Middleware Architectures 1

Lecture 3: Microservice Architecture

doc. Ing. Tomáš Vitvar, Ph.D.

tomas@vitvar.com • @TomasVitvar • https://vitvar.com

Czech Technical University in Prague

Faculty of Information Technologies • Software and Web Engineering • https://vitvar.com/lectures

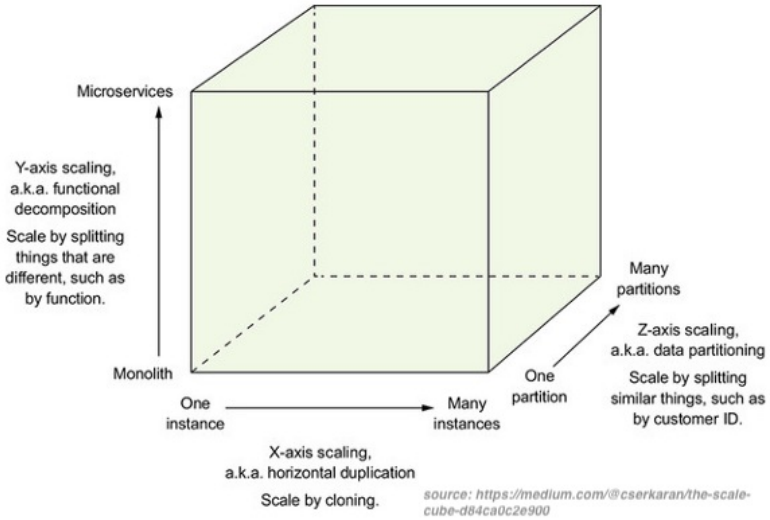
Modified: Sun Oct 26 2025, 20:49:01
Humla v1.0

Overview

- Microservices Architecture
- Design Patterns

The Scale Cube

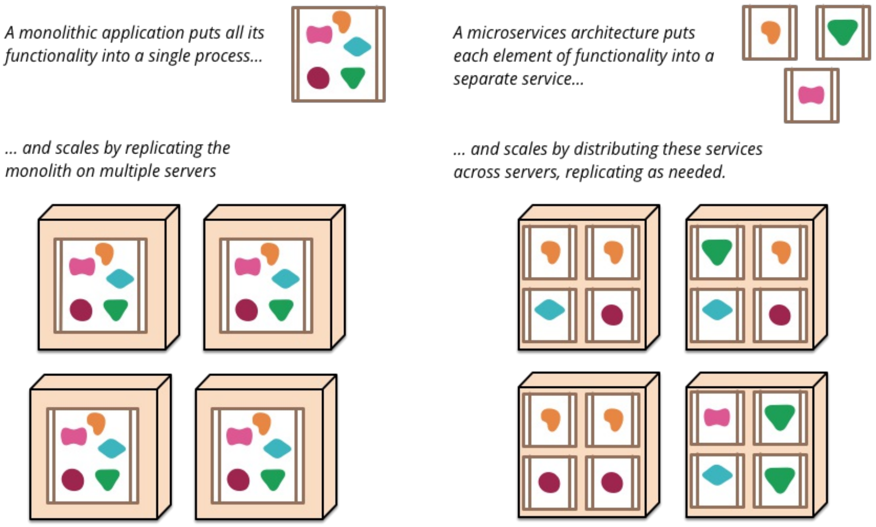
- Three-dimensional scalability model
  - *X-Axis scaling requests across multiple instances*
  - ***Y-Axis scaling decomposes an application into micro-services***
  - *Z-Axis scaling requests across "data partitioned" instances*


Microservices
Y-axis scaling, a.k.a. functional decomposition
Scale by splitting things that are different, such as by function.
Monolith
One instance
Many instances
X-axis scaling, a.k.a. horizontal duplication
Scale by cloning.
One partition
Many partitions
Z-axis scaling, a.k.a. data partitioning
Scale by splitting similar things, such as by customer ID.

source: https://medium.com/@cserkaran/the-scale-cube-d84ca0c2e900

Overview

- Emerging software architecture
  - *monolithic vs. decoupled applications*
  - *applications as independenly deployable services*



A monolithic application puts all its functionality into a single process...

... and scales by replicating the monolith on multiple servers

A microservices architecture puts each element of functionality into a separate service...

... and scales by distributing these services across servers, replicating as needed.

