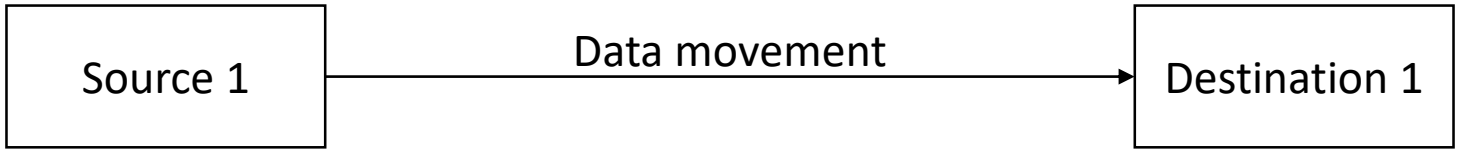
A central component in modern data architecture

Data Integration

Data integration starts something like this



Data Integration

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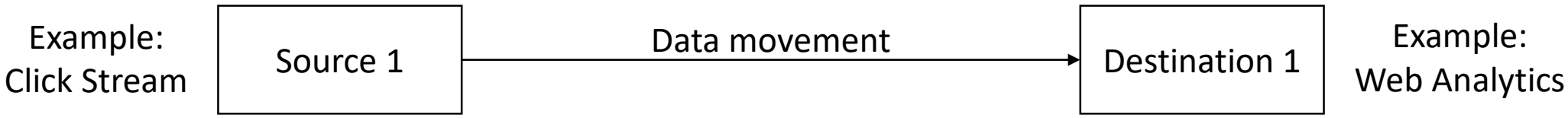

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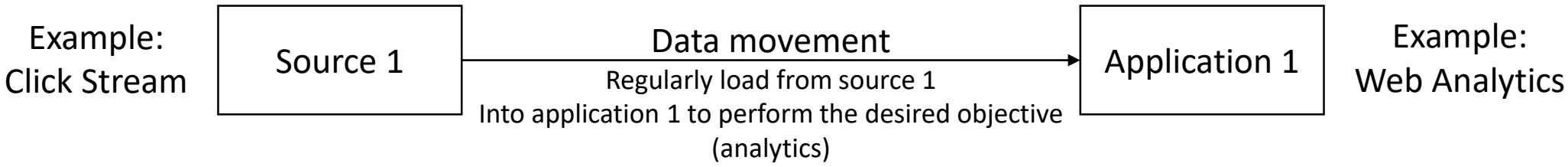
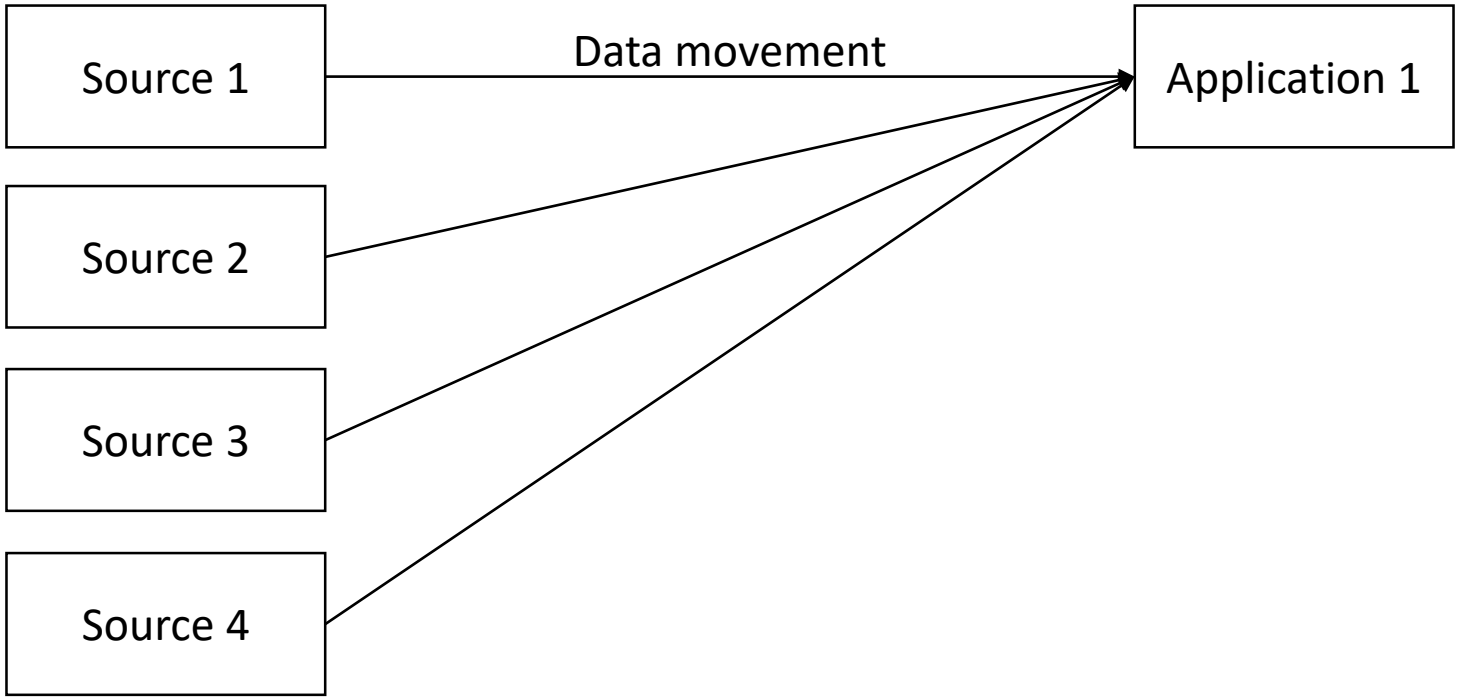


