Team Group 6

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Synopsis:

1. ***What is the application domain?***

   The application domain for the system is library management. It focuses on creating a digital library platform where various services related to library operations will interact and function together, such as borrowing books, returning books, book services, review, and message processing.

2. ***What will the application do?***

   The application is designed to manage a library system using a microservices architecture, incorporating elements of distributed systems. It handles user management book catalogs, borrower records, inventory, and notifications. Employing Spring Boot and Spring Cloud, the system features service discovery, centralized configuration, and distributed database. This setup, integrated with a distributed system approach, ensures robust and scalable library operations, facilitating both synchronous and asynchronous communications among microservices.

Technology Stack:

1. ***List of the main distribution technologies you will use.***

   Spring Boot: *Used for creating stand-alone, production-grade Spring-based applications easily. It streamlines the development process of the application by providing a simplified way to set up and run Spring-based applications, making it ideal for creating individual microservices in a scalable and efficient manner.*

   Spring Cloud: *Provides tools to quickly build some of the common patterns in distributed systems. This includes service discovery, configuration management. Using Eureka, Spring Cloud enables microservices to dynamically discover and communicate with each other, which is fundamental in a distributed system where services frequently scale up and down. Spring Cloud Config is employed to manage application configurations across multiple microservices. This feature ensures that all services have a centralized, consistent, and manageable configuration setup. These implementations highlight Spring Cloud's role in enhancing the communication and operational smoothness of microservices by addressing key distributed system challenges.*

   PostgreSQL: *This database approach simplifies data management, ensuring consistent handling of structured data and complex queries across different parts of the Library application. PostgreSQL's flexibility in managing diverse data types effectively supports the varied data requirements of the system.*

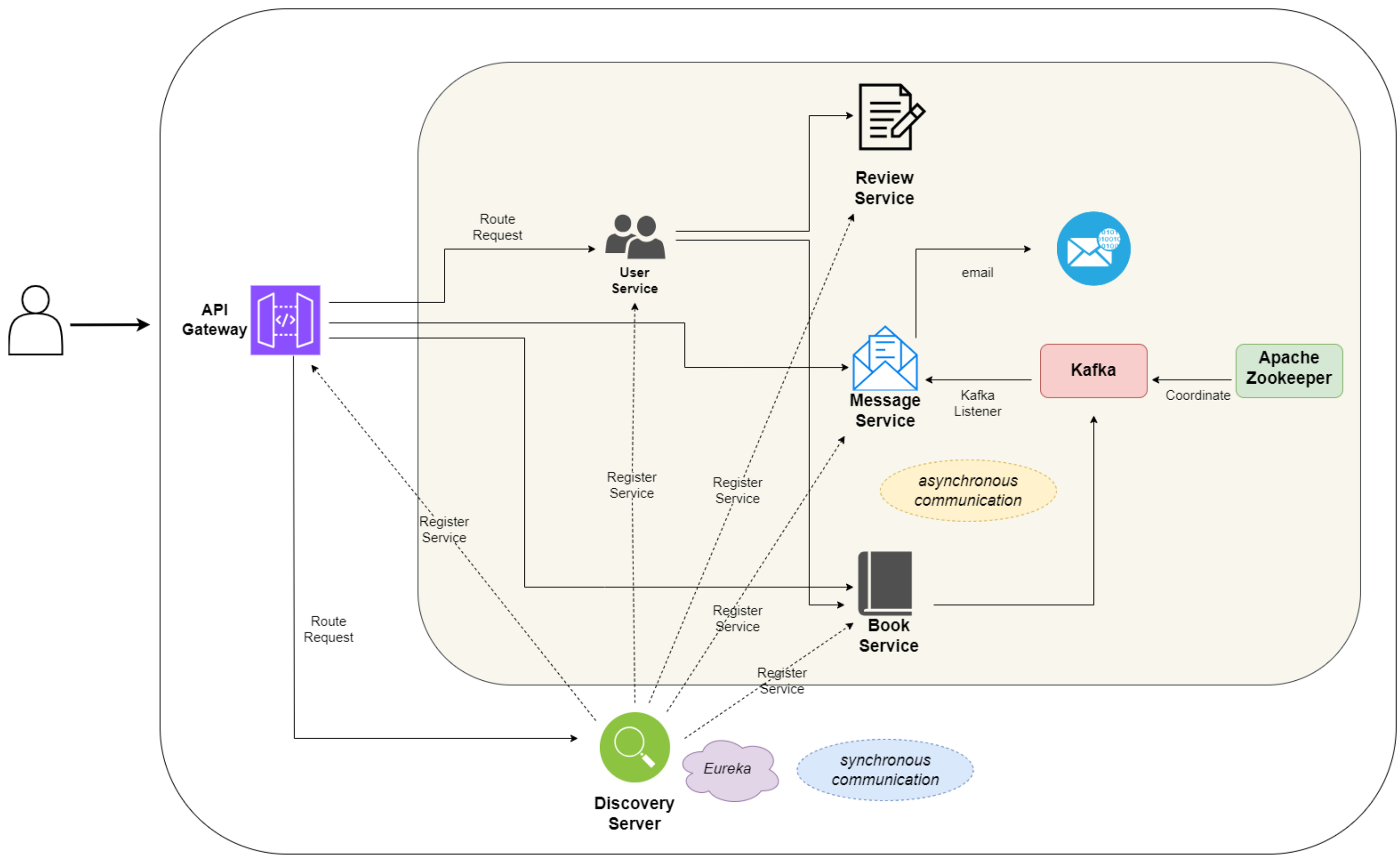
   Kafka: *Kafka is utilized for asynchronous data processing and streaming. It is particularly useful in scenarios where high-throughput and scalable message processing are required, such as event-driven architectures where multiple microservices react to state changes or updates. Kafka's ability to handle high-throughput scenarios ensures that large-scale data changes are efficiently propagated across services.*

