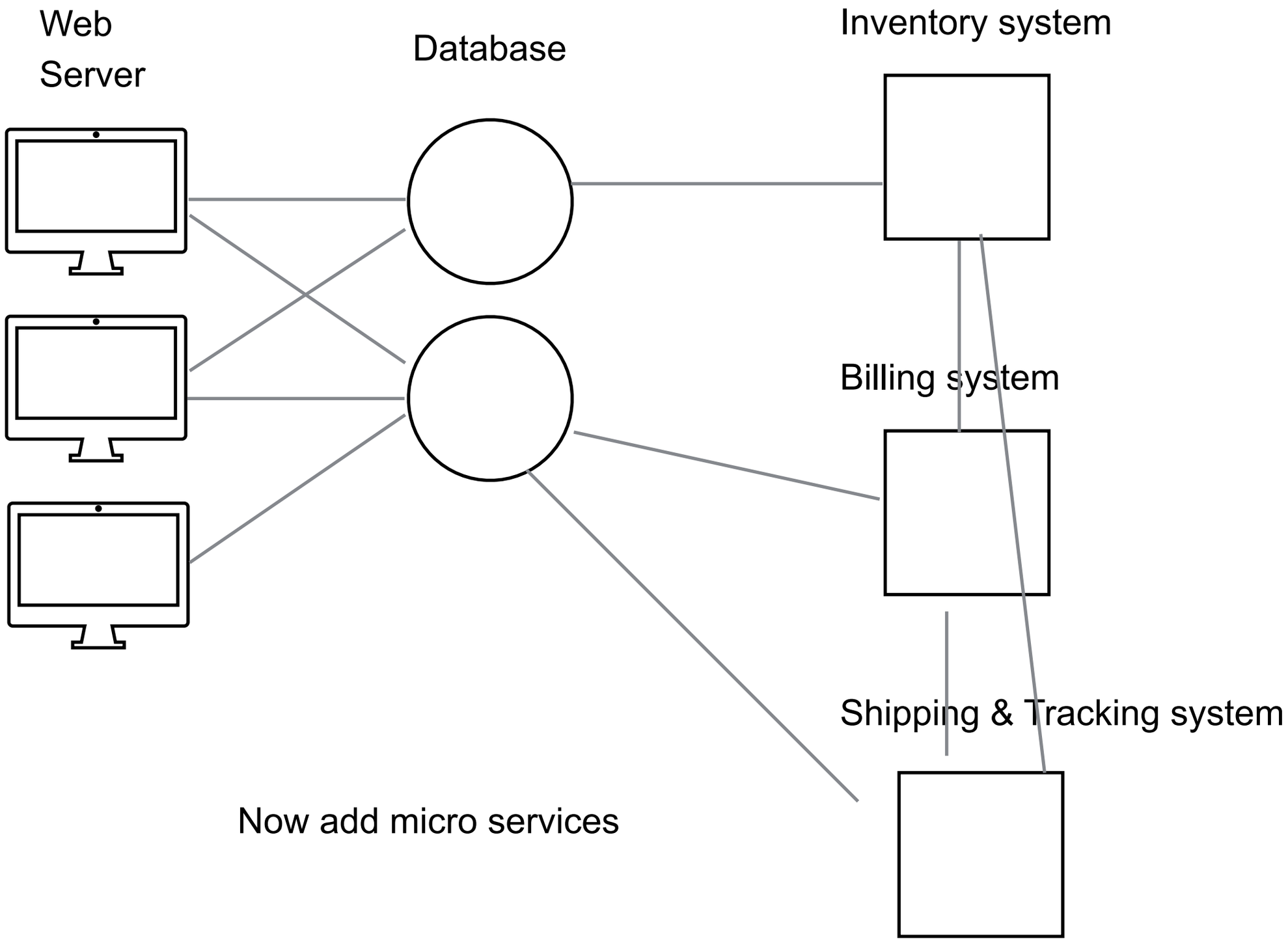
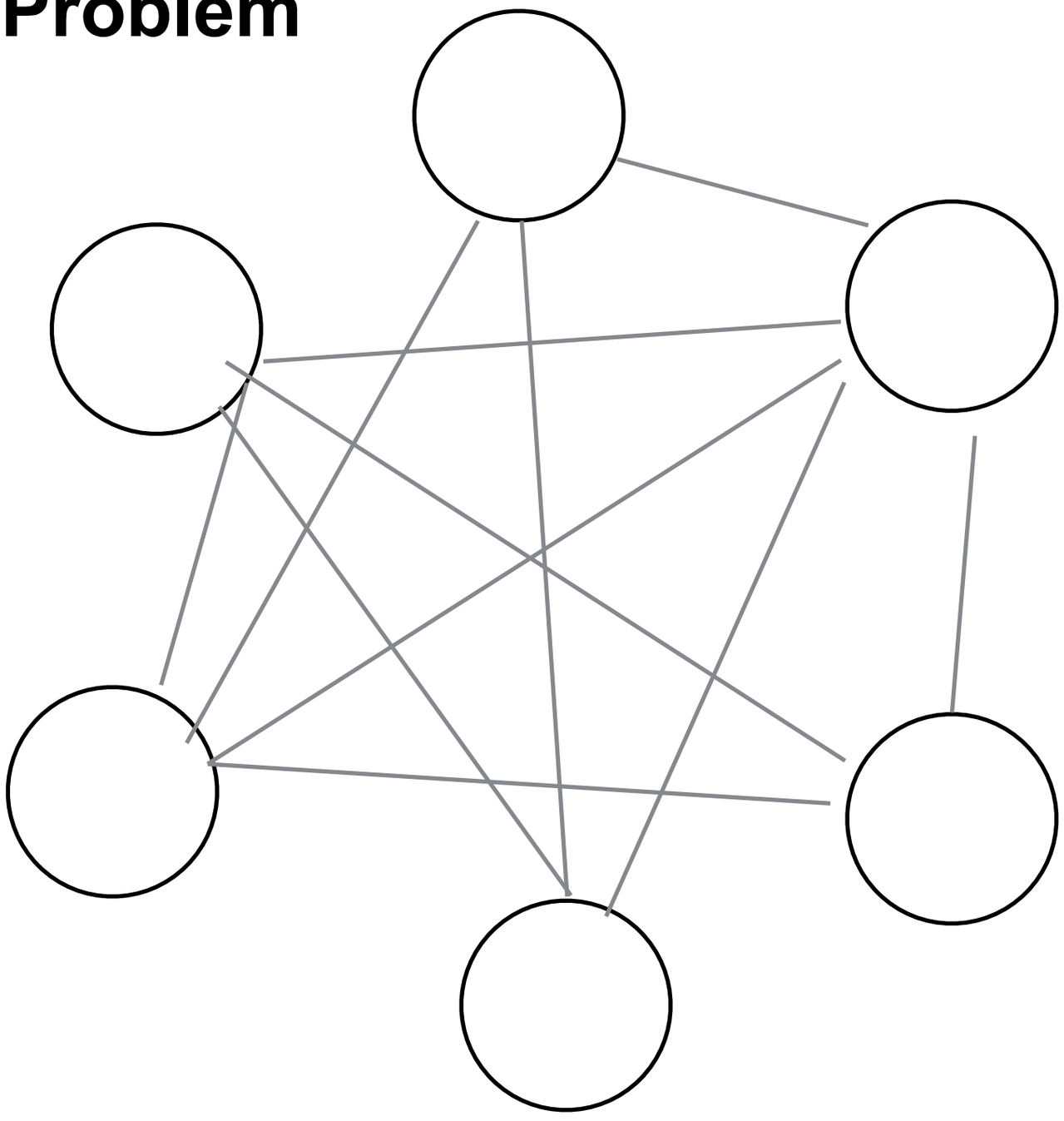
CS 696 Intro to Big Data: Tools and Methods
Fall Semester, 2019
Doc 20 Kafka
Apr 18, 2019

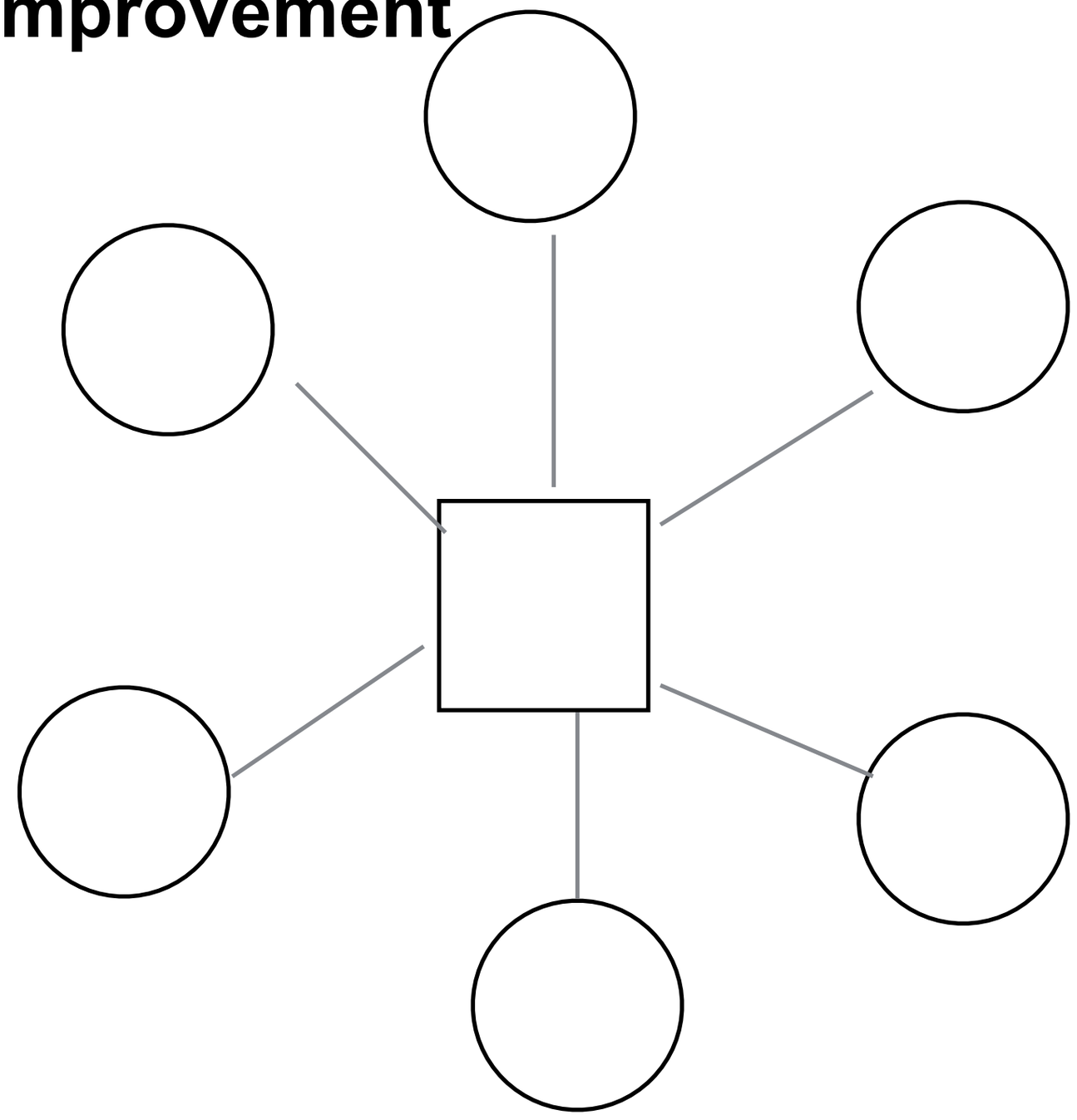
The Problem


Web
Server
Database
Inventory system
Billing system
Shipping & Tracking system
Now add micro services

