Tutorial

Microservices

– Introduction, Challenges, Patterns, and Applications –

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Agenda

Microservices – Introduction

Motivation – A common scenario for a web application

Online shop system with basic functionalities:

- Search for products *(e.g. by name and/or category)*,
- view product details *(including pictures etc.)*,
- purchase products *(place in basket, proceed to checkout)* and
- submit and view product reviews.

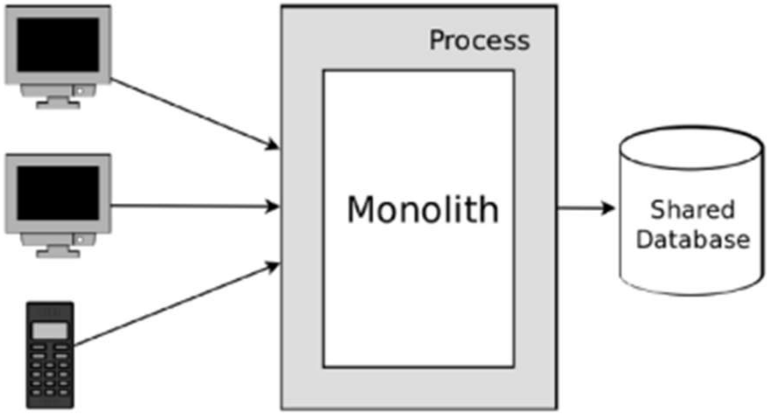
Typical Requirements:

- *Interoperability:* Support a variety of different clients
  (web browser, mobile applications etc.)
- *Maintainability:* Enable frequent and rapid changes
- *Scalability:* Handle sudden increases in user activity
- *Availability:* Minimise downtime *(= financial loss)*

→ Traditional Approach: *Monolithic Architecture*

Microservices – Introduction

Monolithic Architecture – The traditional approach to web applications



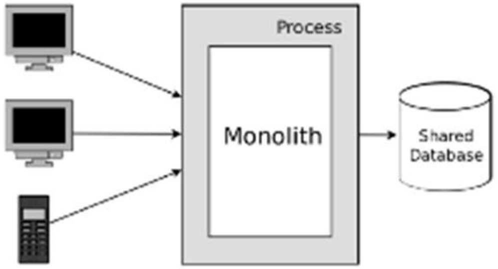
Properties:

- Single process
- Single database

Advantages:

- Easy development
  (for example, communication via simple method calls)
- Easy deployment
  (deployment of a single artefact)
- Application as a whole is scalable
  (via load balancer)

Microservices – Introduction
Monolithic Architecture – Challenges



Scenario: The shop is very successful and the project grows steadily

- Number of components and LOC increases as more features are added
- More project members are required for development, QA, design etc.

Challenges:

- Communication overhead between project members
- Decrease in development speed due to increased complexity
- Deployments (and updates) become less frequent

→ **Idea: Limit responsibilities** of individual project members to **individual components** instead of entire monolith *(e.g. by creating smaller teams).*

Microservices – Introduction

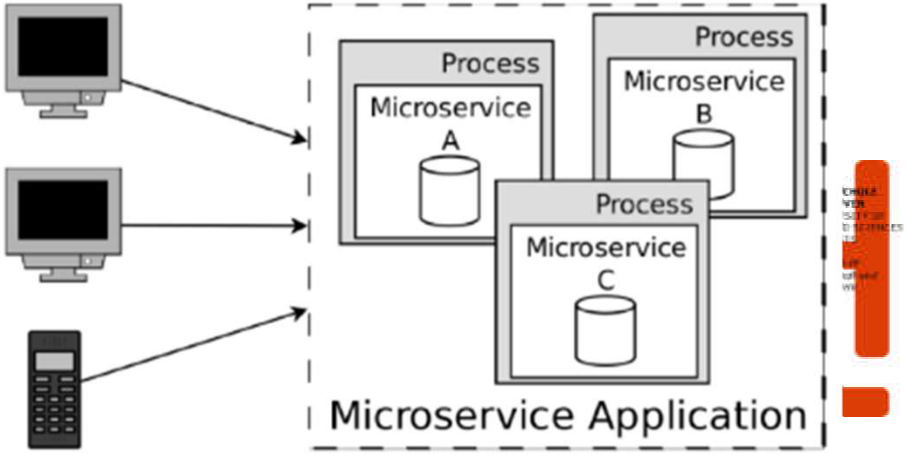
Microservice Architecture – Decomposing the Monolith

Concept: Decompose complex applications into smaller units
(usually single tasks or even subtasks)

Properties of a Microservice:

- Self-contained unit providing its on persistence layer etc.
- May be deployed to an arbitrary number of processes
- Clearly defined scope of responsibility *(loose coupling; high cohesion)*
- **Owned by a single team**
  (responsible for development [and operation])

→ **Motto:** *"You build it, you run it!"*



Microservices – Introduction

Microservice Architecture – What is the difference to a SOA?

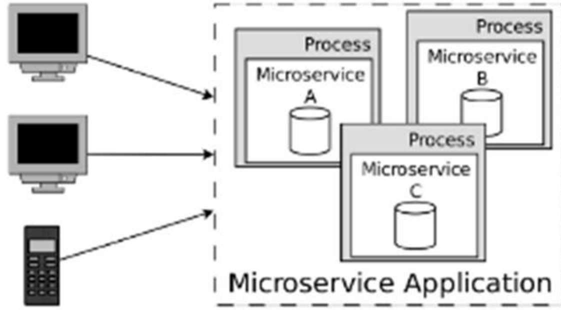
Microservices are considered a **specialisation of SOA**.

Both are “service-based architectures”

- Microservices introduce additional constraints to SOA:
  - All services must be **deployable independent** from one another.
  - **Size and domain** of a microservice are **limited**
    (no limitations in SOA – SOA services are usually relatively coarse-grained).
  - Every service runs in its **own process** and contains its **own storage**.
  - No need for an ESB, services **handle communication individually**.
- A SOA can be comprised of or integrate with multiple microservices.

Microservices – Introduction

Microservice Architecture – Advantages



Advantages:

- Each microservice can be **deployed and scaled independently**
- Ownership by a single, small team *(developer, designer, [administrator] …)* **reduces communication overhead** among project members
- Small size & limited scope allow for **easy replacement** of individual services
- Rapid development lifecycle promotes **continuous integration**

→ **But:** These advantages can quickly turn into challenges!

Consequence:

Microservices require **strict adherence** of developers to guidelines provided by architects to **prevent introduction of dependencies**.

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Microservices – Tasks and Challenges

Decomposition – The art of dividing and decoupling

Problem with Monoliths:

- Refactoring is necessary to conform to initial architectural vision

More: See Keynote Andreas Hausotter

Benefit of Microservices:

- Small enough to replace entire service in case of major changes
- Keeps code rot in check due do limited number of LOC per service

Challenges:

- **Small enough, but not too small**
  Choosing the correct size for a microservice is important to prevent the overhead from outweighing the benefit.
- **Durable Interfaces**
  Replacements should not introduce changes to provided interfaces as this would incur additional changes in other services.

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Microservices – Tasks and Challenges

Deployment – What is deployed when and how frequently?

Problem with Monoliths: Fixed deployment cycles which may lengthen over time

Benefit of Microservices:

More: See Keynote Andreas Hausotter

- No fixed deployment schedule *(e.g. once per month or quarter)*
- Teams may **deploy frequently and independently** from one another
- New features and changes can be **shipped more rapidly**

Challenges:

- **Loose Coupling:** A change in one microservice should not *(or in practice very rarely)* require a change in another microservice.
- **Availability and Continuous Integration (CI):** There must always be a fully tested version available to all other services, while the diversity of deployed versions should be kept low.

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Microservices – Tasks and Challenges

Technology Heterogeneity – Advantages and Challenges

Advantages of Microservices:

- Every services appears as a **black box** to other services.
- Teams can always use the “best tool for the job” within their own service. *(e.g. data storage paradigm, programming language, libraries, build chain)*

Challenges:

- Overall complexity increases *(e.g. licensing, architecture overview)*
- Employees cannot easily be reassigned between teams *(missing expertise)*
- ***“Bus factor”***: Can development on a microservice continue when a developer leaves the company?

