LAB ASSIGNMENT 2

SUBJECT

Software Design and Architecture

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Part 1: Five Major Architectural Problems and Their Solutions

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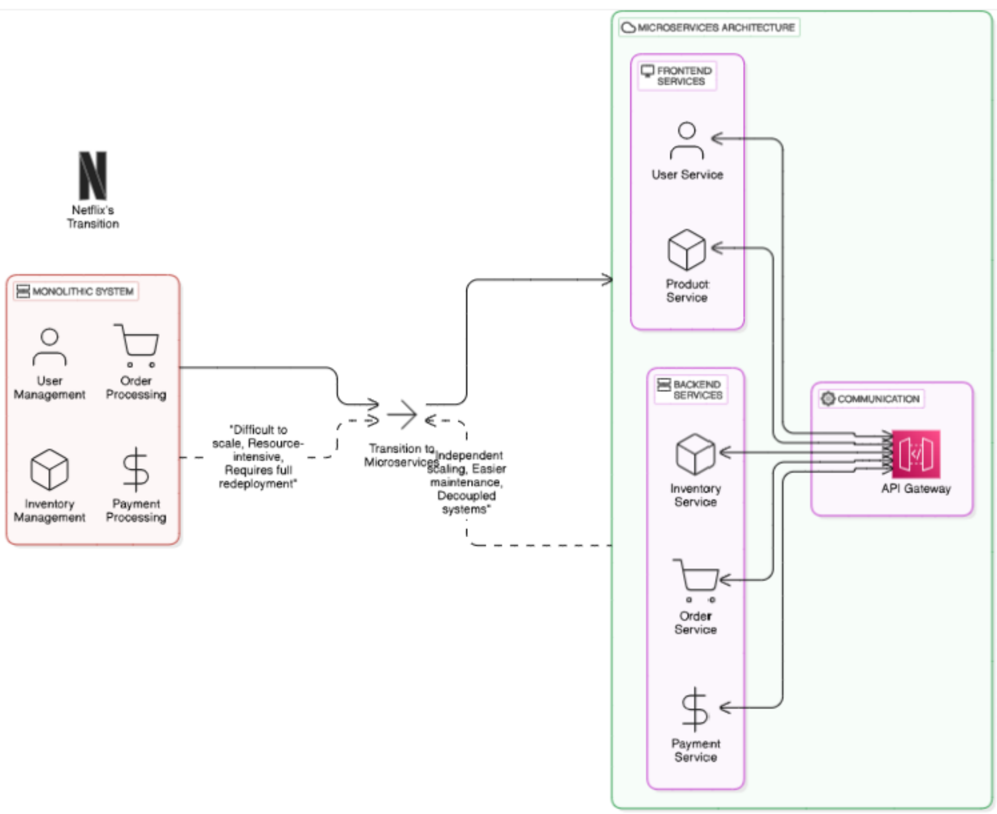
1. Monolithic Architecture Limitations

- **Problem**:
  - A single, tightly coupled system becomes difficult to scale and maintain.
  - Adding a new feature requires modifying and redeploying the entire system.
  - Scaling the entire system is resource-intensive.
- **Solution**:
  - Transition to **Microservices Architecture**, where:
    - Components are independent and communicate via APIs.
    - Individual services can be developed, deployed, and scaled independently.
  - **Example**: Netflix successfully transitioned from a monolithic architecture to microservices.

