



Cloud Native Software Architecture

Walmart

Supercentre



Enter

Exit

2



2002



QA/WARE

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Categories

Shopping cart


Registration

Products

Services

2008

The screenshot shows the Walmart.com homepage. At the top, the Walmart logo is on the left, and navigation links for 'Store Finder', 'Local Ad', 'Top Products', 'Sign In/New', and 'Track Orders' are on the right. Below the logo is a 'See All Departments' link. A search bar is located at the top center. The main content area features a large banner for 'GREAT VALUE, NEW PRODUCTS' with a message about downloading Flash Player. Below this are several promotional tiles: 'Blu-ray Price Drop' for Magnavox, Sony, and Samsung players; '50% Off Top 50 Books' with a list of top sellers; and 'Save on Top-Brand Electronics' featuring laptops. On the left side, there are links for 'Savings Add Up' (Clearance, Rollbacks, \$4 Prescriptions, Video Games Under \$20, Clearance on Baby Items) and 'What's New' (Classifieds, Halloween, Elevenmoms, Better Homes).


Walmart  Free Shipping with **site to store**
Store Finder ▾ Local Ad ▾ Top Products ▾ Sign In/New ▾ Track Orders ▾



See All Departments Search

Apparel & Jewelry ▾
Baby ▾
Books, DVDs & MP3s ▾
Electronics ▾
For the Home ▾
Gifts & Registries ▾
Grocery ETA ▾
Health & Beauty ETA ▾
Outdoor Living ▾
Pharmacy ▾
Photo ▾
Sports & Fitness ▾
Toys & Video Games ▾
[In Stores Now](#)
[See All Departments](#)

GREAT VALUE, NEW PRODUCTS
Download Flash Player version 7 or later for the ultimate Walmart.com shopping experience.
Get **ADOBE** FLASHPLAYER

Blu-ray Price Drop
★★★★★ Magnavox from \$258
Sony Samsung
See all: [Blu-ray Players](#)

50% Off Top 50 Books
 The 50 top sellers are 50% off — get great reads for the whole family, from \$4.
Shop: [50% Off Top 50 Books](#)

Save on Top-Brand Electronics
 

Savings Add Up
[Clearance](#)
[Rollbacks](#)
[\\$4 Prescriptions](#)
[Video Games Under \\$20](#)
[Clearance on Baby Items](#)

What's New
[Classifieds](#) ETA
[Halloween](#)
[Elevenmoms](#)
[Better Homes](#)

INTERNET ARCHIVE
WayBackMachine
http://ad.yieldmanager.com/st?ad_type

Additional services



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2011

Walmart
Save money. Live better.

Shop for College 2011

New customer? [Sign In](#) | [Help](#)

[Value of the Day](#) | [Local Ad](#) | [Store Finder](#) | [Registry](#) | [Gift Cards](#) | [Track My Orders](#) | [My Account](#) | [My Lists](#)

Search [My Cart](#) [Choose My Store](#)

See All Departments

- Electronics & Office >
- Movies, Music & Books >
- Home, Furniture & Outdoor >
- Apparel, Shoes & Jewelry >
- Baby & Kids >
- Toys & Video Games >
- Sports & Fitness >
- Auto & Home Improvement >
- Photo >
- Crafts & Party Supplies >
- Pharmacy, Health & Beauty >
- Grocery & Pets >
- College 2011**

Must-Have College Essentials at Can't-Miss Prices **COLLEGE 2011**

Bedding from \$35 	Futons & Sofas from \$99 	Storage from \$19 	Desks from \$39
 Laptops & Netbooks from \$278	 Appliances from \$57	 TVs from \$149	 iPods from \$49

[Shop for College 2011](#)

Save Big Now

- Amazing Xbox 360 Savings
- Best-Selling Bikes from \$79
- Fragrances from \$5
- Furniture Rollbacks
- Save 10¢ per Gallon on Gas

What's New

- Captain America Is Here
- HP Dandelion Breeze Laptop
- Summer Fun

In the Spotlight

Back to School Essentials

From uniforms to supplies, find everything for school at Every Day Low Prices.

[School Supplies](#)
[Uniforms](#)

Have Your Fun in the Sun

Enjoy hot summer savings on everything you'll need for some outdoor family fun.

[Pools & Waterslides](#)
[Swing Sets](#)
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NEW
Watch New Releases Instantly

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Additional services
(partly personalized)

Bad News



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CHALLENGE

Four years ago, the Walmart Global eCommerce system was a monolithic application, deployed once every 2 months. This represented an unsustainable rate of innovation given the competitive climate. Walmart recognized the need to fundamentally transform technology delivery to compete in the Digital Economy.

Walmart auf <http://www.oneops.com>

- "[...] it was unable to scale for 6 million pageviews per minute and was down for most of the day during peak events."
- "This is the multi-million dollar question which the IT Department of Walmart Canada had to address after they were failing to provide to their users on Black Fridays for two years in a row."

<https://blog.risingstack.com/how-enterprises-benefit-from-microservices-architectures>

Long cycles from dev to prod.

Lack of scalability.

Lack of elasticity.

2016



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Additional services.

Walmart logo and navigation bar. Search bar with 'All' and 'Search' buttons. Navigation links: All Departments, Daily Savings Center, My Local Store, Pick it up TODAY, Tips & Ideas. Promotional banner: 'Rollbacks on iPad Air \$100 off 16GB & 32GB WiFi'. 'Shop Now' button. Product image of iPad Air.

Don't miss a single chance to save Get the Walmart Browser App! Download now.

Featured products:

- 1799.00 (was 1199.00) Save \$600.00 HP Elite Pad 13.6" 15" 17.2" Laptop...
- 135.00 Google Chromecast
- 1321.76 LG Black Chromebase XL-in-One
- 1194.24 Lenovo Black 11.6" 1621 Chromebook PC
- 1276.05 (was 1300.00) Save \$23.95 ASUS Black 15.6" K551M4-4301-4131...

Breakfast-hunting SAVINGS Save big with our best values. Shop Now.

- 149.96 (was 199.96) Save \$50.00 George Foreman 144-egg...
- 1199.97 (was 1299.97) Save \$100.00 Better Homes and...
- 1199.00 ULTRAA 13.3" Touch...
- 1119.00 Volvo Pacer Sofa Bed...

Product detail page for George Foreman grill. Price: \$49.96. List price: \$59.96. Save \$10.00. FREE shipping on orders \$35+. Care plan (optional): None. Quantity: 1. Add to Cart, Add to Registry, Add to List. Shipping: Use delivery address. FREE pickup: Not available. Want to pick up your package for free? Register offers free pickup for most orders placed online. Search for: Enter ZIP code. Find. More about this item.

Customers also viewed these products:

- 156.87 (was 179.96) Save \$23.09 George Foreman 84-egg in 2 Serving...
- 129.92 (was 149.96) Save \$20.04 George Foreman Removable Plate Grill
- 154.99 Hamilton Beach Indoor Grill with Removable...
- From 187.29 George Foreman 240" Indoor/Outdoor Grill
- 1105.44 George Foreman 8-Serving Digital Timer & 2-Serving Classic Plate...
- 139.92 (was 159.96) Save \$20.04 George Foreman 28-egg in 2-Serving Classic Plate...
- 117.52 (was 139.96) Save \$22.44 George Foreman 28-egg in 2-Serving Classic Plate...

Good News



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1000 deployments per day ...
... by the developers

~ 100% availability

New business models, applications
and devices (IoT, mobile, APIs)

Resource efficiency

Elastic scalability

RESULTS

Today the Walmart eCommerce platform is hosted in some of the largest OpenStack clouds and is managed exclusively via OneOps. On a typical day there are now over 1,000 deployments, executed on-demand by development teams, each taking only minutes on average to complete.

Walmart auf <http://www.oneops.com>

"They wanted to prepare for the world by 2020, with 4 billion people connected, 25+ million apps available, and 5.200 GB of data for each person on Earth. Walmart replatformed [...] with the intention of achieving close to 100% availability with reasonable costs."

<https://blog.risingstack.com/how-enterprises-benefit-from-microservices-architectures>

- "In fact, the organization reports that some 3,000 engineers [...] drive 30,000 changes per month to Walmart software."
- "Those new applications, which span everything from mobile devices to the Internet of things (IoT), are crucial weapons in a global e-commerce contest that pits Walmart against the likes of Amazon and Alibaba, as well as a host of other rivals that are emerging as the cost of entry into the online retail sector continues to decline in the age of the API economy."

<http://www.baselinemag.com/enterprise-apps/walmart-embraces-microservices-to-get-more-agile.html>

- "The Walmart [...] servers [...] were able to handle all mobile Black Friday traffic with about 10 CPU cores and 28Gb RAM."
- "On Thanksgiving weekend, Walmart servers processed 1.5 billion requests per day. 70 percent of which were delivered through mobile."

