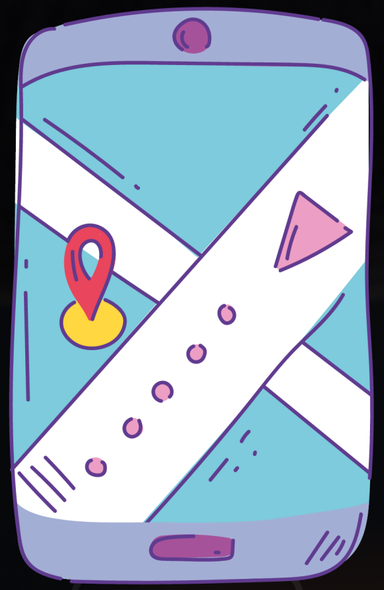
MPRASHANT

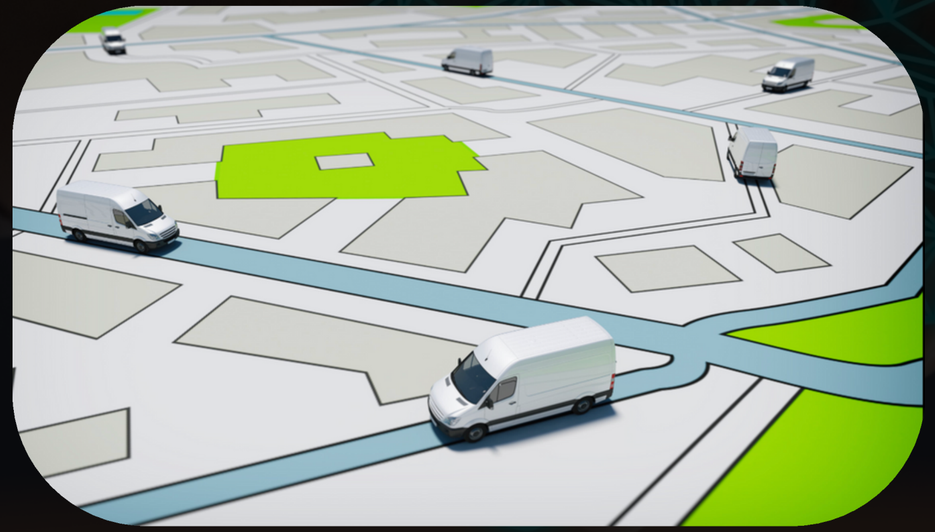
MPRASHANT

Importance of real-time data streaming

MPRASHANT



Delivery

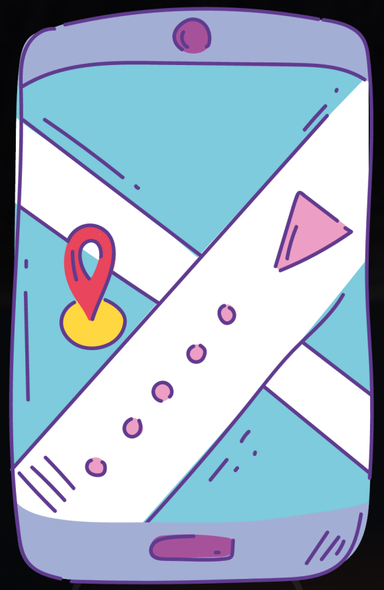


parcel

food

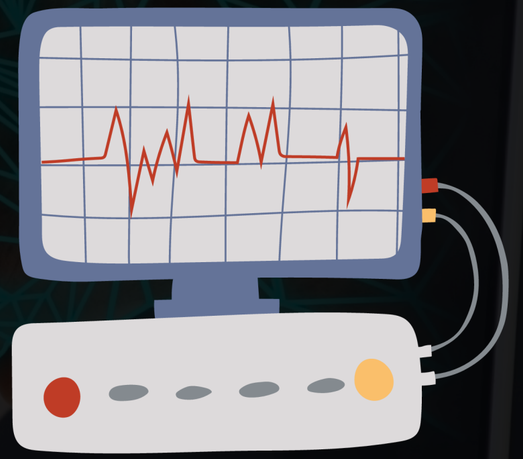
car

MPRASHANT



Delivery

Stock Price



Health Monitor

MPRASHANT

WHAT IS APACHE KAFKA?

MPRASHANT

Kafka is a distributed streaming platform.

Allows applications to send, store, and process data in real time.

APACHE KAFKA

More than 80% of all Fortune 100 companies trust, and use Kafka.

Apache Kafka is an open-source distributed event streaming platform used by thousands of companies for high-performance data pipelines, streaming analytics, data integration, and mission-critical applications.

10 OUT OF 10

MANUFACTURING

7 OUT OF 10

BANKS

10 OUT OF 10

INSURANCE

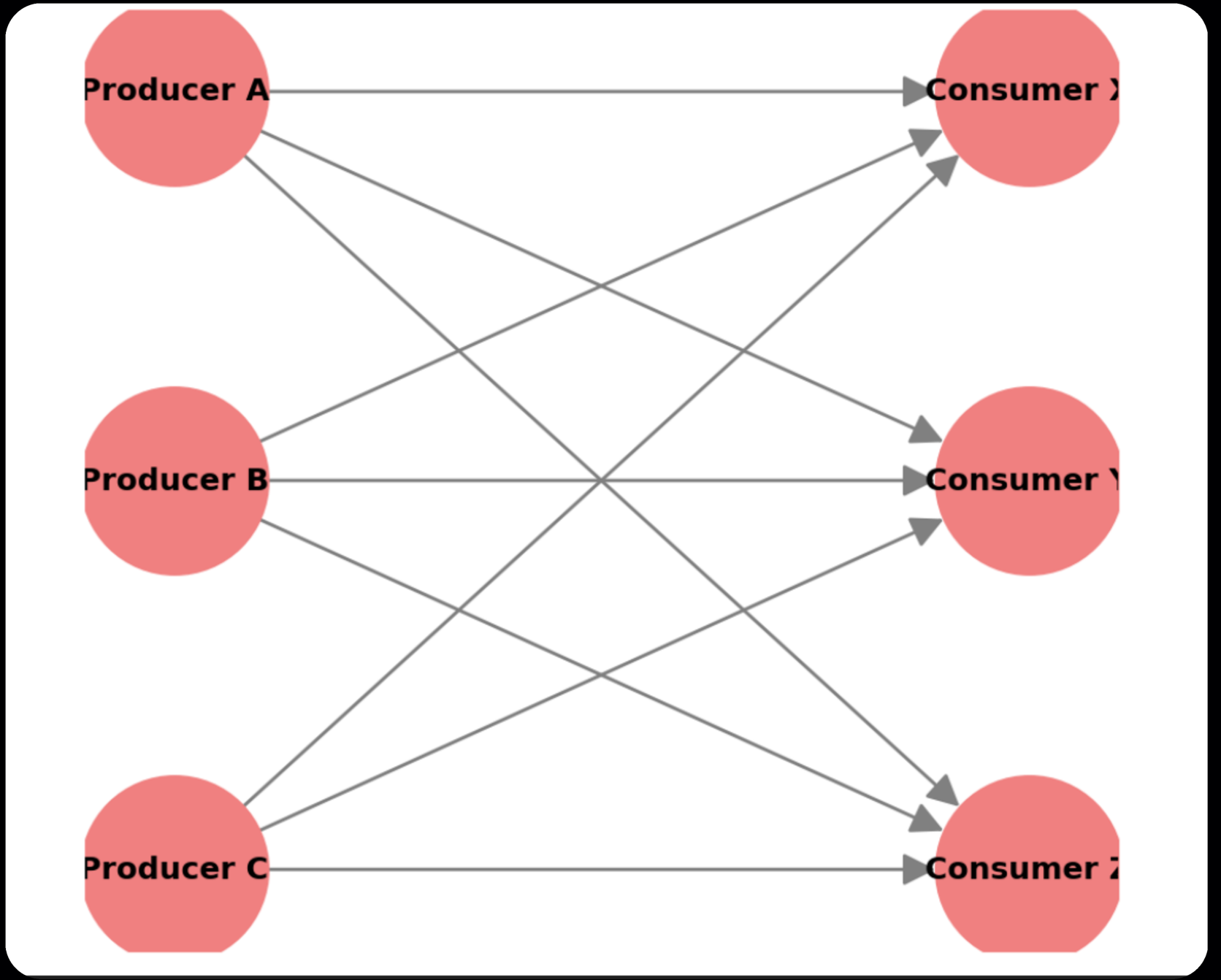
8 OUT OF 10

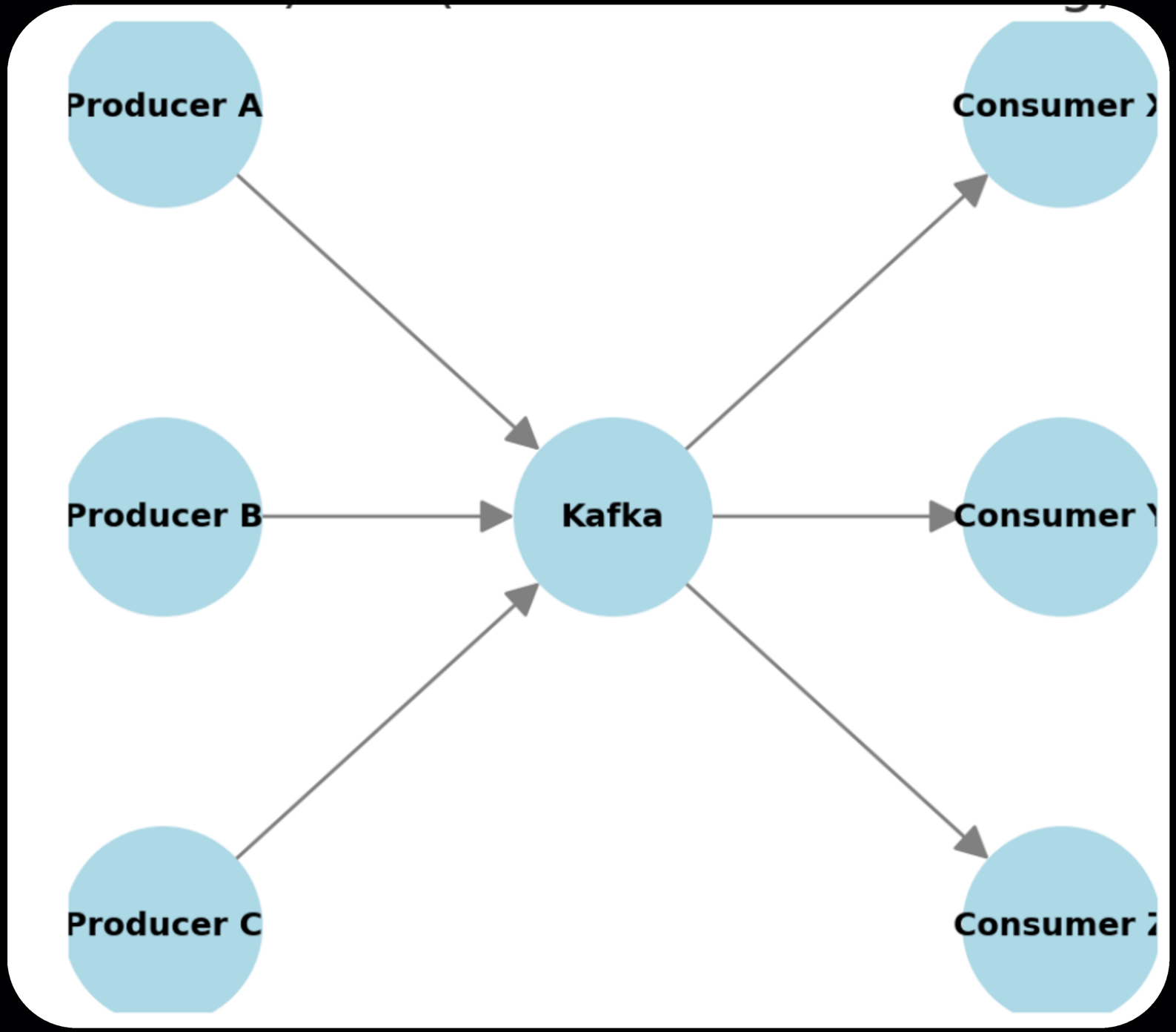
TELECOM

MPRASHANT

DEVELOPED BY LINKEDIN AND OPEN-SOURCED UNDER THE APACHE SOFTWARE FOUNDATION.

Why was Kafka created?

