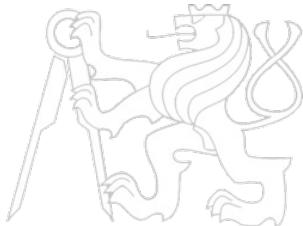


Middleware Architectures 1

Lecture 3: Microservice Architecture

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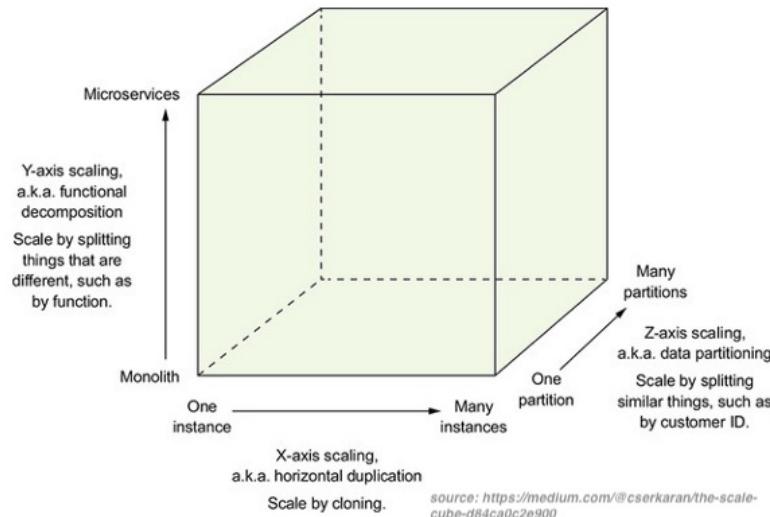
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Overview

- 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*



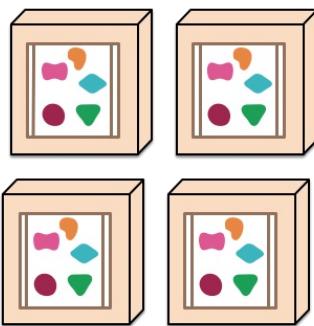
Overview

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

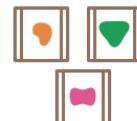
A monolithic application puts all its functionality into a single process...



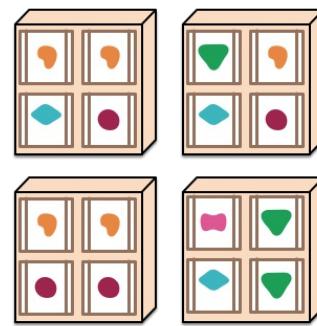
... and scales by replicating the monolith on multiple servers



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.*
- Implemented 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

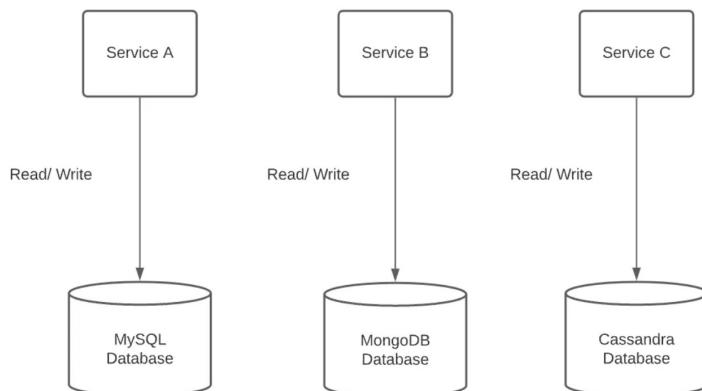
- Data management patterns
 - *Database per service*
 - *Saga pattern*
 - *Command query responsibility segregation (CQRS)*
- Communication patterns
 - *API Gateway*
 - *Aggregator design pattern*
 - *Circuit breaker design pattern*
 - *Sidecar pattern*
- Other patterns
 - *Strangler pattern*

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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

