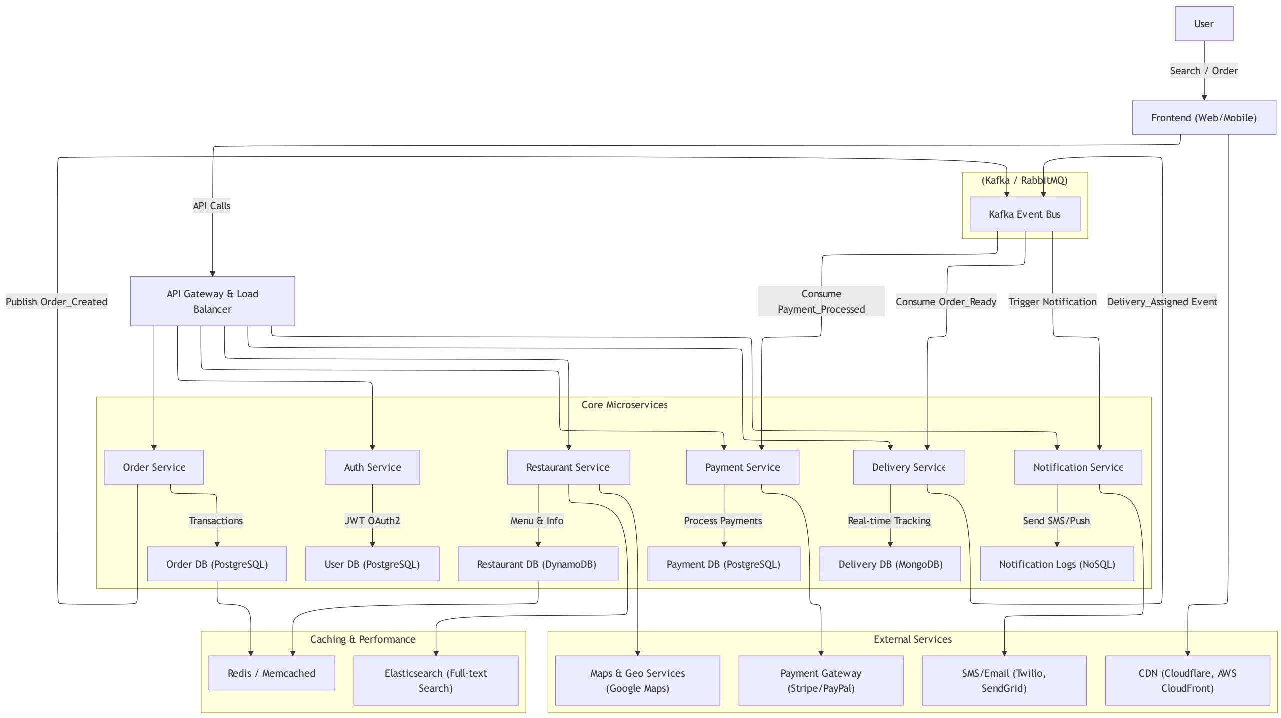
PIZZA DELIVARY SYSTEM (GLOBAL SYSTEM)



1. API Gateway & Load Balancer

- **API Gateway (Kong / AWS API Gateway / Nginx)**
  - Handles authentication, rate limiting, request routing, and caching.
- **Global Load Balancer (AWS ALB / GCP Load Balancer)**
  - Distributes traffic across multiple regional instances.

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2. Frontend Clients

- **Mobile App (React Native / Flutter)**
- **Web App (React / Angular)**
- **Admin Dashboard (React / Angular)**
- **Third-Party API Clients (Partner Integration for Orders)**

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3. Core Microservices

User & Authentication

- **User Service** (Manages user profiles, authentication, and authorization)
  - **Auth0 / Firebase Auth / AWS Cognito**
  - PostgreSQL for user data storage.
  - JWT / OAuth2 for authentication.

Order Management

- **Order Service** (Handles order creation, updates, and tracking)
  - PostgreSQL (ACID compliance for transactions).
  - Uses Kafka for event-driven updates.

Payment Processing

- **Payment Service** (Handles transactions, refunds, and fraud detection)
  - Integrates **Stripe, PayPal, Razorpay, UPI**.
  - Ensures compliance with **PCI DSS**.
  - Uses **Kafka** for asynchronous order updates.

Restaurant & Menu Management

- **Restaurant Service** (Stores restaurant details and menus)
  - DynamoDB / MongoDB for fast access.
  - Elasticsearch for search functionality.

Kitchen & Order Fulfillment

- **Kitchen Service** (Manages order preparation, estimated time, and workflow)
  - Uses WebSockets for real-time order status updates.

