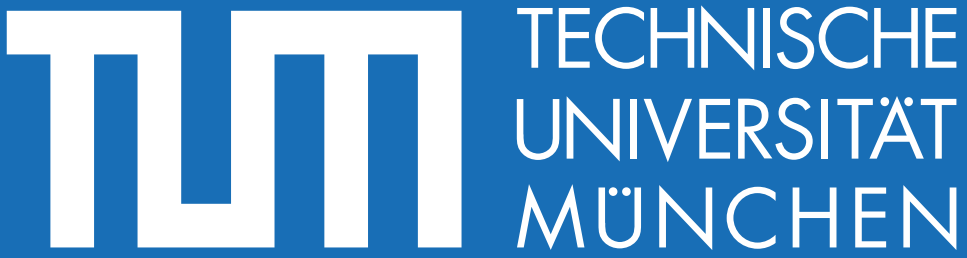
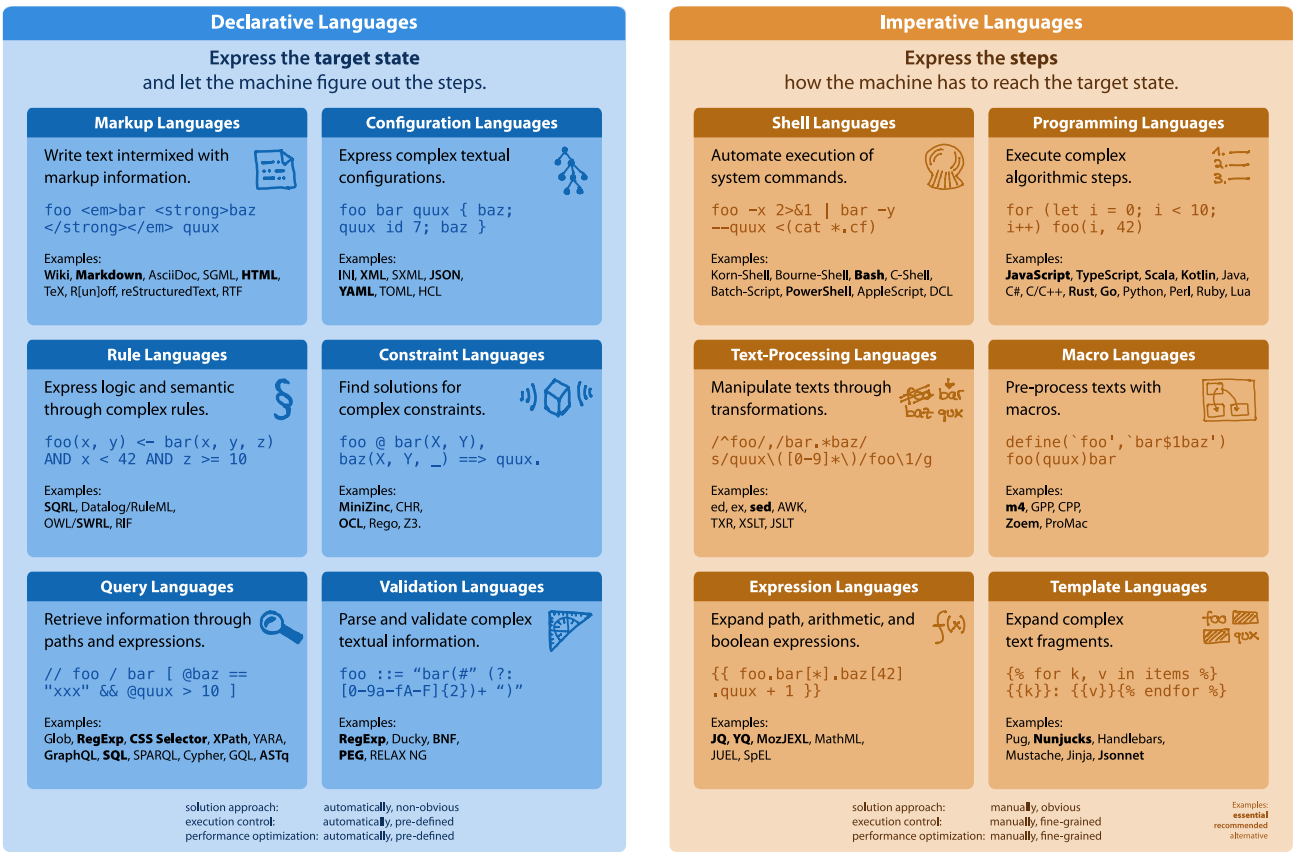


Software Engineering in der industriellen Praxis (SEIP)

Dr. Ralf S. Engelschall

Formal Languages



There are innumerable **Formal Languages**. In a technology stack, usually, almost a dozen such languages are used at the same time. The architect must therefore select them very carefully.

