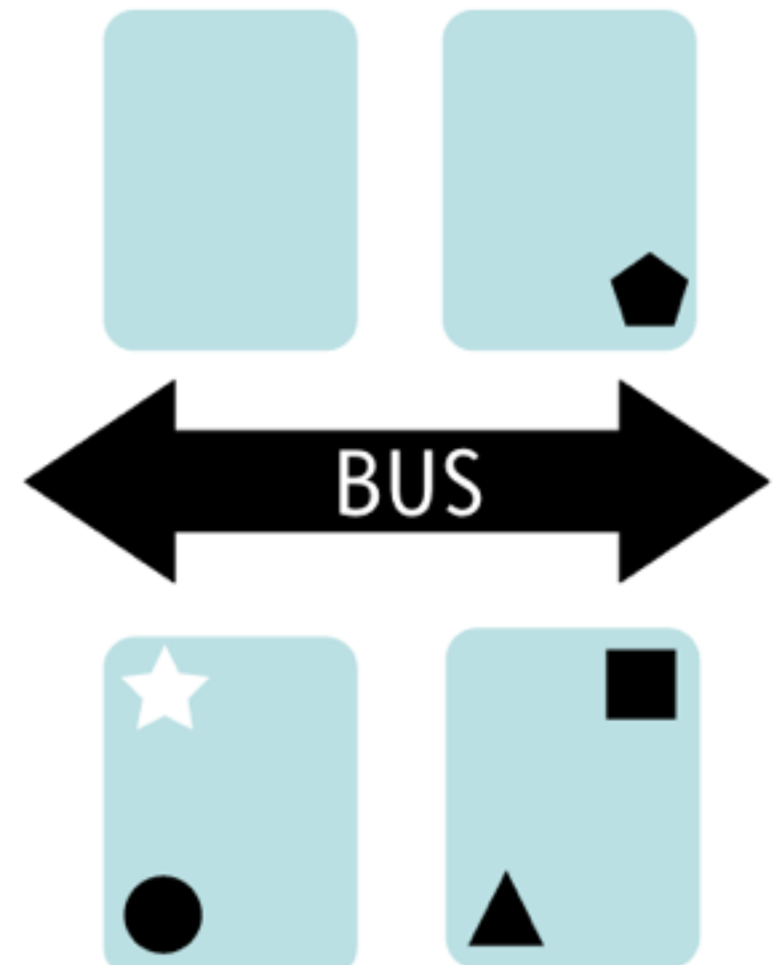


Sensor Monitoring · Complex Event Processing

Publish/Subscribe

- Event driven + opposite roles
- Subscription to queues or topics
- Limited scalability
- Loose coupling



Twitter · RSS Feeds · Email

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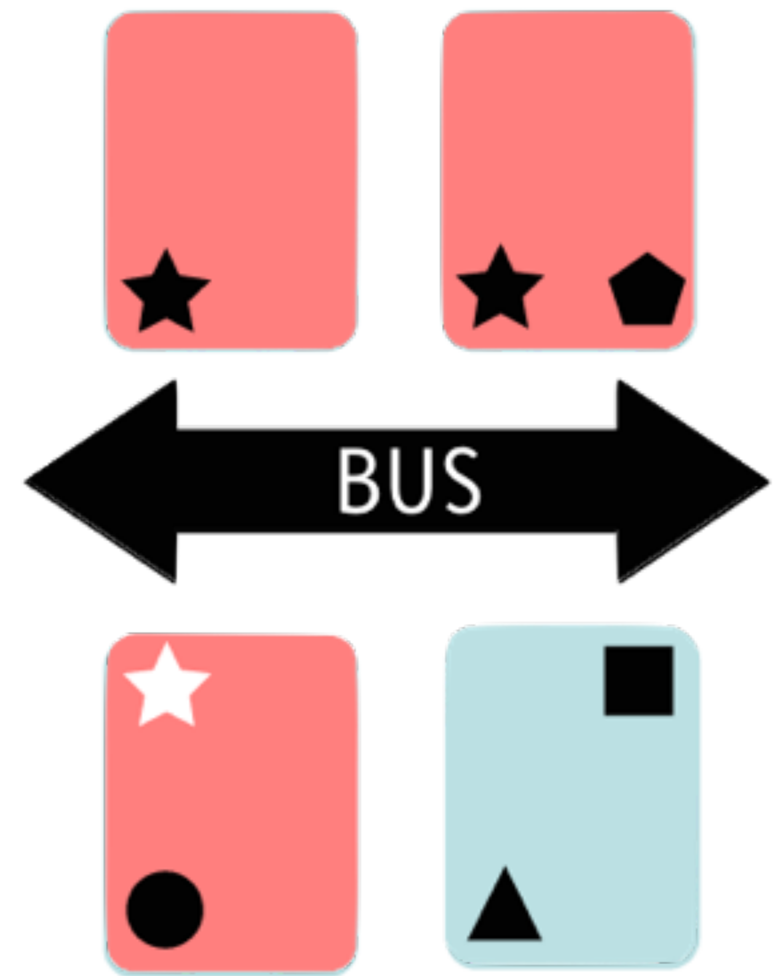

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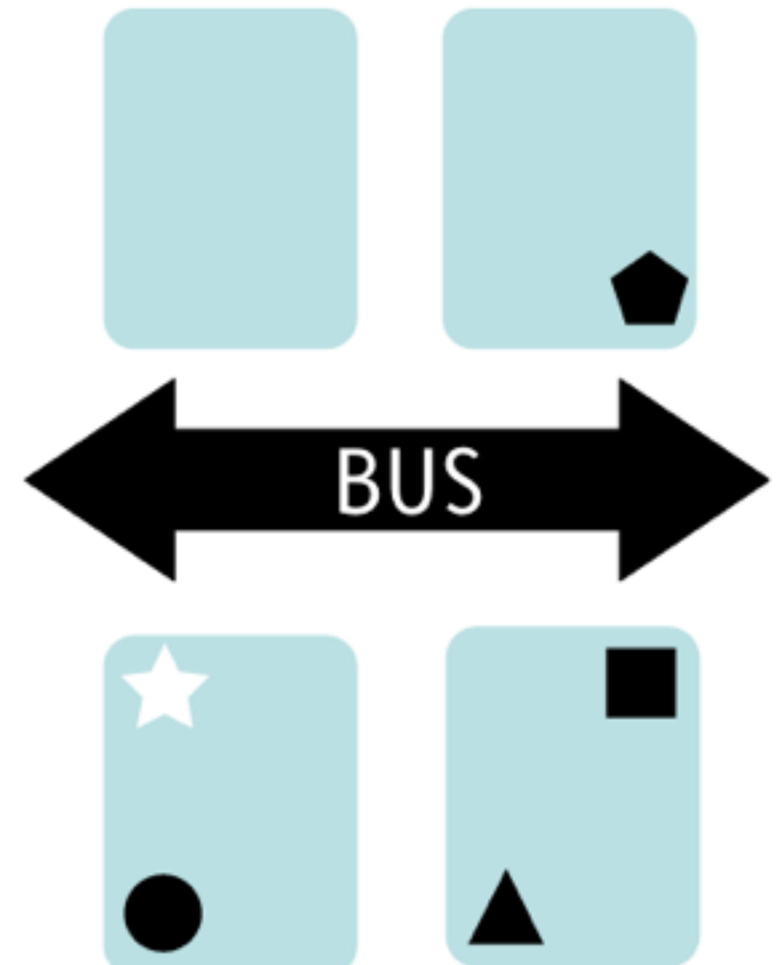
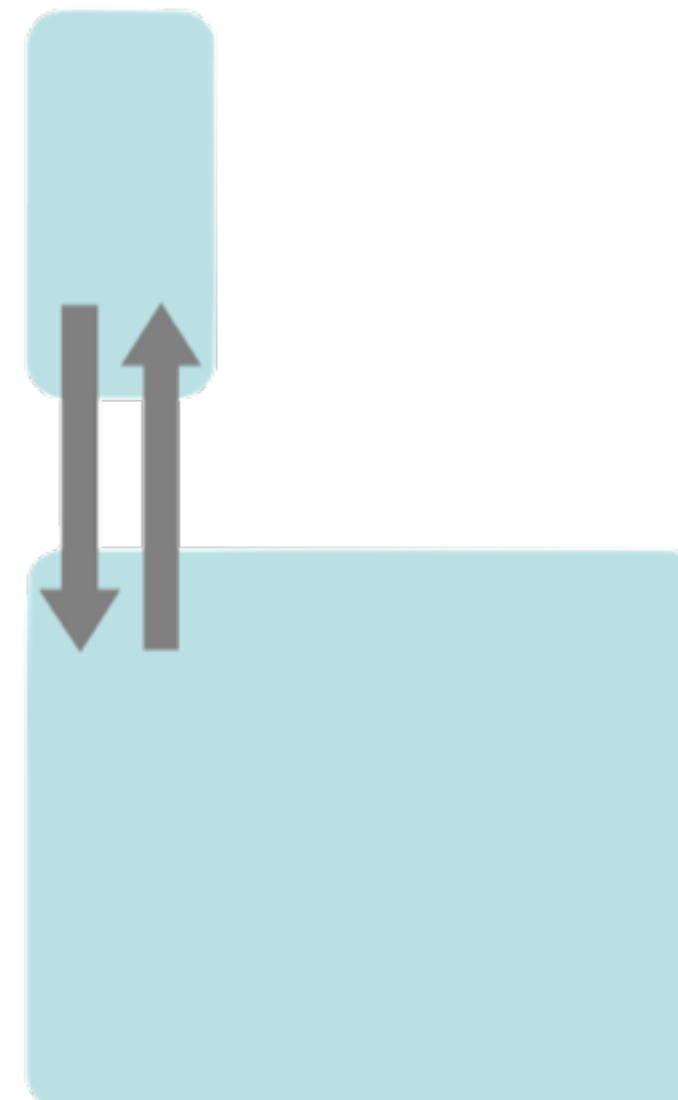


Twitter · RSS Feeds · Email

Client/Server

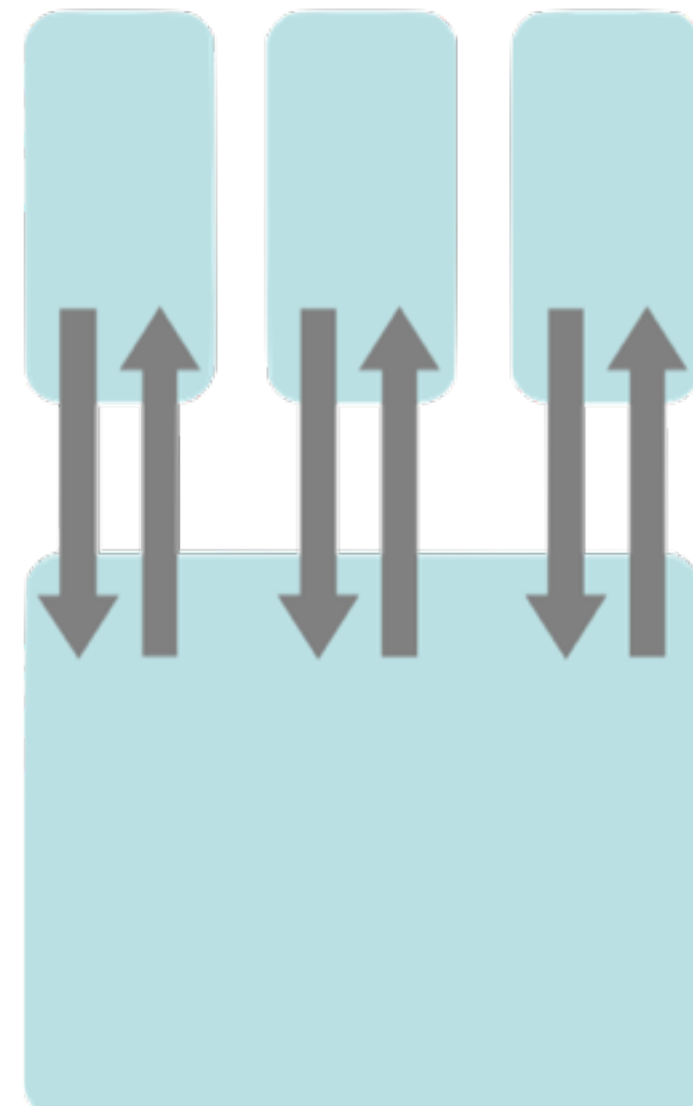
- Many clients, active, close to users
- One server, passive, close to data
- Single point of failure, scalability
- Security, scalability



Web Browser/server · Databases · File Servers · Git/SVN

Client/Server

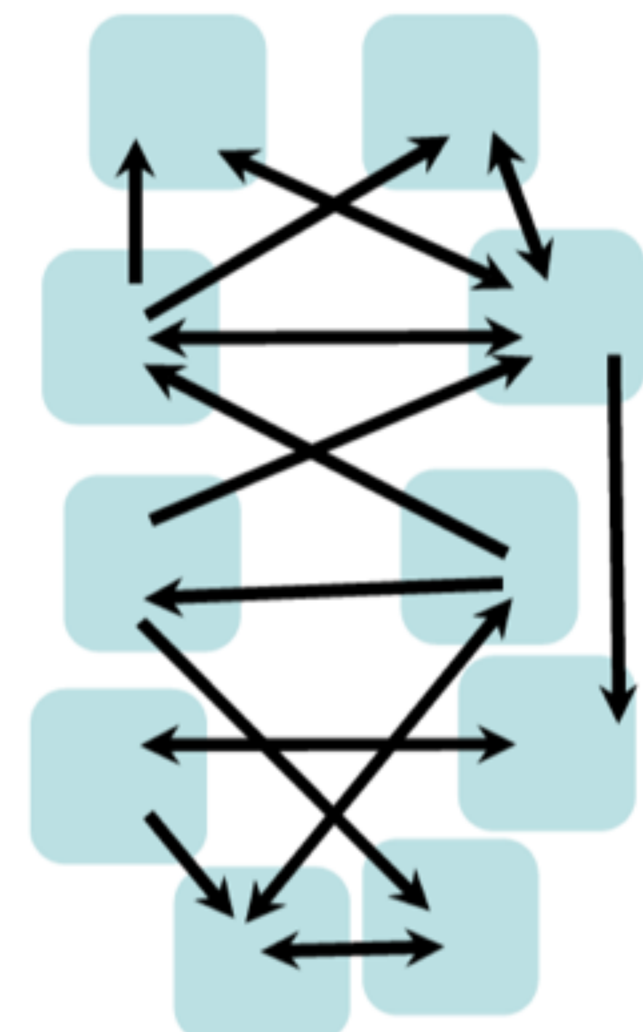
- Many clients, active, close to users
- One server, passive, close to data
- Single point of failure, scalability
- Security, scalability