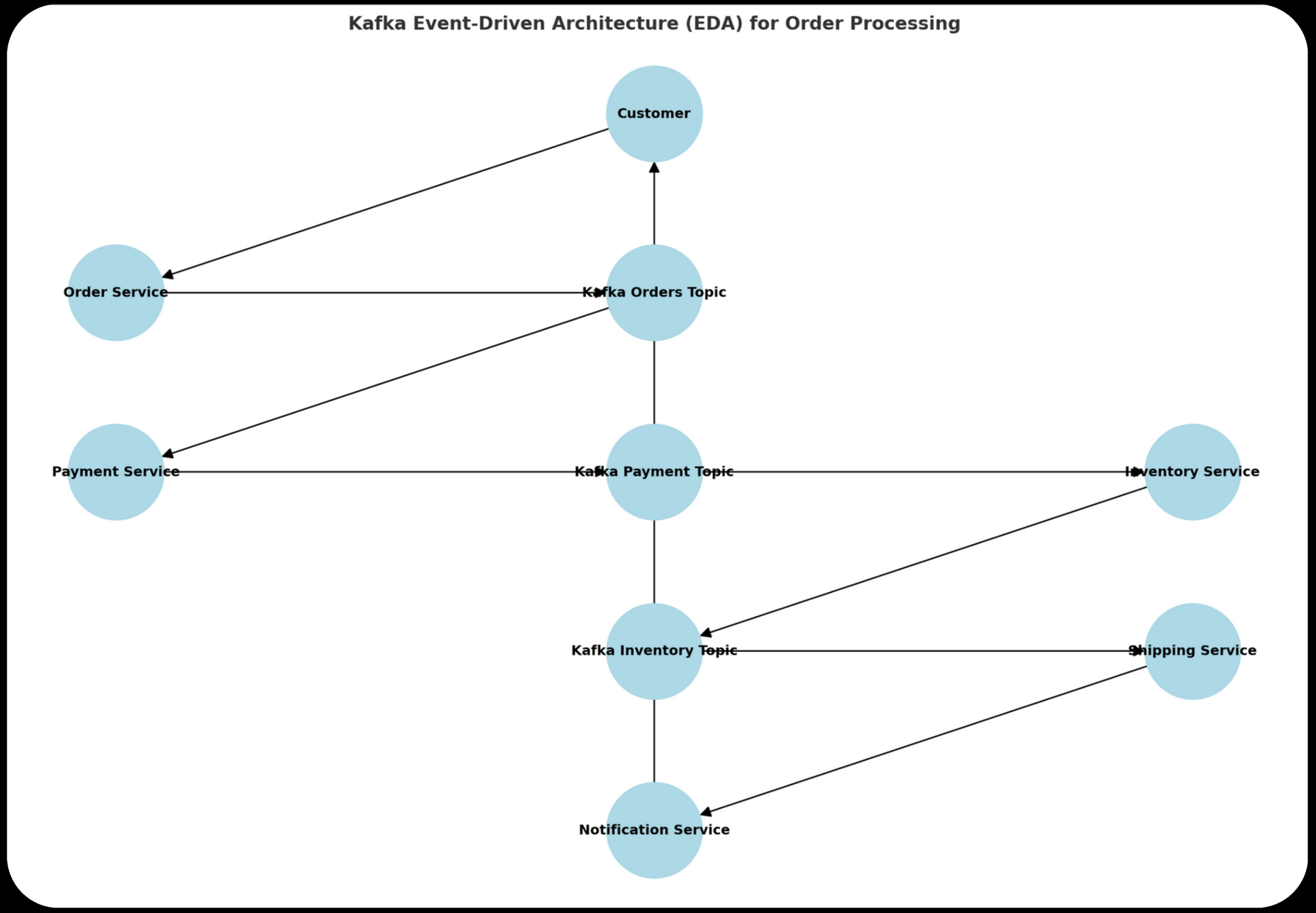

Producer A
Producer B
Producer C
Consumer X
Consumer Y
Consumer Z


Producer A
Producer B
Producer C
Kafka
Consumer X
Consumer Y
Consumer Z

EDA (Event Driven Architecture)

EDA is a system design where services communicate through events instead of direct calls.

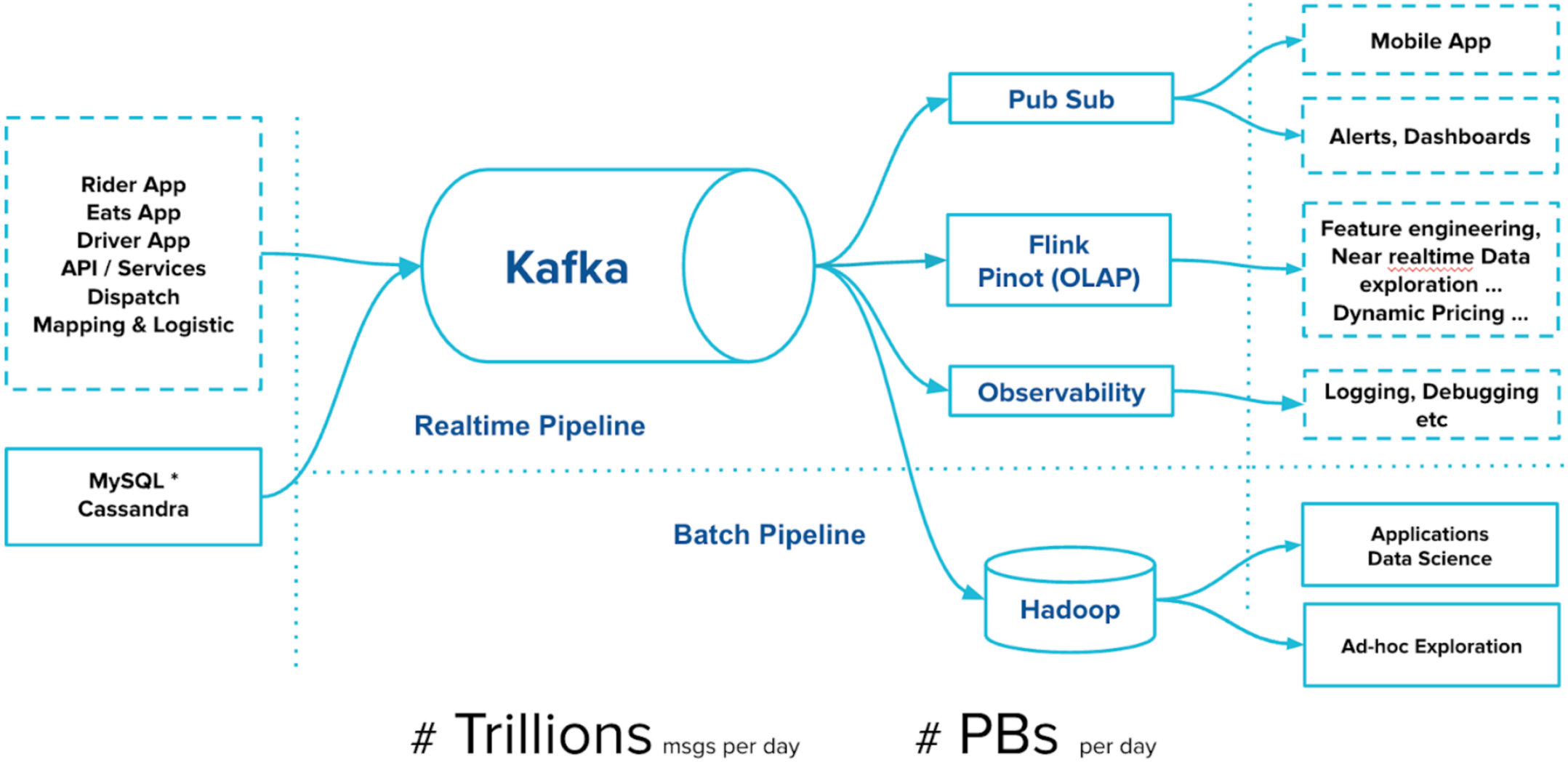
In EDA, one service publishes an event (e.g., "Order Created"), and other services react to it asynchronously (e.g., process payment, update inventory, ship the product).


Kafka Event-Driven Architecture (EDA) for Order Processing
Customer
Order Service
Kafka Orders Topic
Payment Service
Kafka Payment Topic
Inventory Service
Kafka Inventory Topic
Shipping Service
Notification Service

Apache Kafka

A Distributed Streaming Platform.

Apache Kafka


Rider App
Eats App
Driver App
API / Services
Dispatch
Mapping & Logistic
MySQL *
Cassandra
Kafka
Realtime Pipeline
Batch Pipeline
Pub Sub
Flink
Pinot (OLAP)
Observability
Hadoop
Mobile App
Alerts, Dashboards
Feature engineering,
Near realtime Data
exploration ...
Dynamic Pricing ...
Logging, Debugging
etc
Applications
Data Science
Ad-hoc Exploration
Trillions msgs per day
PBs per day

MPRASHANT

BENEFITS OF USING KAFKA

- **SCALABILITY**: HANDLE LARGE AMOUNTS OF DATA.
- **FAULT TOLERANCE**: REPLICATION OF DATA.
- **HIGH THROUGHPUT**: CAPABLE OF PROCESSING MILLIONS OF MESSAGES PER SECOND.
- **DURABILITY**: RELIABLE STORAGE OF MESSAGES.

KEY COMPONENTS OF KAFKA

- TOPICS
- PRODUCERS
- CONSUMERS
- BROKERS
- PARTITIONS
- ZOOKEEPER / KRAFT

Kafka Broker

When you run Kafka, you start one or more “broker” processes. It is basically the server (or node) in a Kafka cluster.

- Stores messages
- Handle Read/write requests

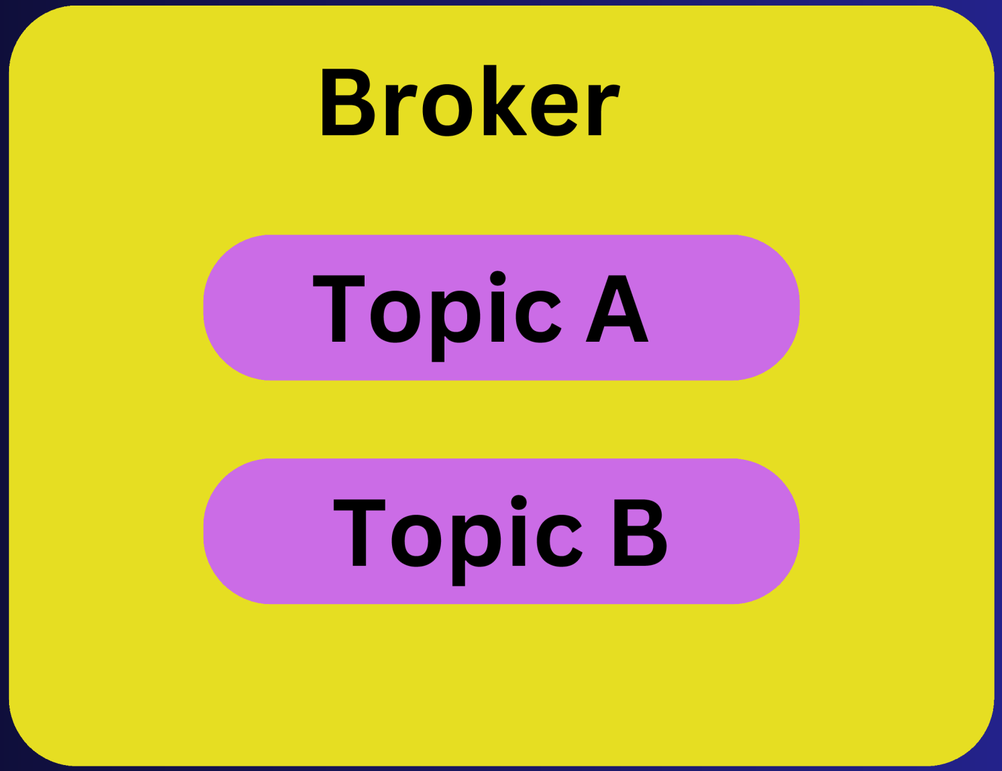
MPRASHANT

Kafka Topic

A Kafka topic is like a “channel” or “category” where messages (data) are published. Think of it as a folder that holds all the messages belonging to a specific stream of data.

- When you send a message to Kafka, you choose which topic to send it to.
- Consumers then subscribe to that topic to receive the messages.