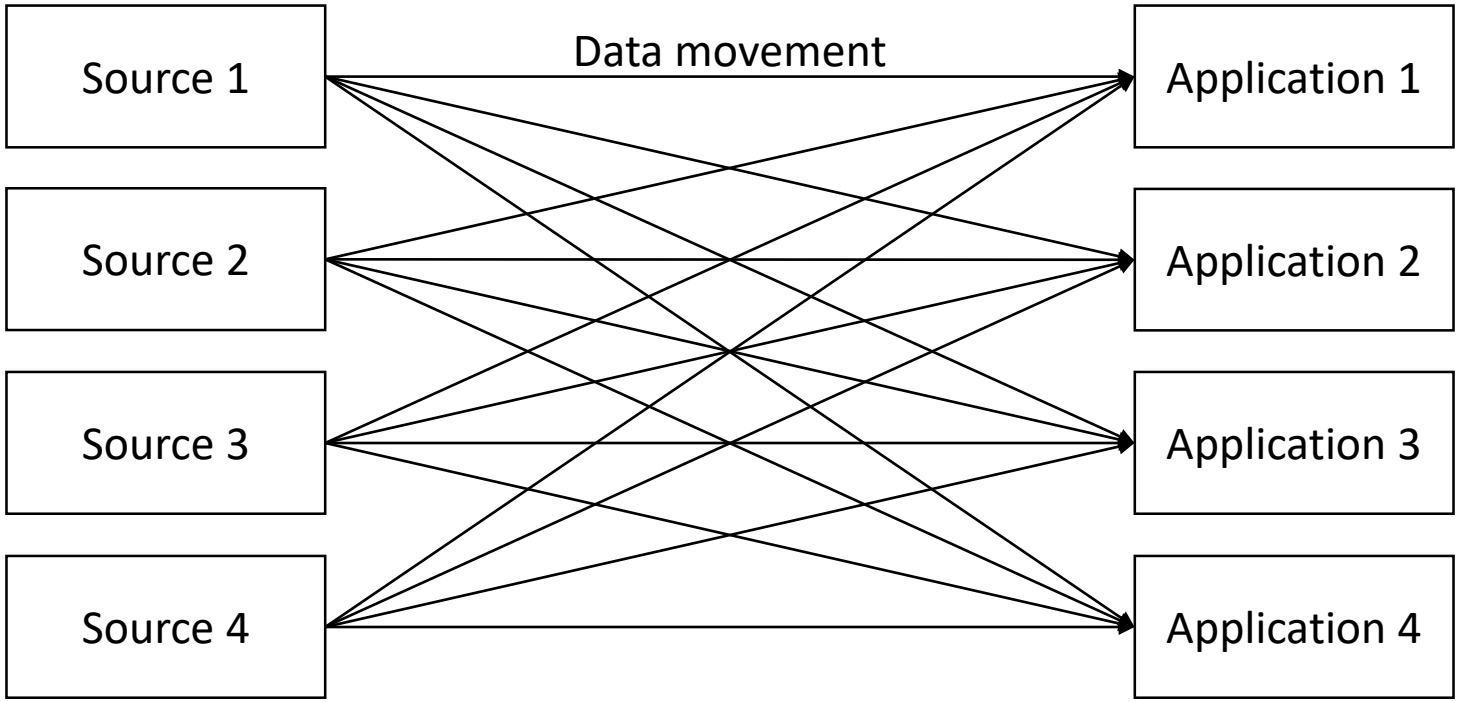
Data Integration

Then we reuse our integration for different objectives



Data Integration

The reality is much complex: multiple sources and destinations



Data Integration

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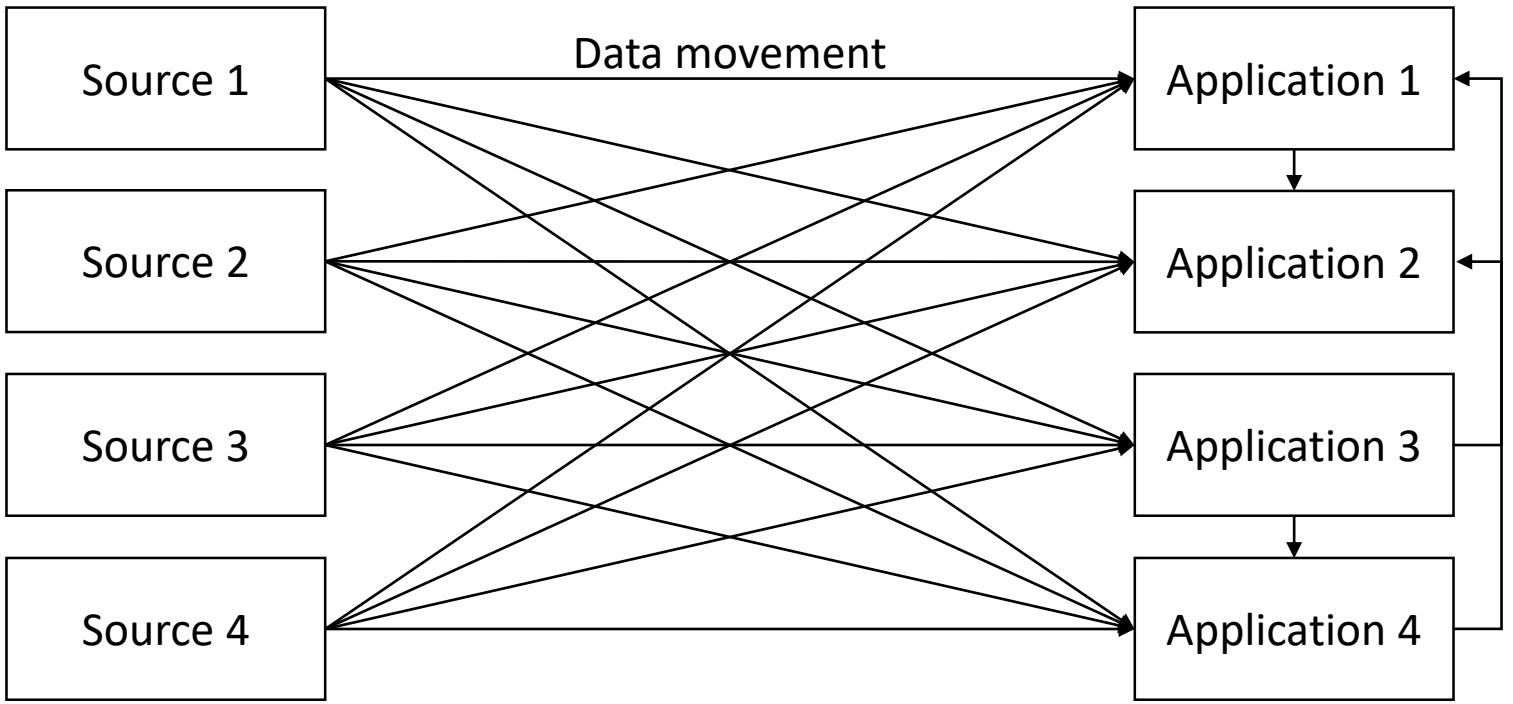
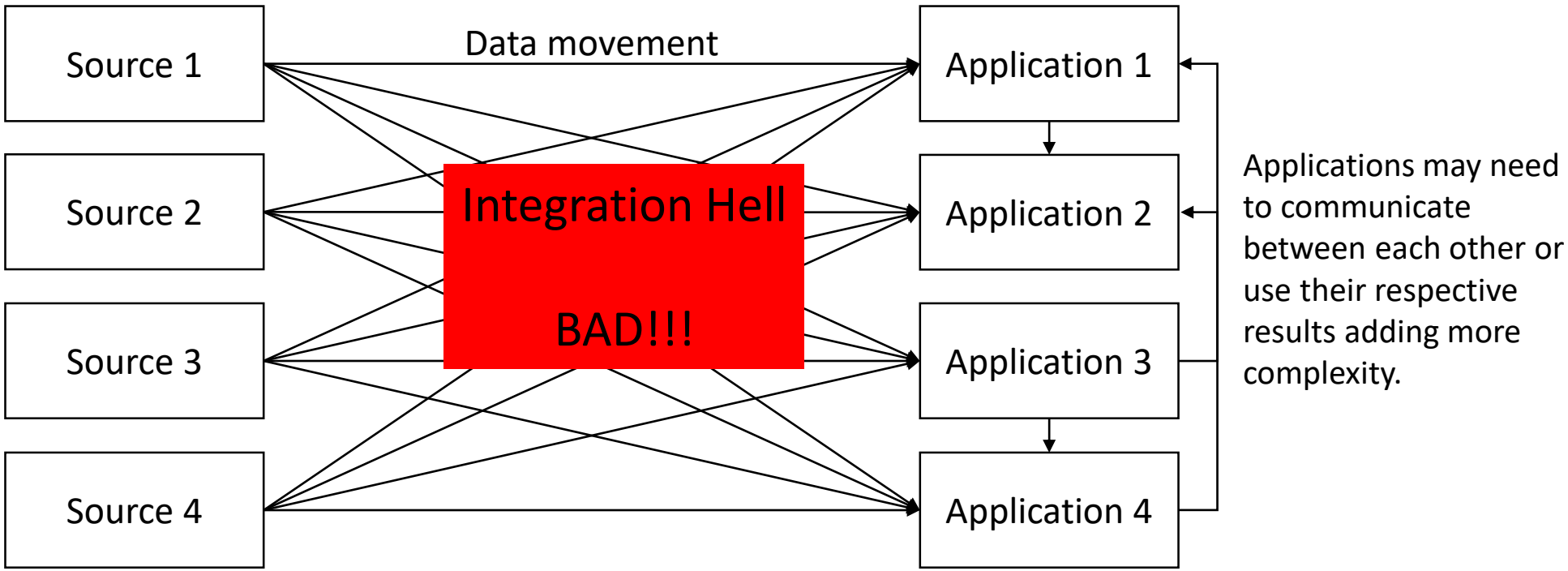


Applications may need to communicate between each other or use their respective results ➔ adding more complexity.

