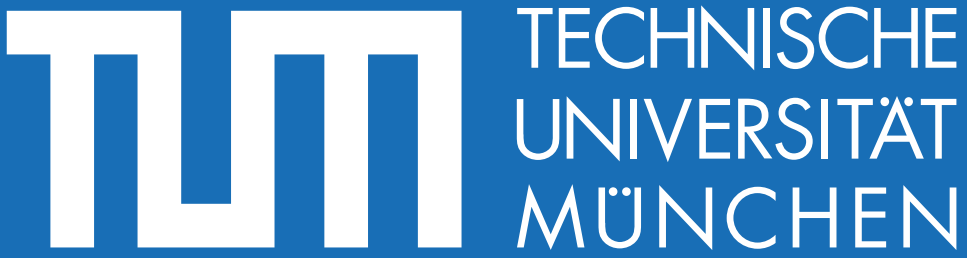
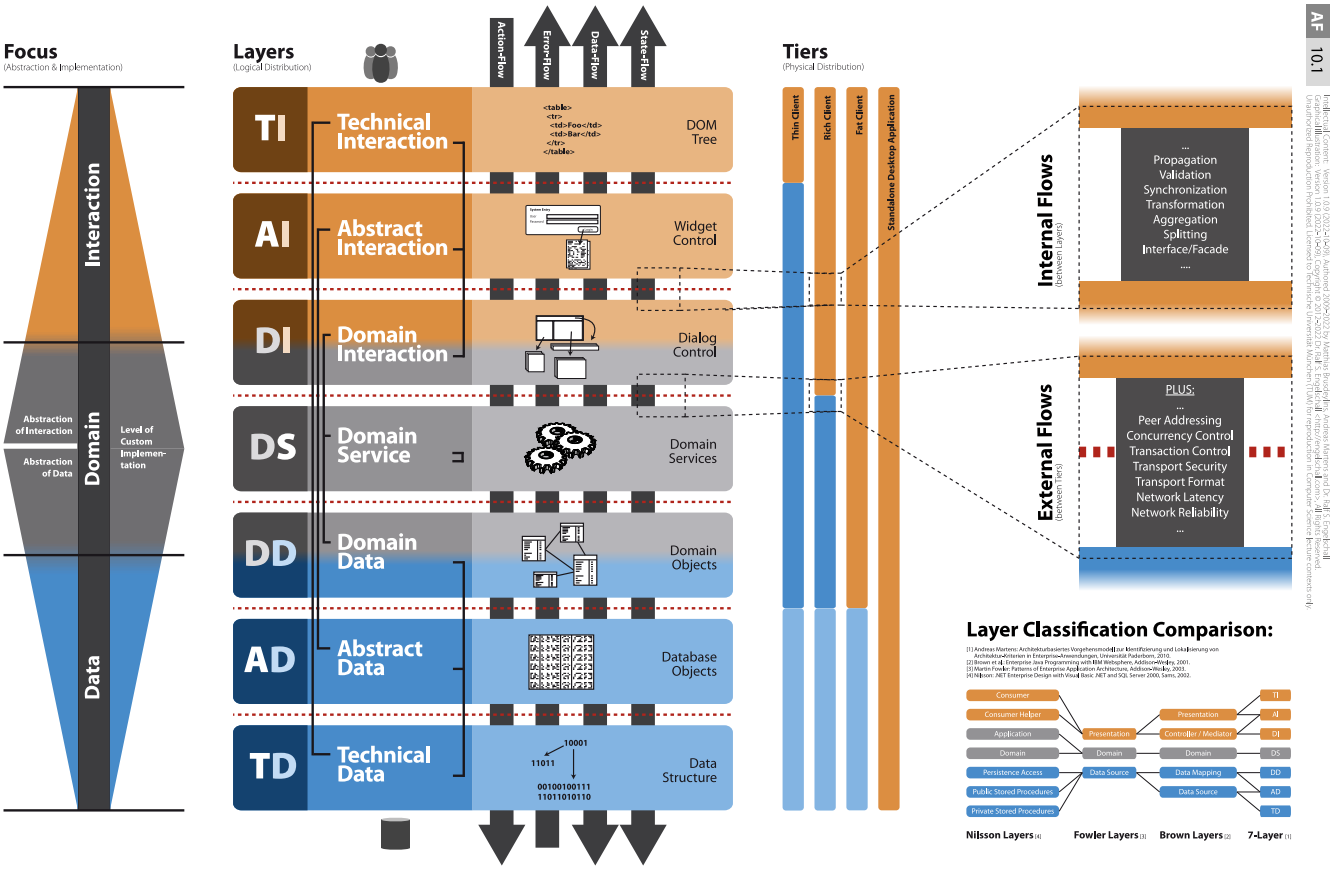


