Kafka Fundamentals

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Your Instructors: Petter Graff

- Serial entrepreneur, architect, consultant, teacher, and sometime CXX
- Owner/Partner of Ballista Technology Group and CTO of Praetexo,
- Architect of Yaktor, a scalable event-driven, agent based rapid development platform
- Teaches classes on:
  - BigData (Hadoop, Spark, HBase, Cassandra, etc.)
  - Computer Science Concepts (Scalability, Architectural Thinking, Design Patterns, OOA&D, etc.)
  - Languages (Java, Scala, C++, JavaScript, ...)
  - And much more...
- Lives in Austin
- O'Reilly author:
  Design Patterns in Java

Ballista Technology Group

- Accelerator for scale-ups, including:
  - Definition of architecture
  - Custom software development
  - Strategic advice to the C-suite
- Consultant, and mentor to many large organizations worldwide
- Big Data and Machine Learning
- Custom training to leading firms worldwide

- http://www.ballista.com
- Solving the Hardest Problems

PRATEXO

- Helping companies move algorithms to the edge
  - Orchestration of edge solution
  - Setup of private clouds
    - On premise
    - On edge computing nodes
  - Swarm computing for ad-hoc collaboration of edge nodes
- Accelerates the move from months to days using a set of cloud deployed tools

2021

Outline

- Introduction to Kafka
- Kafka core concepts
- Producing data to Kafka using the Producer API
- Consuming data from Kafka using the Consumer API
- Kafka Streaming
- Kafka Administration and Integration
- Exactly once delivery, what does that mean?

What is Kafka?

- *"Kafka is a distributed, partitioned, replicated commit log service"*
  - Fault tolerant
  - Near linearly scalable (horizontally)
  - Durable
- Often used as a publish-subscribe messaging system
- Apache project
- Originally developed by LinkedIn

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Kafka History

- Publish/subscribe system with an interface where
  - Publishing is similar to a typical messaging system
  - Subscription divert as it works on batches
  - A storage layer like a log aggregation system

- As of August 2015, LinkedIn produces over one trillion messages and a petabyte of data consumed daily!

- Kafka was released as open source in late 2010 and became an Apache project in 2011

The Name

I thought that since Kafka was a system optimized for writing using a writer's name would make sense. I had taken a lot of lit classes in college and liked Franz Kafka. Plus the name sounded cool for an open source project.

So basically there is not much of a relationship.

Jay Kreps, Lead Developer at LinkedIn

Notable Users

- Cisco Systems
- Netflix
- PayPal
- Spotify
- Uber
- HubSpot
- Betfair
- Shopify

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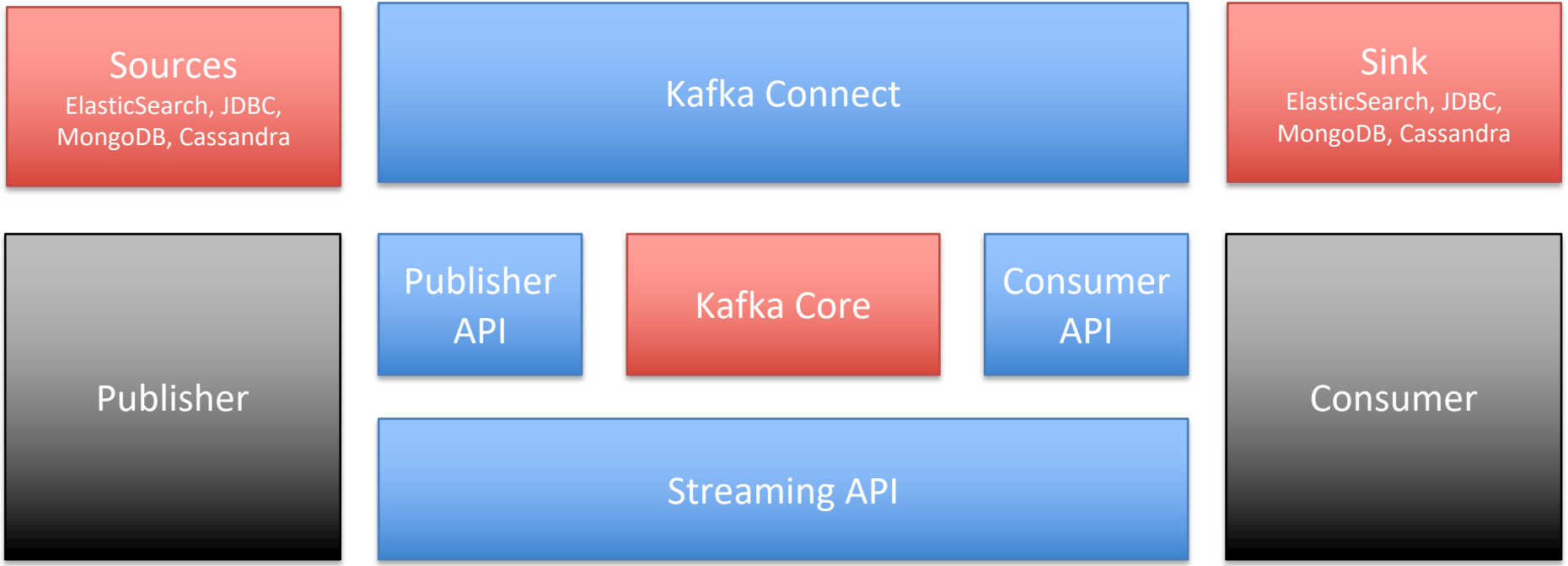
Kafka API's