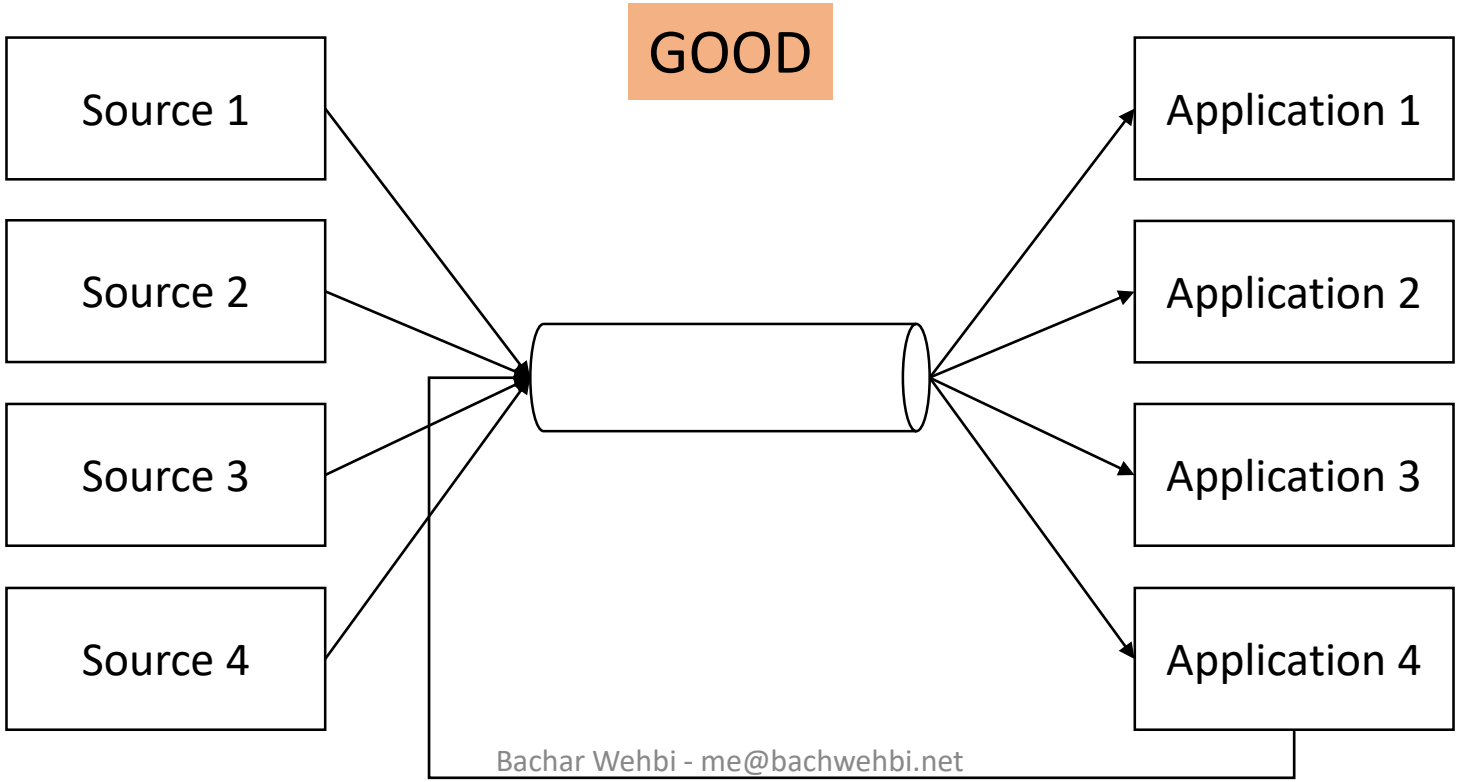
Data Integration

The reality is much complex: multiple sources and destinations



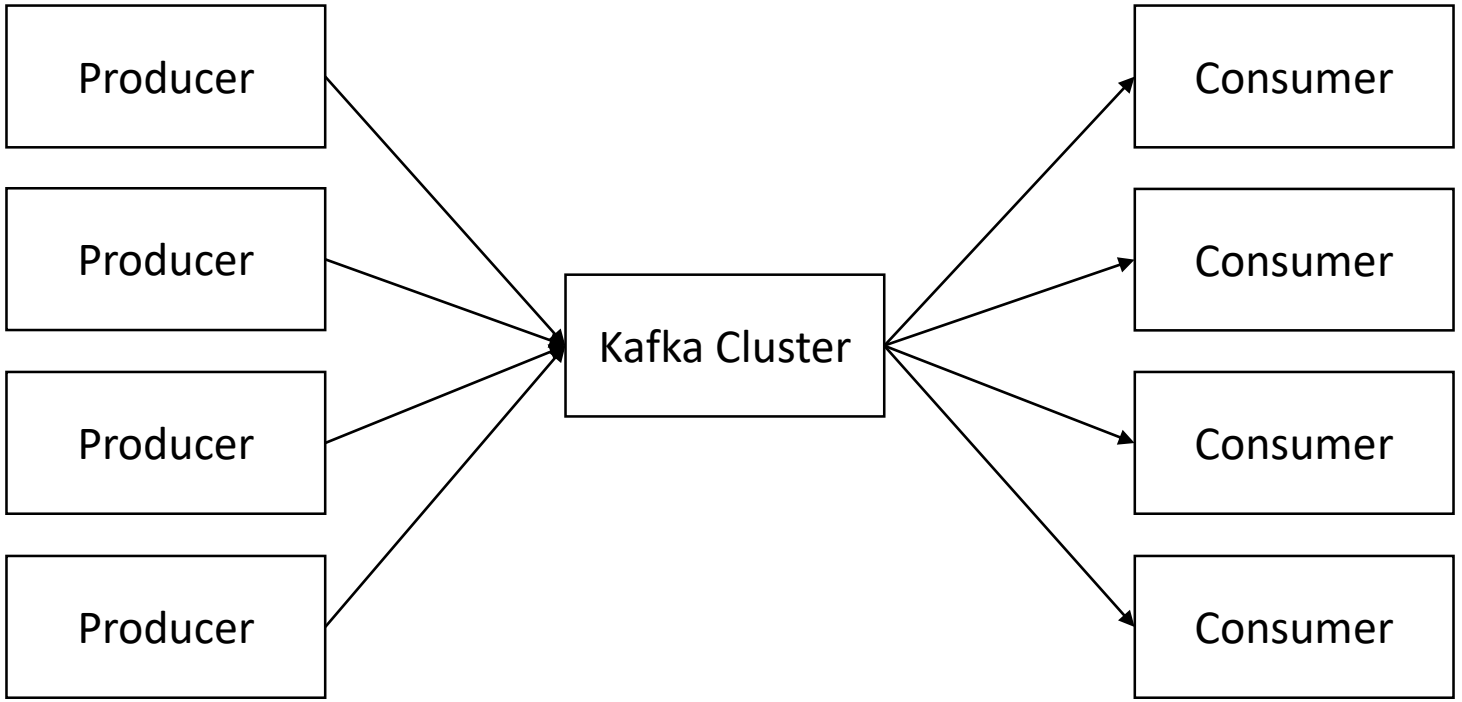
Data Integration

Simplify using a “messaging system”