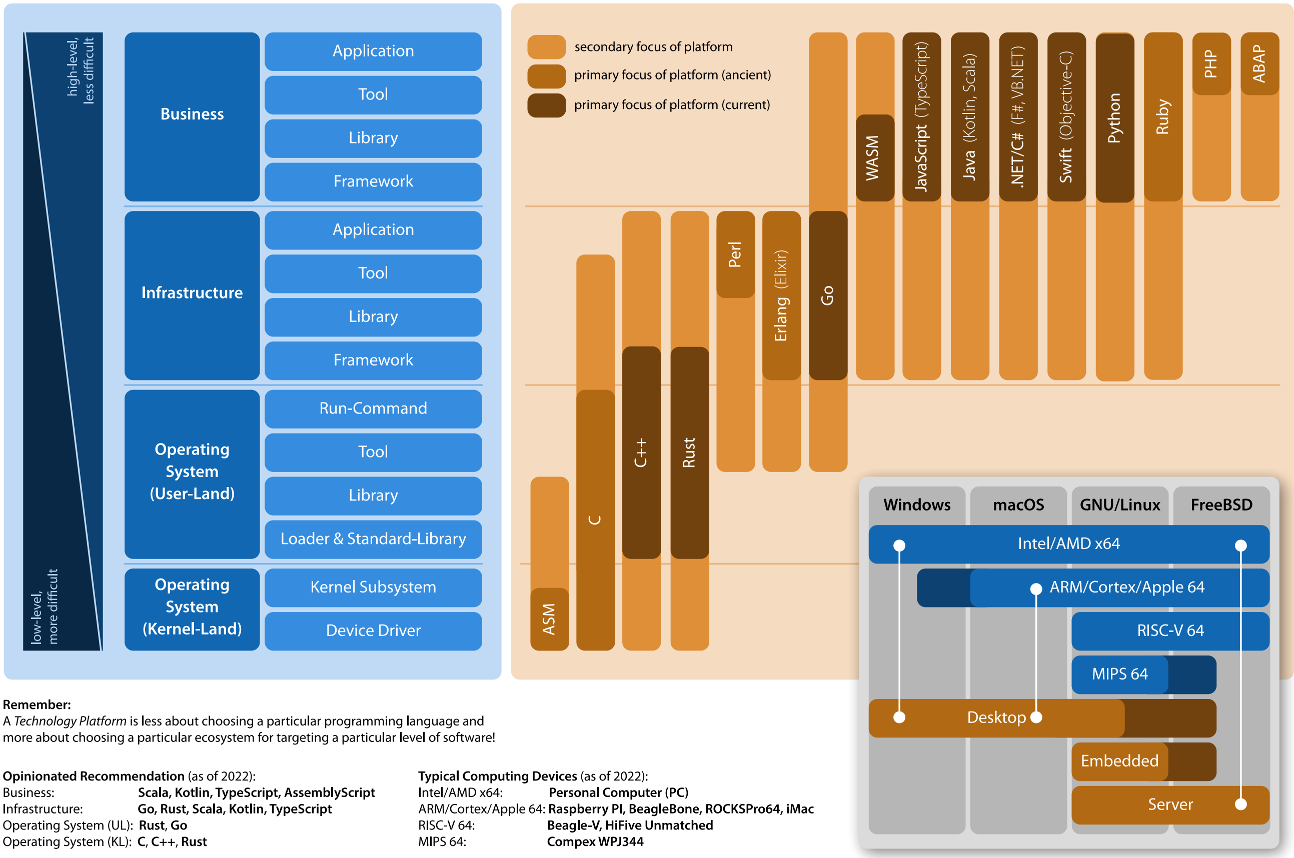
The formal languages can first be divided into **Declarative Languages** and **Imperative Languages**. The former expresses a target state ("WHAT"), the latter expresses the way to get there ("HOW").

Declarative approaches are usually to be preferred to imperative approaches because they leave it to the implementation (and not to the programmer) to find the optimal way. In addition, they permit incremental approaches, where the next step is determined by the particular difference between the current state and the desired target state. This is especially important for recovery in very dynamic and error-prone environments.

Questions

- Into which two classes can **Formal Languages** be divided?

Technology Platforms



Remember:
A *Technology Platform* is less about choosing a particular programming language and more about choosing a particular ecosystem for targeting a particular level of software!

Opinionated Recommendation (as of 2022):
Business: **Scala, Kotlin, TypeScript, AssemblyScript**
Infrastructure: **Go, Rust, Scala, Kotlin, TypeScript**
Operating System (UL): **Rust, Go**
Operating System (KL): **C, C++, Rust**

Typical Computing Devices (as of 2022):
Intel/AMD x64: **Personal Computer (PC)**
ARM/Cortex/Apple 64: **Raspberry PI, BeagleBone, ROCKSPro64, iMac**
RISC-V 64: **Beagle-V, HiFive Unmatched**
MIPS 64: **Compex WPJ344**