Web Browser/server · Databases · File Servers · Git/SVN

Peer to Peer

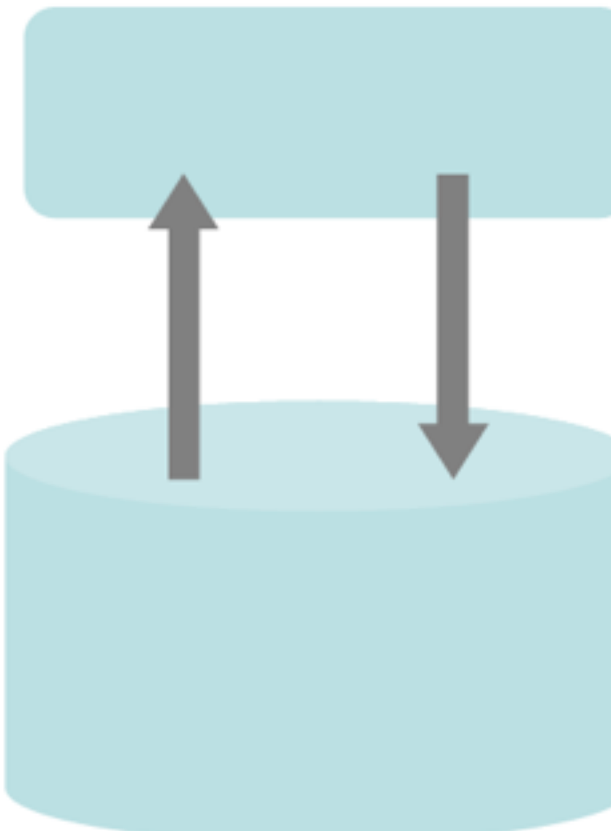
- Both server and client at the same time
- Dynamic join/leave
- Difficult administration, data recovery
- Scalability, dependability/robustness



File Sharing · Skype (mixed style) · Distributed Hash Tables

Data Centric

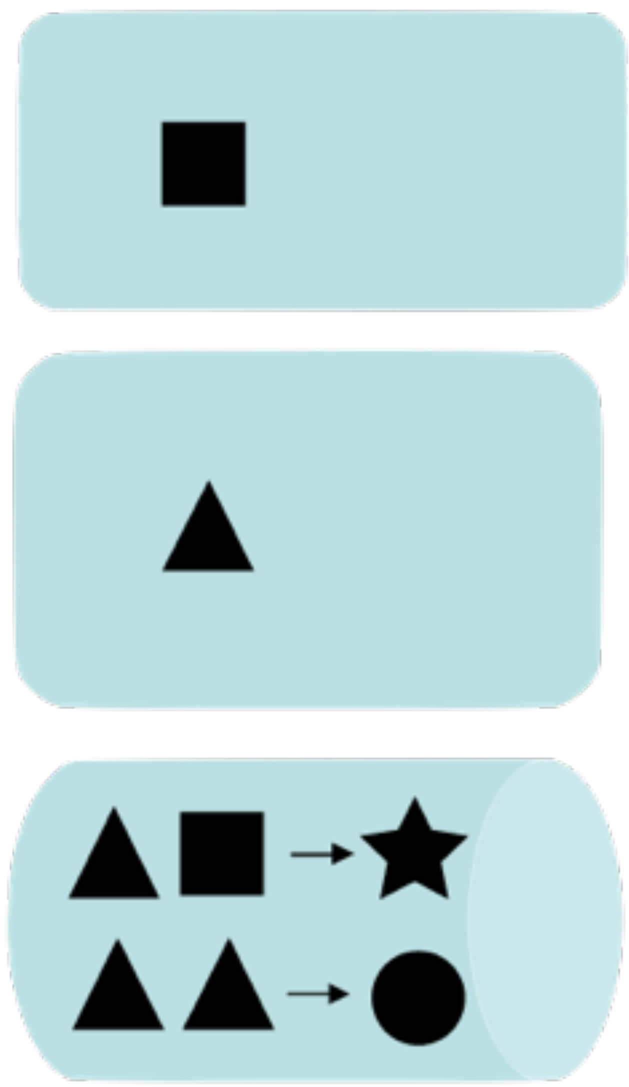
- Persistence layer
- Black board like
- Single point of failure
- (Eventual) Consistency (BASE/ACID)



Relational DB · Key-Value Stores

Rule Based

- Rules dynamically triggered
- Layered
- Possibly hard to understand and maintain
- Evolvability



Business Rule Engines · Expert Systems · Prolog

Rule Based

- Rules dynamically triggered
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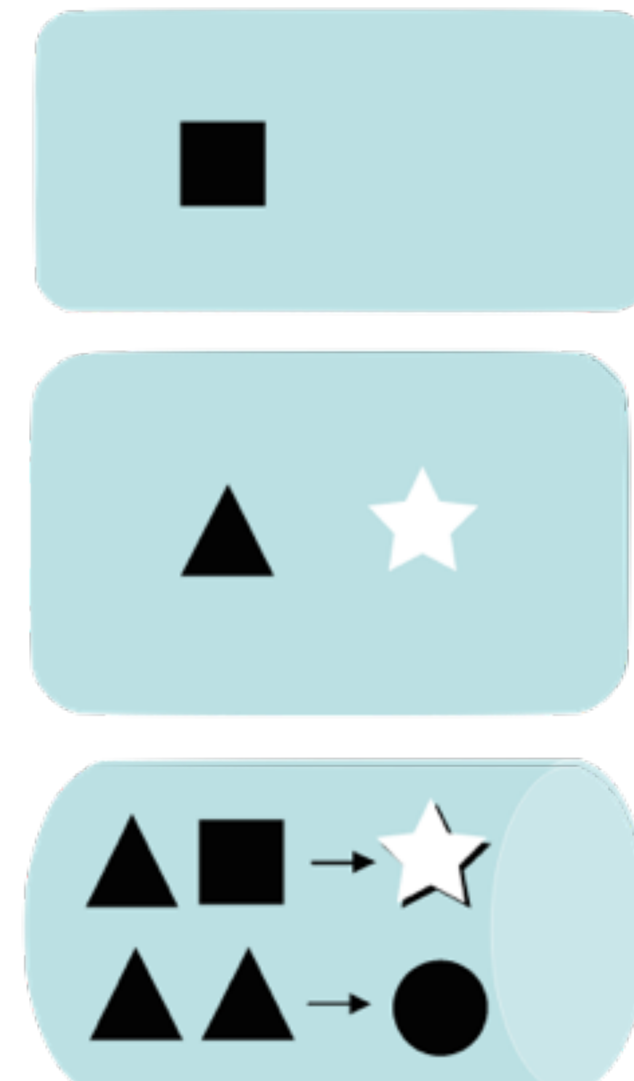
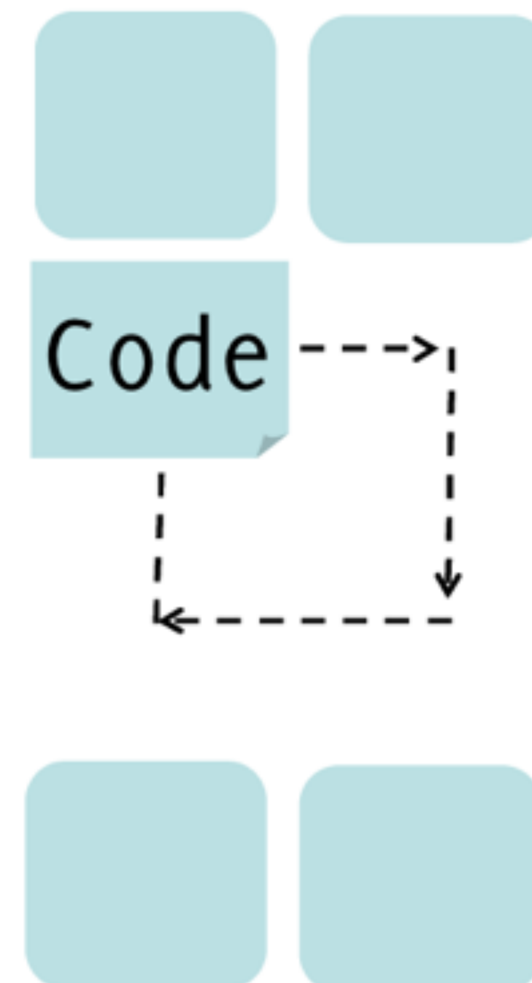
- Evolvability



Business Rule Engines · Expert Systems · Prolog

Mobile Code

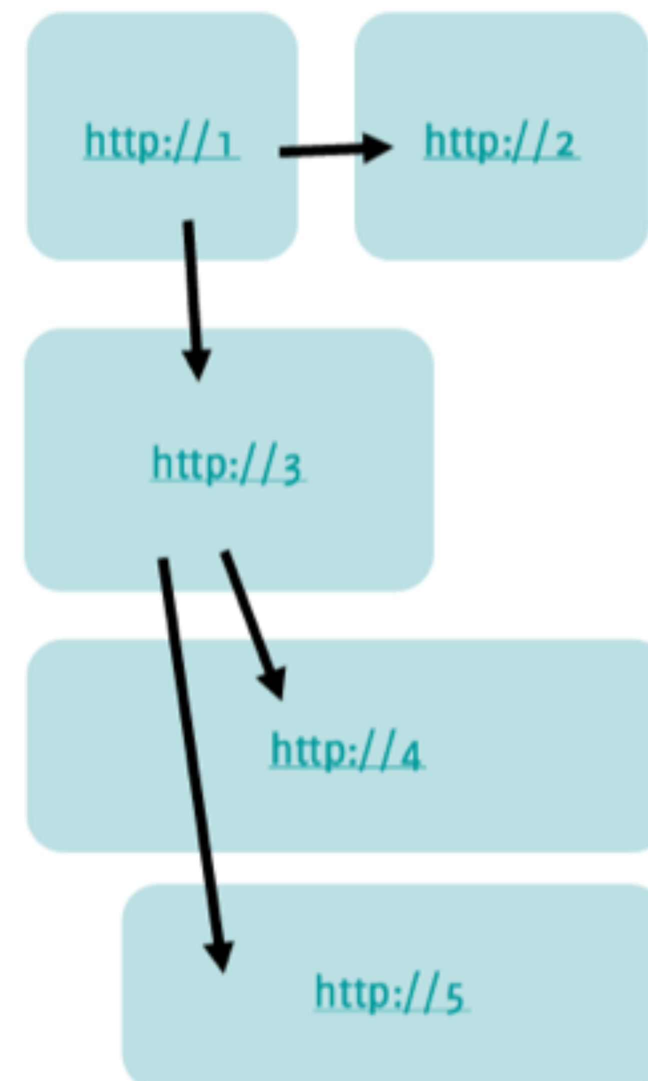
- Code migrates (weak)
- Code+execution state migrate (strong)
- Security
- Fault tolerance, performance



JavaScript · Flash · Java Applets · Mobile Agents · Viruses

REST

- Hybrid style
- Stateless interactions/Stateful resources
- Loose coupling, scalability, interoperability

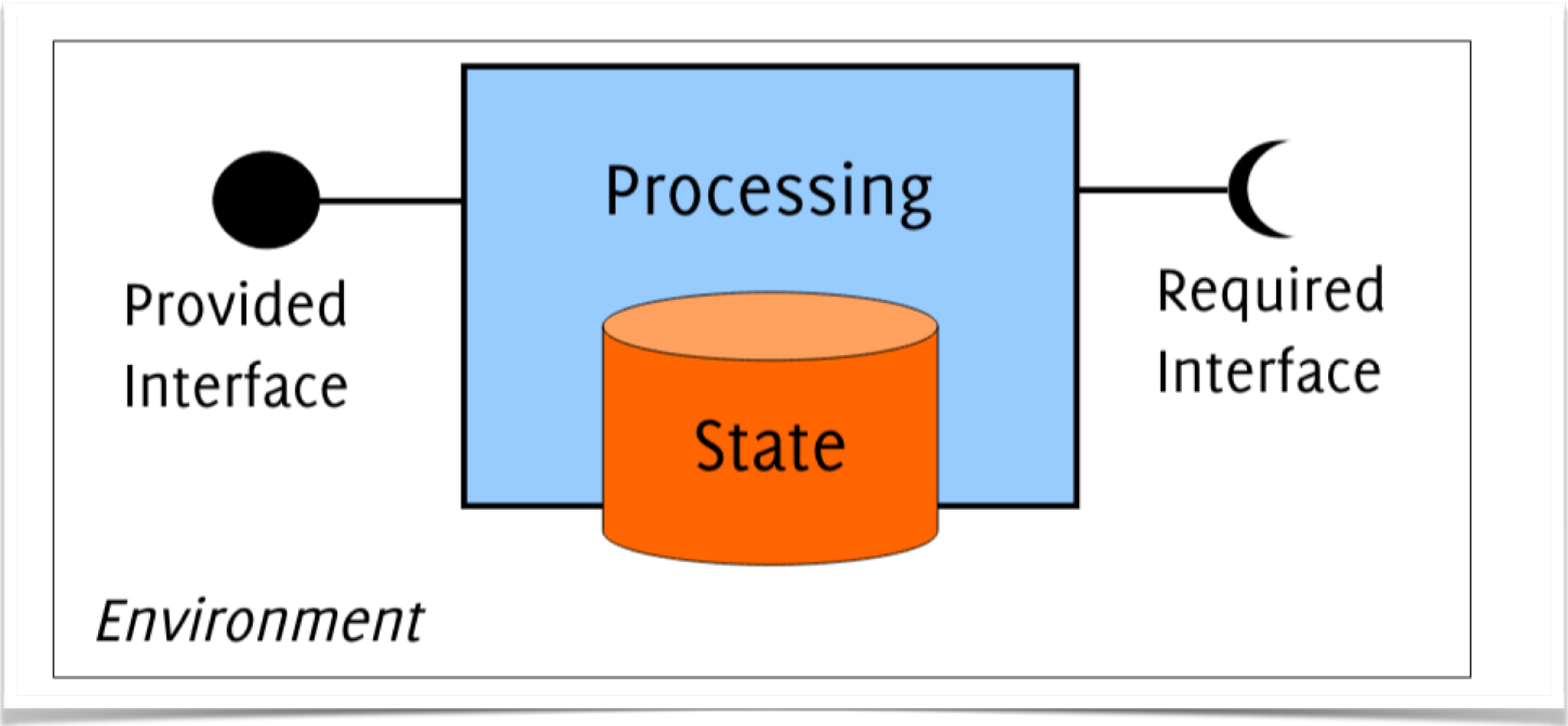


World Wide Web · RESTFul Web APIs

Summary

- A great architecture likely combines aspects of several other architectures
- Do no limit to just one pattern, but avoid the use of unnecessary patterns
- Different styles lead to architectures with different qualities, and so might do the same style
- Never stop at the choice of patterns and styles: further refinement is *always* needed

Modeling


Processing
State
Provided
Interface
Required
Interface
Environment

Why modeling?