Apache Kafka

Decouples data producers from data consumers



Apache Kafka: History

- Created at LinkedIn
- Donated to the Apache Foundation in 2011
- Graduated from Apache Incubator in 2012
  - Top level Apache project
- Creators of Kafka founded Confluent in 2014
- Supported by all Hadoop distributions
- V-1.0.0 released in November 2017
- V-2.0.0 released in July 2018

Apache Kafka: Capabilities

- Streaming data integration pipeline
  - Publish Subscribe architecture
  - Enterprise messaging system, similar to message queues

- Stores (retains) data messages in a **write-ahead log**
  - Fault-tolerant durable way

- Stream processing:
  - Process streams of records as they occur

Let’s get to know Logs

Called also: Write-ahead logs, Commit logs or Transaction logs

A data structure at the heart of many data stores

What is a log

```
::ffff:54.243.49.1 - - [01/Mar/2018:23:07:31 +0000] "POST /v1/data/write/Ras_Beirut/statusRas_Beirut4 HTTP/1.1" 200 4 "-" "beebotte node.js SDK v1.2.0"
::ffff:54.243.49.1 - - [01/Mar/2018:23:07:31 +0000] "POST /v1/data/write/Ras_Beirut/statusRas_Beirut1 HTTP/1.1" 200 4 "-" "beebotte node.js SDK v1.2.0"
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```
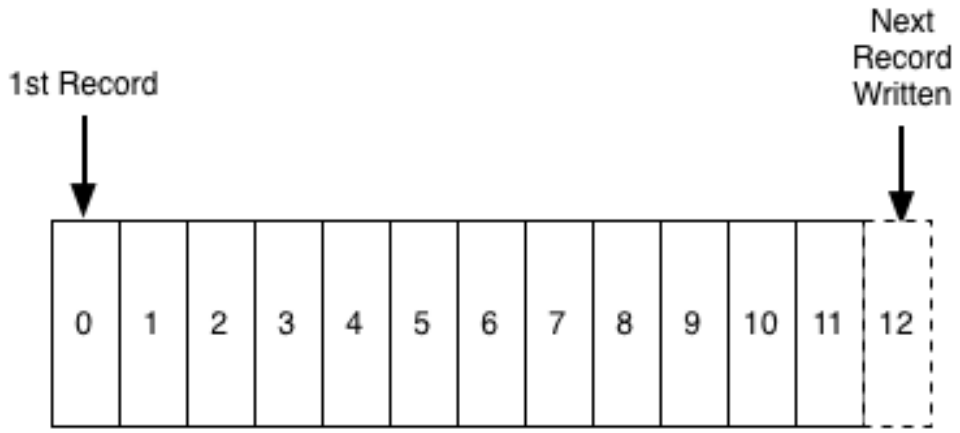

We are not talking about Log Files but rather about Log Data Structure

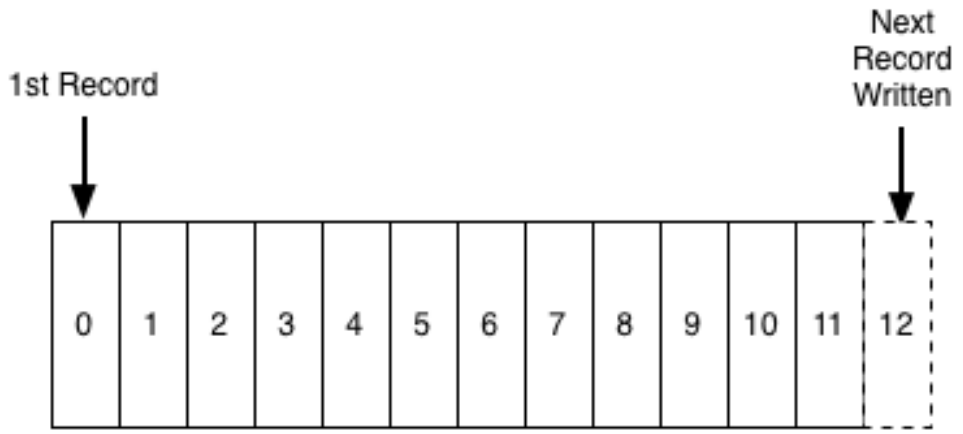
What is a log

- Probably the simplest storage abstraction
- Append only
- Totally ordered records by time
- immutable



Why it is important

Q. What is the purpose of a log?

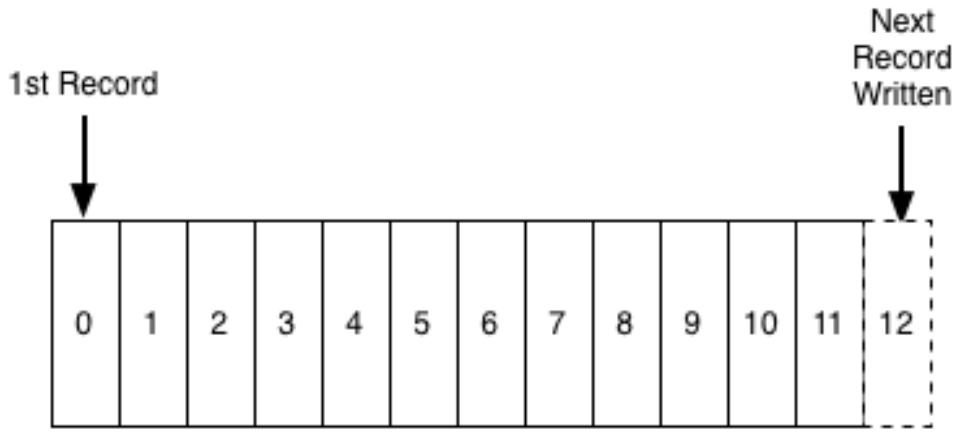


Why it is important

Q. What is the purpose of a log?

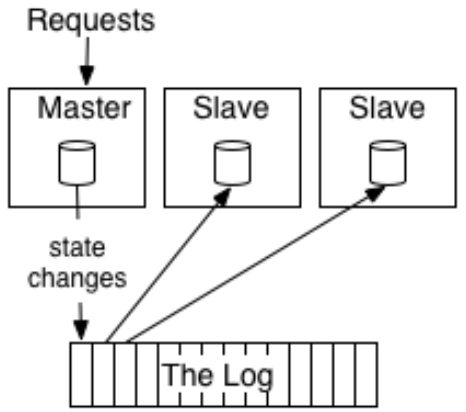
A. Record what happened and when.

For distributed data systems this is the very heart of the problem.



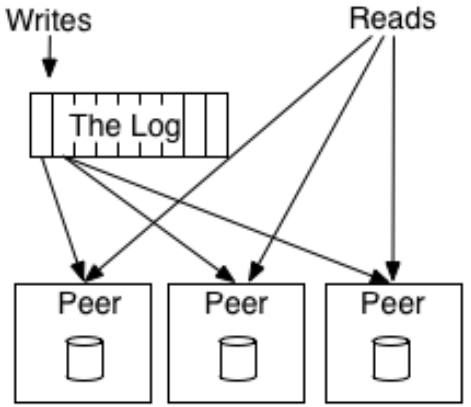