The Problem



An Improvement



The Log

What every software engineer should know about real-time data's unifying abstraction

https://engineering.linkedin.com/distributed-systems/log-what-every-software-engineer-should-know-about-real-time-datas-unifying

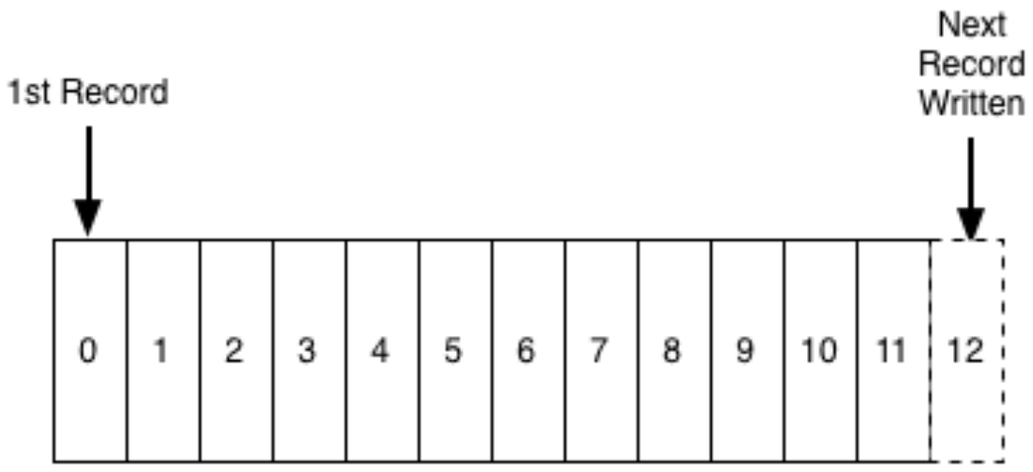
http://tinyurl.com/qc43s5j

Jay Kreps

Lead developer of Kafka

Why logs are the basic data structure for distributed computing

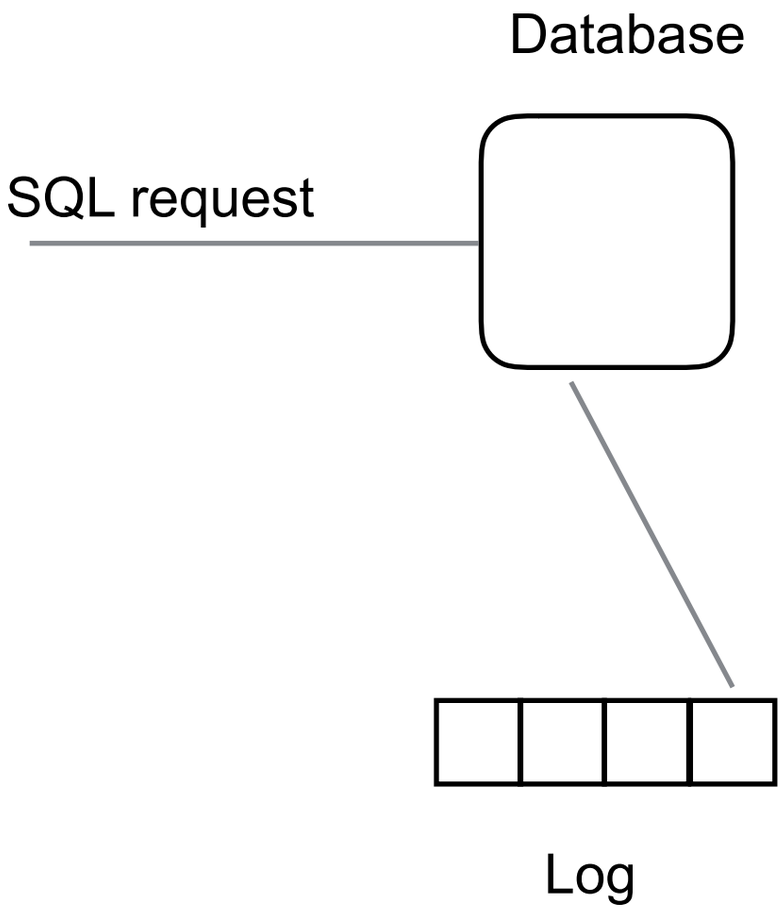
What Is a Log?