- Record decisions
- Communicate decisions
- Evaluate decisions
- Generate artifacts


WHAT DO WE MODEL ?!
imgflip.com

The problem (Domain model)

The environment

System context

Stakeholders

The problem (Domain model)

The system-to-be (Design Model)

Static and dynamic architecture

The environment

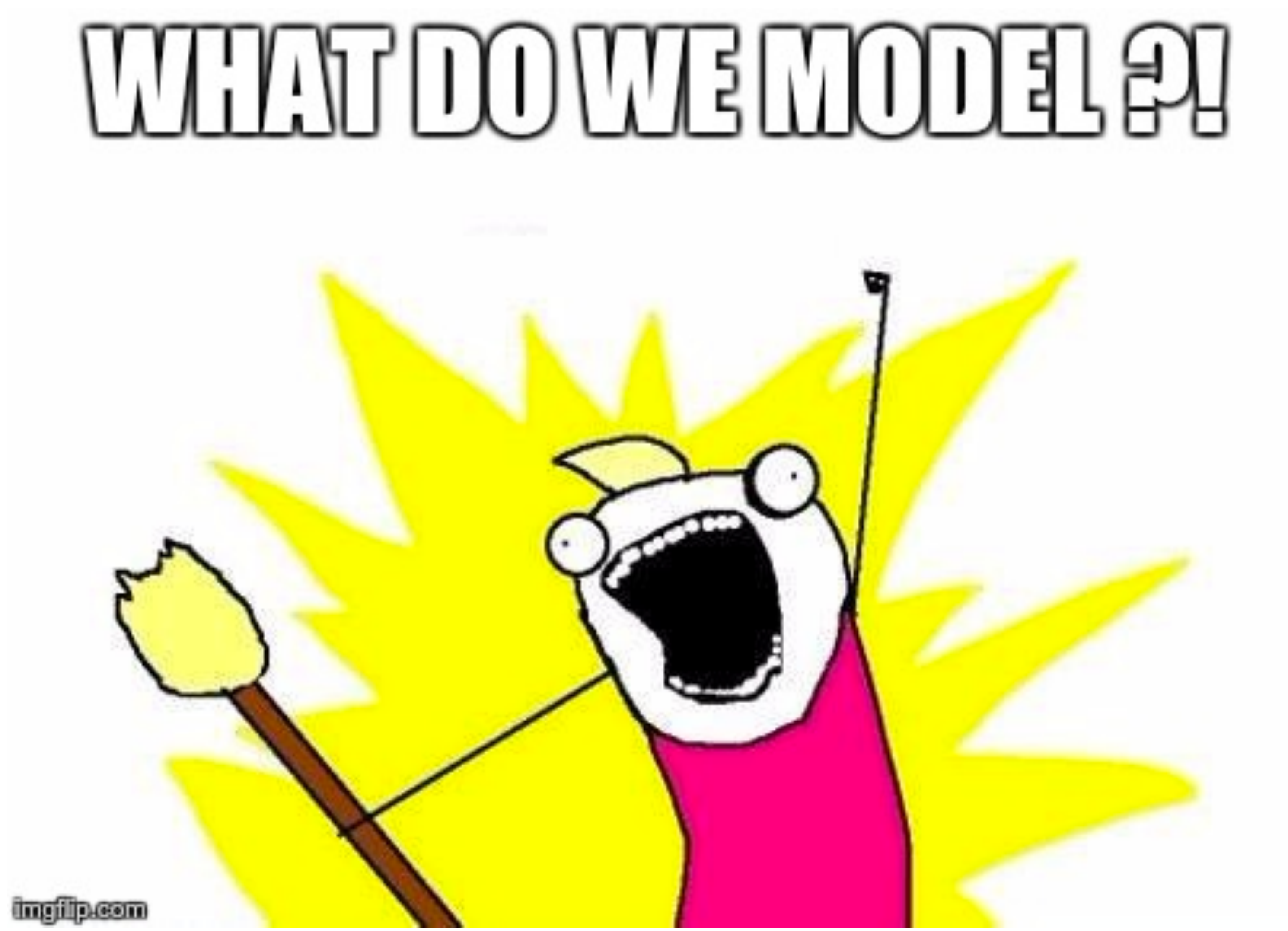
System context

Stakeholders

The problem (Domain model)

The system-to-be (Design Model)

Static and dynamic architecture



The environment

System context

Stakeholders

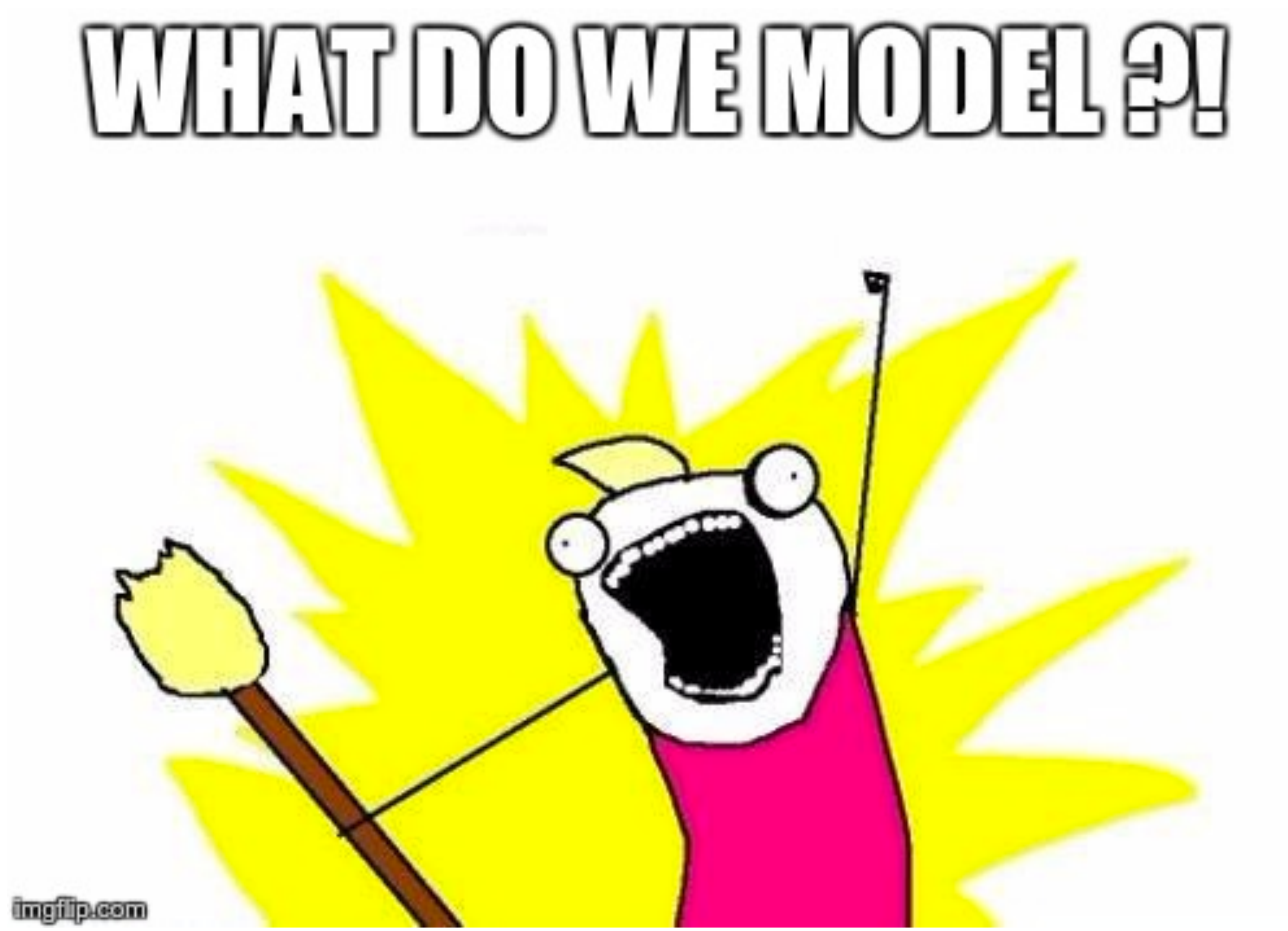
The problem (Domain model)

Quality attributes and non-functional properties

The system-to-be (Design Model)

Static and dynamic architecture

The design process



The environment

System context

Stakeholders

The problem (Domain model)