Logs: Example usages

- Primary backup in master slave mode: master writes to Log, slaves read from log and update their state



Primary-Backup

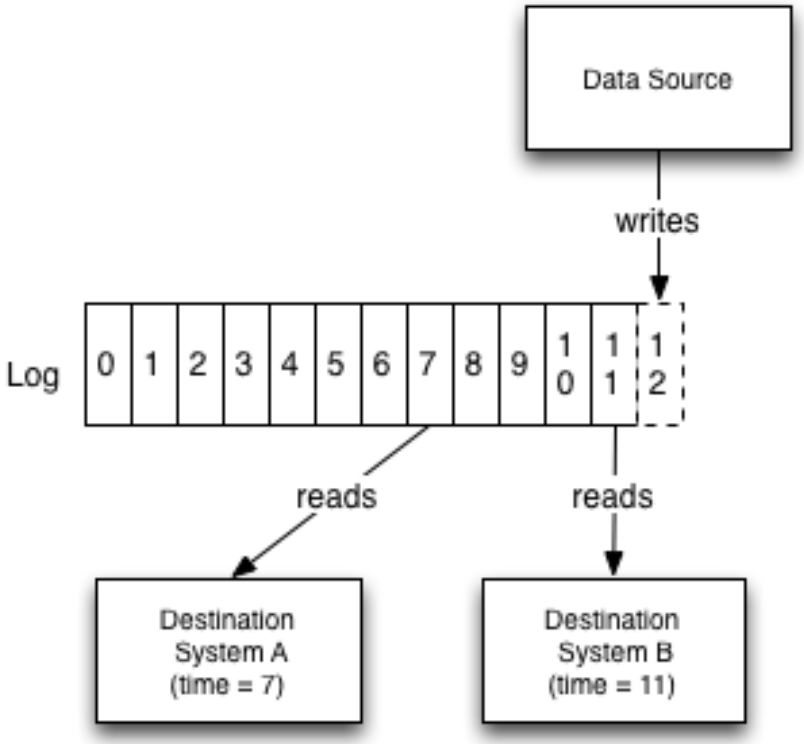
- State machine replication: keep a log of incoming events and each replica processes independently these events



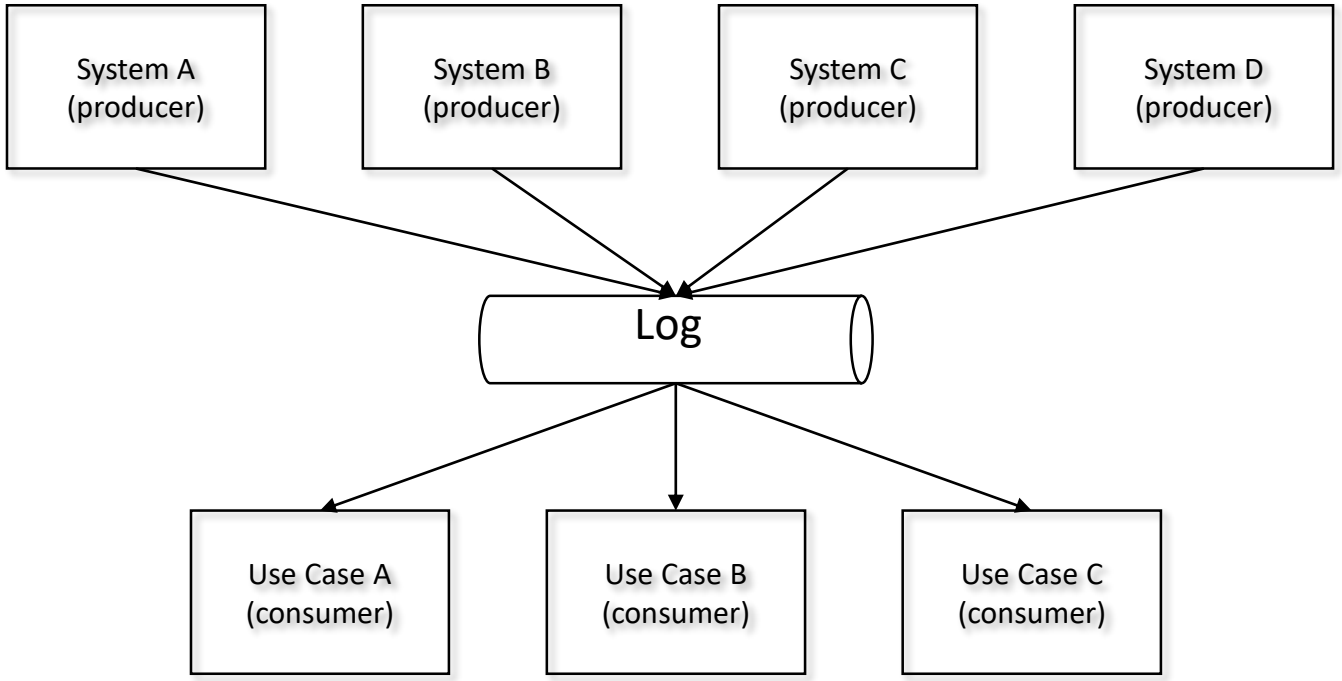
State-Machine Replication

Logs: seperation of concerns

- Data producers (writers) do not need to know about data consumers (readers)
- Multiple consumers can coexist
- Reprocessing history is possible by reading from the start of the log



Log as data integration infrastructure



Apache Kafka: Characteristics

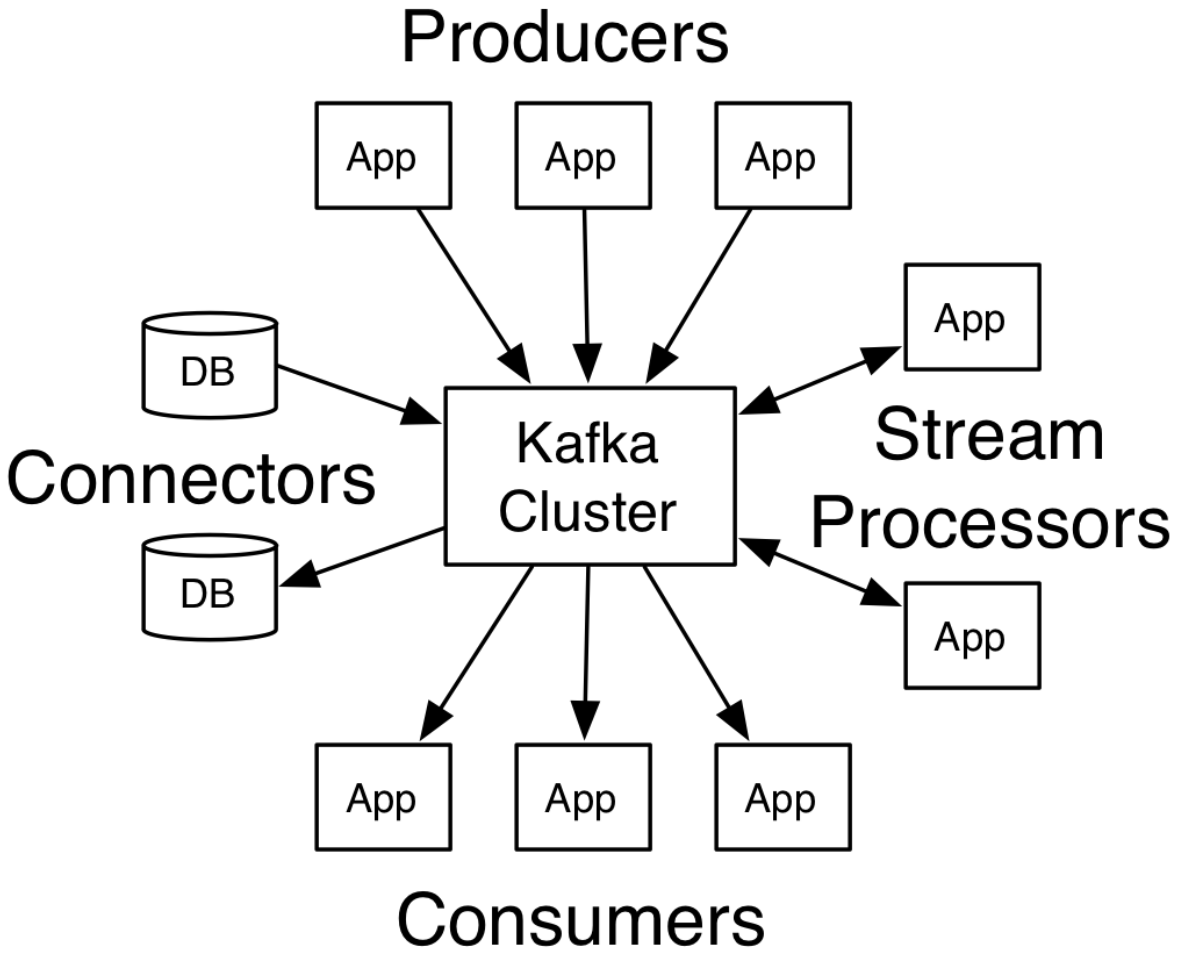
- High Scalability
  - Cluster instead of servers: supports multiple nodes
  - High throughput per node: hundreds of MB/sec/node
  - High volume of retained messages per node: multiple TB
- High Guarantees
  - Messages are strictly ordered: a consumer will receive messages in the same order they were produced
  - Data durability: messages can be replicated to multiple nodes to tolerate failures
- Highly Distributed
  - Through **replication** and **partitioning**
  - Avoid needless data copies

Apache Kafka: Use Cases

- Messaging
- Website activity tracking
- Metrics
- Log Aggregation
- Stream Processing
- Event Sourcing
- Commit Log

Source: https://kafka.apache.org/uses

Apache Kafka: High Level Architecture



Apache Kafka: Terminology

- Message
  - A message in Kafka is a data record published to the broker.
- Topic
  - A named stream of records (messages).
- Producer
  - A process or program that publishes messages to Kafka. Messages are always published to topics.
- Consumer
  - A process or program that subscribes to a topic to process the stream of messages.
- Broker
