Experiment 2

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Branch: CSE **Section/Group: KRG 3-A**
Semester: 6th **Date of Performance:15/01/2026**
Subject Name: System Design **Subject Code: 23CSH-314**

1. **Aim**: To design and implement an E-commerce platform like Amazon/Flipkart that allows users to search products, view product details, add items to cart, checkout & payment, and track orders with proper inventory handling.

2. **Objective**:

- To understand E-commerce system workflow.
- To design functional and non-functional requirements.
- To create system architecture (HLD).
- To design modules/classes (LLD).
- To implement APIs for products, cart, checkout, payment, orders.
- To ensure stock consistency during flash-sale / concurrent orders.

3. **Tools Used:**

- **Python** – Backend logic implementation and URL generation algorithms.
- **Flask** – Lightweight web framework for developing RESTful APIs.
- **Draw.io** – Designing system architecture diagrams (HLD & LLD).

4. **System Requirements:**

A. Functional Requirements

User Module

1. User registration & login
2. Profile management (address, phone, email)

Product Module

3. Search products by title/name/category
4. Filter products (price, rating, brand)
5. View product details (image, description, price, available quantity, reviews)

Cart Module

6. Add item to cart (choose quantity)
7. Update quantity in cart
8. Remove item from cart

Checkout + Payment Module

9. Checkout cart (address selection)

10. Payment via UPI/Card/COD
11. Generate invoice/order confirmation

Order Module

12. Place order
13. Track order status (Placed/Shipped/Delivered/Cancelled)
14. Order history

Inventory Module

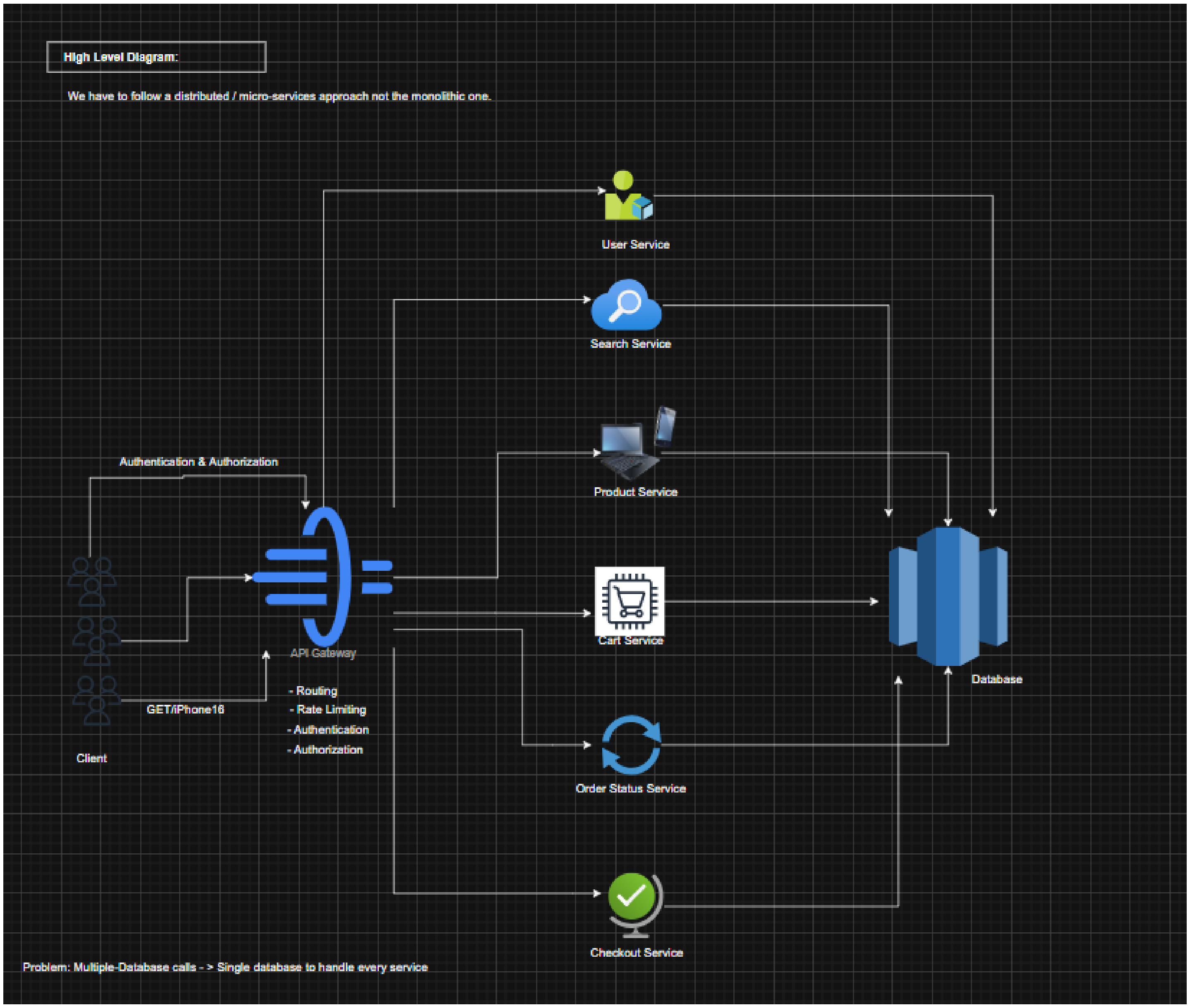
15. Maintain product stock count
16. Handle limited stock + flash-sale race condition