Delivery & Rider Management

- **Delivery Service** (Manages riders and order tracking)
  - Uses **Firebase Firestore / MongoDB** for real-time updates.
  - WebSockets / gRPC for real-time communication.

Notification & Customer Engagement

- **Notification Service** (Sends push, SMS, email notifications)
  - Uses **Twilio, Firebase Push, SendGrid**.

Review & Feedback

- **Review Service** (Manages customer ratings and reviews)
  - Uses PostgreSQL or DynamoDB.

Search & Recommendation

- **Search Service** (Helps users find restaurants and dishes)
  - **Elasticsearch** for full-text search.
  - **Redis / Memcached** for caching.

Loyalty & Rewards

- **Loyalty Service** (Handles discounts, coupons, and rewards)
  - PostgreSQL / DynamoDB for storage.

Customer Support

- **Support Service** (Chatbots, helpdesk, and complaint resolution)
  - Uses **Zendesk / ChatGPT API**.

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4. Backend Infrastructure

Database & Storage

- **PostgreSQL / MySQL** (For transactional data: orders, users, payments)
- **DynamoDB / Cassandra** (For restaurant data, menu caching)
- **MongoDB / Firestore** (For real-time delivery tracking)
- **Elasticsearch** (For fast search queries)
- **Redis / Memcached** (For caching frequently accessed data)
- **BigQuery / Snowflake** (For analytics & reporting)

Event-Driven Architecture

- **Apache Kafka / RabbitMQ** (For asynchronous communication)
  - Order events, payment processing, restaurant updates.

Distributed Transaction Management

- **Saga Pattern (Camunda / Temporal / Orchestration Engine)**

Caching & Performance Optimization

- **Redis / Memcached** (Reduces DB load)
- **CDN (Cloudflare / AWS CloudFront)** (For static assets)

Rate Limiting & Security

- **API Gateway Throttling**
- **DDoS Protection (Cloudflare / AWS Shield)**
- **Data Encryption (AES-256, TLS 1.2/1.3)**

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5. DevOps & Deployment

Containerization & Orchestration

- **Kubernetes (K8s) / Docker** (Manages microservices)
- **Helm Charts** (For Kubernetes deployment)

Continuous Integration & Deployment (CI/CD)

- **GitHub Actions / Jenkins / ArgoCD** (Automates deployments)

Logging & Monitoring

- **Prometheus & Grafana** (Metrics collection & visualization)
- **ELK Stack (Elasticsearch, Logstash, Kibana)** (Log analysis)
- **Jaeger / OpenTelemetry** (Distributed tracing)

