

Middleware Architectures 1

Lecture 3: Microservice Architecture

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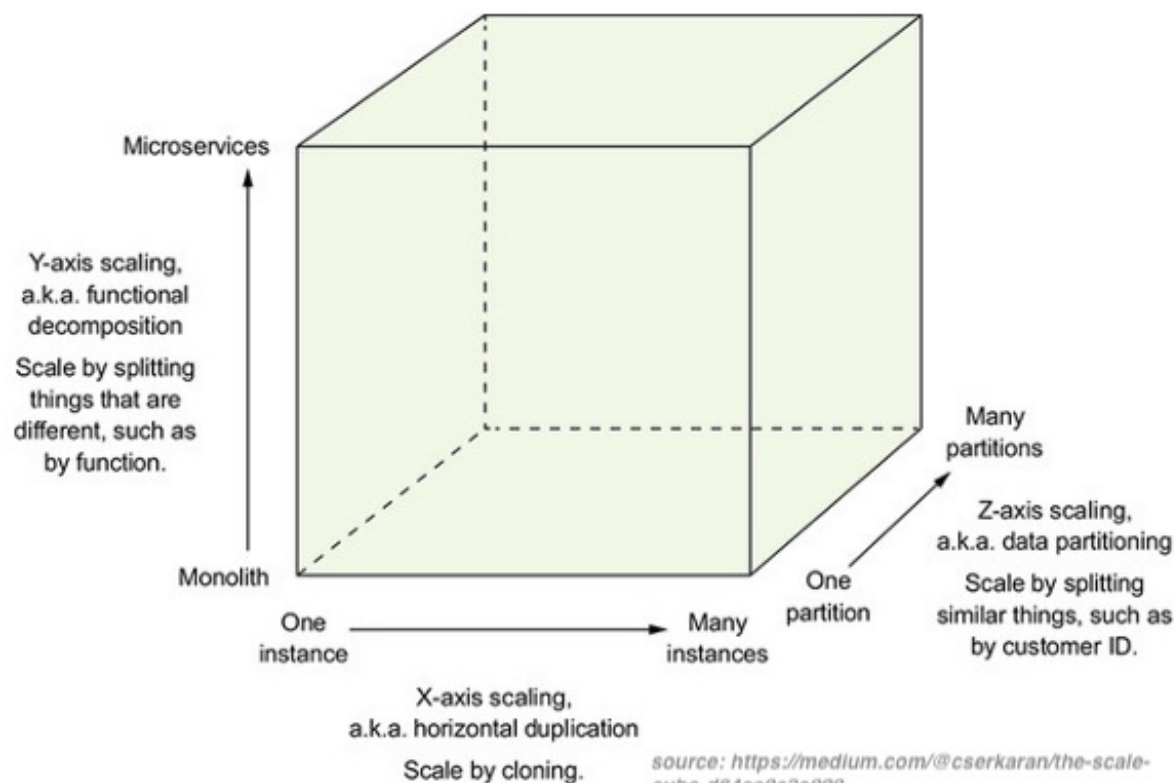
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Overview

- **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*



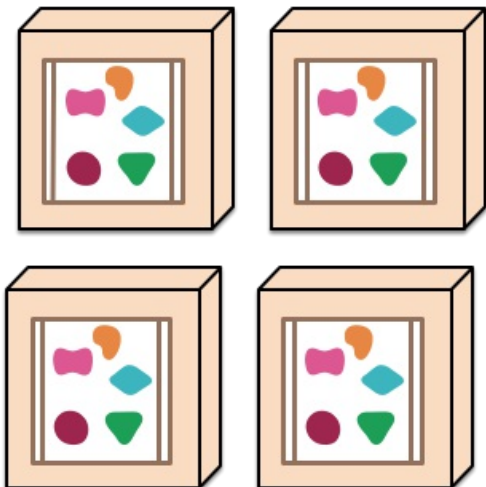
Overview

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

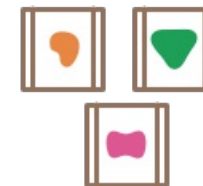
A monolithic application puts all its functionality into a single process...



