Introduction to Apache Kafka

Overview

Apache Kafka is a realtime publish-subscribe based durable messaging system

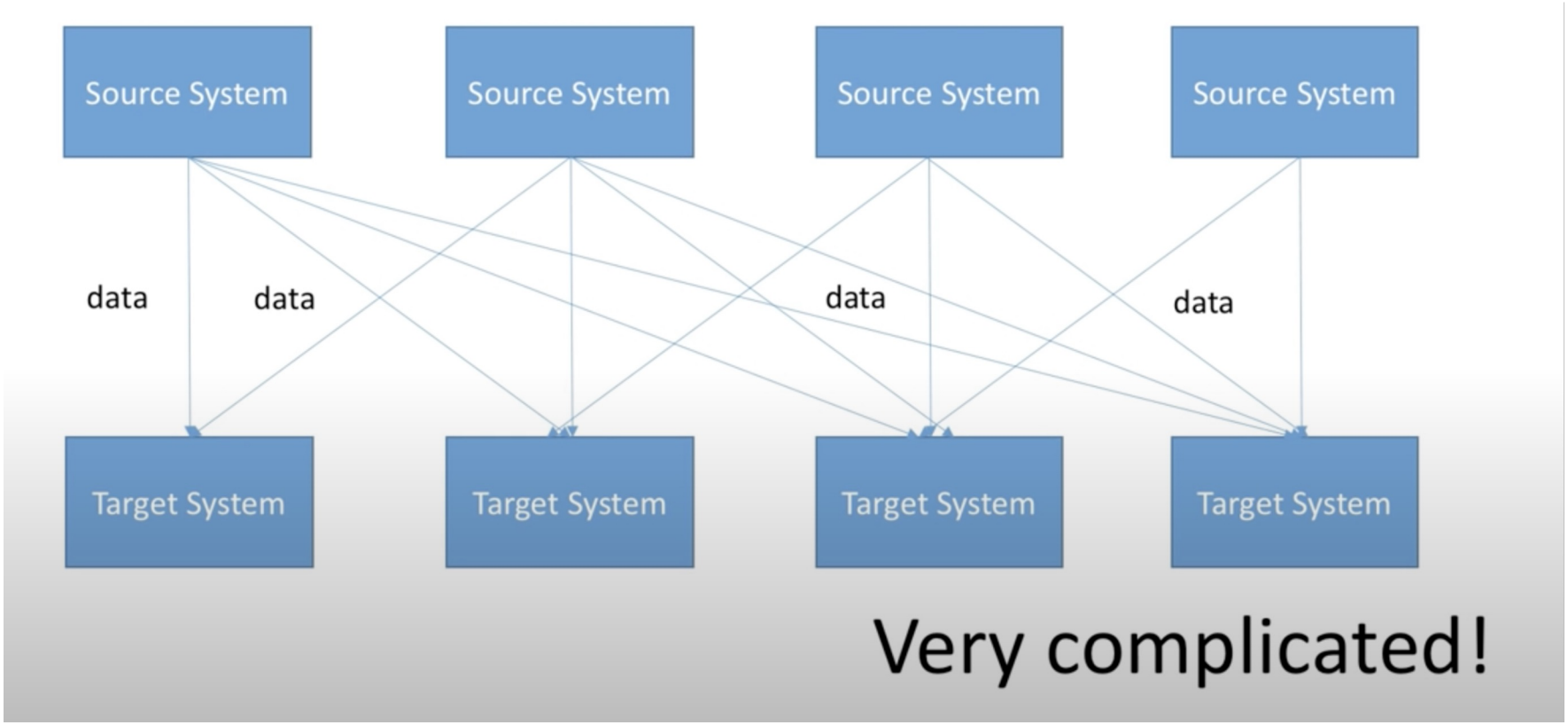
- Process streams of records as they occur.
- Store streams of records in a fault-tolerant durable way.
- Maintains FIFO order for streams
- It is a high-throughput, highly distributed, fault-tolerant platform developed by linkedin and written in Scala and Java
- Eg – When Someone publish video on YouTube, subscriber gets notified.

Why do we need Kafka?

Fenil Shah

How company starts

After a while..



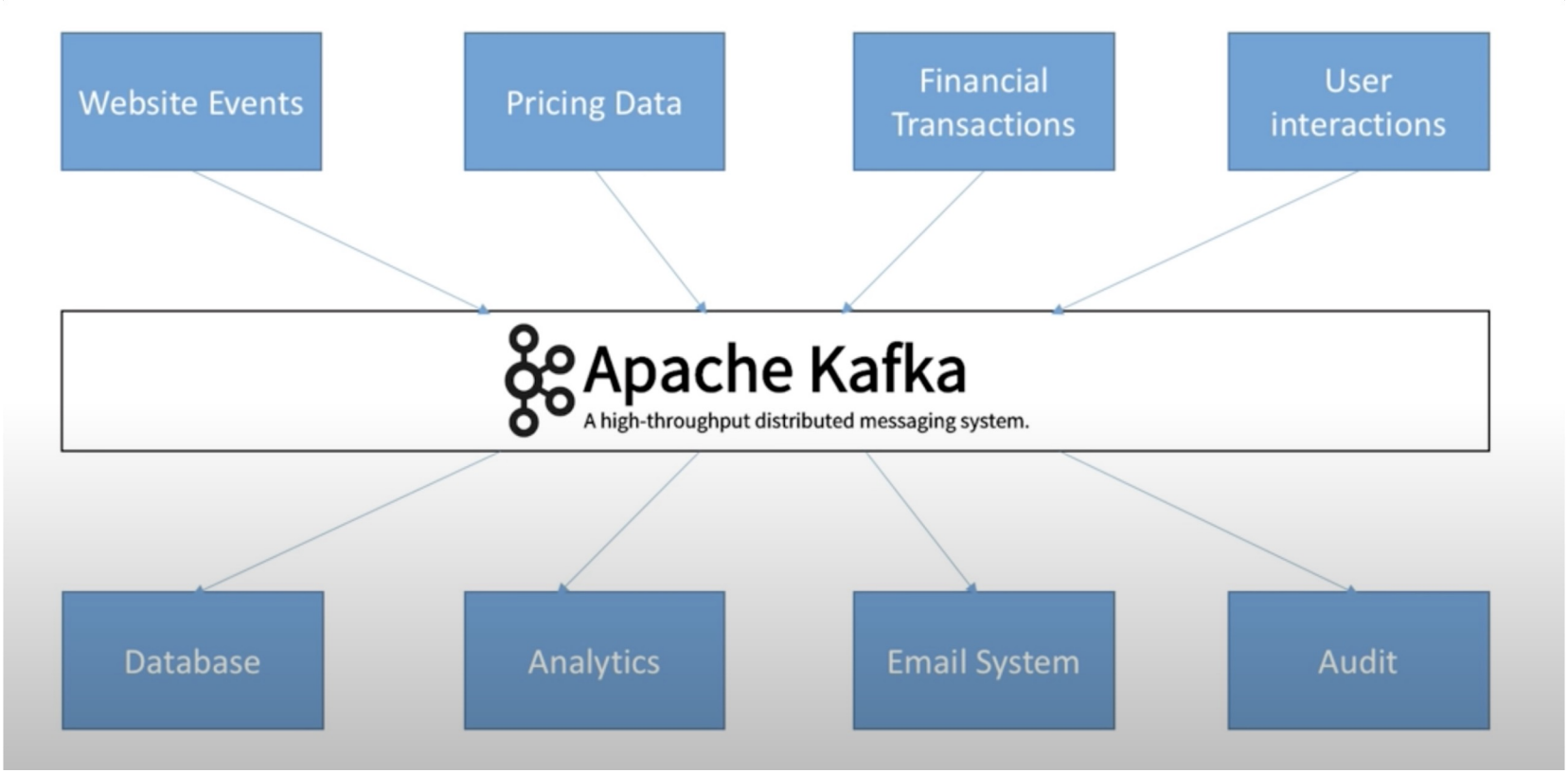
Problems with previous architecture

- If you have 4 source systems, and 6 target systems, you need to write 24 integrations!