MPRASHANT



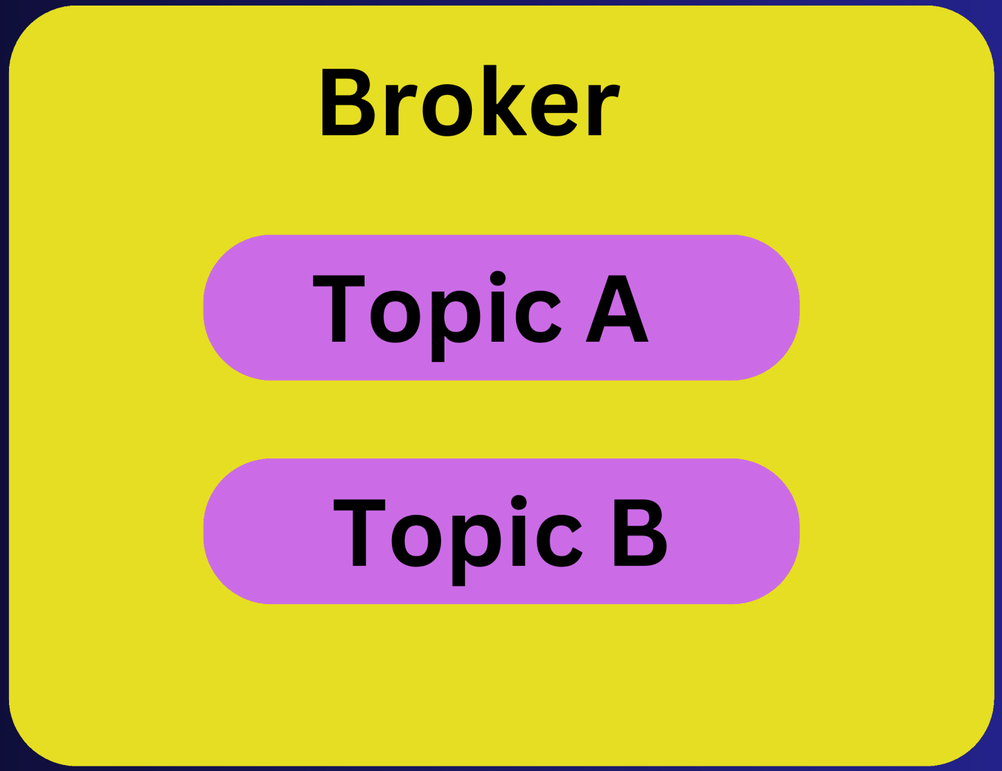
Producer:

- An application or process that sends events to Kafka topics. Producers write data to Kafka.

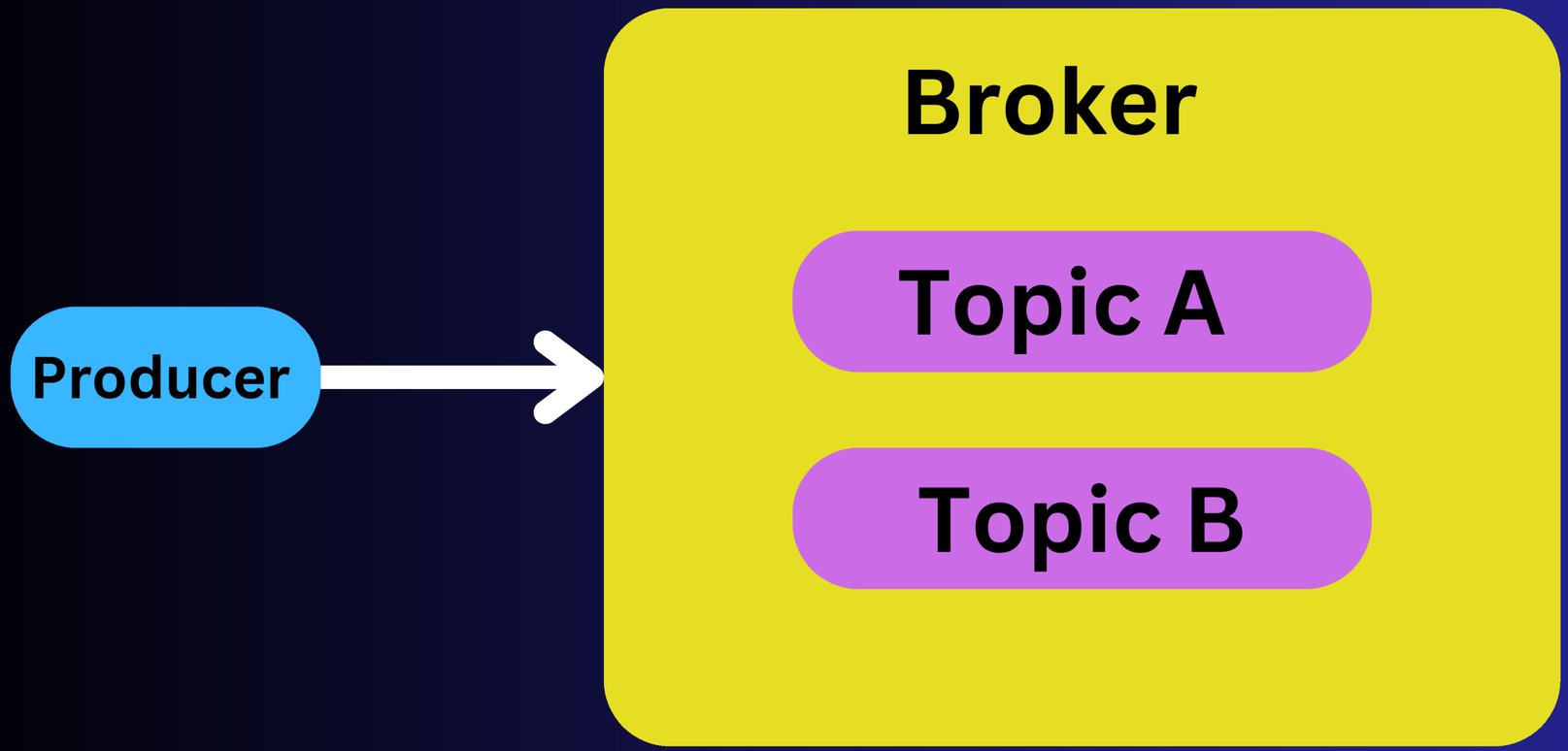
Consumer:

- An application or process that reads events from Kafka topics.
- Consumers subscribe to topics and process the data.

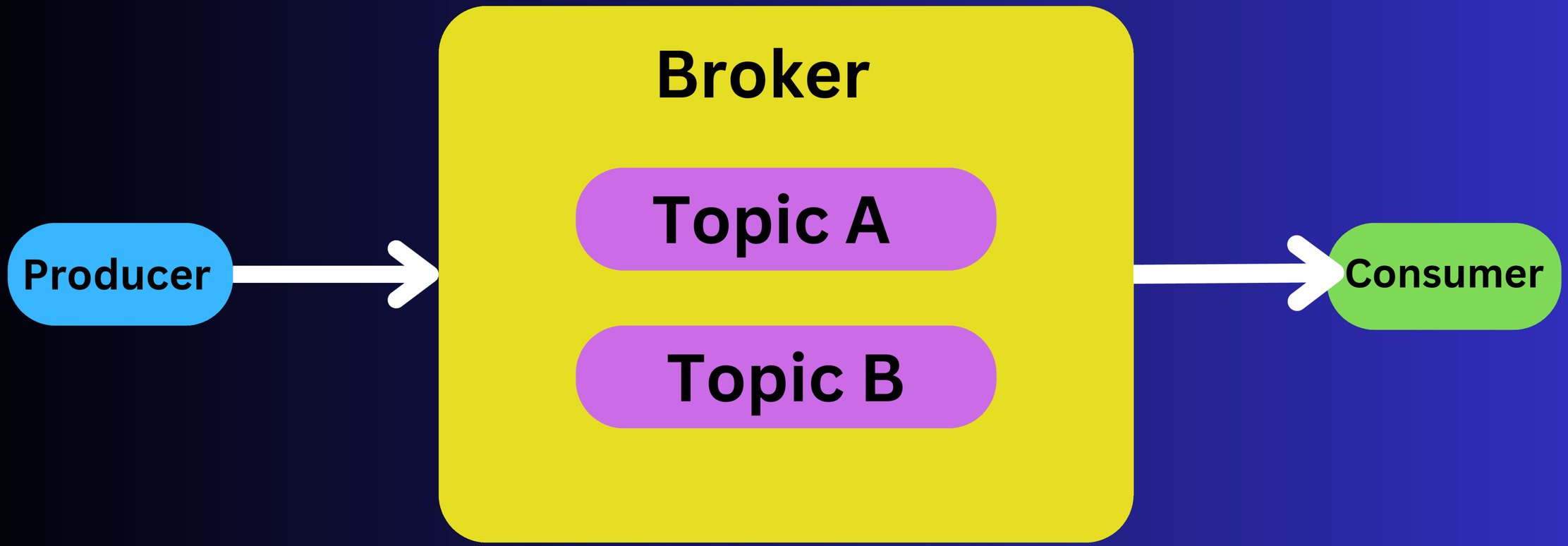
MPRASHANT



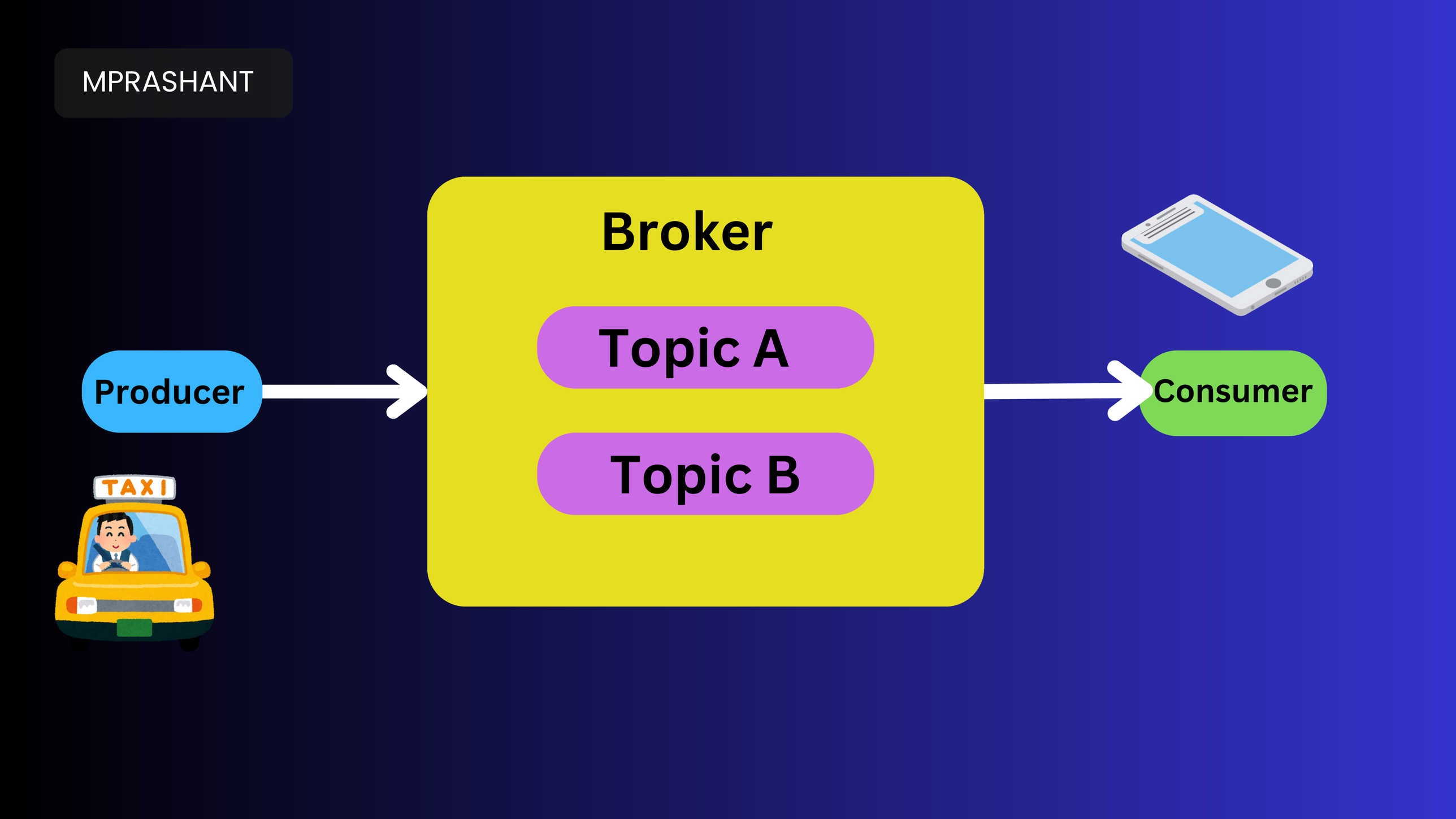
MPRASHANT



MPRASHANT



MPRASHANT



Some systems that can act as producers for Kafka:

SQL or NoSQL Databases
REST APIs
Log Aggregators
Message Queues
Stream Processing Frameworks
IoT Devices and Sensors
Data Integration Tools
Custom Applications
Data Analytics and BI Tools

💡 Kafka Producers Can Be Built Using:

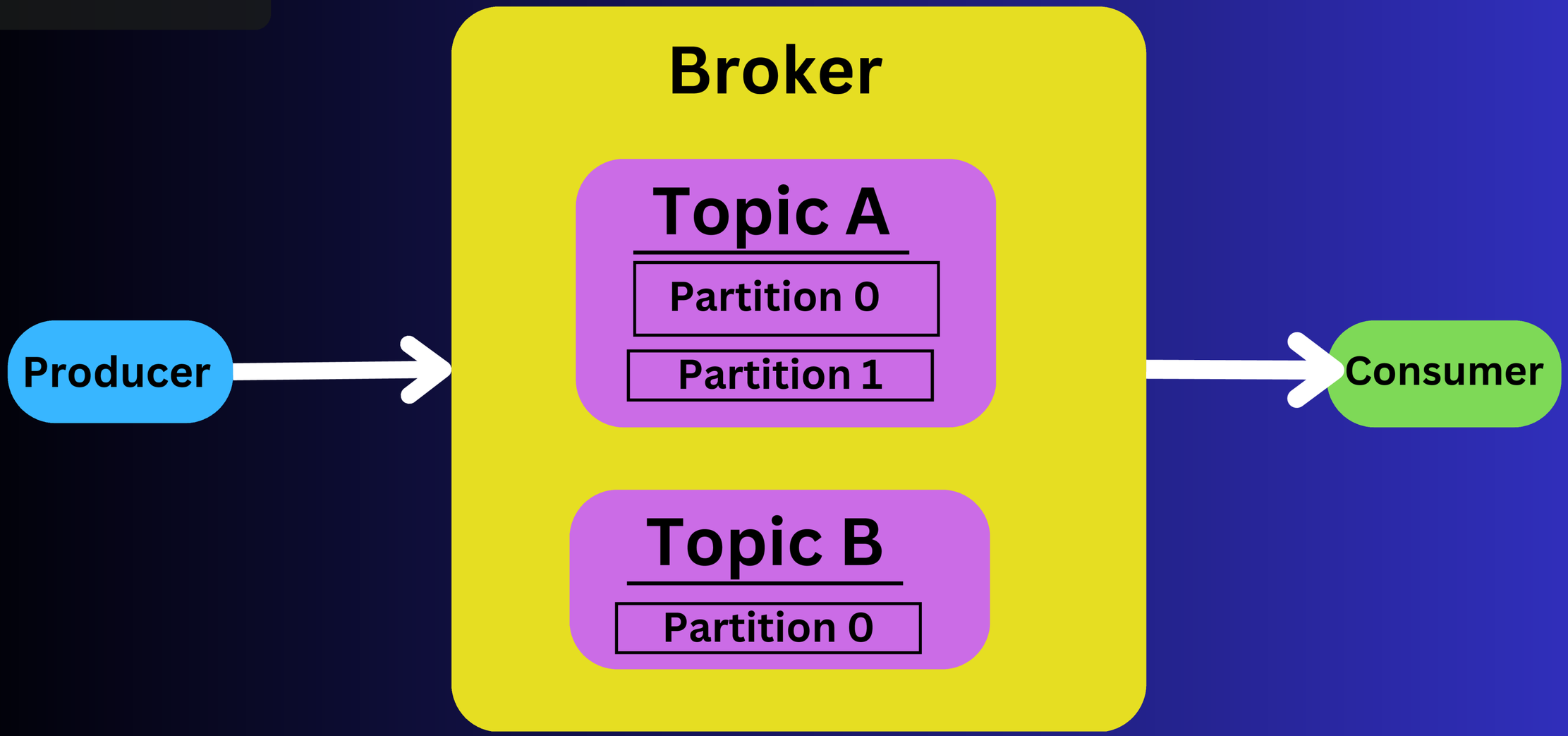
✅ Kafka Connect (JDBC, Debezium, HTTP Source)
✅ Custom Producers (Java, Python, Go, Node.js)
✅ Open-source Agents (Fluentd, Logstash, Filebeat)

Kafka Partition

A partition is a subsection of a Kafka topic. Topics can have multiple partitions so data can be spread out across brokers.

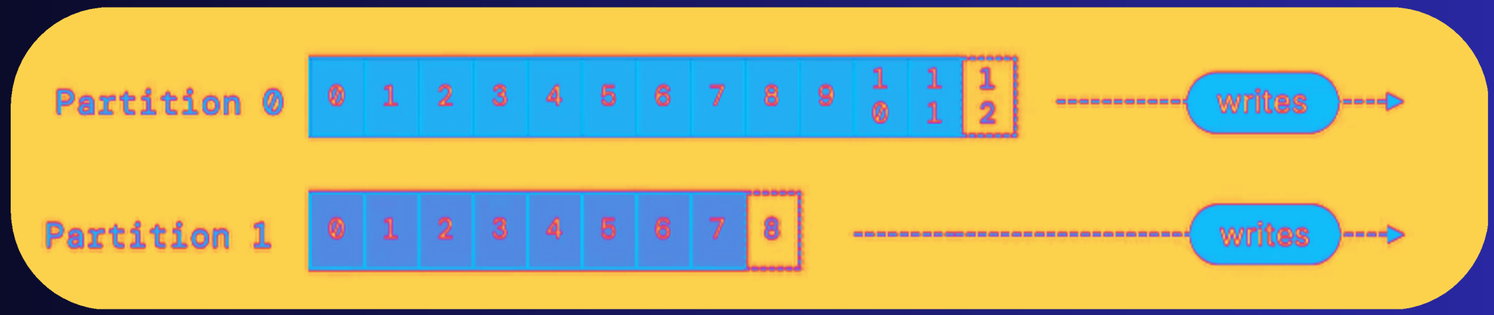
Each partition maintains a sequential order of messages, allowing parallel read and write for higher performance.

MPRASHANT


Broker
Topic A
Partition 0
Partition 1
Topic B
Partition 0
Producer
Consumer

Kafka Offset

A Kafka offset is a sequential number assigned to each message within a partition. Think of it like page numbers in a book.
Offsets are unique per partition, helps in tracking.



Topic A

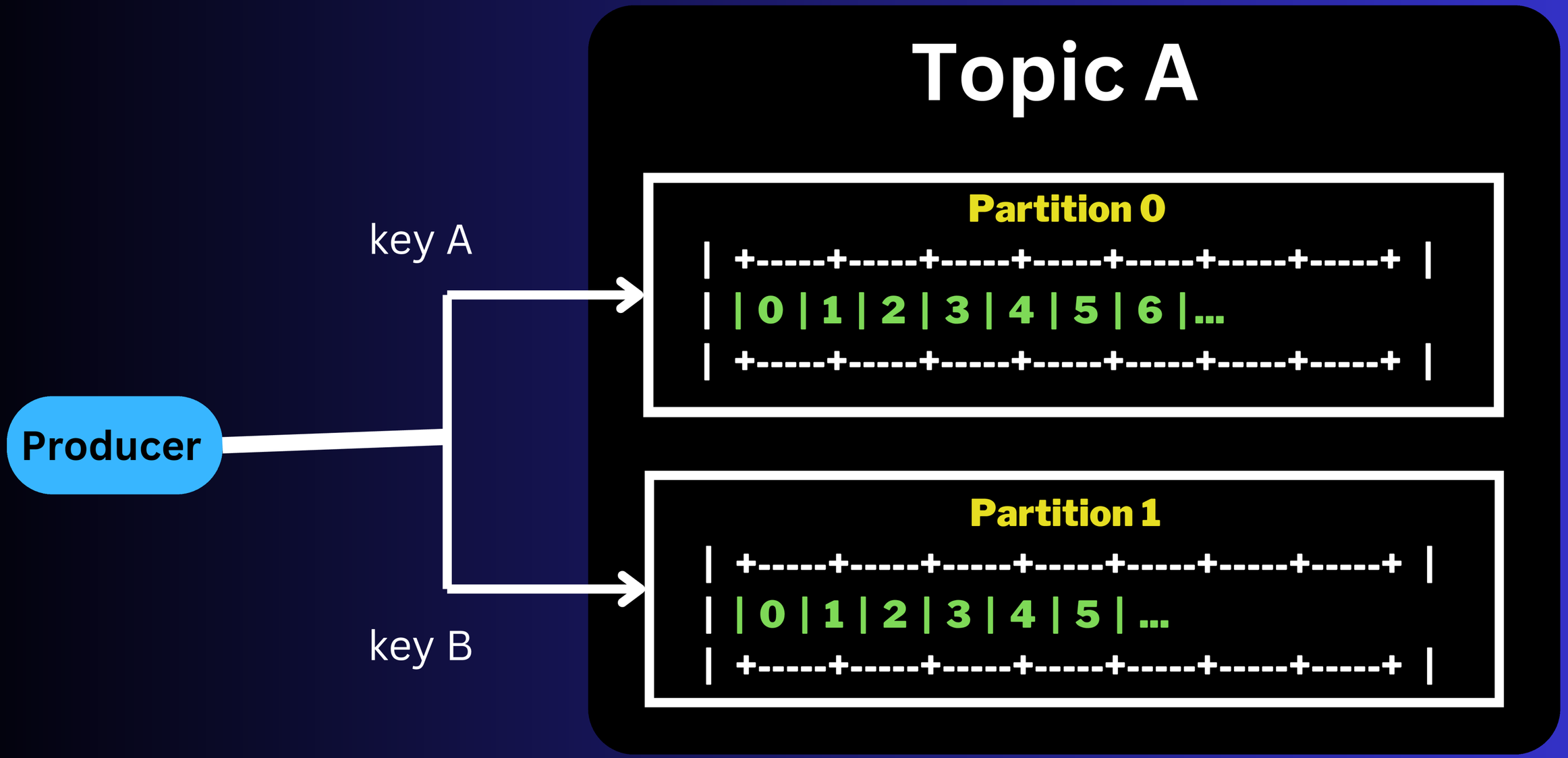
- Assigned by Kafka – The Kafka broker assigns offsets, not the producer.
- Unique per Partition – Each partition has its own independent offsets (e.g., Partition 0: 0,1,2..., Partition 1: 0,1,2...).
- Maintains Order (Per Partition) – Messages are always read in order within a partition.
- Tracks Consumer Progress – Consumers store their last read offset to resume processing.
- Supports Message Replay – Consumers can rewind or seek to reprocess older messages.
- Stored in Kafka (__consumer_offsets) – Kafka tracks offsets internally, unless configured otherwise.
- Retention Affects Offsets – If a message exceeds Kafka's retention period, it may no longer exist.

Message Key

- Used for Partitioning – Kafka uses the message key to decide which partition the message should go to.
- Ensures Ordering – Messages with the same key always go to the same partition, preserving order.

- Optional – Producers can send messages with or without a key (if no key, Kafka distributes messages round-robin).
- Stored with Message – The key is stored along with the message in Kafka but does not affect the message content.

- Can Be Any Data Type – Typically a string, but can be any serializable data.

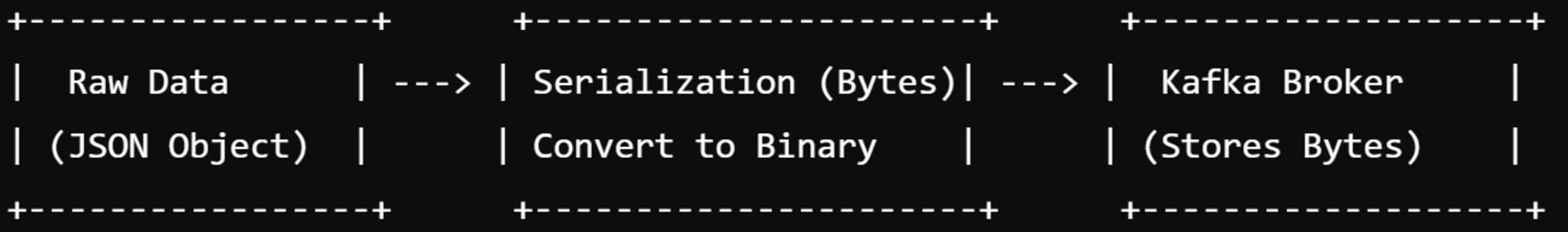

Topic A
Partition 0
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |...
Partition 1
| 0 | 1 | 2 | 3 | 4 | 5 | ...
key A
key B
Producer


Kafka Message (Record)
Topic: "orders"
Partition: (Decided by Key or Round-robin)
Key: "order-12345" (Ensures Ordering per Key)
Value: {
"order_id": "12345",
"customer": "John Doe",
"amount": 250.75,
"status": "pending"
}
Headers: { "source": "web-app", "timestamp": "1700000000000" }
Timestamp: "1700000000000"

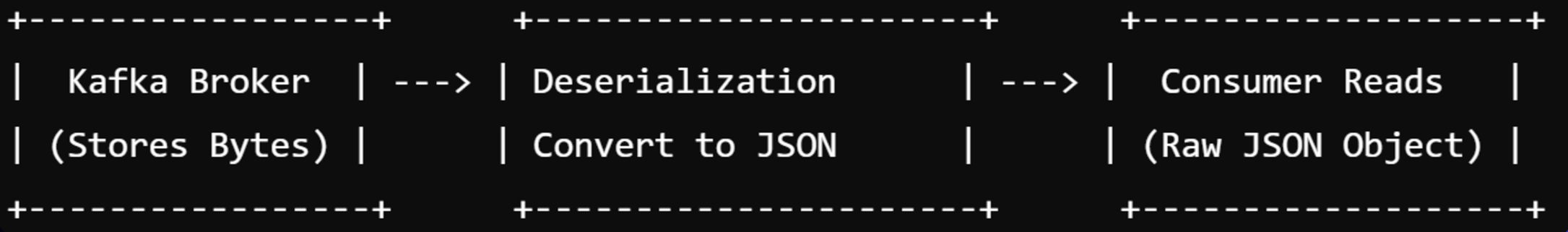
Kafka Serialization - Key Points & Flow

Serialization in Kafka is the process of converting data into bytes before sending it to Kafka (Producer Side) and deserializing it back when reading from Kafka (Consumer Side).