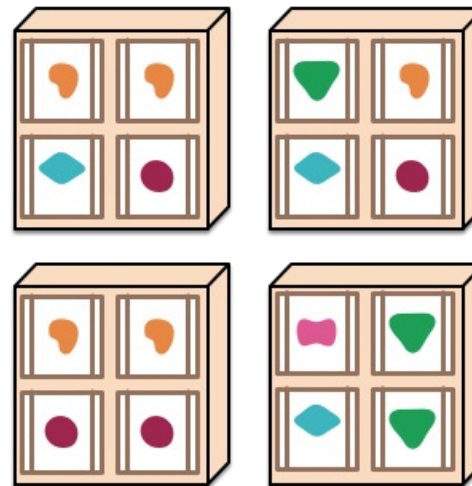
... and scales by replicating the monolith on multiple servers



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

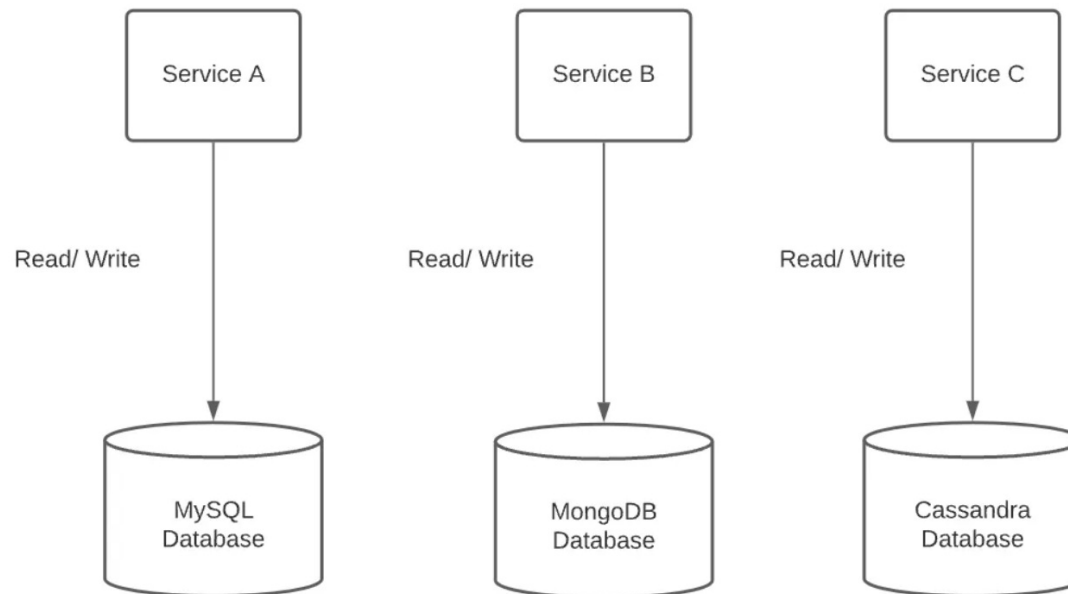
- Data management patterns
 - *Database per service*
 - *Saga pattern*
 - *Command query responsibility segregation (CQRS)*
- Communication patterns
 - *API Gateway*
 - *Aggregator design pattern*
 - *Circuit breaker design pattern*
 - *Sidecar pattern*
- Other patterns
 - *Strangler pattern*