Quality attributes and non-functional properties

Design Model

Boundary Model

System Context
Interfaces/API
Quality Attributes

Externally visible behavior

Design Model

Boundary Model

System Context
Interfaces/API
Quality Attributes

Externally visible behavior

Internal Model

Software Components
Software Connectors
Component assembly

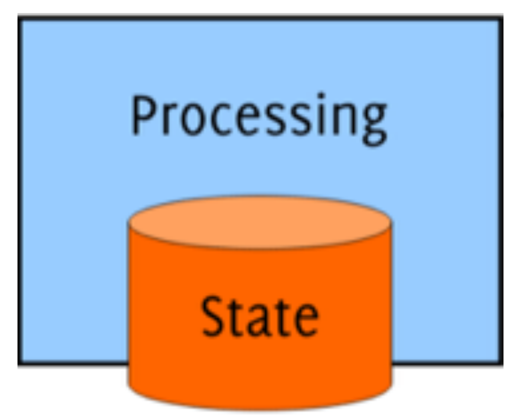
Internal behavior

Software Components

Reusable unit of composition

Can be composed into larger systems

Locus of computation



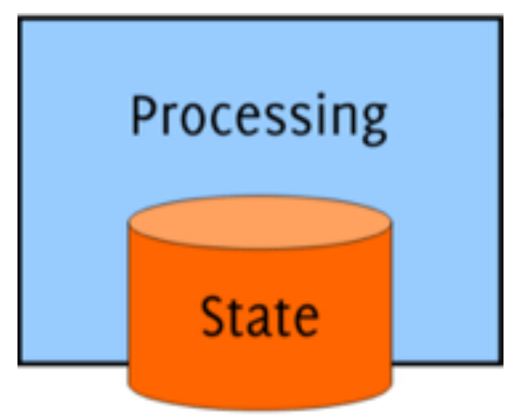
State in a system

Software Components

Reusable unit of composition

Can be composed into larger systems

Locus of computation



State in a system

Application-specific

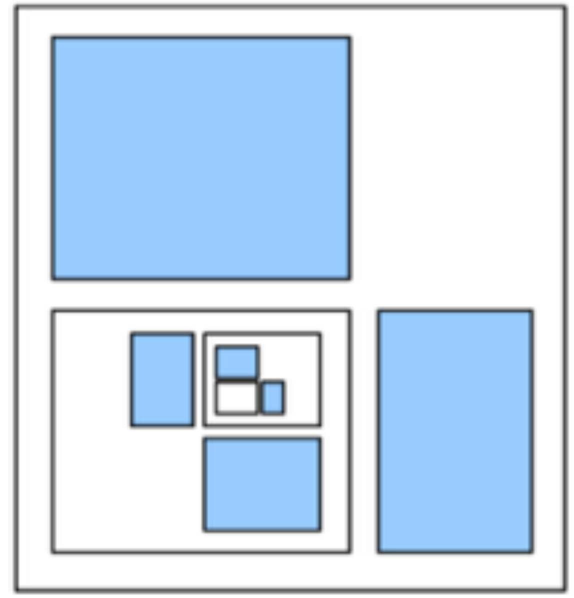
Media Player

Math Library

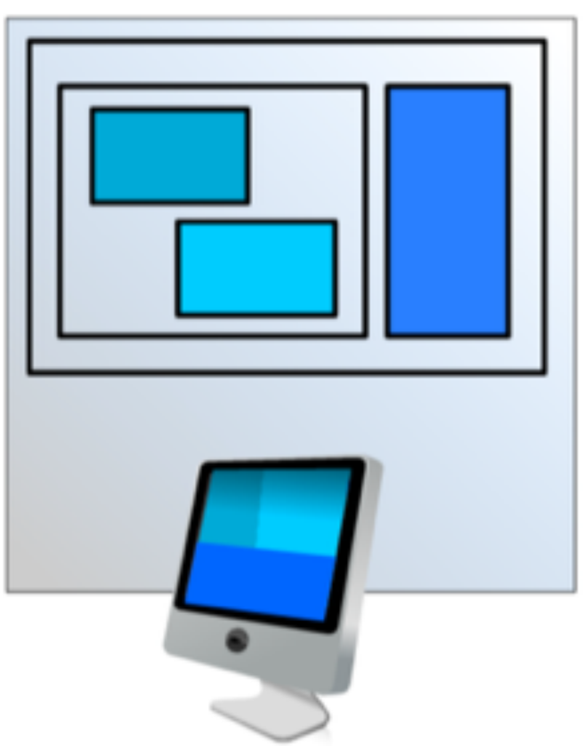
Infrastructure

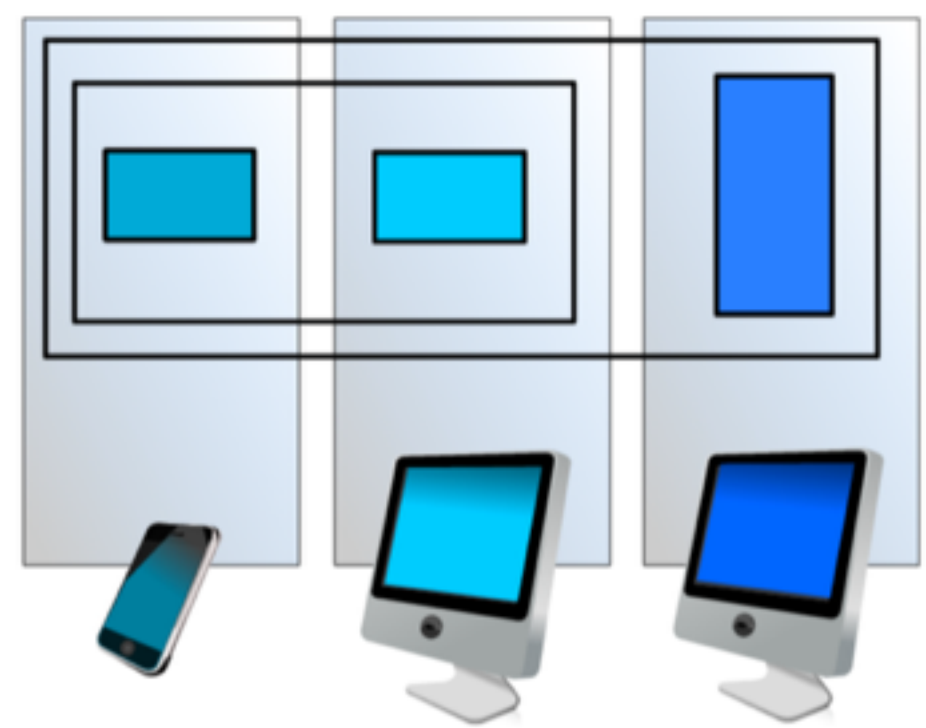
Web Server

Database

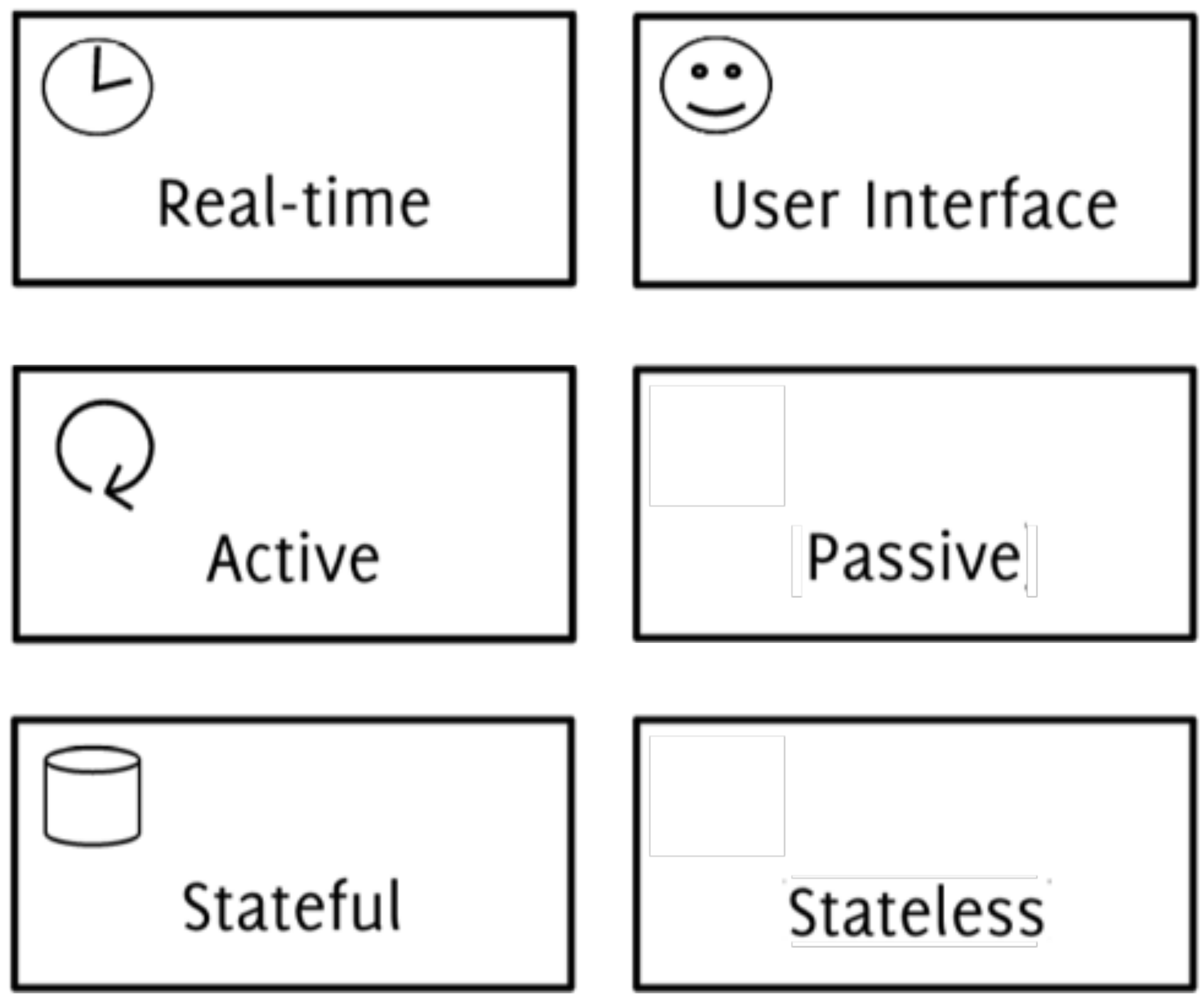


Composition vs Distribution





Component Roles



Components

Encapsulate state and functionality
Coarse-grained
Black box architecture elements
Structure of architecture

VS

Objects

Encapsulate state and functionality
Fine-grained
Can “move” across components
Identifiable unit of instantiation

VS

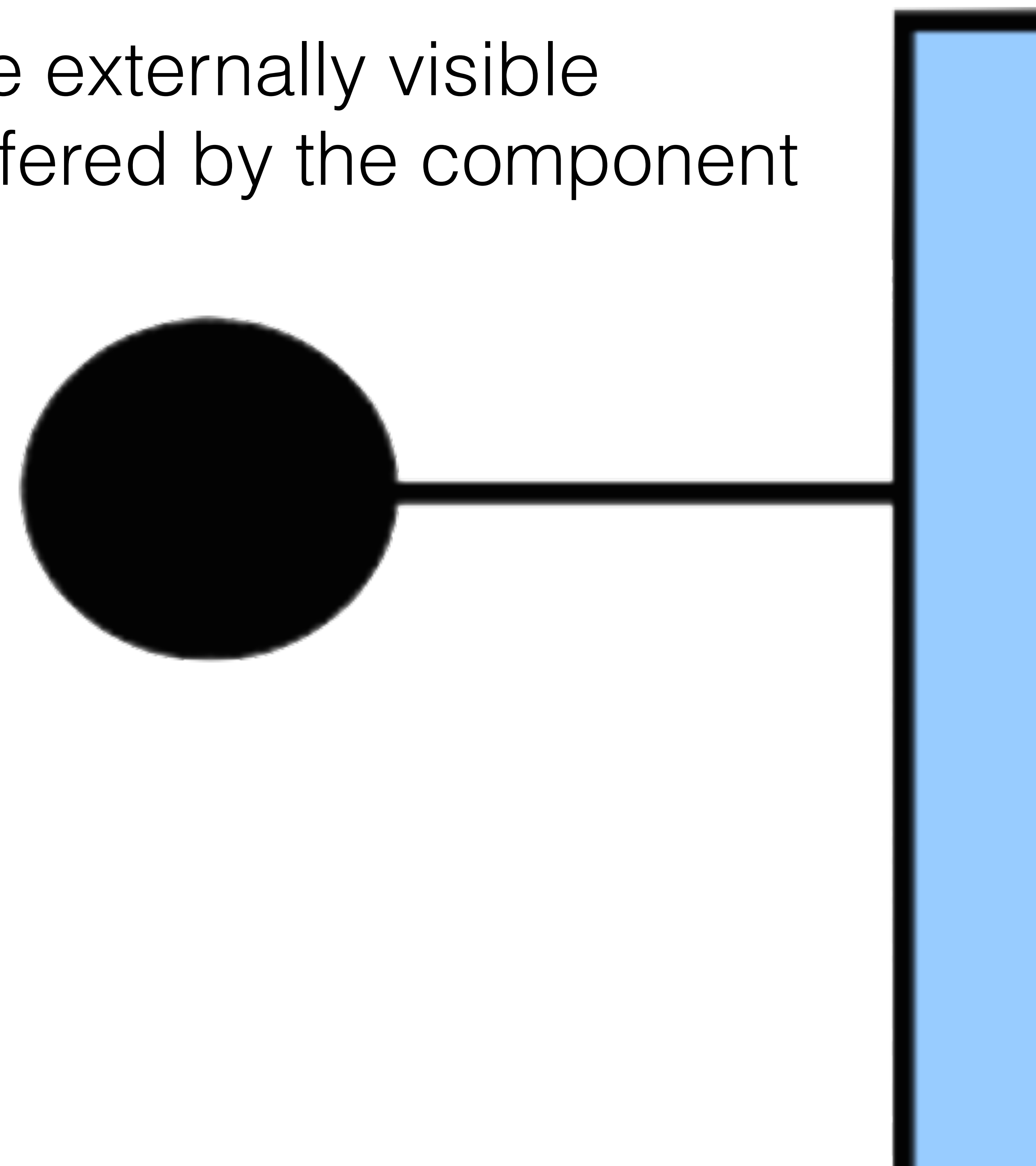
Modules

Rarely exist at run time
May require other modules to compile
Package the code

Component Interfaces

Provided Interfaces

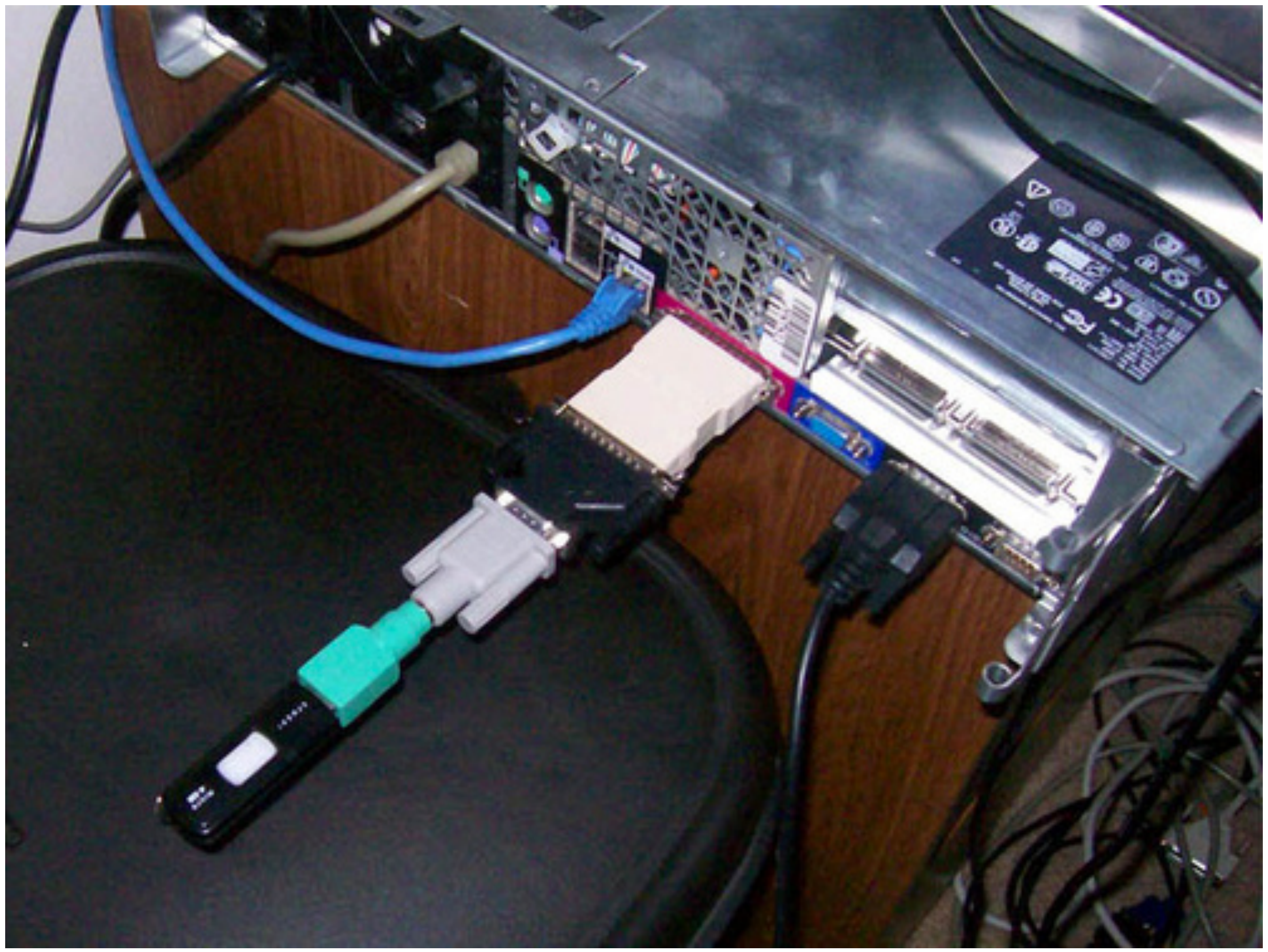
- Specify and document the externally visible features (or public API) offered by the component
  - *Data types and model*
  - *Operations*
  - *Properties*
  - *Events and call-backs*



Required Interface

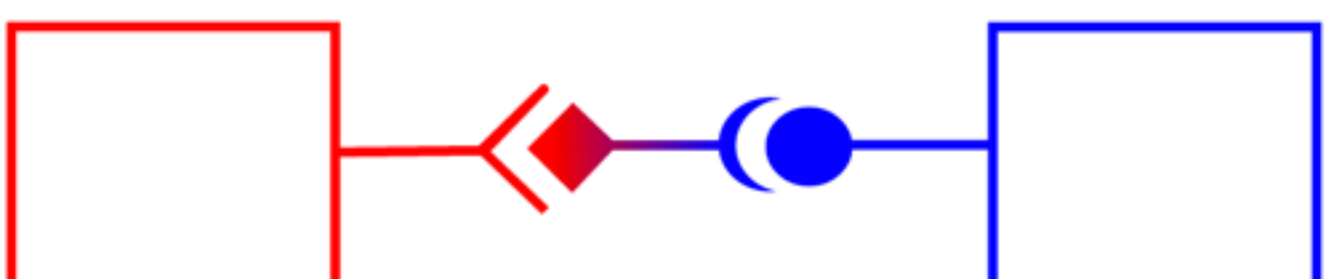
- Specify the conditions upon which a component can be (re)used
  - *The platform is compatible*
  - *The environment is setup correctly*