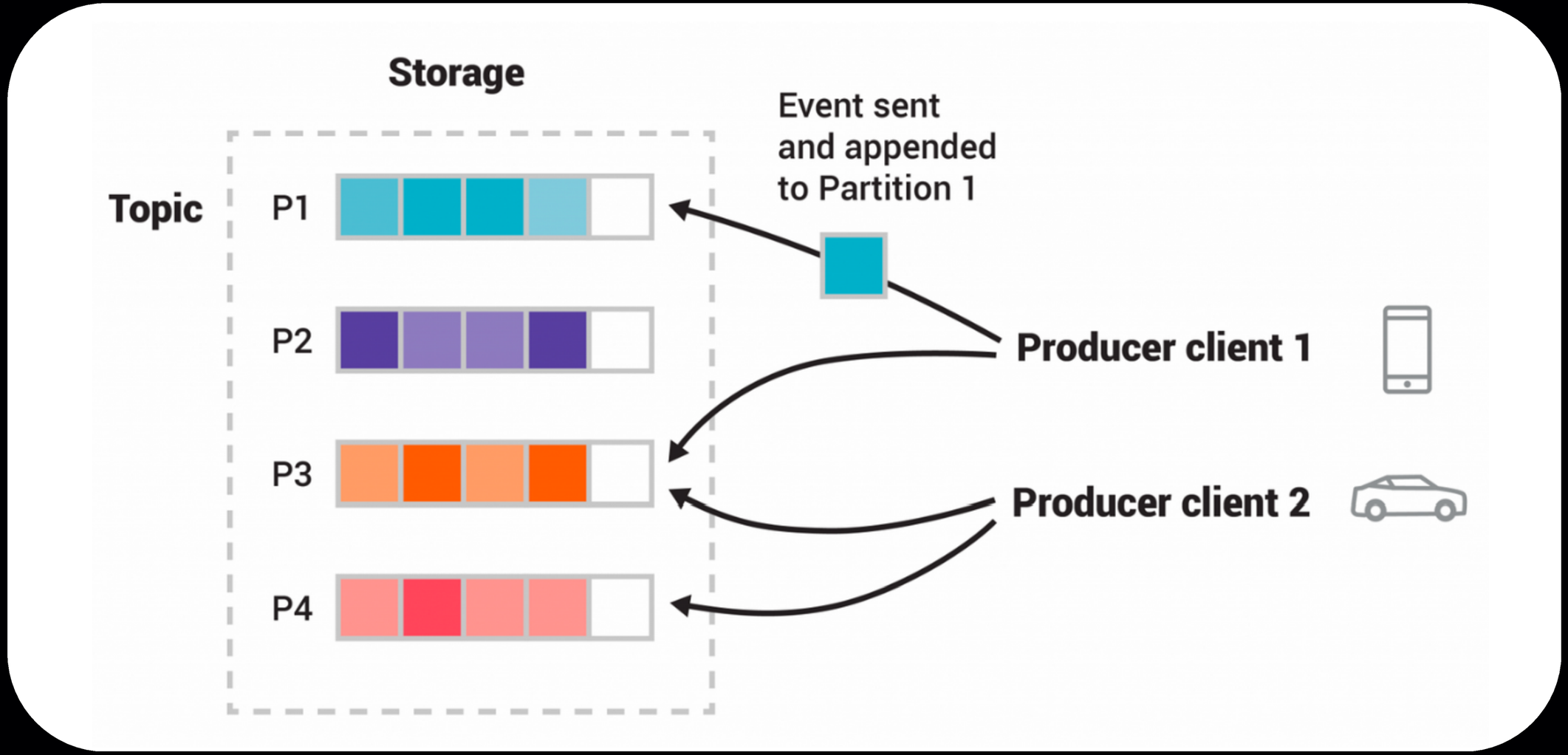
1️⃣ Producer Side: Serialization



2️⃣ Consumer Side: Deserialization

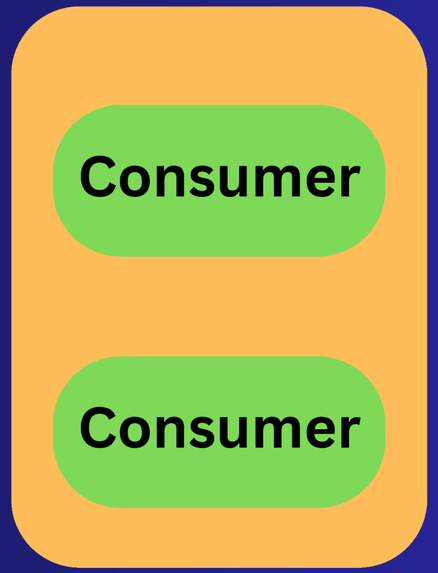


MPRASHANT

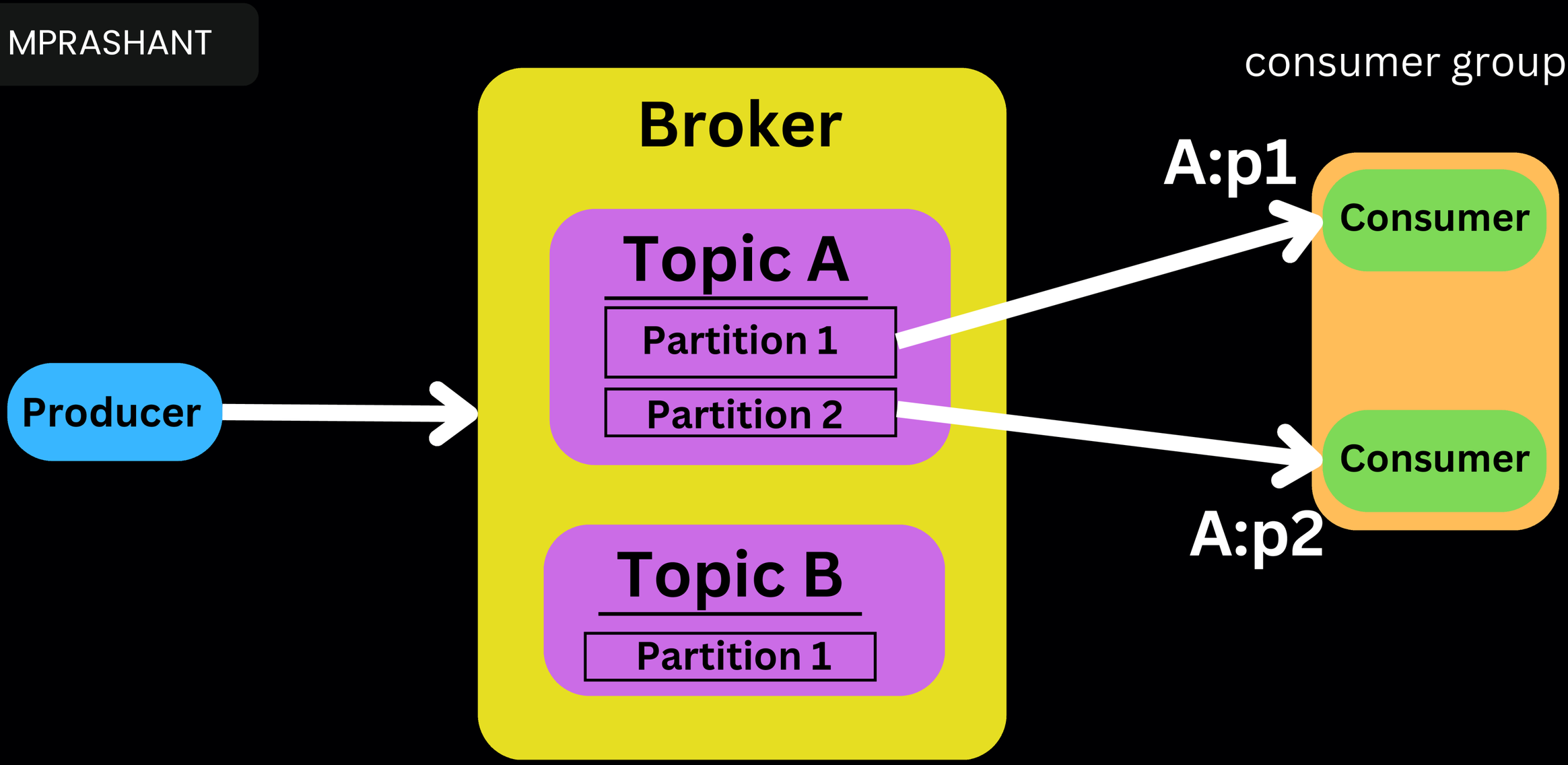

Storage
Topic
P1
P2
P3
P4
Event sent
and appended
to Partition 1
Producer client 1
Producer client 2

What is a Consumer Group in Kafka?

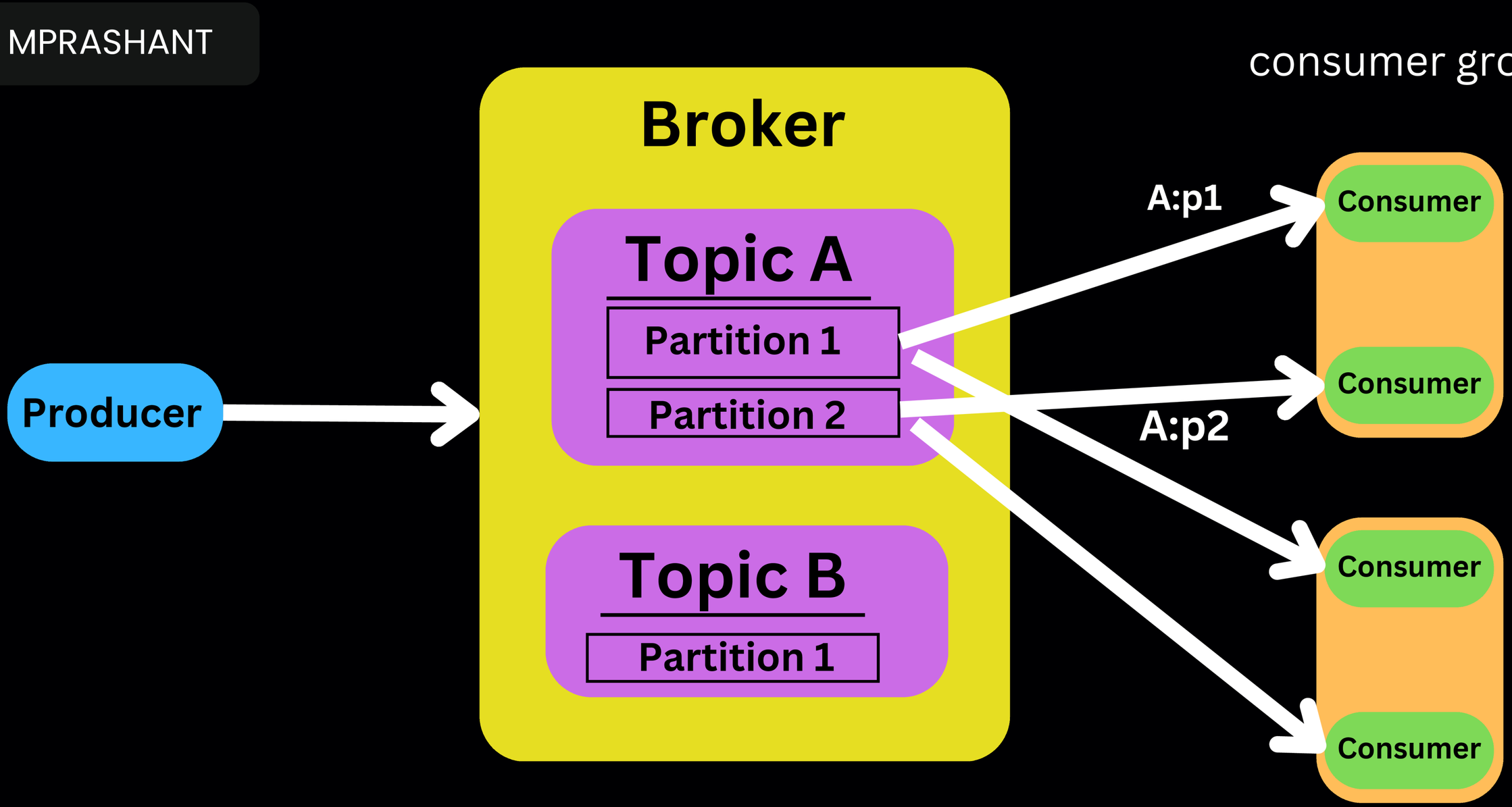
A Consumer Group in Kafka is a logical group of consumers that work together to consume messages from a Kafka topic in parallel.