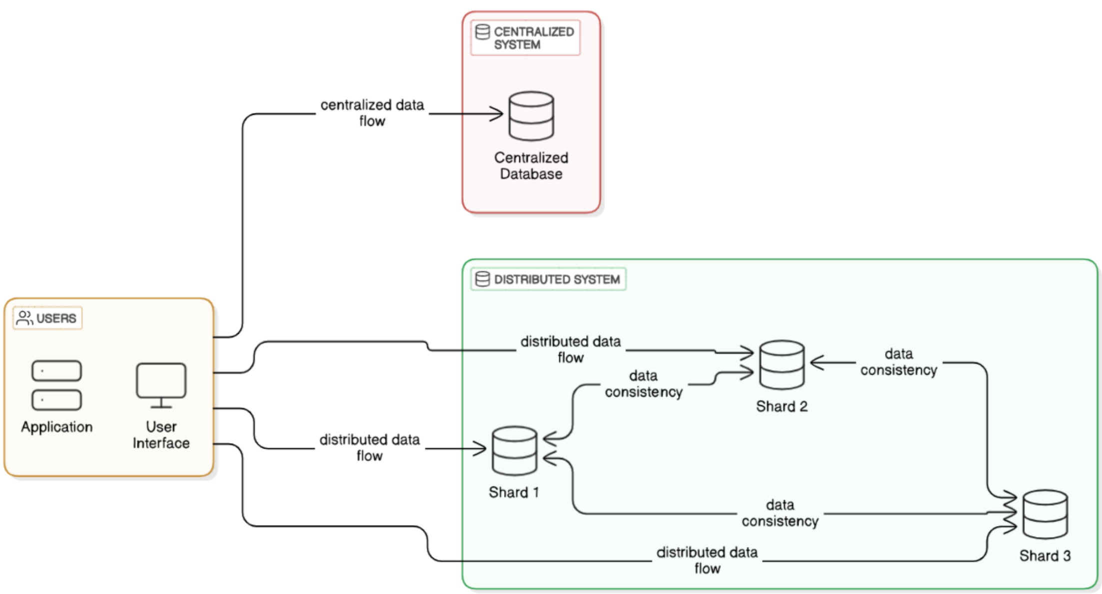
Diagram:



2. Database Bottleneck

- **Problem**:
  - Centralized databases create performance bottlenecks in high-traffic applications.
  - Latency increases, and downtime becomes more likely as the load grows.
- **Solution**:
  - Implement a **Distributed Database System** or **Database Sharding** to spread the load across multiple nodes.
  - **Example**: Amazon moved to DynamoDB for a scalable and distributed database solution.

Diagram:

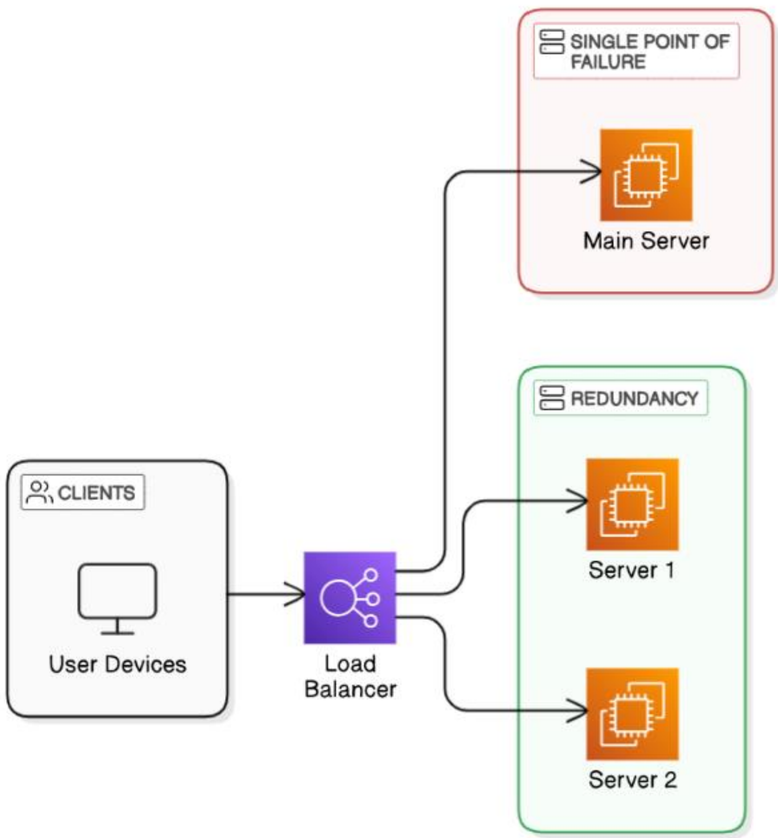


3. Single Point of Failure

- **Problem**:
  - Dependency on a single server or component can lead to system-wide outages.
  - Example: Early Twitter's "Fail Whale" incidents were caused by server overloads.
- **Solution**:

- Introduce **Redundancy** and **Load Balancing** to distribute traffic across multiple servers.
- **Example**: AWS Elastic Load Balancer ensures high availability by distributing workloads.