- Each integration comes with difficulties around
  - Protocol – how the data is transported *(TCP, HTTP, REST, FTP, JDBC…)*
  - Data format – how the data is parsed *(Binary, CSV, JSON, Avro…)*
  - Data schema & evolution – how the data is shaped and may change

- Each source system will have an increased load from the connections

What we'd really like



Why Apache Kafka

- Created by LinkedIn, now Open Source Project mainly maintained by Confluent
- Distributed, resilient architecture, fault tolerant
- Horizontal scalability:
  - Can scale to 100s of brokers
  - Can scale to millions of messages per second
- High performance (latency of less than 10ms) – real time
- Used by the 2000+ firms, 35% of the Fortune 500:

Kafka use cases

- **Netflix** uses Kafka to apply recommendations in real-time while you're watching TV shows
- **Uber** uses Kafka to gather user, taxi and trip data in real-time to compute and forecast demand, and compute surge pricing in real-time
- **LinkedIn** uses Kafka to prevent spam, collect user interactions to make better connection recommendations in real time.

- Remember that Kafka is only used as a transportation mechanism!

How Kafka works?

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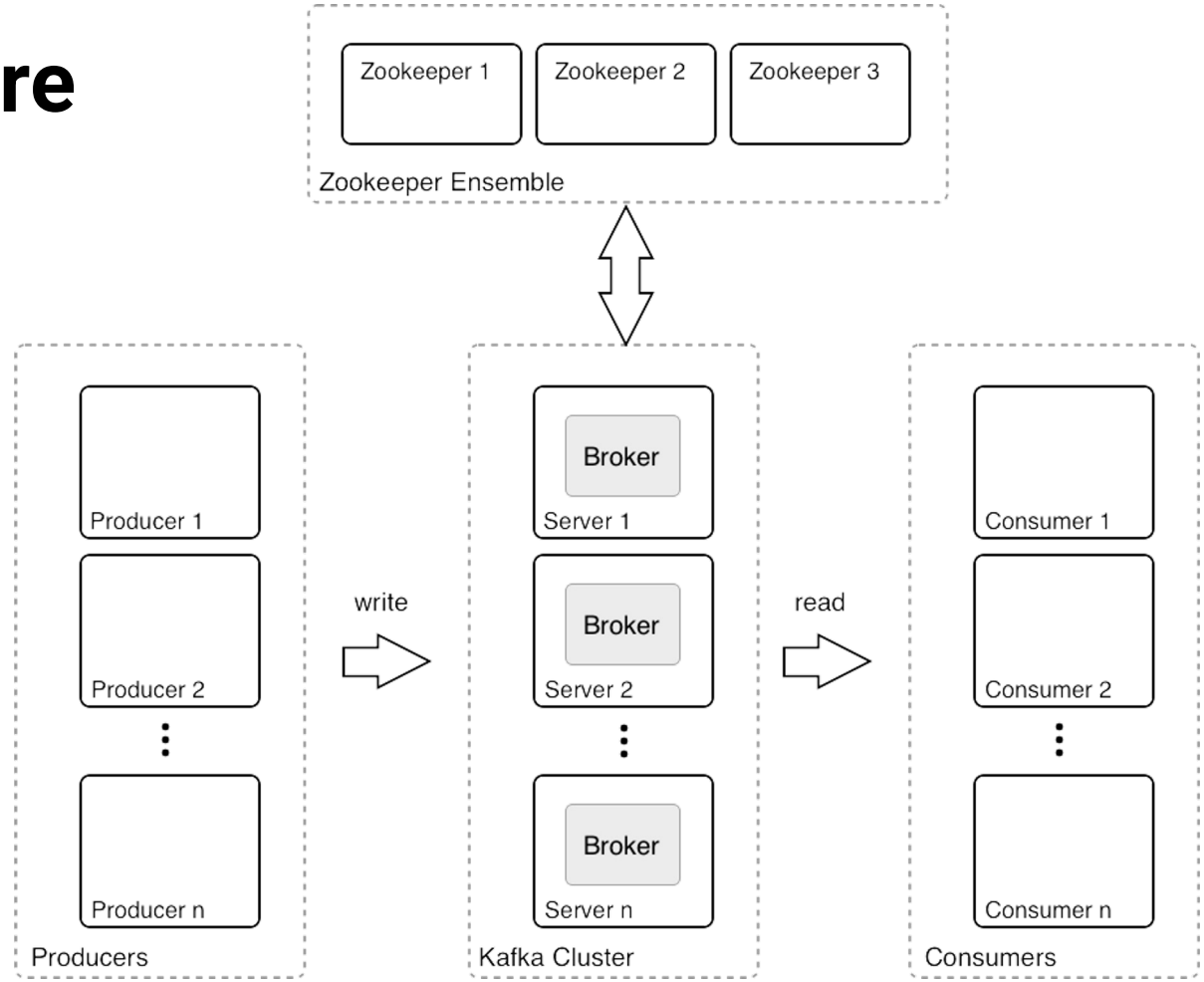
Kafka components

These are four main parts in a Kafka system:

- Producer: Sends records to a broker.
- Broker: Handles all requests from clients (produce, consume, and metadata) and keeps data replicated within the cluster. There can be one or more brokers in a cluster.
- Consumer: Consumes batches of records from the broker.
- Zookeeper: Keeps the state of the cluster (brokers, topics, users, offset).

Architecture



Zookeeper

- ZooKeeper is a distributed co-ordination service to manage large set of hosts. Co-ordinating and managing a service in a distributed environment is a complicated process. ZooKeeper solves this issue with its simple architecture and API. ZooKeeper allows developers to focus on core application logic without worrying about the distributed nature of the application.

- **Naming service** − Identifying the nodes in a cluster by name. It is similar to DNS, but for nodes.

- **Configuration management** − Latest and up-to-date configuration information of the system for a joining node.

- **Cluster management** − Joining / leaving of a node in a cluster and node status at real time.

- **Leader election** − Electing a node as leader for coordination purpose.

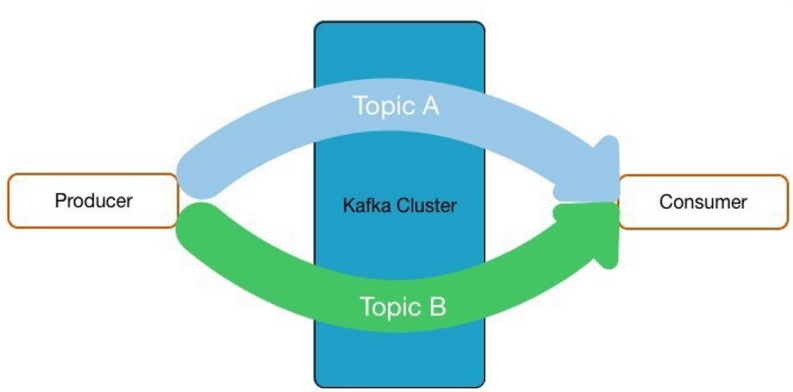
- **Locking and synchronization service** − Locking the data while modifying it. This mechanism helps you in automatic fail recovery while connecting other distributed applications like Apache HBase.

- **Highly reliable data registry** − Availability of data even when one or a few nodes are down.