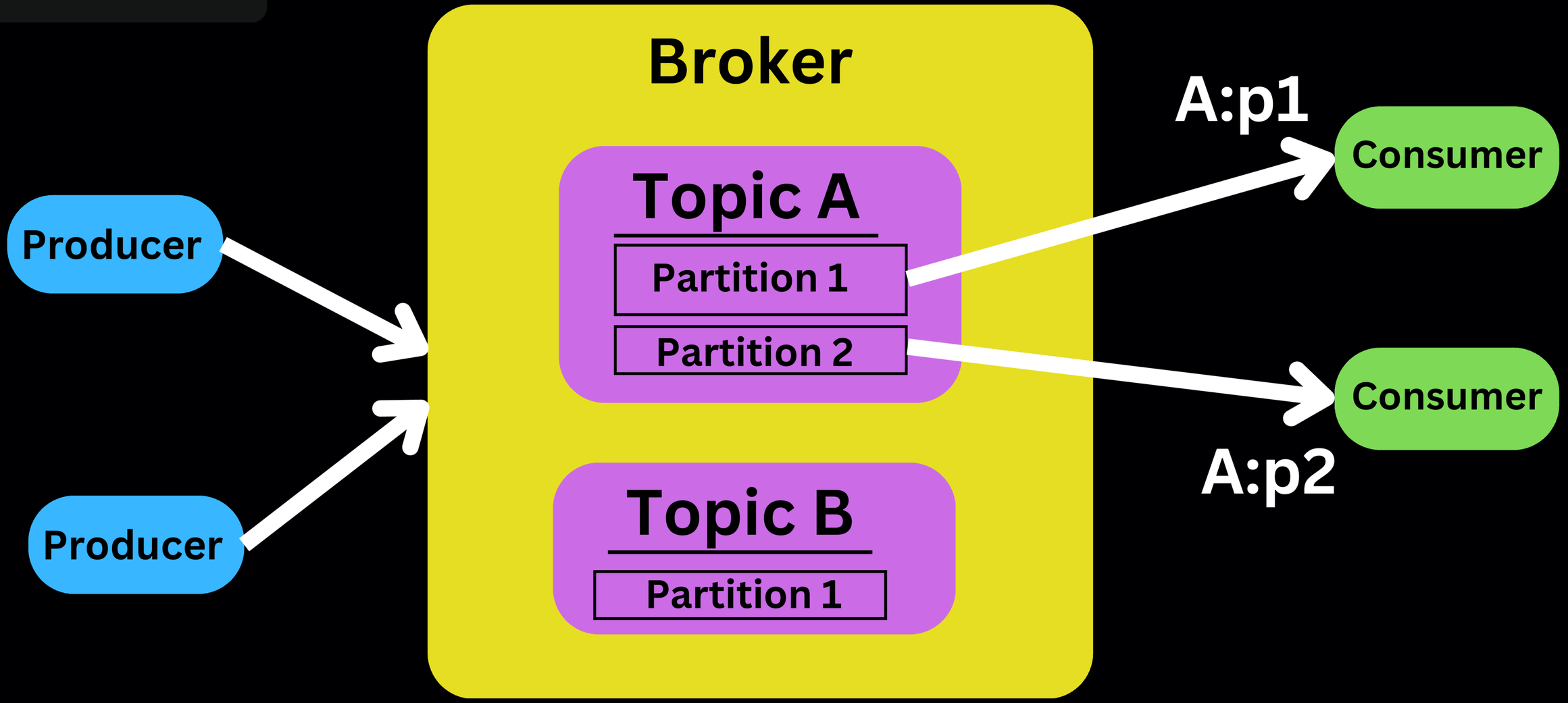
MPRASHANT

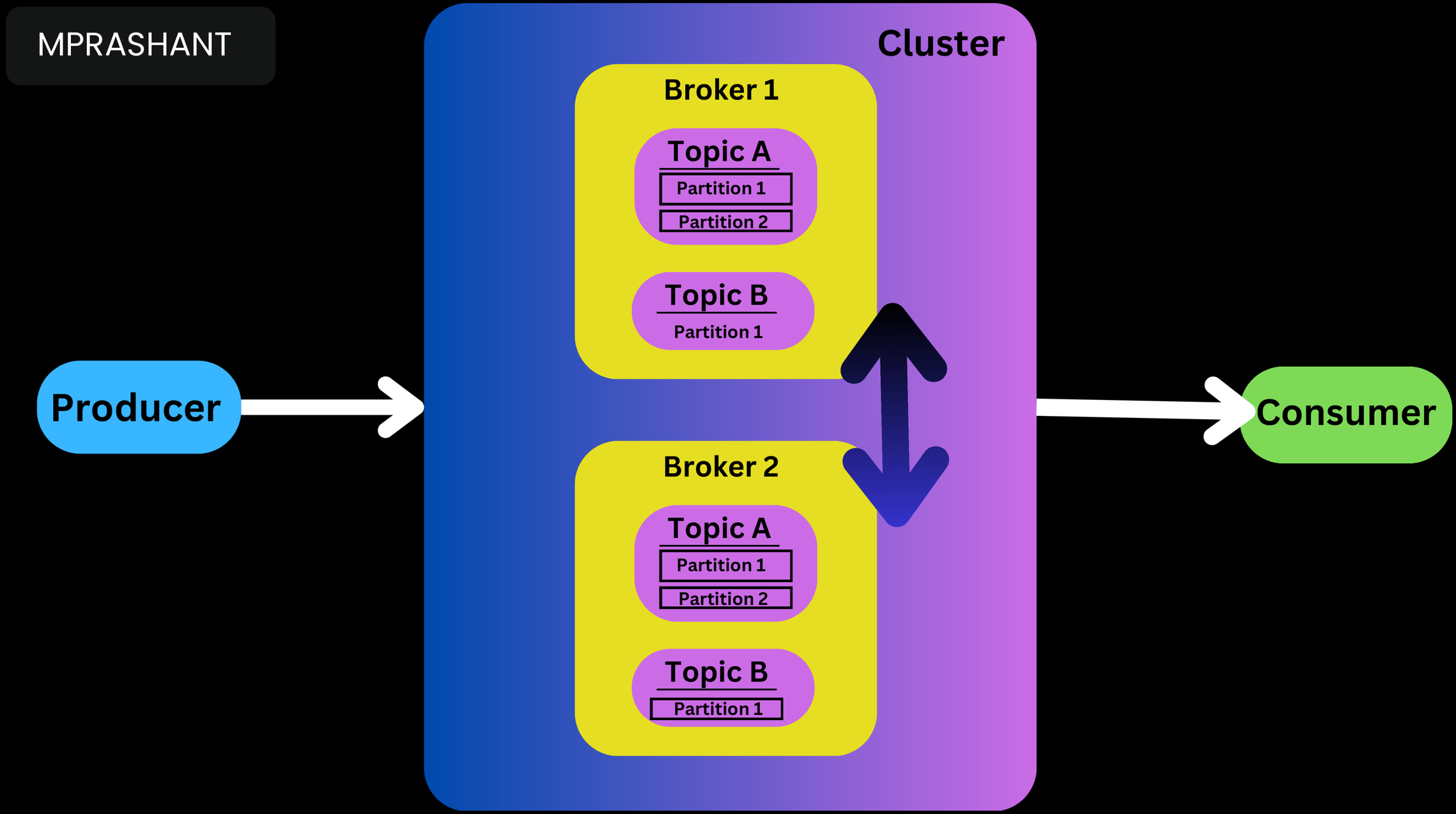

consumer group
Broker
Topic A
Partition 1
Partition 2
Topic B
Partition 1
Producer
A:p1
A:p2
Consumer
Consumer

MPRASHANT


consumer group
Broker
Topic A
Partition 1
Partition 2
Topic B
Partition 1
Producer
A:p1
A:p2
Consumer
Consumer
Consumer
Consumer

MPRASHANT


Broker
Topic A
Partition 1
Partition 2
Topic B
Partition 1
Producer
Producer
A:p1
Consumer
Consumer
A:p2


MPRASHANT
Cluster
Broker 1
Topic A
Partition 1
Partition 2
Topic B
Partition 1
Producer
Broker 2
Topic A
Partition 1
Partition 2
Topic B
Partition 1
Consumer

1 Broker, 3 Partitions, Replication Factor 1 (No Replication)

pgsql

```
Kafka Cluster: 1 Broker (No Replication)
+-----------------+
|   Broker 1      |
|   P0 (Leader)   |
|   P1 (Leader)   |
|   P2 (Leader)   |
+-----------------+
```

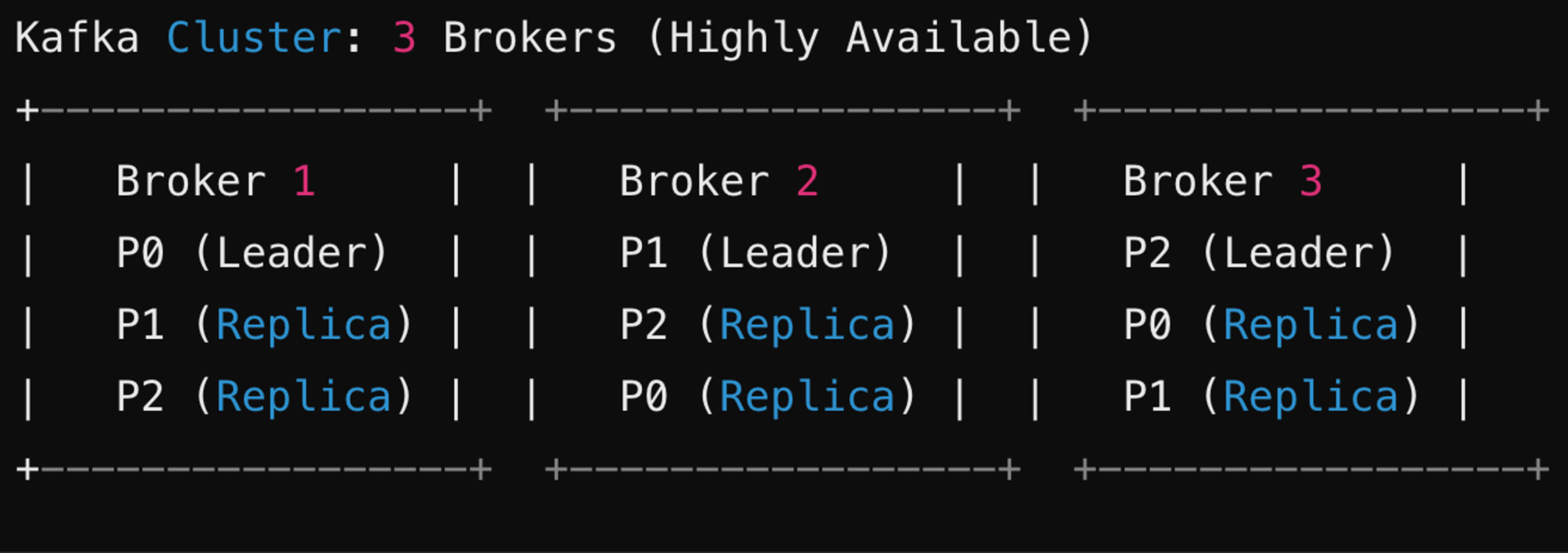
Here is the **Kafka cluster representation** for **2 brokers, 2 partitions, replication factor 2**:

pgsql Copy

```
Kafka Cluster: 2 Brokers, 2 Partitions, Replication Factor 2
+-----------------+  +-----------------+
|   Broker 1      |  |   Broker 2      |
|   P0 (Leader)   |  |   P1 (Leader)   |
|   P1 (Replica)  |  |   P0 (Replica)  |
+-----------------+  +-----------------+
```

3 Brokers, 3 Partitions, Replication Factor 3 (Highly Available)

pgsql



👉 **Each partition is replicated across all brokers** for **maximum availability**.

What it Zookeeper?

ZooKeeper is a distributed coordination service that manages synchronization, configuration, and leader election in distributed systems.