  - Kafka runs in a cluster comprised of one or multiple brokers. A Broker is a Kafka instance (server or process).
- Kafka Connector
  - A reusable producer or consumer that connects Kafka topics to existing applications or systems
- Kafka Streams
  - A stream processing API that consumes messages from input topics, transform them and publishes new messages to output topics.

Apache Kafka: Messages

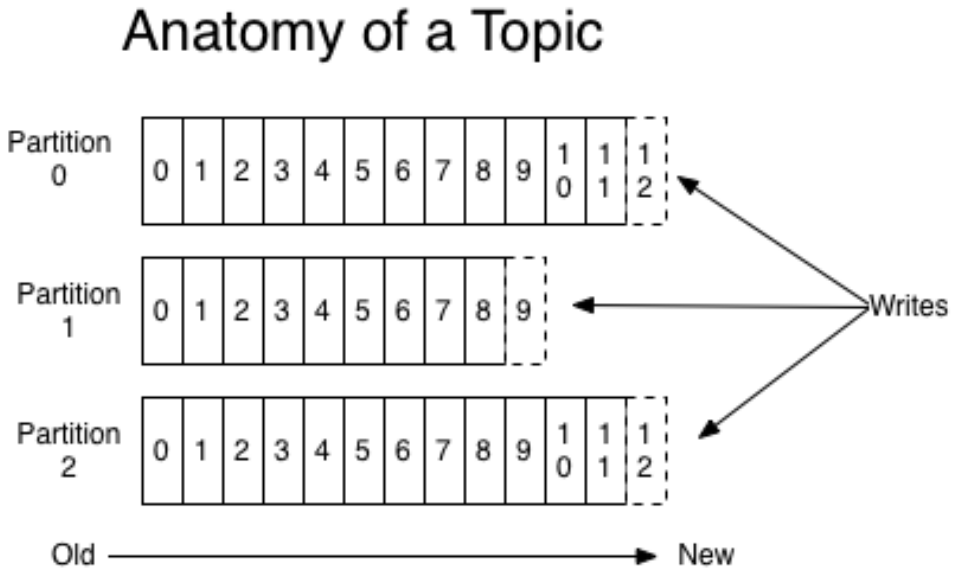
- Kafka messages are byte arrays of variable length
  - The content of the message is arbitrary & completely opaque
    - Design decision not to make a serialization choice
  - The message content format is application specific
    - It can be raw text, JSON, Avro, ProtoBuffer, etc.

- Kafka does not enforce limits on message size
  - It performs better with relatively small messages (few KB)

- Kafka messages are always written in batches named '*record batch*'
  - a record batch contains one or more records.
  - Allows Kafka to achieve high throughput
    - less network overhead
    - Produce and consume batches instead of individual messages

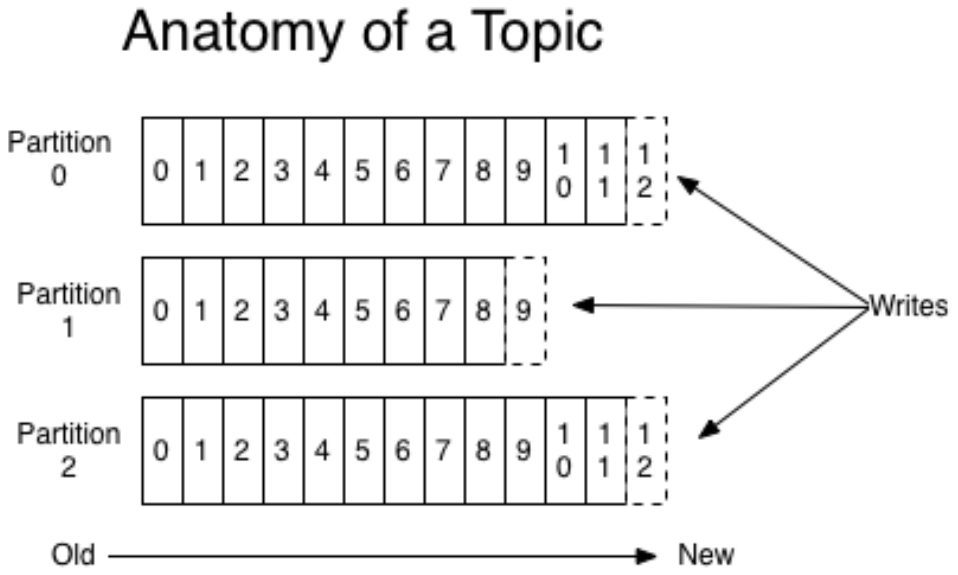
Apache Kafka: Topics

- A topic is a category or feed name to which records are published.
- Multi subscriber: A topic can have 0, 1 or multiple subscribers
- Topics are divided into partitions
  - Partitions help scale out topics on multiple nodes
  - Message order is guaranteed within a partition
- A partition is an ordered, immutable sequence of messages appended to a commit log
- Each message in a partition is assigned a sequential id number called offset that uniquely identifies the message within the partition



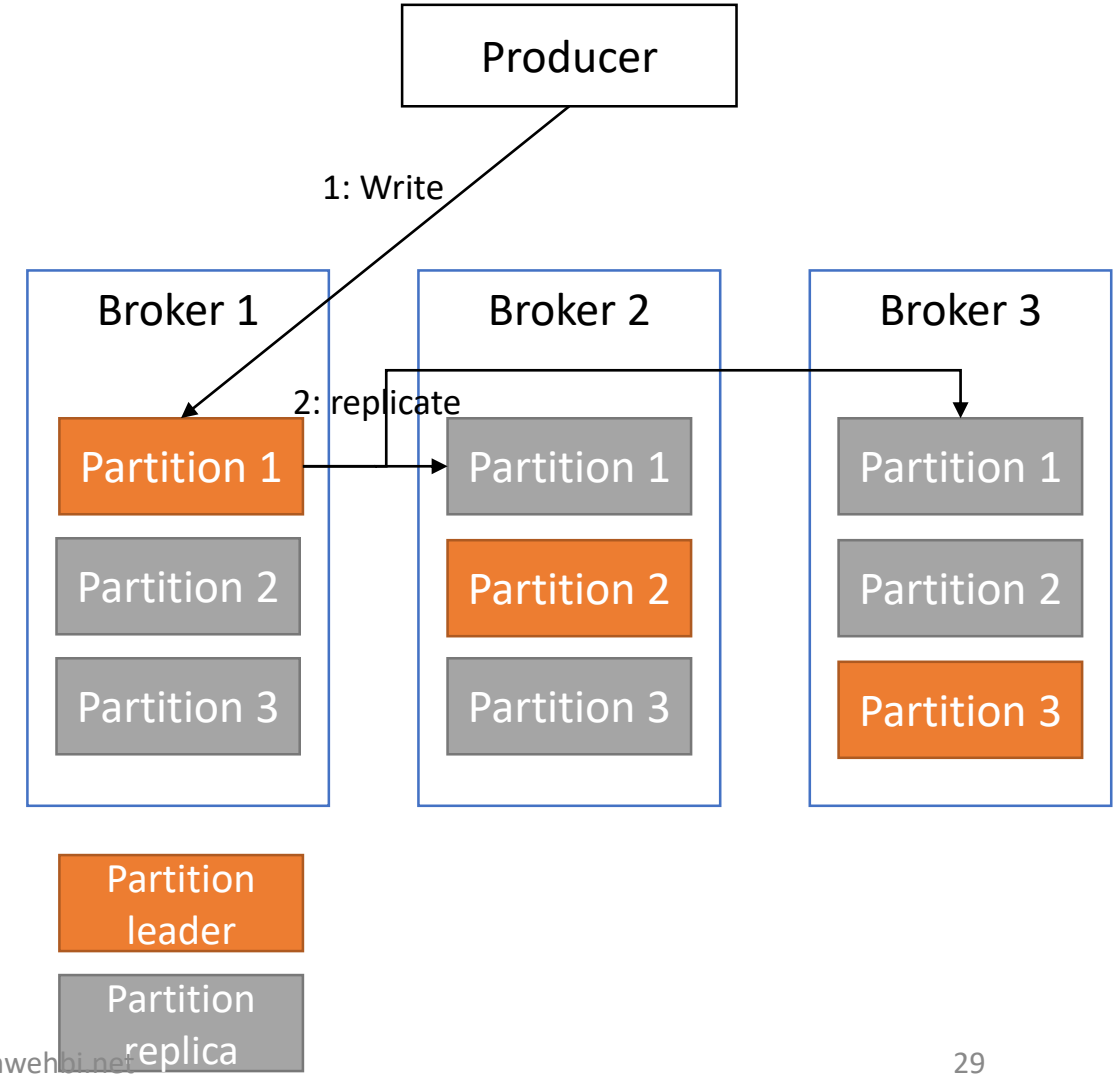
Apache Kafka: Topics

- Kafka is known to perform better with a relatively small number of large topics compared to a large number of small topics.
