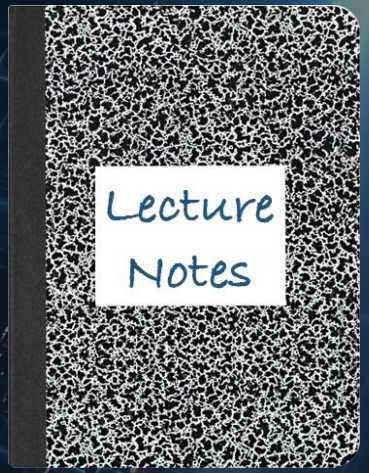


CS 417 – DISTRIBUTED SYSTEMS

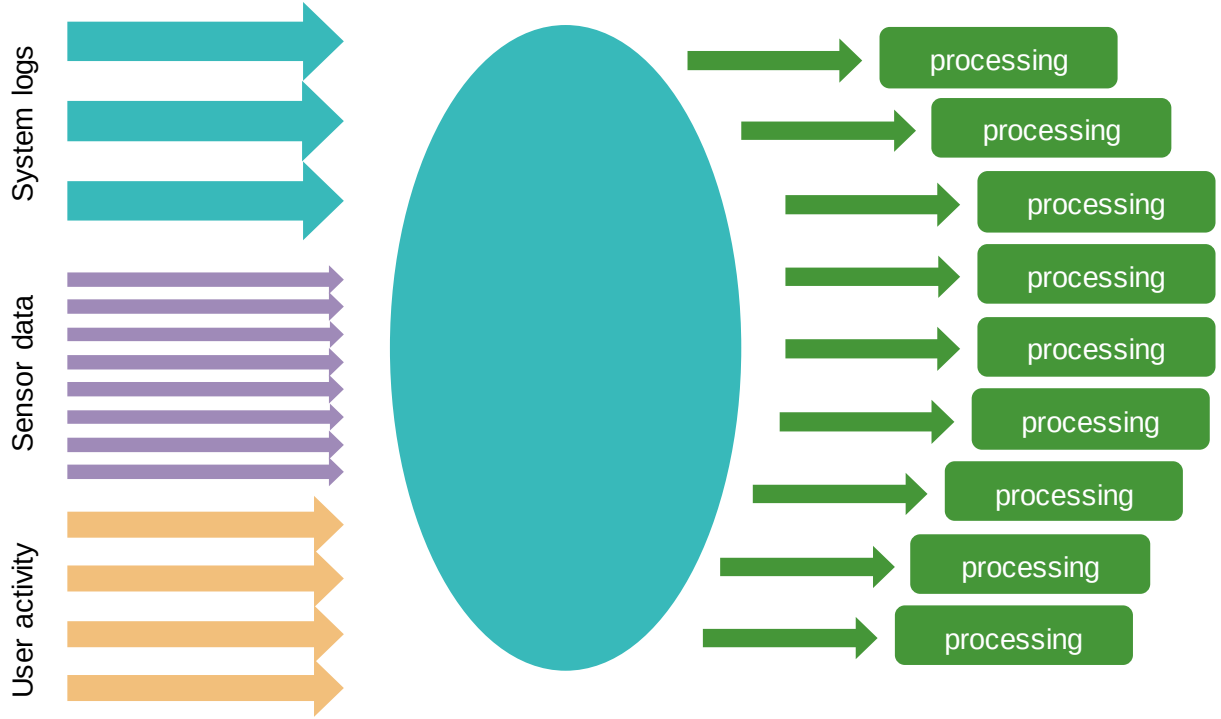
Week 11: Content Delivery

Part 1: Event Streaming – Kafka

Paul Krzyzanowski

Message Processing

How do we design a computing cluster to process huge, never-ending streams of messages from multiple sources?