Software Engineering in der industriellen Praxis (SEIP)

Dr. Ralf S. Engelschall

Application Reference Architecture



In an application, it is possible to distinguish 7 logical layers, each grouped in two ways: on the one hand, there are the three sequential layer groups **Technical/Abstract/Domain Interaction**, **Domain Service** and **Domain/Abstract/Technical Data**, on the other hand, there are the three nested layer groups **Technical Interaction/Data**, **Abstract Interaction/Data** and **Domain Interaction/Service/Data**.

In addition, one can distinguish 4 primary flows in an application: the **Action Flow** consequently runs from top to bottom only because all actions at the top are triggered by the user (or neighboring systems); the **Error Flow** consistently runs only in the opposite direction, i.e., from the bottom to the top, because errors, in the worst case, must be reported to the user; the (domain-specific) **Data Flow** and the (technical) **State Flow** run in both directions because data and states have to be persisted as well as displayed.

The abstraction of Interaction/Data in the layers increases from the top/bottom towards the middle, so most of the functional code of an application is written there. For the upper/lower layers, one usually massively relies on Open Source libraries/frameworks.

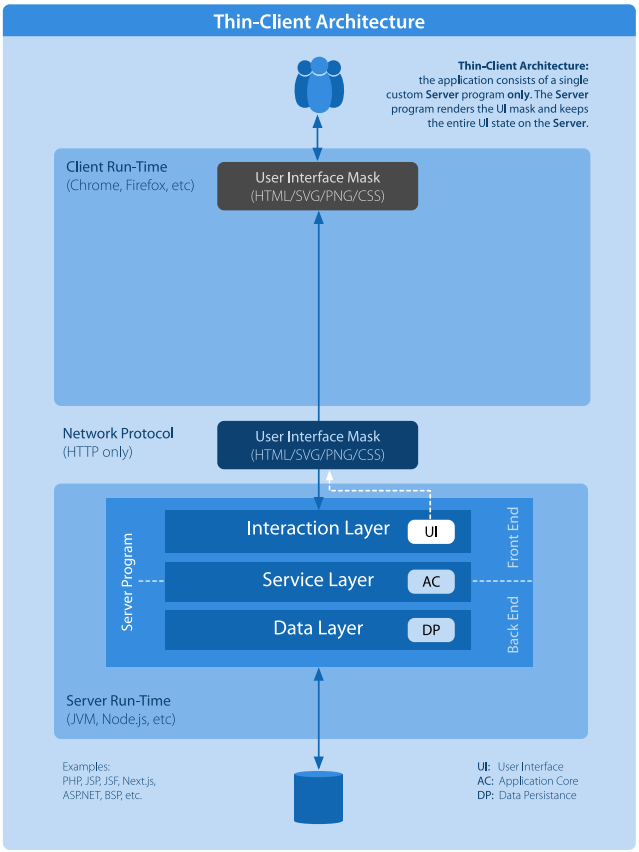
If instead of a logical cut (resulting in an **Internal Flow** between the layers) between two layers, one makes a physical cut (which then results in an **External Flow**), i.e., one distributes the application into single programs on different computers, then the resulting architecture is called according to the scope and responsibility of the client.