Major Characteristics

- Loosely coupled
  – *Integrated using well-defined interfaces*
- Technology-agnostic protocols
  – *HTTP, they use REST architecture*
- Independently deployable and easy to replace
  – *A change in small part requires to redeploy only that part*
- Organized around capabilities
  – *such as accounting, billing, recommendation, etc.*
- Impplemented using different technologies
  – *polyglot – programming languages, databases*
- Owned by a small team

Overview

- Microservices Architecture
- Design Patterns
  – *Data Management Patterns*
  – *Communication Patterns*
  – *Other Patterns*

Design Patterns

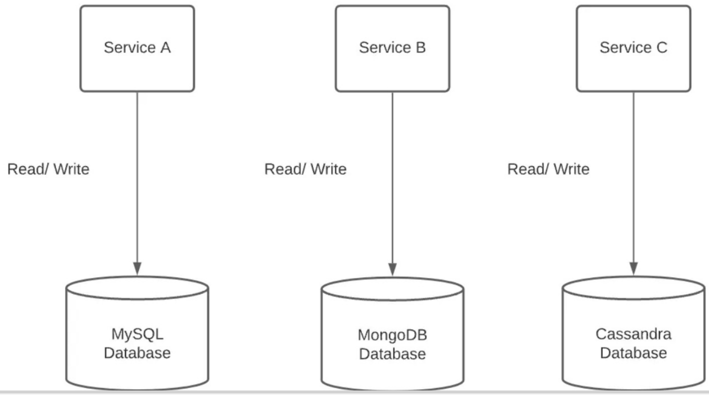
- Data management patterns
  - *Database per service*
  - *Saga pattern*
  - *Command query responsibility segregation (CQRS)*
- Communication patterns
  - *API Gateway*
  - *Aggregator design pattern*
  - *Circuit breaker design pattern*
  - *Sidecar pattern*
- Other patterns
  - *Strangler pattern*

Overview

- Microservices Architecture
- Design Patterns
  - *Data Management Patterns*
  - *Communication Patterns*
  - *Other Patterns*

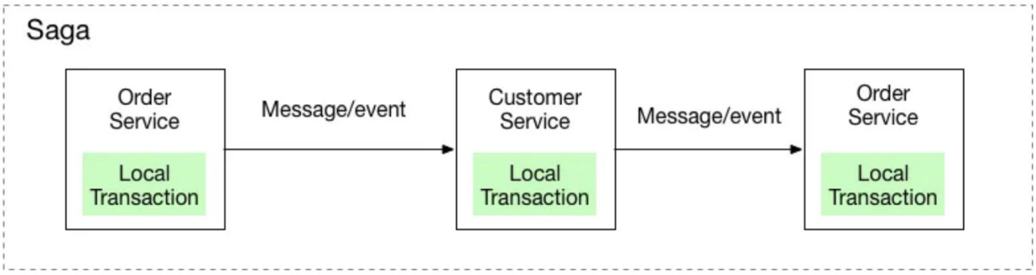
Database per Service

- Every service has its own database (or at least its own schema)
  - *A database dedicated to one service can't be accessed by other services.*
  - *Decouples services from each other*
  - *Enables polyglot persistence*
    - → *Different services can use different database technologies*
- Challenges
  - *Data consistency*
  - *Complex queries and transactions*



Saga Pattern

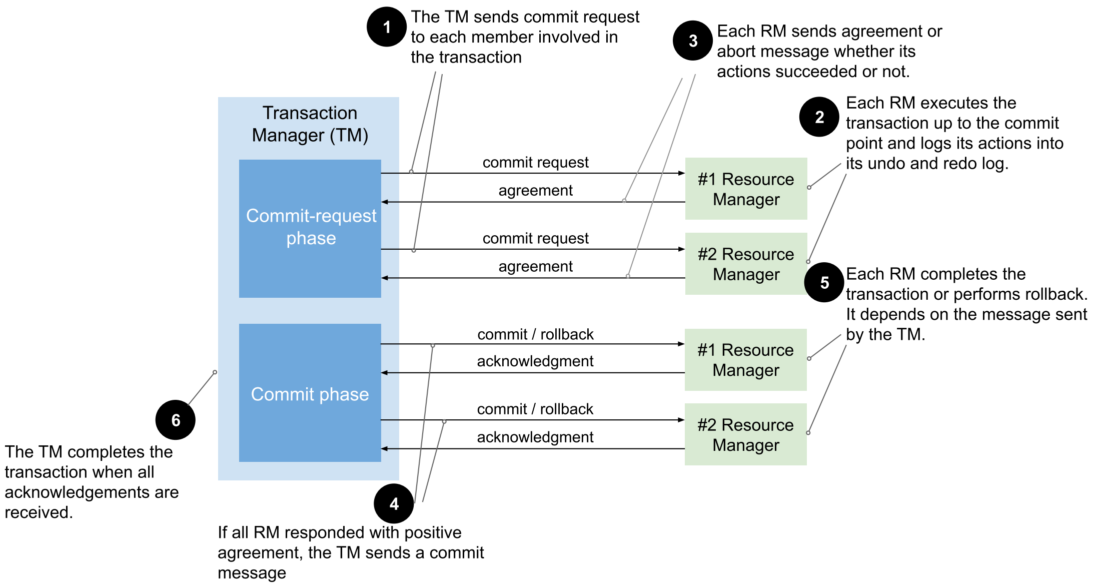
- Manages data consistency across services
  - *A series of local transactions*
  - *This requires **compensating** transactions to undo changes if needed*
  - *An alternative to Two-phase commit*
- Two types of Sagas
  - *Choreography-based Sagas*
    - → *Each service produces and listens to events*
    - → *No central coordinator*
  - *Orchestration-based Sagas*
    - → *Central coordinator (orchestrator) tells the participants what local transactions to execute*