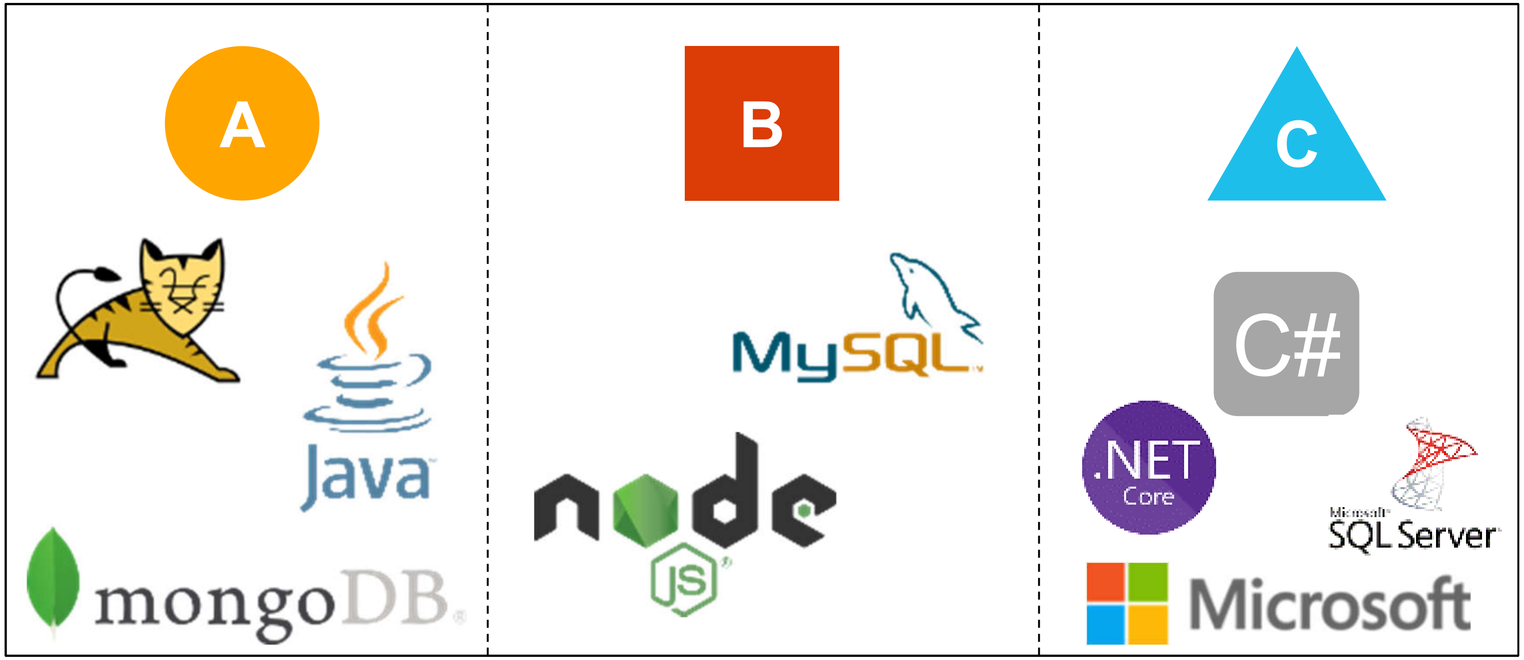
Microservices – Tasks and Challenges

Technology Heterogeneity – Advantages and Challenges

Examples

Different microservices may use fundamentally different technology stacks.

(Graphics © of their owners)



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Microservices – Tasks and Challenges

Scalability – Independence vs. communication overhead

Advantages of Microservices:

- Each service runs in a process of its own and provides its own storage.

  → Microservices can be **scaled independently** from each other.
- Modularity allows easy deployment of additional service instances.

Challenges:

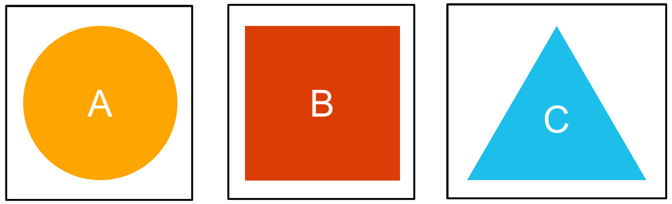
- Services must be able to **scale vertically** as well as horizontally.
- Every instance must be able to answer a request, potentially introducing **communication overhead** between instances.

Microservices – Tasks and Challenges

Scalability – Independence vs. communication / synchronization overhead

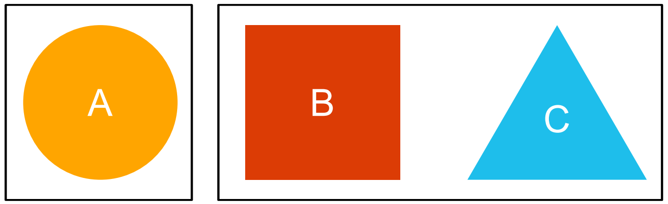
Scenario 1:

- All services are provided with an *equal amount of resources*.



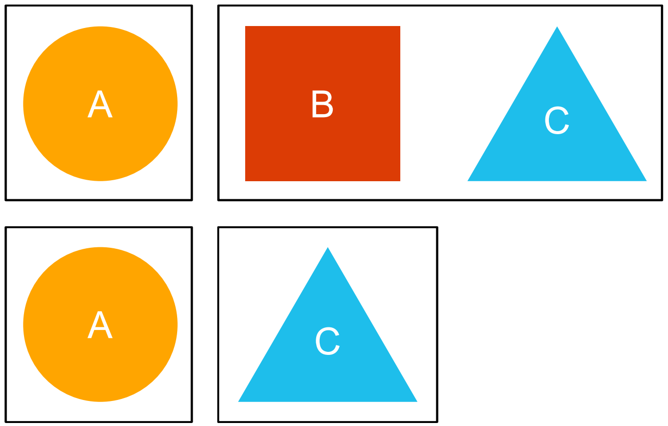
Scenario 2:

- B and C continue to *share resources*.
- A is provided with *dedicated resources*.



Scenario 3:

- B and C continue to *share resources*.
- *Additional instances* of A and C are created with dedicated resources.



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Microservices – Tasks and Challenges

Communication between Microservices – Patterns and Models

Advantages of Microservices:

- Direct communication between services lifts the requirement for a centralised enterprise service bus.
- Inter-service communication patterns can be chosen as needed.

Challenges:

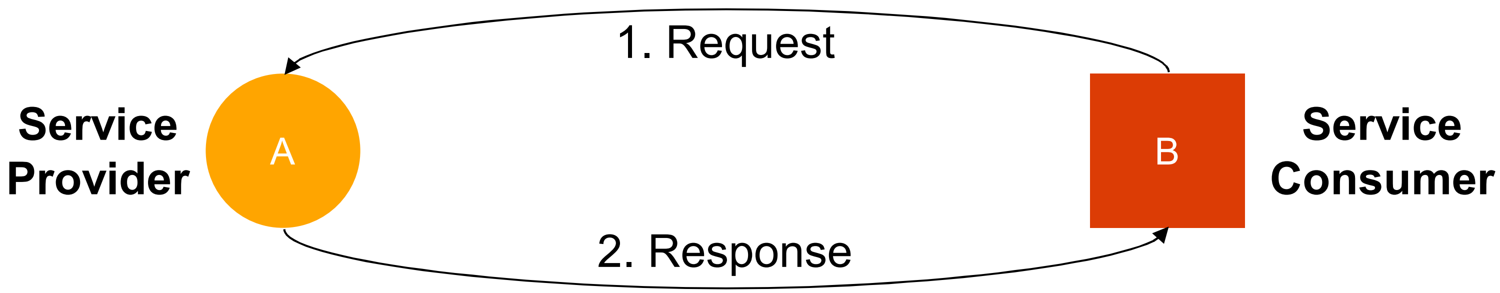
- Communication between services becomes more complex:
  - Will **cross** process and potentially even data center **boundaries**,
  - can no longer be handled via method calls *(monolith)* and
  - requires *(potentially expensive)* **inter-process communication**.
- Interfaces should **not be too fine-grained** to reduce overhead.
- Calls to other services **can not be considered instantaneous** and must be handled in a non-blocking manner.