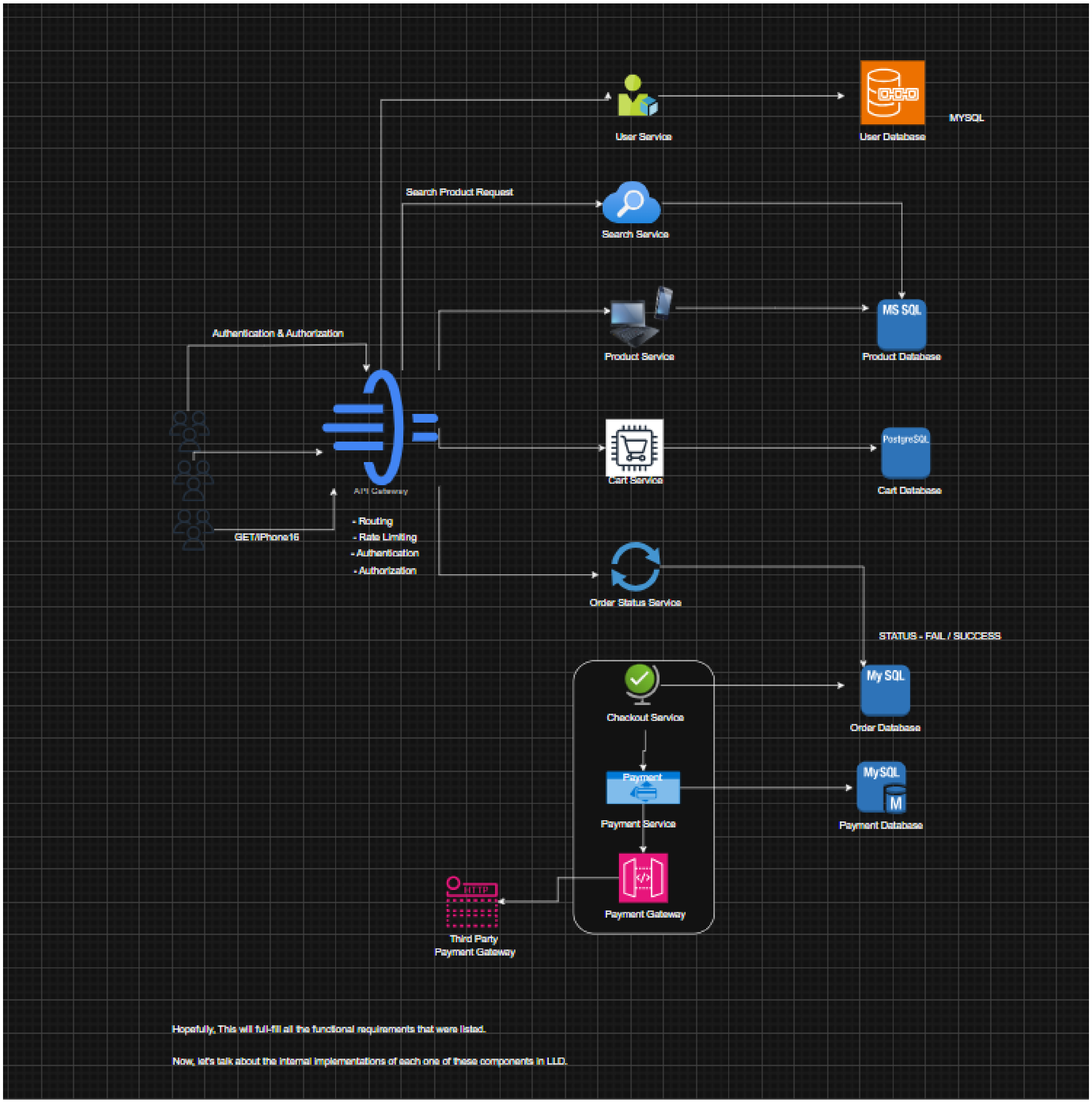
B. Non-Functional Requirements

- Scalability: 100M DAU, 10+ orders/sec
- Availability: 99.9% uptime
- Latency: search & product listing under ~200ms
- Consistency:
- Strong consistency for payment + inventory
- Eventual consistency acceptable for search indexing
- Security: JWT auth, encrypted passwords, HTTPS
- Reliability: rollback on payment failure
- Maintainability: modular services
- Logging & Monitoring: request logs + failure alerts