Diagram:



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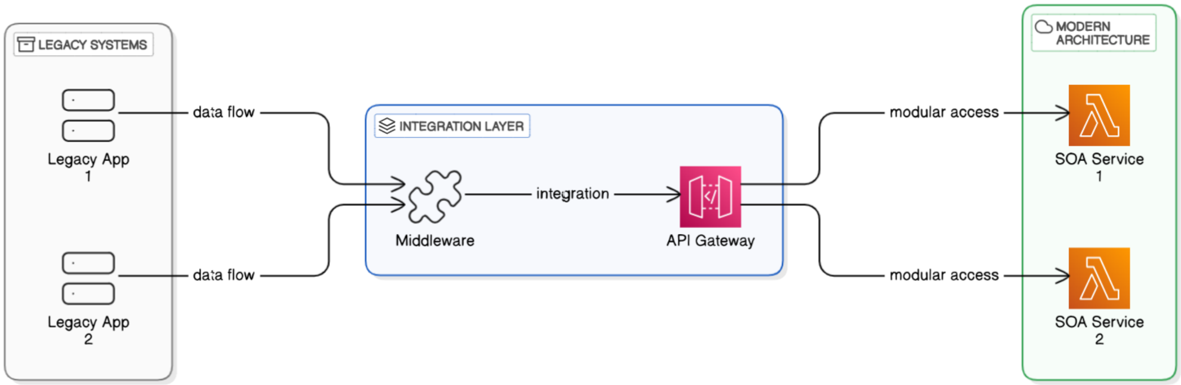
4. Legacy Code and Incompatibility

- **Problem**:
  - Legacy systems are difficult to integrate with modern software.
  - Incompatibility leads to delays, errors, and high maintenance costs.
- **Solution**:
  - Use **APIs** and **Middleware** to facilitate gradual migration.
  - Adopt **Service-Oriented Architecture (SOA)** for better modularity and integration.

Diagram:



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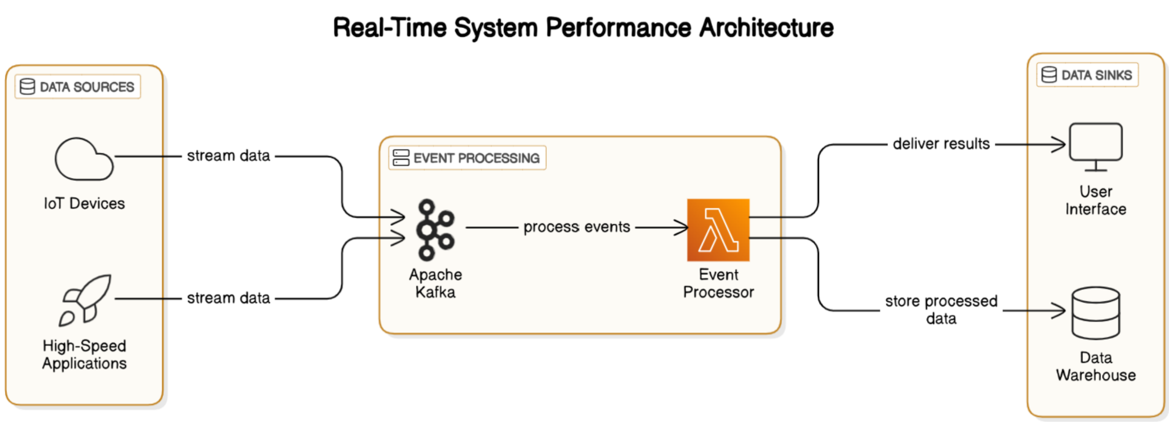
5. Performance Issues in Real-Time Systems

- **Problem**:
  - Latency in real-time data processing leads to slow responses in IoT systems or high-speed applications.
- **Solution**:
  - Use **Event-Driven Architecture** and tools like **Apache Kafka** for real-time data streaming and processing.

Diagram:



Part 2: Replicating and Solving a Problem

Problem: Monolithic to Microservices Transition

Scenario:

- A monolithic e-commerce system has a tightly coupled "Order Management" module.
- Placing an order slows down unrelated features like browsing and searching.
- This creates scalability and performance issues.