Apache Kafka

Kafka is

- Open-source
- High-performance
- Distributed
- Durable
- Fault-tolerant
- Publish-subscribe messaging system

Messages may be anything:

IoT (Internet of Things) reports, logs, alerts, user activity, data pipelines, …

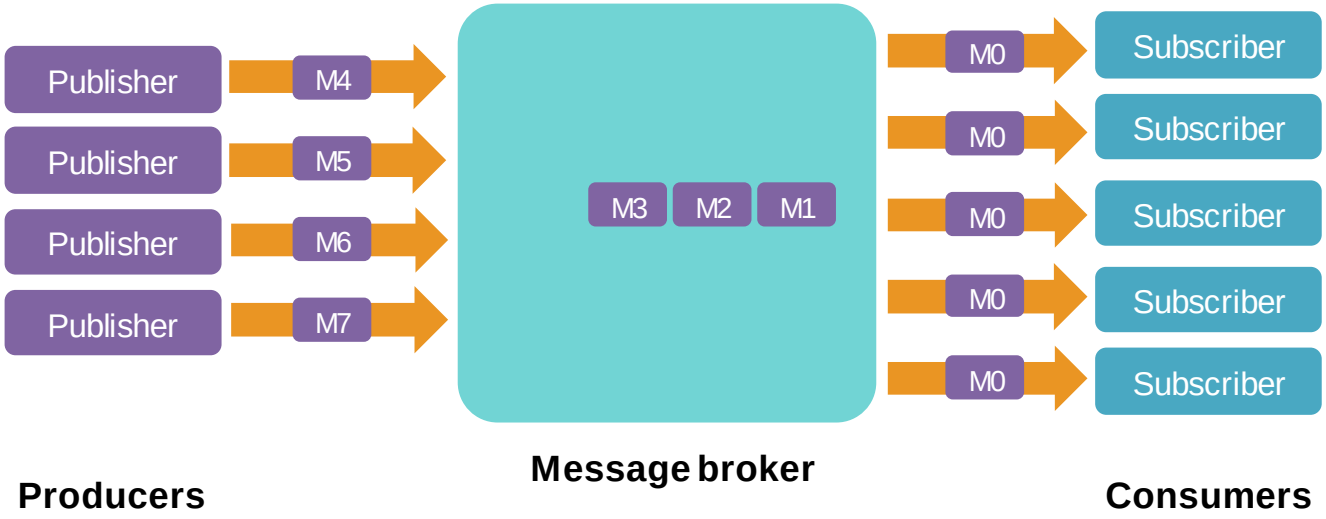
Publish-Subscribe Messaging

Publishers send streams of messages = ***producers***

Subscribers receive messages = ***consumers***

Message broker = messaging system

– A service that provides a loose coupling between producers & consumers

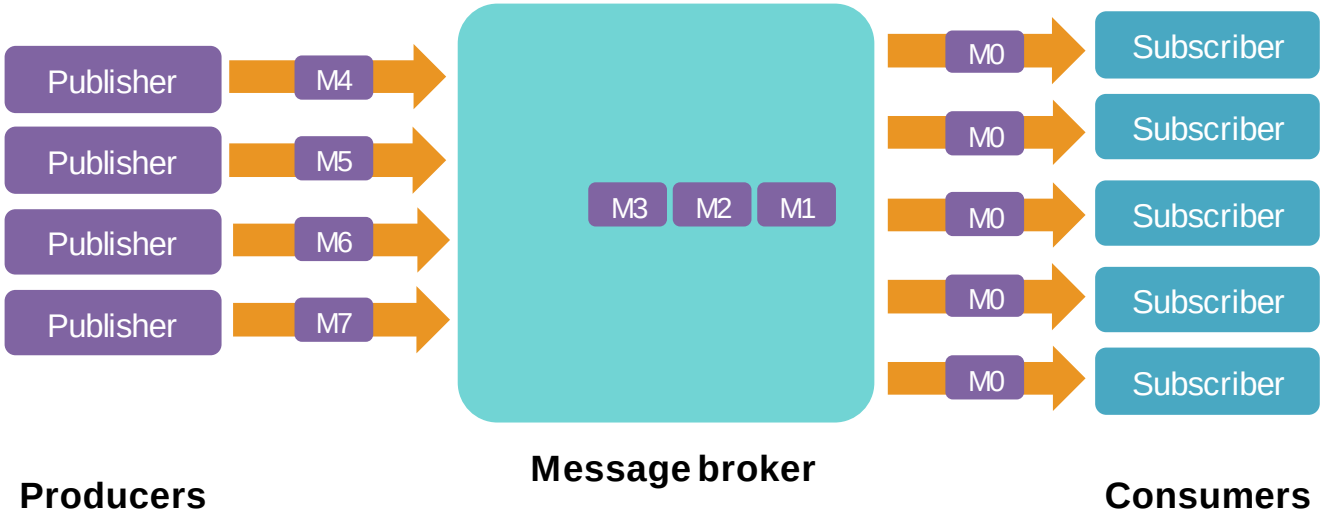


Publish-Subscribe Messaging: Message broker

Message broker stores messages in a **queue** (**log**)