Sequence number becomes timestamp

Databases and Logs

How to make actions ACID



Log each operation

Use the log to recover past state

Physical logging

Log the state of the row that is changing

Logical logging

Log the SQL statement

The log contains Database History

With a complete log file we can

Recreate the current state of the database

Recreate the database for any time in the past

Used by in-memory databases

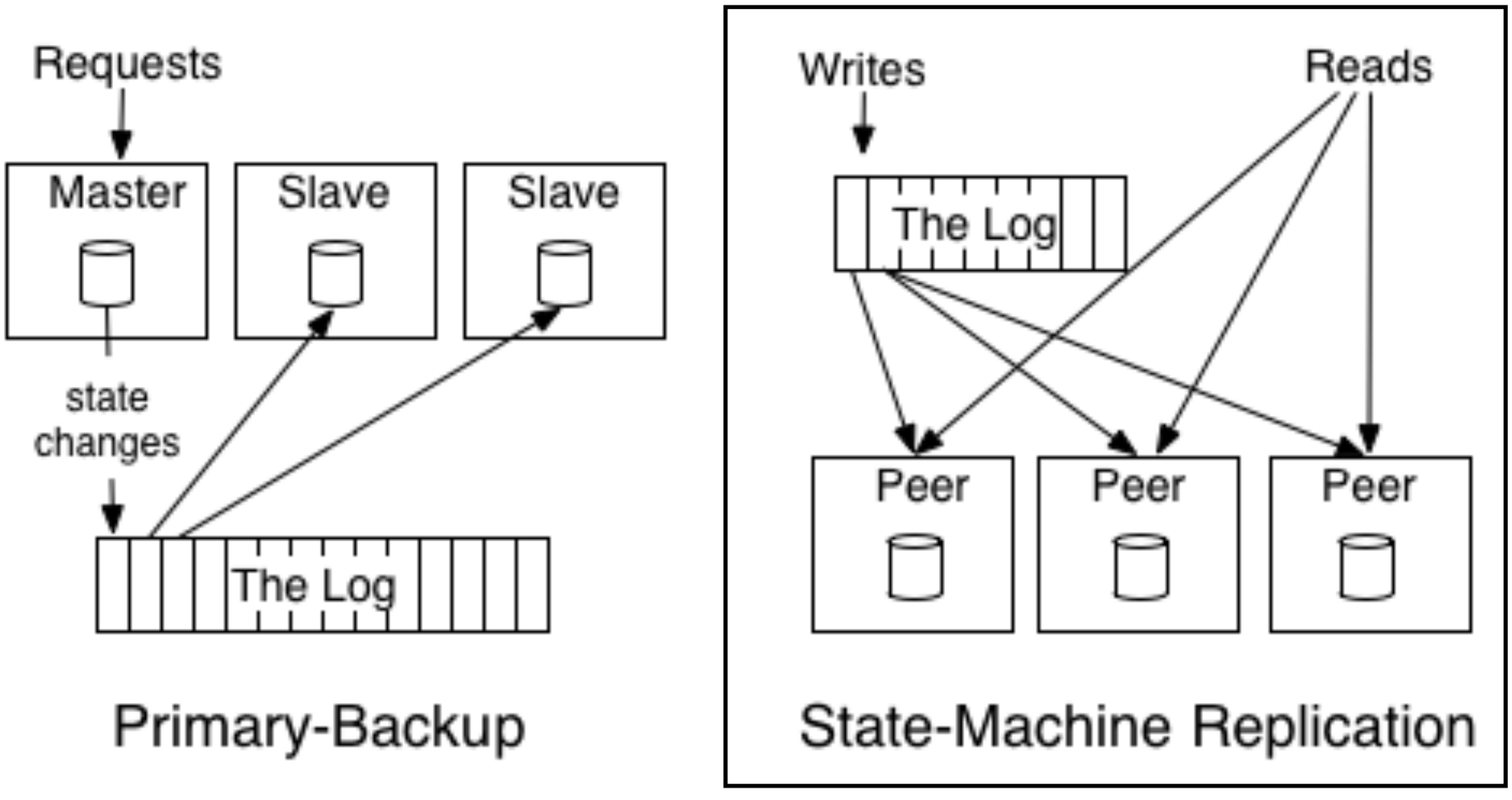
Keep current state of tables in memory

Each write operation is logged

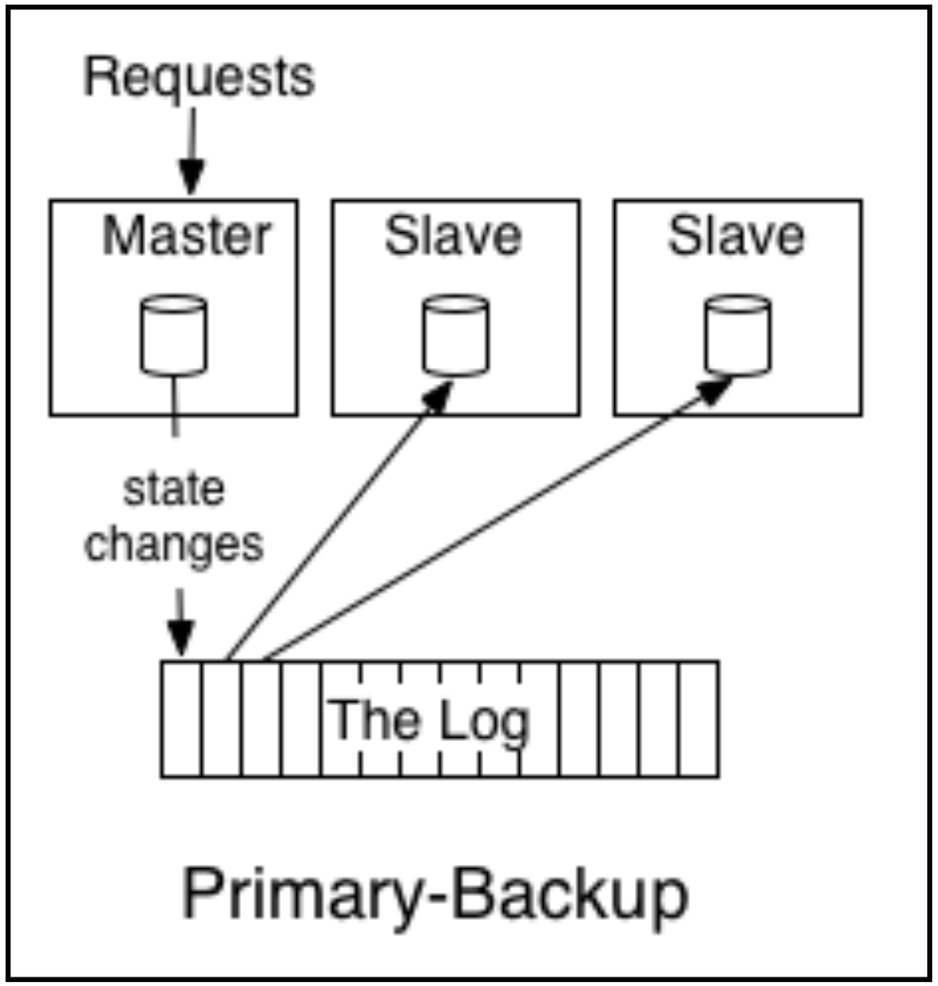
To restart database replay log file

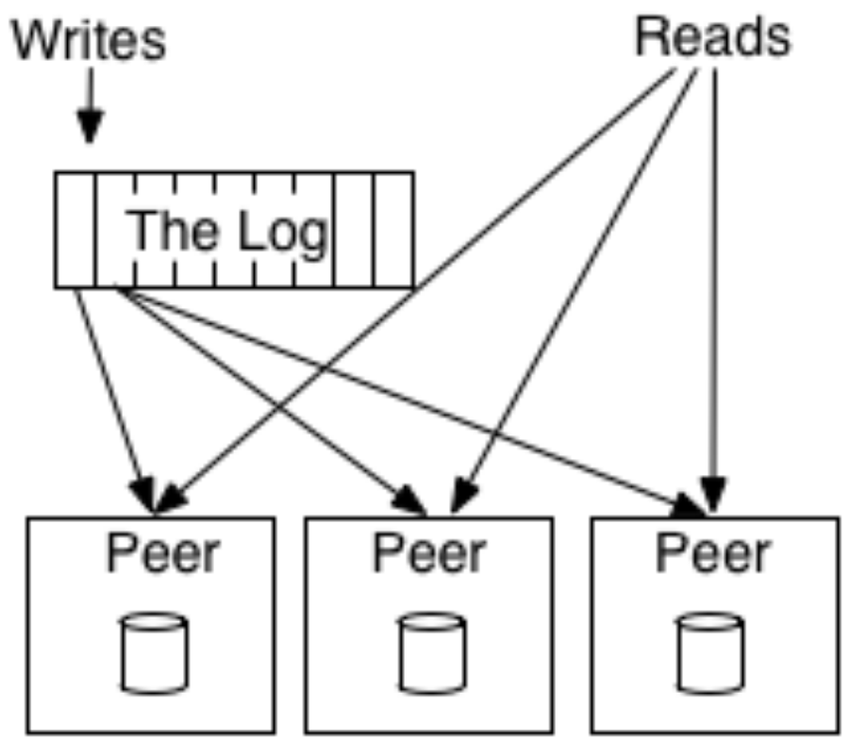
Replicating Databases

We can use the log to replicate the database

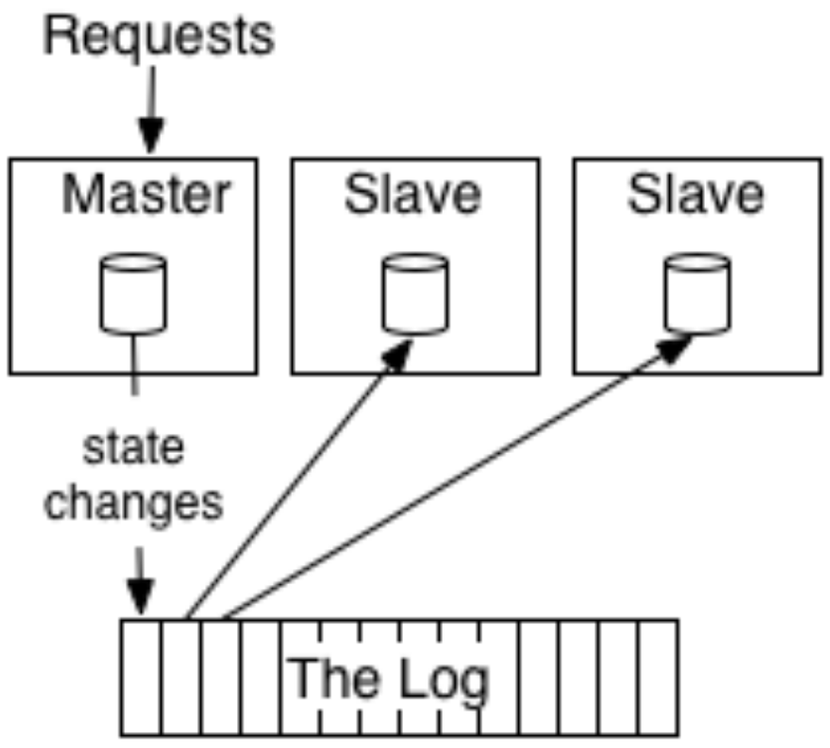


Inverting the Structure

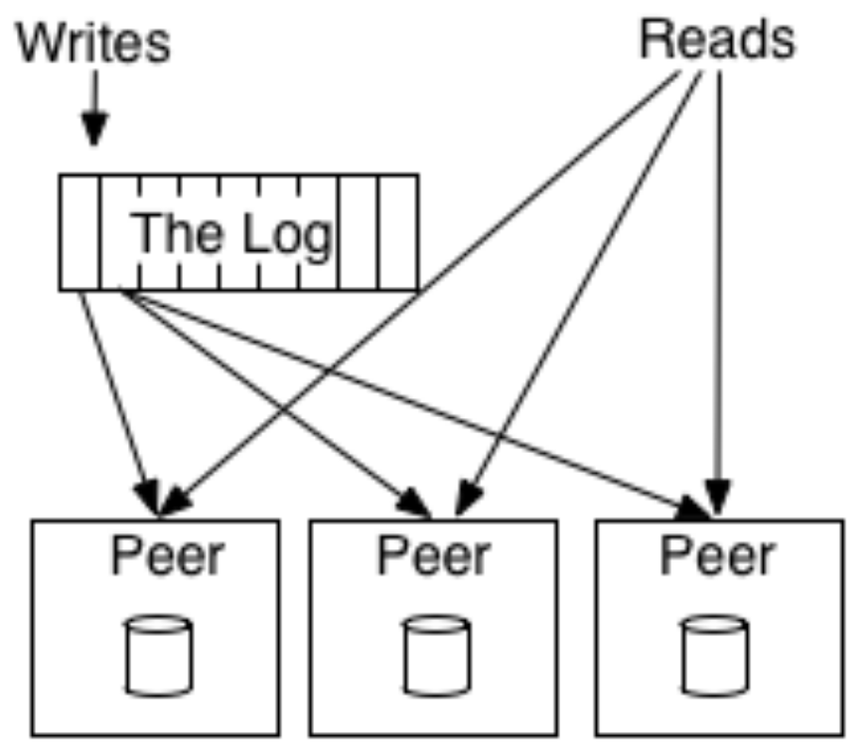




Distributed Systems & Replication

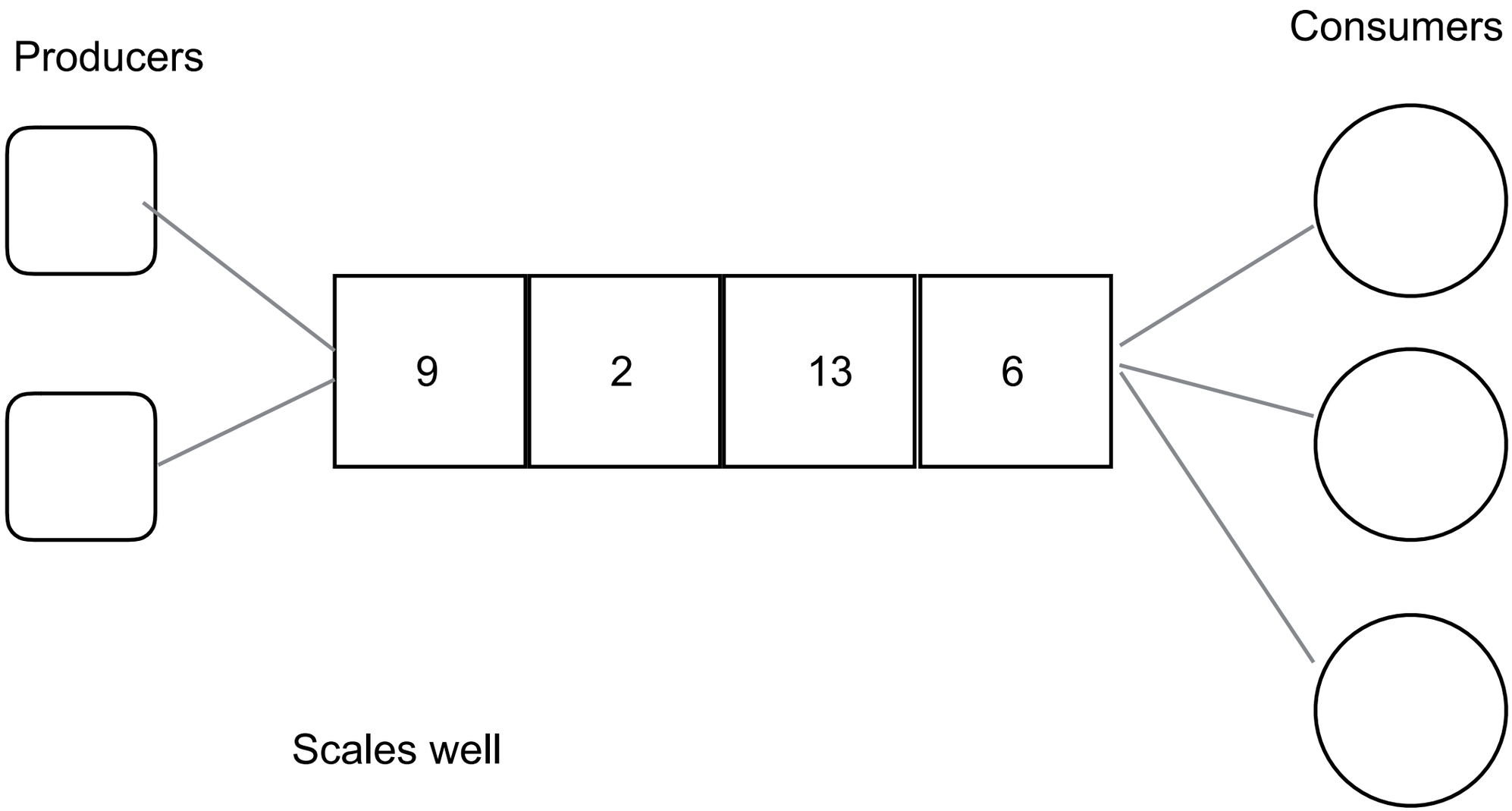


Primary-Backup



State-Machine Replication

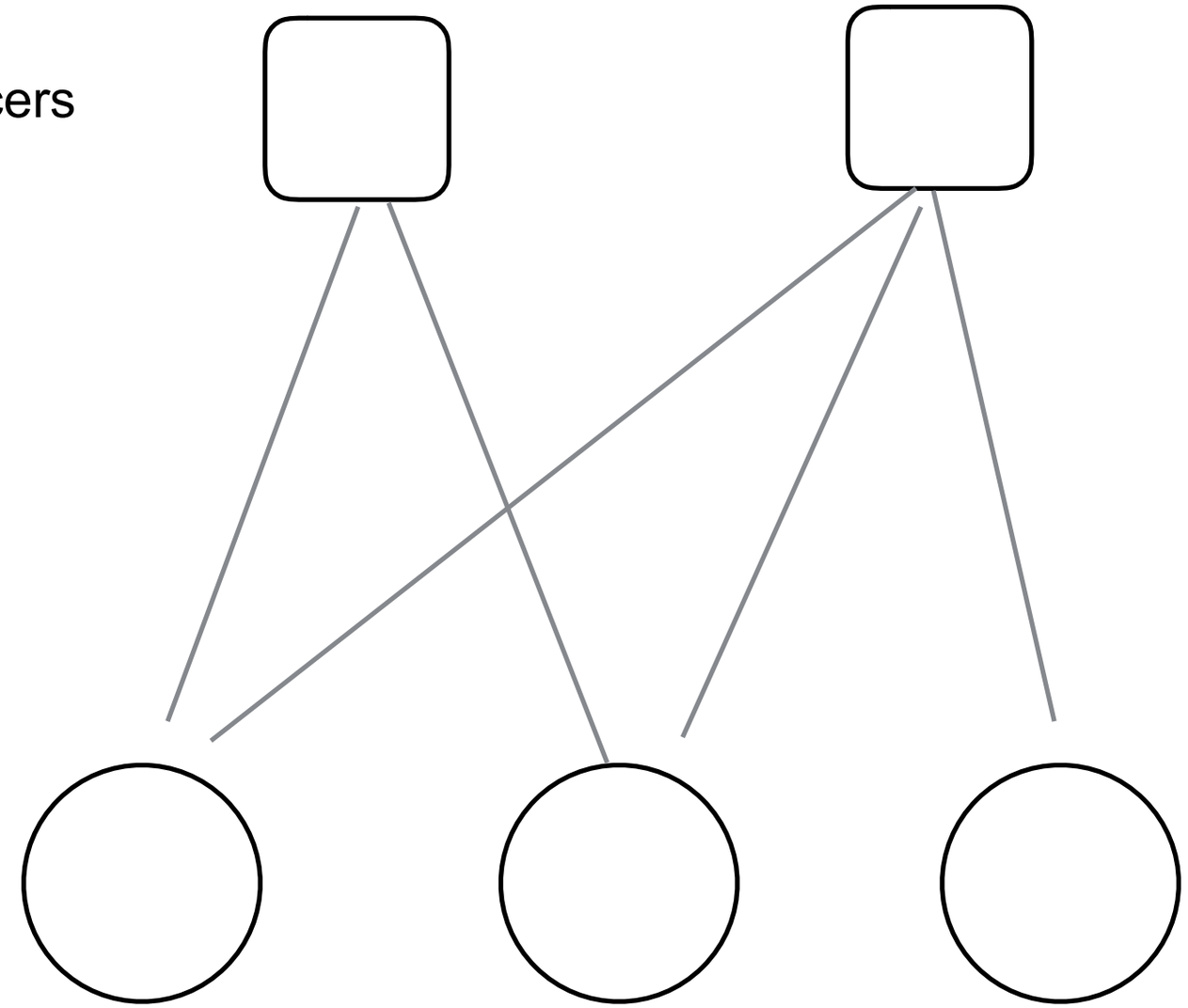
Message System - Queue



Scales well

No multi subscribers - once read data is gone

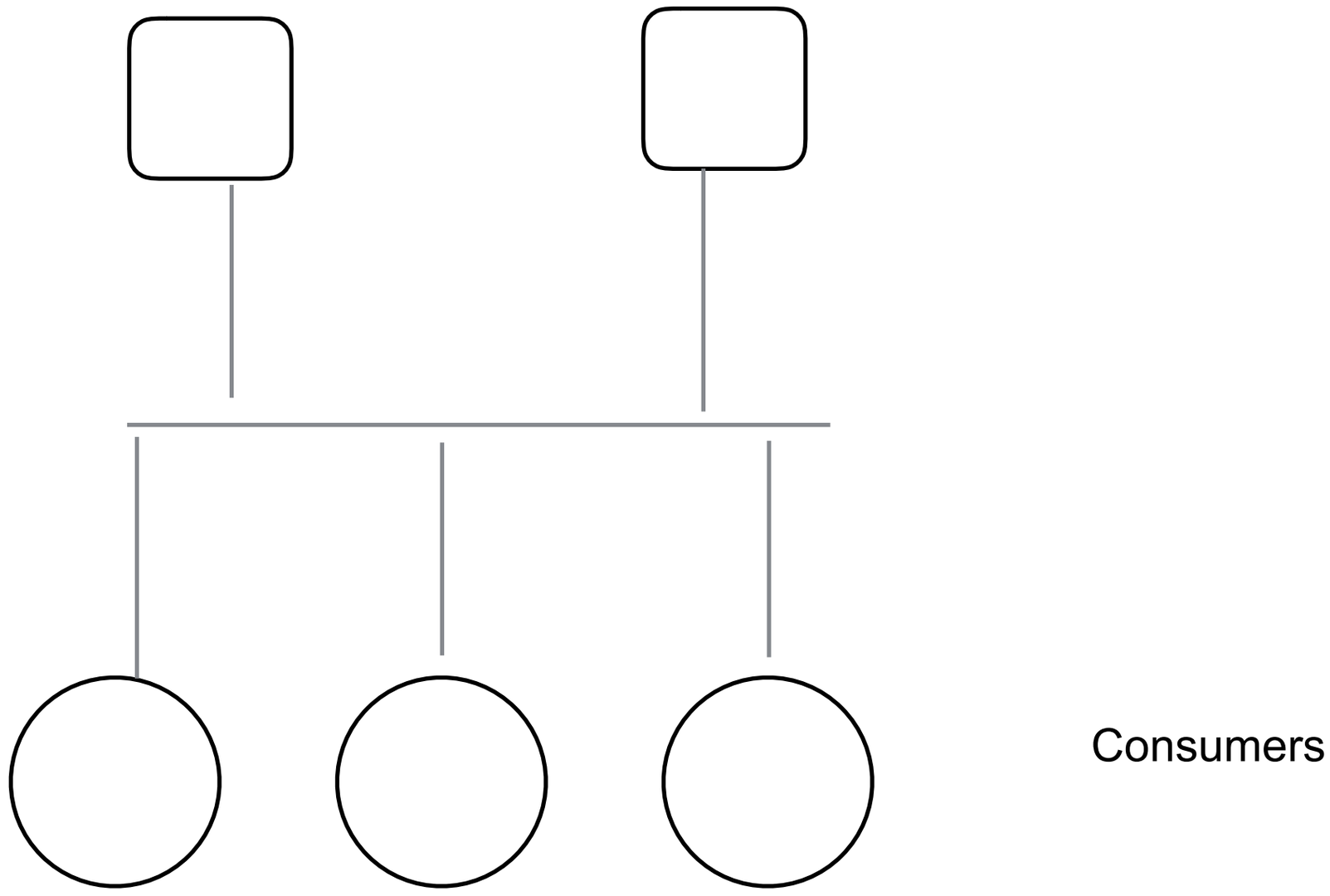
Message System Publish-Subscribe/Broadcast



Multi subscribers

Does not scale

Message System Publish-Subscribe/Broadcast



Multi subscribers

Does not scale

Message System Issues

Failure

Multi-machine
- Load balancing
- Redundancy

Basic Messaging System Issue

How to handle failure

- Publisher fails
- Consumer fails
- Messenger node fails
- Messenger system fails

Message Delivery Semantics

At most once

Messages may be lost but are never redelivered

At least once

Messages are never lost but may be redelivered

Exactly once

What you want

Each message is delivered once and only once

Apache Kafka

Unified, high-throughput, low-latency platform for handling real-time data feeds

Started at LinkedIn

Named after Franz Kafka - author
- Kafka is a writing system
- Lead developer liked Kafka's works

Developers left LinkIn formed Confluent

First release Jan 2011

Version 1.0 Nov 1, 2017

Few Users of Apache Kafka

Cisco Systems

eBay

IPinYou

Netflix

- 36 Kafka clusters
- 700 billion messages per day
- Good article on problems running Kafka on AWS

The New York Times

- Publish content to applications & system to make it available to readers

Spotify

- Used to send logs from all hosts to Hadoop cluster
- Reduced transfer time from 4 hours to 10 seconds