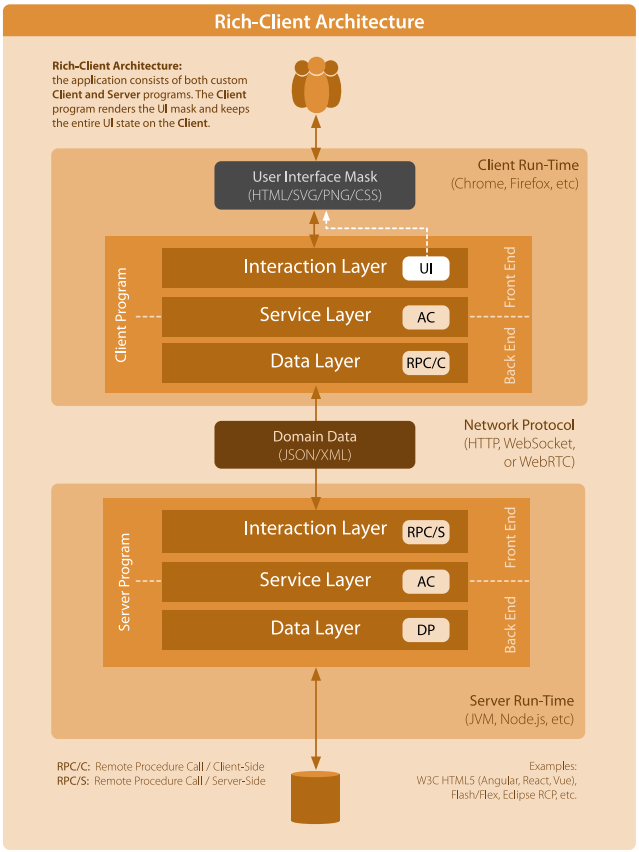
With **Thin Client**, only the **Technical Interaction** is offloaded to the client, while with **Rich Client** the entire user interface (i.e., all three layers **Technical/Abstract/Domain Interaction**) is autonomously offloaded to the client (usually as a so-called “HTML5 Single-Page-Application”), with **Fat Client** there is no more associated server at all, and with the **Standalone** application, there is only one single program.

Questions

- What is the name of the application architecture in which the entire user interface runs autonomously on the client, while the server only provides purely functional services?
- What are the web applications named that implement a **Rich Client** architecture?

Client-Server Architecture





In the **Thin-Client Architecture**, the application consists of a single custom Server program only. This Server program renders the User Interface Mask and keeps the entire state of the User Interface on the Server.

The advantage of this architecture is that the application can be updated very easily. The disadvantage of this architecture is that the user interface reacts sluggishly, and the state of the user interfaces of all clients must be kept on the server, which can make the server a bottleneck.