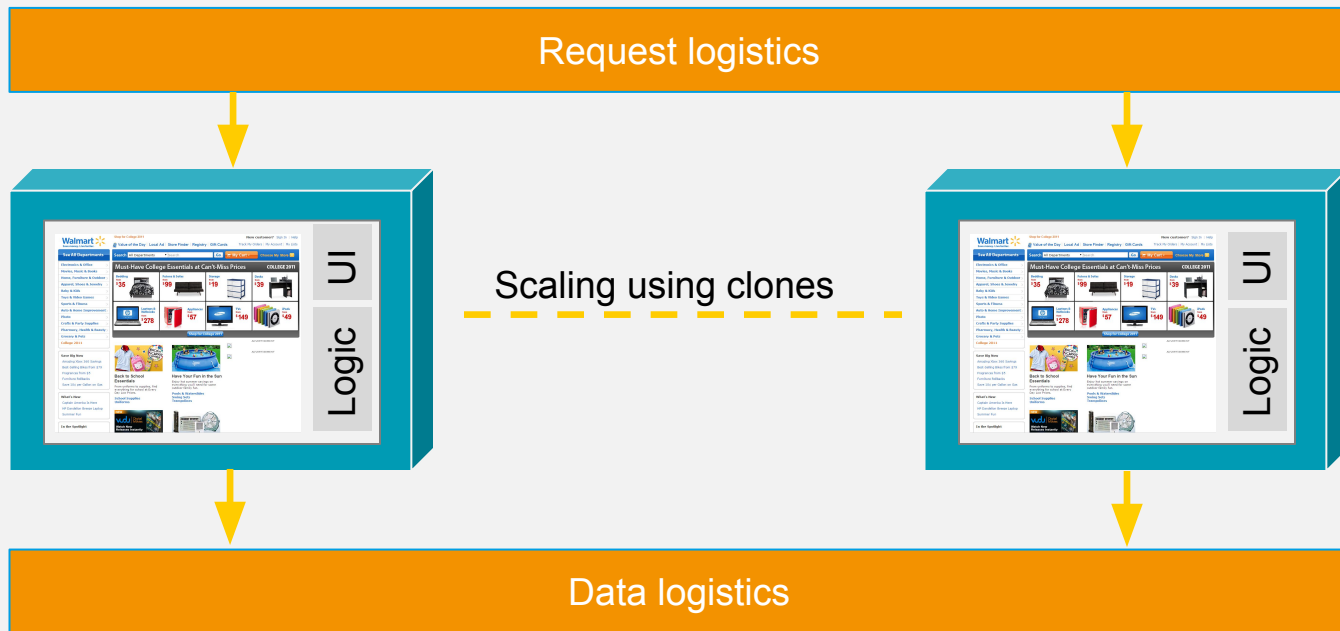
<http://techcrunch.com/2014/12/02/walmart-com-reports-biggest-cyber-monday-in-history-mobile-traffic-at-70-over-the-holidays>



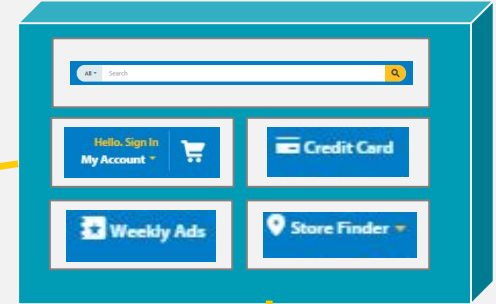
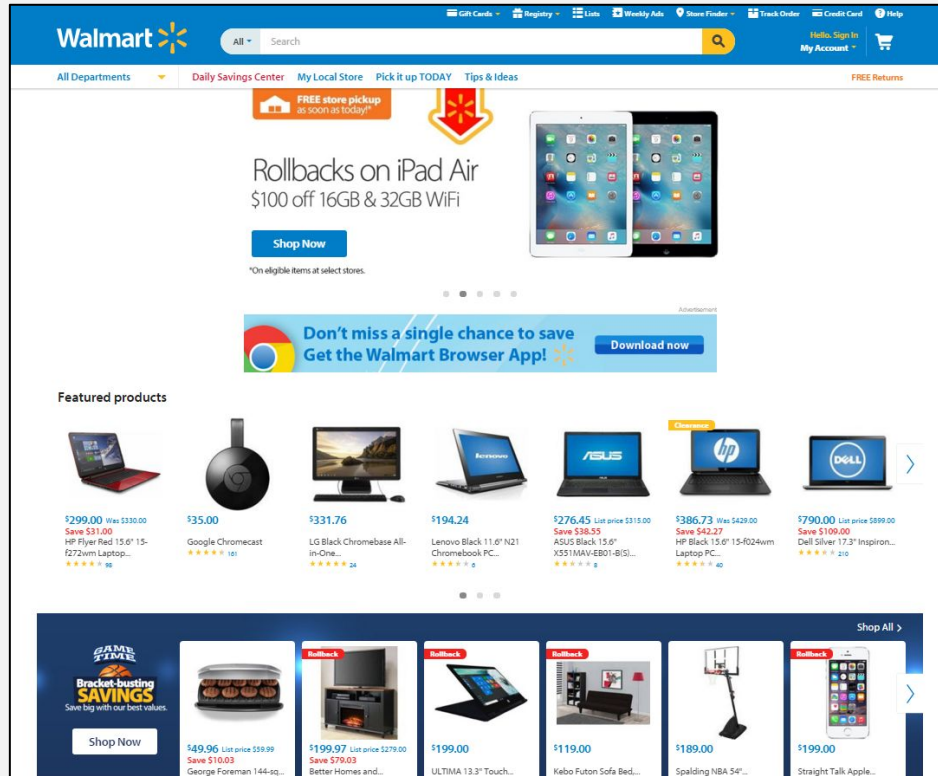
WHAT DID THEY DO?



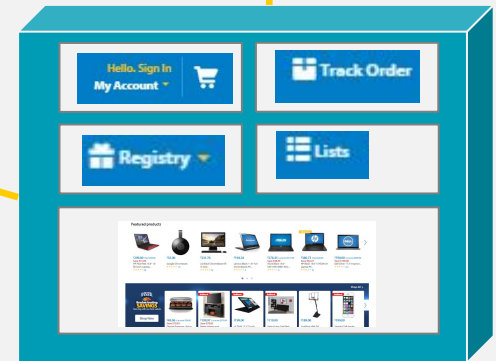
From operating monoliths ...



... to operating components



Scaling through distribution and clones



Cloud Native Application Development: Components All Along the Software Lifecycle



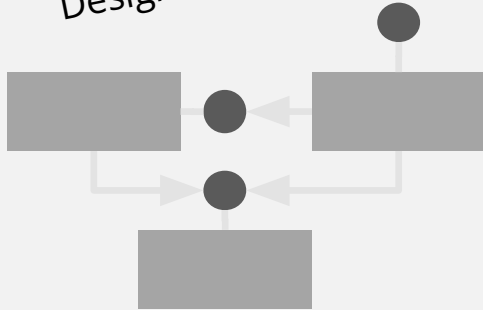
DESIGN

BUILD

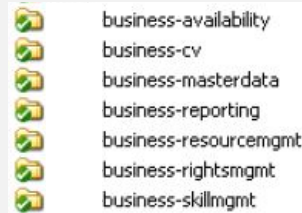
RUN

NEW!

Design Components



Dev Components



Ops Components



1:1

n:1

- Complexity unit
- Data integrity unit
- Coherent and cohesive features unit
- Decoupled unit

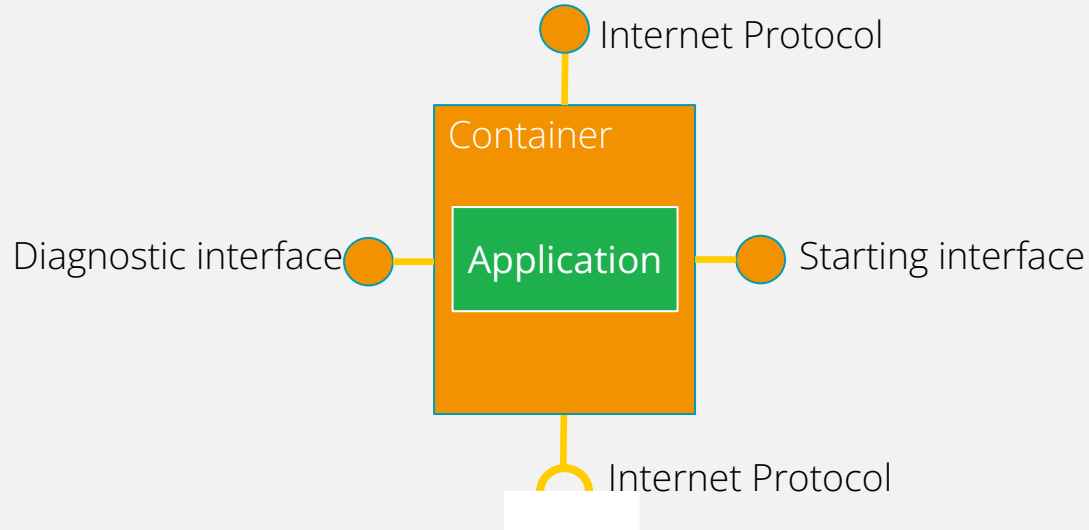
- Planning unit
- Team assignment unit
- Knowledge unit
- Development unit
- Integration unit

- Release unit
- Deployment unit
- Runtime unit (crash, slow-down, access)
- Scaling unit

The anatomy of an operation component



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Dev Components



Ops Components



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Good starting point

System

Subsystems

Components

Services

Monolith

Macroservices

Microservices

Nanoservices

Decomposition Trade-Offs

- + More flexible to scale
- + Runtime isolation (crash, slow-down, ...)
- + Independent releases, deployments, teams
- + Higher utilization possible

- Distribution debt: Latency
- Increasing infrastructure complexity
- Increasing troubleshooting complexity
- Increasing integration complexity

Rule #1 for operating services in the cloud



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"Everything fails all the time."