Saga Pattern Examples

- Example Services
  - *Order Service*
  - *Payment Service*
  - *Inventory Service*
- Choreography (no central coordinator)
  - *Order Service → publishes* `OrderCreated`
  - *Payment Service → listens, reserves funds → publishes* `PaymentCompleted`
  - *Inventory Service → listens, deducts stock → publishes* `InventoryUpdated`
  - *Order Service → listens, marks order as* `Completed`
- Orchestration (central coordinator)
  - ***Orchestrator*** *→ sends* `ReservePayment` *to Payment Service*
  - *Payment Service → responds* `PaymentConfirmed`
  - ***Orchestrator*** *→ sends* `ReserveStock` *to Inventory Service*
  - *Inventory Service → responds* `StockReserved`
  - ***Orchestrator*** *→ calls* `CompleteOrder` *in Order Service*

Two-phase Commit



1 The TM sends commit request to each member involved in the transaction

2 Each RM executes the transaction up to the commit point and logs its actions into its undo and redo log.

3 Each RM sends agreement or abort message whether its actions succeeded or not.

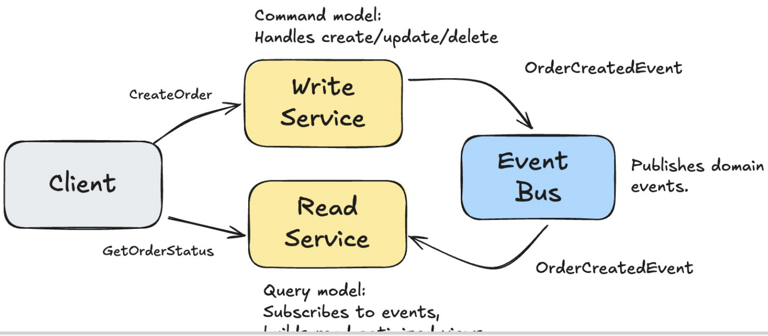
4 If all RM responded with positive agreement, the TM sends a commit message

5 Each RM completes the transaction or performs rollback. It depends on the message sent by the TM.

6 The TM completes the transaction when all acknowledgements are received.

CQRS

- Command Query Responsibility Segregation
- A pattern that separates read and write operations in a system.
  - ***Command side:*** *Handles create/update/delete operations*
  - ***Query side:*** *Handles read operations with optimized views*
- **Example:** Online Order System
  - *User places order →* `CreateOrder`
  - *Order Service stores order, publishes* `OrderCreatedEvent`
  - *Read Service updates denormalized* `orders_view`
  - *Client queries* `GetOrderStatus` *→ served from* `orders_view`

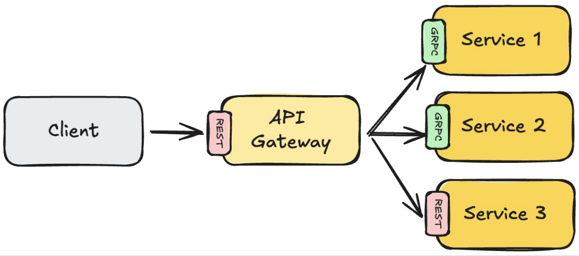


Overview

- Microservices Architecture
- Design Patterns
  - *Data Management Patterns*
  - *Communication Patterns*
  - *Other Patterns*