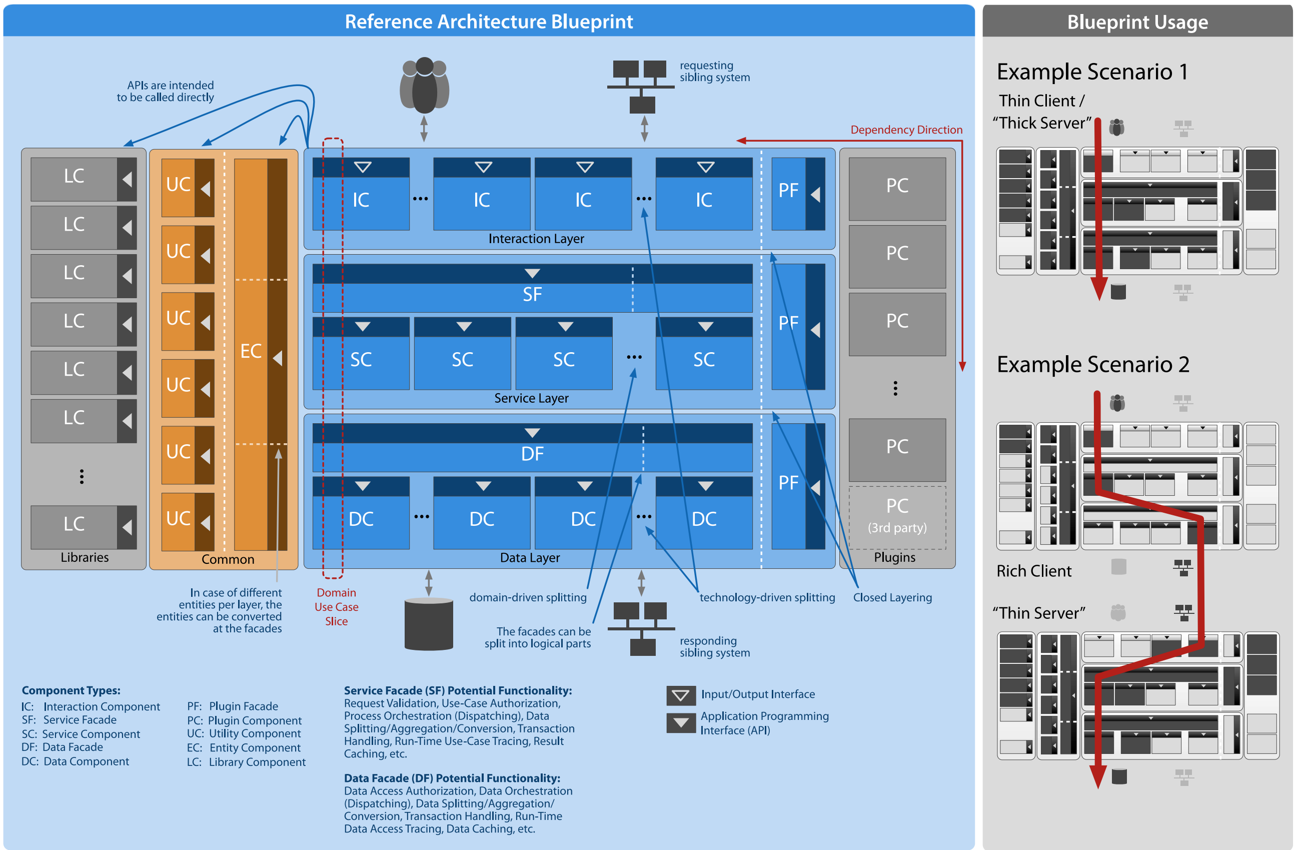
In the **Rich-Client Architecture**, the application consists of both custom Client and Server programs. The Client program renders the User Interface mask and keeps the entire state of the User Interface on the Client.

The advantage of this architecture is that the user interface is highly responsive, only domain-specific data has to be exchanged between the client and the server and the server server becomes less of a bottleneck. The disadvantage of this architecture is that, if necessary, the client has to be updated explicitly via an installation procedure.

Questions

- With which Client Architecture does the User Interface offer the higher responsiveness?

Information System Architecture



A (business) Information System usually follows a stringent component-based reference architecture. This is represented "full blown" and can be arbitrarily "slimmed down."

First, this reference architecture consists of 3 substantial Layers: the **Interaction Layer** with the (technically cut) components, which provide the I/O-based interfaces to the user (User Interface) and/or requesting neighboring systems (via Network interface), the **Service Layer** with the (domain-specifically cut) service components (also called Application Core) and the **Data Layer** with the (technically cut) components that provide the connection to the own database and/or neighboring systems to be queried.

Note that the "docking position" of a neighboring system depends on its roles: if it requests, it docks to the Interaction Layer; if it is queried, it docks at the Data Layer. If it happens to have both roles, it docks twice. The other view is that both the user and the database can be understood as special "neighbor systems."

To connect the N **Interaction Components** (IC) with M **Service Components** (SC) a decoupling **Service Facade** (SF) is usually inserted. For the same reason, there is usually also a **Data Facade**.

The Data Model is offloaded to common **Entity Components** (EC). Together with possibly shared code, both live in one **Common Slice**. Libraries and Plugins are also offloaded to separate slices, but there are two major differences: Libraries are passive and provide their functionality to the application via their interfaces. Plugins are active and control the application in that they hook into the application via Service Provider Interfaces (SPI) of the **Plugin Facades**.