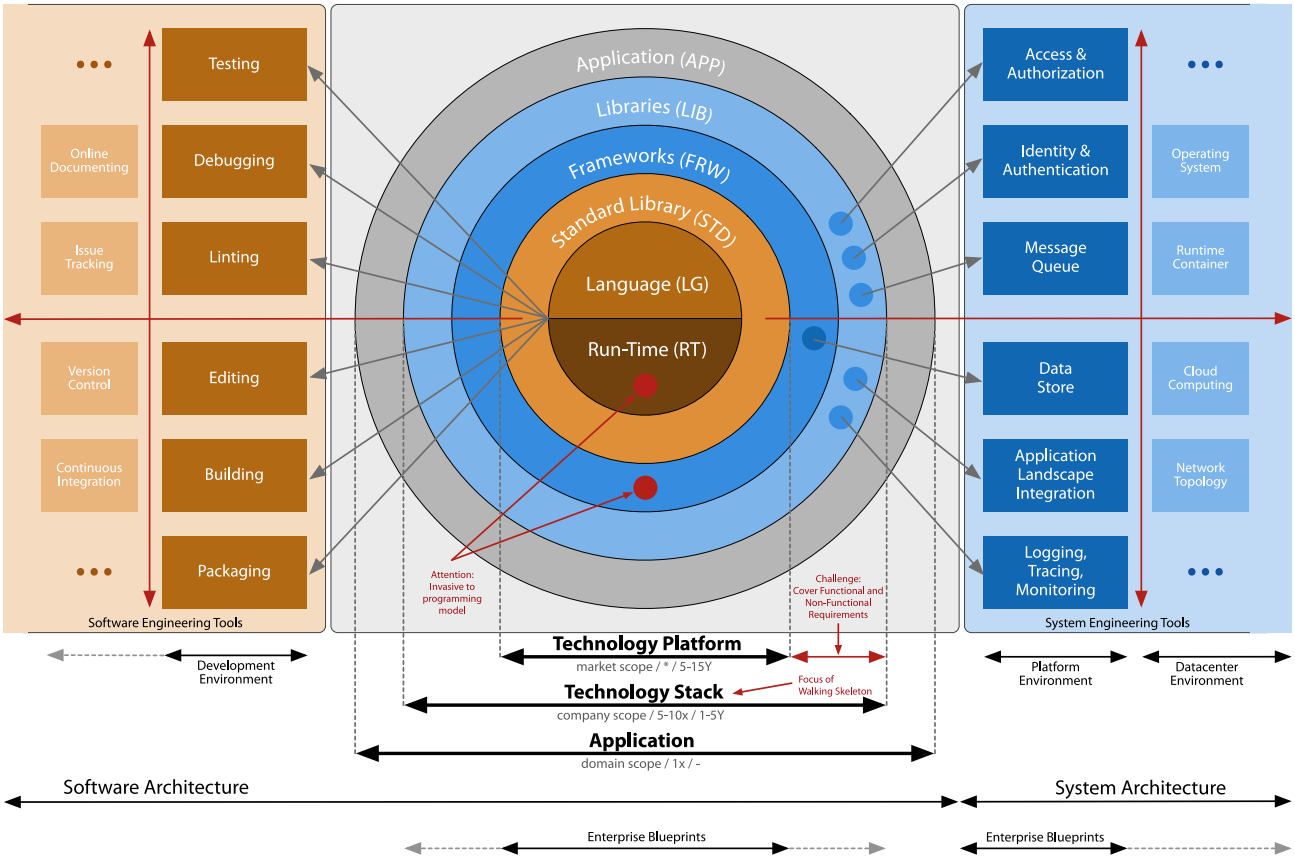
There are various levels of software, ranging from low-level and more difficult (operating system related) to high-level and less difficult (business-logic related).

A Technology Platform is less about choosing a particular programming language and more about choosing a particular ecosystem for targeting a particular kind of software!

Questions

❓ Is the Technology-Platform **Node.js** suitable to implement a Kernel-Subsystem at the level of the operating system?

Technology Stack



A **Technology Platform** consists of a **Language**, an optional **Run-Time** environment and a **Standard Library**. On top of this, **Frameworks** and **Libraries** extend this to a **Technology Stack**, in which with them especially all the prerequisites for the functional and non-functional requirements in the **Application** are achieved.

It has to be noted that the **Run-Time** and the **Frameworks** are usually extremely "invasive" to the programming model and thus can almost never be replaced afterwards. Therefore, with the so-called **Walking Skeleton**, the focus is mainly on the **Technology Stack** to be defined and integrated.

While the **Application** has a functional scope and is implemented only once, a particular **Technology Stack** is usually defined by a company and then reused several times over a period of a few years.

The underlying particular **Technology Platform**, on the other hand, is implemented by a third party for the market, is reused as often as required and must exist for quite a long period of time.

Large companies, therefore, usually stringently define the **Technology Platforms** and **Technology Stacks** in their **Enterprise Blueprints**.

For the **Software Engineering Tools** one should take into account the tools for **Testing**, **Debugging**, **Linting**, **Editing**, **Building** and **Packaging** of the **Development Environment**, because these are usually directly dependent on the particular **Technology Stack**.

The situation is similar for the **System Engineering Tools** of the **Platform Environment**: these require at least the associated **Libraries** in the **Technology Stack**, in order to be addressed during the run-time of the **Application**.

Questions

- What are the three components of a **Technology Platform**?
- Which two additional components make up a **Technology Stack**, compared to the **Technology Platform**?
- Which two components of a **Technology Stack** are most "invasive" to the programming model?