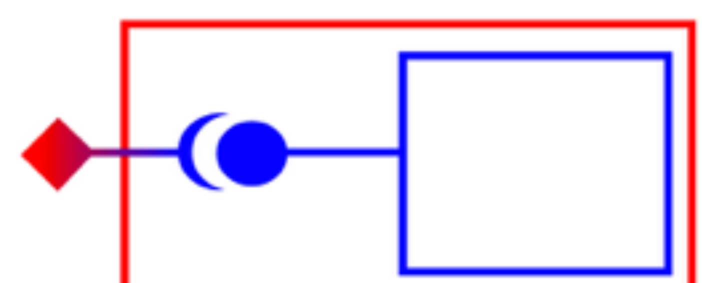
Compatible Interfaces



Adapter

Wrapper



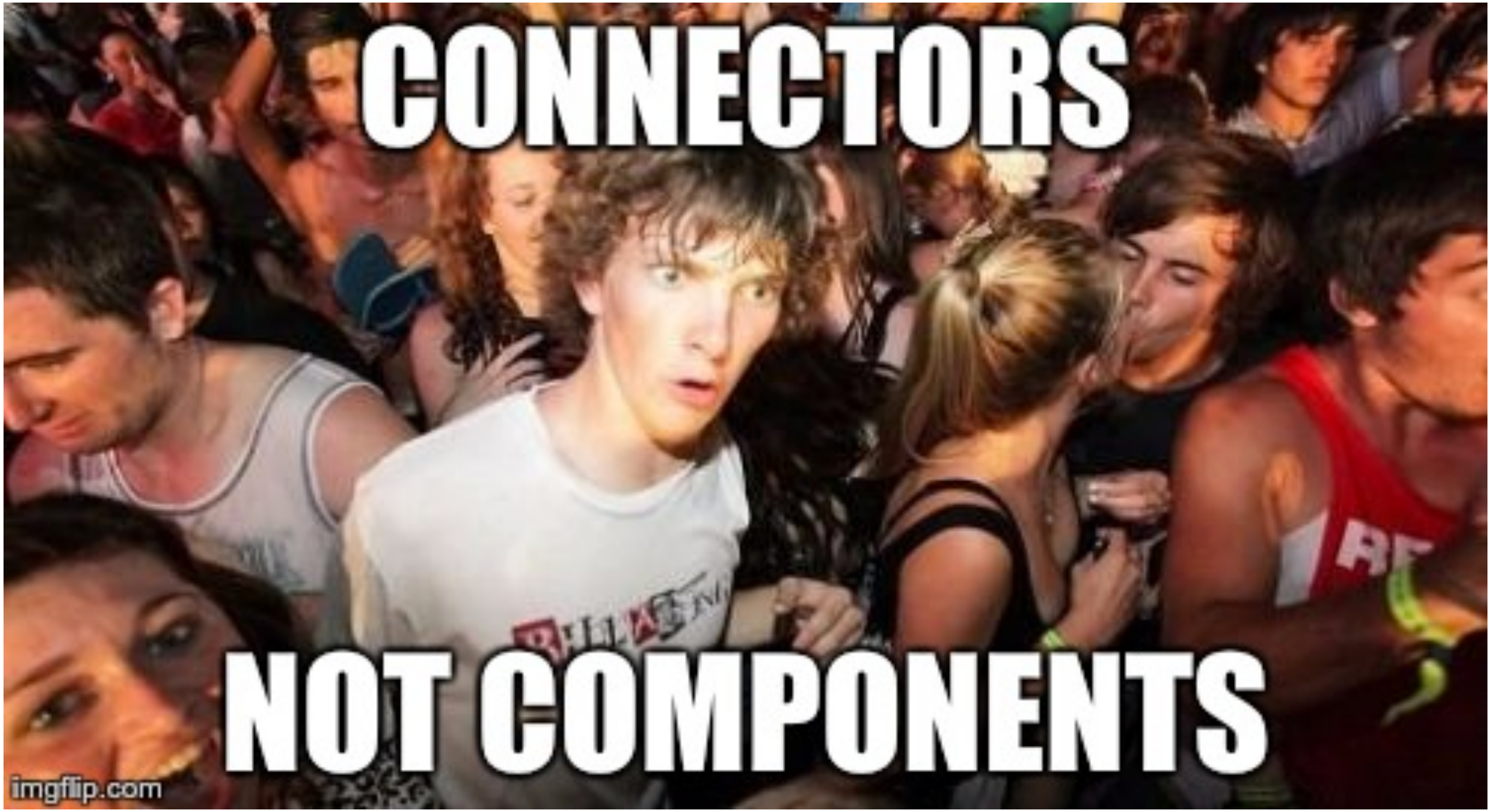


Software Connectors

Model static and dynamic aspects of the **interaction** between component interfaces

Connector Roles

- Communication
  deliver data and transfer of control
- Coordination
  separate control from computation
- Conversion
  enable interaction of mismatched components
- Facilitation/Mediation
  govern access to shared information



not always directly visible in the code

mostly application-independent

Connectors are abstractions

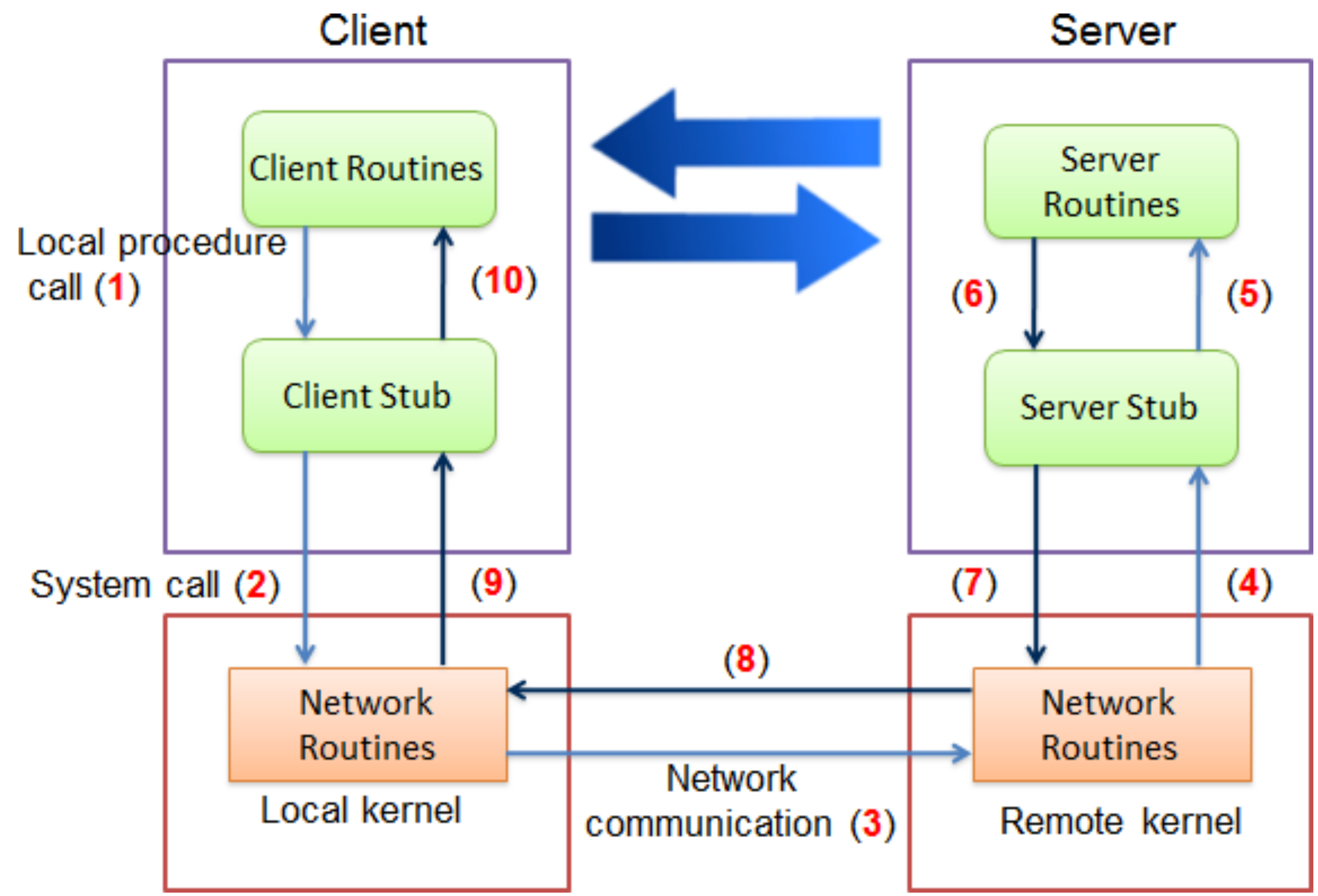
When to hide components inside a connector?