Microservices – Tasks and Challenges

Communication between Microservices – Patterns and Models

Examples of Communication Patterns:

- **Request Response**
  - Immediate answer *(e.g. via HTTP using a RESTful API)*
  - Simple, direct and intuitive, but potentially blocking.
  - Requires polling if service A wants to keep track of the state of B

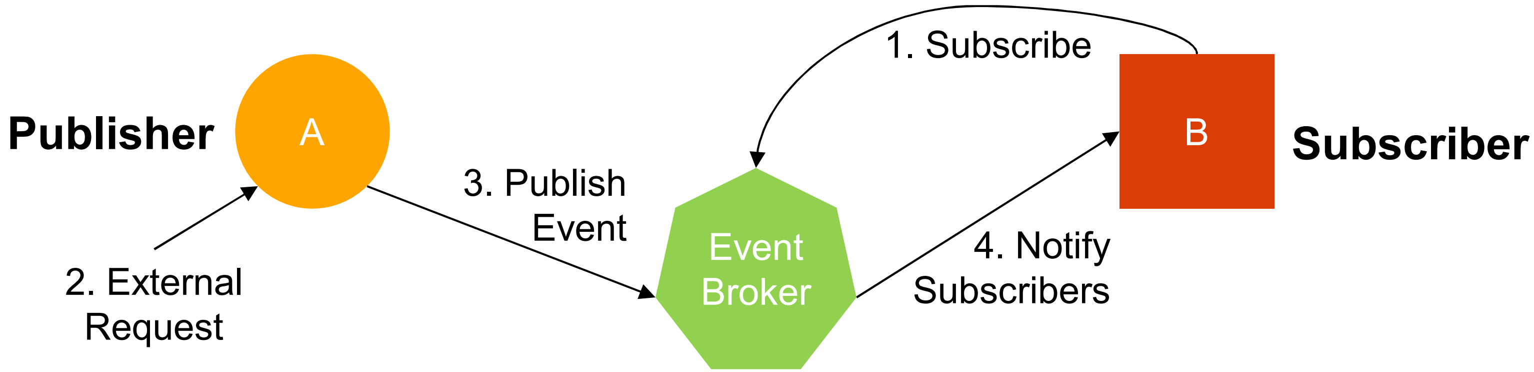


Microservices – Tasks and Challenges

Communication between Microservices – Patterns and Models

Examples of Communication Patterns:

- **Publish Subscribe (Event-based communication)**
  - Spatial Decoupling: Arbitrary number of publishers and subscribers
  - Temporal Decoupling: Messages may be delivered at any time
  - Subscribers are automatically notified on new messages
  - Asynchrony may increase complexity



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Microservices – Tasks and Challenges

Monitoring – Keeping Track of Key Metrics

Advantages of Microservices:

- Replaceability and small scope of individual services allows for **quick reactions** and **precise localisation** of issues.

Challenges:

- **Distributed logs** etc. need to be collected and aggregated
- Events pertaining to the **same, initiating request** need to be **correlated across all APIs** to trace back downstream errors *(e.g. using a shared request id)*.
- Must keep track of various metrics and **key performance indicators** (KPI)
  - **System Level:** CPU load, memory consumption, I/O operations, …
  - **Application Level:** Response times, error rates, …
- **Reliable and fail-safe:** Monitoring blackouts are a worst-case scenario, as there is no way to tell, how the entire system behaves during that time.

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Microservices – Patterns for Resilience and QoS

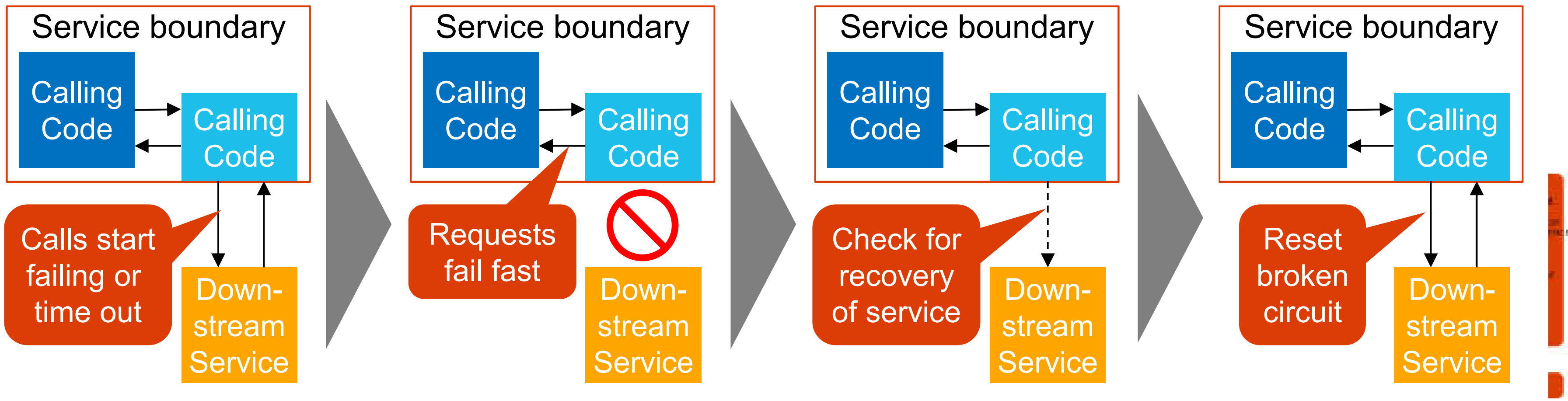
Circuit Breakers – Preventing Failures from Cascading

Problem:

Performance issues of a downstream service can **impact upstream services**.

Idea:

- Monitor services to **detect issues** and potential failure as early as possible
- Provide **fail-fast or fall back mechanism** to prevent upstream cascades



Based on: [Newman2015]

Microservices – Patterns for Resilience and QoS

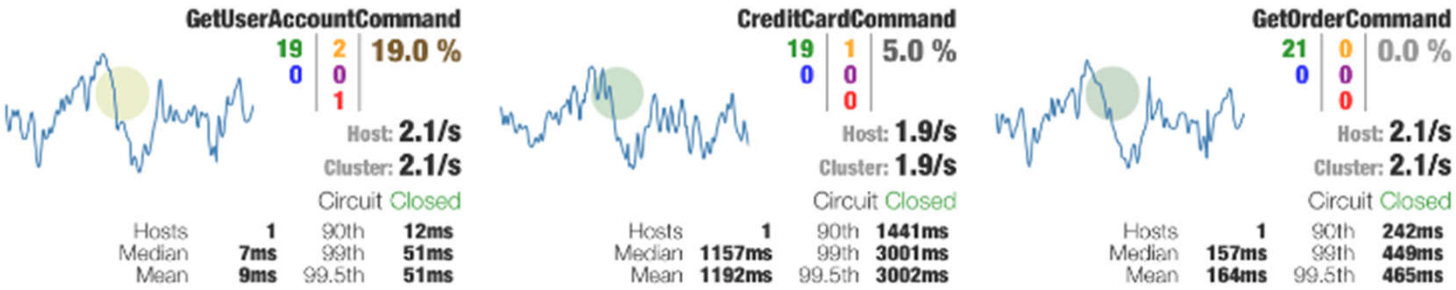
Circuit Breakers – Example: Netflix OSS – Hystrix

Hystrix – An OSS resilience solution for microservices

(Note: Hystrix is limited to Java 8; Resillience4J is another more recent option)

- Wraps calls to dependencies to track successes, failures, timeouts, …
- Provides a fail fast mechanism to **prevent blocking** requests during high load
- Trips **circuit-breakers** to stop all requests to a particular service
  (triggered e.g. when error percentage reaches threshold)
- Executes **fall-back logic** in case of failed requests etc.

→ **Goal: Prevent failures** or high latencies in individual services **from cascading** to other parts of the system: *Fail fast, degrade gracefully (if possible).*