   Eureka: *Utilized for service discovery, Eureka acts as a registry where microservices register themselves and discover other services. This enables easy inter-service communication and load balancing.*

System Overview

1. **Diagram**

Library Management Application Architecture Diagram



2. ***Explain how your system works based on the diagram.***

__API Gateway:__ Acts as the system's entry point, routing client requests to the correct service. It enhances security and manages traffic, ensuring efficient service utilization.

- *__Central Entry Point:__ The API Gateway serves as the primary interface for all client requests, efficiently routing them to designated services, like the user service. It simplifies client interactions by being the sole point of communication.*
- *__Load Balancing:__ Leveraging Eureka for service discovery, the gateway distributes incoming requests across multiple service instances. This ensures balanced load handling, improving performance and reliability.*
- *__Routing Configuration:__ It has predefined routes targeting specific services (e.g., user service, discovery server), optimizing request routing and ensuring requests reach their intended destinations.*
- *__Logging and Monitoring:__ Configured logging levels (info and trace) in your gateway facilitate detailed monitoring of operations and assist in troubleshooting, allowing you to track request flows and gateway performance effectively.*

By functioning as the single point of entry, the API Gateway significantly simplifies the interaction between the client side and microservices, enhancing the system's overall manageability and security.

__Discovery Server:__ The part is configured as a Eureka Server, a service discovery mechanism in Spring Cloud.

- *__Self-Registration Disabled:__ It's set not to register itself with Eureka, as it's the service registry.*
- *__Client Fetch Registry Disabled:__ Prevents the server from trying to fetch the registry from other Eureka nodes.*
- *__Service Port Configuration:__ It runs on port 8761.*
- *__Service Discovery Role:__ Other microservices register with this server, allowing them to discover each other dynamically.*

Kafka cluster with Zookeeper:

- ***Zookeeper Service:*** *Acts as the coordinator for Kafka, managing brokers and ensuring cluster stability. It runs on the default client port 2181.*
- ***Kafka Broker Service:*** *This is the Kafka server (broker) that handles message storage and transmission. It depends on Zookeeper and is configured with various environment variables for Kafka settings, like broker ID, Zookeeper connect, listener configurations, and replication factors.*

This setup creates a Kafka environment suitable for development and testing, providing a message broker system for handling high-throughput, distributed messaging or event streaming.

