



Experiment 2

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Subject Name: System Design

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1. Aim: To design and analyze a scalable E-commerce platform similar to Amazon / Flipkart that allows users to search products, manage carts, place orders, perform payments, and track order status while ensuring high availability, consistency, scalability, and low latency.

2. Objective:

- To identify functional and non-functional requirements of an online shopping system.
- To design a scalable architecture using **microservices**.
- To analyze **CAP theorem trade-offs** for different system components.
- To design **high-level architecture (HLD)** for product search, cart, order, payment, and inventory.
- To understand the role of **Kafka, ElasticSearch, and CDC pipeline** in large-scale systems.
- To handle **race conditions** during flash sales and limited inventory scenarios.

3. Tools Used:

- **Draw.io** – Designing system architecture (HLD).
- **PostgreSQL** – Relational database design.
- **ElasticSearch** – Product search and indexing.
- **Apache Kafka** – Event streaming.
- **CDC Pipeline** – Syncing product data to ElasticSearch.

4. System Requirements:

A. Functional Requirements:

- 1) User should be able to **search products** using product name or title.
- 2) User should be able to **view product details** such as description, images, price, available quantity, and reviews.
- 3) User should be able to **select quantity** and add products to the **cart**.
- 4) User should be able to **checkout and make payment** successfully.
- 5) User should be able to **track order status** after placing an order.
- 6) System should be able to **manage limited inventory stock** efficiently.

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- 7) System should handle **concurrent transactions during flash sales** without overselling.

B. Non-Functional Requirements:

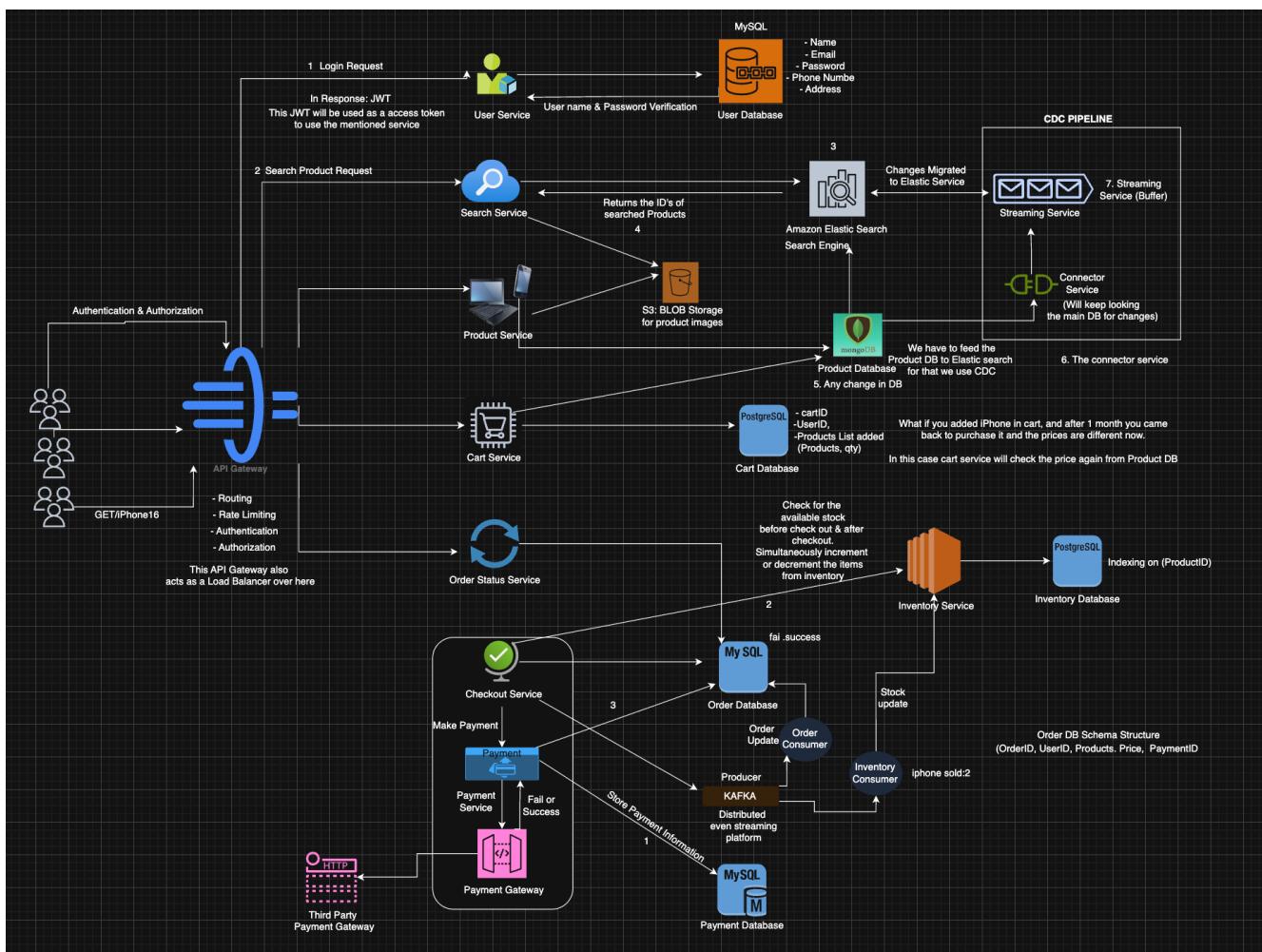
- 1) Scalability
 - a. Target scale: 100 million DAU
 - b. Order processing rate: ~10 orders/sec
- 2) Availability & Consistency
 - a. High Availability required for:
 - i. Product search
 - ii. Product listing
 - b. Strong Consistency required for:
 - i. Payment processing
 - ii. Order placement
 - iii. Inventory management
- 3) Latency
 - a. System response time should be \leq 200 ms
- 4) Reliability
 - a. System should tolerate failures and recover automatically.
- 5) Scalability Type
 - o Horizontal and vertical scaling supported.