ARCHITECTURE FUNDAMENTALS

Rich-Client Aspects

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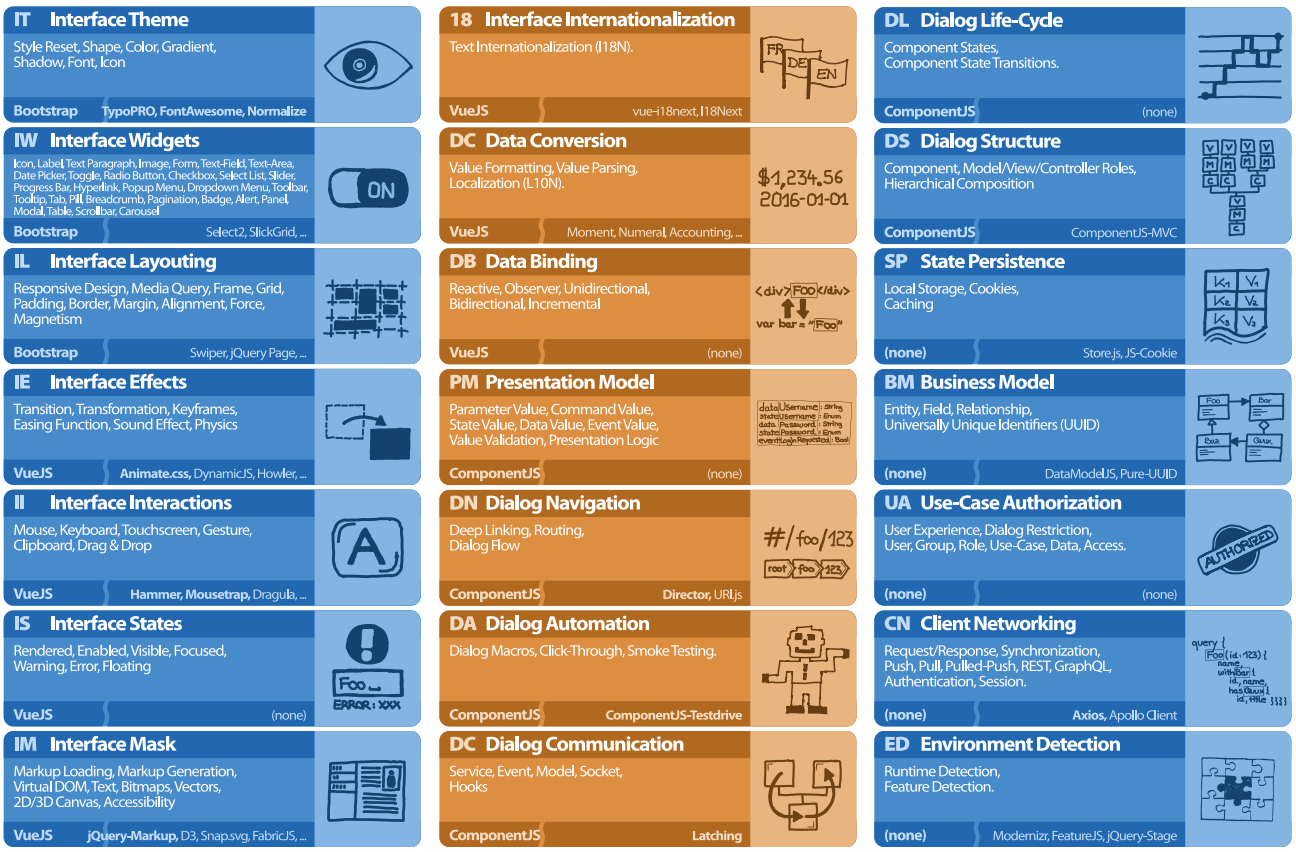
AF 12.5



To define a Technology Stack for a **Rich Client**, 21 **Aspects** have to be considered. Each aspect is covered by at least one **Framework** or **Library**. In practice, each aspect is usually covered by one Framework and zero or more Libraries. The goal always is: to achieve the greatest possible coverage of the aspects with a minimum number of Frameworks and Libraries.

It is advisable to use Open Source Software (OSS) for both Frameworks and Libraries and, if possible, to no own custom implementations, as the effort usually is not in proportion to the benefit. Because all aspects are technical — and not functional — aspects of a user interface.

In the case of a Thin-Client Architecture (instead of a Rich-Client Architecture), a few aspects like **Client Networking** and **Environment Detection** are omitted. All other aspects are still valid, even if, in the case of a Thin-Client Architecture, the frontend (and thus the aspects of the user interface) of the application runs on the server.

Two important aspects deal with the data model: the **Business Model** is a data model that comes directly from the server and is exactly the same in slicing and granularity than the business data model of the server. Its data is synchronized with a **Presentation Model**, which in slicing and granularity is more like the (more technical) data model of the user interface (especially via the aspects **Interface Mask** and **Data Binding**).

Questions

- How does one ensure in a **Rich-Client Architecture** that the numerous technical **Aspects** of a user interface are addressed?
- Which two **Aspects** of a **Rich-Client Architecture** hold the data model and take care of the fact that the data supplied by the server cannot be used directly in the user interface?

ARCHITECTURE FUNDAMENTALS

Thin-Server Aspects

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AF 12.6

ED Environment Detection
Detect the run-time environment, like underlying operating system, execution platform, network topology, feature toggles, etc.
Node | process, syspath

AP Argument Parsing
Parse options and arguments of the Command-Line Interface (CLI) to bootstrap application parameters.
(none) | yargs

CP Configuration Parsing
Load and parse directives from configuration file to bootstrap application parameters.
(none) | js-YAML

PD Process Daemonizing
Detach from the startup terminal and host process in order to run fully independently.
(none) | daemonize2

PM Process Management
(Pre-)fork child processes and/or threads of execution and monitor and control them during the life-cycle of the application.
(none) | cluster, nodemon

CM Component Management
Structure the code into components, instanciate them under run-time and manage them in a stateful component life-cycle.
Microkernel | (none)

CC Component Communication
Provide inter-component communication mechanisms like events, hooks, registry, etc.
Microkernel | Latching

SN Server Networking
Listen to network sockets, accept connections and manage request/response and message communication.
HAPI | hapi-plugin-websocket, ws

PI Peer Information
Determine unique identification and add-on information about the client peer.
HAPI | hapi-plugin-peer, geoip

SH Session Handling
Manage secured per-connection sessions to keep state between communication requests and/or client sessions.
HAPI | YAR

UA User Authentication
Determine and validate the unique identity of the user communicating over the current network connection.
HAPI | JWT, Passport

RV Request Validation
Validate the syntactical and semantical compliance of the requests and sanitize the requests.
HAPI | Joi, DuckyJS

RP Request Processing
Process the request by dispatching execution according to the provided request and determined context information.
HAPI | GraphQL.js

RA Role Authorization
Determine whether the role of the current user is allowed to execute the current request.
(none) | GraphQL-Tools-Sequelize