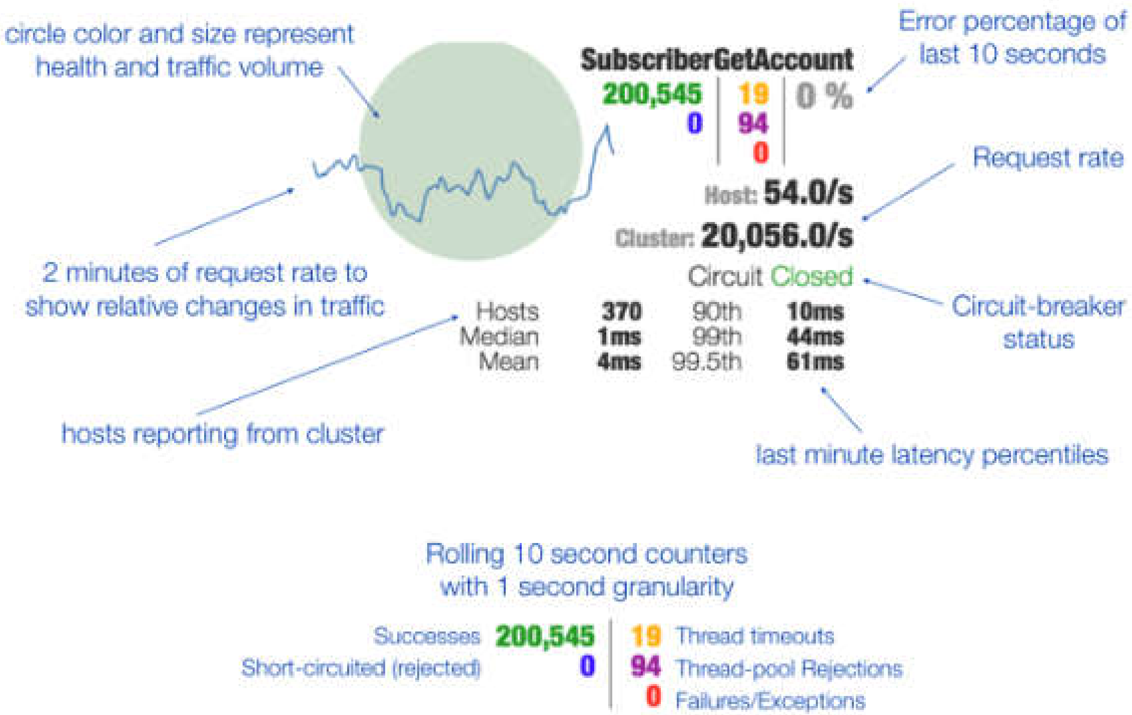


Source: https://github.com/Netflix/Hystrix

Microservices – Patterns for Resilience and QoS

Circuit Breakers – Example: Netflix OSS – Hystrix

Hystrix Dashboard – Key Performance Indicators



Source: https://github.com/Netflix/Hystrix

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Microservices – Patterns for Resilience and QoS

Chaos Testing – Because Chaos is Closer to Reality

Problem:

On **microservice level**, code tests can identify potential failures and load tests can point out scalability limitations, but neither tests the entire ecosystem.

→ Most production failures are related to **issues elsewhere in the ecosystem**.

Idea:

- **Push** microservices **to fail** in production:
  Make it **fail all of the time** and in every way possible.
- Run **scheduled** tests as well as **random tests**:
  Catch developers off guard as well as in prepared states of readiness.
- Provide chaos testing **as a service**:
  Dedicated team, no ad hoc cooperation across multiple teams.
- Break **every microservice** and **every piece of infrastructure** *(multiple times!)*.

Based on: [Fowler2017]

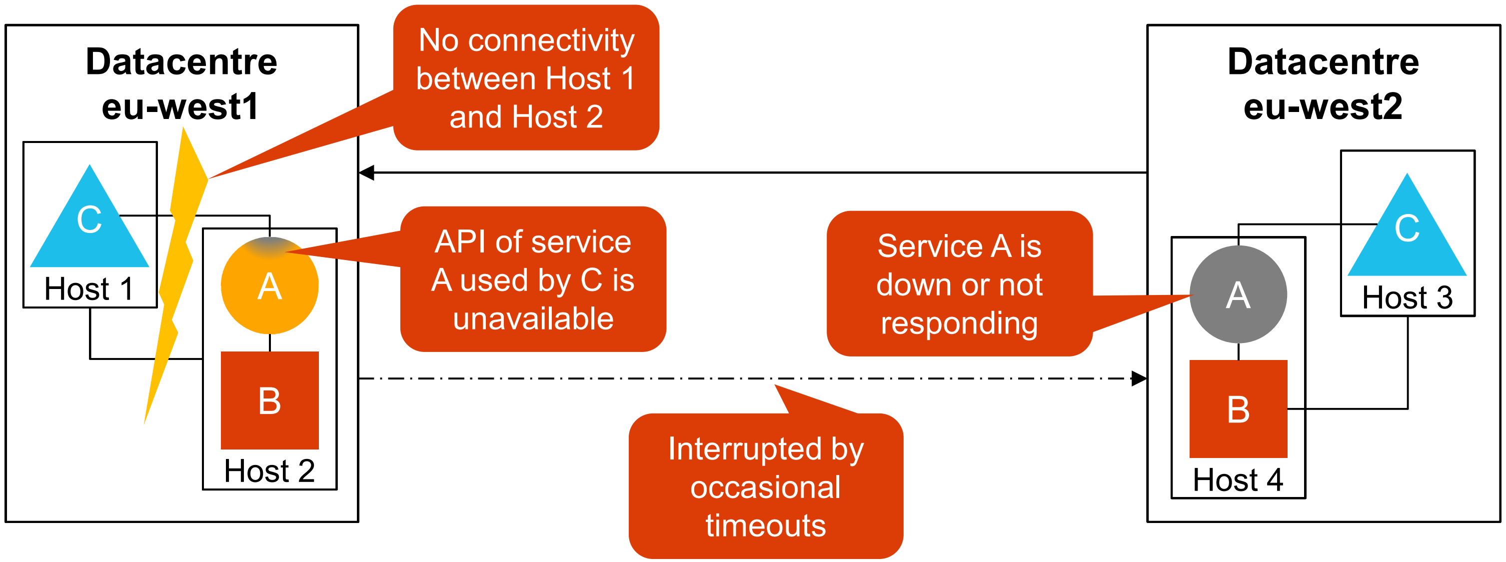
Microservices – Patterns for Resilience and QoS

Chaos Testing – Because Chaos is Closer to Reality

Example:

- Block individual APIs, stop single services, introduce network latency, break entire hosts, disconnect entire regions or datacentres …

→ Even though it is called Chaos Testing, it has to be **well controlled** to prevent it from bringing down the entire ecosystem or go rogue!



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Microservices – Patterns for Resilience and QoS
Canary Environments – The Last Stage before Full Release

Problem:

Even after passing all tests, actual **production traffic** may still cause unexpected failure, which might **brings down the entire production environment**.

Idea:

- Do **not** switch the **entire production traffic** over to the new version **at once**.
- Deploy new versions to a **Canary Environment**, which servers only about 5 – 10 % of the production traffic.
- Once the canary **survived an entire traffic cycle** *(interval after which traffic patterns repeat)*, deploy it to the entire production platform.

→ If a canary fails, **only a small number of clients will be affected** and the deployment can be rolled back easily.

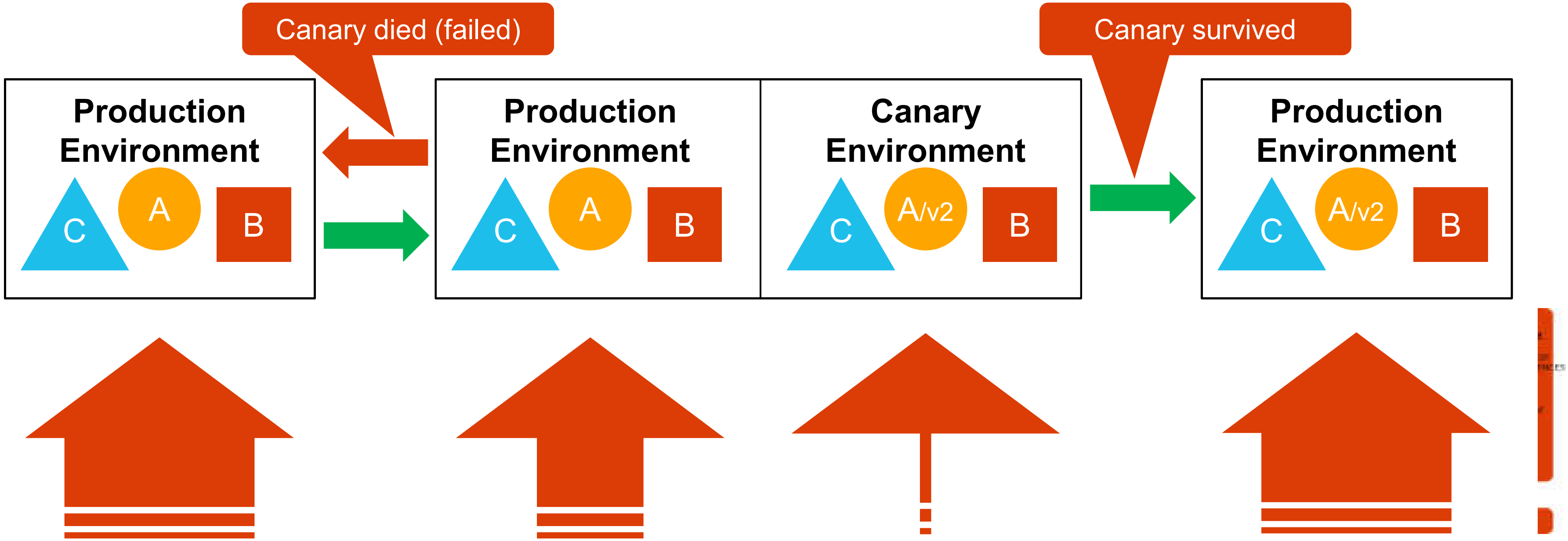
Based on: [Fowler2017]

Microservices – Patterns for Resilience and QoS

Canary Environments – The Last Stage before Full Release

Example:

- Rollout of a new version for service A to the canary environment
- New canary environment only serves a small portion of production traffic



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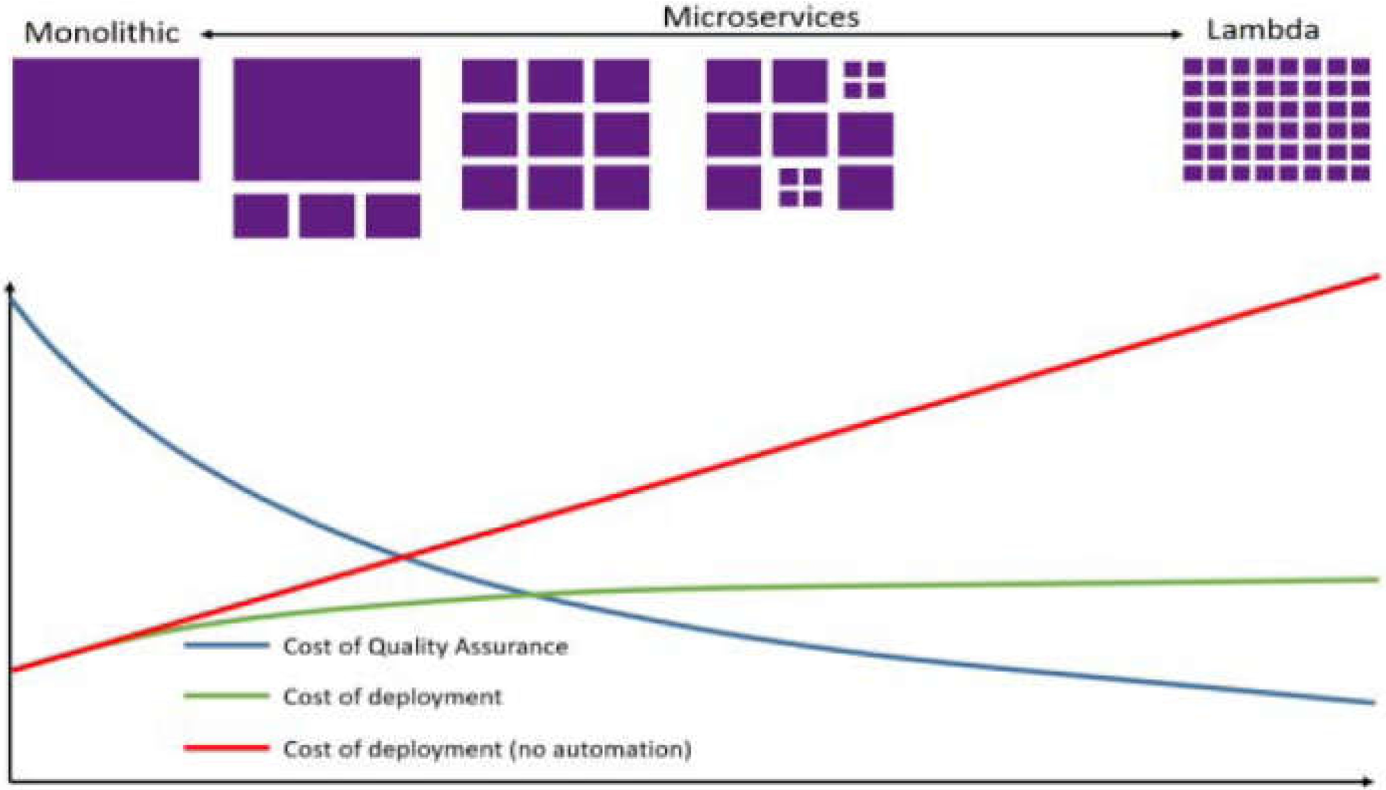
Microservices – Applications and Examples

Service Granularity – Software Company MGDIS SA

Cost-based definition of service granularity



Source: [Gouigoux2017]

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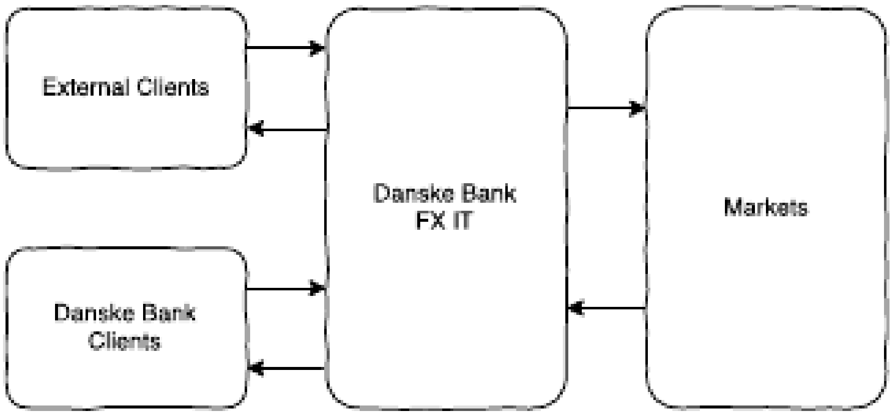
Microservices – Applications and Examples
Case Study – Danske Bank

Foreign Exchange (forex, FX):

- Exchange of one currency for another or the conversion of one currency into another currency.
- Encompasses the conversion of currencies at an airport kiosk to pay-ments made by corporations, financial institutions and governments.
- Largest financial market in the world



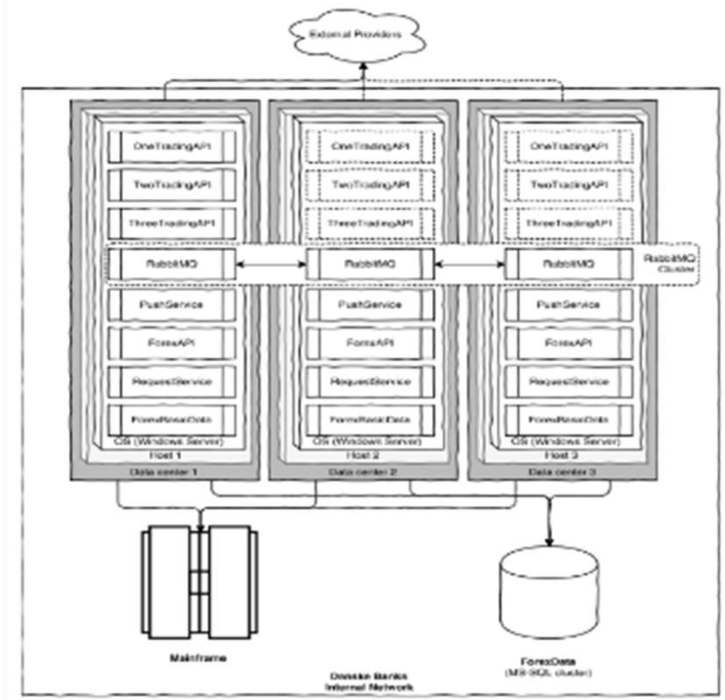
Danske Bank **FX System**

- Mission critical system of the Danske Bank, implements FX
- Gateway between the international markets and the Danske Bank clients

Source: [Dragoni2017]

Microservices – Applications and Examples

Case Study – Danske Bank



Problems with the **FX System** system:

- **Large Components** with little cohesion and **tight coupling**
- Multiple **communication** and integration **paradigms** (RPC, messaging)
- Complex and manual **deployment**
- No global **monitoring** and **logging**
- **Technology dependencies** (MS .NET)

→ Great **expense** with respect to **maintenance**, **quality assurance**, and **deployment**

Idea:

Migration of the FX system from a **monolithic** to a **microservice** architecture.