Subscribers retrieve messages from the queue

- First-in, First-out (FIFO) ordering
- Producers & consumers do not have to be synchronized: read & write at different rates



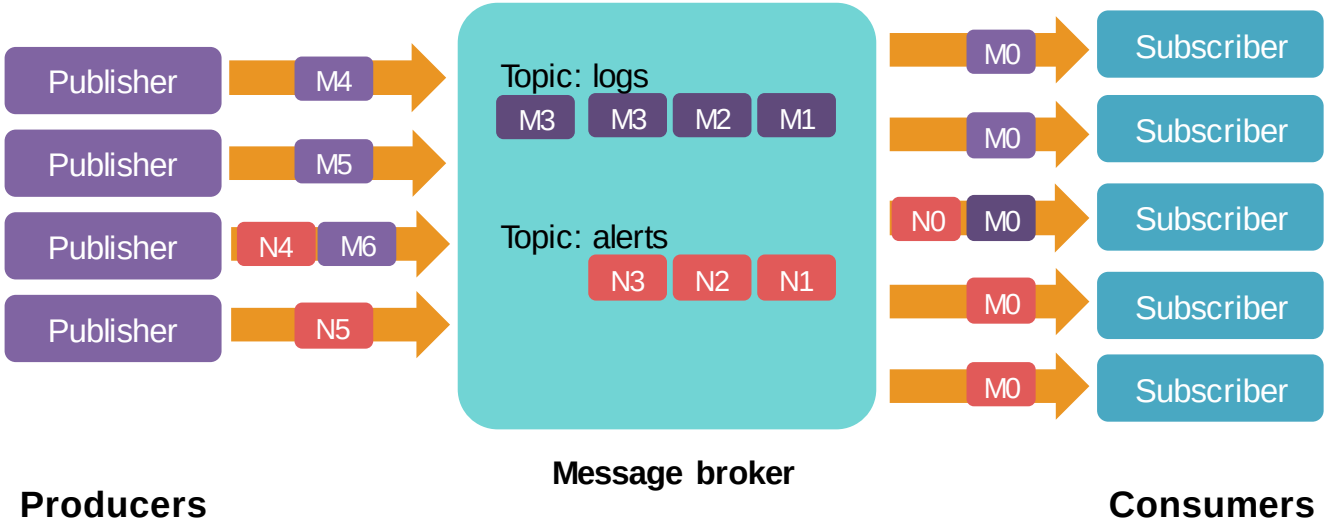
Publish-Subscribe Messaging: Multiple topics

We will often have various message streams

- Different purposes – e.g., IoT temperature reports, error logs, page views, …
- Different consumers will be interested in different streams