5. High Level Design (HLD):

- The system follows a microservices-based architecture:
- API Gateway
 - o Handles routing, authentication, authorization, and rate limiting.
- User Service
 - o Manages user authentication and profile data.
- Product Service
 - o Manages product catalog and metadata.
- Search Service
 - o Uses ElasticSearch for fast product search.
- Cart Service
 - o Manages user cart and price validation.
- Order Service

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- Handles order creation and status tracking.
- Inventory Service
 - Maintains stock levels and prevents overselling.
- Payment Service
 - Handles payment processing via third-party gateway.
- Kafka + CDC Pipeline
 - Syncs product data changes to ElasticSearch.



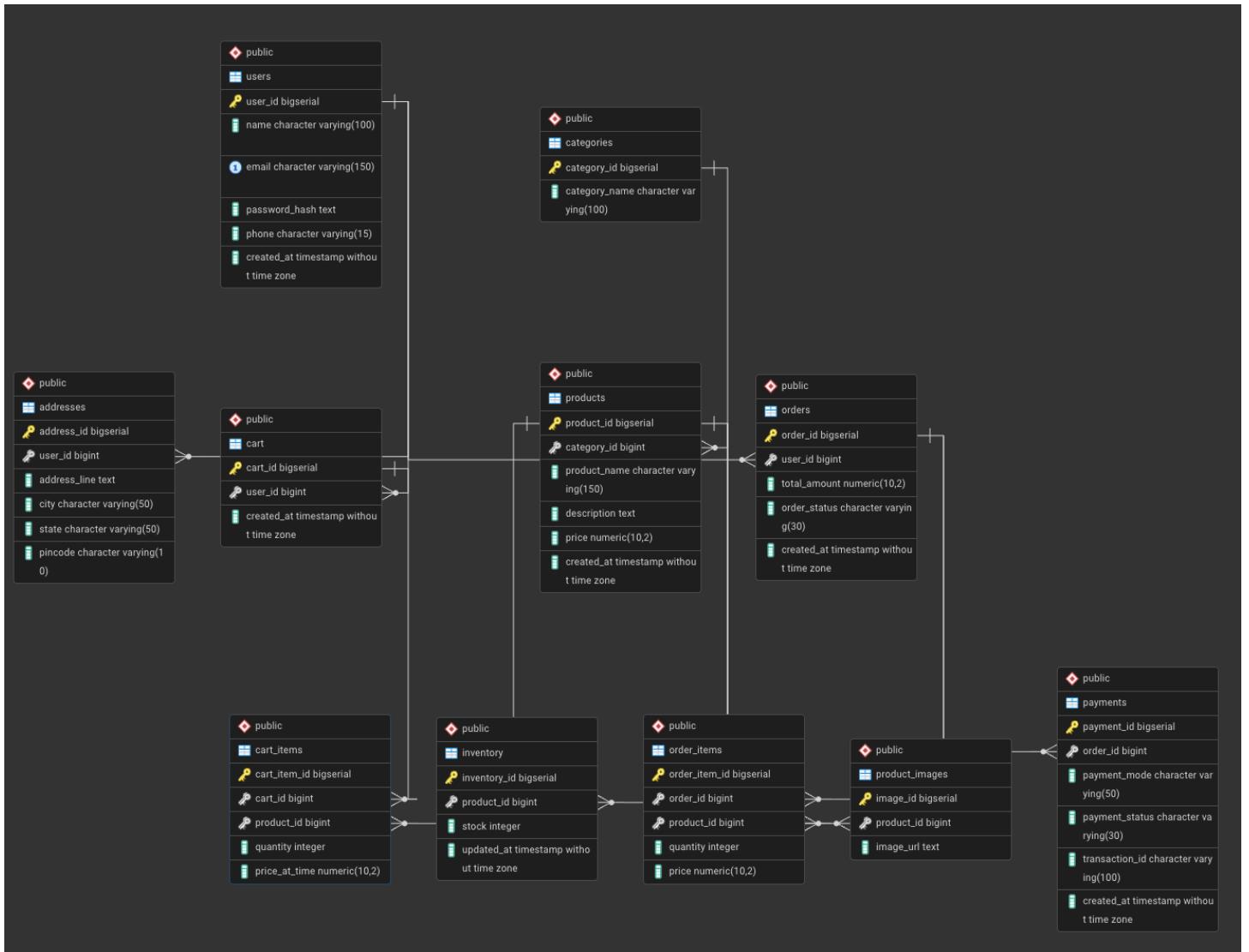
6. Database Design (ER Diagram):

- The database for the E-commerce platform is designed using an **Entity Relationship (ER) model**. The ER diagram represents the **core entities, their attributes, and relationships** required to support user management, product catalog, cart handling, order processing, inventory control, and payment management.
- The ER diagram is generated using **PostgreSQL (pgAdmin ERD Tool)** based on tables defined with **primary keys and foreign keys**, ensuring referential integrity.

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Relationships Between Entities:

- A User can have multiple Addresses (One-to-Many).
- A User can have one Cart (One-to-One).