Message Service: *Manages communication between user and bookservices. It uses Kafka for handling asynchronous communication and event-driven processes, such as sending notifications via email upon book checkout and return events.*

- ***Event-Driven Communication:*** *It listens to Kafka topics for checkout and return events. When an event occurs, it triggers the corresponding message handling.*
- ***Email Notification:*** *The service sends emails to users about their book checkout or return, enhancing user engagement.*
- ***Dynamic Email Configuration:*** *It dynamically configures email settings to send notifications, ensuring reliability in communication.*
- ***Logging and Monitoring:*** *Logs actions for checkout and return events, aiding in monitoring and auditing system activity.*
- ***Service Discovery:*** *Registered as a Eureka client, it enables easy discovery and communication within the microservices ecosystem.*

Book service: *Manages the library's books, handling operations like listing all books, checking stock availability, book checkouts, and returns.*

- ***Database Interaction:*** *Uses a repository to interact with the database for retrieving and updating book information.*
- ***Transactional Operations:*** *The check out and return functions are transactional, ensuring database integrity during operations like updating book stock.*
- ***Kafka Messaging:*** *For asynchronous communication, it sends messages via Kafka when books are checked out or returned, enhancing user experience.*
- ***Stock Validation:*** *It checks and updates the stock availability of books, a crucial aspect for library management.*
- ***Service Discovery:*** *Registered as an Eureka client, it enables easy discovery and communication within the microservices ecosystem.*

This service centralizes book-related operations, ensuring efficient and reliable management of the library's catalog and transactions.

Review Services: *Handles the creation and retrieval of book reviews. It allows users to post reviews and fetch reviews for a specific book.*

- ***Database Interaction:*** *Integrates with PostgreSQL for storing and retrieving review data.*
- ***Data Transfer Objects (DTOs):*** *Utilizes DTOs like ReviewRequest and ReviewResponse to manage data exchange in review operations.*
- ***Service Layer:*** *The ReviewService class encapsulates the business logic for handling reviews, interfacing with the ReviewRepository for database operations.*
- ***Eureka Client Integration:*** *As a Eureka client, it registers with the Eureka server for service discovery, enabling it to interact with other microservices in the system.*

User Service: *Manages all user-related functionalities like book checkouts, returns, and handling reviews.*

- ***Centralized Logic for User Operations:*** *Reduces complexity in handling user requests by centralizing logic related to books and reviews in one service.*
- ***Microservice Communication:*** *Utilizes WebClient for RESTful communication with other services, ensuring efficient interaction for user actions.*
- ***Load Balancing and Service Discovery:*** *As an Eureka client, it balances loads across instances and discovers other services within the microservice architecture.*

3. Explain how your system is designed to support scalability and fault tolerance.

To enhance its ability to scale and remain robust in the face of challenges, the system incorporates a range of architectural elements and methodologies:

- *Microservices Architecture: This approach divides core services (such as User, Message, Book, and Review Services) into distinct microservices. Each of these can be scaled independently, allowing for precise resource allocation according to the specific needs of each service. This modular design not only optimizes resource use but also enables targeted scaling without impacting other services.*
- *Service Discovery with Eureka: The system uses a Discovery Server configured with Eureka, a critical component for scalable and fault-tolerant design. Eureka facilitates the dynamic registration and discovery of microservices, streamlining the addition or removal of service instances. This flexibility is key in managing increased traffic loads and in the quick replacement of any failed instances, thereby bolstering fault tolerance.*
- *Load Balancing via API Gateway: The API Gateway, integrated with Eureka, ensures effective distribution of incoming requests across various service instances. This load balancing is essential in preventing overload on any single service instance and contributes to the system's scalability and fault tolerance, ensuring smooth handling of traffic.*
- *Distributed Database Architecture: By employing a distributed database, the system can manage data across multiple servers or locations. This approach is particularly applied to the Review and Book services, ensuring that even if one node in the database cluster fails, these services can continue to operate seamlessly by accessing data from other nodes.*
- *Asynchronous Communication Through Kafka: The system employs Kafka for its Message Service, enabling asynchronous communication and event-driven processes. Kafka is renowned for its scalability and fault tolerance, especially in handling high-volume, distributed messaging. This choice allows the system to efficiently process a substantial number of events and notifications, which is vital for maintaining performance under diverse load conditions.*