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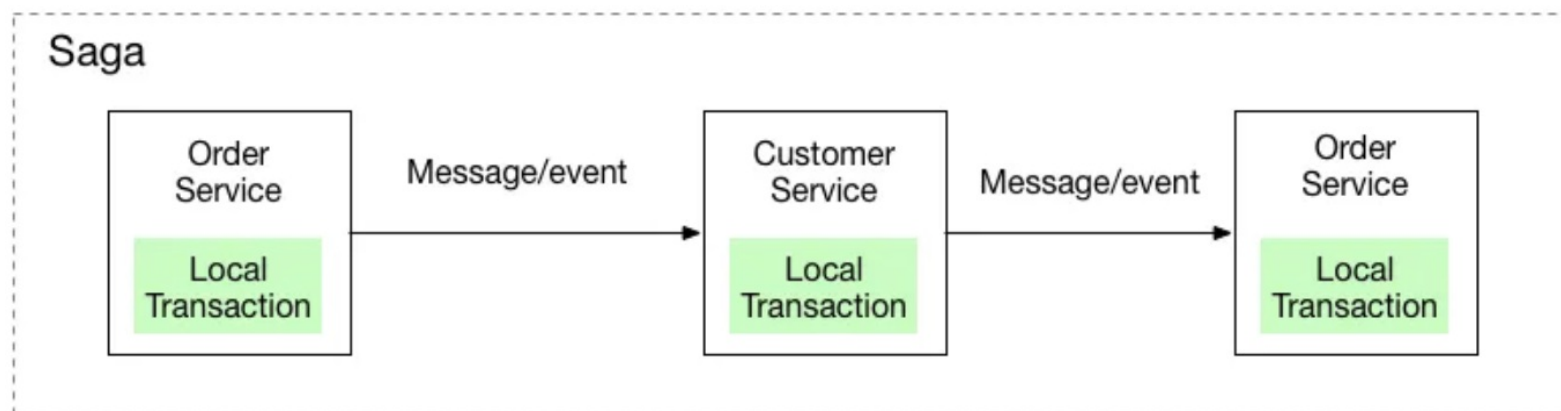
Database per Service

- 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*



Saga Pattern

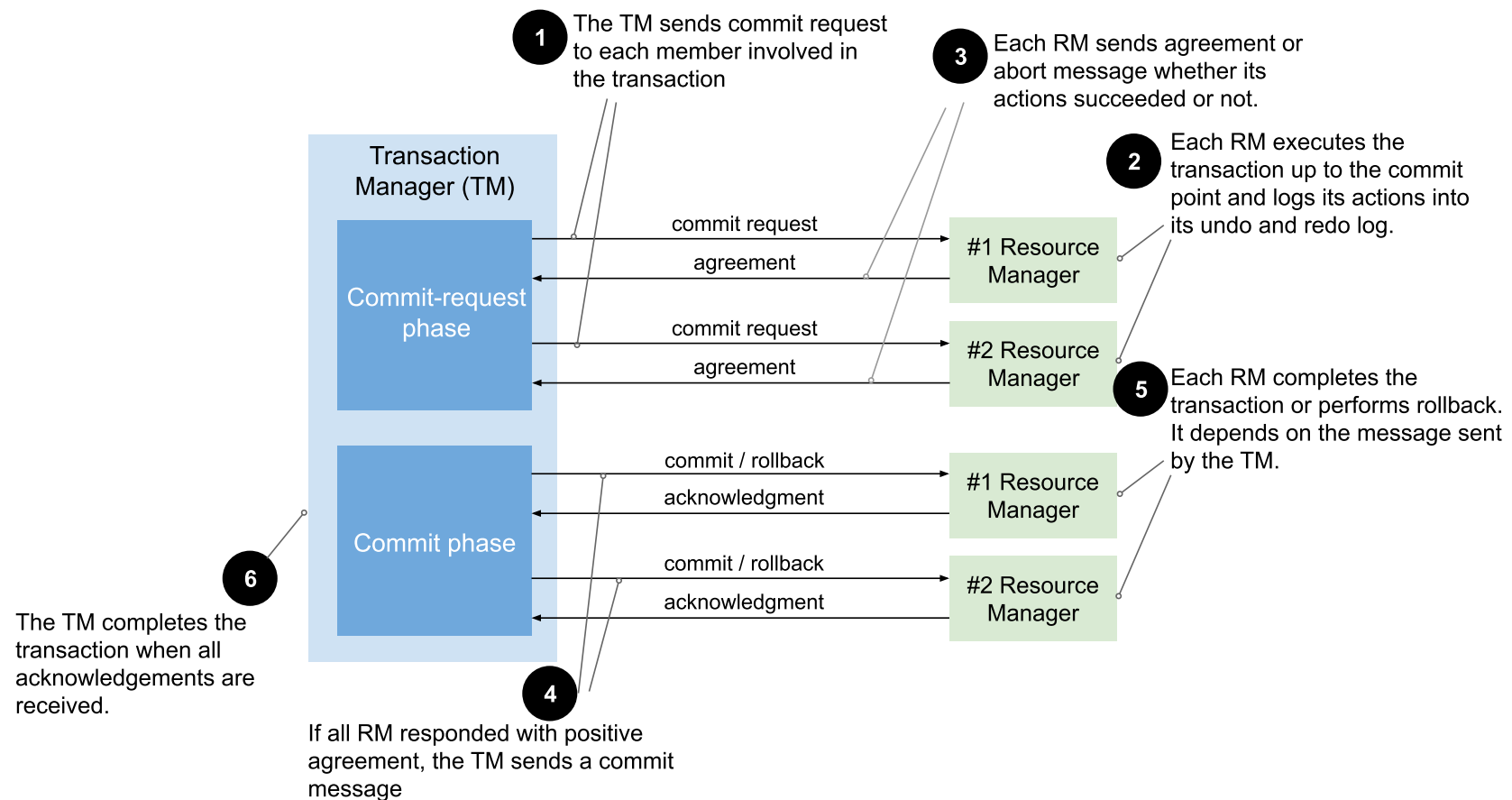
- Manages data consistency across services
 - *A series of local transactions*
 - *This requires **compensating** transactions to undo changes if needed*
 - *An alternative to Two-phase commit*
- Two types of Sagas
 - *Choreography-based Sagas*
 - *Each service produces and listens to events*
 - *No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



