Middleware Architectures 1

Lecture 2: Microservice Architecture

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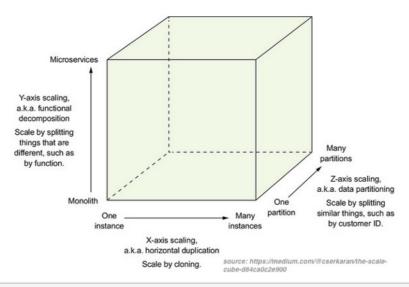
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Overview

- 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



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Overview

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

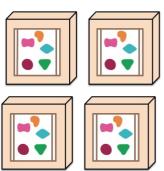
A monolithic application puts all its functionality into a single process...



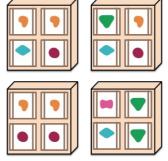
A microservices architecture puts each element of functionality into a separate service...



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



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



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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

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Overview

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

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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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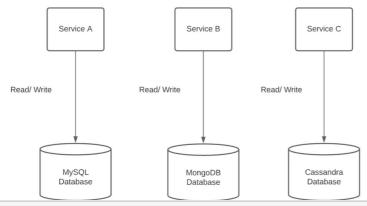
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Database per Service

- 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

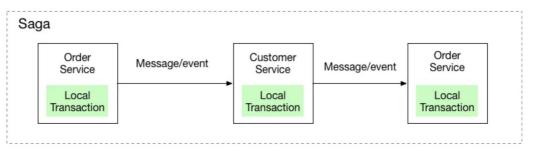


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Saga Pattern

- 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
 - \rightarrow 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 \rightarrow publishes OrderCreated
- Payment Service \rightarrow listens, reserves funds \rightarrow publishes PaymentCompleted
- Inventory Service \rightarrow listens, deducts $stock \rightarrow publishes$ InventoryUpdated
- Order Service \rightarrow listens, marks order as Completed

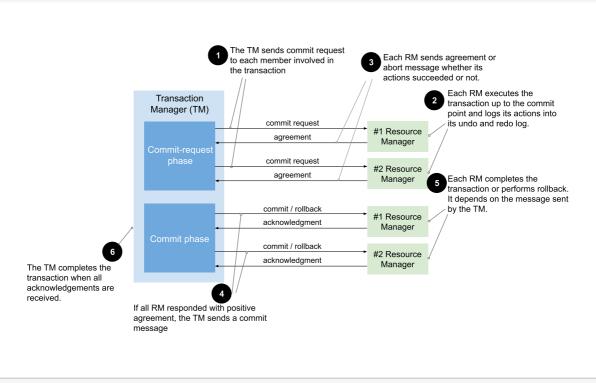
• Orchestration (central coordinator)

- *Orchestrator* → *sends* ReservePayment *to Payment Service*
- Payment Service → responds PaymentConfirmed
- *Orchestrator* → *sends* ReserveStock *to Inventory Service*
- Inventory Service \rightarrow responds StockReserved
- *Orchestrator* \rightarrow *calls* CompleteOrder *in Order Service*

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Two-phase Commit

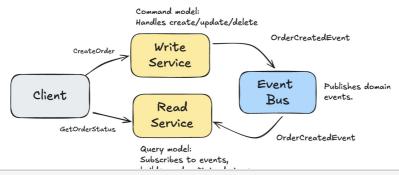


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CQRS

- 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 \rightarrow served from orders_view



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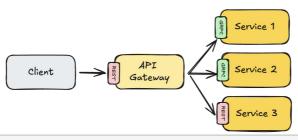
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API Gateway

- 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



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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

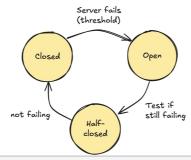
- A service stops trying to execute an operation that is likely to fail
 - Monitors for failures and opens the circuit if failures exceed a threshold
 - When the circuit is **open**, calls to the failing service are blocked for some time
 - After a timeout, the circuit half-opens to test if the service 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



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Circuit Breaker Example

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

• Example Flow

- Order Service \rightarrow calls Payment API (fails 3×)
- Circuit opens → returns "Payment service unavailable"
- After $30s \rightarrow one trial call allowed$
- If trial succeeds \rightarrow circuit closes and normal traffic resumes

Sidecar Pattern

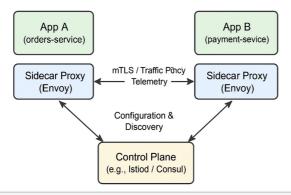
- Deploys auxiliary components alongside the main service
 - Handles logging, monitoring, configuration, and networking
 - Runs in a separate process or container but shares the same lifecycle as the main service
- Benefits
 - Decouples auxiliary functionality from the main service
 - Enables reuse of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

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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

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