5. High Level Design (HLD):

The system follows a **Client–Server–Database architecture**:

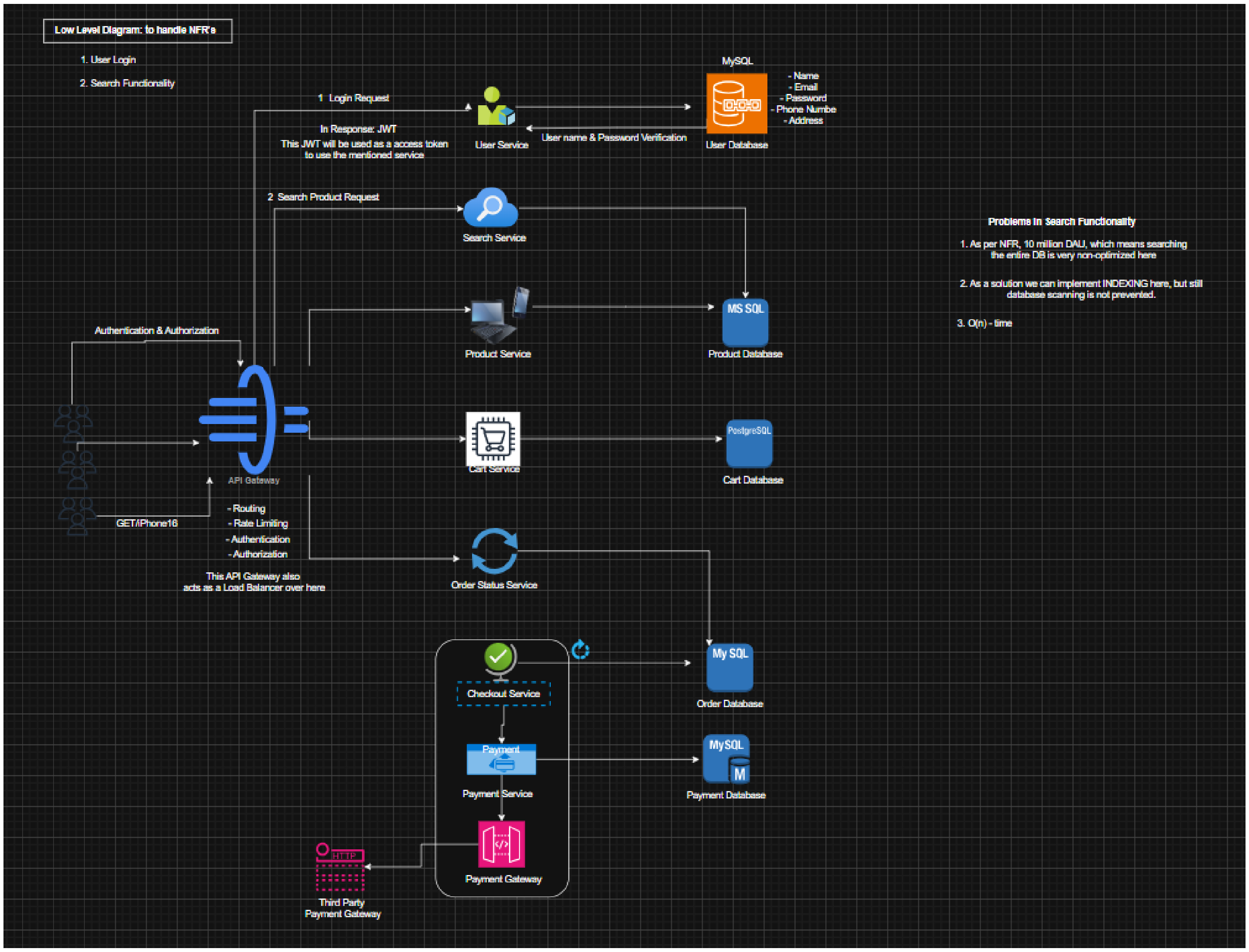




Hopefully, This will full-fill all the functional requirements that were listed.