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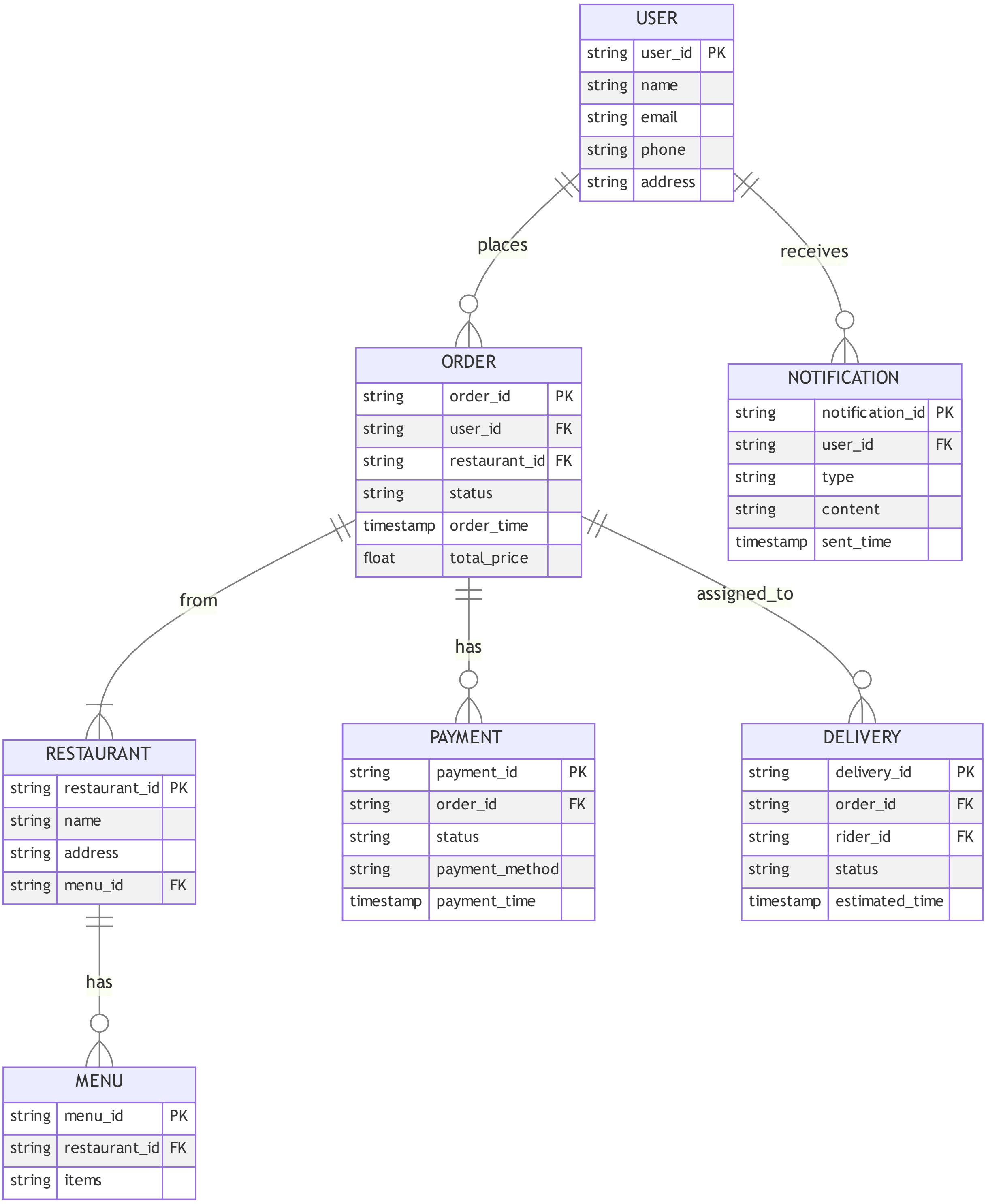
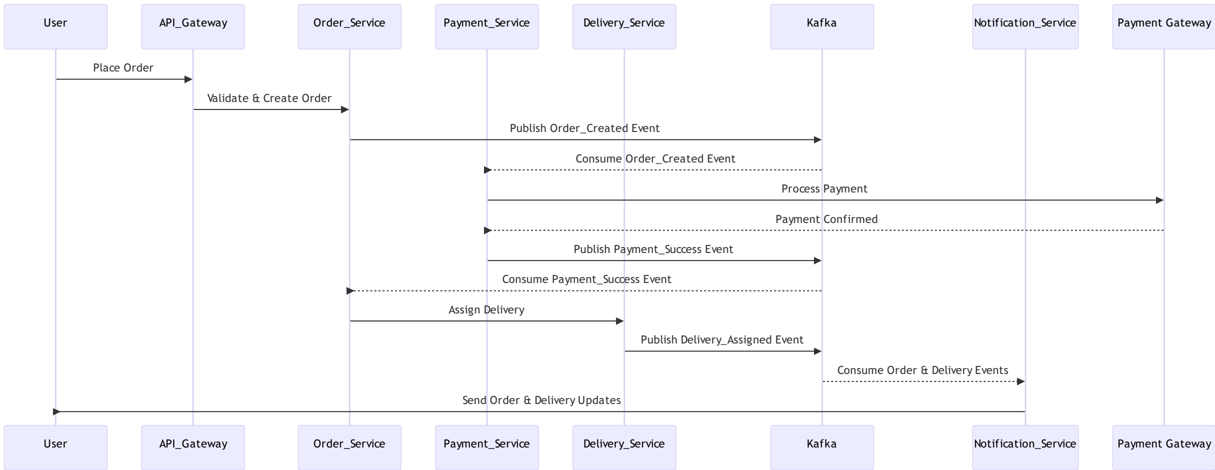
6. Third-Party Integrations

- **Payment Gateways:** Stripe, PayPal, Razorpay, UPI.
- **SMS & Email Notifications:** Twilio, SendGrid.
- **Geo Services:** Google Maps API, OpenStreetMap.
- **Analytics & Reporting:** Snowflake, AWS QuickSight.



Final Architecture Categories

☑ **Frontend Clients** – Apps, Website, Dashboard
☑ **Core Microservices** – Orders, Payments, Users, etc.
☑ **Infrastructure** – Database, Messaging, API Gateway
☑ **DevOps & Monitoring** – CI/CD, Logging, Kubernetes
☑ **Third-Party Integrations** – Payment, Maps, Notifications



Indexing & Sharding Strategy for the Global Pizza Delivery System

When designing a **global-scale pizza delivery system**, handling **high query loads, low-latency search, and massive datasets** is crucial. Below, I'll cover **indexing, sharding, partitioning, replication, and why specific choices are made**.