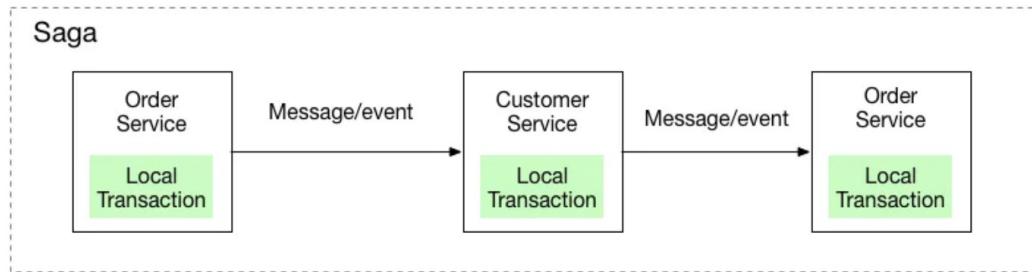


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Saga Pattern

- 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



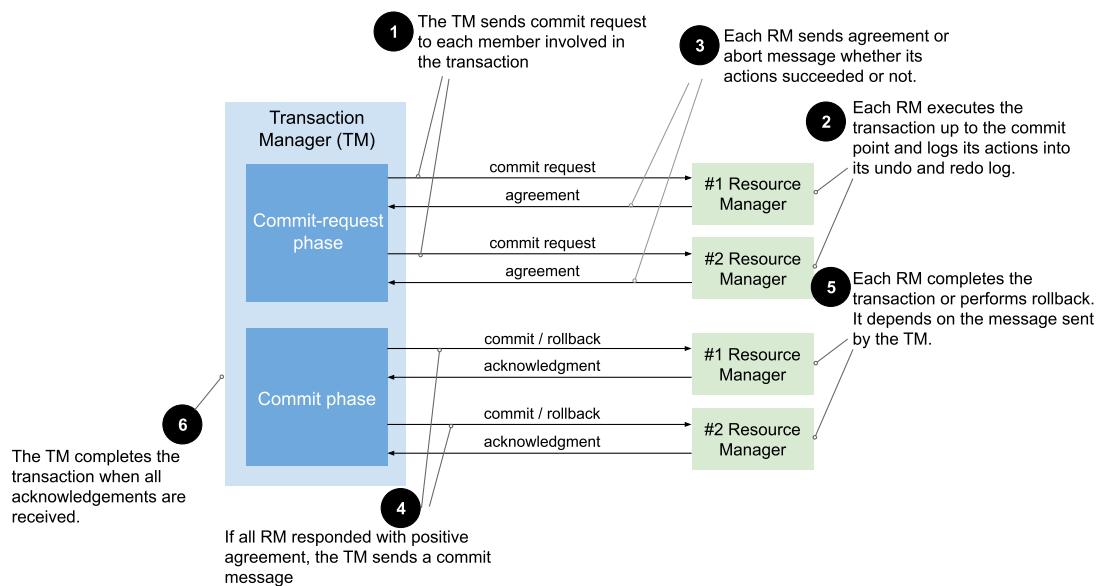
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Saga Pattern Examples

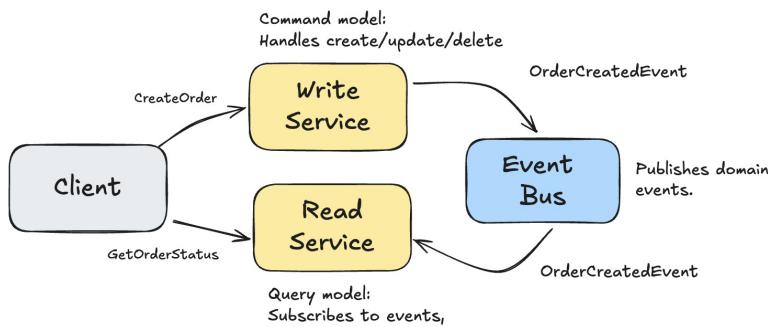
- Example Services
 - Order Service
 - Payment Service
 - Inventory Service
- Choreography (no central coordinator)
 - Order Service → publishes OrderCreated
 - Payment Service → listens, reserves funds → publishes PaymentCompleted
 - Inventory Service → listens, deducts stock → publishes InventoryUpdated
 - 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



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`

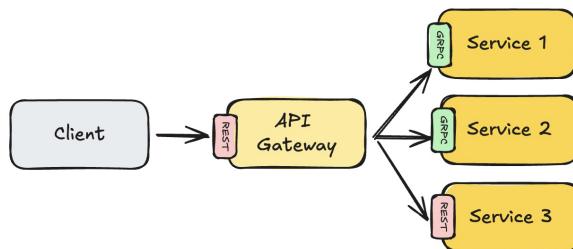


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API Gateway

- 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

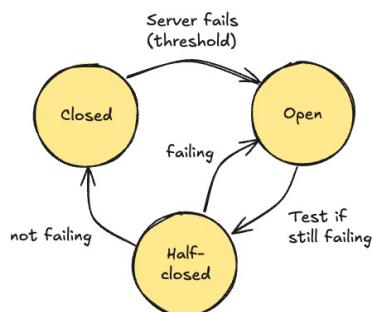


Aggregator Design Pattern

- 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

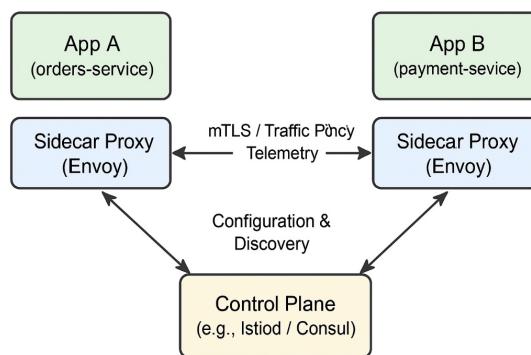
- **Scenario:** Order Service calls Payment Service
 - Under normal conditions → call succeeds, response is fast
 - When Payment Service slows down or fails repeatedly → circuit "opens"
 - Further calls are blocked immediately → fallback response returned
 - After a timeout → circuit "half-opens" to 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



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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*