In the application, there has to be only exactly one **Dependency Direction** so that the application (in the opposite direction of the dependencies) can be built cleanly. The reference architecture is usually also instantiated twice in order to design both a Rich Client and an associated "Thin Server" from it.

Questions

- With which layer pattern can in an Information System the **Interaction Components** be decoupled from the **Service Components**?
- In which order are the components of an application built?

ARCHITECTURE FUNDAMENTALS

Reactive System Architecture

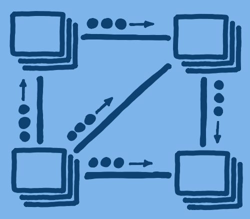
TECHNISCHE UNIVERSITÄT MÜNCHEN

Architecture & Systems

DEF Definition

Reactive System Architecture enables the realization of *Reactive Systems.*

Reactive Systems are in *subordinated interaction* with their *dominating environment*. They *continuously* process *endless data streams* as *small messages*, react at *any time* and respond within *tight time limits*. For this, they continuously *observe* their *environment* and adapt their *behaviour* to the current situation.



Demand & Deliverables

CTX Context

Real-time communication in the context of Digitization, Internet, Internet of Things (IoT), Systems of Engagement, Media and Analytics.

VAL Values

Non-blocking input/output data processing, fast responses within *tight time limits*, and *continuous availability* of the provided services.

REQ Requirements

Services are *elastic* and provide high scalability, and are *resilient* and provide high fault tolerance.

PRP Properties

Services run *fully autonomously, monitor themselves*, and *automatically adapt* to changes in the environment.

Principles

Stay Responsive Always respond in a timely manner.

Accept Uncertainty Build reliability despite unreliable foundations.

Embrace Failure Expect things to go wrong and design for resilience.

Assert Autonomy Design components that act independently and interact collaboratively.

Tailor Consistency Individualize consistency per component to balance availability and performance.

Decouple Time Process asynchronously to avoid coordination and waiting.

Decouple Space Create flexibility by embracing the network.

Handle Dynamics Continuously adapt to varying demand and resources.

Patterns & Paradigms

ARC Architecture

Microservices, Cloud-Native Architecture (CNA), Event-Driven Architecture (EDA).

COM Communication

Asynchronous Communication, Non-Blocking I/O, Sequence, Push, Backpressure, Quality of Service (QoS).

DAT Data

Semantical Event, Small Message, Endless Stream.

STY Style

Functional Programming, Asynchronous Programming.

EXE Execution

Parallelization, Concurrency, Actors, Threads, Thread-Pool, Event-Loop.

INF Infrastructure

Message Queue (MQ), Load Balancer, Reverse Proxy, Service Mesh, Virtual Private Network (VPN).

PRC Processing

Complex Event Processing (CEP), EAI Patterns, Stream Processing (map, flatMap, filter, reduce), Event Sourcing.

ASY Asynchronism

Callback, Promise/Future, Observable, Publish & Subscribe.

Reactive System Architecture enables the realization of **Reactive Systems**. Reactive Systems are in **subordinated interaction** with their **dominating environment**. They **continuously process endless data streams** as **small messages**, react at **any time** and respond within **tight time limits**. For this, they continuously **observe** their **environment** and **adapt** their **behaviour** to the current situation.

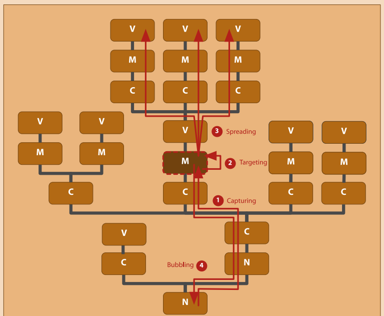
Reactive Systems are primarily used in the context of real-time communication where services are provided, which have to be **elastic** and provide high scalability, and which have to be **reliable** and provide high fault tolerance.