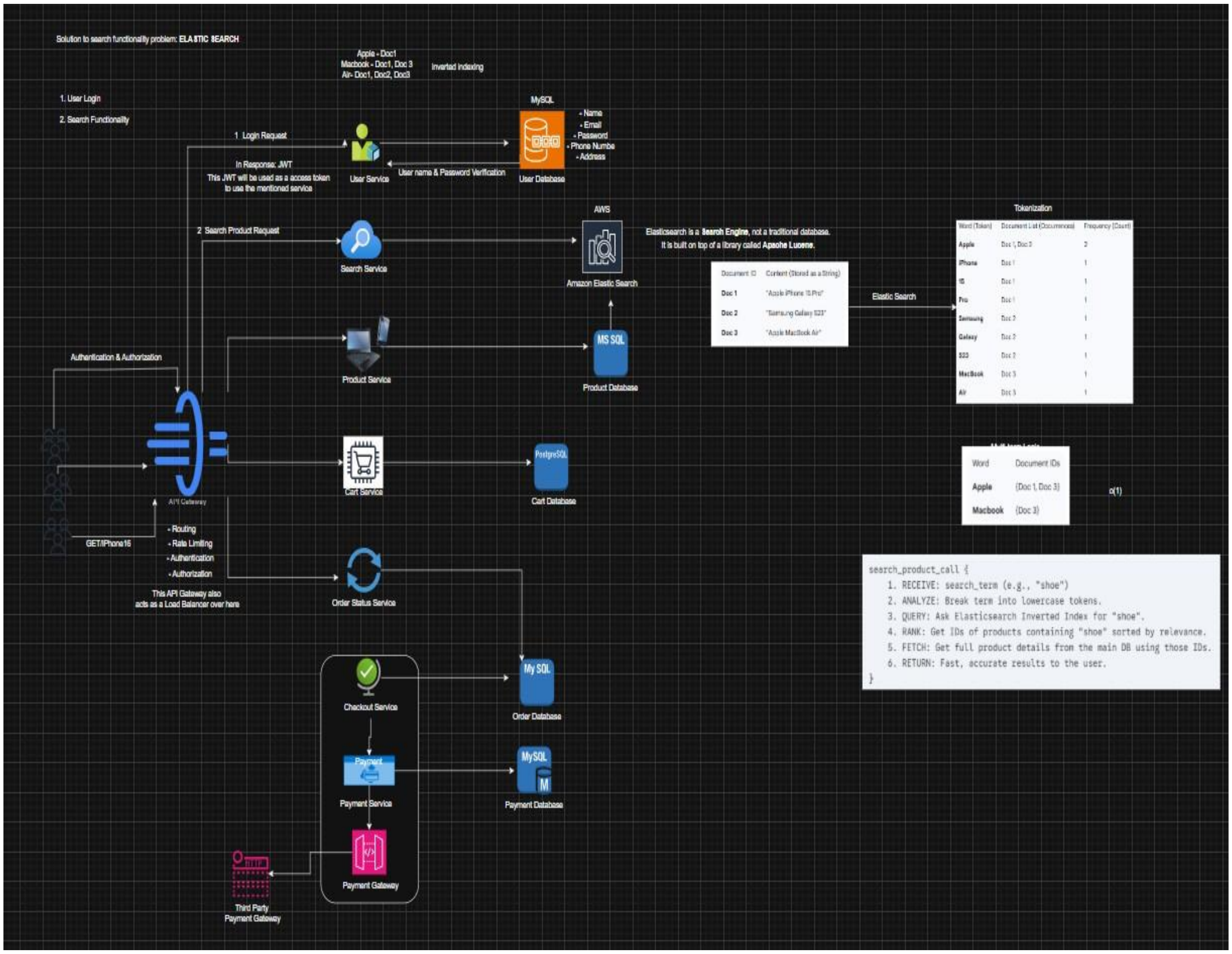
Now, let's talk about the internal implementations of each one of these components in LLD.

6. Low Level Design (LLD):



Problems In Search Functionality

1. As per NFR, 10 million DAU, which means searching the entire DB is very non-optimized here
2. As a solution we can implement INDEXING here, but still database scanning is not prevented.
3. O(n) - time