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1 Indexing Strategy

Indexing helps in **fast lookups** for frequently accessed data. Let's break it down by service.

📌 Order Service (PostgreSQL)

- **Indexes**:
  - **B-Tree Index** on `order_id` (Primary Key) – Faster lookups.
  - **Hash Index** on `user_id` – Efficient filtering by user.
  - **GIN Index** on `status` – Fast lookups for `Pending`, `Completed`, etc.
  - **Partial Index** on `created_at` for last `7 days` – Optimized queries.
- **Why B-Tree?** PostgreSQL defaults to **B-Tree** because it works well for **range queries** (`BETWEEN`, `<`, `>`).
- **Why Hash Index?** Hash indexes are efficient for **exact match lookups**, such as finding all orders by a `user_id`.

📌 Restaurant & Menu Service (DynamoDB)

- **Indexes**:
  - **Partition Key** → `restaurant_id`
  - **Global Secondary Index (GSI)** on `city_name`
  - **Local Secondary Index (LSI)** on `cuisine_type`
  - **Elasticsearch Sync for Full-Text Search on Menus**
- **Why GSI & LSI?**
  - **GSI** allows querying restaurants by `city_name`, helpful for geo-based lookups.
  - **LSI** allows efficient filtering by `cuisine_type` within a restaurant.
  - **Elasticsearch** enhances **fuzzy search** for menu items like `"Cheese Pizza" ~ "Cheesy Pizza"`.

📌 Delivery Service (MongoDB)

- **Indexes**:
  - **2D GeoSpatial Index** on `(latitude, longitude)`
  - **Compound Index** on `rider_id, status`
  - **TTL Index** on `delivery_time` (Expire after 24 hours)
- **Why GeoSpatial Index?**
  - Helps find **nearest delivery agents** within a given radius.
  - Enables **fast searches based on real-time location updates**.
- **Why TTL Index?**
  - Automatically deletes old records to **keep DB size manageable**.

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2 Sharding Strategy

Sharding ensures the system can handle **millions of queries per second**. Here's how we'll distribute data.

📌 Order Service (PostgreSQL)

- **Sharded by `user_id` (Range-Based Sharding)**
  - Each shard contains **orders of a range of users** (`1-10M`, `10M-20M`).
  - Reduces **hotspotting** since users place orders across different shards.
  - **Replication per region** for **fault tolerance**.
- **Alternative: Hash-Based Sharding**
  - **Pro:** Uniform distribution of load.
  - **Con:** Can't efficiently query **"all orders of a city"**.

📌 Restaurant & Menu Service (DynamoDB)

- **Sharded by `restaurant_id` (Partition Key)**
  - **Each restaurant has its menu data** stored separately.
  - **GSI on `city_name`** ensures we can query "restaurants in a city".
  - **Read replicas** in **multiple regions** ensure **faster local access**.
- **Why Not Range-Based?**
  - Restaurant names aren't **evenly distributed** (e.g., many start with "Pizza").
  - **Hashing avoids hotspots** in a distributed database.

📌 Delivery Service (MongoDB)

- **Sharded by `city_name` (Geo-Sharding)**
  - Each **city has its delivery tracking database**.
  - Within each city, **GeoSpatial indexing** helps find riders.
- **Why Not Hash-Based?**
  - **Location-based lookups** would be inefficient.
  - **GeoPartitioning keeps data close to riders** and improves **real-time updates**.

3️⃣ Partitioning & Replication Strategy

Partitioning splits large tables into smaller **manageable units**.

📌 Order Service (PostgreSQL)

- **Time-Based Partitioning** (`Monthly`)
  - Orders older than **6 months** move to **cold storage (S3, Glacier)**.
  - Speeds up recent order lookups.
- **Read Replicas per Continent**
  - US, EU, Asia each have a **read-only replica** to **reduce query latency**.

📌 Restaurant Service (DynamoDB)

- **Partitioned by Region**
  - US-East, US-West, Europe, Asia.
  - **Multi-active replication** ensures **restaurants can update data from any location**.

📌 Delivery Service (MongoDB)

- **GeoPartitioned & Read-Replicated**
  - India's deliveries stay in India, US in US.
  - **Read-optimized replicas for mobile clients**.

4️⃣ Caching Strategy

We need **caching** to avoid **hitting the database too often**.