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Use Cases

- Messaging
- Website Activity Tracking
- Metrics
- Log Aggregation
- Stream Processing
- Event Sourcing
- Commit Log

Website Activity Tracking

- The original use case for Kafka was to be able to rebuild user activity as a set of real-time publish-subscribe feeds
- Site activity such as page views, searches, or other user actions are published to central topics with one topic per activity type
- These feeds are then available for subscription for processing, monitoring, and loading into offline processing/reporting
- Activity tracking can be **very high volume** as many messages are generated for each user page view

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Messaging

- Kafka can be a replacement for a more traditional message broker such as ActiveMQ or RabbitMQ
  - But only for publish-subscribe type use cases

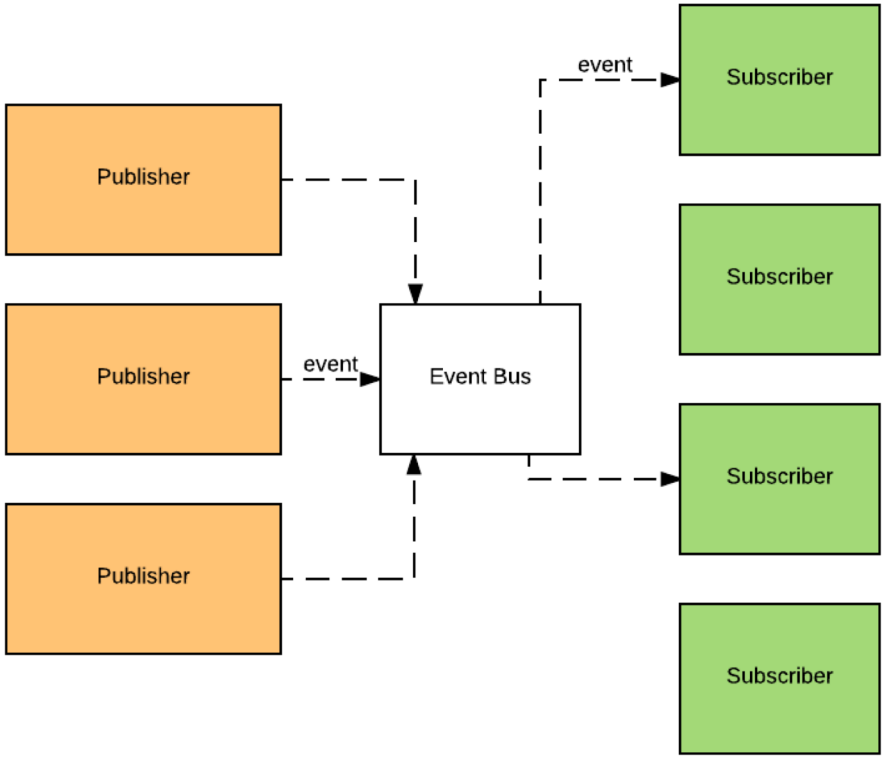
- Message broker scan be used to decouple processing from data producers, buffer unprocessed messages, etc.