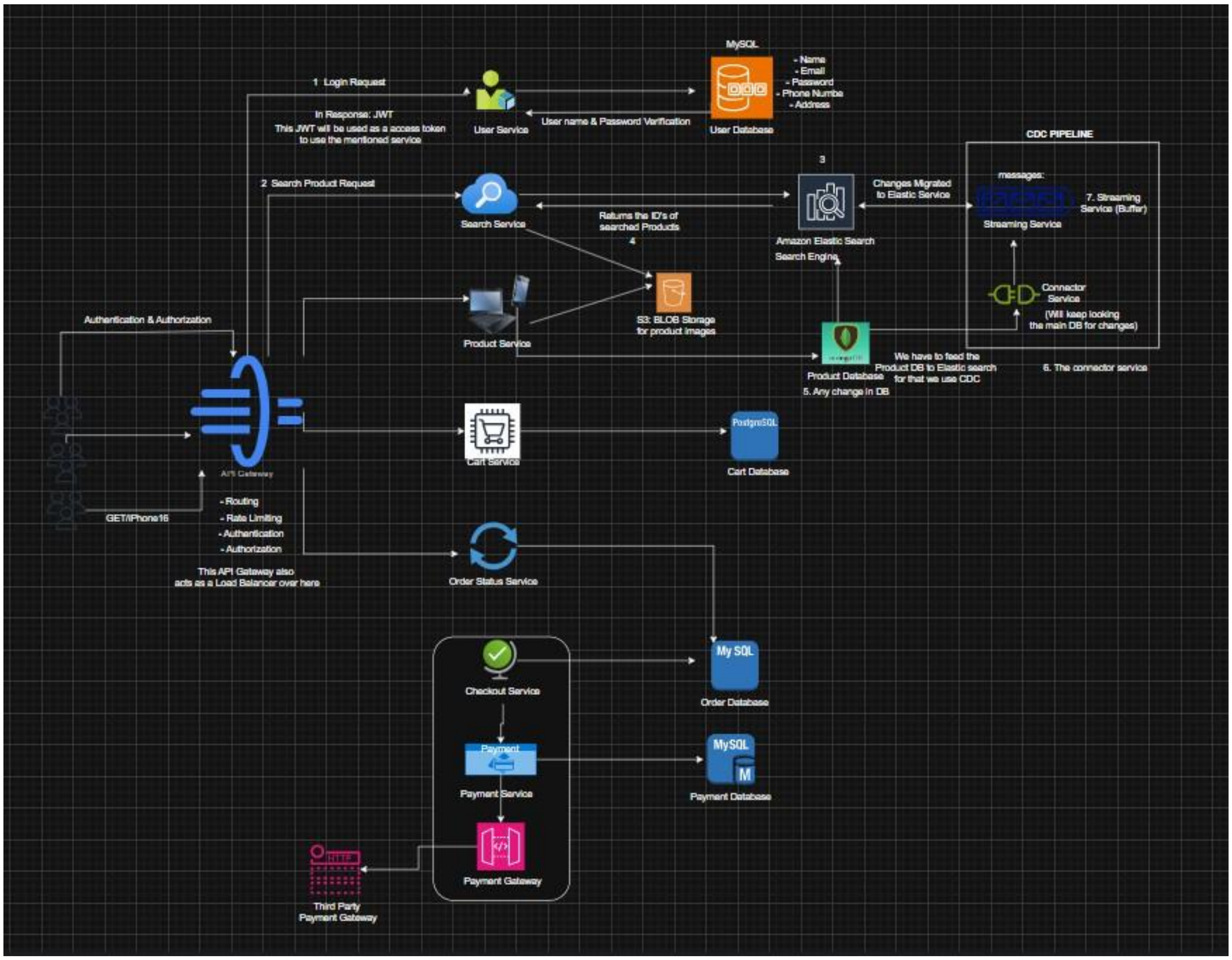


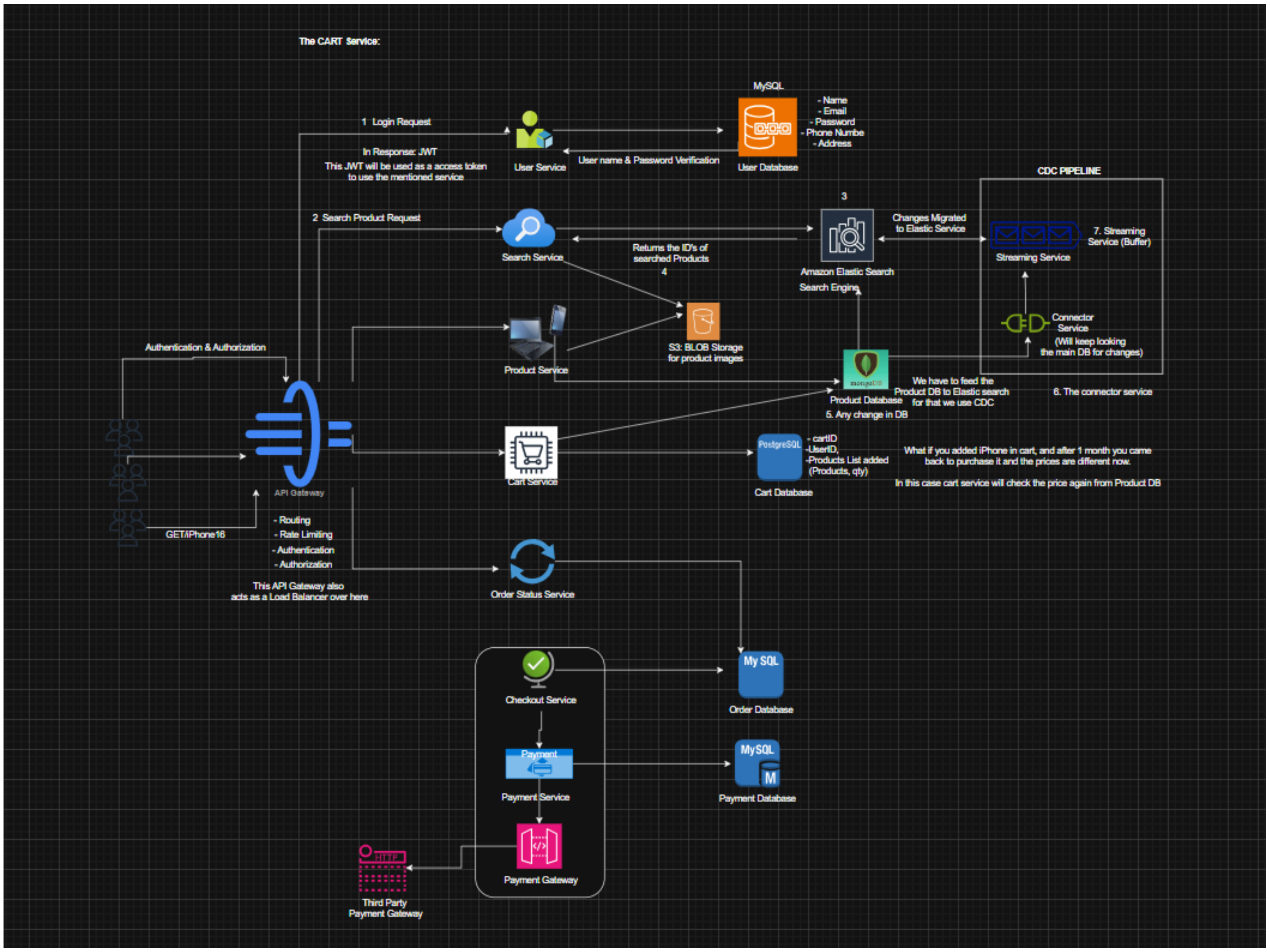
Document ID	Content (Stored as a String)
Doc 1	"Apple iPhone 15 Pro"
Doc 2	"Samsung Galaxy S23"
Doc 3	"Apple MacBook Air"