CN Client Networking
Provide mechanisms to connect to peers over the network and perform request/response and/or publish/subscribe communication.
(none) | Axios, MQTT.js, ws

TS Task Scheduling
Schedule and execute recurring tasks independent of regular I/O operations.
(none) | node-scheduler

ET Execution Tracing
Provide mechanisms for tracing the execution by logging event and measurement information at certain points of interest.
Microkernel | Winston

DA Database Access
Map in-memory domain entities onto data store dependent persistent data structure.
Sequelize | GraphQL-Tools-Sequelize

DC Database Connectivity
Locally or remotely connect the database access layer to the underlying data store.
Sequelize | sqlite3, pg

DS Database Schema
Create, update or downgrade the data schema inside the underlying data store.
Sequelize | (none)

DB Database Bootstrapping
Create, update or downgrade both mandatory bootstrapping and optional domain-specific data inside the underlying data store.
Sequelize | ini

To define a Technology Stack for a **(Thin-)Server**, 21 **Aspects** have to be considered. Each Aspect is covered by at least one **Framework** or **Library**. In practice, each Aspect is usually covered by one Framework and zero or more Libraries. The goal always is: to achieve the greatest possible coverage of the Aspects with a minimum number of Frameworks and Libraries.

It is advisable to use Open Source Software (OSS) for both Frameworks and Libraries and, if possible, to no own custom implementations, as the effort usually is not in proportion to the benefit. Because all Aspects are technical — and not functional — Aspects of a user interface.

It is to be noted that a server usually does not only have the Aspect **Server Networking** (for the connection of the Rich Clients), but also the Aspect **Client Networking**, in order to be able to query other servers.

In addition, it is to be noted that, above all, two important Aspects address security issues: the Aspect **User Authentication** identifies and authenticates the user ("Is the user the one?"). The Aspect **Role Authorization**, on the other hand, before all business processes, checks whether the authenticated user really is authorized to initiate the processes due to his role(s) ("Is the user allowed to do this?").

Questions

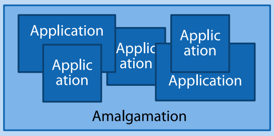
- Why does a **(Thin-)Server** usually have, besides the obvious aspect **Server Networking**, also the aspect **Client Networking**?
- Which Aspect of a **(Thin-)Server** takes care of the Question "Is the user the one"?
- Which aspect of a **(Thin-)Server** takes care of the question "Is the user allowed to do this"?

Software Deployment

AMA Bare Amalgamation

Manually deploy all applications into a single, shared, and unmanaged filesystem location. Dependencies are resolved manually. Examples: Windows Fonts, Unix 1990th /usr/local.

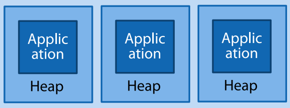
Pro: simple deployment
Con: incompatibilities, hard uninstallation



UHP Unmanaged Heap

Manually deploy all applications into multiple, distinct, and unmanaged filesystem locations. Dependencies are resolved manually. Examples: macOS *.app, OpenPKG LSYNC.

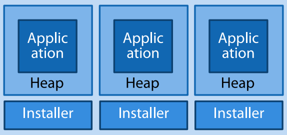
Pro: simple deployment, easy uninstallation
Con: no repair mechanism



MHP Managed Heap

Let individual installers deploy applications into multiple, distinct, and managed filesystem locations. Dependencies are manually resolved or bundled. Examples: macOS *.pkg, Windows MSI, InnoSetup.

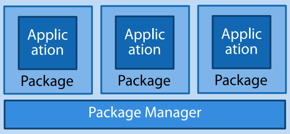
Pro: easy uninstallation, repairable
Con: requires installer, diversity, no dep.



PKG Managed Package

Let a central package manager deploy all applications into a single, shared, and managed filesystem location. Dependencies are automatically resolved. Examples: APT, RPM, FreeBSD pkg, MacPorts, Gradle, NPM.

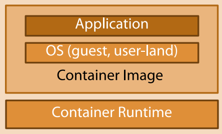
Pro: easy uninstall., repairable, dependencies
Con: P.M. pre-installation, P.M. single instance



CON Container Image

Bundle an application with its stripped-down OS dependencies and run-time environment into a container image. Examples: Docker/ContainerD, Kubernetes/CRI-O, Windows Portable Apps.

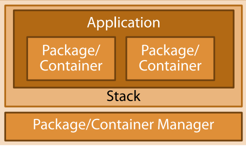
Pro: independent, simple deployment
Con: fewer variations, no dependencies



STK Package/Container Stack

Establish an application out of multiple Managed Packages. Examples: OpenPKG Stack, Docker Compose, Kubernetes/Kompose, Kubernetes/Helm.

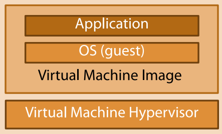
Pro: independent, flexible
Con: overhead



VMI Virtual Machine Image

Bundle an application with its full OS dependencies and run-time environment into a virtual machine image and deploy and execute this on a hypervisor. Examples: VirtualBox, VMWare, HyperV, Parallels, QEMU.

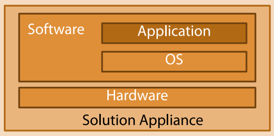
Pro: all-in-one, independent
Con: overhead, sealed, inflexible



APP Solution Appliance

Bundle an application with its full OS dependencies, run-time environment and underlying hardware. Examples: AVM Fritz! Box, SAP HANA.

Pro: all-in-one, independent
Con: expensive, sealed, inflexible



During **Software Deployment**, an **Application** is installed on a file system for execution. With the **Bare Amalgamation**, the files are copied into a central directory (e.g., Windows `C:\Windows\system32`). This is easy to realize but makes the clean removal later on very hard.