— Werner Vogels, CTO of Amazon



Rule #2 for operating services in the cloud

If you want the sky to be the limit, then only horizontal scaling works.



Rule #3 for operating services in the cloud



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If you want to be in the cloud, you should speak cloud.

TCP

DHCP

HTTP

DNS

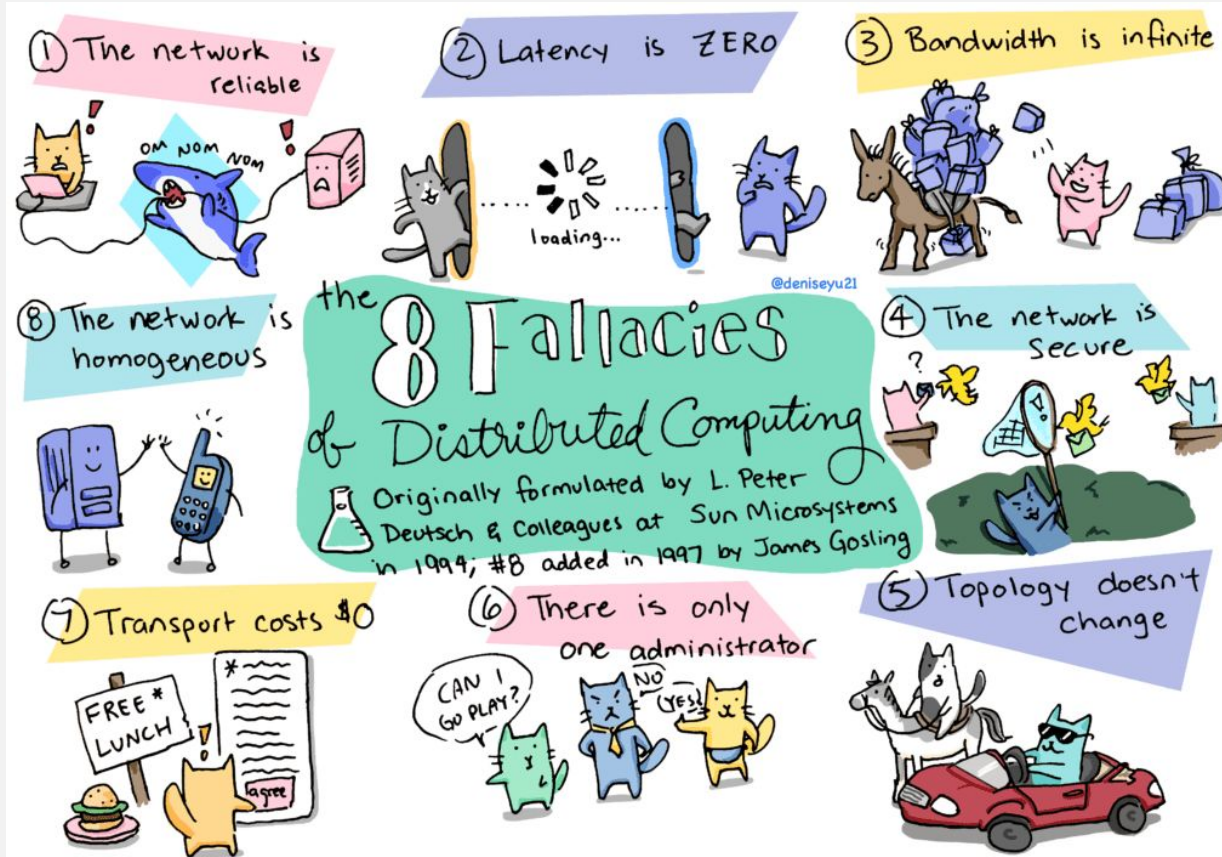
The 5 Commandments of the Cloud

- Everything fails all the time
- Focus on MTTR, not on MTTF
- Respect the eight fallacies of distributed computing
- Scale out, not up
- Treat resources as cattles, not as pets



Source: https://de.wikipedia.org/wiki/Zehn_Gebote

Eight fallacies of distributed computing



Cloud architecture from a software architecture perspective: Design for Failure.



- Each component runs independently and in isolation.
- The operating components communicate with each other via internet protocols HTTP, UDP, ...
- Each operating component can run in multiple instances, thus providing redundancy. There is no “common point of failure”. Cluster Orchestrator
- Each operating component has diagnostic interfaces to detect faulty behavior.
- Each microservice can be restarted at any time and deployed to another node. It has no state of its own.
- The implementation behind each microservice can be replaced without the users noticing.

Operating components require an infrastructure around them: a microservice platform.

Typical tasks:

- Authentication
- Load shedding
- Load balancing
- Failover
- Rate limiting
- Request monitoring
- Request validation
- Caching
- Logging

Typical tasks:

- HTTP handling
- configuration
- diagnostic interface
- control lifecycle
- provide APIs

Typical tasks:

- Collect metrics
- Collect logs
- Collect traces

Typical tasks:

- Service Discovery
- Load Balancing
- Circuit Breaker
- Request Monitoring

Typical tasks:

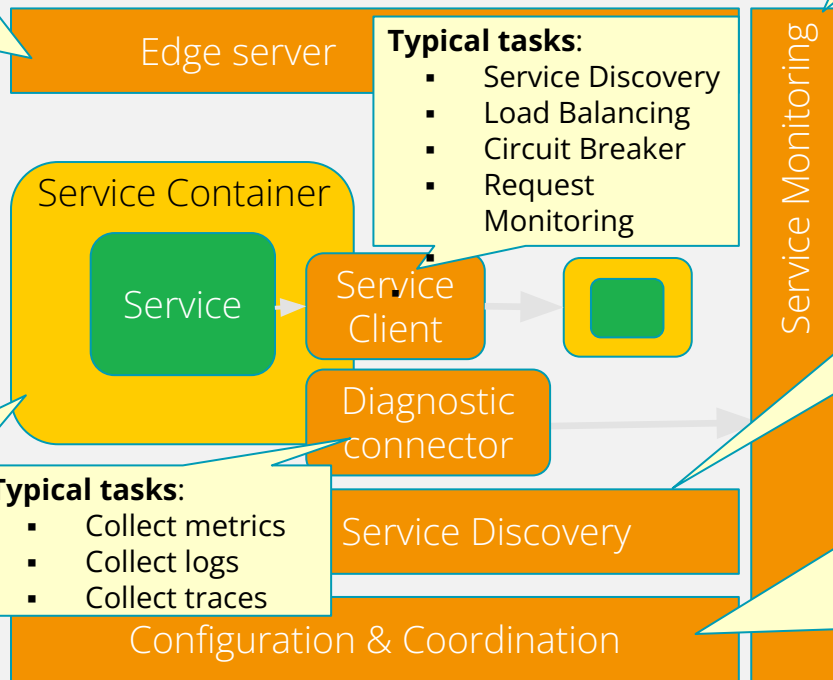
- Aggregation of metrics
- Collection of logs
- Collection of traces
- Analysis / visualization
- Alerting

Typical tasks:

- Service Registration
- Service Lookup
- Service Description
- Membership Detection
- Failure Detection

Typical tasks:

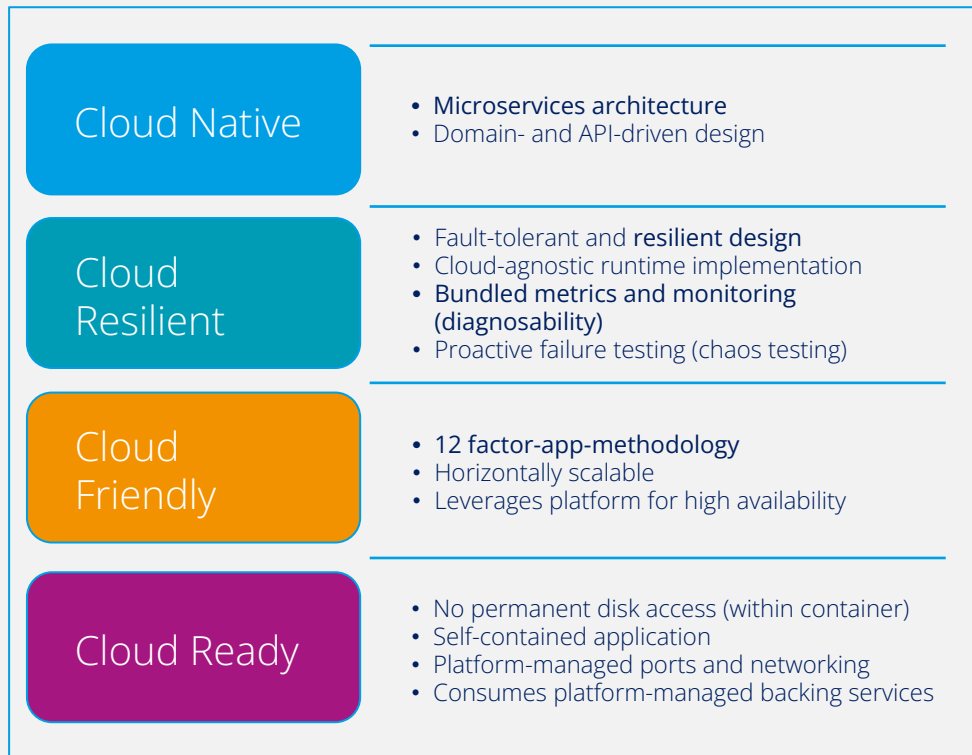
- Key-value store
- Sync of configuration files
- Watches, notifications, hooks, events
- Coordination with locks, leader election and messaging
- Establishing consensus in the cluster