API Gateway

- Single entry point for all clients
  - *Handles requests by routing them to the appropriate microservice(s)*
  - *Perform request aggregation, protocol translation, authentication, rate limiting*
- Benefits
  - *A single entry point for a group of microservices*
  - *Clients don't need to know how services are partitioned*
  - *Service boundaries can evolve independently*
  - *Can implement authentication, TLS termination and caching*
- Challenges
  - *Potential bottleneck and single point of failure*
  - *Increased complexity in API Gateway implementation*

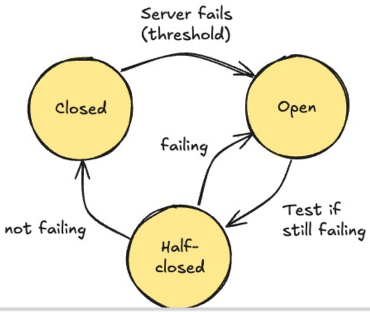


Aggregator Design Pattern

- Combines data from multiple services into a single response
  - *Useful when a client request requires data from multiple microservices*
- Benefits
  - *Reduces the number of client requests*
  - *Simplifies client logic*
- Challenges
  - *Increased complexity in the aggregator service*
  - *Potential performance bottleneck*

Circuit Breaker

- A service stops trying to execute an operation that is likely to fail
  - *Monitors for failures and opens the circuit if failures exceed a threshold*
  - *When the circuit is **open**, calls to the failing service are blocked for some time*
  - *After a timeout, the circuit **half-opens** to test if the service has recovered*
  - *If the test call succeeds, the circuit **closes** and normal operation resumes*
- Benefits
  - *Improves system resilience and stability*
  - *Prevents cascading failures in distributed systems*
- Challenges
  - *Requires careful configuration of thresholds and timeouts*



Circuit Breaker Example

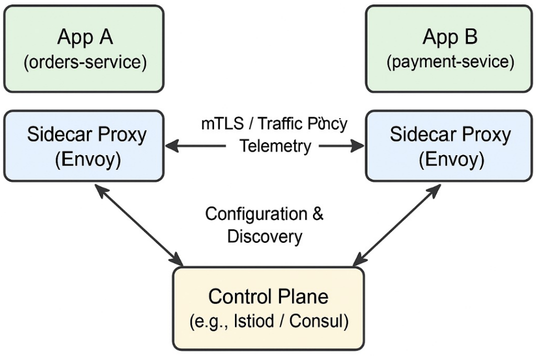
- **Scenario:** Order Service calls Payment Service
  - *Under normal conditions → call succeeds, response is fast*
  - *When Payment Service slows down or fails repeatedly → circuit "opens"*
  - *Further calls are blocked immediately → fallback response returned*
  - *After a timeout → circuit "half-opens" to test recovery*
  - *If test succeeds → circuit "closes" and normal calls resume*
- Example Flow
  - *Order Service → calls Payment API (fails 3×)*
  - *Circuit opens → returns* `"Payment service unavailable"`
  - *After 30s → one trial call allowed*
  - *If trial succeeds → circuit closes and normal traffic resumes*

Sidecar Pattern

- Deploys auxiliary components alongside the main service
  - *Handles logging, monitoring, configuration, and networking*
  - *Runs in a separate process or container but shares the same lifecycle as the main service*
- Benefits
  - *Decouples auxiliary functionality from the main service*
  - *Enables reuse of common functionality across multiple services*
- Challenges
  - *Increased operational complexity*
  - *Resource overhead due to additional processes/containers*

Sidecar Pattern and Service Mesh

- **Service Mesh:** A dedicated infrastructure layer for managing service-to-service communication
- Service mesh uses sidecar proxies (e.g. Envoy) to manage traffic
- Example: Istio injects Envoy sidecar to handle
  - *Service discovery and routing*
  - *mTLS security*
  - *Retries, rate limiting, and metrics*



Overview

- Microservices Architecture
- Design Patterns
  - *Data Management Patterns*
  - *Communication Patterns*
  - *Other Patterns*

Strangler Pattern

- Incrementally replace a monolith with microservices
- New functionality is implemented as microservices
- Existing functionality is gradually "strangled" and replaced
- Benefits
  - *Reduced risk by not rewriting the entire system at once*
  - *Allows for gradual migration and testing*
- Challenges
  - *Complexity in managing both monolith and microservices*
  - *Potential performance overhead during transition*