Streams are identified by a ***topic***

- Publishers send messages to a *topic* and subscribers subscribe to a *topic*



Publish-Subscribe Messaging: Brokers

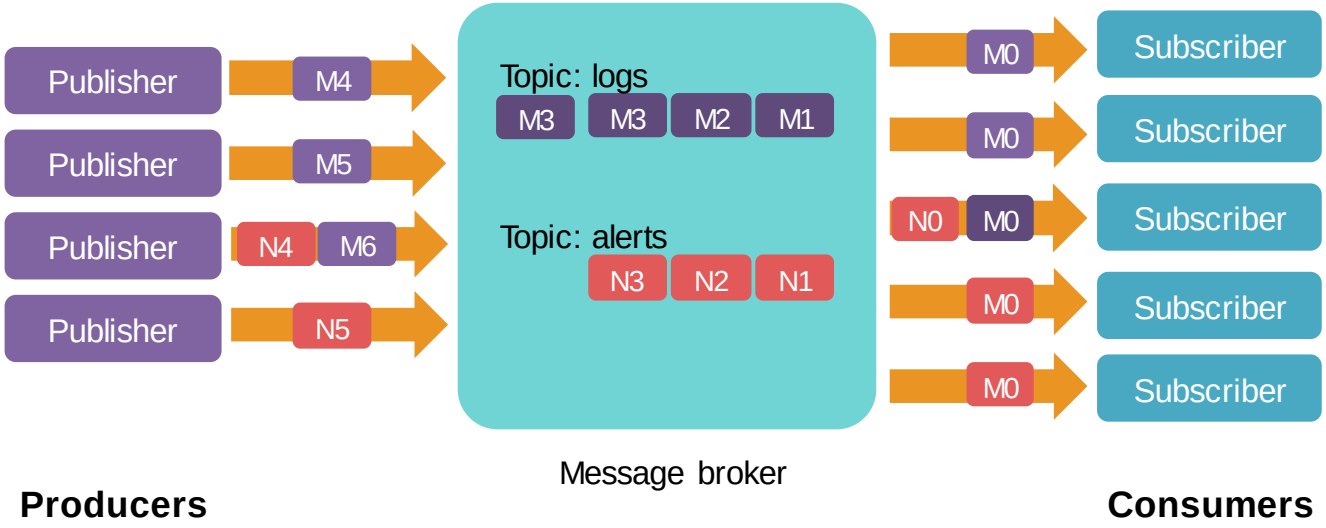
Kafka runs as a cluster on one or more servers

Each server is called a ***broker***

- A Kafka deployment may have anywhere from 1 to 1000s of brokers

Kafka can feed messages to

- Real-time systems: e.g., Spark Streaming
- Batch processing: e.g., store to Amazon S3 or HDFS & then use MapReduce or Spark

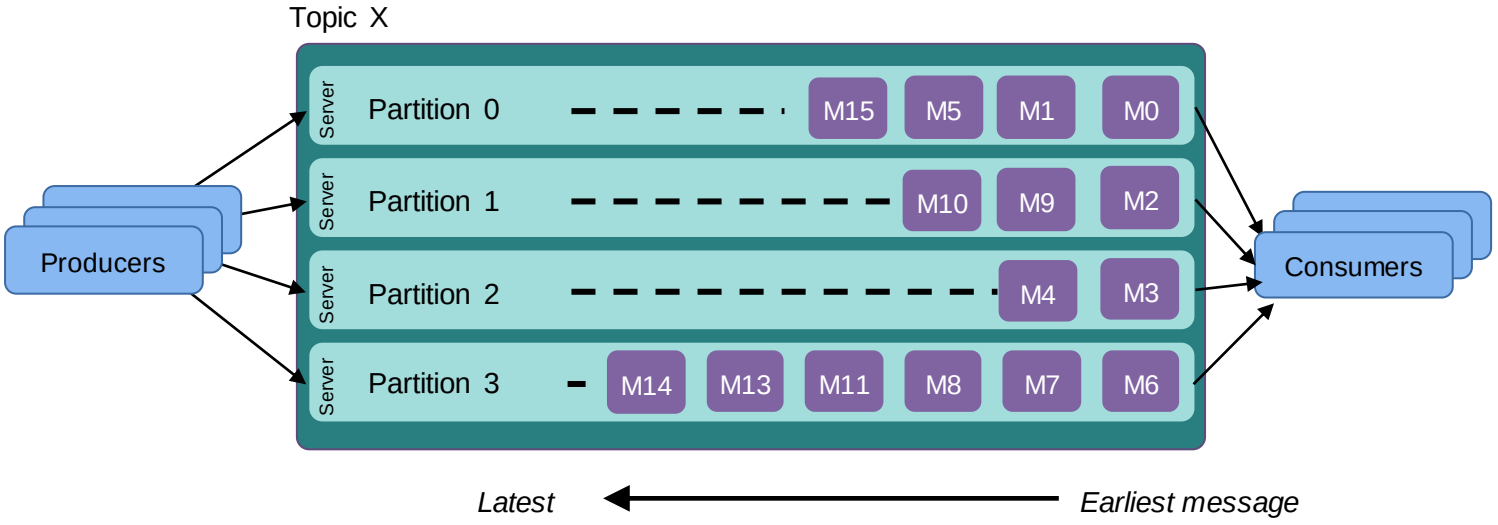


Scaling: Partitions

Each topic is stored as a **partitioned log**

- One message log is broken up (partitioned) into multiple smaller logs
- Each chunk is a ***partition*** and can be stored on a different server