Word (Token)	Document List (Occurrences)	Frequency (Count)
Apple	Doc 1, Doc 3	2
iPhone	Doc 1	1
15	Doc 1	1
Pro	Doc 1	1
Samsung	Doc 2	1
Galaxy	Doc 2	1
S23	Doc 2	1
MacBook	Doc 3	1
Air	Doc 3	1

Word	Document IDs
Apple	{Doc 1, Doc 3}
Macbook	{Doc 3}

```
search_product_call {
    1. RECEIVE: search_term (e.g., "shoe")
    2. ANALYZE: Break term into lowercase tokens.
    3. QUERY: Ask Elasticsearch Inverted Index for "shoe".
    4. RANK: Get IDs of products containing "shoe" sorted by relevance.
    5. FETCH: Get full product details from the main DB using those IDs.
    6. RETURN: Fast, accurate results to the user.
}
```


1 Login Request
In Response: JWT
This JWT will be used as a access token to use the mentioned service
User Service
User name & Password Verification
MySQL
User Database
- Name
- Email
- Password
- Phone Numbe
- Address
2 Search Product Request
Search Service
Returns the ID's of searched Products
4
3
Amazon Elastic Search
Search Engine
Changes Migrated to Elastic Service
CDC PIPELINE
messages:
Streaming Service
7. Streaming Service (Buffer)
Connector Service
(Will keep looking the main DB for changes)
6. The connector service
Product Service
S3: BLOB Storage for product images
Product Database
5. Any change in DB
We have to feed the Product DB to Elastic search for that we use CDC
Authentication & Authorization
API Gateway
GET/iPhone16
- Routing
- Rate Limiting
- Authentication
- Authorization
This API Gateway also acts as a Load Balancer over here
Cart Service
PostgreSQL
Cart Database
Order Status Service
Checkout Service
My SQL
Order Database
Payment
Payment Service
MySQL
M
Payment Database
Payment Gateway
HTTP
Third Party Payment Gateway