The Cloud Native Application Maturity Model



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Exercise 1 (20 min): Twelve Factor Apps

12 Factor App



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- | | |
|--|---|
| <p>1 Codebase
One codebase tracked in revision control, many deploys.</p> | <p>7 Port binding
Export services via port binding.</p> |
| <p>2 Dependencies
Explicitly declare and isolate dependencies.</p> | <p>8 Concurrency
Scale out via the process model.</p> |
| <p>3 Configuration
Store config in the environment.</p> | <p>9 Disposability
Maximize robustness with fast startup and graceful shutdown.</p> |
| <p>4 Backing Services
Treat backing services as attached resources.</p> | <p>10 Dev/Prod Parity
Keep development, staging, and production as similar as possible</p> |
| <p>5 Build, release, run
Strictly separate build and run stages.</p> | <p>11 Logs
Treat logs as event streams.</p> |
| <p>6 Processes
Execute the app as one or more stateless processes.</p> | <p>12 Admin processes
Run admin/management tasks as one-off processes.</p> |

<https://12factor.net/de/>

<https://www.slideshare.net/Alicanakku1/12-factor-apps>



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Resilience

Resilience



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$$\text{Availability} = \text{MTTF} / (\text{MTTF} + \text{MTTR})$$



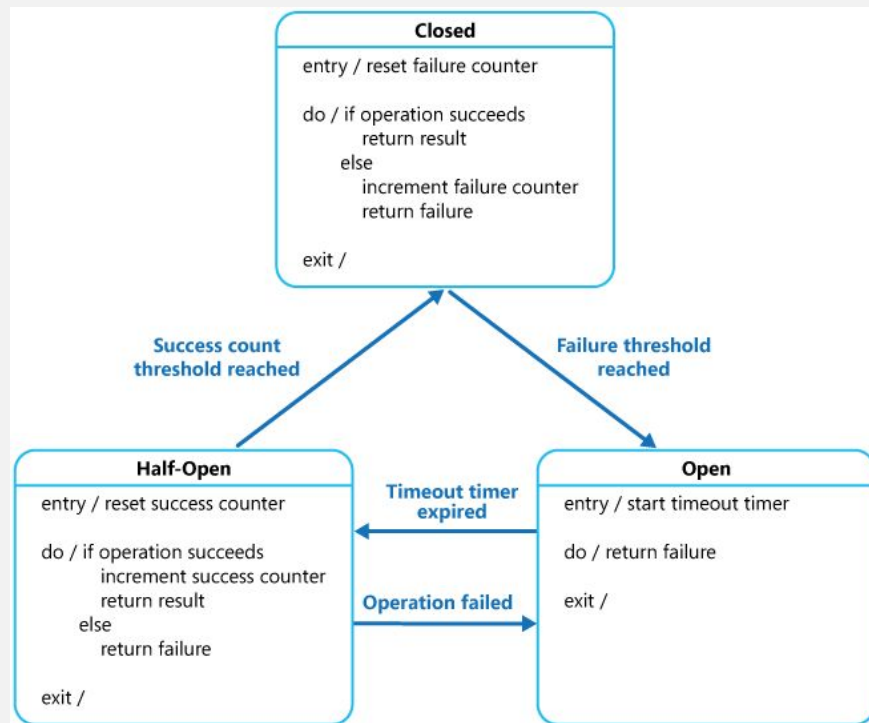
Resilience: The ability of a system to deal with unexpected and faulty situations

- Without the user noticing (best case)
- With a “graceful degradation” of the service (worst case)

Resilience pattern: circuit breaker



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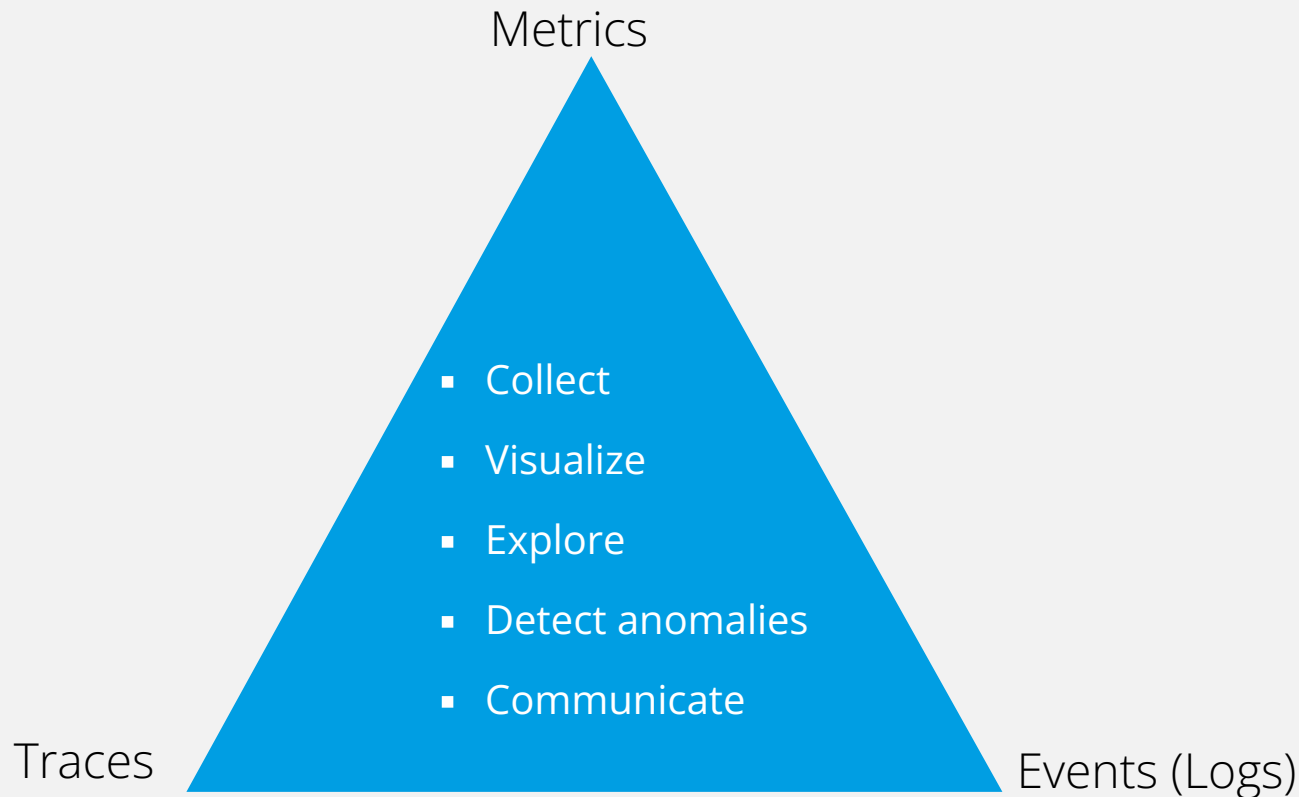
Source: <https://learn.microsoft.com/en-us/azure/architecture/patterns/circuit-breaker>

Further patterns: <https://learn.microsoft.com/en-us/azure/well-architected/reliability/design-patterns> |