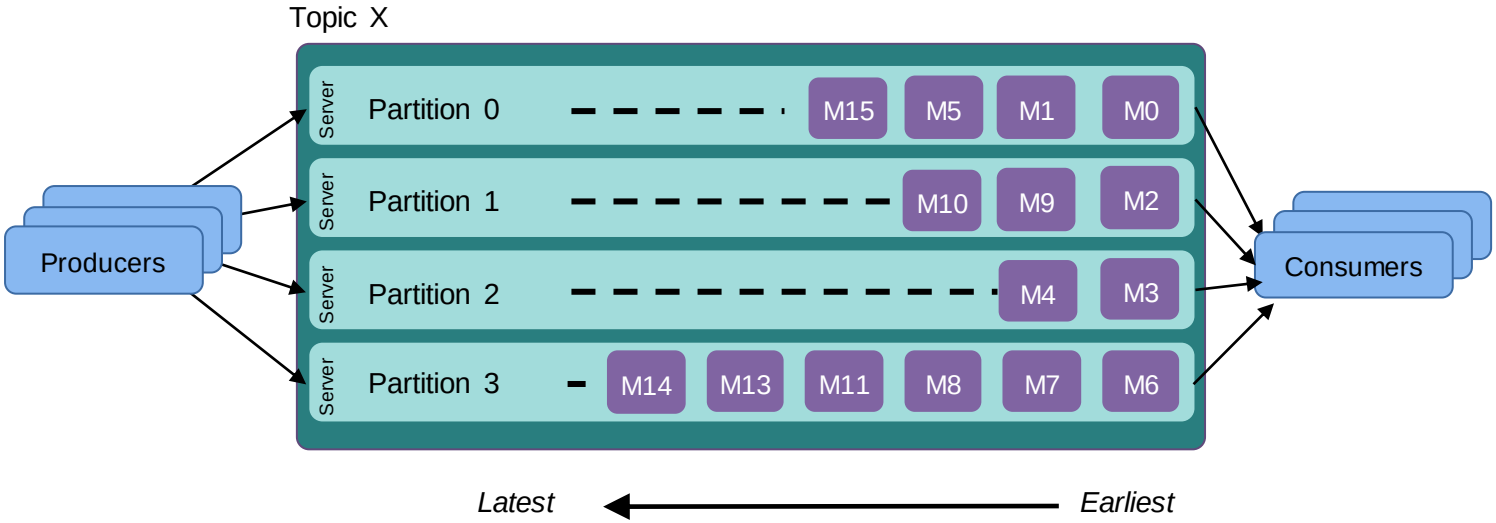
A **partitioned log** enables messages for a topic to scale beyond the capacity of a single server



Scaling: Partitions

Partition = ordered, immutable sequence of messages that is continually appended to

Each message record contains a sequential ID # to identify the message in its partition



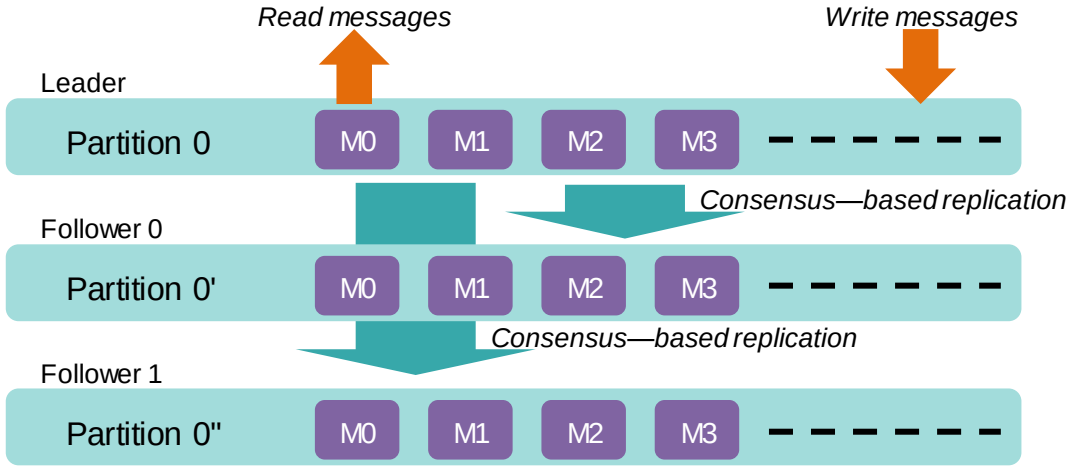
Fault Tolerance & Replication

Messages in a partition are **durable**: written to disk

- Persist for a configurable time period – then erased

Consensus-based state machine replication (similar to Raft)