Questions

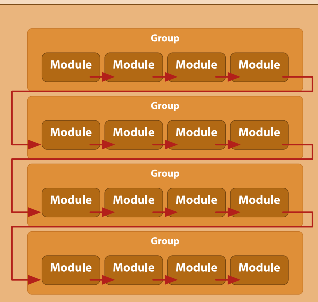
- Which two essential requirements do Reactive Systems fulfill?
- What characterizes Reactive Systems in respect to their data processing?

Component-System Architecture

Component Structure & Dependencies (Dialogs / Services)

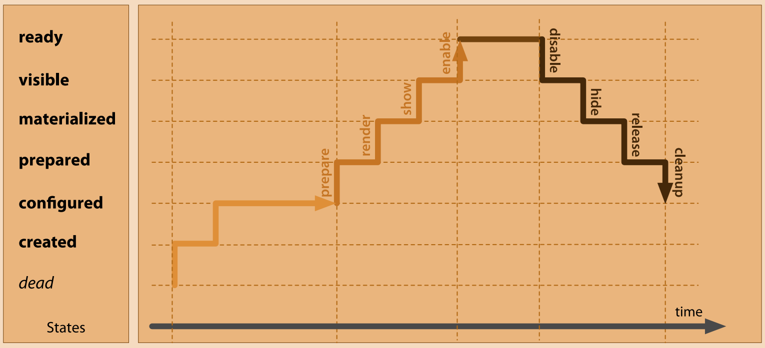


Hierarchical Structure (Dialogs)



Linear Structure (Services)

Component States & Life-Cycle (e.g. Dialogs)



Component Management & Communication

Component Creation & Lookup

Create Components and either establish a (life-cycle-based) dependency hierarchy out of them, or topologically sort them into a (processing-based) dependency linearization. Additionally, allow a flexible path- or identifier-based lookup.

State Definition & Transition

Define one or more distinct Component states and trigger state transitions. The state transitions are performed either directly or hierarchically by ensuring the life-cycle dependencies are always met.

Property Observation & Modification

Provide key/value-based properties which can be read and written and whose value changes can be observed via callbacks. The property value resolution is either hierarchically transitive or direct.

Socket Definition & Plugging

Provide named and unnamed sockets to plug/unplug partial results into/from a result store/queue. The plugging/unplugging on the provider side is realized through custom callbacks. The socket resolution is either hierarchically transitive or direct.

Event Subscription & Publishing

Provide subscription and publishing of event objects. The subscription is realized through custom callbacks and an event is dispatched onto all subscribers either directly or hierarchically in the phases Capturing, Targeting, Spreading and Bubbling.

Hook Latching & Execution

Provide named execution hooks and the latching into those hooks via callbacks. The resolution of the hooks is always direct. The hooks receive an input, optionally allow the catchers to process it and finally send the output back.

Service Registration & Calling

Provide named execution services and the calling of them. The service execution is provided by callbacks. The resolution of the services is either direct or hierarchical.

In order to implement the maxim "Component Orientation" meaningfully in practice, a so-called **Component System** is usually used. Its functionality allows the management and communication of a large number of components and thus the mastering of the overall complexity of an application.

The functionality of a **Component System** usually includes the following essential aspects: **Component Creation & Lookup** for structuring the components, **State Definition & Transition** for the life-cycle of the components, **Property Observation & Modification** for the data of the components, **[Result] Socket Definition & Plugging** for the results of the components, **Event Subscription & Publishing** for the events of the components, **Hook Latching & Execution** for the connection between components and **Service Registration & Calling** for the calls between components.