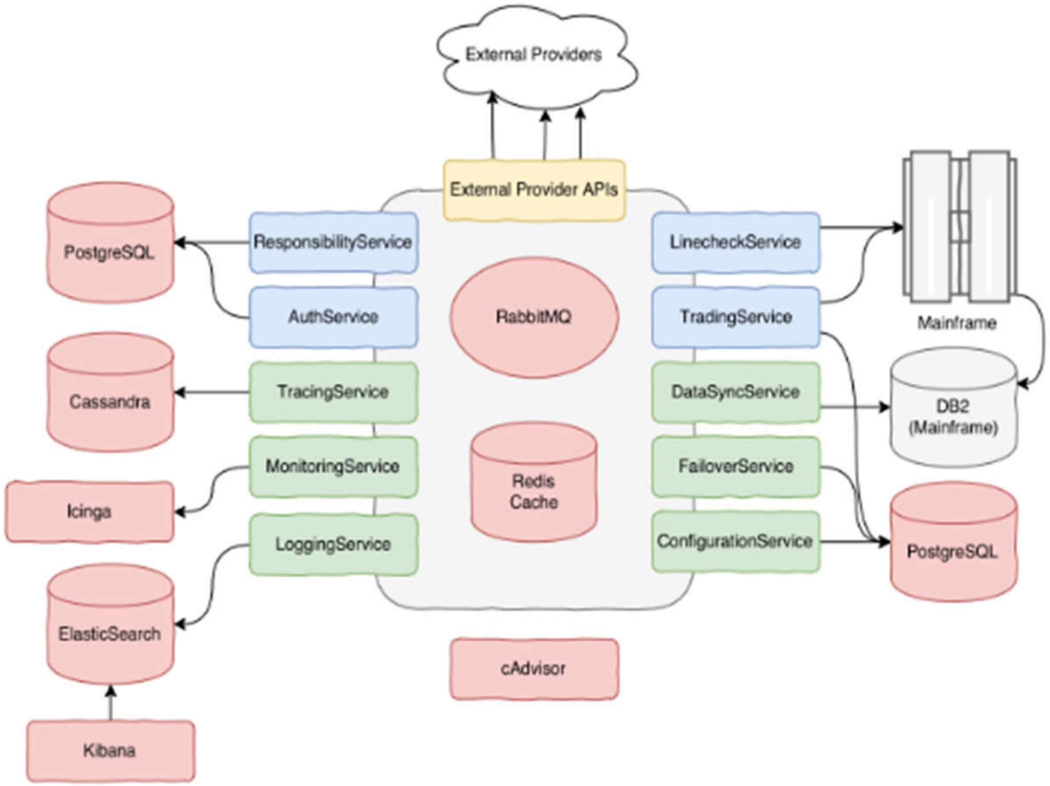
Source: [Dragoni2017]

Microservices – Applications and Examples

Case Study – Danske Bank

Approach:

- Shift business logic in **dedicated services**
- Provide “foundation services” for **system management** tasks
- Provide infrastructure services
- Use **Docker** and **Docker Swarm** for deployment, load balancing, and fail over
- Introduce **Continuous Integration**



Source: [Dragoni2017]

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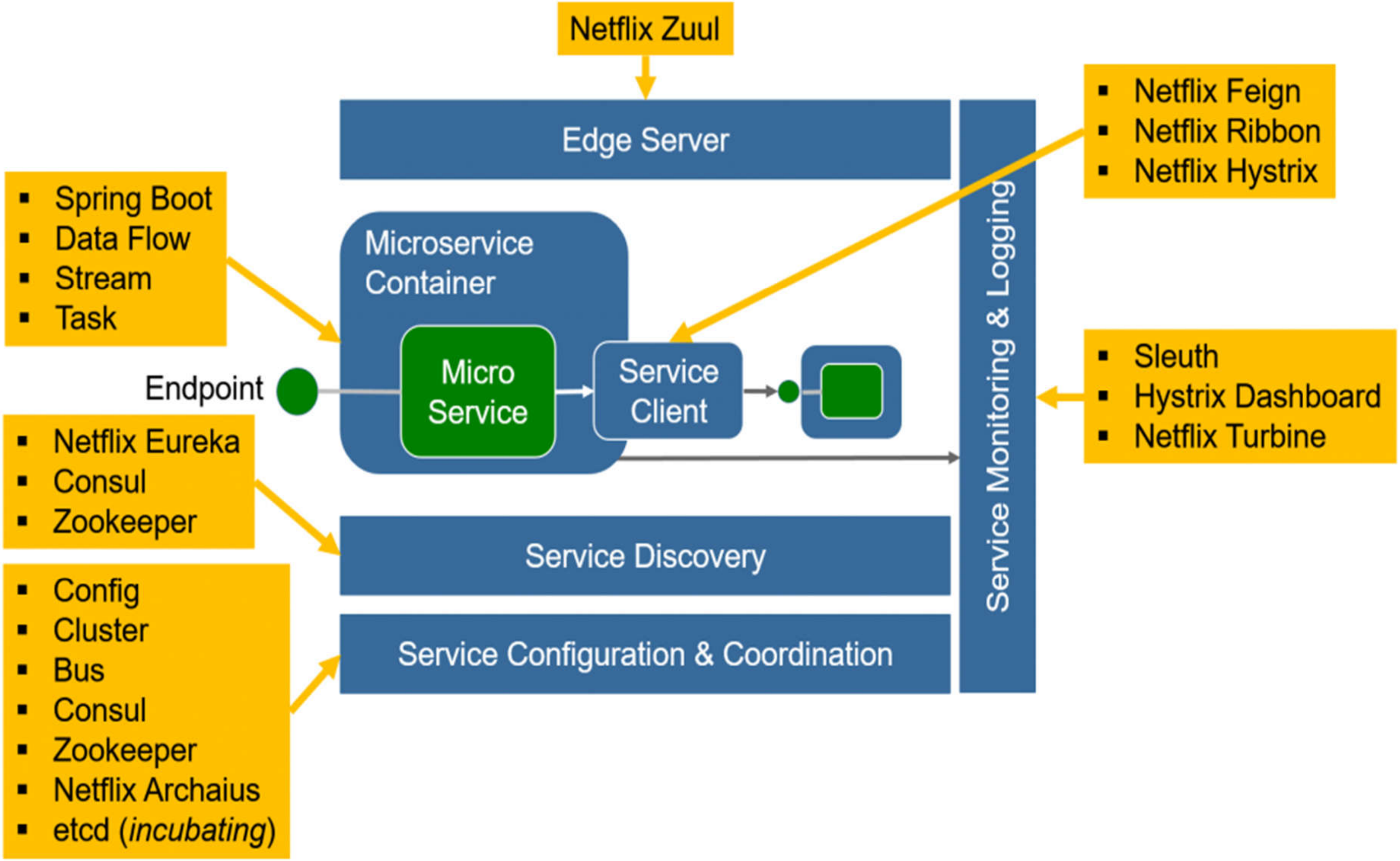
Microservices – Technology Solutions

Spring cloud – Overview of an Ecosystem



Source: : https://jaxenter.de/cloud-native-anwendungen-42976

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Microservices – Technology Solutions

Netflix OSS – Overview of an Ecosystem

Netflix has open-sourced a great number of their tools and services.

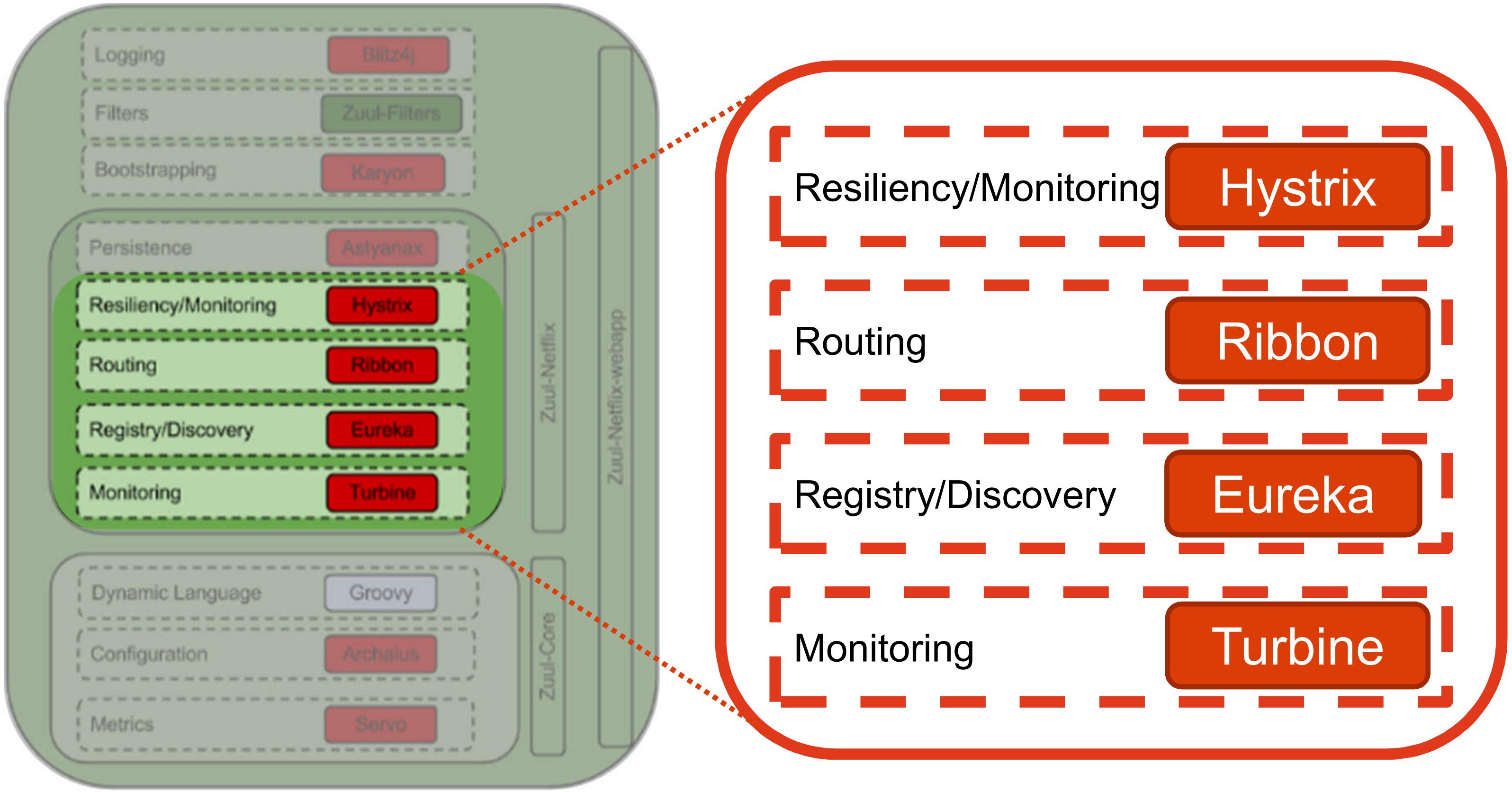
Some examples taken from their open-source ecosystem:

Runtime Services & Libraries	Build and Delivery Tools	Insight Reliability & Performance	Other Areas
Archaius	Nebula	Atlas	Security
Eureka	Animator	Chaos Monkey	User Interface
Hystrix	Spinnaker	Edda	Data Persistence
Zuul		Spectator	Content Encoding
		Vector	Big Data

Source: https://netflix.github.io

Microservices – Technology Solutions

Netflix OSS – Zuul: The Edge Service – Component Overview



Source: http://techblog.netflix.com/2013/06/announcing-zuul-edge-service-in-cloud.html

Microservices – Technology Solutions

Netflix OSS – Zuul: The Edge Service

Zuul – The Gatekeeper

- Provides various filters to enable dynamic routing, monitoring, resiliency and security.
- Uses a number of other services to perform certain tasks, e.g.:
  - **Hystrix** – Real time metrics and resilience
  - **Ribbon** – Routing and load balancing
  - **Eureka** – Service and instance location
  - **Turbine** – Server-Sent Event (SSE) stream aggregation
  - **Archaius** – Thread-safe configuration management

Source: Ghost Busters (Columbia Pictures 1984)

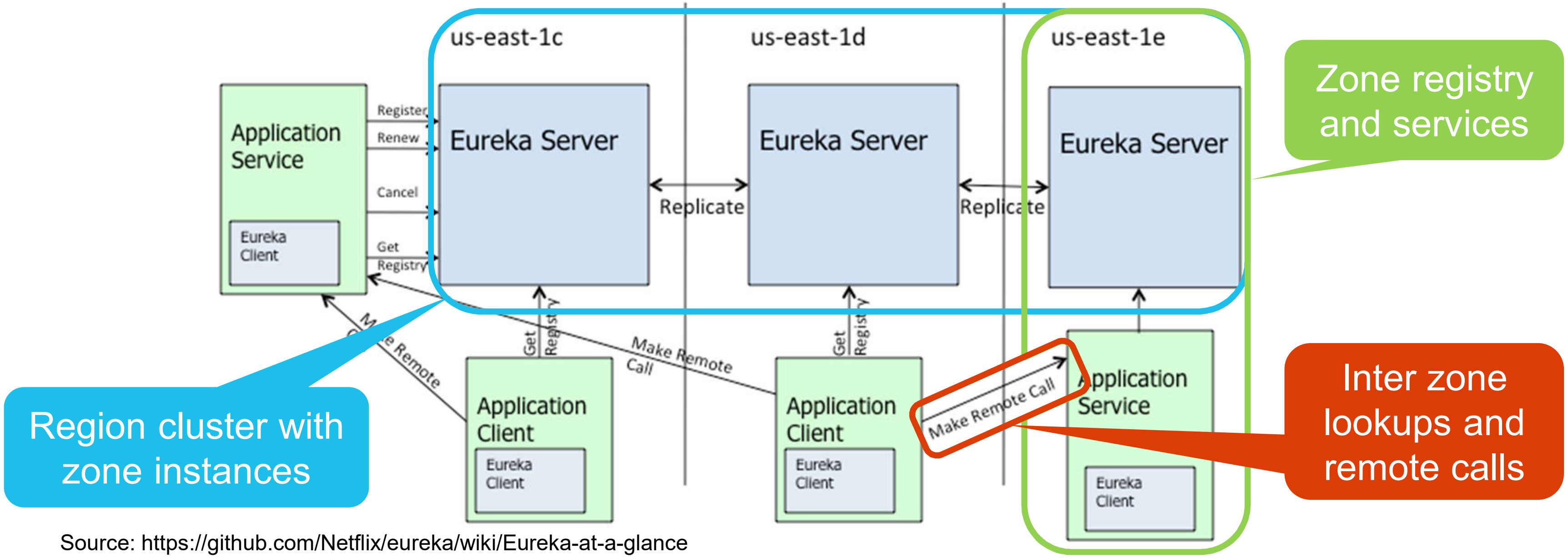
Source: http://techblog.netflix.com/2013/06/announcing-zuul-edge-service-in-cloud.html

Microservices – Technology Solutions

Netflix OSS – Example “Eureka”: Service and Instance Discovery

Eureka – The Service Registry

- Used to locate services in an AWS cloud environment
- Additional **load balancing and failover mechanism** for middle-tier servers
- Automated service removal via **registration renewal heartbeat**