- One server is elected to be the **leader** for a partition
- 0 or more other servers are **followers**
- Replication amount is configurable
- Leader handles all read/write requests
  - Data propagated to followers
  - Clients do not communicate with followers



Fault Tolerance & Replication

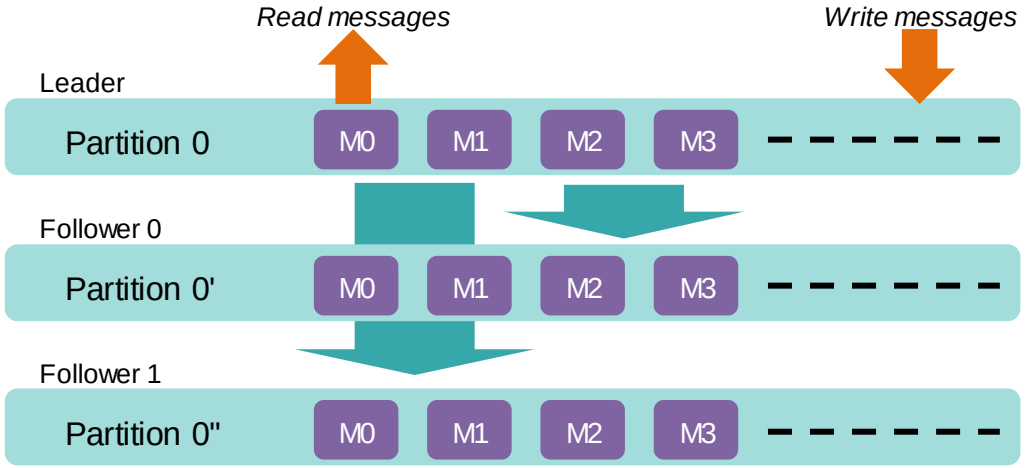
What if the leader dies after receiving a message but before replicating it to followers?

Producer can choose:

- Receive an acknowledgment when the broker receives a message

  or

- Receive an acknowledgment only when the message is replicated to followers



Achieving Scale

Producers

- Clients choose which partition to write message to
  - Default: round-robin distribution to balance the load evenly across multiple brokers
- Create more partitions for a topic ⇒ **more load distribution**

Consumers

- **Consumer group** = one or more consumers
- Group members share the same message queue for the topic
  - Messages to the topic get distributed among the members of the consumer group
- More consumers in a group ⇒ **more processing capacity**

Queuing vs. Publish-Subscribe

Queuing model

- Pool of consumers that take messages from a shared queue
- When any consumer gets a message, it is out of the queue
- Only one consumer gets each message
- Great for distributing processing among multiple subscribers