The CART Service:
MySQL
- Name
- Email
- Password
- Phone Numbe
- Address
1 Login Request
User Service
User Database
In Response: JWT
This JWT will be used as a access token
to use the mentioned service
User name & Password Verification
CDC PIPELINE
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Search Service
Returns the ID's of
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Amazon Elastic Search
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API Gateway
Cart Service
PostgreSQL
- cartID
-UserID,
-Products List added
(Products, qty)
Cart Database
What if you added iPhone in cart, and after 1 month you came
back to purchase it and the prices are different now.
In this case cart service will check the price again from Product DB
GET/iPhone16
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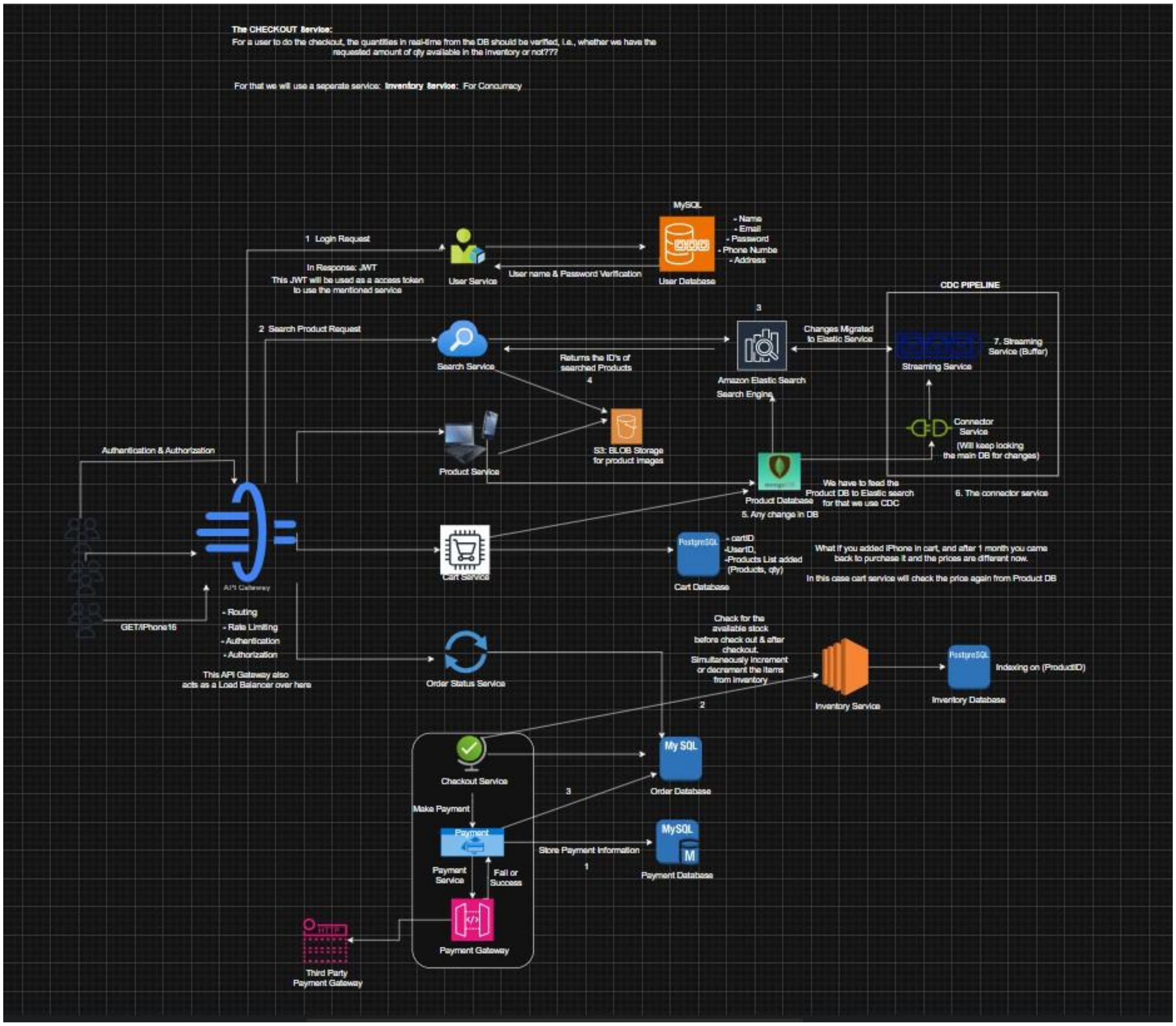

The CHECKOUT Service:
For a user to do the checkout, the quantities in real-time from the DB should be verified, i.e., whether we have the requested amount of qty available in the inventory or not???

For that we will use a seperate service: **Inventory Service:** For Concurracy

In Response: JWT
This JWT will be used as a access token to use the mentioned service