Saga Pattern Examples

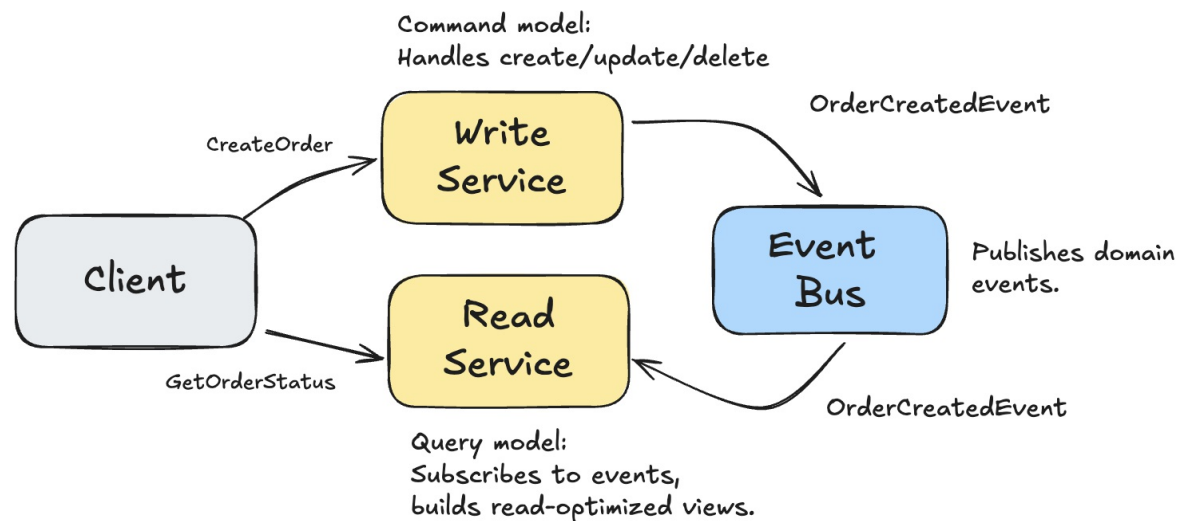
- Example Services
 - *Order Service*
 - *Payment Service*
 - *Inventory Service*
- Choreography (no central coordinator)
 - *Order Service* → publishes **OrderCreated**
 - *Payment Service* → listens, reserves funds → publishes **PaymentCompleted**
 - *Inventory Service* → listens, deducts stock → publishes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