- Kafka has replication, built-in partitioning, and fault-tolerance making it a good solution for large scale applications

Publish-Subscribe Pattern

- Sender (publisher) wants to send a piece of data (message)
- The message is not specifically directed to a receiver (subscriber)
- The sender classifies the message and the receiver subscribes to receive certain classes of messages
- Usually there is a central broker where messages are published

Publish-Subscribe Illustrated



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Log Aggregation

- Log aggregation collects physical log files off servers and put them in a central place such as a file server of HDFS for processing

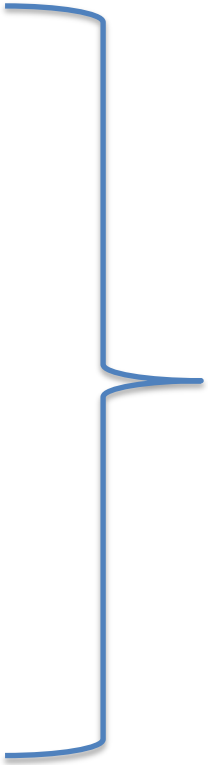
- Kafka abstracts away the details of files and gives a cleaner abstraction of log or event data as a stream of messages

Why Kafka?

- Able to connect a large number of clients (Producers and Consumers)
- Durable
  - Disk based retention
  - Data is replicated across brokers
- Scalable
  - Expansions can be performed while the cluster is online
- High Performance
  - Producers, consumers, and brokers can all be scaled to handle very large message streams
  - Sub-second message latency to consumers

How Big is Big?

- Per day:
  - 800 billion messages
  - 175 TB of data
  - 650 TB of consumed data
- Per second:
  - 13 million messages
  - 2.75 GB of data
- Configuration
  - 1100 Kafka brokers
  - 60 clusters



Numbers from LinkedIn

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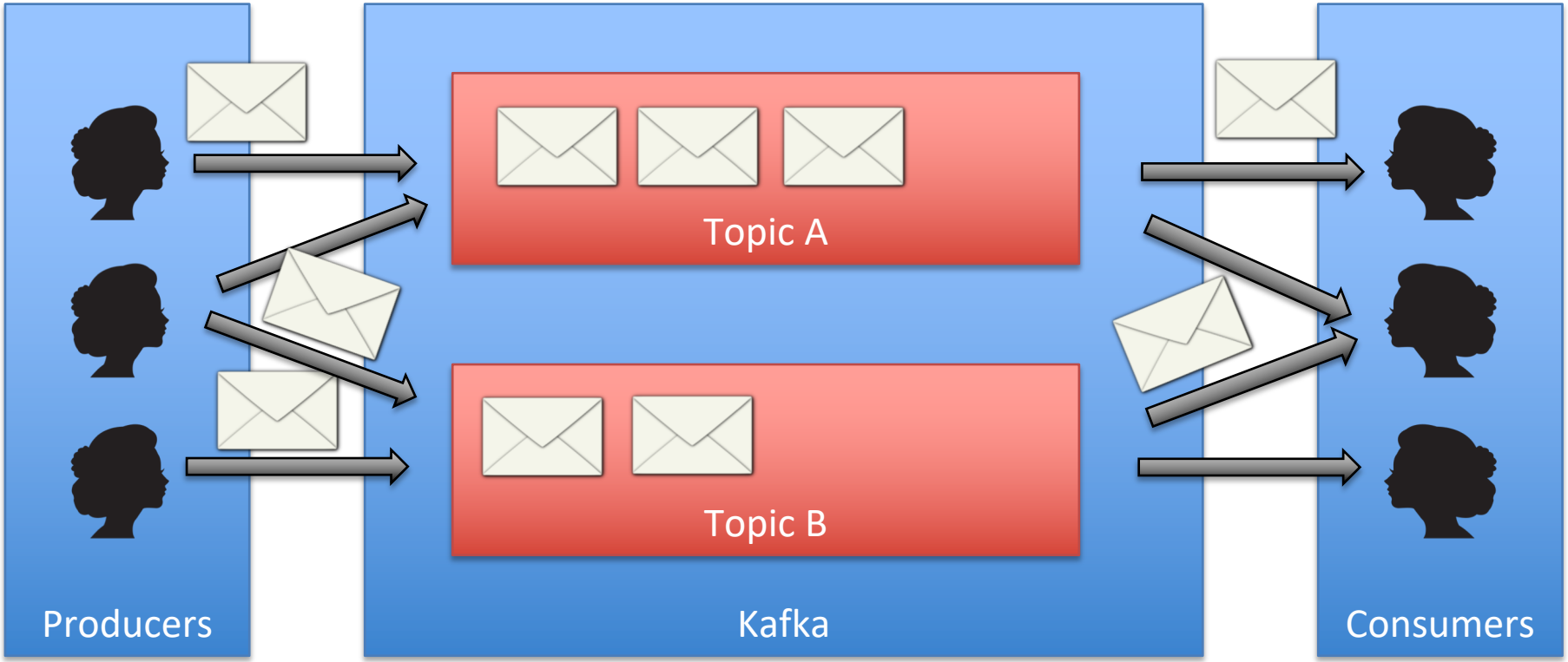
Kafka Main Concepts: Topics