Diagnosability



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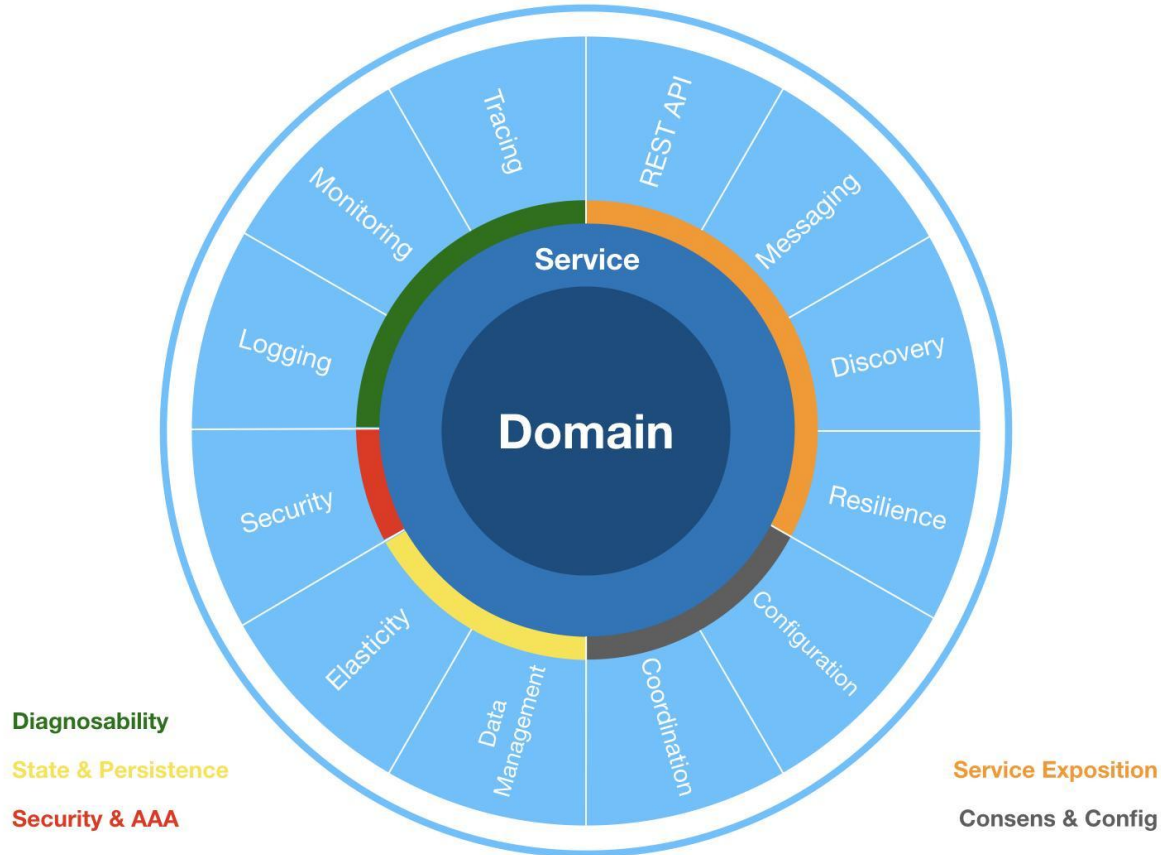




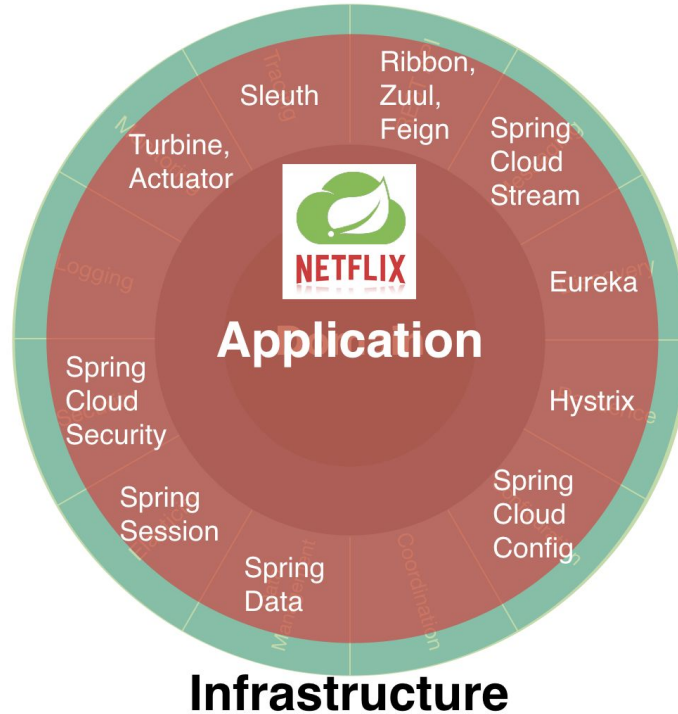
QA|WARE

Technical aspects of microservices

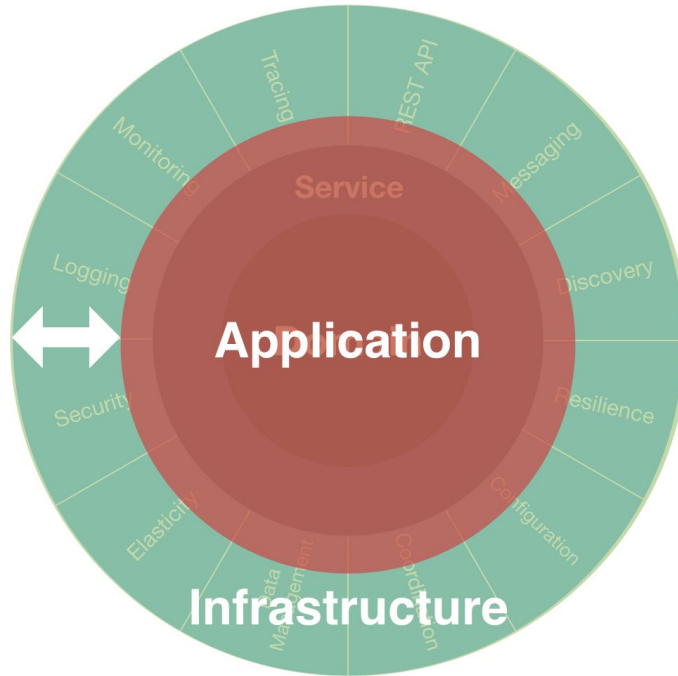
Technical aspects of microservices



Technical aspects of microservices: The library solution

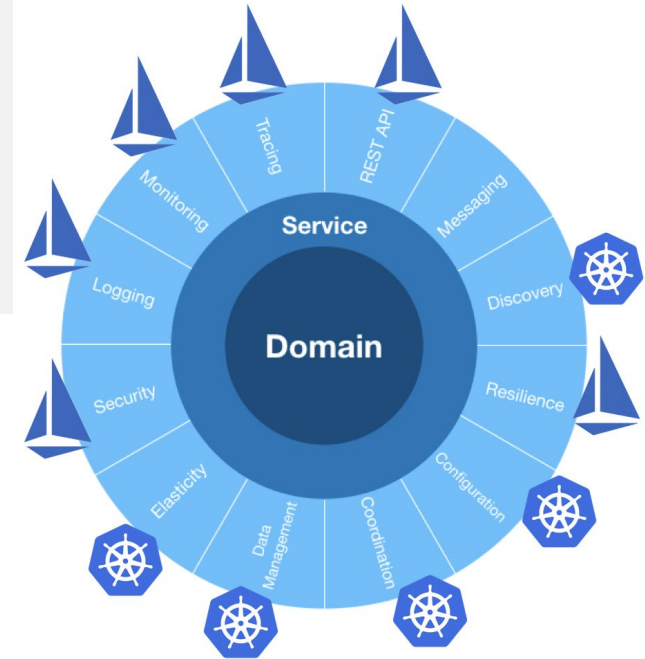
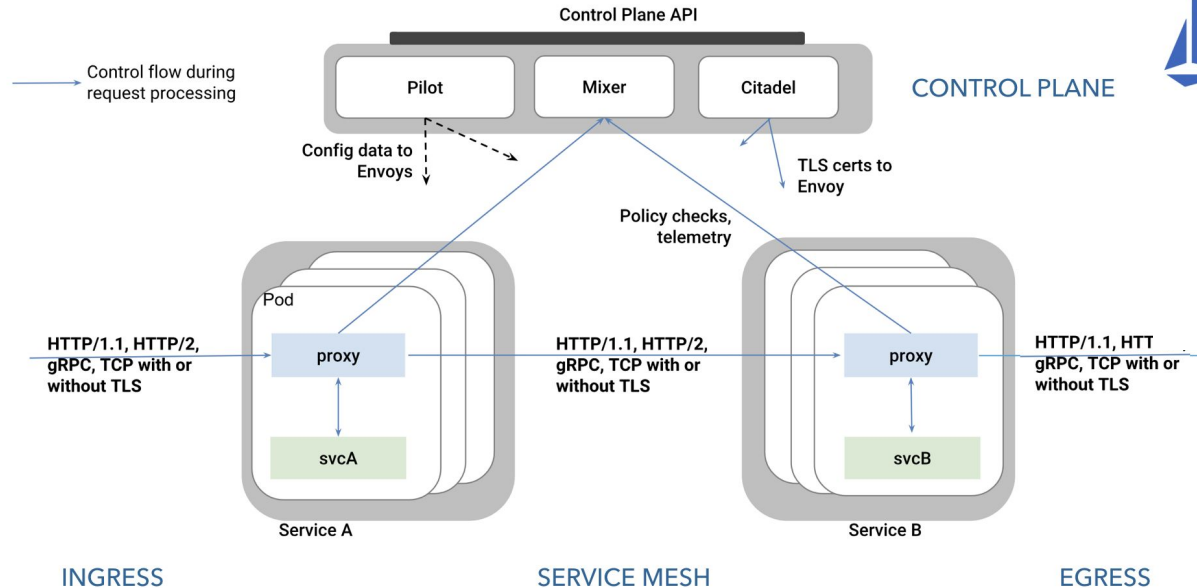