With **Unmanaged Heap**, each application is copied into a separate directory (e.g., macOS `*.app`). This is very easy to realize and also allows easy removal. But one still has no repair possibilities. With **Managed Heap**, an own installer is required for each application, among other things, to get repair possibilities (e.g., Windows MSI).

With **Managed Package**, a central Package Manager is used, which standardizes the administration (e.g., DPKG/APT or RPM). It also allows the resolving of dependencies. If, on the other hand, one wants to make the application more independent of the operating system and install it as a shielded unit, the **Container Image** deployment offers itself (e.g., Docker). This is where the application is bundled together with all its dependencies and a part of the operating system.

To be more flexible, one can keep the **Managed Packages** or **Container Images** very small and instead define an application through an entire **Package/ Container Stack** (e.g., Docker Compose).

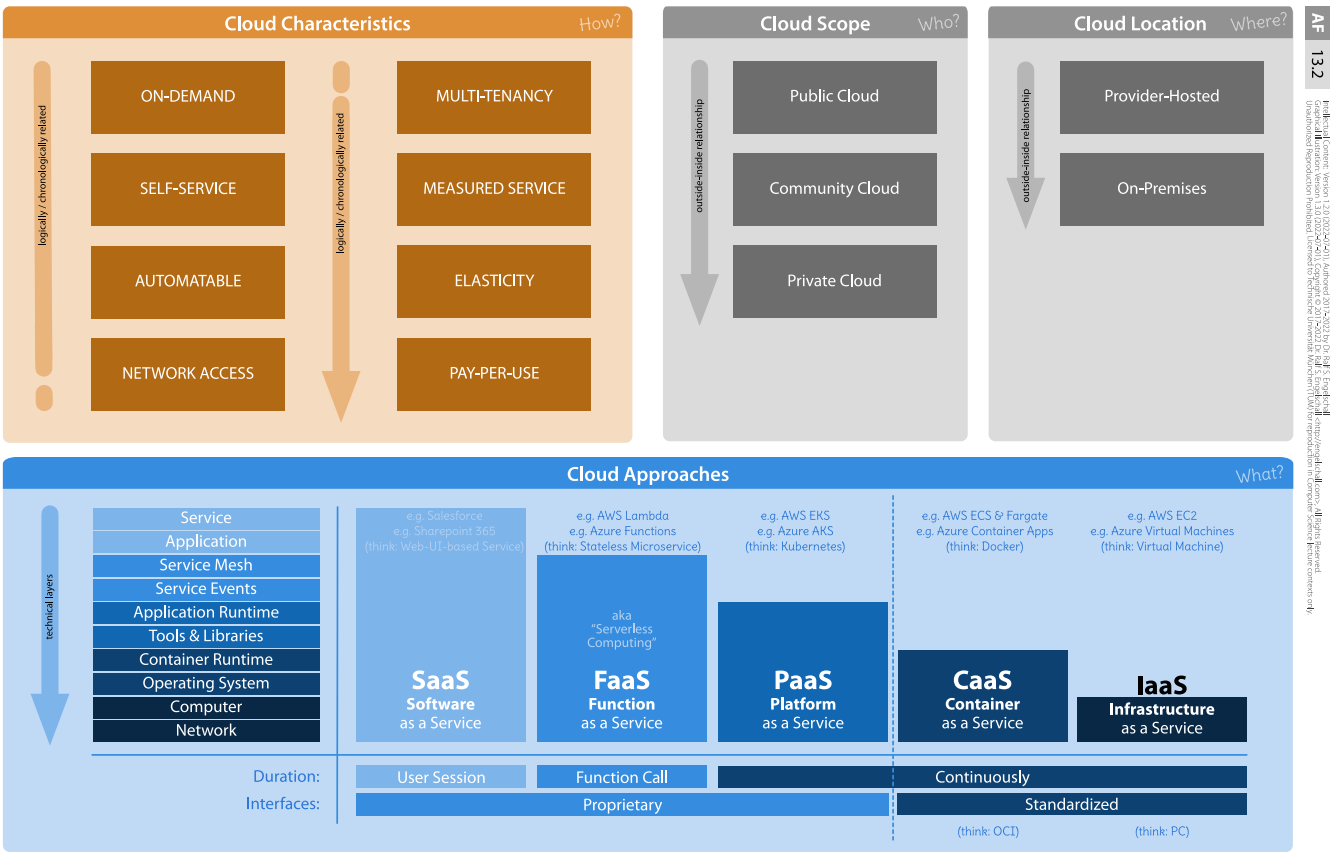
If one needs more shielding, a **Virtual Machine Image** offers itself. Here the application is bundled with all its dependencies and the complete operating system and is installed on a virtual machine (e.g. ORACLE VirtualBox). As the maximum expansion level, the application can be installed as a **Solution Appliance**, where the application, its dependencies, the associated operating system, and the underlying hardware are bundled into one total solution (e.g., SAP HANA).

In practice, the various approaches occur mainly in combined form. A **Container Stack** consists of **Container Images**. These, in turn, are built by installing dependencies via **Managed Packages**, and the application itself as an **Unmanaged Heap**, into the container. The **Managed Packages**, beforehand during packaging, are created with **Bare Amalgamation** steps.

Questions

? Which type of **Software Deployment** bundles and installs an application with all its dependencies and part of the operating system?