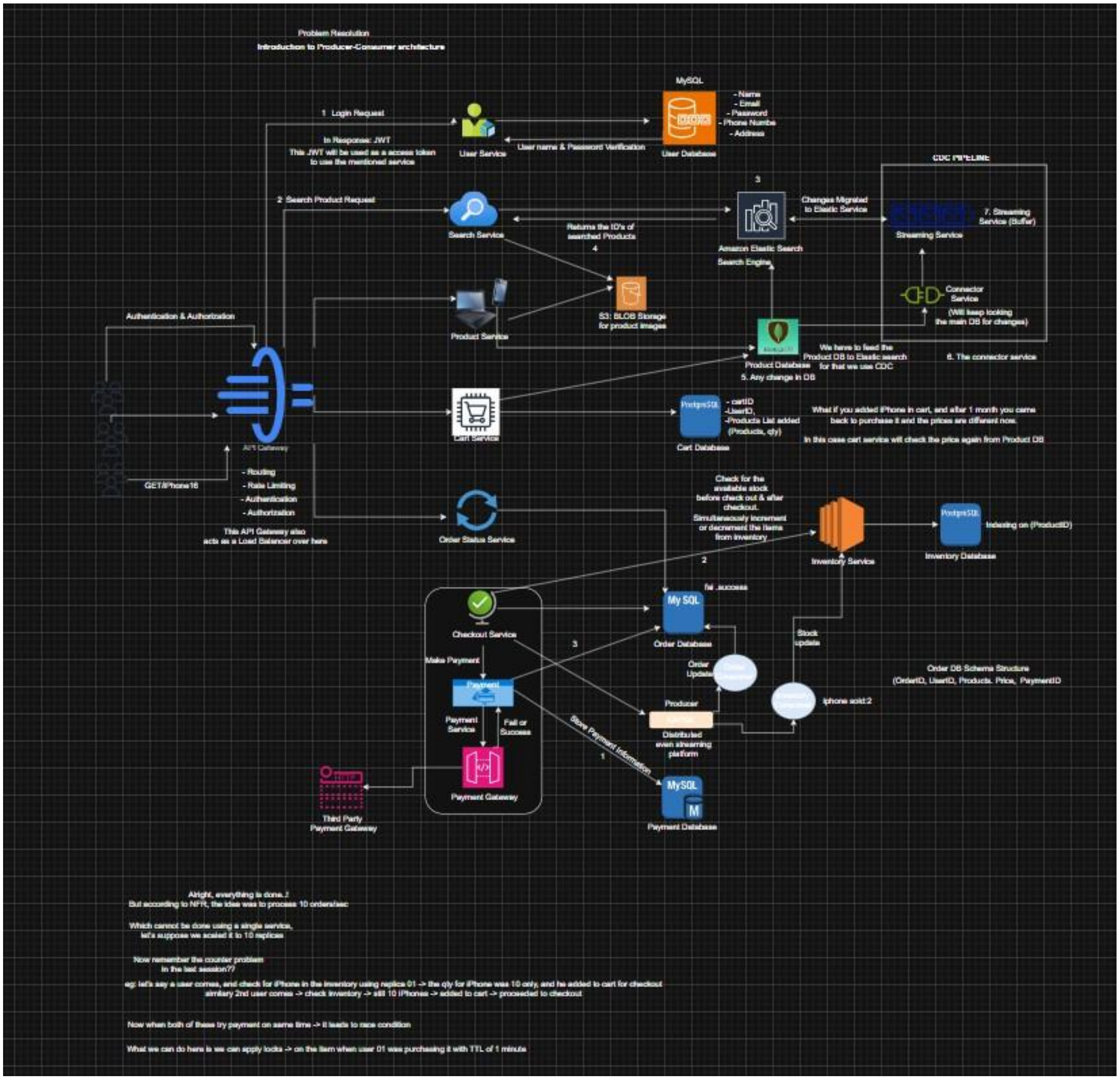
We have to feed the Product DB to Elastic search for that we use CDC

What if you added iPhone in cart, and after 1 month you came back to purchase it and the prices are different now.

In this case cart service will check the price again from Product DB

Check for the available stock before check out & after checkout. Simultaneously increment or decrement the items from inventory

This API Gateway also acts as a Load Balancer over here


Problem Resolution
Introduction to Producer-Consumer architecture
1 Login Request
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MySQL
User Database
- Name
- Email
- Password
- Phone Number
- Address
User name & Password Verification
In Response: JWT
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Search Service
Returns the ID's of searched Products
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In this case cart service will check the price again from Product DB
Order Status Service
Check for the available stock before check out & after checkout.
Simultaneously increment or decrement the items from inventory
Inventory Service
PostgreSQL
Inventory Database
Indexing on (ProductID)
2
fail ,success
Checkout Service
Make Payment
Payment
Payment Service
Fail or Success
Payment Gateway
Third Party Payment Gateway
3
My SQL
Order Database
Order Update
Stock update
Order DB Schema Structure
(OrderID, UserID, Products, Price, PaymentID)
Producer
Distributed even streaming platform
iphone sold:2
Store Payment information
1
MySQL
Payment Database

Alright, everything is done..!
But according to NFR, the idea was to process 10 orders/sec

Which cannot be done using a single service,
let's suppose we scaled it to 10 replicas

Now remember the counter problem
in the last session??

eg: let's say a user comes, and check for iPhone in the inventory using replica 01 -> the qty for iPhone was 10 only, and he added to cart for checkout
similary 2nd user comes -> check inventory -> still 10 iPhones -> added to cart -> proceeded to checkout

Now when both of these try payment on same time -> it leads to race condition

What we can do here is we can apply locks -> on the item when user 01 was purchasing it with TTL of 1 minute

7. Scalability Solution

- Use horizontal scaling + auto-scaling to handle high traffic.
- Apply load balancer to distribute user requests across servers.
- Use Redis caching + CDN to reduce database load and speed up responses.

- Implement DB read replicas + sharding to avoid database bottlenecks.
- Use Kafka/RabbitMQ queues for asynchronous processing of heavy tasks.

8. Learning Outcomes (What I Have Learnt)

- Understood the complete E-commerce purchase flow from search to delivery.
- Learned to identify functional and non-functional requirements clearly.
- Designed HLD architecture using services/modules for the system.
- Created LLD entities/tables and relationships for database design.
- Learned scalability + race condition handling for flash-sale inventory.