Remote Procedure Call

- Call

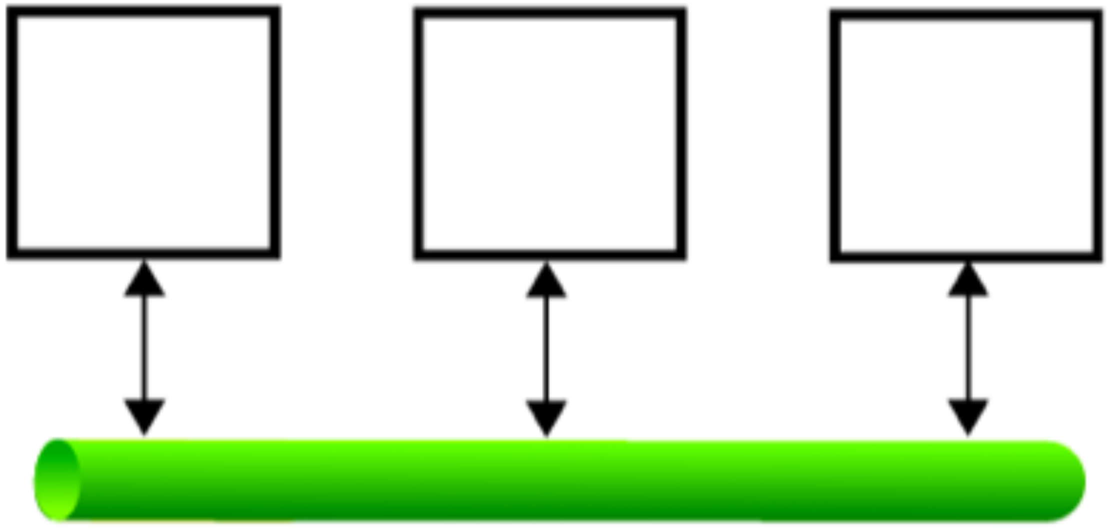
Remote Procedure Call

- Call



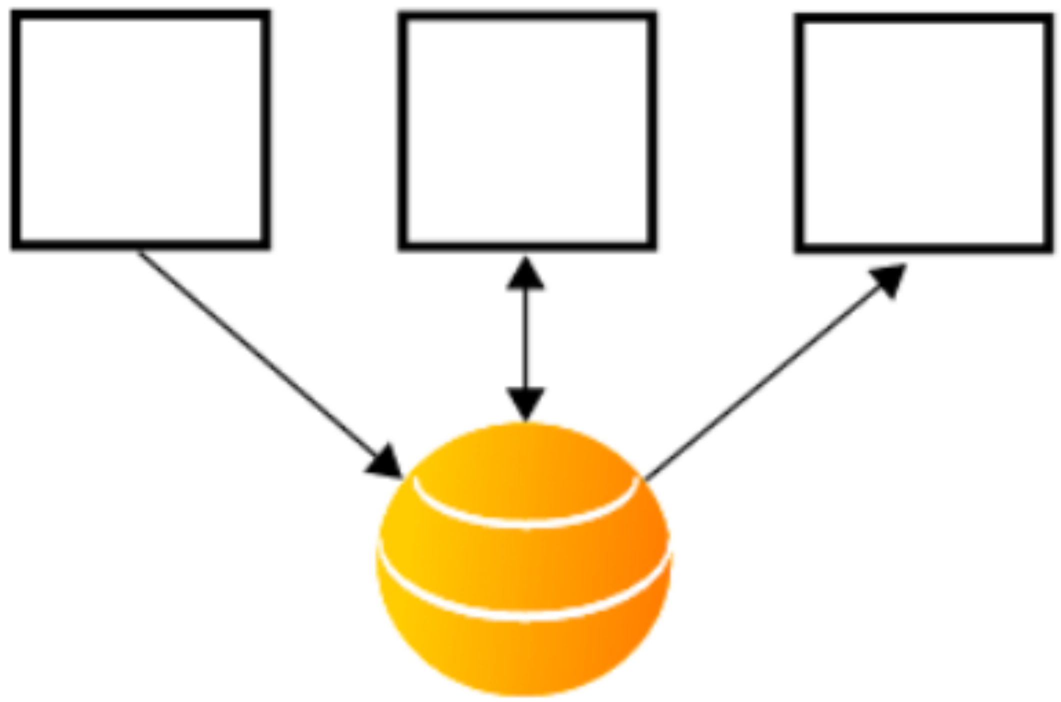
Message Bus

- Publish
- Subscribe
- Notify

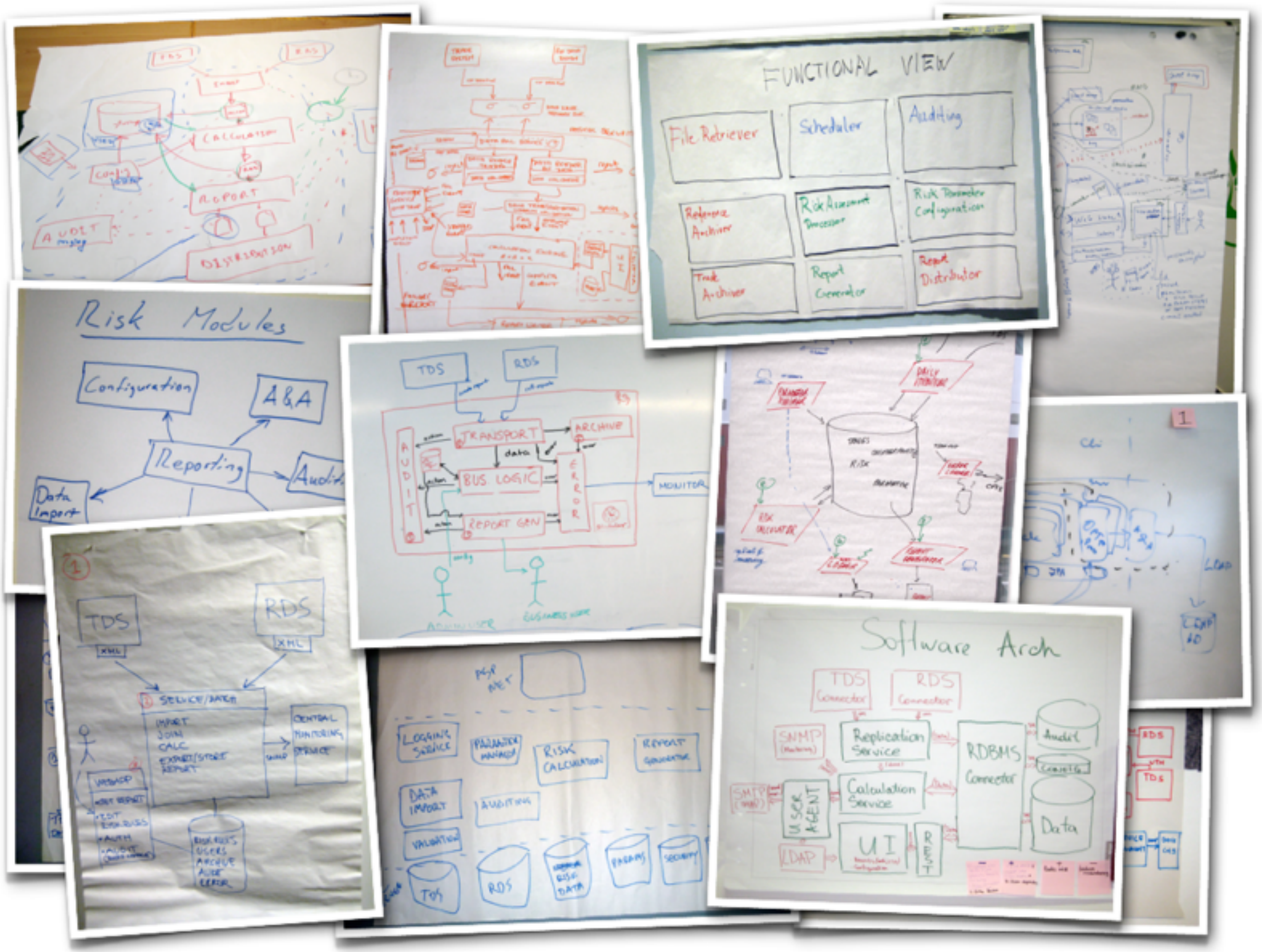


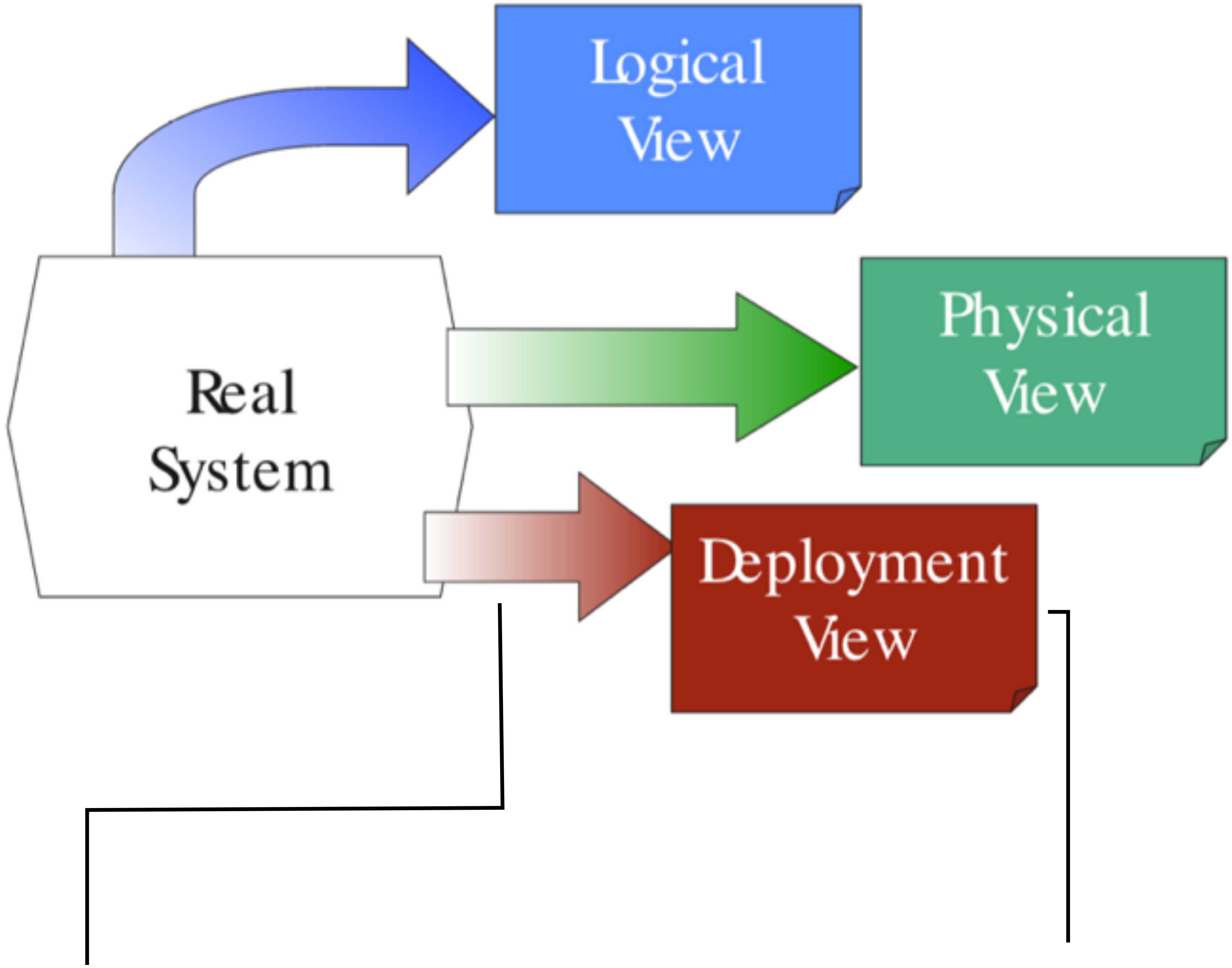
Web

- Get
- Put
- Post
- Delete



Views and Viewpoints





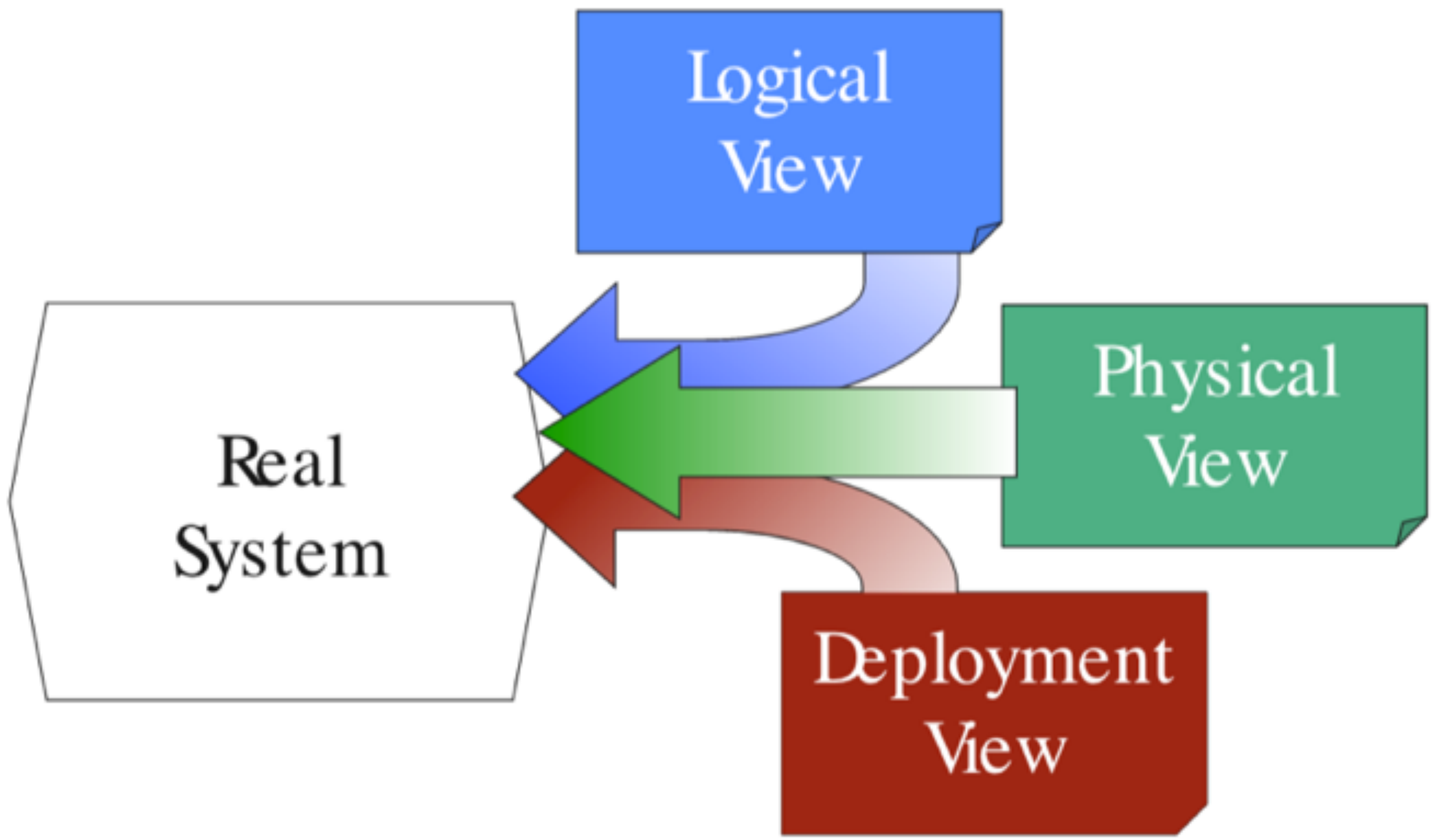
Viewpoint

The common concerns shared by a view

View

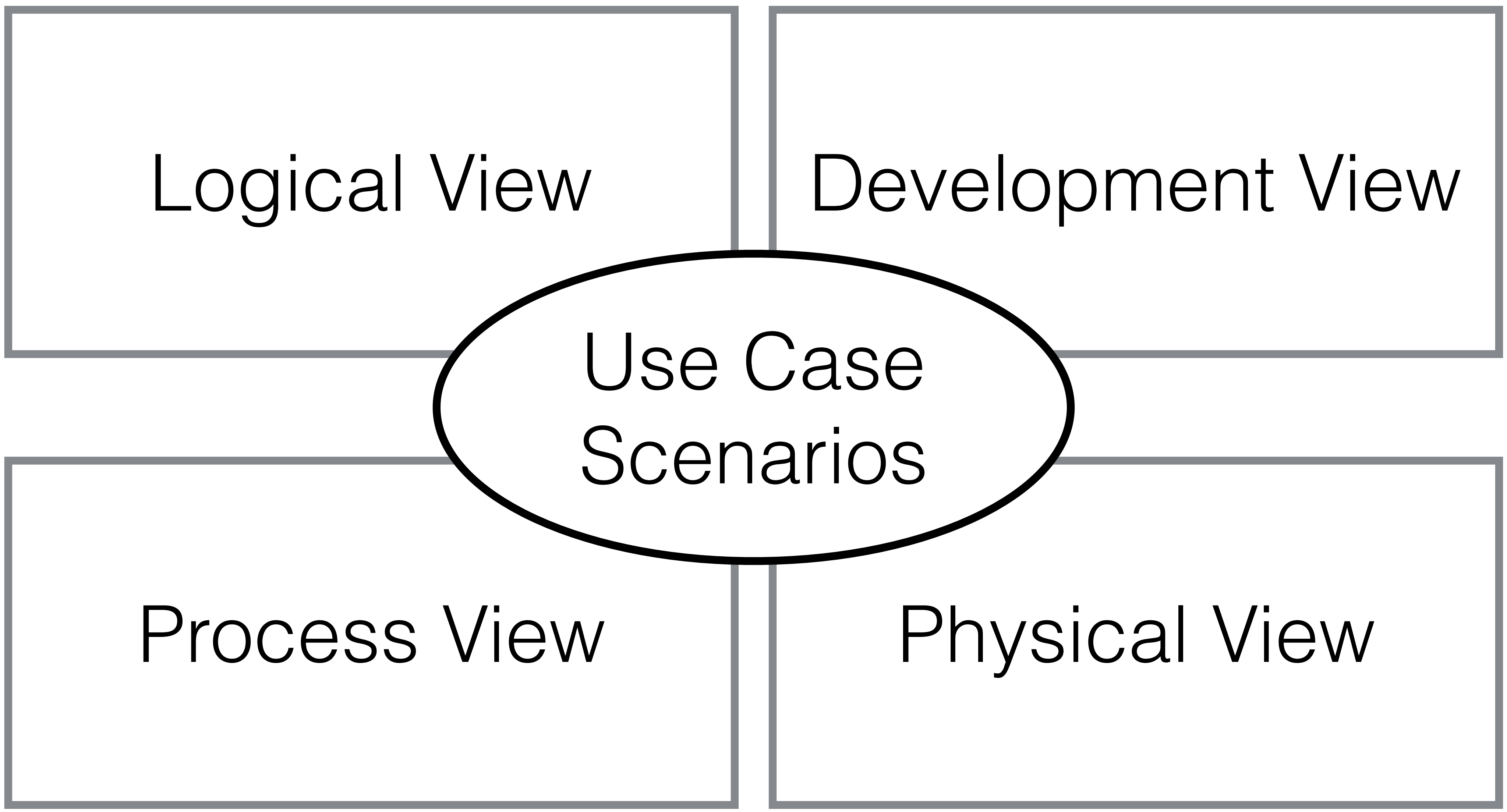
A subset of related architectural design decisions

Consistency



Views are not always orthogonal and might become inconsistent if design decision are not compatible (*erosion*)