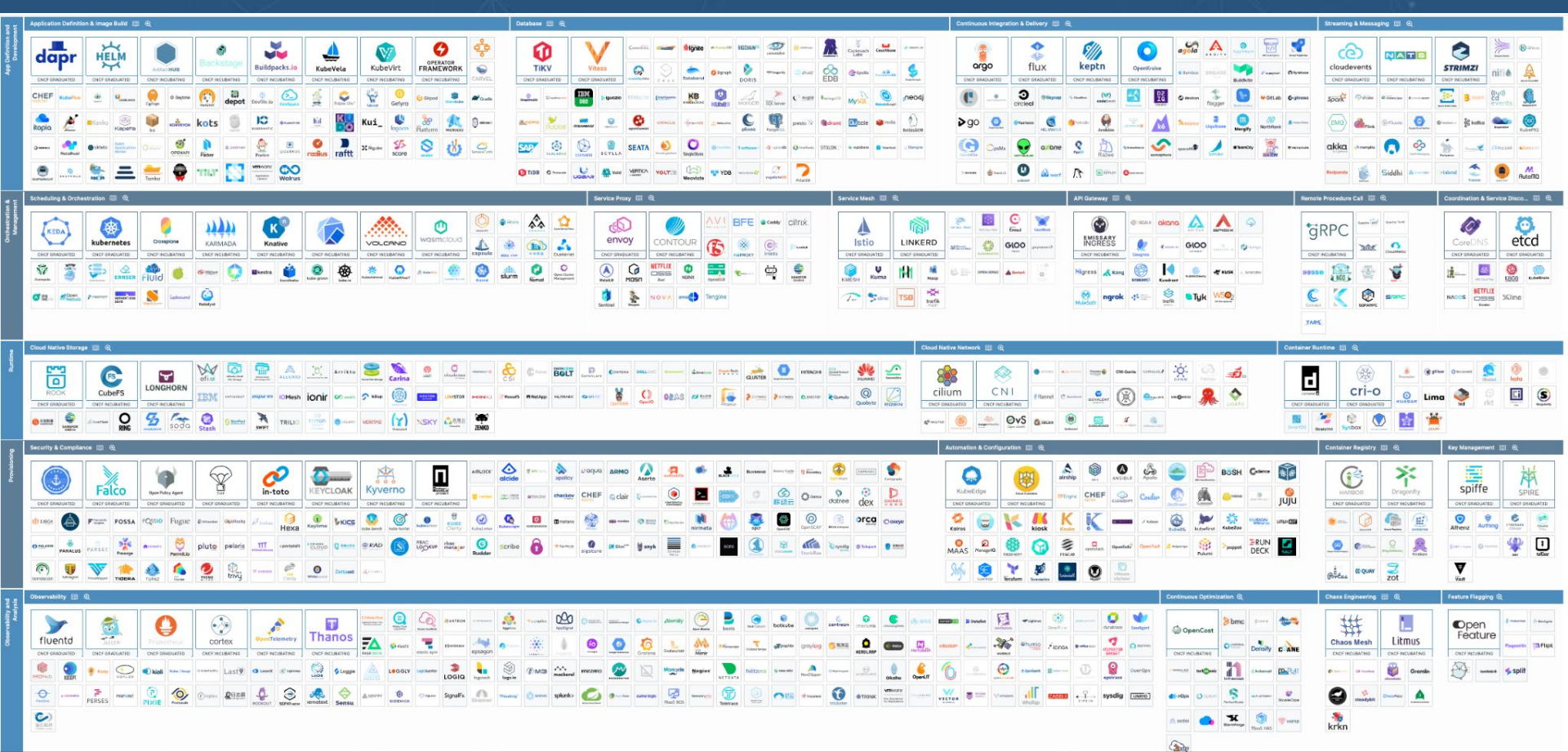
Technical aspects of microservices: The infrastructure solution



Istio Service Mesh

- Open-Source-Projekt von Google, IBM, Lyft, RedHat u.A.
- Aufsatz auf Kubernetes, der wichtige technische Aspekte
- auf Infrastruktur-Seite ergänzt





<https://landscape.cncf.io/>
<https://github.com/cncf/landscape>



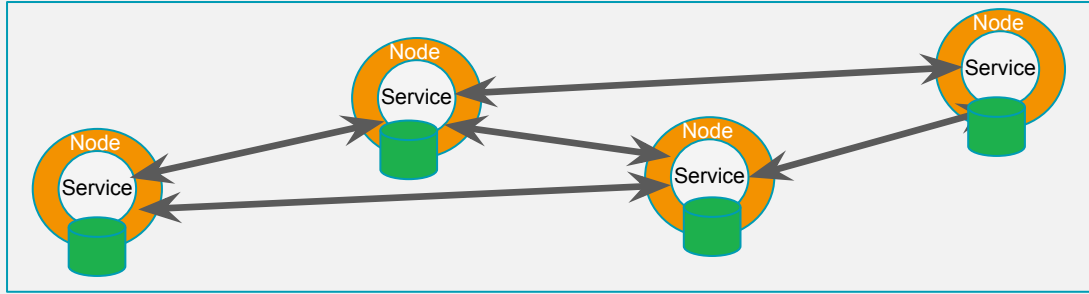
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Configuration & Coordination: Distributed State and Consensus

A distributed configuration memory



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How is the state of the configuration memory synchronized in the cluster?

The CAP Theorem



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Brewer's theorem for properties of stateful distributed systems – now also formally proven. [1]

There are three essential properties that a distributed system can only have two of at a time:

- Consistency **(C)**
- Availability **(A)**
- Partition tolerance **(P)**

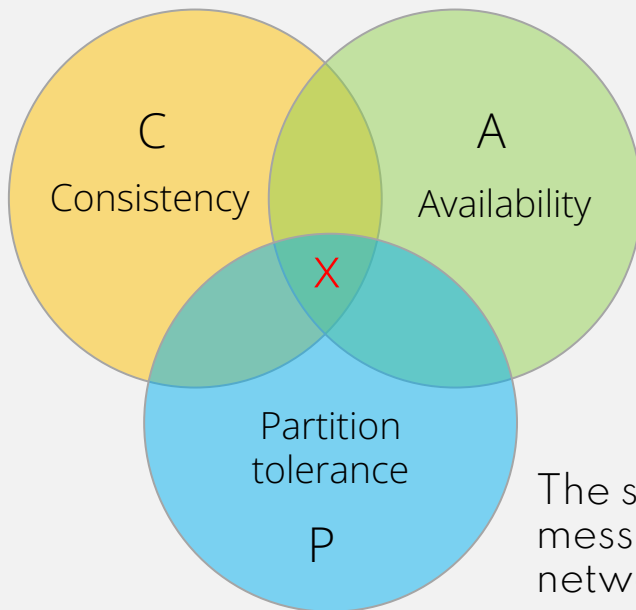
[1] Brewer, Eric A. "Towards robust distributed systems." PODC. 2000.

The CAP Theorem



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All nodes see the same data at the same time. All copies are always the same.



The system will continue to operate even if individual nodes fail. Failures of nodes and channels do not prevent the surviving nodes from functioning.

The system also works in the case of lost messages. The system can handle the network being divided into nodes in several partitions that do not communicate with each other.

In the case of a network partition, you have to choose between consistency and availability; you can't have both.

Gossip protocols for high availability

Basis: A network of agents with their own state

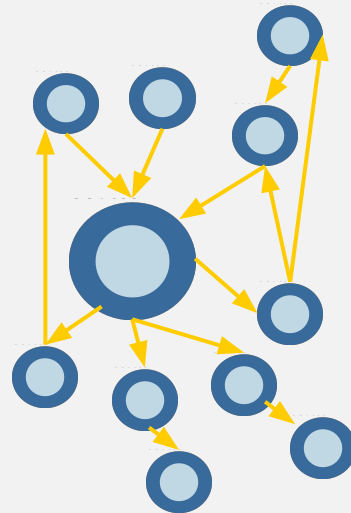
- Agents distribute a gossip stream
- Message: Source, content / state, timestamp
- Messages are sent periodically at fixed intervals
- to a certain number of other nodes (fanout)

Viral spread of the gossip stream

- Nodes that are in a group with me will definitely receive a message
- The top x% of nodes that send me messages will receive a message

Messages that are trusted are adopted into the local state if

- the same message has been heard from several pages
- the message comes from nodes that the agent trusts
- no more current message is available