Service	Cache Strategy	Why?
Order Service	Redis (LRU) for recent orders	Users check recent orders often
Restaurant Menu	Redis / Memcached	Speeds up restaurant & menu queries
Delivery Tracking	In-Memory Cache (10s TTL)	Reduces DB calls for real-time updates
Search & Filters	Elasticsearch	Full-text search for restaurant names

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5️⃣ Load Balancing & API Gateway

To handle **millions of requests per second**, we use:

Component	Load Balancer / Proxy
API Gateway	**Nginx / AWS API Gateway**
Backend Services	**Kubernetes Ingress + Internal Load Balancers**

Caching Layer	**Redis Cluster Mode**
Database	**Read Replicas & Auto-Scaling**

6️⃣ Deployment & Scaling Strategy

📌 Horizontal Scaling

- **Kubernetes (K8s) & Auto-Scaling**
- Each service runs **independently in containers**.
- **Event-driven scaling** → Auto-scale when high load detected.

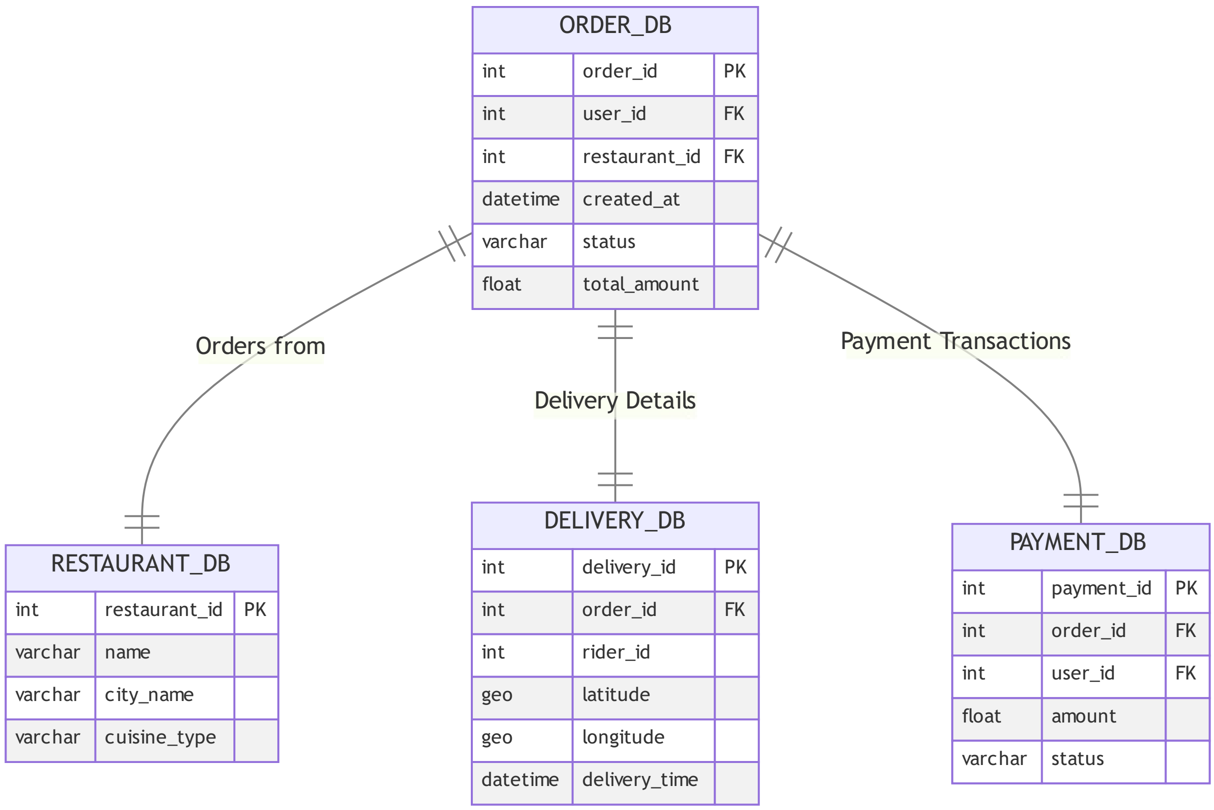
📌 Global Deployment

- **Multi-Region AWS / GCP Setup**
- **Load Balancers** route traffic to nearest server.
- **Edge caching (CDN)** for static assets.