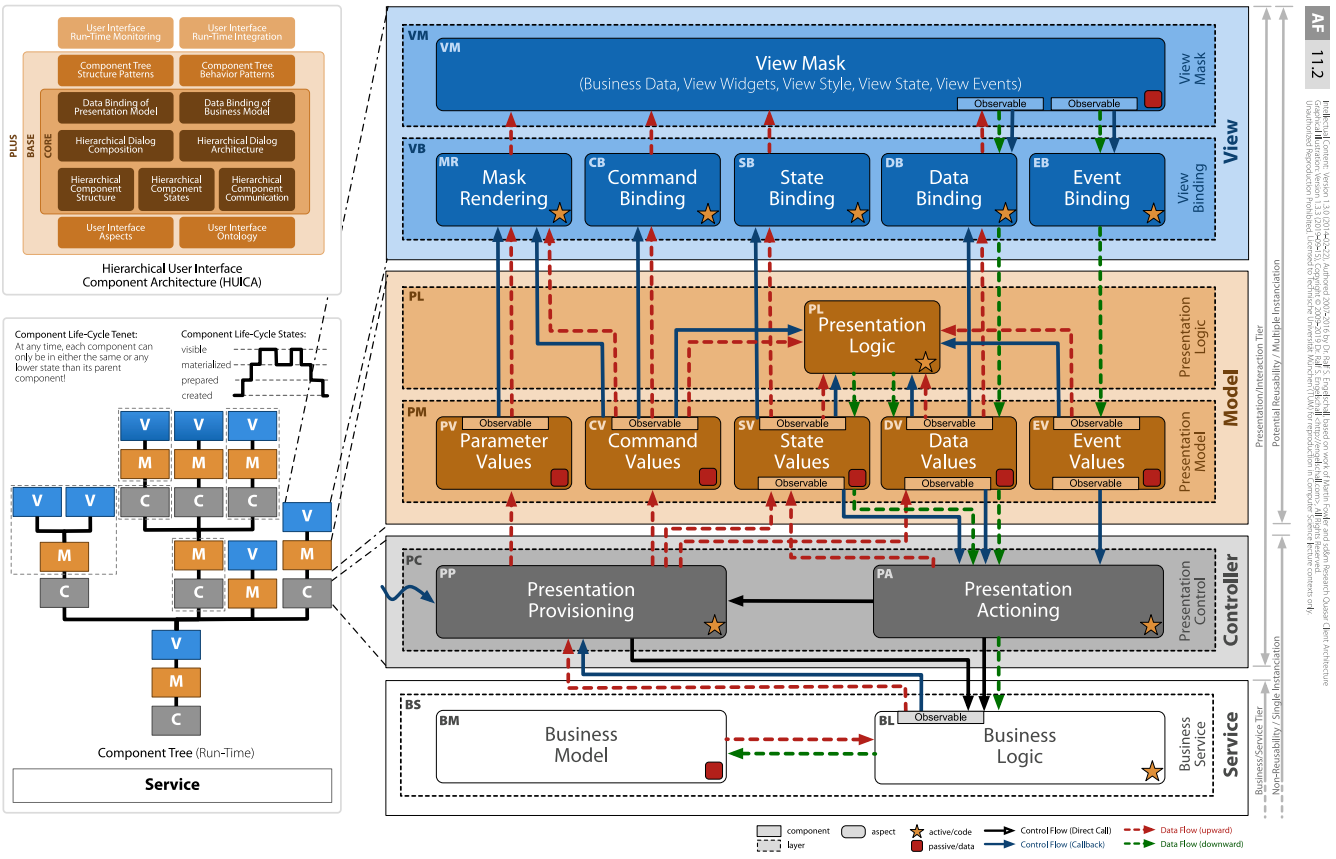
There are primarily two types of component structures and dependencies that a **Component System** supports: a **Hierarchical Structure** for for clients (since user interfaces are inherently hierarchical) and a **Linear Structure** for servers (since the request/response processing is inherently linear).

For the life-cycle of components, a **Component System** usually allows the definition of arbitrary conditions which components can have over the time and which are centrally administered by the **Component System**.

Questions

- How can you master the overall complexity of managing and communicating of a multitude of components at the maxim **Component Orientation**?
- Which two types of component structures are most commonly supported by **Component Systems**?