- Kafka can be configured to create topics implicitly: when message is first published to a new topic
  - Nice to have in dev mode, not in production (accidental creating a large number of topics)
- Data retention on Kafka topics can be configured:
  - For a specific period of time (example: last 30 days)
  - Based on data volume on the topic (example: 64GB)
- Kafka avoids needless copying of data



Apache Kafka: Topic Replication

- Topics can be replicated to ensure durability in case of failure
- Replication is applied to topic partition level
- A replicated partition has one leader (master) and one or multiple replicas
  - Replicas will try always to be in-sync with the leader
  - In-sync replicas are called ISR
- The replication factor is set on the topic level. The replication factor can only be changed to improve durability (higher), it can never be lowered.



Apache Kafka: Producer

- Kafka producers publish messages to topics. Producers never communicate with consumers.
  - Messages are persisted to disk upon reception
- Publish load is load balanced by partitions
  - In round robin fashion or based on message keys (optional)
  - All messages with the same key will be published to the same partition
- Message acknowledgments can have different configuration
  - No Acks (fire and forget): The producer will not wait a confirmation the message was received
  - Ack by the leader: The leader successfully received the message
  - Ack by in-sync replicas: the leader waits the replication of the message before confirming its reception to the consumer
- These different configuration settings have an impact on the data durability

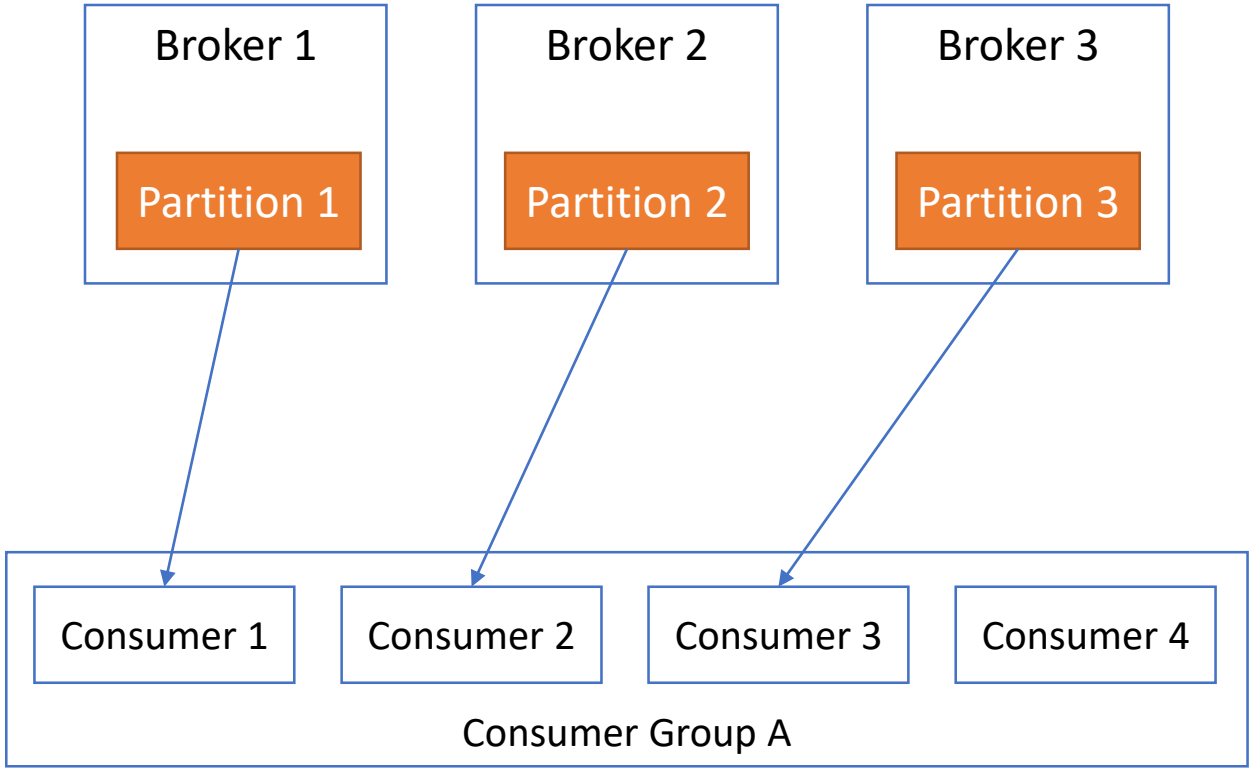
Apache Kafka: Consumer

- Kafka consumers read data from topics
- Multiple consumers can simultaneously read from the same topic
  - Every consumer maintains its status: the offset it read last