Uber

Walmart

Yelp

Related Tools

Apache ZooKeeper

Distributed hierarchical key-value store

KSQL

Streaming SQL for Apache Kafka

Kafka Versions

1.0.0
  Nov 1, 2017

0.11.0.0
  June 2017
  Guaranteed delivery

0.10.0.0
  May 2016
  Streams API

1.0.0

Improved Streams API

Better metrics on Kafka performance

Supports Java 9
  Faster encryption

Tolerates disk failure better
  JBOD broker tolerates one disk failure

Improved throughput on transactions

Kafka - Key Capabilities

Publish and subscribe to streams of records

Message queue or enterprise messaging system

Store streams of records in a fault-tolerant way

Process streams of records as they occur

Kafka is run as a cluster on one or more servers

The Kafka cluster stores streams of records in categories called topics

Each record consists of a key, a value, and a timestamp

Core API

Producer

Allow an application to publish stream of records to 1 or more topics

Consumer

Allow an application to subscribe to 1 or more topics and read stream of records

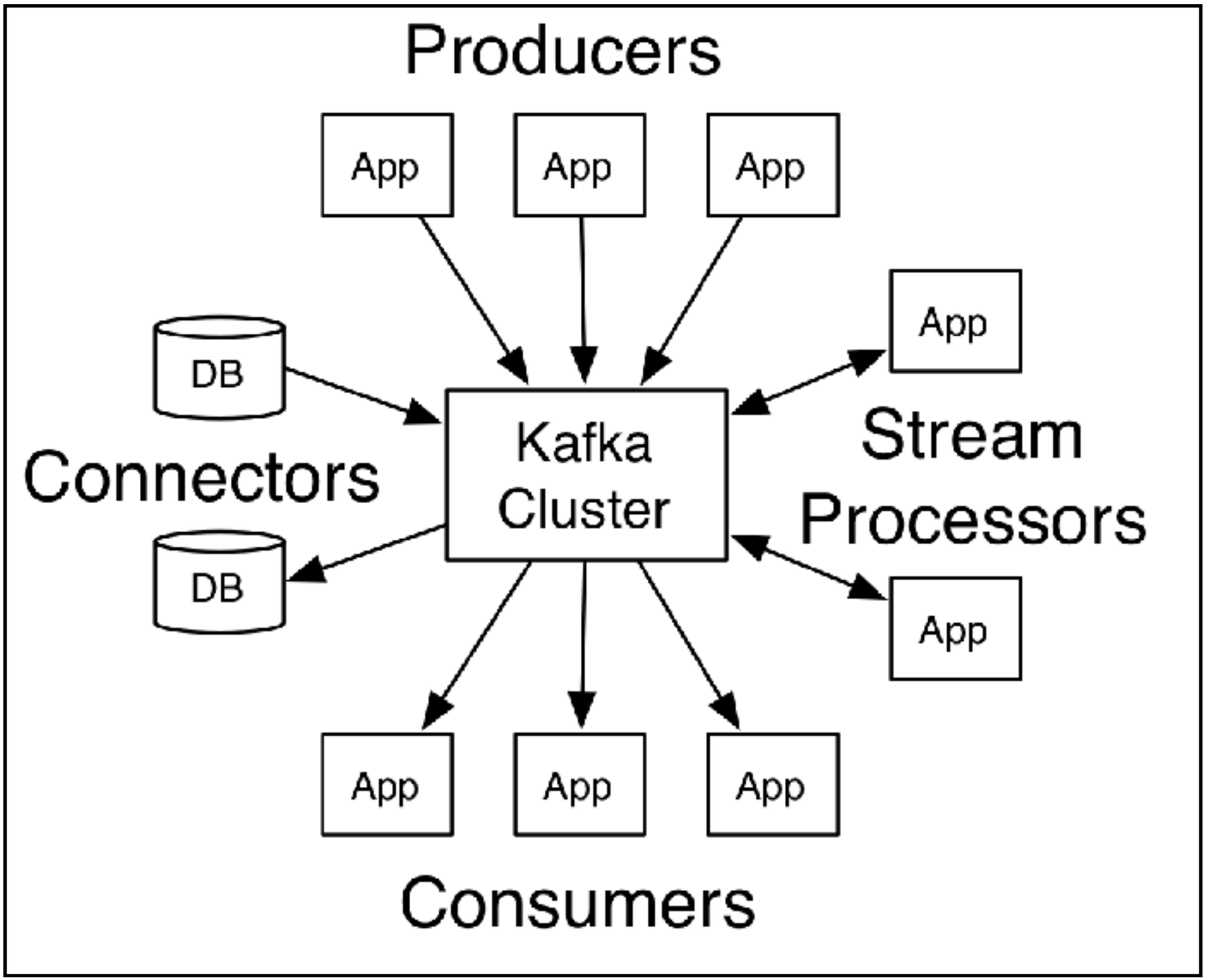
Streams

An application consume an input stream and produce an output stream

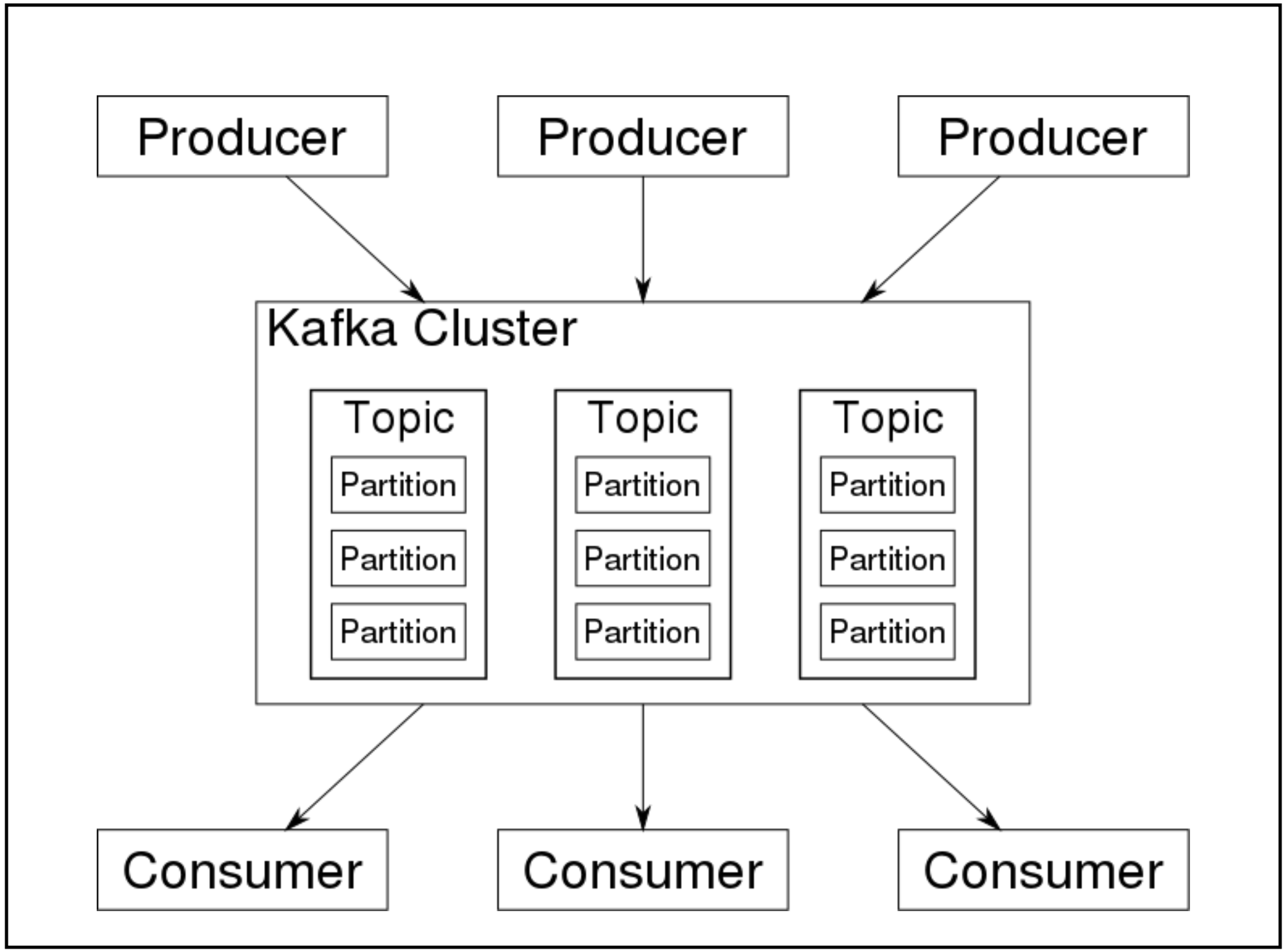
Connector

Producer or consumer connect Kafka topic to existing data systems

Connect to database could capture every change to a table


Producers
App
App
App
DB
Kafka
Cluster
App
Stream
Processors
Connectors
DB
App
App
App
App
App
Consumers

Kafka - Topic, Partitions, Logs



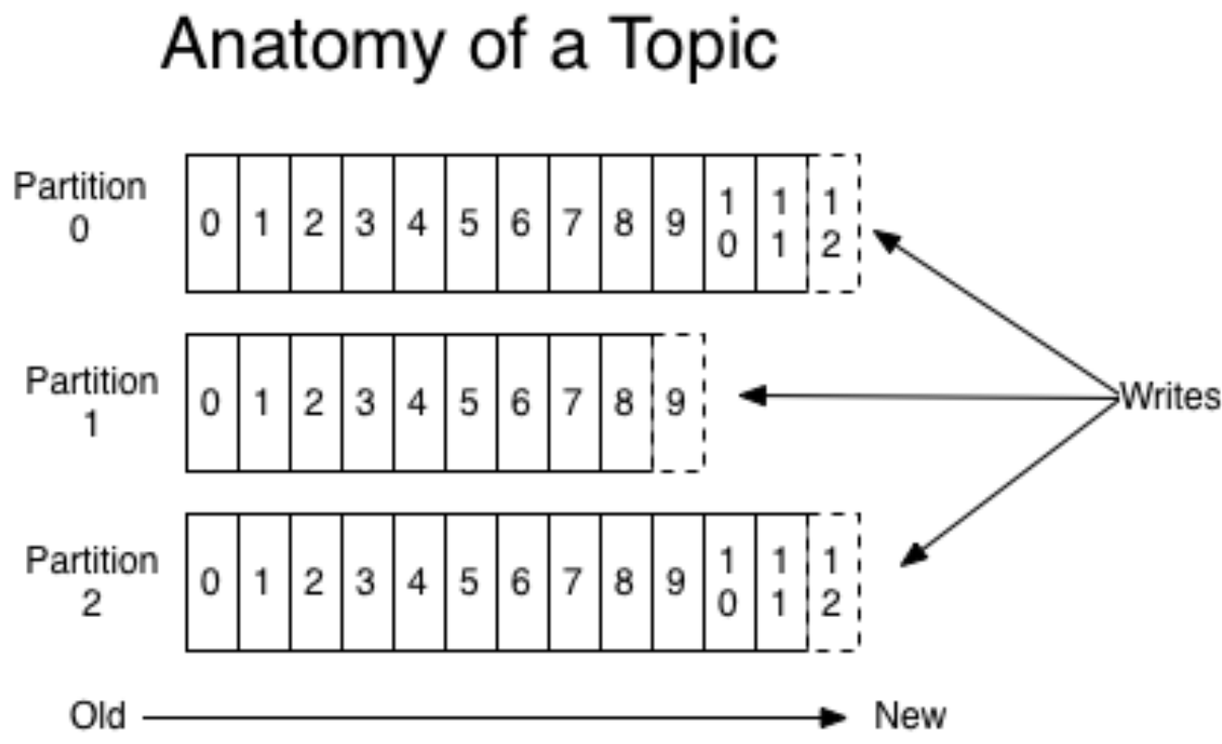
Topics, Partitions, Logs

Topic

- A category for a stream of records
- Can have 0, 1, or many consumers subscribe to it
- Can have multiple partitions

Partition

- Log of records for a topic
- Stored on disk
- Records are given sequential id
- Each partition on different machine
- Each partition replicated



Retaining records

Records are retained for a fixed time

- Configurable

Records are not deleted after a read

Records are deleted at end of retention period even if not read

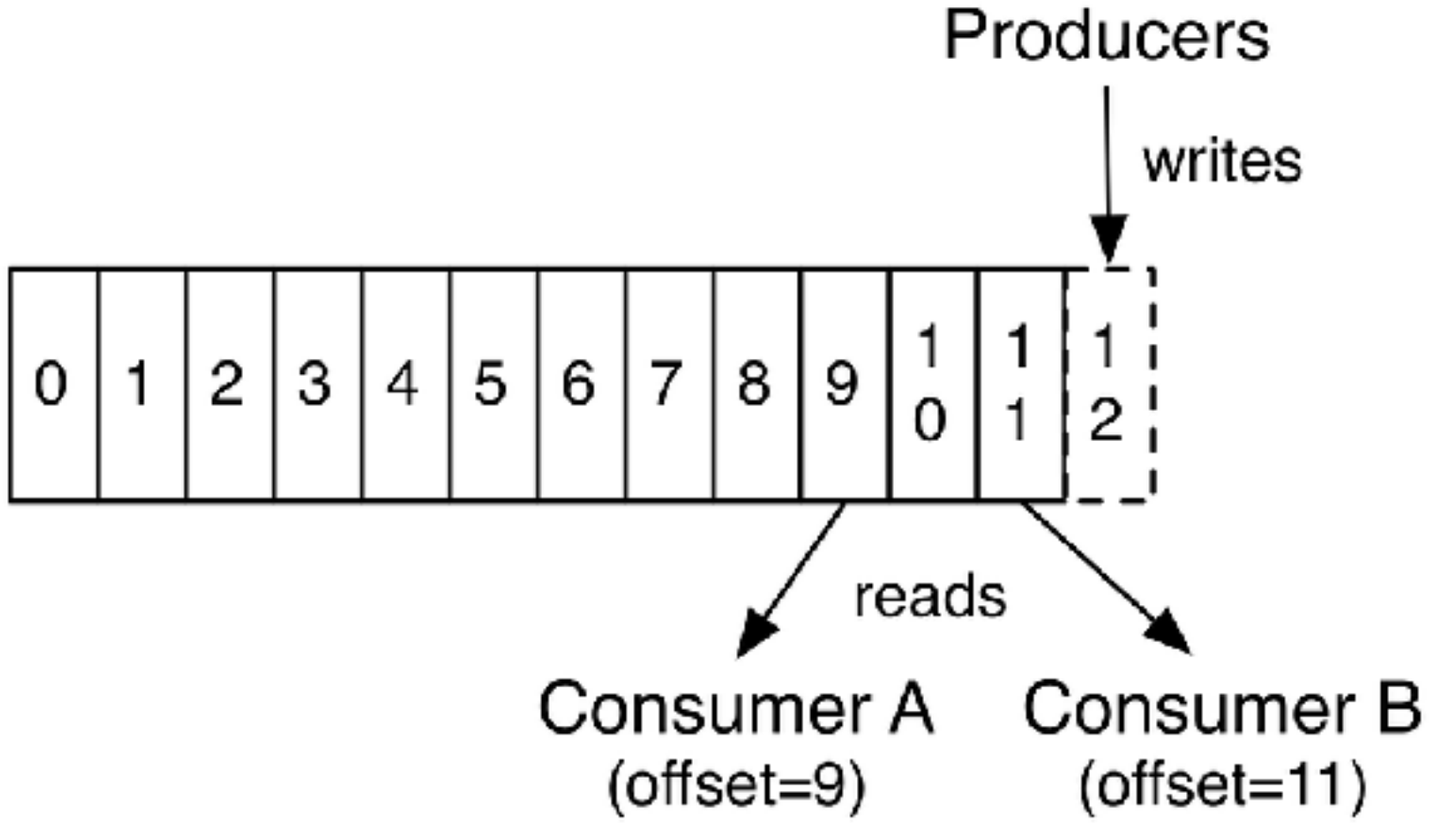
Number of records in single partition

- Does not affect performance
- Single partition must fit on one machine

Consumers & Partitions

Kafka server maintains offset for each consumer
- Last read record
- Makes consumers cheap to support