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Kafka Main Concepts: Message

- Kafka looks at every message as a sequence of bytes
- The bytes are separated into:
  - Key
    - Used to determine partition (more about that later)
  - Value
    - The actual payload of the message

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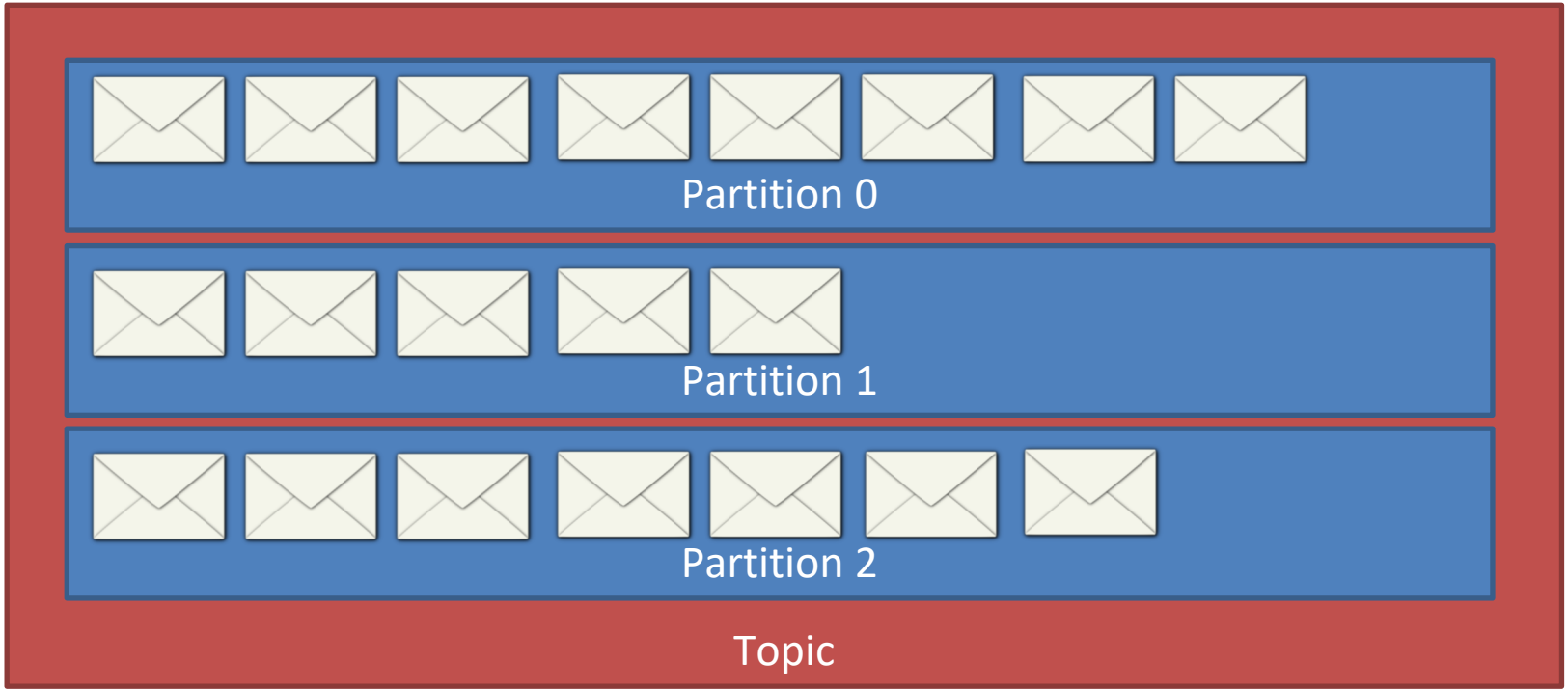
Kafka Key Concepts: Partitions