Gossip protocols for high availability

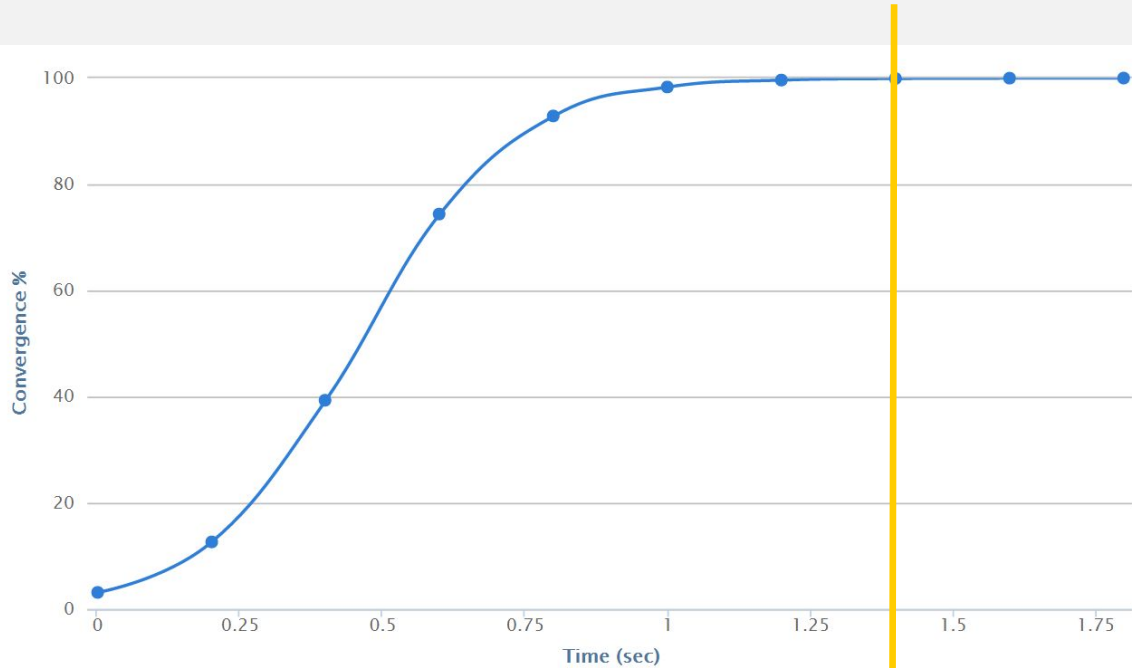
Advantages:

- No centralized units necessary.
- Defective partitions in the network are bypassed. Communication does not have to be reliable.

Disadvantages:

- The state is potentially inconsistently distributed (but converges over time)
- Overhead due to redundant messages.

The convergence of the data and thus the time of complete consistency can be calculated.



Vollständige
Konsistenz

Estimated max bandwidth: 328.1 kbps/node

Gossip Interval

The gossip interval controls how often messages are gossiped to other nodes

seconds

Gossip Fanout

The gossip fanout controls how many nodes we gossip with

nodes

Nodes

This controls how many simulated nodes are in the cluster

Packet Loss

This controls the amount of simulated packet loss [0, 100)

% lost packets

Node failures

This controls what percent of simulated nodes are failed

% failed

<https://www.serf.io/docs/internals/simulator.html>

The Fediverse



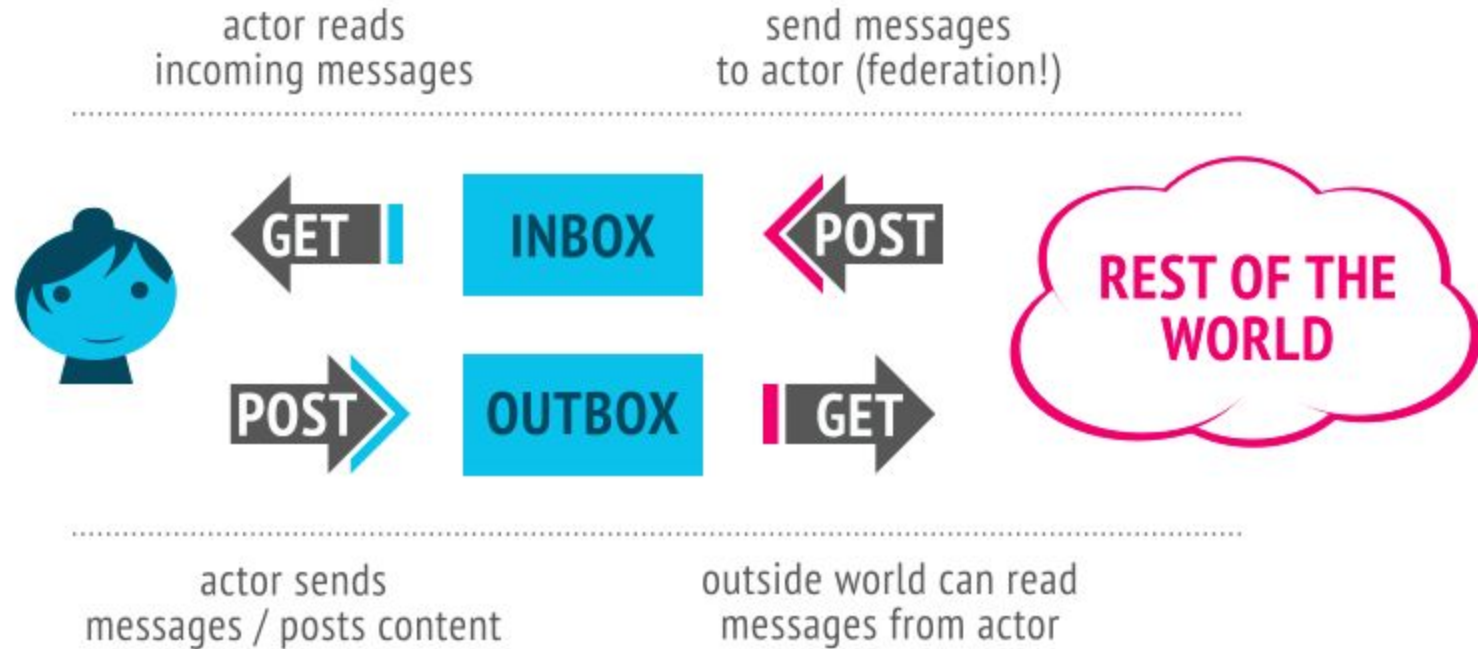
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<https://framatube.org/w/9dRFC6Ya11NCVeYKn8ZhiD>

Example for a Gossip protocol: ActivityPub



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Source: <https://www.w3.org/TR/activitypub/>

Protocols for distributed consensus: consistent, but not highly available, in contrast to gossip protocols



Basis: network of agents

Principle: it is sufficient if the state is consistent on a simple majority of the nodes and the remaining nodes recognize their inconsistency.

Procedure:

- the network agrees on a leader agent by a simple majority – initially and if the leader agent is not accessible. A partition in the minority cannot elect a leader agent.
- All changes are routed through the leader agent. The leader agent periodically distributes change messages to all other agents via multicast.
- If a simple majority of agents acknowledge the change message, the change is activated in the leader and (via message) also in the agents that have acknowledged. Otherwise, the state is assumed to be inconsistent.

Specific consensus protocols: **Raft**, **Paxos**

Protocols for distributed consensus: consistent, but not highly available, in contrast to gossip protocols



Advantages:

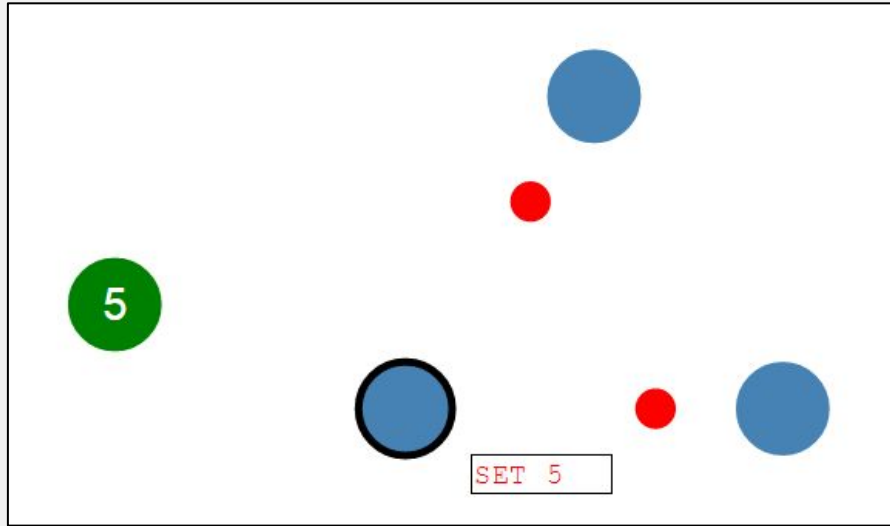
- Faulty partitions in the network are tolerated and automatically consistent again after the error has been rectified.
- Strictly consistent data.

Disadvantages:

- The central leader agent limits the throughput of changes.
- Not highly available: in the case of a network partition, the smaller partition cannot continue to work. If the majority is not in any partition, then overall work cannot continue.

The Raft Consensus Protocol

Ongaro, Diego; Ousterhout, John (2013).
"In Search of an Understandable Consensus Algorithm".