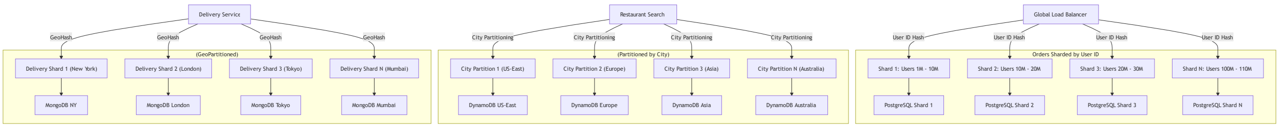
🛠 Why This Design?

✅ **Optimized Reads** – Using **indexes, caching, partitioning**.
✅ **Low Latency** – **Sharding, Replication, CDN, GeoPartitioning**.
✅ **Scalable** – **Event-Driven, Auto-Scaling, Kubernetes**.
✅ **Fault-Tolerant** – **Redundant regions, Replication, Kafka**.
✅ **Real-time Capable** – **GeoSpatial Indexing, WebSockets, Event Bus**.

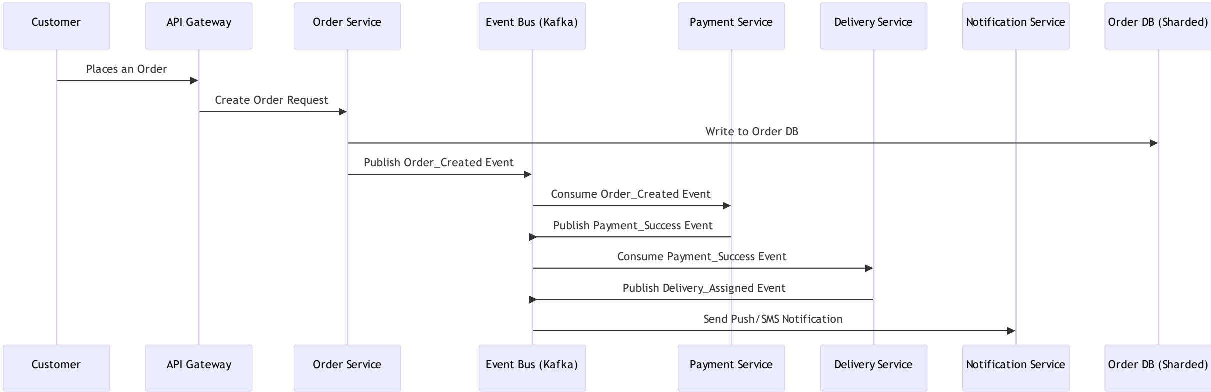
1️⃣ Database Indexing Strategy



2️⃣ Sharding & Partitioning Strategy



3️⃣ Event-Driven Architecture & Replication



Why This Design?

✔ **Indexes** optimize search queries across **PostgreSQL, DynamoDB, MongoDB**.
✔ **Sharding by User ID, GeoPartitioning, and City-Based Partitions** distribute load.
✔ **Event-Driven Architecture with Kafka** reduces synchronous calls & improves scalability.
✔ **Read Replicas in Multiple Regions** reduce database load.

Deep Dive into Data Storage & Architecture for a Global Pizza Delivery System 🍕

A **global-scale pizza delivery system** needs a highly efficient **data architecture** that balances:
✔ **Scalability** (handling billions of orders)
✔ **Low Latency** (fast search & tracking)
✔ **Reliability** (ACID for payments, eventual consistency for tracking)
✔ **Cost Efficiency** (hot vs. cold storage)

📌 1. Key Data Entities & Size Estimations

1️⃣ Orders

- **Contains:** Order details, status, payment, delivery info, tracking, etc.
- **Scale:** 500M+ orders/day → ~1TB/day (~365TB/year)
- **Storage Choice: PostgreSQL (Sharded) + Cold Storage (S3/GCS)**
- **Partitioning Strategy:**
  - **Sharded by `user_id`** (even distribution of load)
  - **Partitioned by `created_at`** (for fast retrieval & archival)
- **Indexing:**
  - **B-Tree index on `order_id`, `user_id`** (fast lookup)
  - **GIN index on `status` (JSONB column)** (query orders by status efficiently)
  - **GeoIndex on `delivery_location`** (for nearest driver assignment)

2️⃣ Users

- **Contains:** Name, email, phone, preferences, addresses, loyalty points
- **Scale:** 500M users (~1.5TB)
- **Storage Choice: PostgreSQL + Redis Cache**
- **Indexing:**
  - **Primary Key: `user_id`**
  - **B-Tree index on `phone_number, email`**
  - **Cache recent lookups in Redis** (low latency reads)