Consumer controls offset
- Can go back
- Skip ahead



Distribution of Partitions

Each Kafka server handles a share of partitions
  Typically there are many topics

Each partition
  Replicated on multiple machines
  One machine is leader of partition
  Others are followers

Each machine is leader for some partitions

When leader fails follower becomes leader

Producers

Publish data to topics of their choice

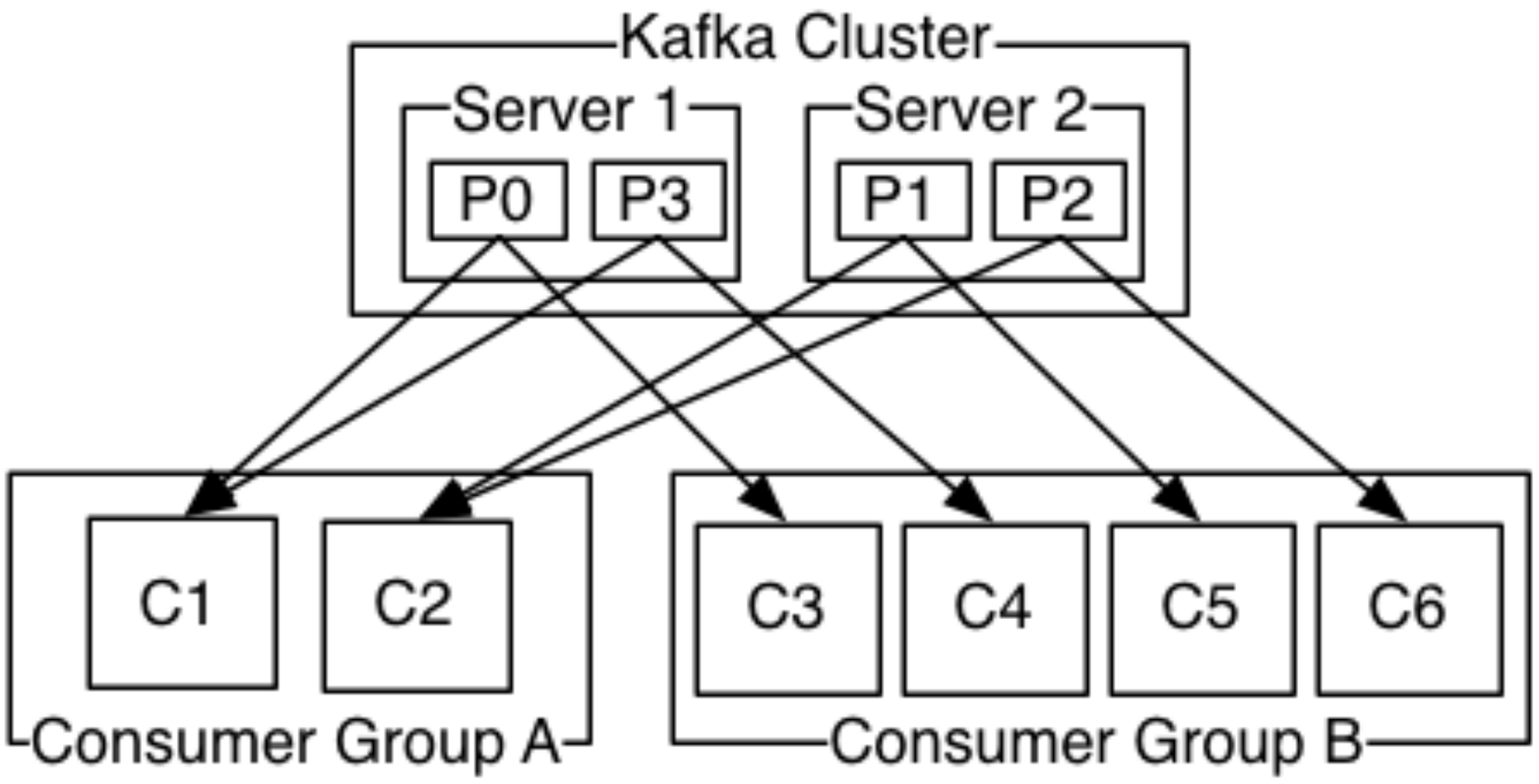
Producer chooses with partition to write to

- Round robin
- Select by key

Consumers

Consumers have a consumer group name

Each record in a topic is delivered to one consumer in each subscribing consumer group



Guarantees

Topic partition appends messages from same producer in the order they are sent

A consumer instance sees records in the order they are stored in partition log

For a topic with replication factor N,
we will tolerate up to N-1 server failures without losing any records committed to the log

What does not happen

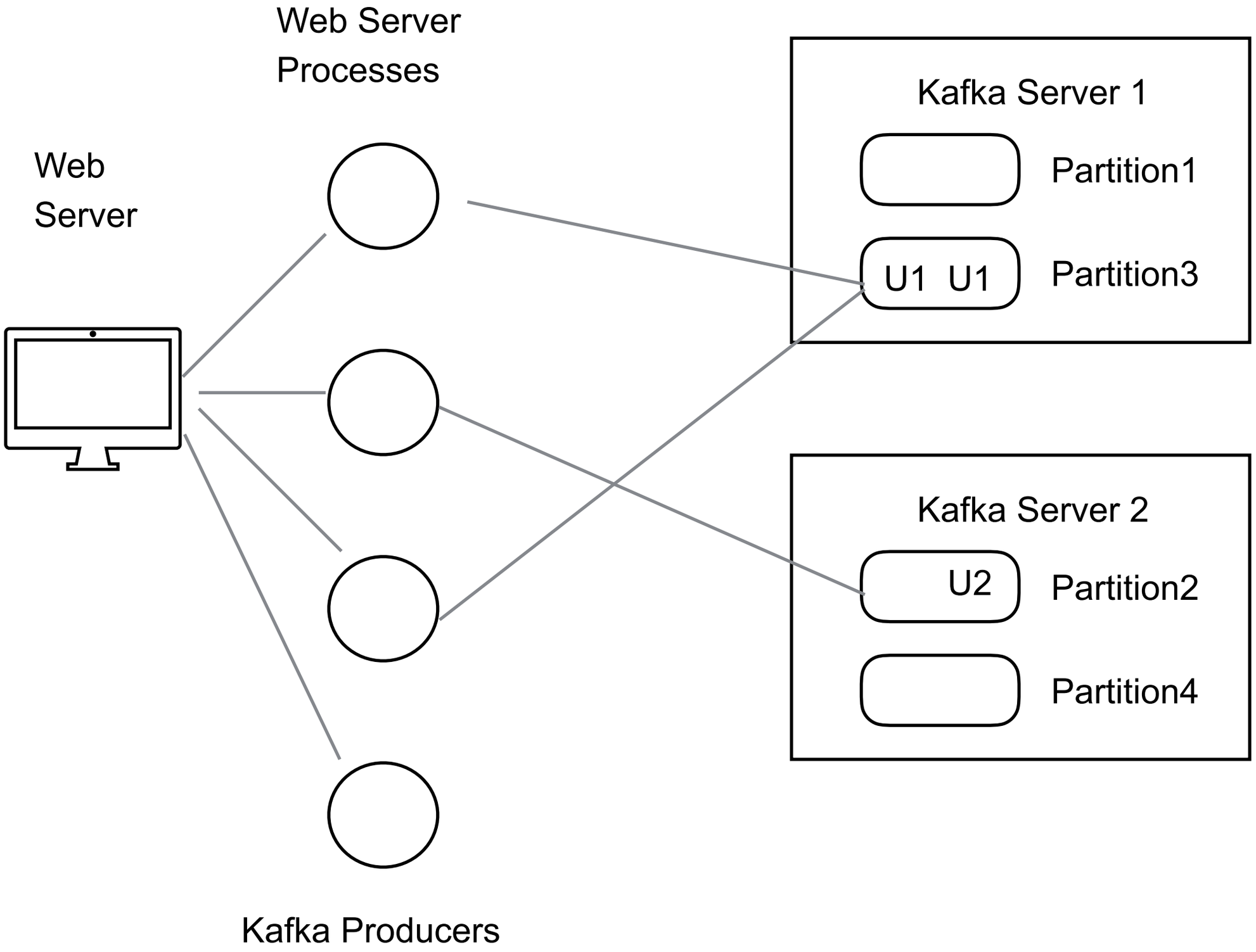
Individual partitions are ordered by when messages arrive

There is no order kept between partitions in the same topic

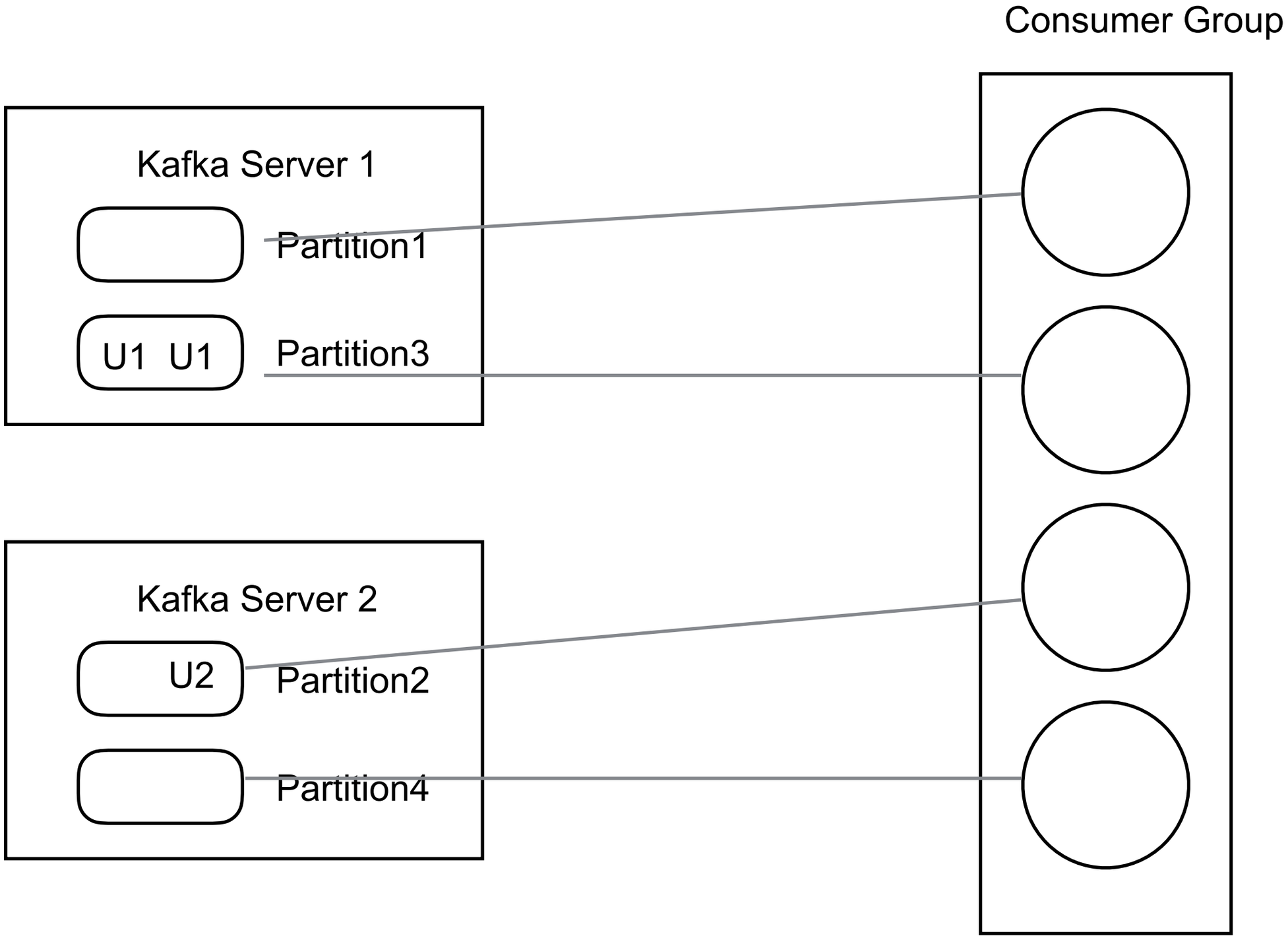
Producer
Sends M1 to partition A
Then send M2 to partition B in same topic
Kafka does keep track that M1 arrived first
Partition A and B could be on different machines