  - Kafka will keep messages after they are read: data will always be there for new consumers (as the retention strategy permits).
- A consumer might stop reading (planned or accidental)
  - When resuming reading from a topic it can specify the offset from which to receive data

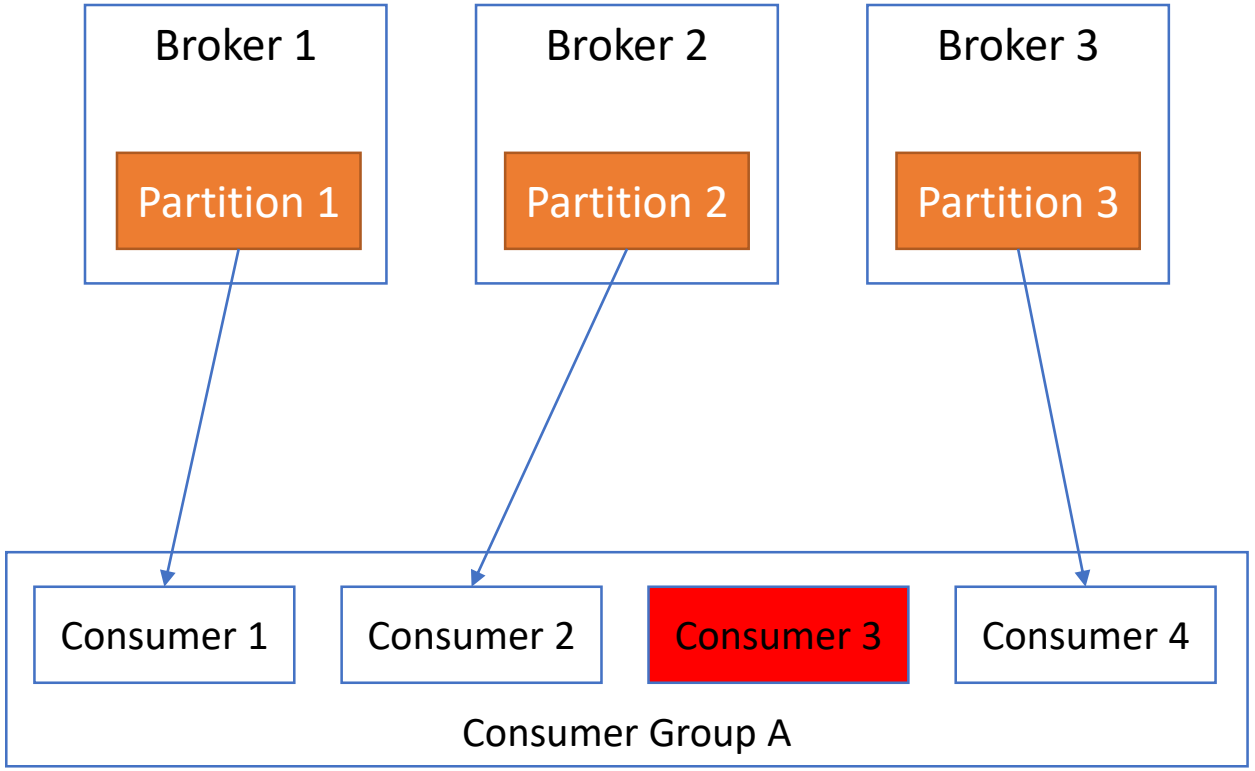
Apache Kafka: Consumer Groups

- Kafka consumers can be grouped into Consumer Group
- All consumers in a group subscribe to the same topic
  - They all share the same group id
- A message is delivered to only one consumer in a group
- A topic partition will only be delivered to one consumer in a group
  - If we have more consumers than topics: some consumers will be idle (failover)
  - If we have more topics than consumers: some will receive multiple topics
  - Kafka will always try to balance the load in a consumer group

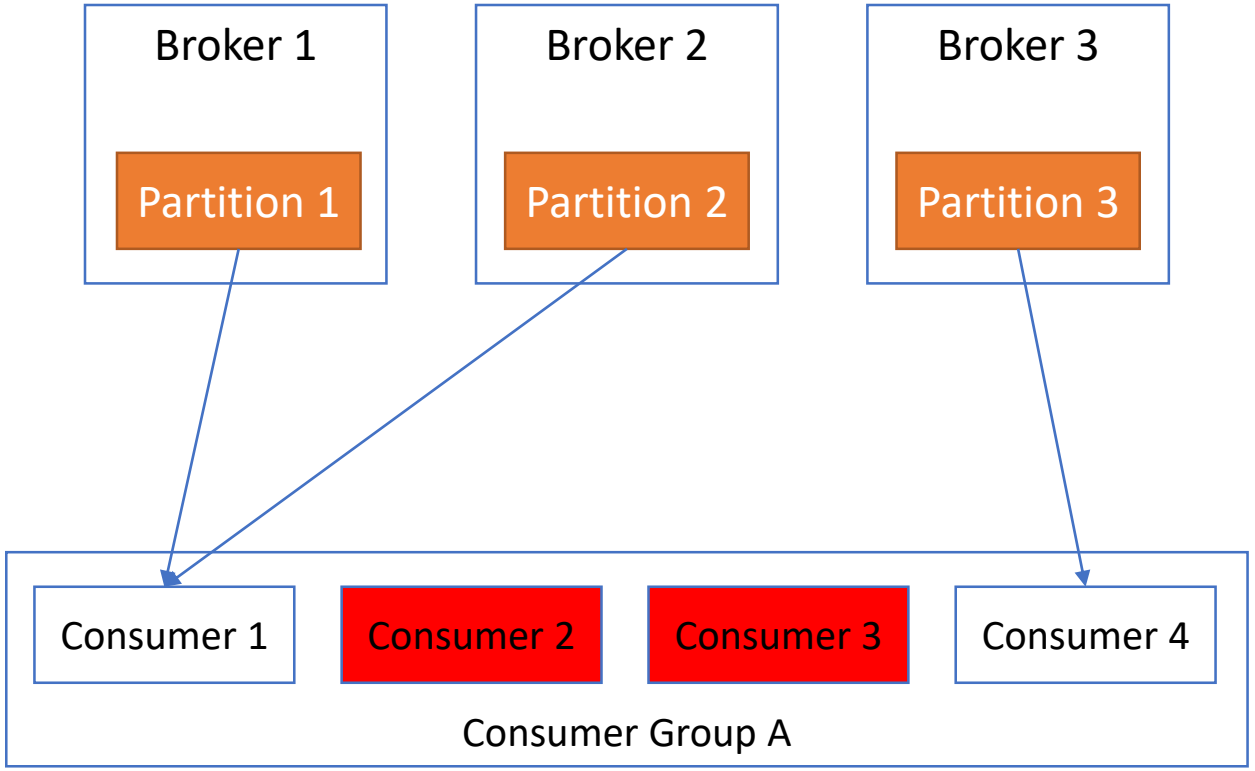
Apache Kafka: Consumer Groups



Apache Kafka: Consumer Groups



Apache Kafka: Consumer Groups



Apache Kafka: Message Delivery Semantics

- Apache Kafka provides different delivery semantics
- At most once delivery
  - This is also called fire and forget. The producer in this case does not request an acknowledgment of published messages.
  - The broker might or might not have received it ➔ at most once
  - The message can be lost and never delivered
- At least once delivery
  - This is the default configuration
  - If the producer failed to receive the acknowledgment, it will retry sending the message ➔ multiple deliveries
  - Mechanisms exist to identify and remove duplicates: using the message sequence number
- Exactly once delivery
  - This is the most complex mechanism as it requires the collaboration of both systems (sender and receiver)
  - Exactly once delivery is now possible with Kafka Streams and transactions support