By combining these components and strategies, the system is structured to adaptively respond to varying demands and maintain operational integrity, even in scenarios of service disruptions or component failures.

Contributions

Yuxin Zhao:

- *Microservices Architecture Design: Instrumental in developing the overall microservices architecture. This involved planning and structuring the system's core services, ensuring scalability and fault tolerance.*
- *User Service: Played a key role in the creation and implementation of the User Service, focusing on efficient user operations handling.*
- *Book Service: Contributed significantly to the Book Service, which involved managing the library's books and handling operations such as stock availability and transactional processes.*
- *Database Design: Led the design and implementation of the database structures, ensuring robust and scalable data management across services.*

Ruiqi Zhao

- *User Service and Book Service: Worked alongside Yuxin Zhao in developing and fine-tuning the User and Book Services, focusing on functionality and integration within the microservices architecture.*
- *Database Design: Collaborated in the database design process, ensuring the database's scalability and effective integration with various services.*
- *Report Writing: Responsible for compiling and writing the project report, detailing the system's architecture, functionalities, and design rationale.*

Miaomiao Shi

- *Message Service: Key contributor to the Message Service, managing asynchronous communication and event-driven processes using Kafka. This involved setting up and maintaining message flow for various system events.*
- *Front-end Implementation: Played a significant role in implementing the front-end components of the system, ensuring seamless user interaction and interface design.*

Judith Smolenski

- *Review Service: Led the development of the Review Service, focusing on creating and retrieving book reviews. This involved database interactions and integration with the microservices architecture.*
- *Front-end Implementation: Collaborated with Miaomiao Shi in front-end development, focusing on user experience and interface functionality, ensuring the front end aligns with the system's microservices architecture.*
- *Project Video Recording: Took the initiative in recording a comprehensive video of the entire project. This involved capturing the system's functionalities, demonstrating the architecture's flow, and showcasing the team's collaborative efforts.*

Reflections

1. ***What were the key challenges you have faced in completing the project? How did you overcome them?***

   Reflecting on the project, we encountered several significant challenges, particularly in dockerizing services, managing the messaging service asynchronous processing. Here's how we navigated these issues:

   Complexities in Dockerizing Services:
   - *The initial challenge was creating Docker images for each microservice. The diversity in service configurations and dependencies made this a complex task. We overcame this challenge by using Jib, a tool for building optimized Docker and OCI images for Java applications without a Docker daemon. Jib streamlined the image creation process, allowing us to build container images directly from our build tools (like Maven or Gradle). This significantly simplified our Dockerization process and ensured that our images were lightweight and consistent.*
   - *Another challenge we faced was during the 'docker compose up' phase. We encountered various errors related to service connections, which were often difficult to diagnose due to the interdependencies of microservices. To address this, we conducted a meticulous examination of logs and service interactions. We paid particular attention to network configurations, inter-service communication protocols, and environment variables that were essential for the services to interact correctly. By systematically identifying and resolving these issues, we were able to ensure that all services connected smoothly and functioned as intended in the Docker environment.*

   Handling Message Service Asynchronous Processing :
   - *Kafka Setup and Configuration: Initially, configuring Kafka for the Message Service was complex. We tackled this by diving deep into Kafka's documentation and online tutorials, which provided the insights needed to properly set up topics, partitions, and brokers.*
   - *Concurrency and Parallelism: Implementing asynchronous processing raised concurrency and parallelism issues. We addressed these by carefully designing our asynchronous components to allow simultaneous processing of multiple tasks without conflicts.*

- *Ensuring Data Consistency: Maintaining data consistency in an asynchronous environment was challenging. We resolved this by employing transactional operations and message sequencing to preserve data integrity.*

In both messaging and asynchronous processing, thorough planning, research, and the use of appropriate tools and frameworks were key to overcoming challenges. Collaboration among team members and leveraging community resources also played a vital role in addressing challenges and achieving project success.