Per-partition ordering + the ability to partition data by key is sufficient for most applications

Example - Logging User Web Activity



Example - Logging User Web Activity



If Need Strict Ordering of Messages

Use one partition for the topic

Means only one client per consumer group on that topic

Kafka Performance

On three cheap machines

http://tinyurl.com/ng2h9uh

Setup

6 machines

Intel Xeon 2.5 GHz processor with six cores
Six 7200 RPM SATA drives
32GB of RAM
1Gb Ethernet

Kafka cluster - 3 machines
Zookeeper - 1 machine
Generating load - 3 machines

Test uses 100 byte messages

6 partitions

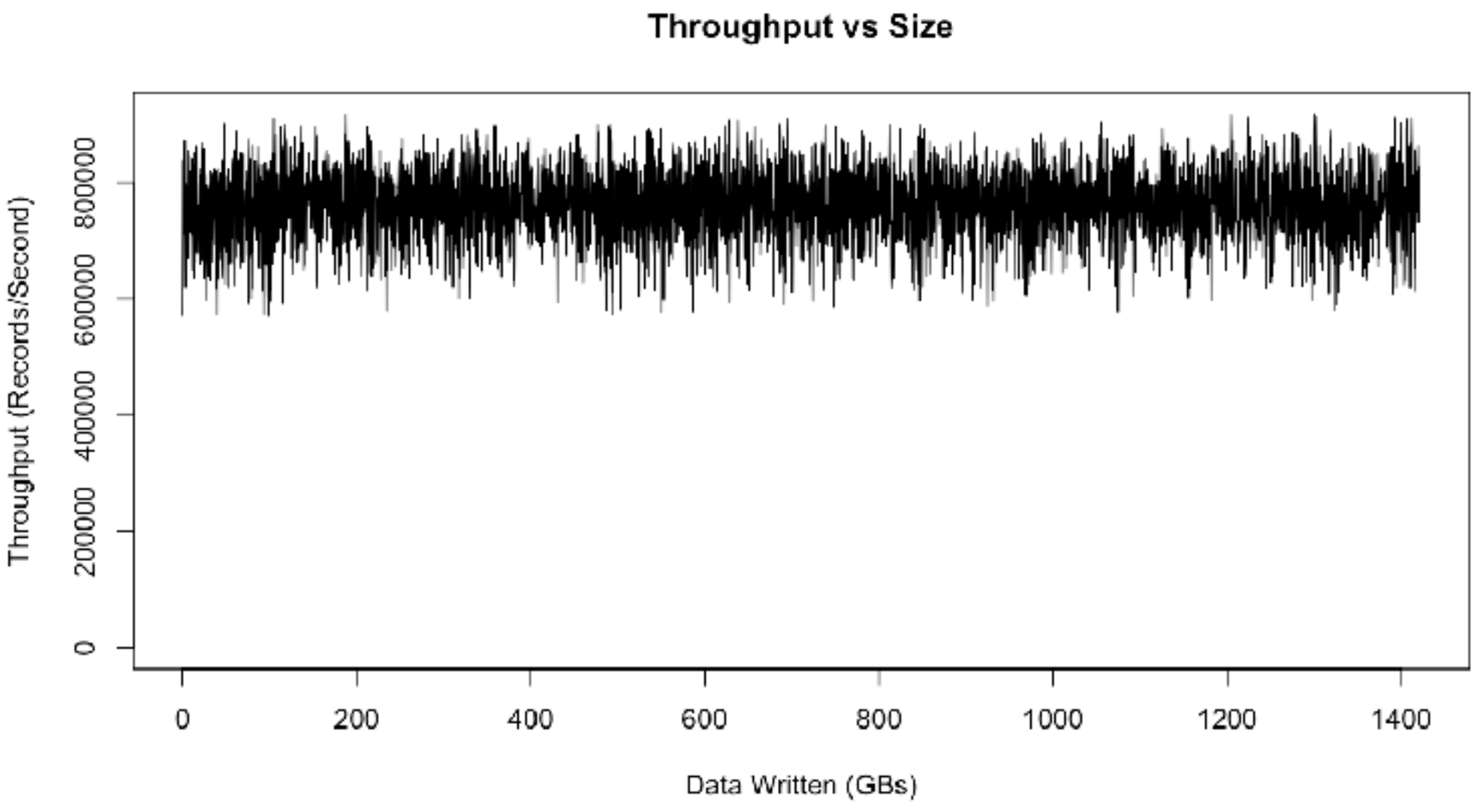
Producer Throughput

	Records/Second	MB/sec
1 producer, no replication of partition	821,557	78.3
1 producer, 3 async replication	786,980	75.1
1 producer, 3 sync replication	421,823	40.2
3 producers, 3 async replication	2,025,032	193.0

7,290,115,200 Records/Hour

Producer Throughput Versus Stored Data

Does the amount of stored data affect performance?



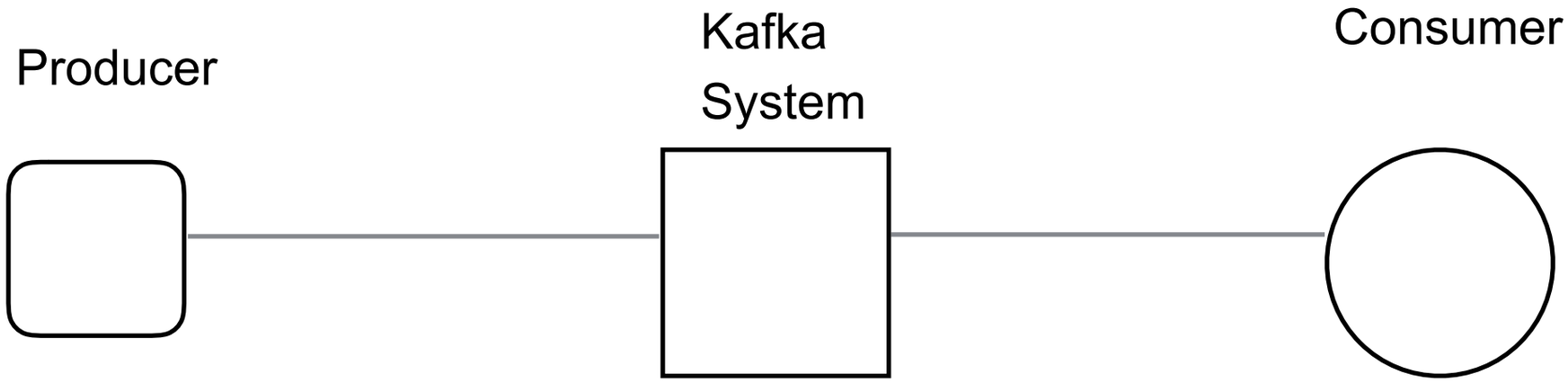
Persisting messages is O(1)

Consumer Throughput

	Records/Second	MB/sec
1 consumer	940,521	89.7
3 consumers - same topic	2,615,968	249.5

6 partitions, 3x async replicated

End-to-end Latency



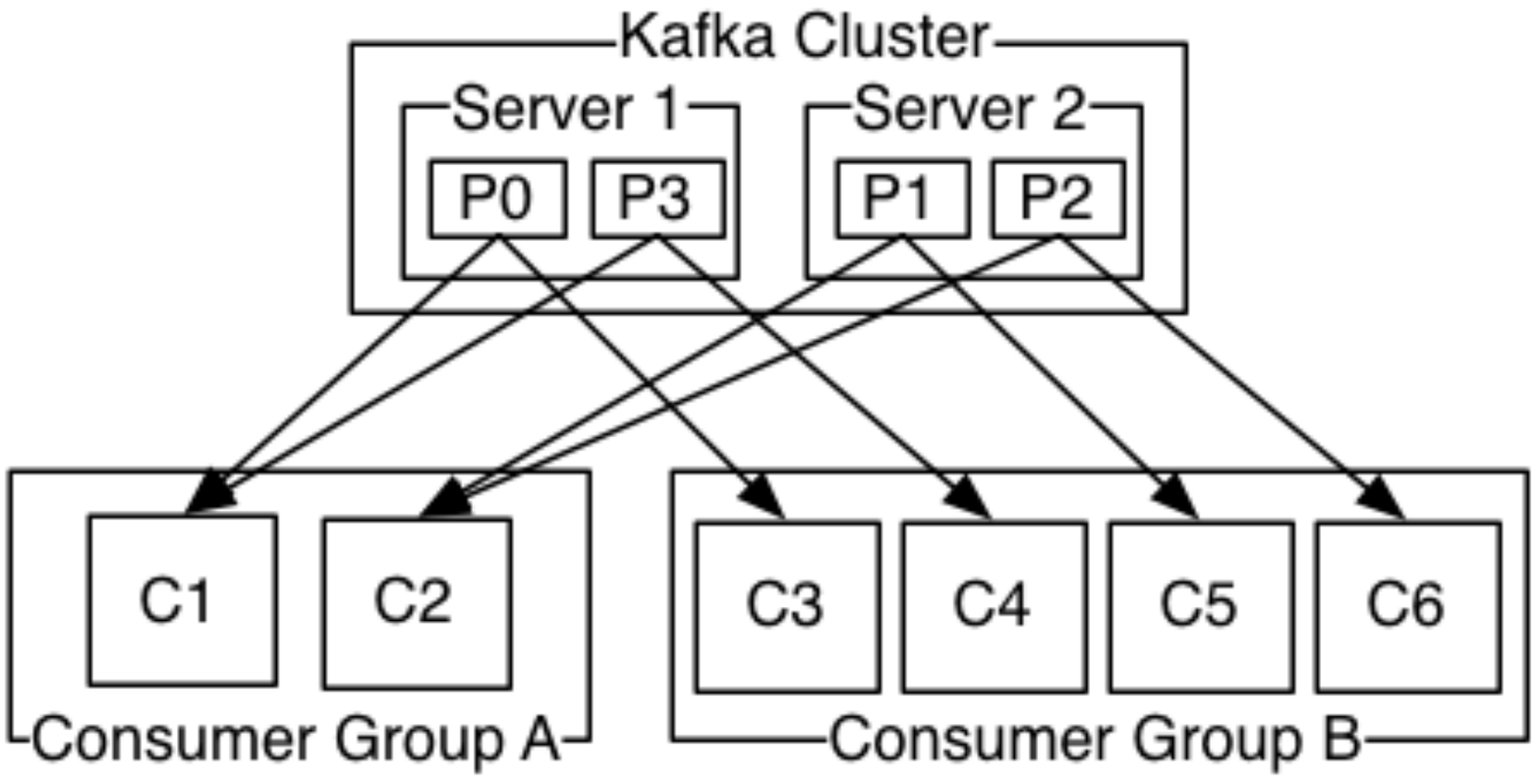
2ms - median

3ms - 99th percentile

14ms - 99.9 percentile

What Makes Kafka Fast - Partitions

Allows concurrent writes & reads on same topic



What Makes Kafka Fast - Messages

Messages
- Binary format
- Batched
- Compressed

bit 0~2:
- 0: no compression
- 1: gzip
- 2: snappy
- 3: lz4

Producer convert message into binary

Kafka treats message as bits

Consumer needs to know how to unpack message

Producer supplies schema

Adds schema to ZooKeeper

What Makes Kafka Fast - Use the Filesystem

Linear read/writes are very fast on hard drives
- JBOD configuration six 7200rpm SATA drives 600MB/sec