Client Component Architecture



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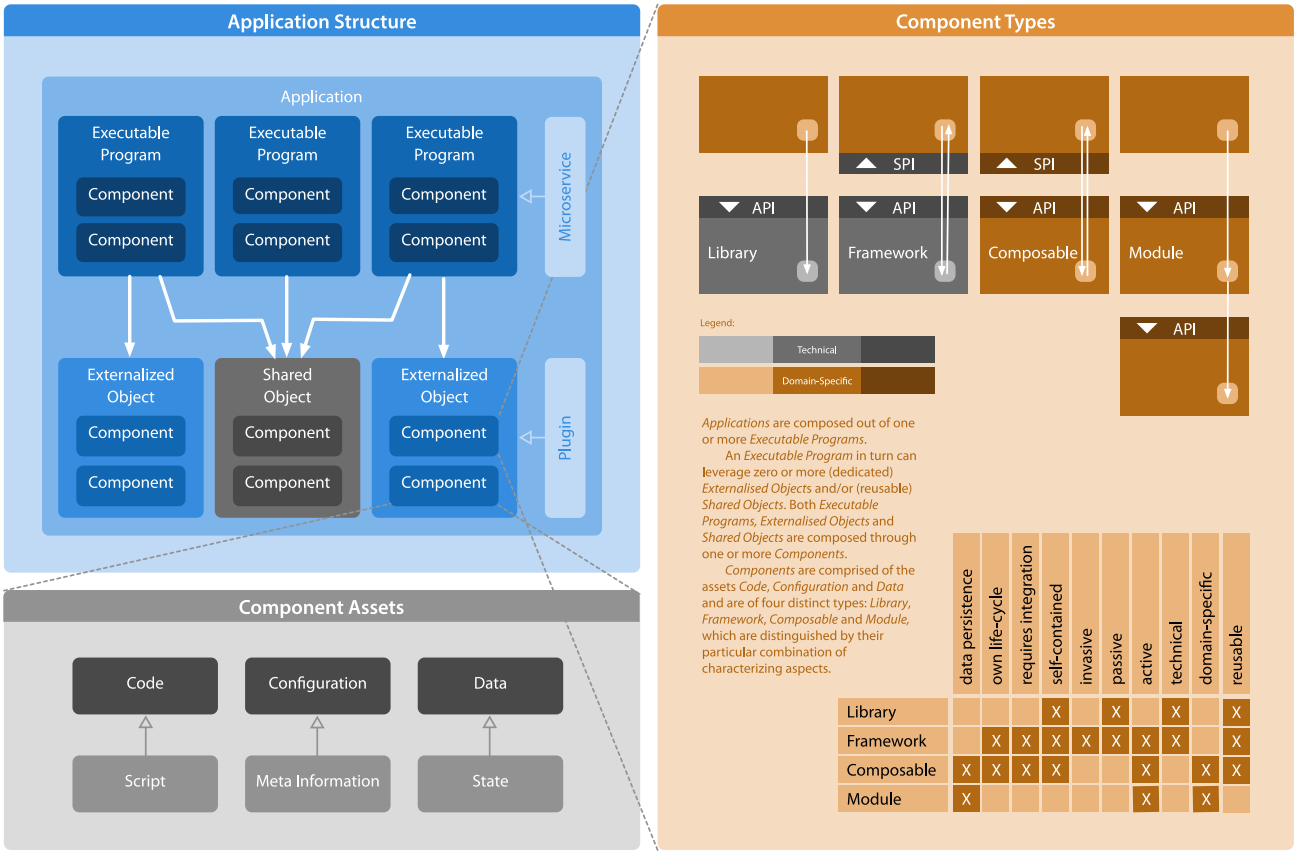
Questions

- FIXME

Application Composition



Applications are composed out of one or more Executable Programs. An Executable Program in turn can leverage zero or more (dedicated) Externalised Objects and/or (reusable) Shared Objects. Both Executable Programs, Externalised Objects and Shared Objects are composed through one or more Components. In a Microservice Architecture, the Executable Programs are called Microservices. In a Plugin Architecture, the Externalised Objects are called Plugins.

There are four distinct types of Components: Library, Framework, Composable and Module. They can be distinguished by their particular combination of characterizing aspects. Most prominently, whether they provide an Application Programming Interface (API) to the consumer of the Component and/or whether they require the consumer of the Component to fulfill some sort of Service Provider Interface (SPI).

Questions

- What is the main difference between a Library and a Framework?