

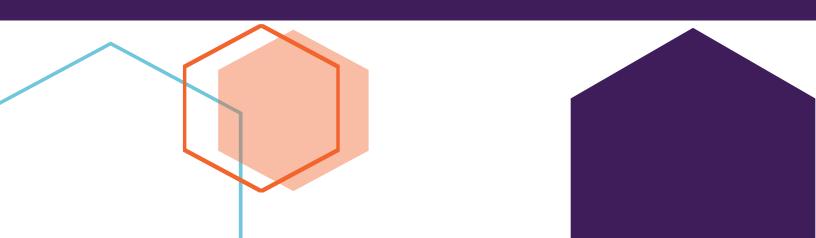
Assignment #2 Software Design and Architecture

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Identifying 5 Major Architectural Problems

1. Twitter (Scalability Issues)

· Problem:

Twitter struggled to handle increased traffic, especially during major events like elections or global sports tournaments, leading to frequent downtimes or delays in posting and retrieving tweets.

Causes:

- Monolithic Architecture: All components of the application (tweet posting, user management, timelines) were tightly coupled, creating bottlenecks under heavy load.
- Lack of Horizontal Scalability: The monolithic system couldn't efficiently distribute load across multiple servers.
- Single Points of Failure: Failure in one module (e.g., timeline service) cascaded into failures across the entire system.

Solution:

- o **Microservices Transition**: Twitter split its monolithic system into smaller, independently deployable services (e.g., Tweet Service, Timeline Service, Notification Service).
- Distributed Data Storage: Implemented distributed databases like Apache Storm to handle real-time streaming data for timelines.
- Caching: Used caching mechanisms (e.g., Redis) to reduce database load during peak traffic.

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Prevention:

Scalable Design: Adopt modular and loosely coupled architectures.

- o **Load Testing**: Simulate high-traffic conditions to identify bottlenecks.
- Monitoring and Redundancy: Use tools like Prometheus for monitoring and ensure failover mechanisms are in place.

2. Netflix (Latency Issues)

Problem:

Netflix faced delays in delivering video content globally, resulting in poor user experience, especially in regions far from their centralized data centers.

Causes:

- Centralized Data Centers: Streaming data from a single location caused high latency for geographically distant users.
- Network Congestion: Increased demand for high-quality video streaming added strain on network infrastructure.

Solution:

- Content Delivery Network (CDN): Deployed a globally distributed CDN (Open Connect) that stores video content closer to users, significantly reducing latency.
- o **Adaptive Streaming**: Introduced dynamic bitrate adjustments to provide uninterrupted streaming even under constrained bandwidth.

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Prevention:

 Distributed Architecture: Build systems with edge computing to bring services closer to end-users.

 Regional Optimization: Monitor regional demand and optimize resource allocation dynamically.

3. Facebook (Data Consistency Problems)

· Problem:

Facebook experienced issues with maintaining data consistency in its massive social graph, leading to delays in syncing friend requests, messages, and notifications.

Causes:

- Overloaded Relational Databases: Relational databases couldn't handle the growing volume and complexity of data.
- Inefficient Synchronization: Slow synchronization across distributed databases led to inconsistencies.

Solution:

- Graph-Based Databases: Migrated to NoSQL databases like Cassandra and HBase for scalable and efficient handling of graph data.
- Eventual Consistency Model: Implemented an eventual consistency model for noncritical data while maintaining strict consistency for critical operations.

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Prevention:

 Database Choice: Use a database system that aligns with data structure and scale requirements.

 Partitioning and Sharding: Distribute data intelligently to avoid overloading specific nodes.

4. Amazon (Downtime Issues)

· Problem:

Amazon encountered significant downtime during high-traffic events like Black Friday and holiday sales, resulting in lost revenue and customer trust.

Causes:

- Monolithic Architecture: A single application managing all services became overwhelmed during traffic spikes.
- Resource Contention: Simultaneous requests overloaded shared resources, causing failures.

Solution:

- Service-Oriented Architecture (SOA): Decoupled services like Payment, Inventory, User Management, and Order Management into independent components.
- Load Balancing and Auto-Scaling: Introduced Elastic Load Balancing (ELB) and autoscaling to dynamically adjust resources based on traffic.

Prevention:

- Stress Testing: Conduct periodic stress tests to prepare for high traffic.
- o **Redundancy**: Deploy multiple instances of critical services for failover support.

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 Monitoring: Use real-time monitoring tools like AWS CloudWatch to detect anomalies early.

5. Microsoft Azure (Security Breaches)

· Problem:

Microsoft Azure faced security vulnerabilities in its multi-tenant cloud environments, exposing sensitive user data to breaches.

Causes:

- Weak Tenant Isolation: Poorly designed mechanisms to isolate tenants allowed unauthorized access.
- Lack of Encryption: Insufficient encryption protocols made data vulnerable during transit and at rest.

Solution:

- Zero-Trust Architecture: Adopted a zero-trust model requiring strict identity verification for every access request.
- Enhanced Encryption: Introduced end-to-end encryption and hardware-level security measures like Azure Secure Boot.

Prevention:

- Security Audits: Conduct regular audits to identify and fix vulnerabilities.
- Proactive Threat Detection: Use Al-driven tools to monitor and detect threats in real time.
- Data Segregation: Ensure clear boundaries between tenants using advanced isolation techniques.

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Problem: Amazon's Downtime Issues During Peak Traffic

Description of the Problem

Amazon faced significant downtime issues, particularly during high-traffic periods such as the holiday season or major sales events. This downtime directly impacted customer satisfaction and resulted in revenue loss.

Causes

- 1. **Monolithic Architecture**: The system was built as a single large application. Any failure in one part of the system caused the entire system to go down.
- 2. **Scalability Challenges**: Limited ability to handle a sudden surge in traffic due to centralized processing and lack of horizontal scalability.
- 3. Single Points of Failure: If a critical component failed, it affected the entire system.
- 4. **Code Base Complexity**: The tightly coupled codebase made it difficult to implement updates or fixes without impacting the entire application.

Solution

Breaking Down the Monolith

- Microservices: Separate services for user, order, and inventory management.
- Independent Services: Each service operates independently with its own logic and database.

Dynamic Service Discovery

- Consul: Allows dynamic registration of services.
- API Gateway: Routes client requests to the appropriate microservices via the discovery server.

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Routing Requests

• The **API Gateway** ensures seamless routing and returns "Service Unavailable" if a service is down, maintaining system integrity.

Fault Tolerance

- Service failures do not impact other services, ensuring operational continuity.
- Faulty services are isolated without crashing the entire system.

Scalability

• High-demand services can scale horizontally (e.g., running multiple instances of inventory-service during peak sales).

Future proofing

New features can be added as independent services without affecting existing ones.

Prevention of Downtime

- 1. **Load Testing**: Simulate peak traffic to ensure scalability.
- 2. **Monitoring**: Use tools like Prometheus for health checks and alerts.
- 3. **Redundancy**: Run multiple service instances for failover.
- 4. **Zero-Downtime Updates**: Use rolling or blue-green deployments.
- 5. **Distributed Databases**: Handle traffic efficiently with databases like MongoDB or DynamoDB.