3️⃣ Restaurants

- **Contains:** Name, location, cuisine, ratings, menus, operating hours
- **Scale:** 50M restaurants (~250GB)
- **Storage Choice: DynamoDB (NoSQL, GSI on `city_name`)**
- **Indexing:**
  - **Partition Key: `restaurant_id`**
  - **Global Secondary Index (GSI) on `city_name`**
  - **Local Secondary Index (LSI) on `cuisine_type`**
- **Replication:** Multi-region to keep search fast worldwide

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4️⃣ Menu

- **Contains:** Menu items, descriptions, prices, availability
- **Scale:** 5B menu items (~2.5TB)
- **Storage Choice: MongoDB (NoSQL, Document DB)**

- **Indexing:**
    - **Index on `restaurant_id` (fast lookups by restaurant)**
    - **Text search indexing for menu search**

5️⃣ Live Order Tracking

- **Contains:** Delivery status, driver location, estimated arrival time
- **Scale:** 10M+ concurrent deliveries → **360GB/hour**
- **Storage Choice: MongoDB (GeoSharded) + Redis for hot lookups**
- **Indexing:**
    - **GeoIndex on `current_location` (fast lookups by area)**
    - **TTL Index (auto-delete records after 1 hour)**

6️⃣ Payments

- **Contains:** Payment transactions, refunds, fraud detection data
- **Scale:** 100M+ transactions/day
- **Storage Choice: PostgreSQL (ACID Compliance) + Kafka for async processing**
- **Indexing:**
    - **Primary Key: `transaction_id`**
    - **Index on `user_id`, `order_id`**

7️⃣ Reviews & Ratings

- **Contains:** User reviews, restaurant ratings
- **Scale:** 1B+ reviews
- **Storage Choice: Elasticsearch (Full-text search) + PostgreSQL**
- **Indexing:**
    - **Full-text search index on `review_text`**
    - **B-Tree index on `restaurant_id`**

📌 2. Storage Optimization Techniques

🗂 1. Sharding Strategy

- **PostgreSQL (Orders, Users, Payments)**
    - **Horizontal sharding by `user_id`**
    - **Logical partitions on `created_at`**
- **MongoDB (Live Tracking, Menus)**
    - **GeoSharding by `latitude, longitude`**
- **DynamoDB (Restaurants, Menus)**
    - **Partition by `city_name`** (ensures load balancing)

🚀 2. Caching Strategy

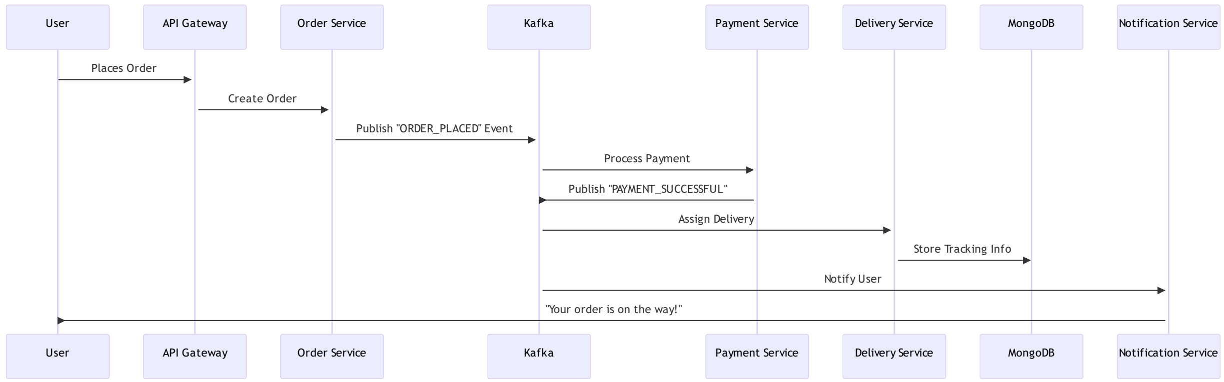
- **Redis for user profiles, session management**
- **CDN (Cloudflare/Akamai) for menu images, static assets**
- **Elasticsearch for fast menu & restaurant search**

📜 3. Archival & Data Retention

- **Orders older than 1 year → Cold Storage (S3/GCS)**
- **Live tracking data auto-deleted after 1 hour (TTL Index)**