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1. Pipe and Filter Pattern

Step 1: Initial Monolithic Architecture

- In the **Monolithic Architecture**, everything (order placement, browsing, searching) is handled in a single class.

```
import java.util.HashMap;
import java.util.Map;

public class EcommerceSystem {
    private Map<String, Integer> inventory = new HashMap<>();
    private Map<String, Integer> orders = new HashMap<>();

    public EcommerceSystem() {
        inventory.put("item1", 10);
        inventory.put("item2", 5);
    }

    public String placeOrder(String item, int quantity) {
        if (inventory.containsKey(item) && inventory.get(item) >= quantity) {
            inventory.put(item, inventory.get(item) - quantity);
            orders.put(item, orders.getOrDefault(item, 0) + quantity);
            return "Order placed successfully";
        }
```

```
        return "Order failed";
    }

    public Map<String, Integer> browseItems() {
        return inventory;
    }

    public String searchItem(String item) {
        return inventory.containsKey(item) ?
               "Available: " + inventory.get(item) : "Item not found";
    }

    public static void main(String[] args) {
        EcommerceSystem ecommerce = new EcommerceSystem();
        System.out.println(ecommerce.placeOrder("item1", 2));
        System.out.println(ecommerce.searchItem("item1"));
        System.out.println(ecommerce.browseItems());
    }
}
```

Step 2: Transition to Pipe and Filter Architecture

- In **Pipe and Filter**, we separate the logic into distinct filters that handle different aspects of the process (inventory, order, search).

Filter: InventoryFilter

```
import java.util.HashMap;
import java.util.Map;

public class InventoryFilter {
    private Map<String, Integer> inventory = new HashMap<>();
```

```
    public InventoryFilter() {
        inventory.put("item1", 10);
        inventory.put("item2", 5);
    }

    public boolean reduceStock(String item, int quantity) {
        if (inventory.containsKey(item) && inventory.get(item) >= quantity) {
            inventory.put(item, inventory.get(item) - quantity);
            return true;
        }
        return false;
    }

    public Map<String, Integer> getInventory() {
        return inventory;
    }
}
```

Filter: OrderFilter

```
public class OrderFilter {
    public String placeOrder(InventoryFilter inventoryFilter, String item, int quantity) {
        if (inventoryFilter.reduceStock(item, quantity)) {
            return "Order placed successfully";
        }
        return "Order failed";
    }
}
```

Filter: SearchFilter

```
public class SearchFilter {
    private InventoryFilter inventoryFilter;
```

```
    public SearchFilter(InventoryFilter inventoryFilter) {
        this.inventoryFilter = inventoryFilter;
    }

    public String searchItem(String item) {
        return inventoryFilter.getInventory().containsKey(item) ?
                "Available: " + inventoryFilter.getInventory().get(item) : "Item not found";
    }
}
```

Main Pipe and Filter Orchestration

```
public class PipeAndFilterExample {
    public static void main(String[] args) {
        // Create filters
        InventoryFilter inventoryFilter = new InventoryFilter();
        OrderFilter orderFilter = new OrderFilter();
        SearchFilter searchFilter = new SearchFilter(inventoryFilter);

        // Pipe data through filters
        System.out.println(orderFilter.placeOrder(inventoryFilter, "item1", 2)); // Order Filter
        System.out.println(searchFilter.searchItem("item1")); // Search Filter
        System.out.println("Inventory: " + inventoryFilter.getInventory()); // Inventory Filter
    }
}
```

---

2. Observer Pattern

Step 1: Initial Monolithic Architecture

- In the **Monolithic Architecture**, all features (order placement, browsing, searching) are handled in a single class.

```
import java.util.HashMap;
import java.util.Map;

public class EcommerceSystem {
    private Map<String, Integer> inventory = new HashMap<>();
    private Map<String, Integer> orders = new HashMap<>();

    public EcommerceSystem() {
        inventory.put("item1", 10);
        inventory.put("item2", 5);
    }

    public String placeOrder(String item, int quantity) {
        if (inventory.containsKey(item) && inventory.get(item) >= quantity) {
            inventory.put(item, inventory.get(item) - quantity);
            orders.put(item, orders.getOrDefault(item, 0) + quantity);
            return "Order placed successfully";
        }
        return "Order failed";
    }

    public Map<String, Integer> browseItems() {
        return inventory;
    }

    public String searchItem(String item) {
        return inventory.containsKey(item) ?
                "Available: " + inventory.get(item) : "Item not found";
    }
```

```java
    public static void main(String[] args) {
        EcommerceSystem ecommerce = new EcommerceSystem();
        System.out.println(ecommerce.placeOrder("item1", 2));
        System.out.println(ecommerce.searchItem("item1"));
        System.out.println(ecommerce.browseItems());
    }
}
```

Step 2: Transition to Observer Pattern

- In **Observer Pattern**, we introduce the **Subject** (inventory) and **Observers** (order and search) that react to changes in the inventory.