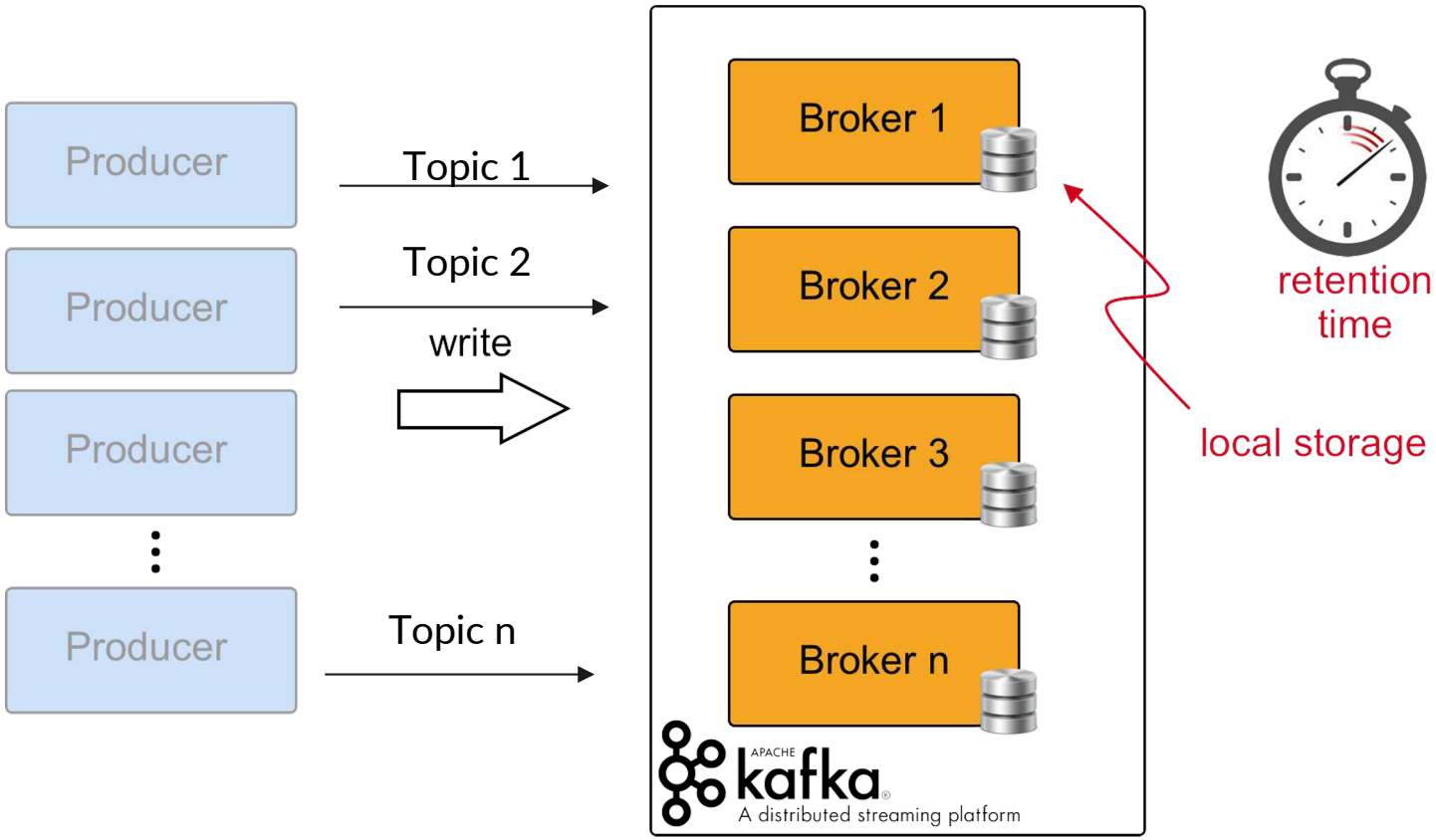
Topics

- Streams of “related” Messages in Kafka
    - Is a Logical Representation
    - Categorizes Messages into Groups
- Developers define Topics
- Producer write data to topics and consumer read from topics

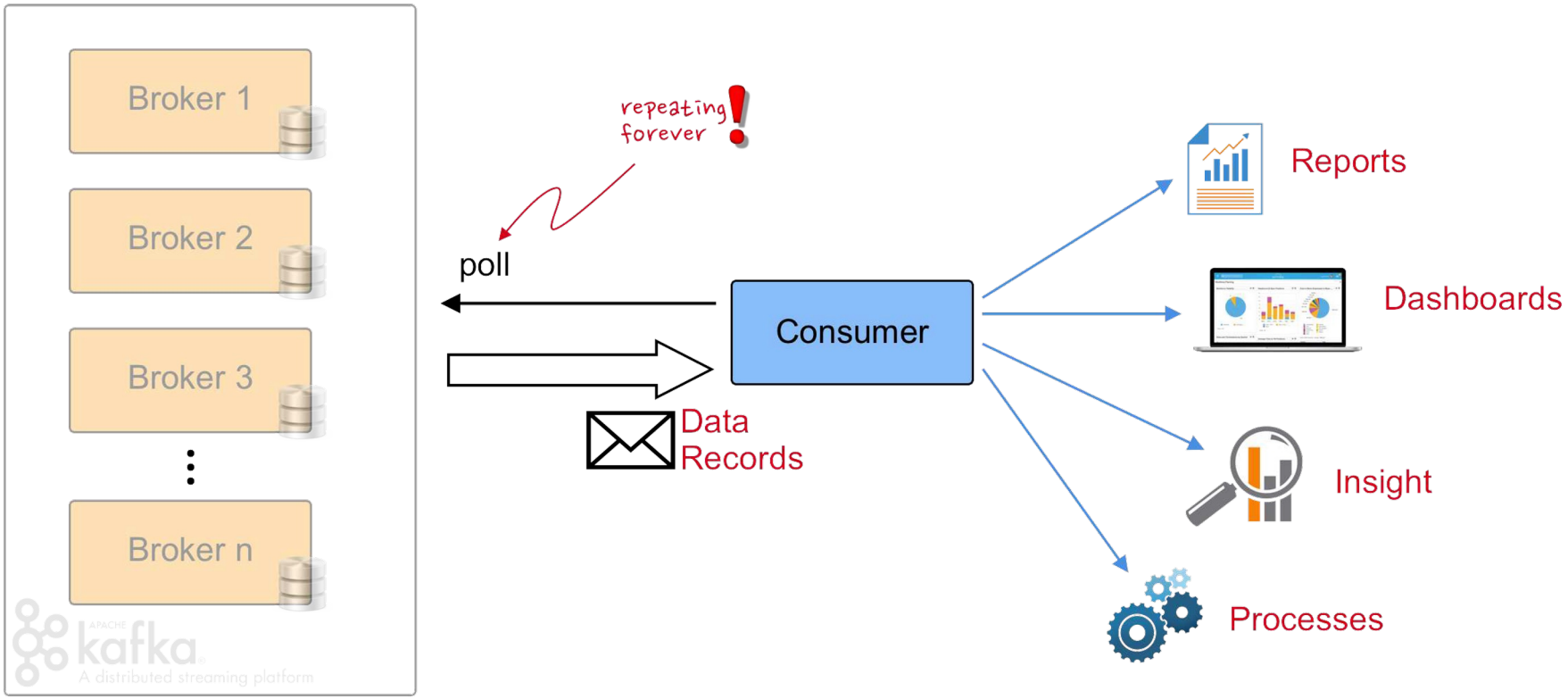
Ex - User_View, User_ Click, Order_created, Product_Updated,