2. ***What would you have done differently if you could start again?***

Looking back at the project, there are a few key areas where a different approach might have enhanced our system's design and efficiency. Initially, integrating UML diagrams from the project's start would have been a game-changer. These diagrams would have offered a clear, visual blueprint of the system's architecture, greatly aiding in both planning stages and team communication.

Also, we would delineate the functionalities of the User Service more distinctly, ensuring it is clearly separated from other services like those related to book functionalities. This would allow us to better exploit the characteristics of a distributed system, making each service more focused and efficient in its role. In doing so, the User Service could be more finely tuned to handle user-related data and interactions, while other services could be dedicated to specific functionalities like book management.

Regarding database technology, we would adopt a hybrid database strategy, combining the strengths of both NoSQL and SQL databases. Specifically, we would use MongoDB for its adeptness in handling unstructured data, like user-generated content or logs. Concurrently, PostgreSQL would be employed for its capabilities with structured data and complex queries. This approach would be particularly beneficial for managing diverse data types. For example, book information, which can be efficiently represented in JSON format, would be ideally stored in a NoSQL database like MongoDB, enhancing our system's flexibility and responsiveness to data variations.

Lastly, employing both RabbitMQ and Kafka could have optimized our messaging infrastructure. RabbitMQ's strength in managing lightweight messaging tasks would have complemented Kafka's capability in handling high-volume, event-driven data streams. This dual approach to message brokering would have offered a more comprehensive and adaptable messaging system.

3. ***What have you learnt about the technologies you have used? Limitations? Benefits?***

Throughout the development of our system, we've gained valuable insights into various technologies, each bringing its unique set of benefits and limitations. The use of Spring Boot and Spring Cloud has been central to this learning experience. Spring Boot simplifies the bootstrapping and development of new Spring applications, significantly reducing development time and increasing productivity. However, it sometimes leads to challenges in fine-tuning configurations for specific needs.

The integration of Eureka for service discovery in Spring Cloud simplifies the management of microservices, but it also introduces challenges in network reliability and resilience. We encountered situations where network fluctuations caused Eureka clients to de-register temporarily, leading to service unavailability. Ensuring consistent service discovery in the face of network inconsistencies required additional safeguards, such as implementing circuit breakers and fallback mechanisms.

Our API Gateway effectively manages traffic and routes client requests, but under high load, we observed challenges in throughput and latency. The gateway became a bottleneck during peak traffic, slowing down request processing. Optimizing its configuration for high-load scenarios, such as tweaking timeout settings and concurrency limits, was necessary to maintain performance.

Kafka's role in handling high-throughput, distributed messaging is undeniable, but its complexity in configuration and cluster management posed significant challenges. Ensuring consistent message delivery and order, particularly in failure scenarios, required careful planning of topic partitions and replication strategies. Additionally, managing Zookeeper's coordination with Kafka for broker management added another layer of operational complexity.

While the microservices architecture offers scalability and fault tolerance, managing data consistency across services was a major challenge. Implementing distributed transactions to ensure data integrity across the User and Book services, without compromising on performance, required intricate coordination. Moreover, network latency and inter-service communication overhead sometimes affected the overall response time of the system.

In conclusion, these technologies have taught us the delicate balance between leveraging advanced features for efficiency and scalability, and the complexities they introduce in terms of setup, configuration, and management. The key lesson is that a well-thought-out architectural plan, alongside a deep understanding of each component, is essential for the system.