Cloud Computing Resources



Cloud Computing has four essential dimensions. The first dimension **Cloud Characteristics** ("How?") describes the eight characteristics of how a resource provisioning must happen in order for the provisioning to be considered as **Cloud Computing**: **On-Demand**, **Self-Service**, **Automatable**, **Network-Access**, **Multi-Tenancy**, **Measured Service**, **Elasticity** (aka Scalability), and **Per-Per-Use**.

With these characteristics, in the second dimension, there are various **Cloud Approaches** ("What?"), which specify what is provided: for **Infrastructure as a Service (IaaS)**, only **Network** and a **Computer** is provided, usually a virtual machine. With **Container as a Service (CaaS)** additionally a (Host) **Operating System** and a **Container Run-Time** are provided.

For **Platform as a Service (PaaS)**, additional surrounding **Tools & Libraries** and an **Application Run-Time** are provided; with **Function as a Service (FaaS)** additionally external **Service Events** and a **Service Mesh** and for **Software as a Service (SaaS)** the **Application** and the its (functional) **Service** are additionally provided.

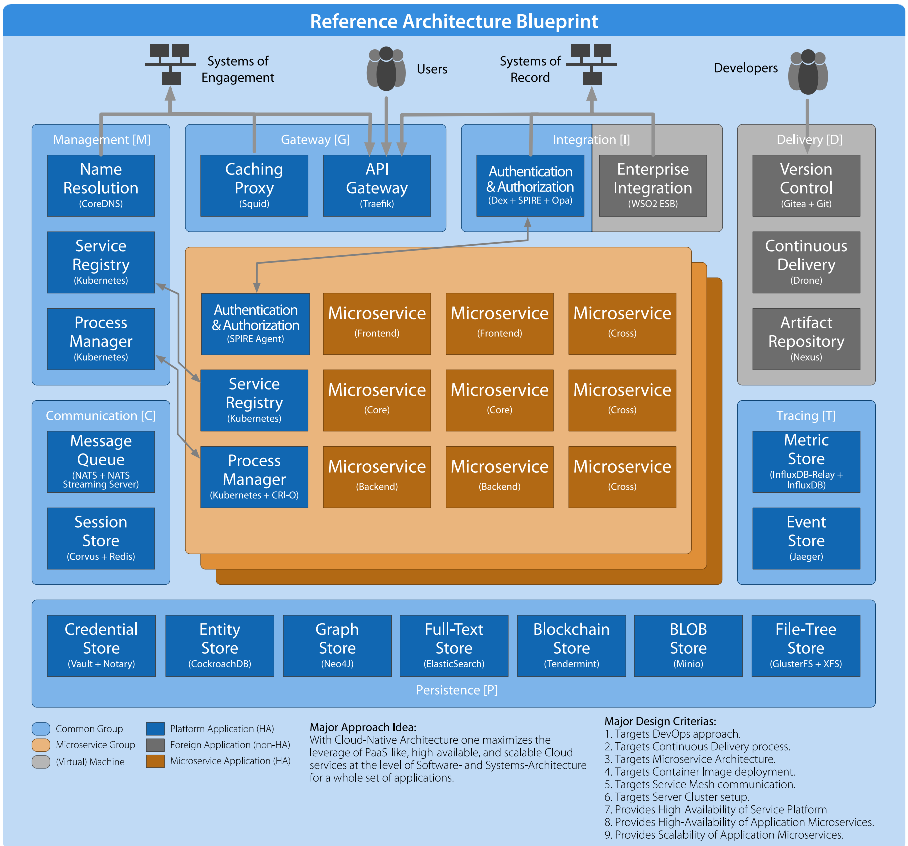
The third dimension **Cloud Scope** ("Who?"), states for whom the resources are provided: **Public Cloud** for public Cloud Computing, **Community Cloud** for Cloud Computing of a closed group of organizations, and **Private Cloud** for Cloud Computing of a single organization.

Finally, the fourth dimension **Cloud Location** ("Where?"), states where the resources are physically provided: **Provider-Hosted** means at an external provider, **On-Premises** means locally at the using organization.

Questions

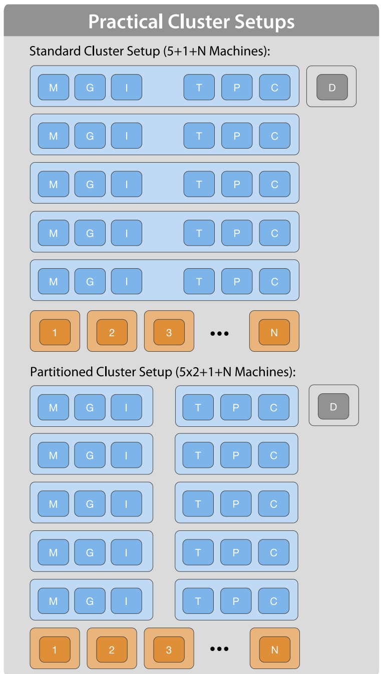
- List at least 5 of the 8 **Cloud Characteristics** that a resource provisioning must fulfill for it to be considered **Cloud Computing**!
- In which **Cloud Approach** is only **Network** and **Computer** provided?

Cloud-Native Architecture



CNCF Cloud-Native Definition 1.0

Cloud-native technologies empower organizations to build and run scalable applications in modern, dynamic environments such as public, private, and hybrid clouds. Containers, service meshes, microservices, immutable infrastructure, and declarative APIs exemplify this approach. These techniques enable loosely coupled systems that are resilient, manageable, and observable. Combined with robust automation, they allow engineers to make high-impact changes frequently and predictably with minimal toil.



In **Cloud-Native Architecture**, applications are developed, installed and operated in such a way that the advantages of **Cloud Computing** are maximized and, in particular, that all infrastructure services are provided by a central **Service Platform**.