Kafka Brokers



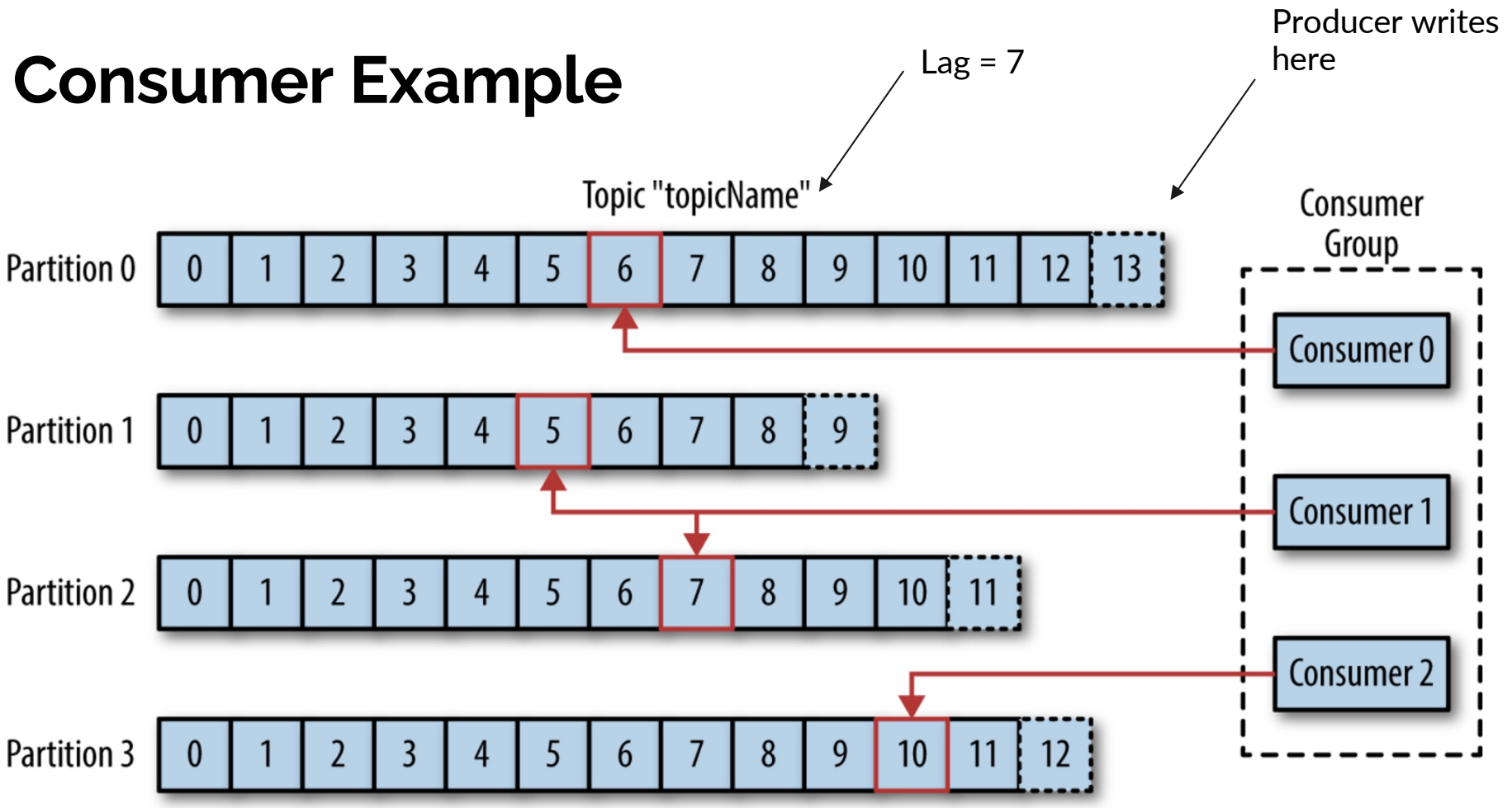
Consumers


Broker 1
Broker 2
Broker 3
Broker n
kafka
A distributed streaming platform
repeating forever
poll
Consumer
Data Records
Reports
Dashboards
Insight
Processes

Consumer Basics

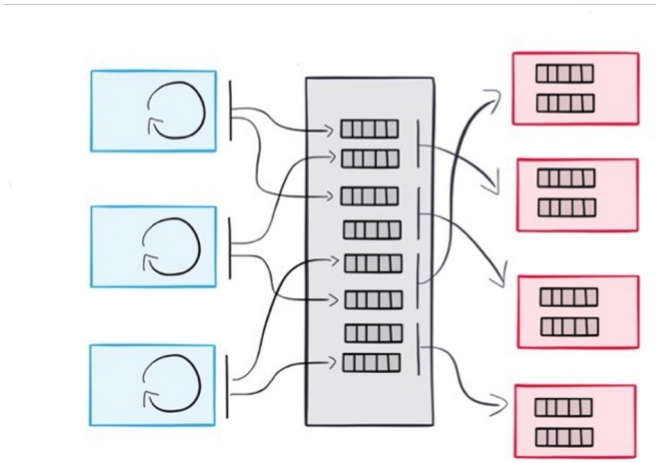
- Consumers **pull** messages from 1..n topics
- New inflowing messages are automatically retrieved
- Consumer will always read from leader
- Consumer committed offset - Keeps track of the last message committed
- Consumer current offset - Keeps track of the last message read

Consumer Example



Decoupling Producers and Consumers

- Producers and Consumers are decoupled
- Slow Consumers do not affect Producers
- Add Consumers without affecting Producers
- Failure of Consumer does not affect System



How do you scale a topic?

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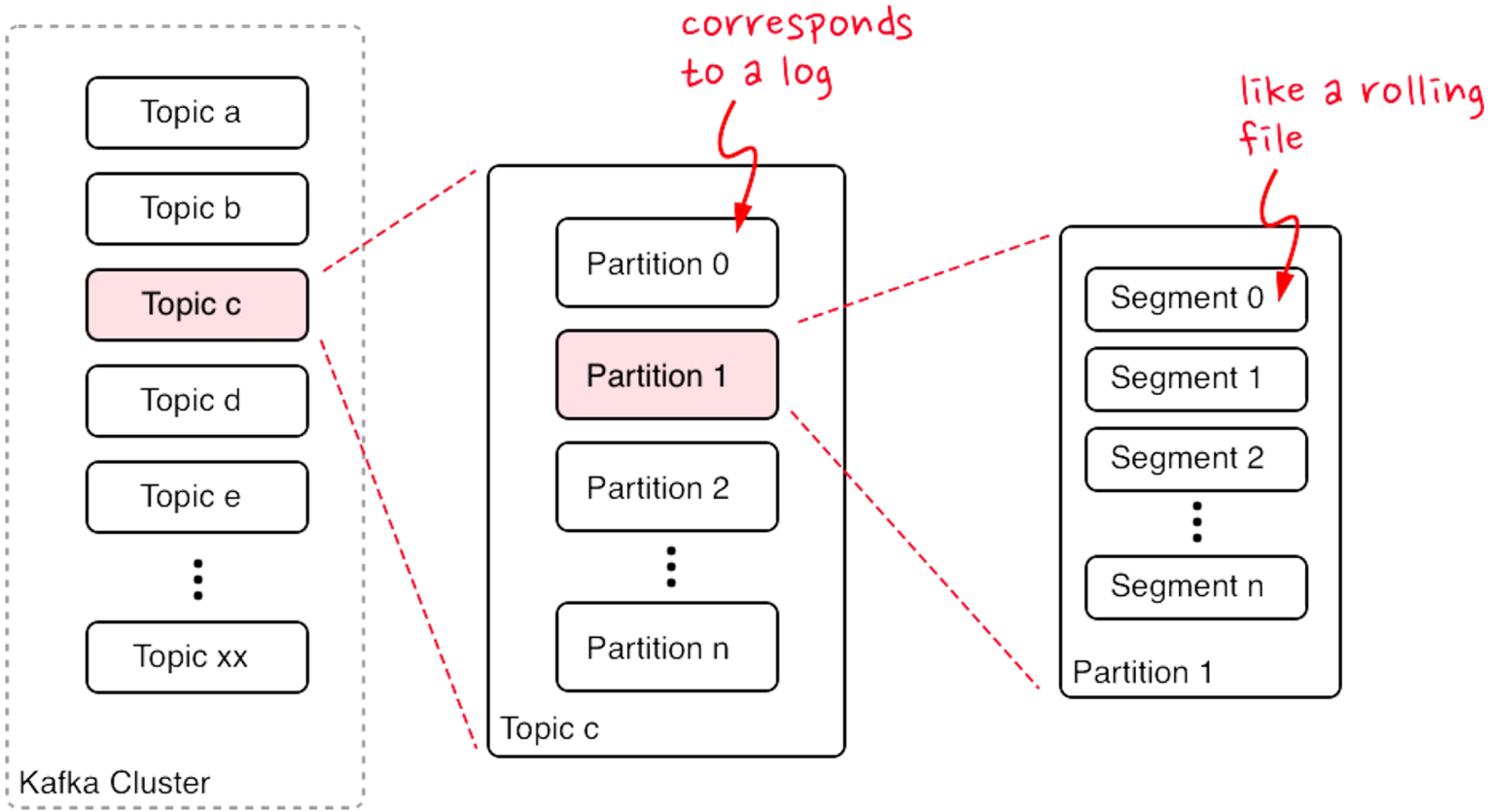
Partitions