<http://thesecretlivesofdata.com/raft>

<https://raft.github.io/>



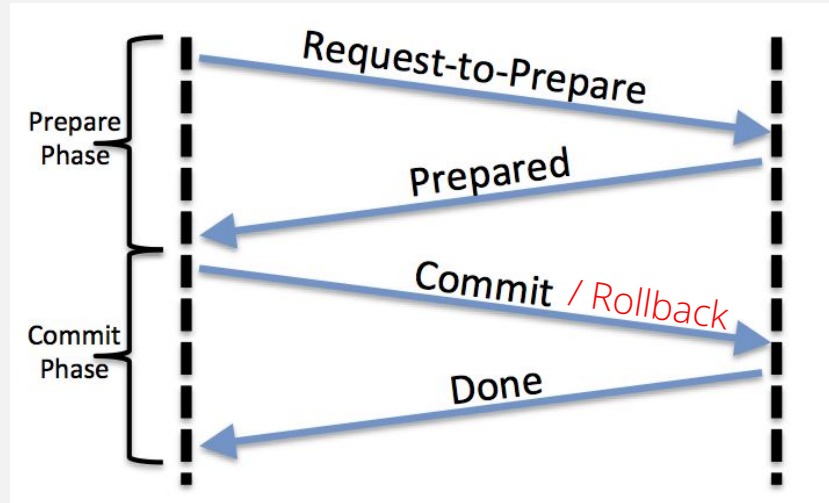
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Exercise 2 & 3 (30 min):

The Raft Consensus Protocol
etcd

If strict consistency across all nodes is necessary, the 2-phase commit protocol (2PC) remains.

A transaction coordinator distributes the changes and activates them only when all have been approved. Otherwise, the changes are undone.



Advantage:

- All nodes are consistent with each other.

Disadvantages:

- Time-consuming, since all nodes must always agree.
- The system no longer works once the network is partitioned.

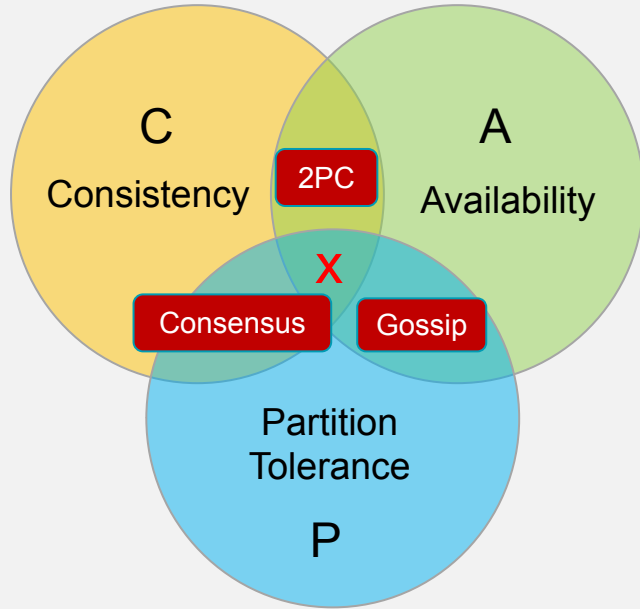
Transaction coordinator

Transaction participants

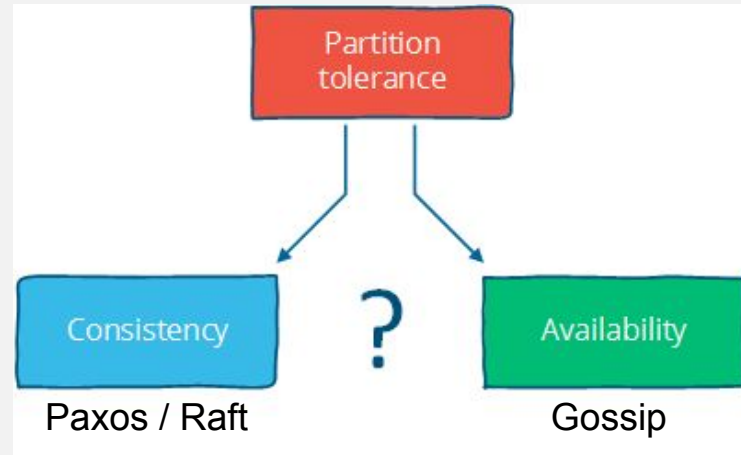
The presented protocols and the CAP theorem



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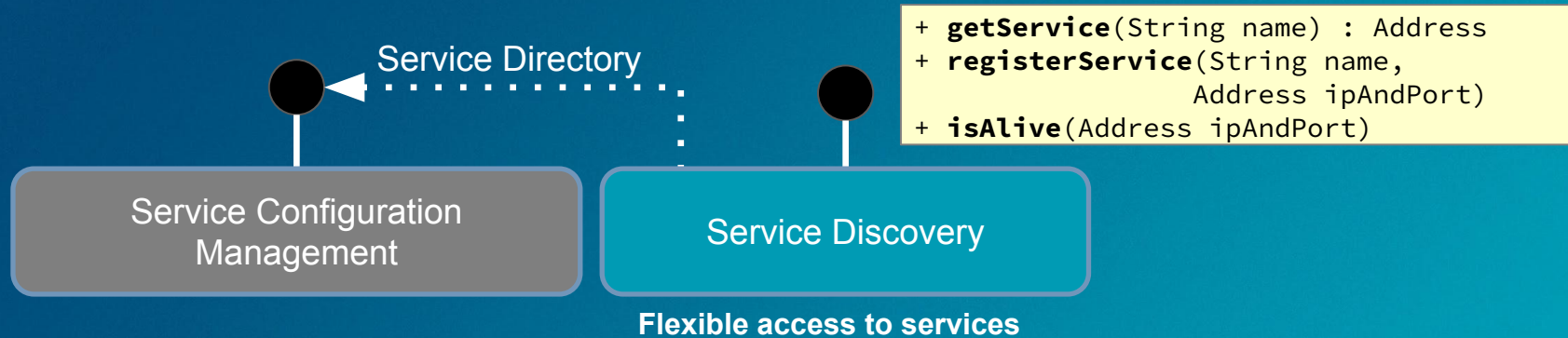


In the cloud, partitions have to be assumed.
This makes the decision binary:
Between consistency and availability.





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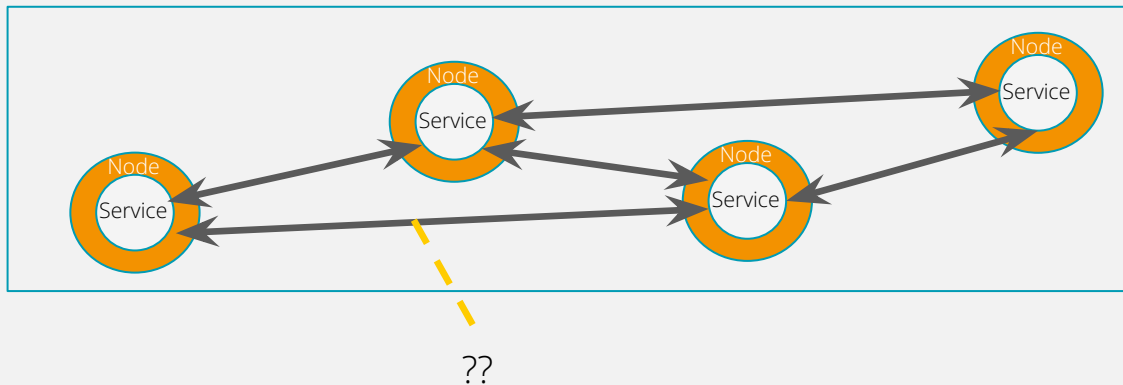


Service Discovery

The problems of a classic linking of services in the cloud



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Problems:

- Lack of redundancy: Each service is used directly. It cannot run in multiple instances to provide redundancy.
- Lack of flexibility: The services cannot be restarted or deployed on a different node without side effects – or even replaced with a different service implementation.

Solutions:

- Dynamic DNS
- Ambassador
- Dynamic configuration files
- and environment variables

The Ambassador Pattern

One ambassador node for each node type (e.g. web server)

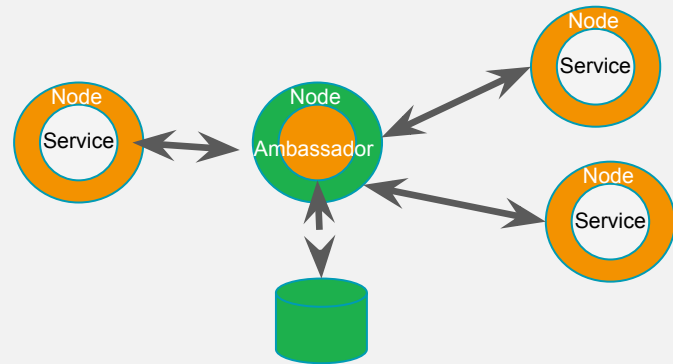
Service Registration:

- Monitors the cluster and recognizes new and sick/dead nodes in its group.
- Stores the currently active nodes in the configuration memory.

Service Discovery: The client communicates with the ambassador node, which then passes the requests on to a node in the group as efficiently as possible.

The ambassador node can provide a range of additional services when connecting to the service (service binding):

- Load Balancing inklusive Failover
- Service Monitoring
- Circuit Breaker Pattern
- Throttling





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Exercise 4: Consul & Traefik