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**

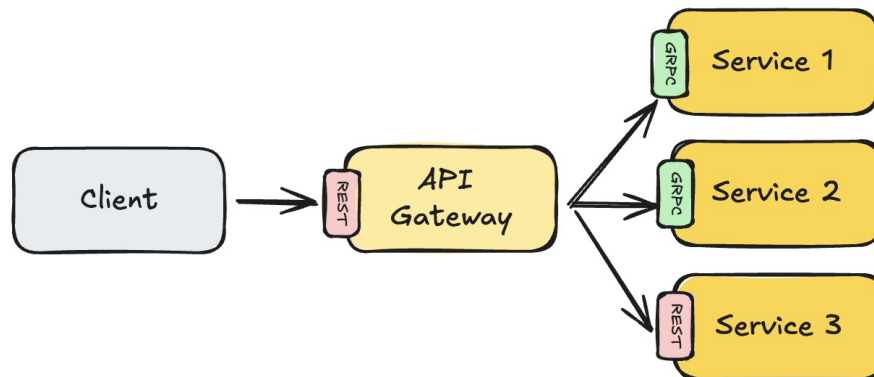


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API Gateway

- 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*

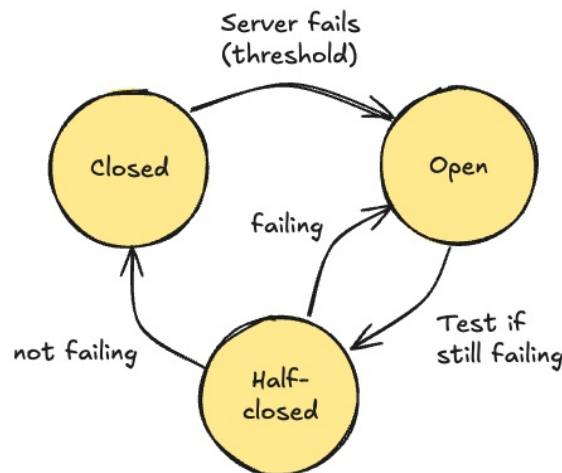


Aggregator Design Pattern

- 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

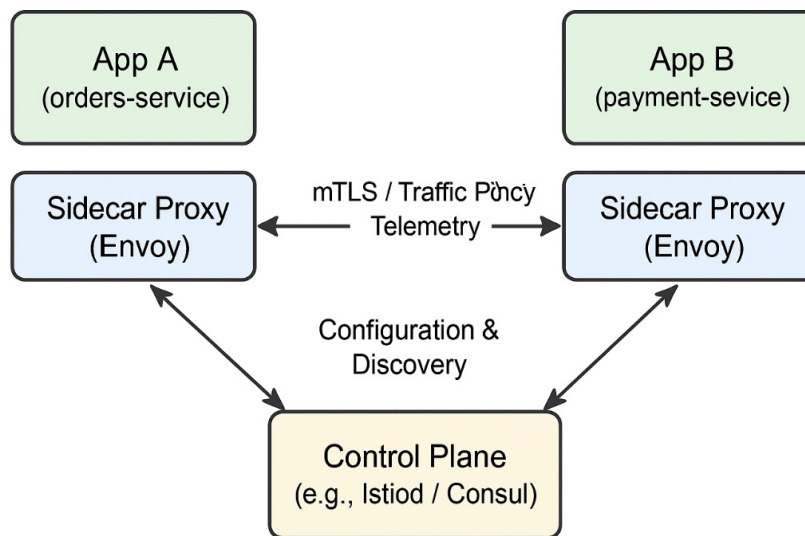
- **Scenario:** Order Service calls Payment Service
 - *Under normal conditions → call succeeds, response is fast*
 - *When Payment Service slows down or fails repeatedly → circuit "opens"*
 - *Further calls are blocked immediately → fallback response returned*
 - *After a timeout → circuit "half-opens"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