- To scale a particular topic, topics are further broken up into several partitions, usually by record key if the key is present.
- Each partition can run its own consumer in a single consumer group
- Each partition consumer combination will maintain its own offset
- Kafka can replicate partitions to multiple Kafka Brokers.
- Partitioning Strategy specified by Producer

  Default Strategy: `hash(key) % number_of_partitions`

  No Key Round-Robin

Topics, Partitions, and Segments



Typical Producer API

```
ProducerRecord<String, String> record =
        new ProducerRecord<>("CustomerCountry", "Precision Products",
          "France"); ❶
try {
  producer.send(record); ❷
} catch (Exception e) {
        e.printStackTrace(); ❸
}
```

Typical Consumer API

```
try {
    while (true) {
        ConsumerRecords<String, String> records = consumer.poll(100);
        for (ConsumerRecord<String, String> record : records) {
            System.out.printf("topic = %s, partition = %s, offset = %d,
            customer = %s, country = %s\n",
            record.topic(), record.partition(),
            record.offset(), record.key(), record.value());
        }
        consumer.commitAsync(); ❶
    }
} catch (Exception e) {
    log.error("Unexpected error", e);
} finally {
    try {
        consumer.commitSync(); ❷
    } finally {
        consumer.close();
    }
}
```

Consumers with Partitions

- Single consumer can read multiple partitions

- If consumer instances are more than partitions for a topic, then there will be no use of extra consumer instances.

- What if we want to consume a partition data from multiple services
  Ex - We want to update data in table in RDBMS
  We want to update in Elasticsearch
  We want to update in Recommendation engine

Consumer groups

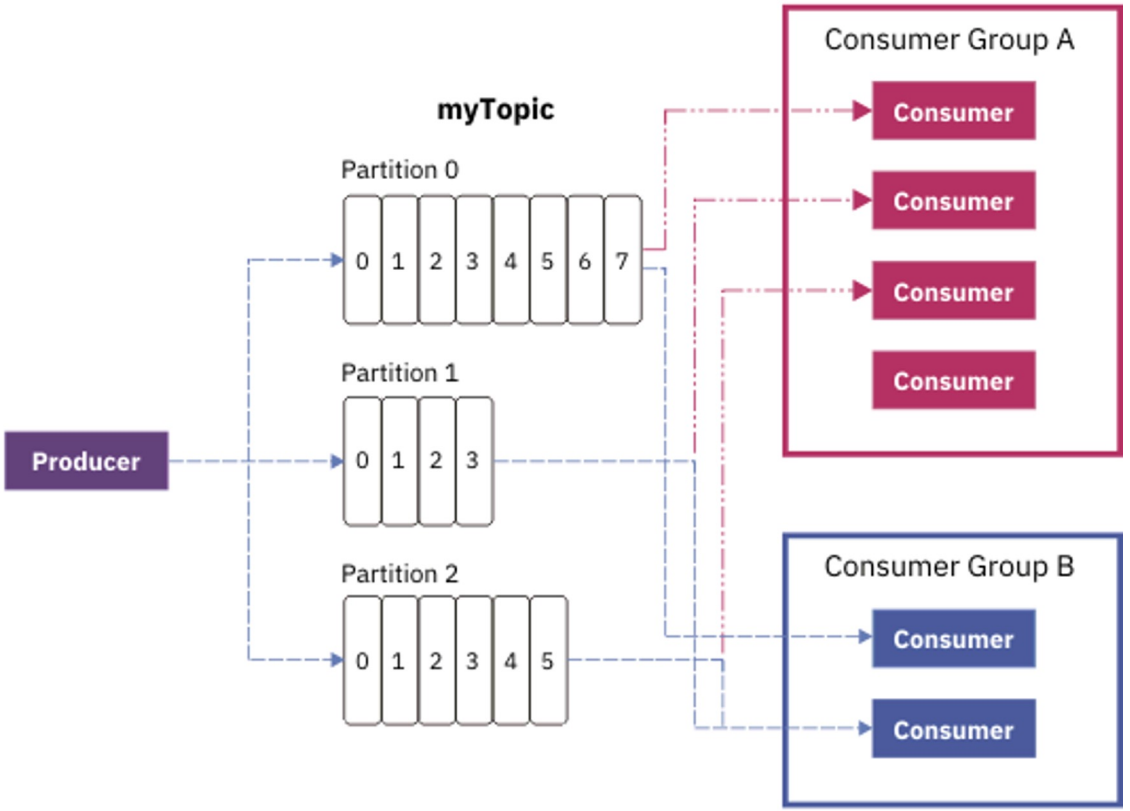
Consumers can be organized into logic consumer groups