Modern OS (Linux)
- Heavily optimized
- read-ahead, write-behind
- Will use all free memory for disk cache

JVM
- Memory overhead of objects is high
- Java garbage collection becomes slow as heap data increases

So
- Write data to disk
- Use as little memory as possible
- Let OS use nearly all memory for disk cache
  - 28-30GB cache on 32GB machine

What Makes Kafka Fast - sendfile

Normal path to send a file on network

1 OS copies file Disk -> page cache in kernel space

2 Application copies data: page cache -> user-space

3 Application copies data: user-space -> socket buffer in kernel space

4 OS copies data: socket buffer -> NIC buffer

Using sendfile to send a file on network

1. OS copies file: Disk -> NIC buffer

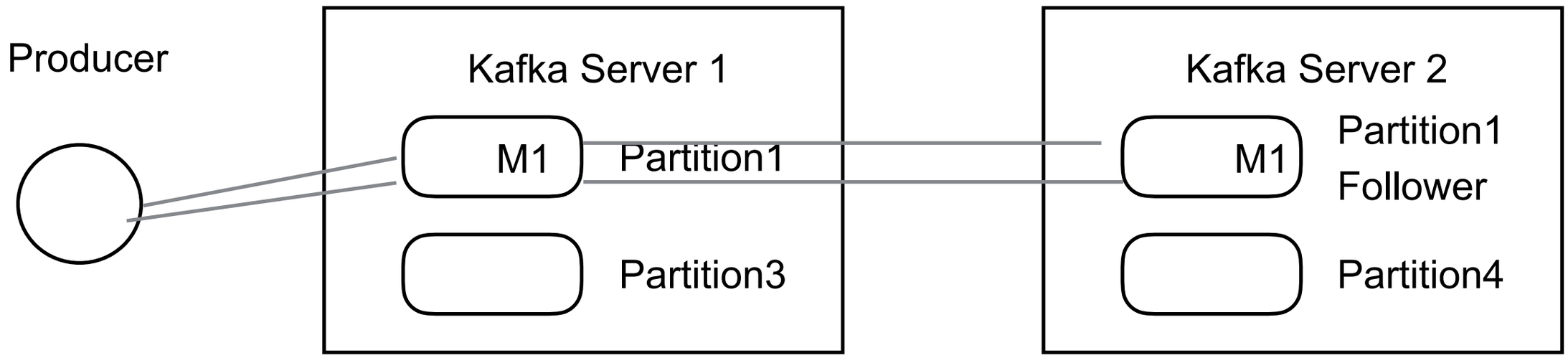
Using OS pagecache + sendfile means when consumers are mostly caught up

Files served from cache

Message Delivery Semantics

How to guarantee delivery producer -> Kafka

When do we consider message delivered?

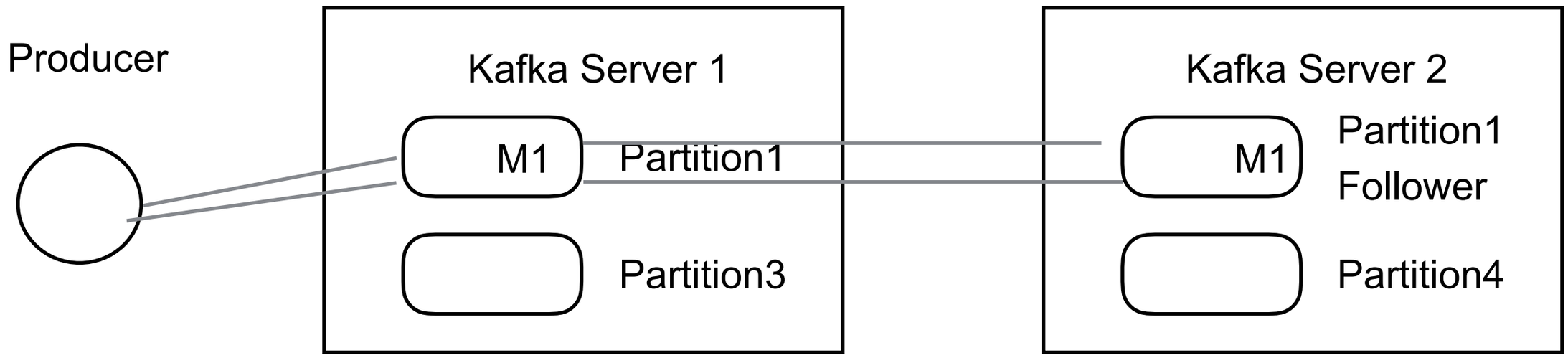


When leader get the message

When all replicated partitions get the message

Message Delivery Semantics

How to guarantee delivery producer -> Kafka



Producer does not know if message was delivered

Producer needs to resend message

Prior to 0.11.0 would create duplicate message in log

Message Delivery Semantics

How to guarantee delivery producer -> Kafka

Idempotent Delivery - Kafka 0.11.0

Each producer
- Has an ID
- Adds sequence number to messages

Kafka server checks for duplicates

Transactions - Kafka 0.11.0
- Producer can send messages to multiple topics
- All either succeed or all fail

Message Delivery Semantics

How to guarantee delivery producer -> Kafka

Producer can specify

- Be notified when leader and all followers have message
- Be notified when leader has message
- Provide a time out
- Receive no notifications

Replication

Each partition has a single leader and zero or more followers (slaves)

Followers are consumers of the leader partition

Allows for batch reads

Live or in-sync node

Node maintains its session with ZooKeeper

If follower must not be too far behind leader

replica.lag.time.max.ms

Failed node

One that is not in-sync

When a Leader Dies

In-sync replicas (ISR)

Follower partitions that are caught-up with leader

A machine may handle 1,000's of topics and even more partitions

ZooKeeper maintains the ISR set for each partition

When partition leader fails

Nodes in ISR vote on new leader

Message Delivery Semantics

How to guarantee delivery producer -> Kafka

Producer can specify

- Be notified when leader and all followers have message
- Be notified when leader has message
- Provide a time out
- Receive no notifications

Producer specifies ack parameter

- 0 - no acknowledgement
- 1 - acknowledgement when leader has message
- all (-1) - acknowledgement when all ISR partitions received the message

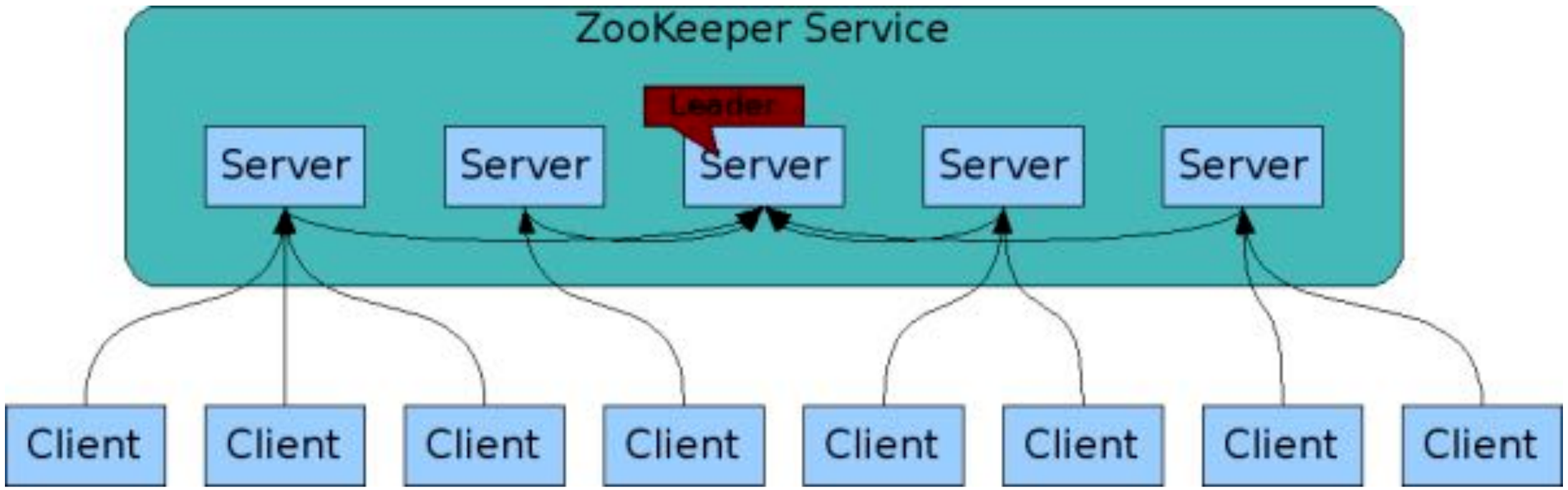
Zookeeper

Because coordinating distributed systems is a Zoo

Distributed hierarchical key-value store

For large distributed systems
- Distributed configuration service,
- Synchronization service,
- Naming registry

Zookeeper


ZooKeeper Service
Leader
Server
Server
Server
Server
Server
Client
Client
Client
Client
Client
Client
Client
Client

Running Kafka

Download and unpack Kafka

In Kafka directory

Start Zookeeper (it comes with Kafka)

```
bin/zookeeper-server-start.sh config/zookeeper.properties
```

Start Kafka Server

```
bin/kafka-server-start.sh config/server.properties
```

Create a topic

```
bin/kafka-topics.sh --create --zookeeper localhost:2181
                    --replication-factor 1 --partitions 1 --topic test
```

You can configure producers to auto-create topics when publish to new topic

Running Kafka

List of topics

```
bin/kafka-topics.sh --list --zookeeper localhost:2181
```

Send some messages

```
bin/kafka-console-producer.sh --broker-list localhost:9092 --topic test
>this is a test
>this is a message
>Hi mom
```

Start a client

```
bin/kafka-console-consumer.sh --bootstrap-server localhost:9092
                              --topic test --from-beginning
this is a test
this is a message
Hi mom
```

Running Kafka

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```

Running Kafka

Setting up a multi-broker cluster

Edit configuration so can run on same machine

cp config/server.properties config/server-1.properties

cp config/server.properties config/server-2.properties

Start the servers

bin/kafka-server-start.sh config/server-1.properties &

bin/kafka-server-start.sh config/server-2.properties &

Running Kafka

Create a new topic with a replication factor of three

```
bin/kafka-topics.sh --create --zookeeper localhost:2181
                    --replication-factor 3
                    --partitions 1
                    --topic my-replicated-topic
```

Get information about topic

```
bin/kafka-topics.sh --describe --zookeeper localhost:2181
                    --topic my-replicated-topic

Topic:my-replicated-topic     PartitionCount:1     ReplicationFactor:3     Configs:
    Topic: my-replicated-topic     Partition: 0     Leader: 1     Replicas: 1,2,0     Isr: 1,2,0
```

In-sync