- A Cart can contain multiple Products through Cart Items (Many-to-Many).
- A User can place multiple Orders (One-to-Many).
- An Order can contain multiple Products through Order Items (Many-to-Many).
- Each Product belongs to one Category (Many-to-One).
- Each Product has one Inventory record (One-to-One).
- An Order has one Payment record (One-to-One).
- A Product can have multiple Images (One-to-Many).



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7. Low Level Design (LLD):

- Inventory Management (Flash Sale Handling)
- Inventory is updated using atomic operations.
- Stock decrement happens only after successful order confirmation.
- Database transactions and row-level locking are used to prevent race conditions.
- Kafka events ensure eventual synchronization across services.

8. Scalability Solution

- Horizontal scaling of microservices.
- API Gateway acts as load balancer.
- ElasticSearch used for read-heavy search traffic.
- Kafka used for asynchronous communication.
- CDC pipeline ensures near real-time data consistency between Product DB and Search index.

9. Learning Outcomes (What I Have Learnt)

- Learned how to design a **real-world scalable E-commerce system**.
- Understood **functional vs non-functional requirements**.
- Gained knowledge of **CAP theorem trade-offs**.
- Learned how **ElasticSearch and Kafka** are used in production systems.
- Understood handling of **concurrency and race conditions**.
- Learned importance of **low latency and high availability** in distributed systems.