Topic -> User Views of Product

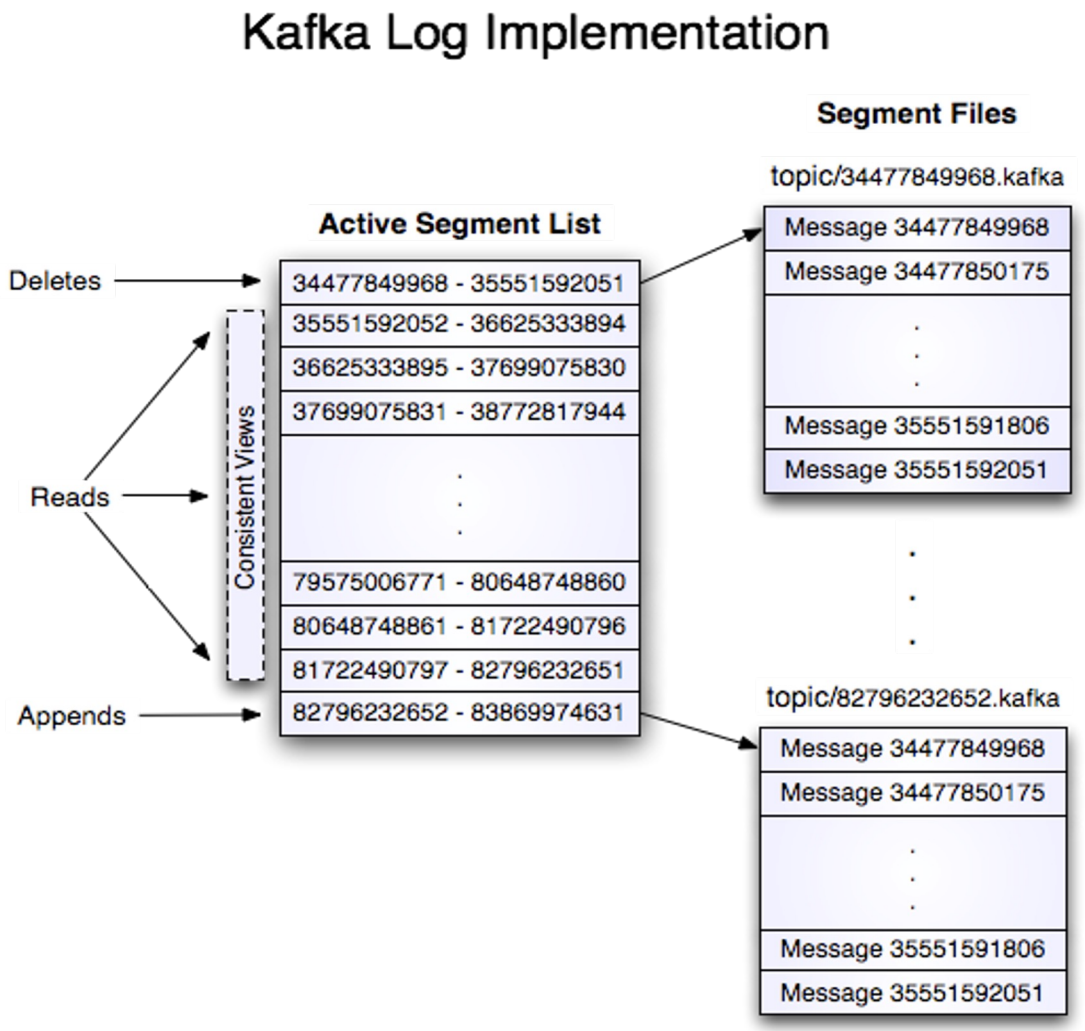
Consumer Group A -> Add view in DB

Consumer Group B -> Update data in EL

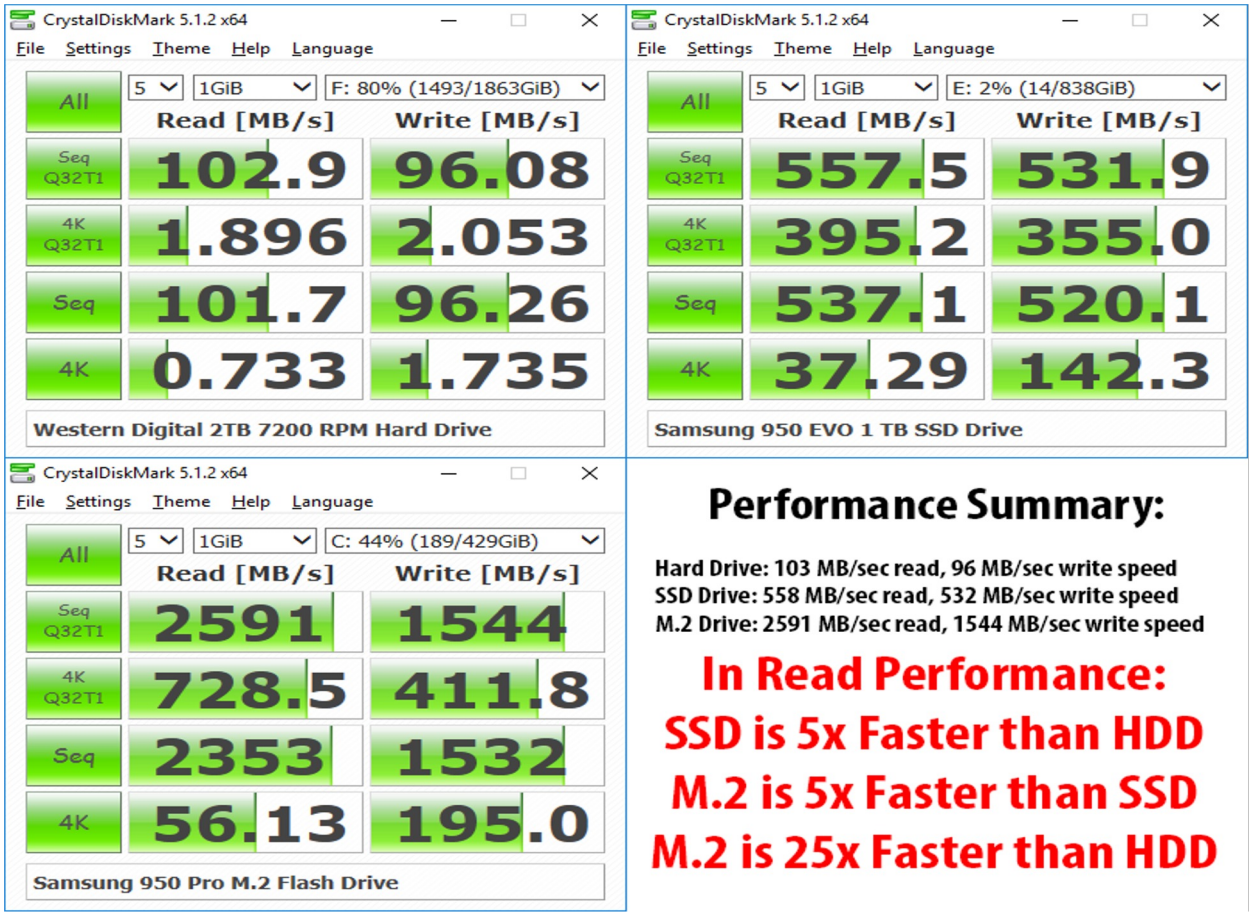
Consumer Group C -> Send data for recommendation engine



Segments


Kafka Log Implementation
Segment Files
topic/34477849968.kafka
Active Segment List
Deletes
Reads
Appends
Consistent Views
34477849968 - 35551592051
35551592052 - 36625333894
36625333895 - 37699075830
37699075831 - 38772817944
79575006771 - 80648748860
80648748861 - 81722490796
81722490797 - 82796232651
82796232652 - 83869974631
Message 34477849968
Message 34477850175
Message 35551591806
Message 35551592051
topic/82796232652.kafka
Message 34477849968
Message 34477850175
Message 35551591806
Message 35551592051