4+1



Philippe Kruchten

Use Case Scenarios

- Unify and link the elements of the other 4 views
- Help to ensure the architectural model addresses all the requirements
- Each scenario can be illustrated using the other 4 views

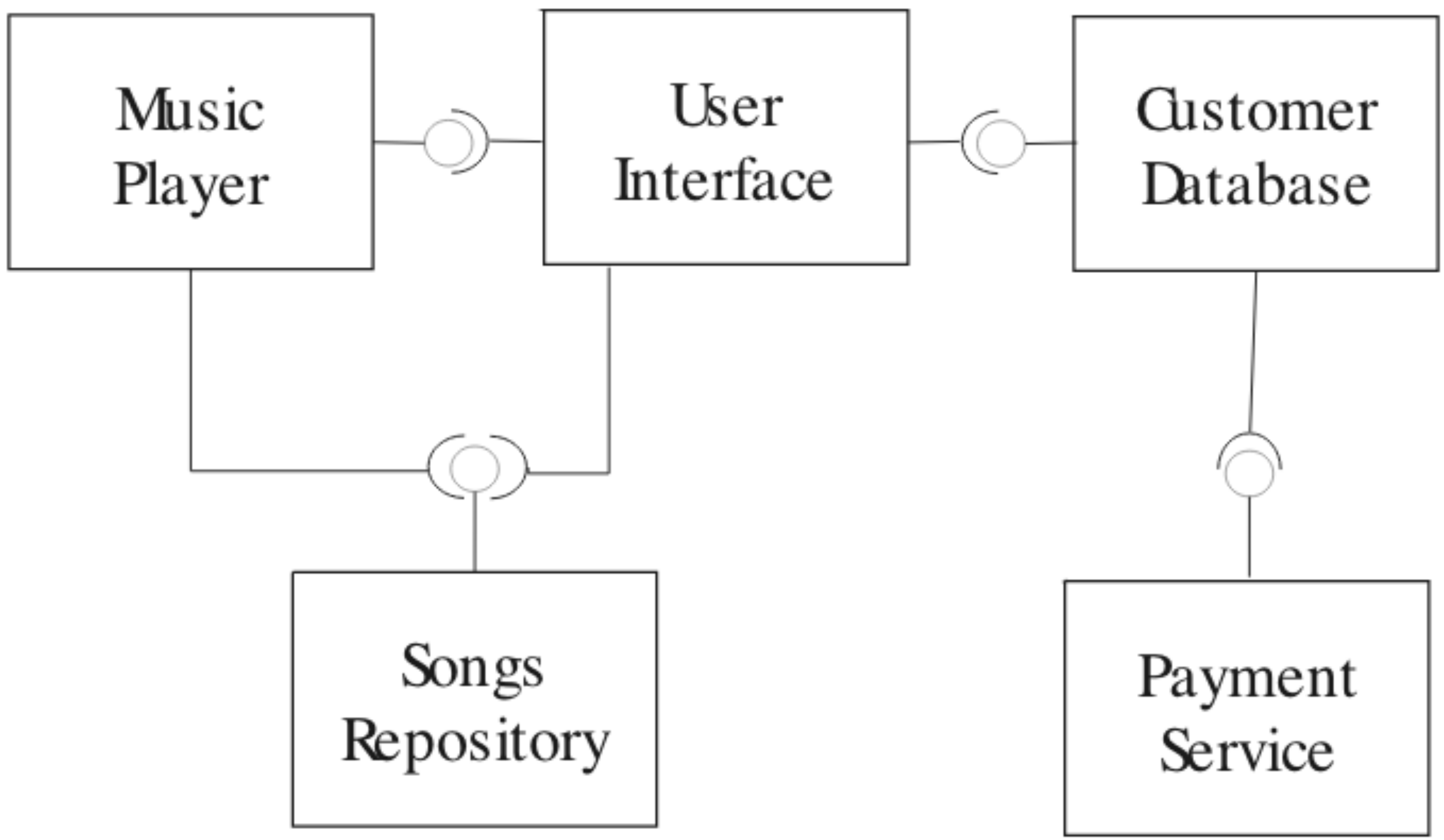
MusicApp Example

Use Case Scenarios

* Browse for new songs
* Buy song
* Download the purchased song on the phone
* Play the song

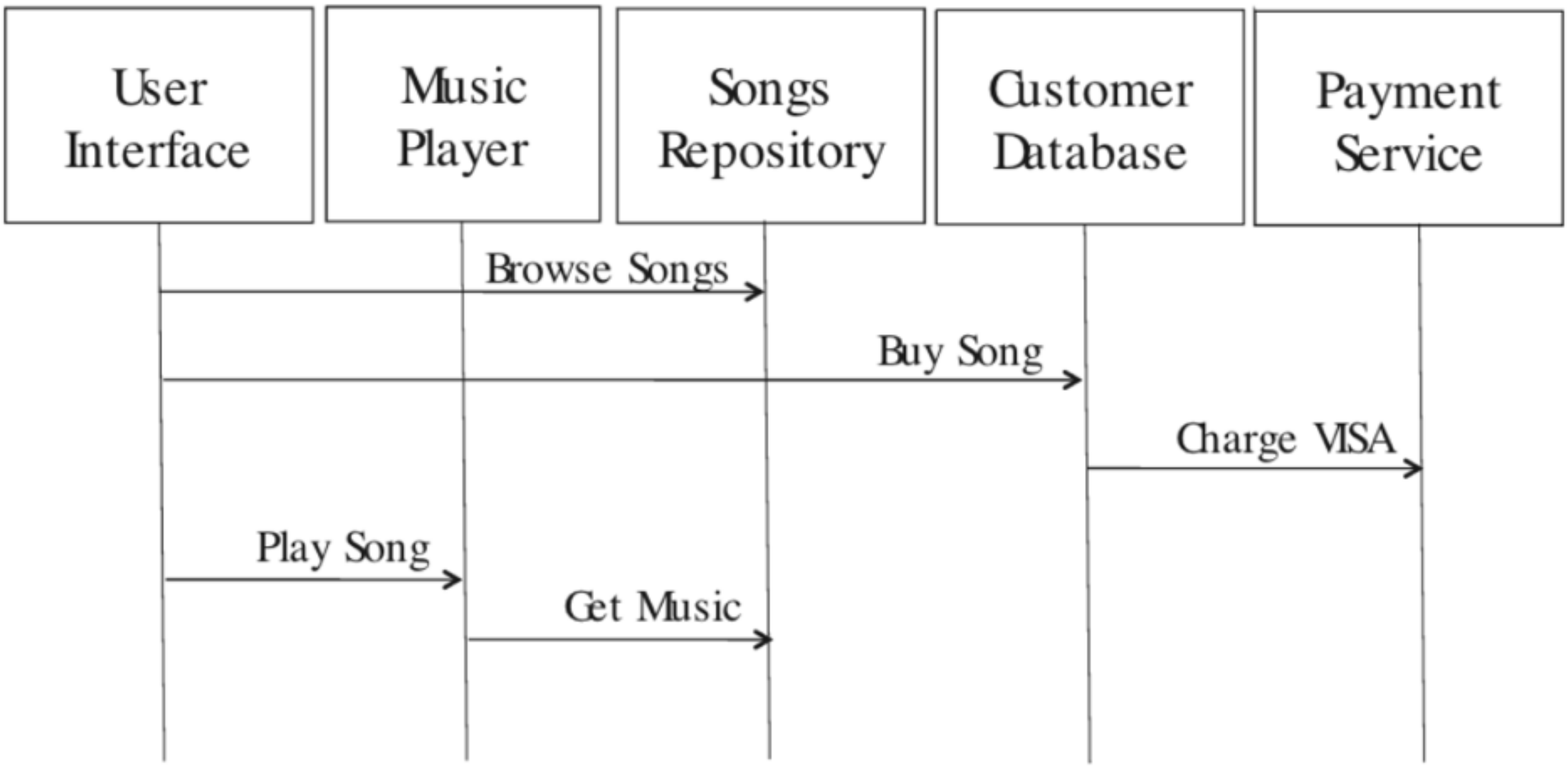
Logical View

- Decompose the system structure into software components and connectors
- Map functionalities (use cases) onto the components


Music Player
User Interface
Customer Database
Songs Repository
Payment Service

Process View

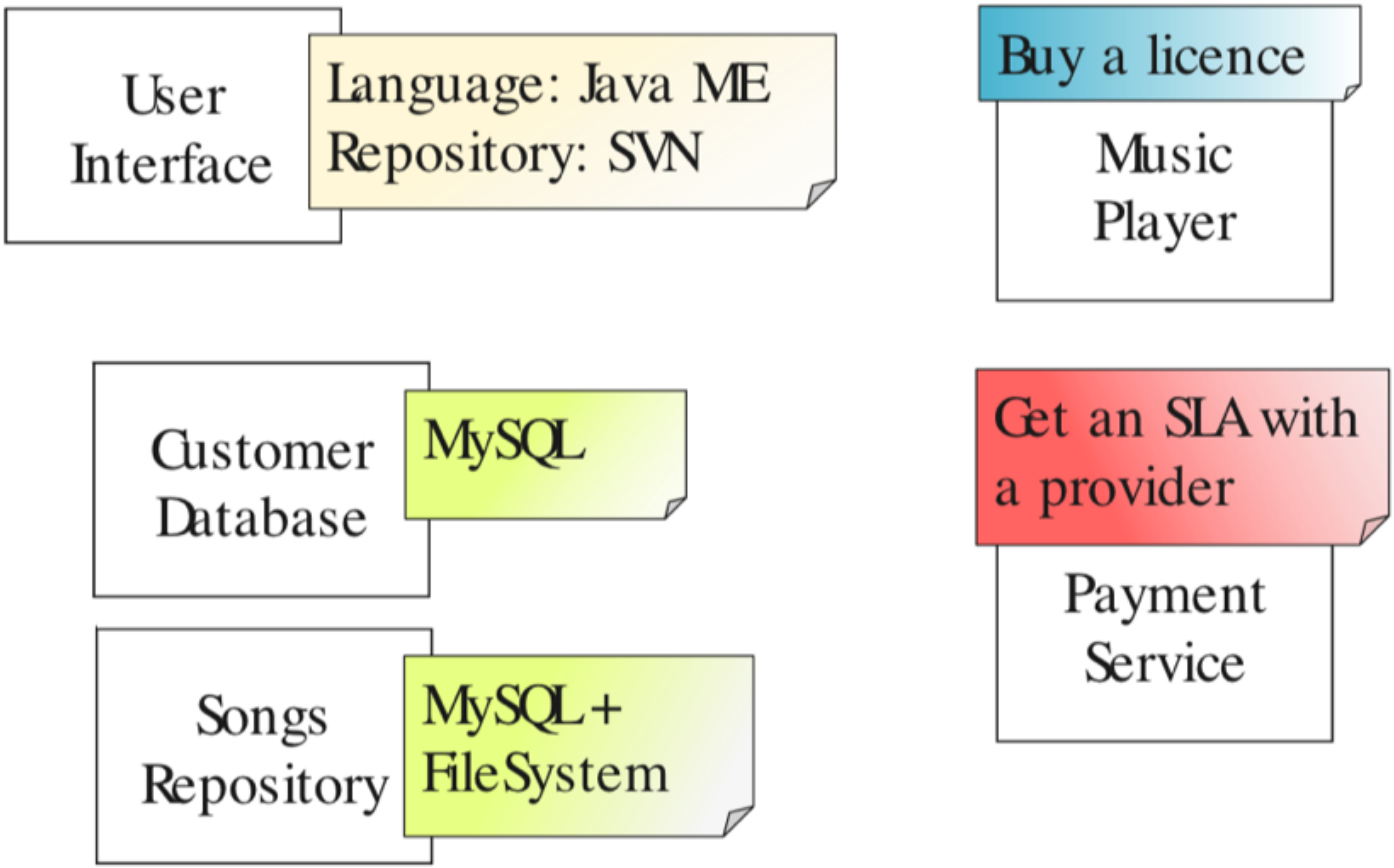
- Model the dynamic aspects of the architecture and the behavior of its parts
- Describe how components/processes communicate



Use Cases: Browse, Pay and Play For Songs

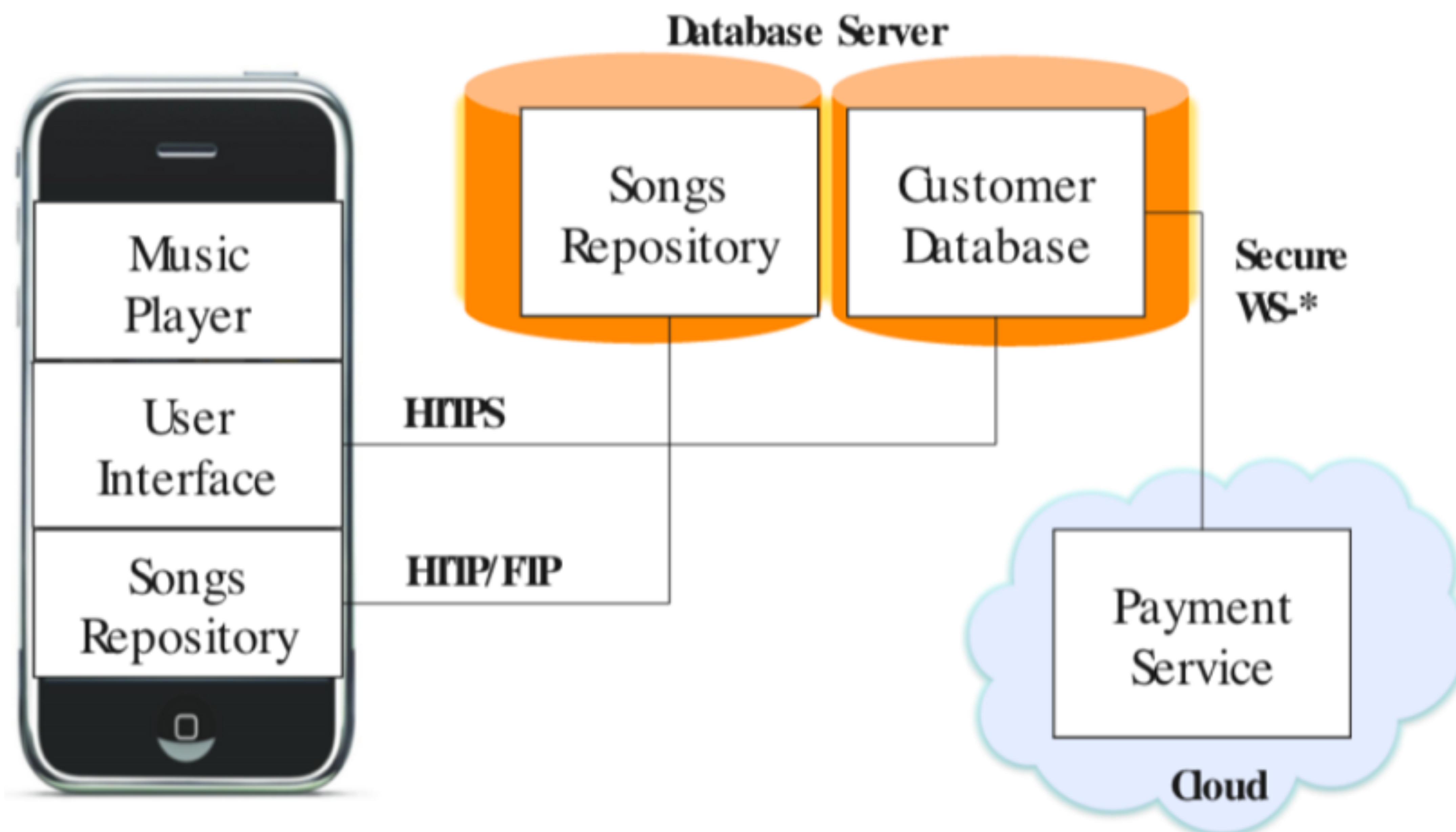
Development View

- Static organization of the software code artifacts
- Map elements in the logical view and the code artifacts