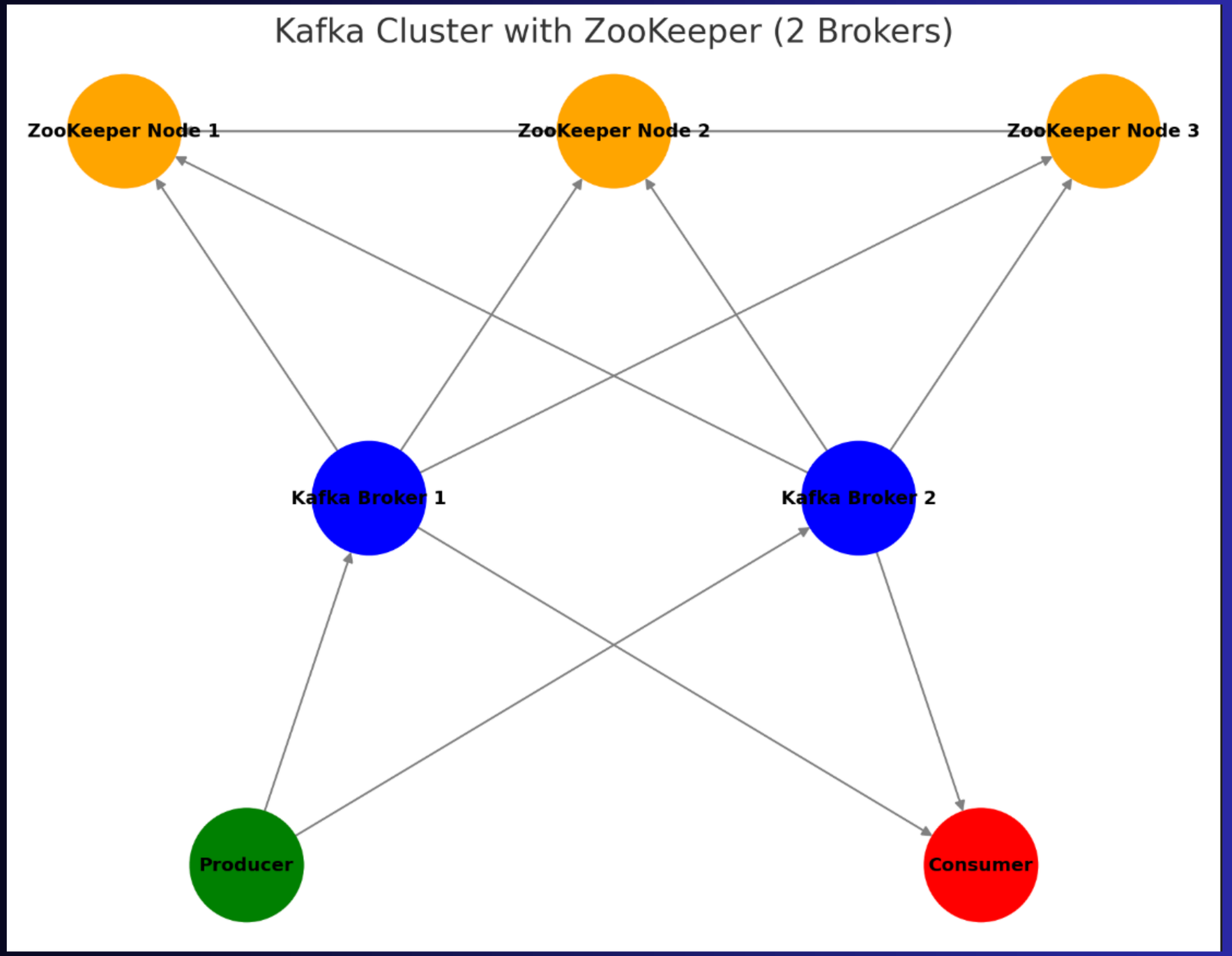
It basically ensures everything stays in sync and knows what’s happening where.

✅ ZooKeeper ensures high availability by electing partition leaders.

✅ Monitors broker health and reassigns leadership on failures.

✅ Stores cluster metadata, including topics, partitions, and replicas.

✅ Coordinates consumer groups for message ordering.


Kafka Cluster with ZooKeeper (2 Brokers)
ZooKeeper Node 1
ZooKeeper Node 2
ZooKeeper Node 3
Kafka Broker 1
Kafka Broker 2
Producer
Consumer

What it Kraft?

Kraft (Kafka Raft) is Kafka’s new way of handling coordination and metadata without needing ZooKeeper.

It uses a built-in Raft consensus protocol so that Kafka brokers manage everything themselves.

Zookeeper vs KRaft (Kafka Raft Mode) - Key Differences

Feature	Zookeeper 🦉	KRaft (Kafka Raft Mode) 🚀
Architecture	Separate service outside Kafka	Built-in to Kafka (No external dependency)
Leader Election	Managed by Zookeeper	Managed by Kafka using **Raft consensus**
Fault Tolerance	Requires multiple Zookeeper nodes for HA	Kafka controllers handle failures natively
Performance	Extra network calls to Zookeeper	Faster (direct in-cluster coordination)
Scalability	Limited scalability due to Zookeeper overhead	Better scalability, more partitions per cluster
Maintenance	Requires separate Zookeeper cluster management	Simplifies deployment (Zookeeper-free Kafka)

🚀 **KRaft is the future** of Kafka, replacing Zookeep[illegible]r **better performance, simplicity, and scalability**!

Practical

- Java
- Kafka
- Start Kafka with Zookeeper
- Start Kafka with KRaft
- More examples

Installation

- Kafka requires Java 11 or higher.
  - Can install openjdk from
    - https://docs.aws.amazon.com/corretto/latest/corretto-11-ug/downloads-list.html
  - Configure JAVA_HOME (if not work, try removing space in the path)
  - Java is using in kafka-run-class file so adjust path according to it or in config file.

Kafka Installation

- https://kafka.apache.org/downloads
  - Download and unzip on your system in any location.

  - Windows
    - Download Scala version
  - MAC / Linux
    - wget <download_link>

Start Kafka with Zookeeper

- **In the installation under bin folder there is a windows folder too for batch script.**

- **Start zookeeper or kraft**
  - ***bin/zookeeper-server-start.sh config/zookeeper.properties***

- **Start kafka broker**
  - ***bin/kafka-server-start.sh config/server.properties***

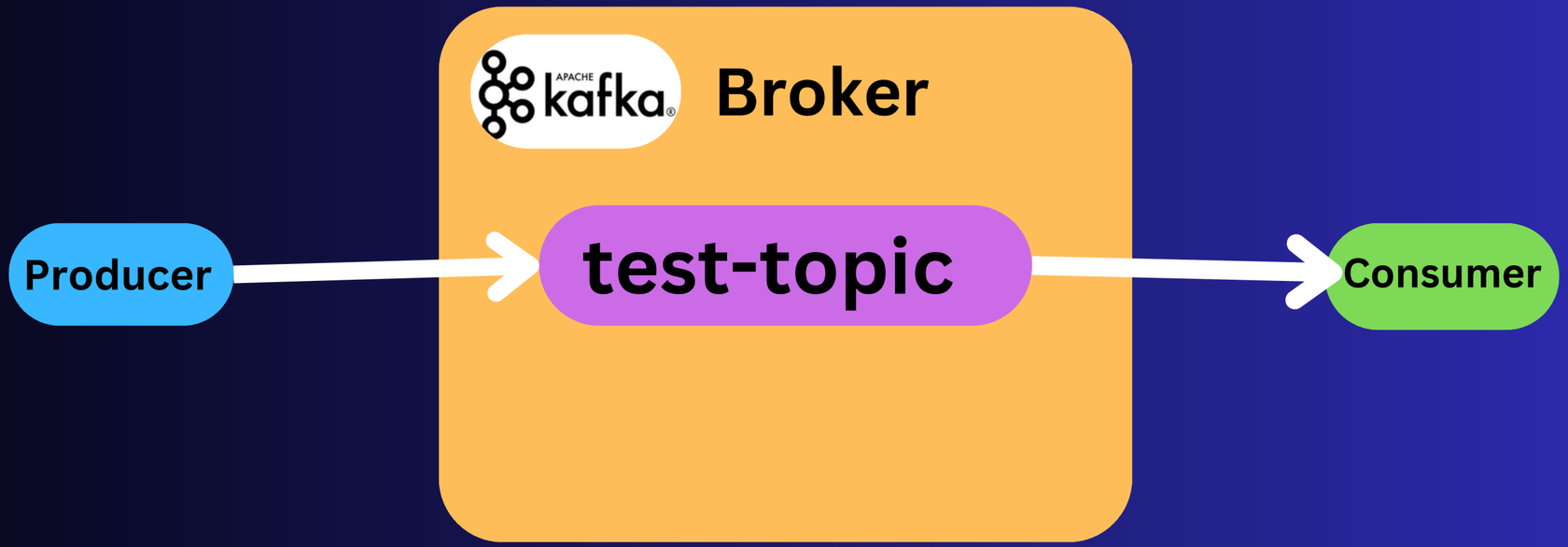
Start Kafka with KRaft

- Generate a unique ID
  - bin/kafka-storage.sh random-uuid
- Format the storage directory with the generated cluster ID
  - bin/kafka-storage.sh format -t UUID -c config/kraft/server.properties
- Start Kafka server
  - bin/kafka-server-start.sh config/kraft/server.properties
  -

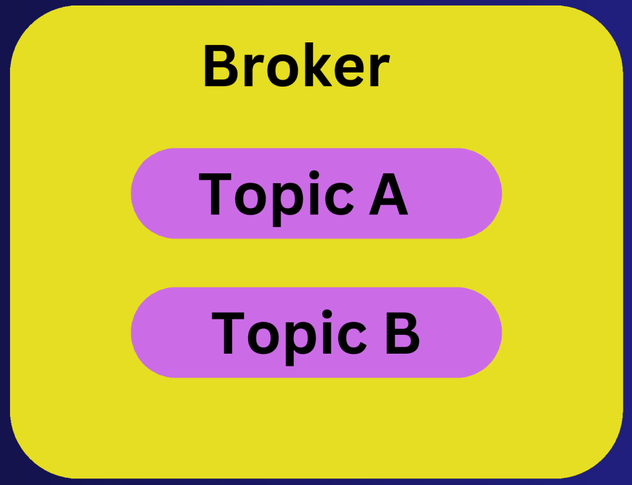
- To delete all Kafka data manually.
  - rm -rf /tmp/kafka-logs
  - rmdir /s /q C:\tmp\kafka-logs

- When you want to reinitialize Kafka in KRaft mode.
  - kafka-storage.sh format

Example 1



Creating Topic



Create a Topic

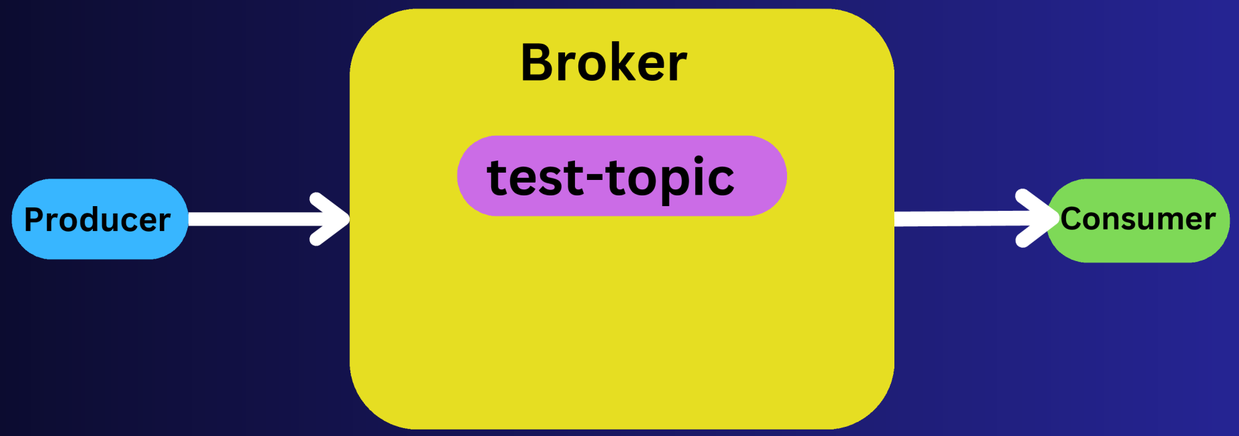
```
bin/kafka-topics.sh --create \
  --topic test-topic \
  --bootstrap-server localhost:9092 \
  --partitions 1 \
  --replication-factor 1
```

Testing created topics

- kafka-topics.sh --bootstrap-server localhost:9092 --list
- kafka-topics.sh --bootstrap-server localhost:9092 --topic chat --describe