Sequential Vs Random read and write speed



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Replication

Fenil Shah

Why do we need replication

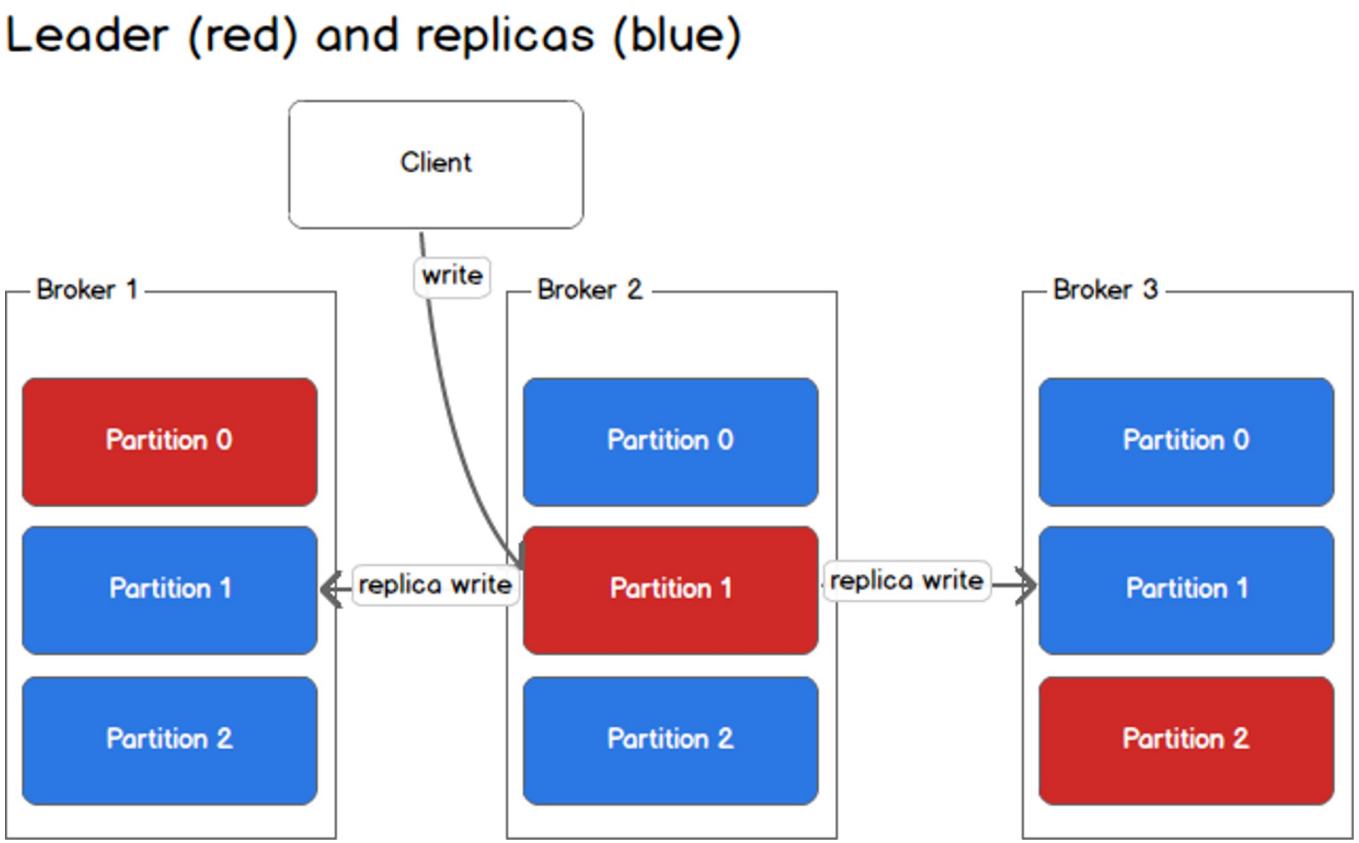
- Stronger durability
- Guarantee that any successfully published message will not be lost
- Higher availability
- Cluster can still accept message if one or more broker are down
- Failures can be caused by machine error, program error and network partitions.

Broker config in cluster

- There can be multiple brokers in a cluster
- Each broker will have unique broker id (broker.id)
- Each broker will store data in seperate folder (logs.dir)
- Each broker will run on a different port (port)
- Default replication factor and partitions for a topic is specified in broker configs
- Data retention time params - log.retention.ms

Replication

Replication factor = 3



Replication

- Replication happens on partition level not topic level
- For every partition, there are leader and followers
- Partition leaders are evenly distributed among brokers to avoid load on a particular broker
- Producer and Consumer both will write and read only on partition leader.
- Replica will poll and read from leader regularly
- Number of replicas can be specified globally or on topic level

In Sync/Out of Sync replicas

- Followers replicate data from the leader to themselves by sending fetch Requests periodically, by default every 500ms.
- In-Sync Replicas are the replicated partitions that are in sync with its leader
- Replicate can go out of sync due to IO limitations, GC or slow network.
- The definition of “in-sync” means that a replica is or has been fully caught up with the leader in the last 30 seconds. (replica.lag.time.max.ms and replica.lag.max.messages)
- In-sync replicas are the subset of all the replicas for a partition having same messages as the leader

Leader Election

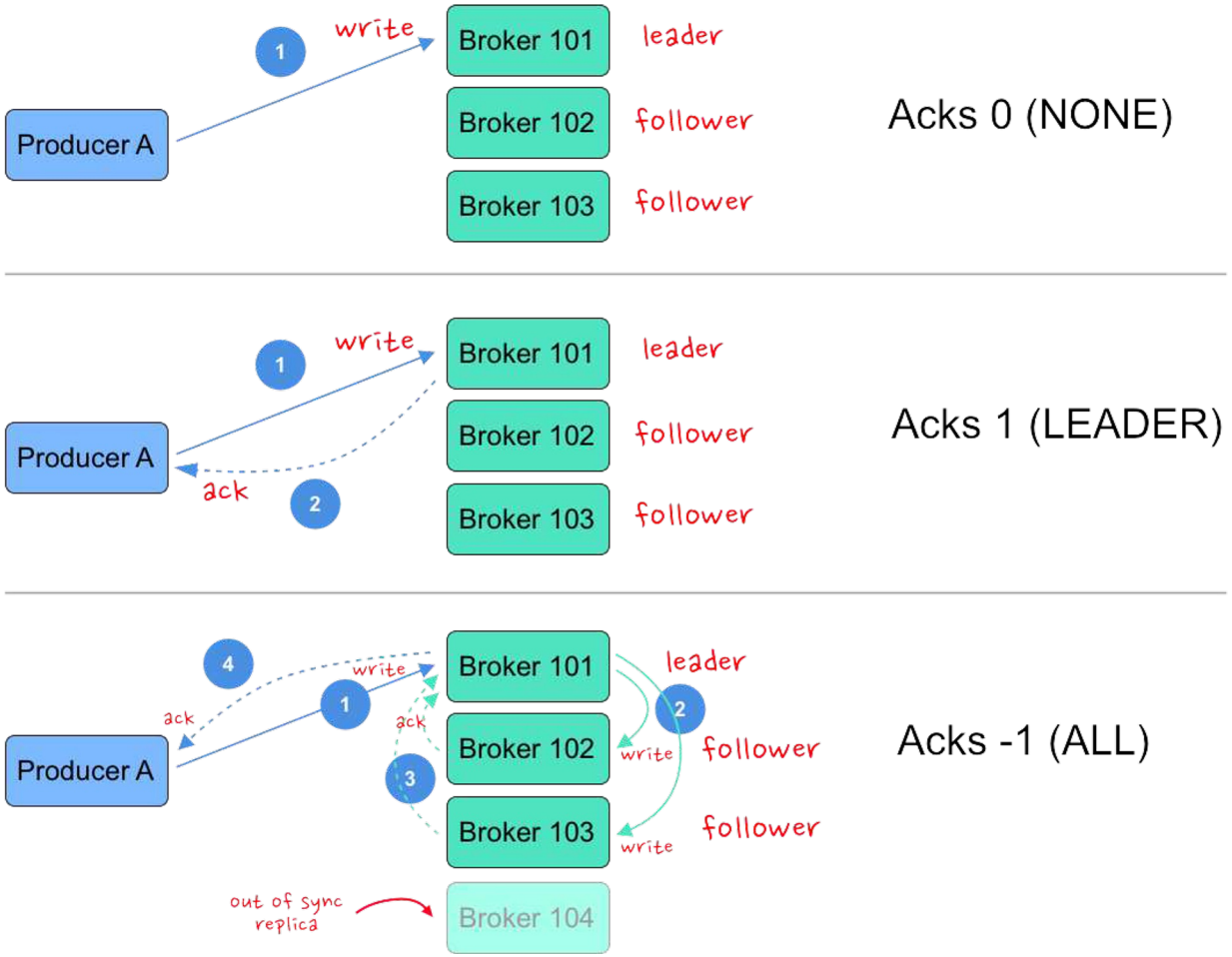
https://bravenewgeek.com/tag/leader-election/

Unclean leader election

- Unclean leader election flag to allow an out-of-sync replica to become the leader and preserve the availability of the partition.
- With unclean leader election, messages that were not synced to the new leader are lost.
- This provides balance between consistency (guaranteed message delivery) and availability.