Subject: InventorySubject

```java
import java.util.HashMap;
import java.util.Map;
import java.util.ArrayList;
import java.util.List;

public class InventorySubject {
    private Map<String, Integer> inventory = new HashMap<>();
    private List<Observer> observers = new ArrayList<>();

    public InventorySubject() {
        inventory.put("item1", 10);
        inventory.put("item2", 5);
    }

    public void addObserver(Observer observer) {
        observers.add(observer);
    }
```

```
    public void removeObserver(Observer observer) {
        observers.remove(observer);
    }

    public void notifyObservers() {
        for (Observer observer : observers) {
            observer.update(inventory);
        }
    }

    public boolean reduceStock(String item, int quantity) {
        if (inventory.containsKey(item) && inventory.get(item) >= quantity) {
            inventory.put(item, inventory.get(item) - quantity);
            notifyObservers(); // Notify observers of the change
            return true;
        }
        return false;
    }


public Map<String, Integer> getInventory() {
        return inventory;
    }
}
```

Observer: OrderObserver

```
public class OrderObserver implements Observer {
    private String orderStatus = "Order not placed";

    public String getOrderStatus() {
```

```
        return orderStatus;
    }

    @Override
    public void update(Map<String, Integer> inventory) {
        // Handle inventory change
        orderStatus = "Order processed with updated inventory";
    }

    public String placeOrder(InventorySubject inventorySubject, String item, int quantity) {
        if (inventorySubject.reduceStock(item, quantity)) {
            return "Order placed successfully";
        }
        return "Order failed";
    }
}
```

Observer: SearchObserver

```
public class SearchObserver implements Observer {
    private String searchStatus = "Searching...";

    public String getSearchStatus() {
        return searchStatus;
    }

    @Override
    public void update(Map<String, Integer> inventory) {
        // Handle inventory change
        searchStatus = "Inventory updated";
    }
```

```
    public String searchItem(InventorySubject inventorySubject, String item) {
        return inventorySubject.getInventory().containsKey(item) ?
                "Available: " + inventorySubject.getInventory().get(item) : "Item not found";
    }
}
```

Observer Interface

```
interface Observer {
    void update(Map<String, Integer> inventory);
}
```

Main Observer Pattern Orchestration

```
public class ObserverPatternExample {
    public static void main(String[] args) {
        // Create the subject (Inventory)
        InventorySubject inventorySubject = new InventorySubject();

        // Create observers
        OrderObserver orderObserver = new OrderObserver();
        SearchObserver searchObserver = new SearchObserver();

        // Register observers
        inventorySubject.addObserver(orderObserver);
        inventorySubject.addObserver(searchObserver);

        // Place an order (Observer will be notified of changes)
        System.out.println(orderObserver.placeOrder(inventorySubject, "item1", 2));
        System.out.println(searchObserver.searchItem(inventorySubject, "item1"));
```

```
        // View inventory and observe changes
        System.out.println("Inventory: " + inventorySubject.getInventory());
        System.out.println("Order Status: " + orderObserver.getOrderStatus());
        System.out.println("Search Status: " + searchObserver.getSearchStatus());
    }
}
```

Summary of Transitions:

1. **Pipe and Filter**:
   - We separated the different responsibilities (inventory management, order placement, and search) into independent filters.
   - Data flows through these filters to achieve the desired functionality.
2. **Observer**:
   - The **InventorySubject** acts as the subject that notifies **Observers** (OrderObserver and SearchObserver) of changes in the inventory.
   - Observers react to changes and update their status accordingly.

Both designs break the monolithic structure into modular components, either through sequential data processing (Pipe and Filter) or event-driven updates (Observer).

Benefits of Microservices Transition

1. **Scalability**:
   - Scale each service independently based on demand.
2. **Maintainability**:
   - Update or debug individual services without affecting others.
3. **Fault Isolation**:
   - A failure in one service (e.g., inventory) does not crash the others.

This Java example demonstrates the transition from a monolithic architecture to microservices by splitting responsibilities into independent classes and coordinating them effectively.