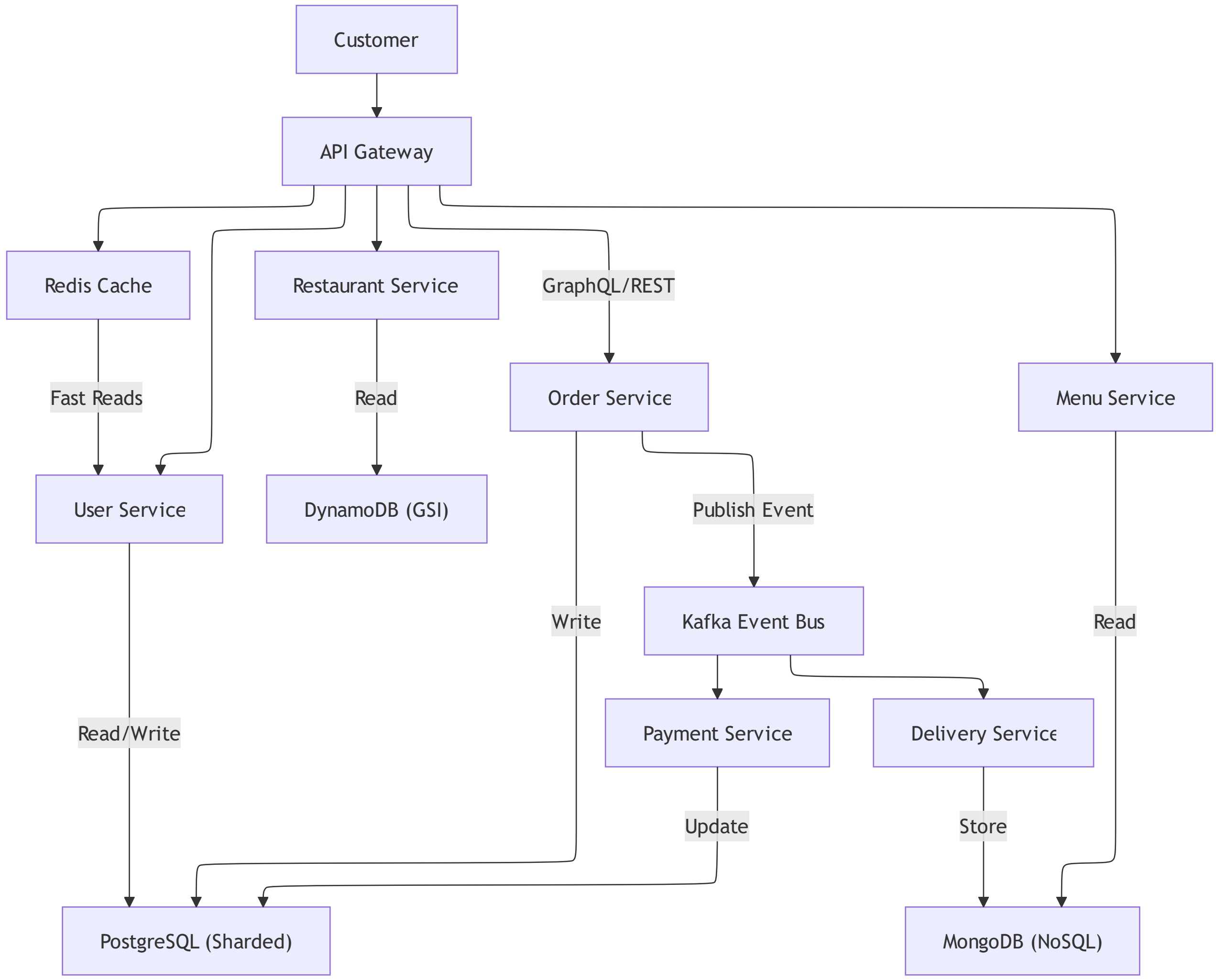
📌 3. Event-Driven Architecture (Async Processing)

To improve **scalability & performance**, use **event-driven architecture** with Kafka.



☑ **Advantages of Kafka-based event processing**:
✔ **Decoupling Services** (Order, Payment, Delivery work independently)
✔ **Scalability** (Millions of orders per second)
✔ **Fault Tolerance** (Kafka retains events for replay)

📌 4. High-Level System Architecture



📌 5. Deployment & Scaling

🛠 Deployment Model

- **Multi-region AWS/GCP Deployment** for low latency
- **Microservices in Kubernetes (EKS/GKE)**
- **Auto-scaling with HPA (Horizontal Pod Autoscaler)**
- **Log aggregation with ELK stack**

🔧 Load Balancing

- **Global Load Balancer (Cloudflare, AWS ALB)**
- **Separate read replicas for PostgreSQL**

☑ Final Thoughts

Key Takeaways

✔ **Hybrid SQL + NoSQL** for best scalability
✔ **Sharding & Partitioning** to handle billions of records
✔ **Kafka-based async processing** for performance
✔ **GeoIndexing for live tracking**
✔ **Redis & CDN for ultra-fast access**