Producer Guarantees

Acks = all only needs acks from min In sync replicas



Producer Delivery Semantics

- Producers can choose to receive acknowledgements for the data writes to the partition using the “acks” setting. (Default value is 1)
- **Acks = 0: At most once delivery, No retries!, fire and forget approach, High data loss**, **Ex - metrics collection, log collection**
- **Acks = 1: At least once, Retry happens in case producer does not get ACK, Moderate data loss, Moderate latency.**
- **Acks = all: acks from all min.insync.replica, exactly once delivery (Yes it is possible! In 0.11.x and later), no data loss, lower throughput and higher latency. Ex- financial applications, IoT applications, and other streaming applications**
- **Command -** kafka-console-producer --broker-list localhost:9092,localhost:9093,localhost:9094 --topic demo8 **--request-required-acks "all"**

Producer Delivery Semantics

	At most once	At least once	Exactly once
Duplicates	No	Yes	No
Data loss	Yes	No	No
Processing	Zero or one time	One or more times	Exactly one time

Acks	Latency	Throughput	Durability
0	Low	High	No guarantee
1	Medium	Medium	Leader only
All	High	Low	All Replicas

Why Kafka promises atleast once delivery not exactly once?

In order to achieve exactly once delivery, we will have to achieve the following -

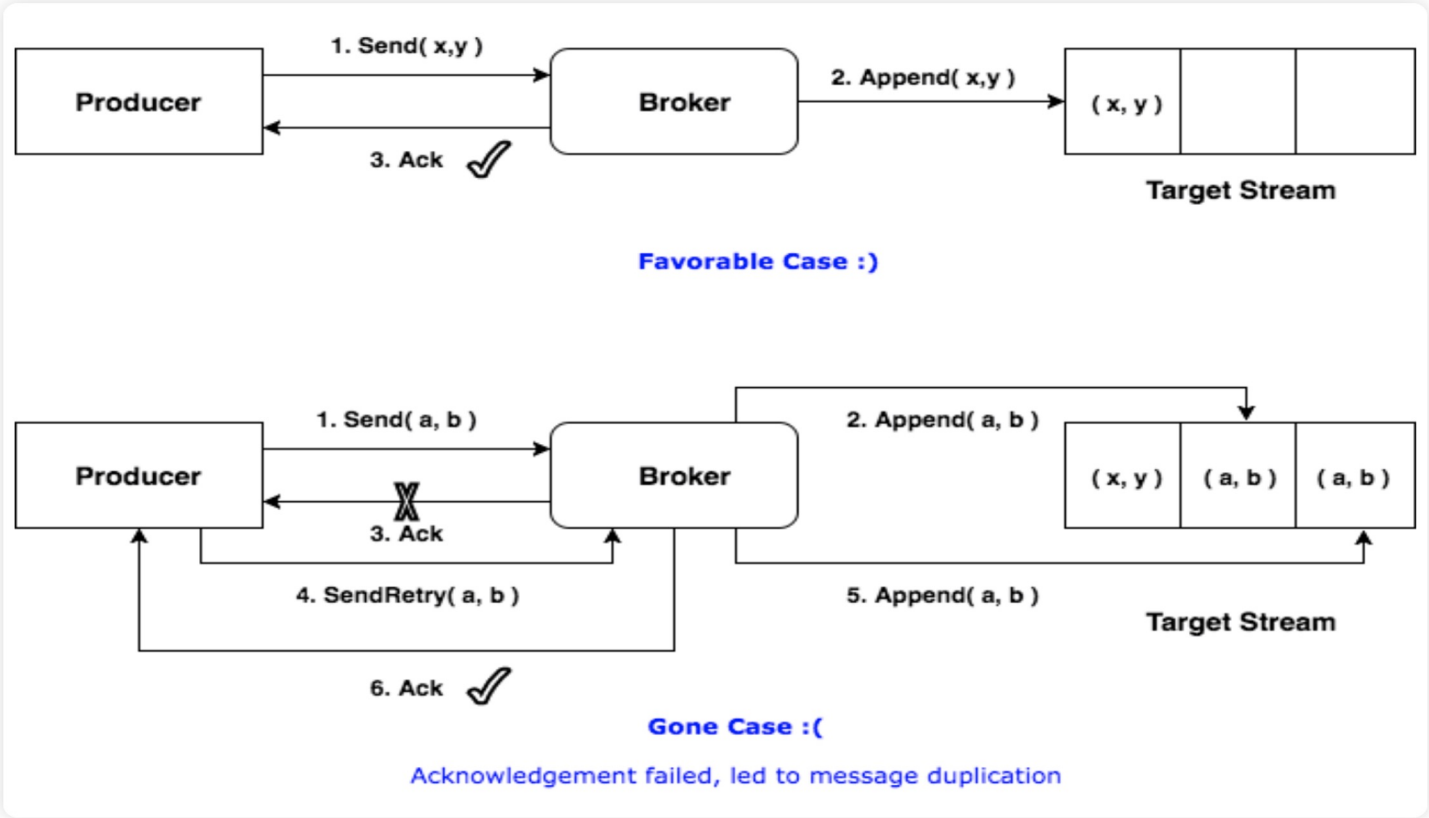
1. Message from Producer to Broker should be delivered only once

2. Message should be consumed only once by consumer

Let's see what are the problems we face in order to achieve above

Why kafka promises atleast once delivery not exactly once?

Producer side Guarantee



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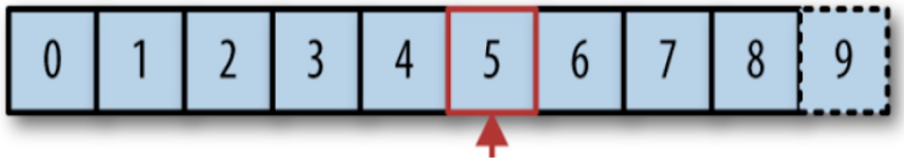

Consumer side Guarantee

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    } finally {
        consumer.close();
    }
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```

Kafka Topic Properties

- bin/kafka-topics.sh --zookeeper localhost:2181 --create --topic yourTopicName --partitions 1 --replication-factor 3 --config min.insync.replicas=2

- --replication-factor = 3 means data partition data should be present in 1 Leader + 2 Followers

  - min.insync.replicas specifies the minimum number of replicas that must acknowledge a write in order to consider this write as successful.

- min.insync.replicas = 3 means 1 Leader + 2 Followers

Min.insync.replicas and Acks Parameter

- min.insync.replicas can be specified on creating topics.
- min.insync.replicas and acks to “all” (or “-1”) specifies the minimum number of replicas that must acknowledge a write in order to consider this write as successful
- If this minimum cannot be met, then the producer will raise an exception (either NotEnoughReplicas or NotEnoughReplicasAfterAppend).
- min.insync.replicas and acks allow you to enforce greater durability guarantees. A typical scenario would be to create a topic with a replication factor of 3, set min.insync.replicas to 2, and produce with acks of “all”. This will ensure that the producer raises an exception if a majority of replicas do not receive a write.

More to explore

- Producer design
- Consumer properties
- Why Kafka is so Fast

References

- https://dzone.com/articles/running-apache-kafka-on-windows-os
- https://book.huihoo.com/pdf/confluent-kafka-definitive-guide-complete.pdf
- https://docs.cloudera.com/documentation/kafka/latest/topics/kafka_ha.html
- https://kafka.apache.org/documentation.html#replication
- https://bravenewgeek.com/tag/leader-election/
- https://www.confluent.io/blog/exactly-once-semantics-are-possible-heres-how-apache-kafka-does-it