Queuing Model

Queuing vs. Publish-Subscribe

Publish-Subscribe model

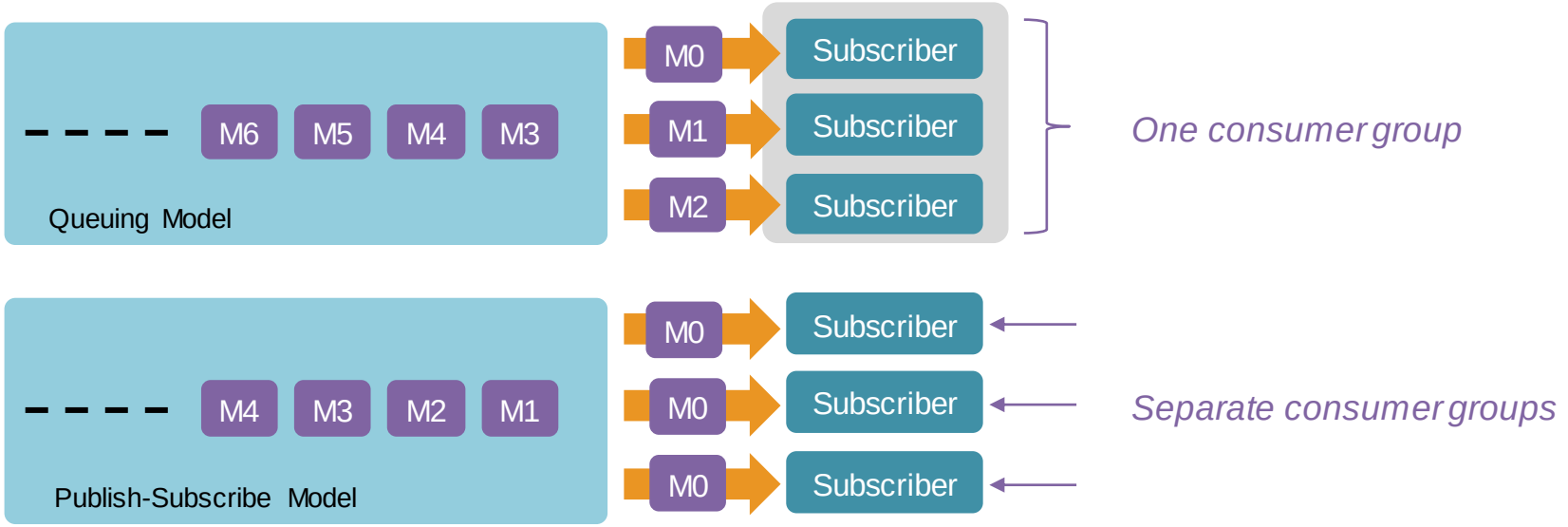
- Each consumer that subscribes to a topic will get every message for that topic
- Allows multiple clients to share the same data … but does not scale

Publish-Subscribe Model

Queuing vs. Publish-Subscribe

Queuing or Publish-Subscribe model? *Kafka offers both!*

- With consumer groups, consumers can distribute messages among a collection of processes
- Each consumer group provides a publish-subscribe model
  - Consumers can join separate groups to receive the same set of messages



Disk storage

Kafka provides durable message logs

- Messages will not be lost if the system dies and restarts

But disks are slow … even SSDs!

- Not necessarily – depends how you use them
- Huge performance difference between random block access and sequential access
- Kafka optimizes for large sequential writes & reads
  - Sequential disk operations can be thousands of times faster than random access

Apache Kafka is

- **Open-source**
  - Developed by LinkedIn and donated to the Apache Software Foundation, writteb in Scala and Java
- **High-performance**
  - Scalable to handle huge volumes of incoming messages by partitioning each message queue (log) among multiple servers
  - Partitioned log enables the log to be larger than the capacity of any one server
  - Consumer groups enable the scaling of message processing
- **Distributed**
  - Each message queue (log) is divided among multiple servers
- **Durable**
  - Message logs are written to disk (via large streaming writes for best performance)
- **Fault-tolerant**
  - Support for redundancy with a leader & followers per partition
- **Publish-subscribe messaging system**
  - Publish & subscribe to *topics*

Kafka Summary

- Solved the problem of dealing with continuous data streams
- Solves the scaling problem by using partitioned logs
- Supports both single queue & publish-subscribe models
- Message ordering is guaranteed per-partition only
- Well-used, proven performance

  Activision, AirBnB, Tinder, Pinterest, Uber, Netflix, LinkedIn, Microsoft, many banks, …

  See https://kafka.apache.org/powered-by

The End

Zookeeper

Kafka uses (required) Apache ZooKeeper for coordination

ZooKeeper ≈ Google Chubby

- Getting heartbeats from brokers
- Leader election
- Configuring replication settings
- Tracking members of cluster
- Etc.

Producers

- Use it to find partitions for a topic

Consumers

- Use it to track the current index # (offset) of the next message in each partition they're reading

Since April 2021, Kafka can be configured to run without ZooKeeper

- Added support for an internal Raft quorum (reliable log replication)
- Metadata can now be stored inside Kafka as a log
  - Internal topic called @metadata
  - Replicated via Raft
  - Brokers can get updates by reading the tail of this log

Colors

- Text goes here – link – followed link
- Here is some callout text … and in blue
- Here is some green callout text

Link color

Followed Link color

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