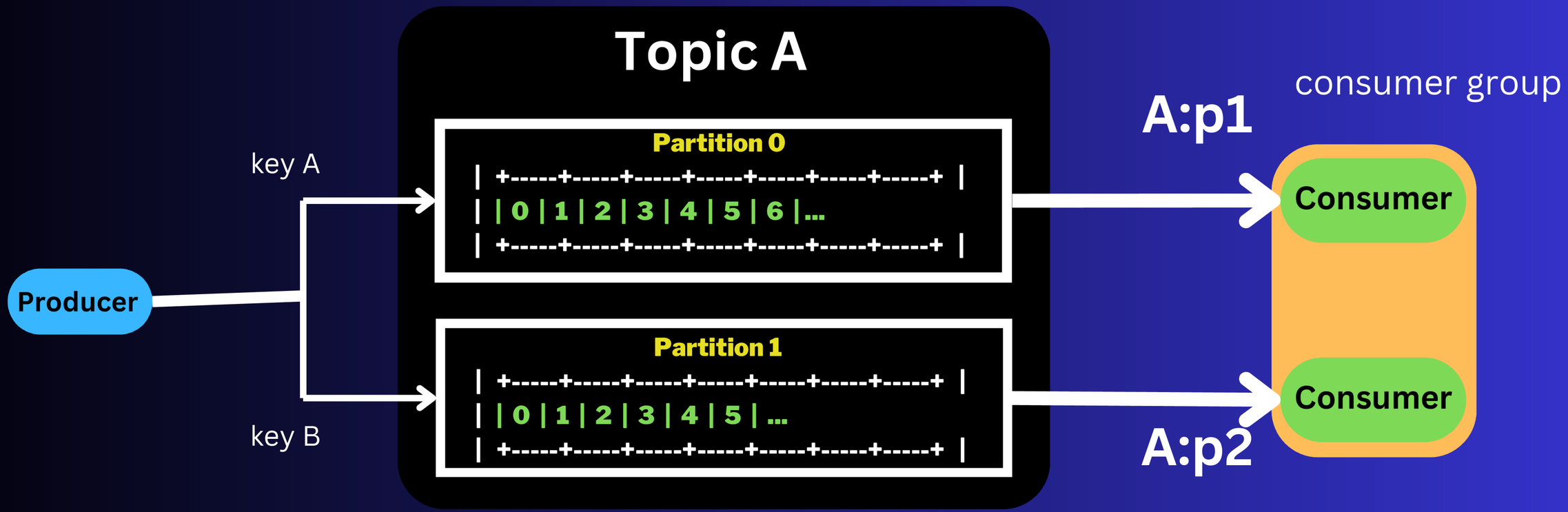
Test Produce/Consume:

- kafka-console-producer.sh --bootstrap-server localhost:9092 --topic test-topic
- kafka-console-consumer.sh --bootstrap-server localhost:9092 --topic test-topic --from-beginning



Example 2

Practical


Topic A
Partition 0
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |...
Partition 1
| 0 | 1 | 2 | 3 | 4 | 5 | ...
key A
key B
Producer
A:p1
A:p2
consumer group
Consumer
Consumer

- Create a Topic with 2 partitions

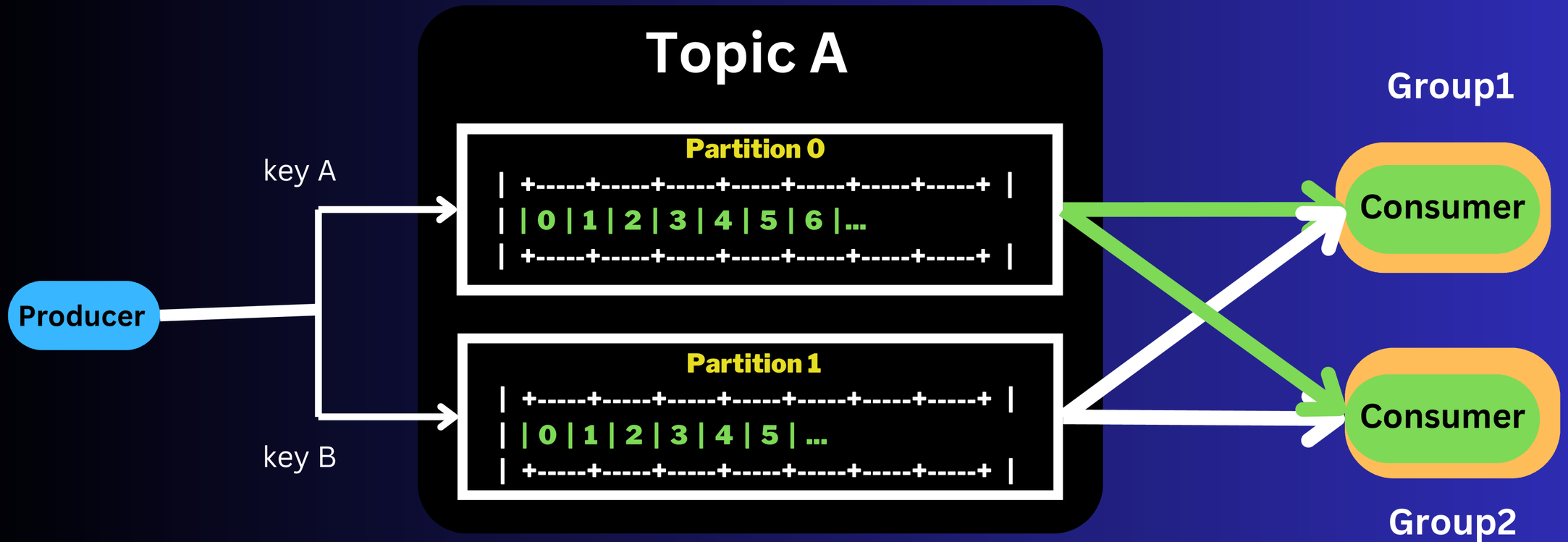
- Start producer and send messages using key so that it will distribute among both partitions
  - kafka-console-producer.bat --bootstrap-server localhost:9092 --topic test-topic3 --property parse.key=true --property key.separator=:

- Create Two consumers connected to topic part of same group
  - kafka-console-consumer.bat --bootstrap-server localhost:9092 --topic test-topic3 --group tg

- Info about consumer group
  - kafka-consumer-groups.bat --bootstrap-server localhost:9092 --describe --group my-group

- check all groups
  - kafka-consumer-groups.bat --bootstrap-server localhost:9092 --list

Example 3


Topic A
Partition 0
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |...
Partition 1
| 0 | 1 | 2 | 3 | 4 | 5 | ...
key A
key B
Producer
Group1
Consumer
Consumer
Group2

Kafka UI

Kafka UI

Web-based open-source tool that provides an easy-to-use interface for monitoring, managing, and interacting with Apache Kafka clusters, including topics, partitions, consumer groups, and messages.

- Edit kraft/server.properties
    - advertised.listeners=PLAINTEXT://<IP>:9092,CONTROLLER://localhost:9093
        - Windows: ipconfig
        - Linux/MAC: ifconfig.
    - Restart kafka
- docker run --rm -d -p 8080:8080 -e KAFKA_CLUSTERS_0_NAME=my-cluster -e KAFKA_CLUSTERS_0_BOOTSTRAPSERVERS=<IP>:9092 --name kafkaui provectuslabs/kafka-ui

Python + Kafka

- Python program which takes user email and store in a text file.

- Producer.py
  - It will keep checking the text file if any new user sign up (email added) and send it to Kafka topic.

- Consumer.py
  - It will keep checking any new data in kafka topic and consume the messages.

Kafka Streams

Kafka Streams is a Java library for real-time stream processing on Kafka topics. It allows you to read, transform, aggregate, and write data back to Kafka—all within your application.

🔷 How Kafka Streams Works?

1️⃣ **Consumes data from a Kafka topic** (reads messages as a continuous stream).

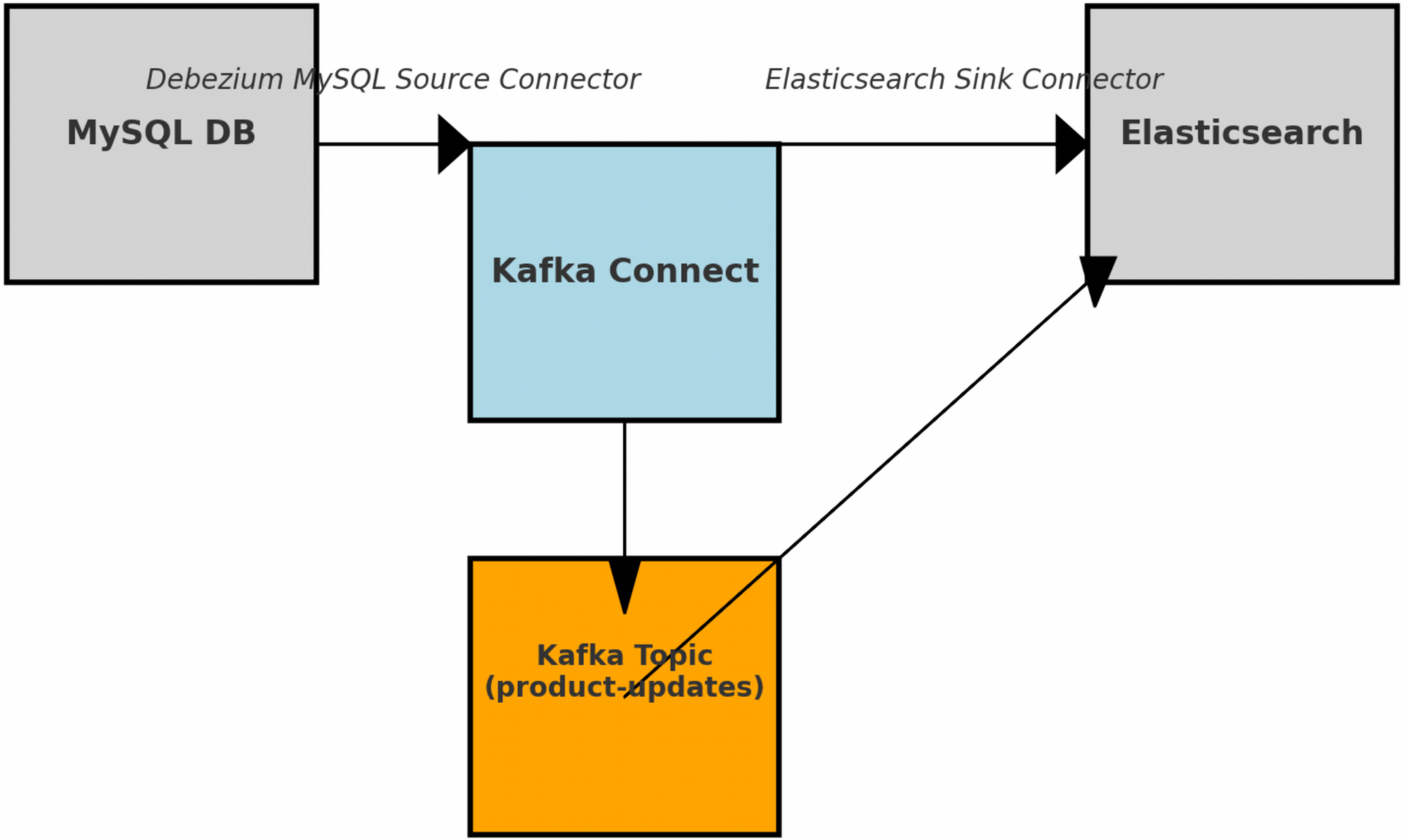
2️⃣ **Processes data in real time** (filters, maps, aggregates, joins, etc.).

3️⃣ **Writes transformed data to another Kafka topic** (or external databases).

Kafka Connect

Kafka Connect is a tool in Apache Kafka that helps move data between Kafka and other systems (like databases, cloud storage, or message queues) automatically using connectors, without needing to write custom code. 🚀

- Uses **Source Connectors** to pull data from external systems into Kafka topics.
- Uses **Sink Connectors** to send data from Kafka topics to external systems.


MySQL DB
Debezium MySQL Source Connector
Kafka Connect
Elasticsearch Sink Connector
Elasticsearch
Kafka Topic
(product-updates)

Interview Questions

Basic Kafka Questions

1. What is Apache Kafka, and why is it used?
2. Explain the core components of Kafka.
3. What is a Kafka broker? How does it function?
4. What is a Kafka topic, and how is it different from a partition?
5. How does Kafka ensure durability and fault tolerance?
6. What is the role of Zookeeper in a Kafka cluster?
7. What is a producer in Kafka, and how does it send messages?
8. What is a Kafka consumer, and how does it consume messages?
9. Explain the difference between consumer groups and partitions.
10. How does Kafka handle message retention and log compaction?

Intermediate Kafka Questions

1. How does Kafka achieve high throughput and scalability?
2. What is ISR (In-Sync Replicas) in Kafka? How does it work?
3. What happens if a Kafka broker goes down? How does Kafka recover?
4. What are Kafka replication factors, and why are they important?
5. How does Kafka handle backpressure when consumers are slow?
6. What is Kafka's exactly-once semantics, and how does it work?
7. Explain the differences between Kafka's at-most-once, at-least-once, and exactly-once delivery guarantees.
8. How does Kafka handle leader election for partitions?
9. What is Kafka Streams, and how is it different from Kafka Connect?
10. What are Kafka's different types of acks (acknowledgment) settings, and how do they impact performance?