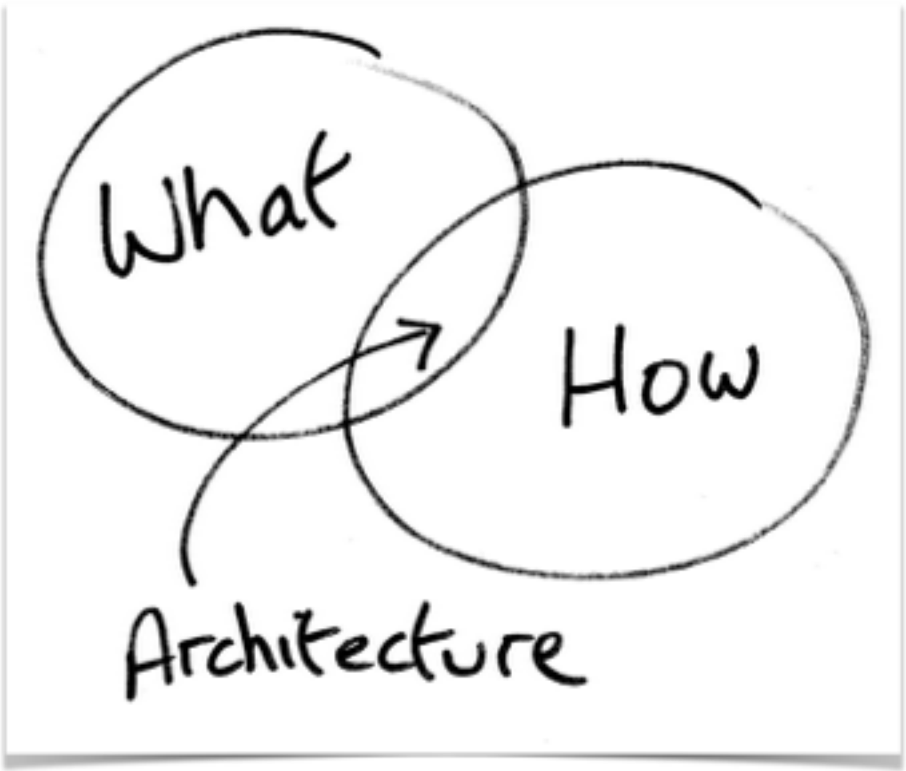

User Interface
Language: Java ME
Repository: SVN
Buy a licence
Music Player
Customer Database
MySQL
Get an SLA with a provider
Payment Service
Songs Repository
MySQL+ FileSystem

Physical View

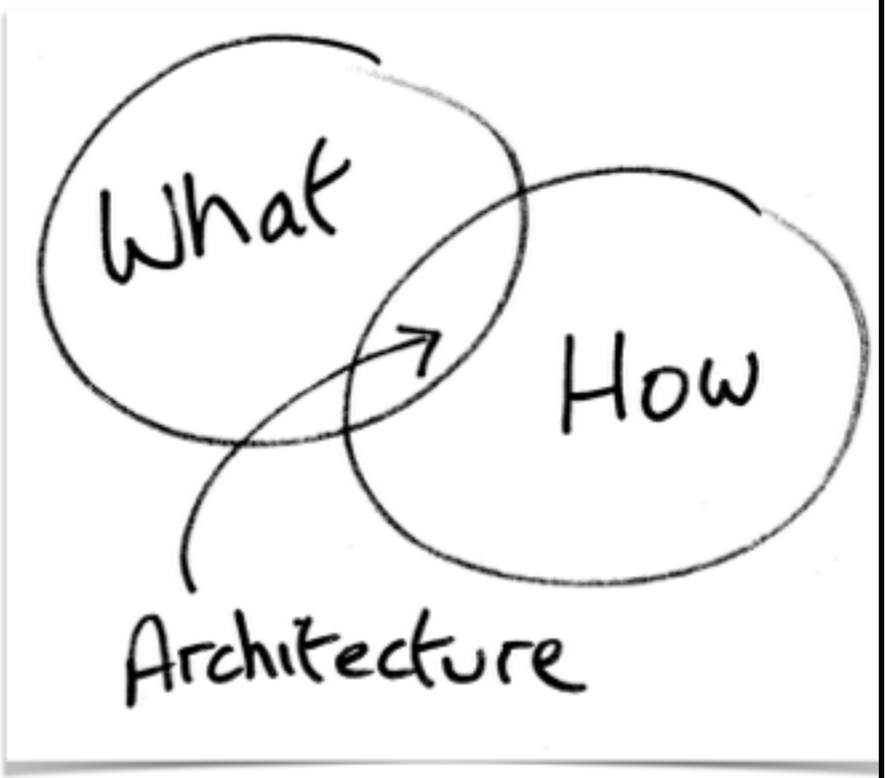
- Hardware environment where the software will be deployed
- Map logical and physical entities


Database Server
Music Player
User Interface
Songs Repository
Songs Repository
Customer Database
Secure WS-*
HTTPS
HTTP/FTP
Payment Service
Cloud

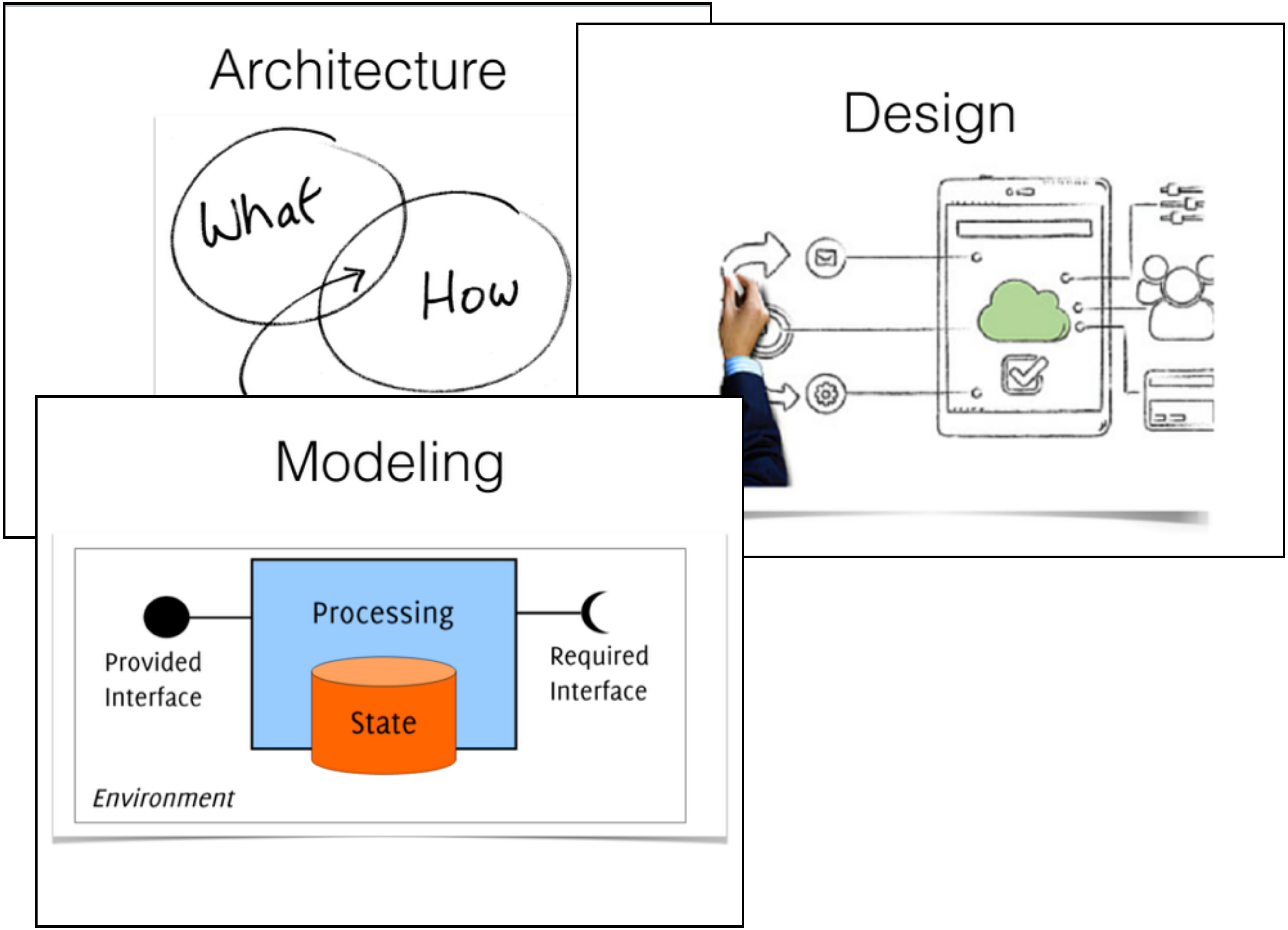
Architecture

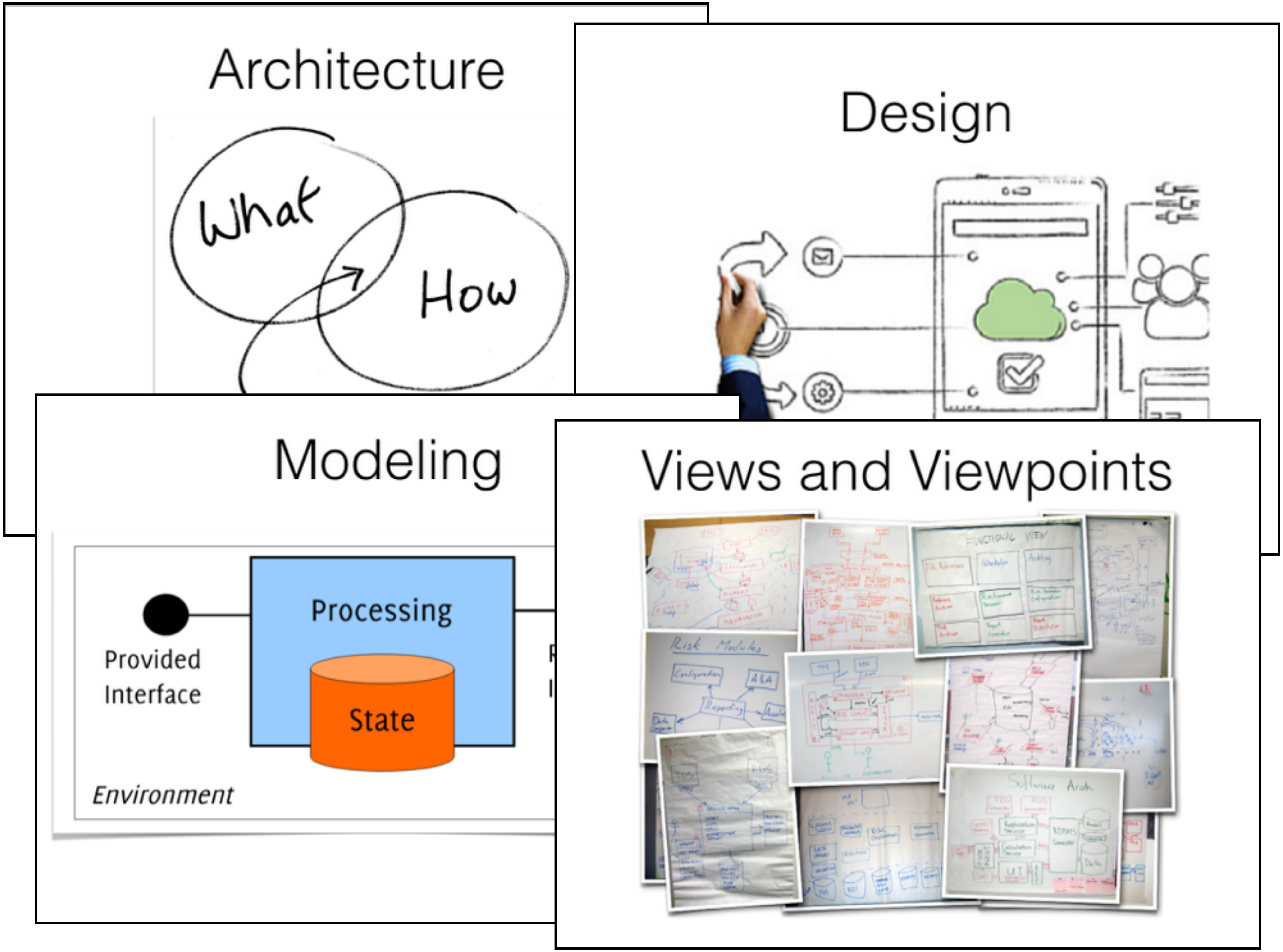


Architecture



Design


Architecture
What
How
Design
Modeling
Processing
Provided
Interface
State
Required
Interface
Environment


Architecture
What
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State
Environment
Views and Viewpoints

References and Readings

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