Source: https://github.com/Netflix/eureka/wiki/Eureka-at-a-glance

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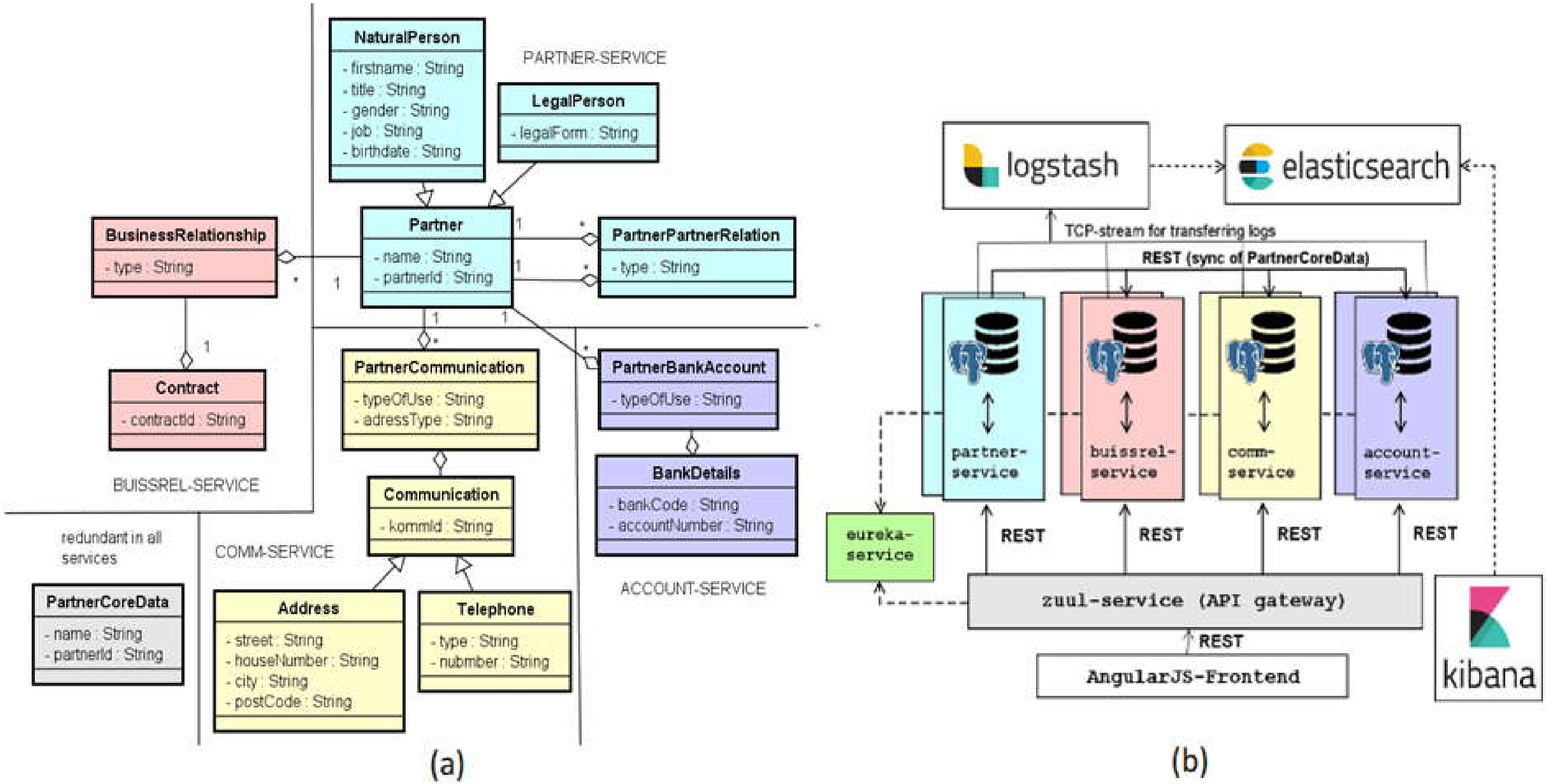
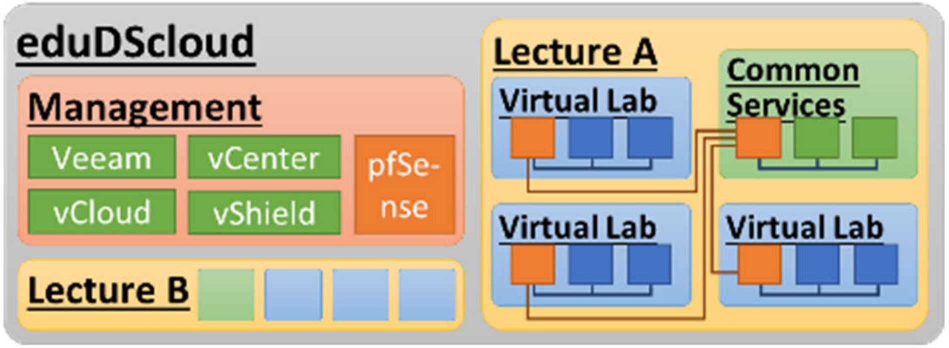
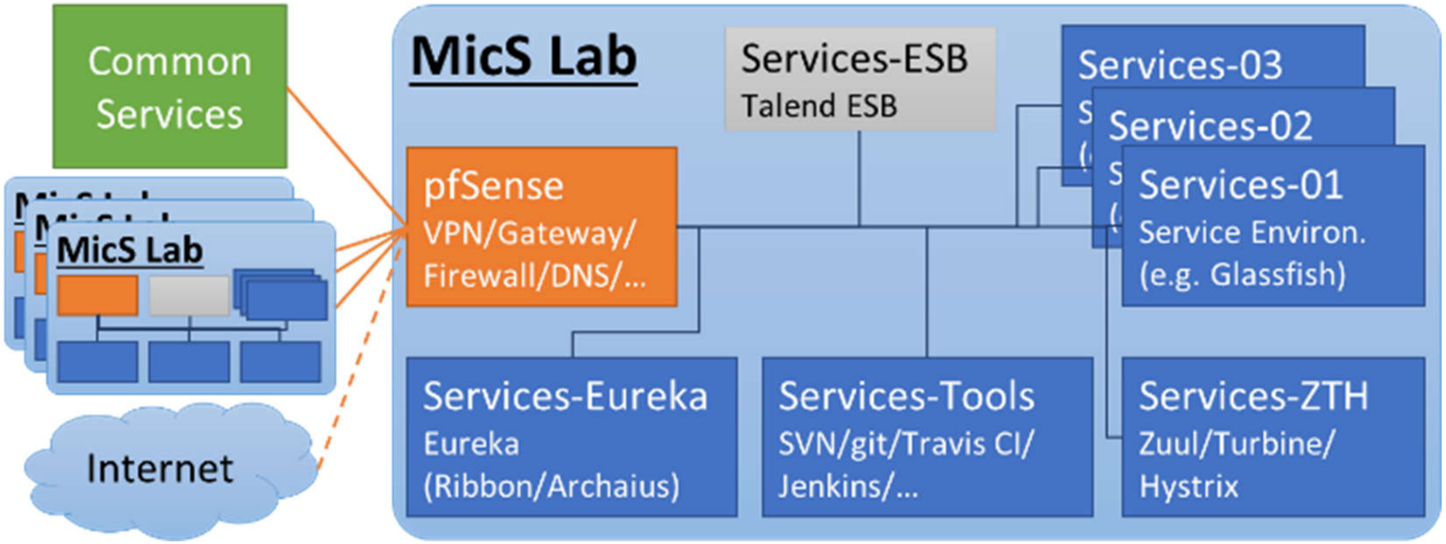
Project with Partner Companies:
Microservices for Insurance Partners



Source: [Koschel2019]

eduDScloud – Microservices Lab

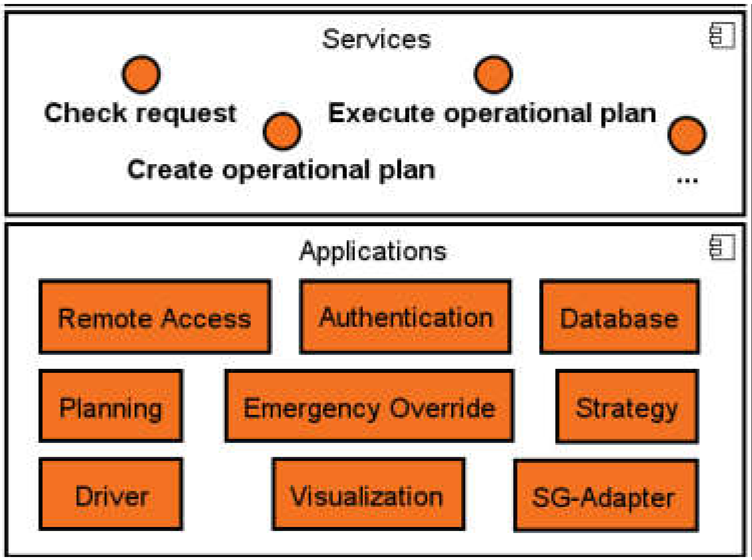




Source: [Schöner2018]

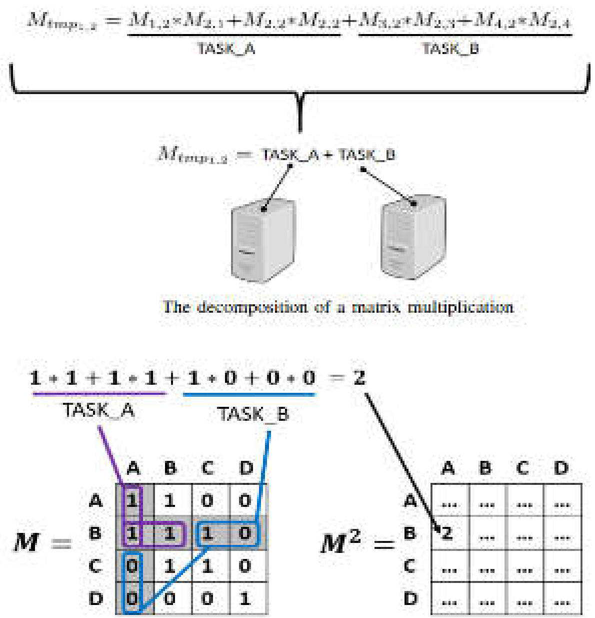
More HsH Projects

- Service-based Architecture (SOA + Microservices) for a pmCHP supervision system



Source: [Pump2018]

- Microservices for parallel matrix multiplication, e.g., within car2car communication scenarios



Source: [Zuch2018]

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Microservices – Summary and Conclusions

- The **microservices paradigm** is a new **promising approach** in provisioning software:
  - **Small** services, **self-contained**, **high cohesion** and **loose coupling**
  - Runs in a separate **process**
  - Maybe **deployed** and **scaled independently** from each other
  - Owned by a **single team** – “You build it, you run it”
  - **Continuous integration – continuous delivery** (CICD)
- Efficient **OSS frameworks** for development & delivery are available
  - Spring Boot / Cloud, Netflix OSS, Docker, Kubernetes, Istio, Prometheus, …
  - BUT: Still quite high rate of tool / tool combination changes
- Some **success stories**: Amazon, Danske Bank, Google, Netflix, Otto,...
- Is the microservices paradigm just a **hype** – or is it the **silver bullet,** which will solve most problems in the software industry – we will see ...

References & Additional Reading

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Thanks for listening! ☺

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