In practice, this ideally means the combination of an agile **DevOps** approach, an end-to-end **Continuous Delivery** process, a flexible **Microservice** software architecture, the use of a stable **Container Image** based software deployment, the use of a **Service Mesh** for internal Microservice communication, and the use of a **Server Cluster** for scaling the Microservices.

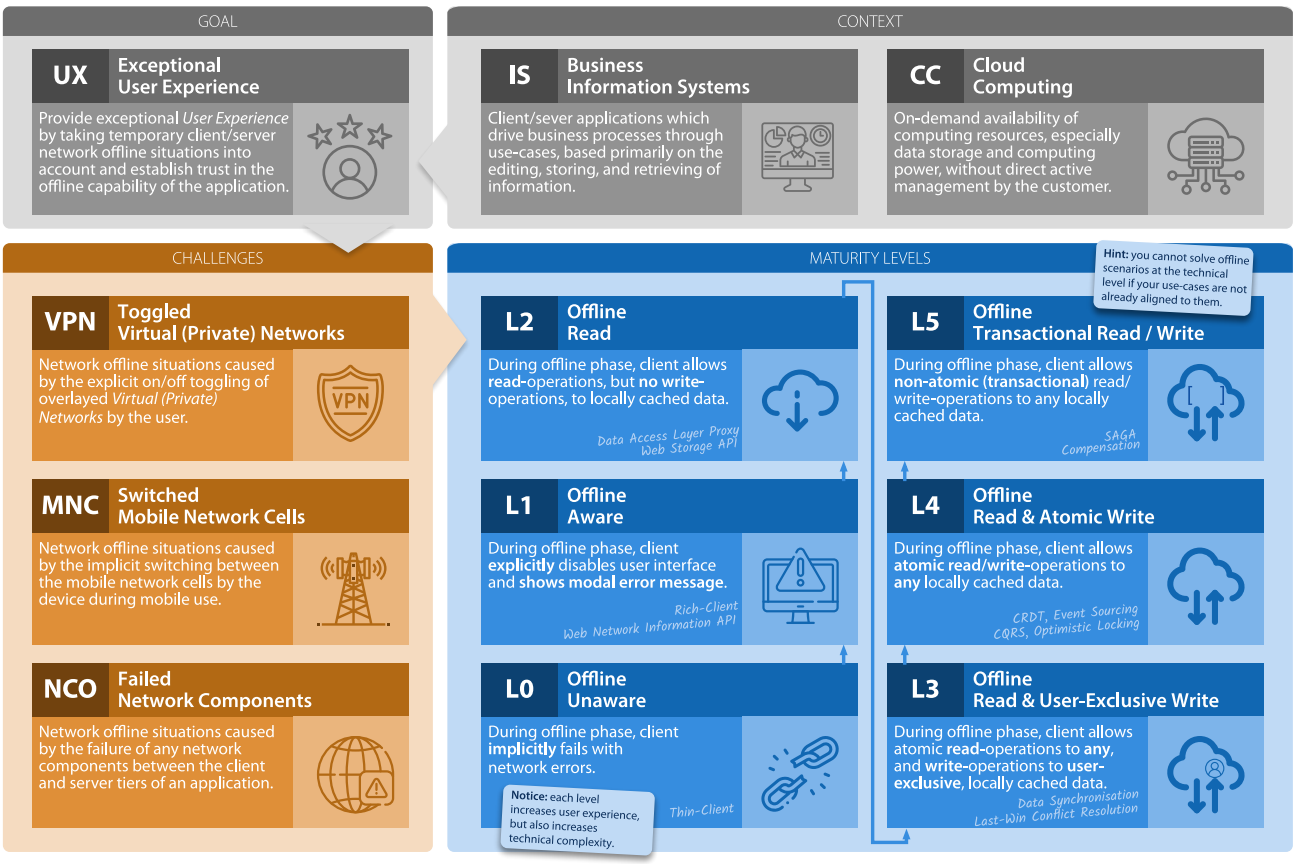
The **Service Platform** is divided into the 7 service areas **Management**, **Gateway**, **Integration**, **Tracing**, **Persistence**, **Communication** plus **Delivery**, which are usually partitioned in a failsafe 5+1 or alternatively in a partially partitioned form on 5x2+1 machines. The Microservices of the application are installed on the **Service Platform** on separate machines.

In a **Cloud-Native Architecture**, it comes down to achieving **High Availability** and **Scalability** for both the services of the platform as well as for the Microservices of the application.

Questions

- On which two essential aspects is the **Cloud-Native Architecture** based?
- What does the **Cloud-Native Architecture** offer to the **Microservices** of an application?

Offline Capability



Offline capabilities can be essential for an exceptional User Experience of client/server-based Business Information Systems in the context of Cloud Computing. The challenges for the temporary network offline situations include toggled Virtual Private Networks (VPN), switched mobile network cells, and failed network components.

In offline scenarios, during an offline phase, an application can support a particular maturity level: At **Offline Unaware**, the client implicitly fails with network errors; At **Offline Aware**, the client explicitly disables user interface and shows modal error message; At **Offline Read**, the client allows read-operations, but no writeoperations, to locally cached data; At **Offline Read & User-Exclusive Write**, the client allows atomic read-operations to any, and write-operations to userexclusive, locally cached data; At **Offline Read & Atomic Write**, the client allows atomic read/write-operations to any locally cached data; At **Offline Transactional Read / Write**, the client allows non-atomic (transactional) read/ write-operations to any locally cached data.

Questions

- Why can offline capability of applications be crucial in the context of Cloud Computing?