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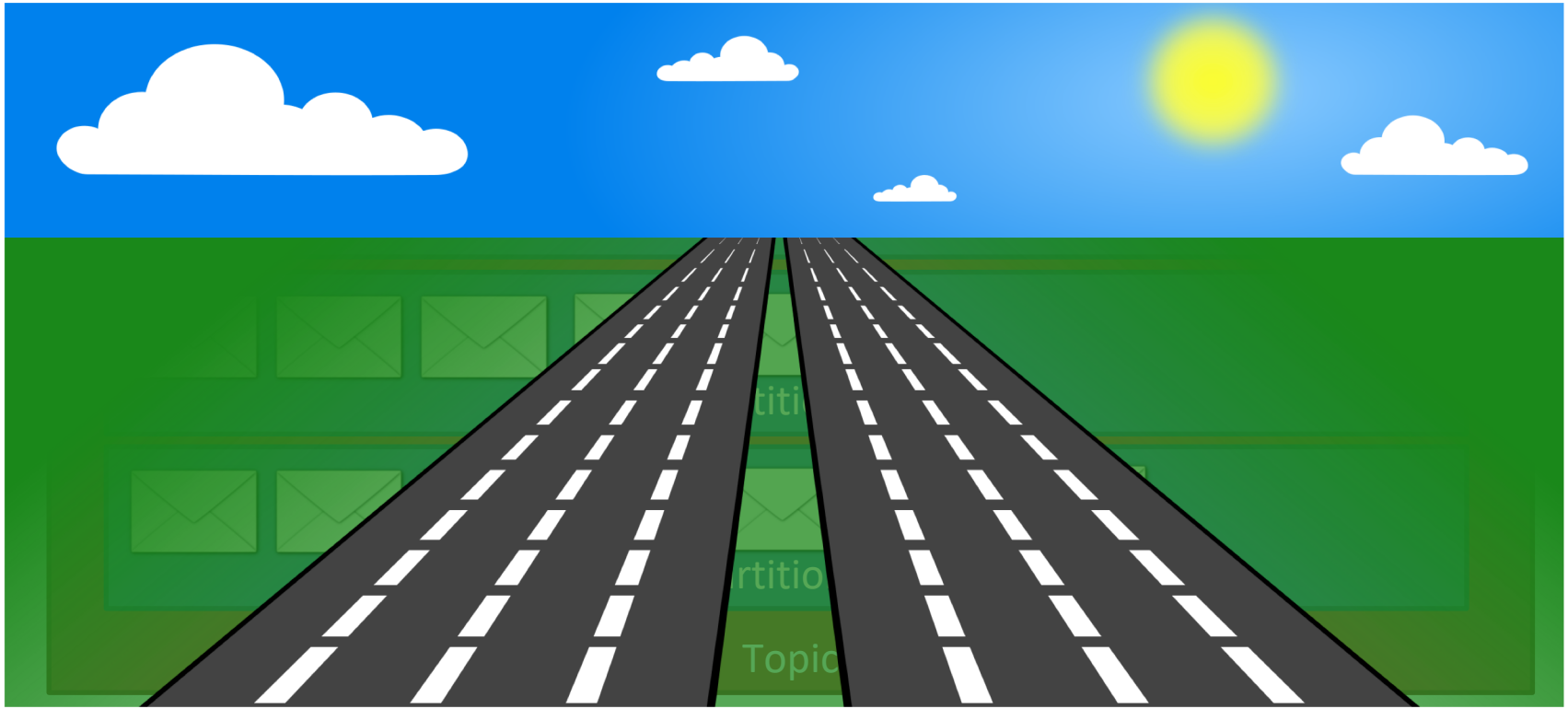
Kafka Key Concepts: Partitions



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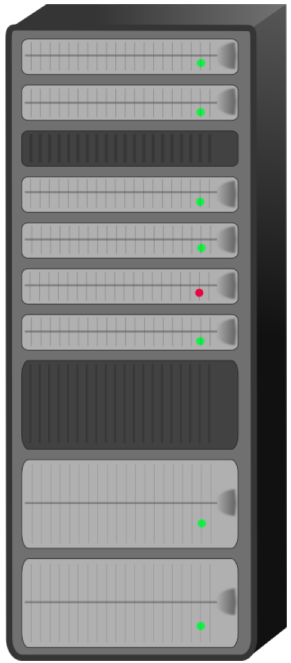
Kafka Main Concepts: Broker



- A server or process running Kafka
- Holds multiple partitions across multiple topics
- The physical manifestation of Kafka

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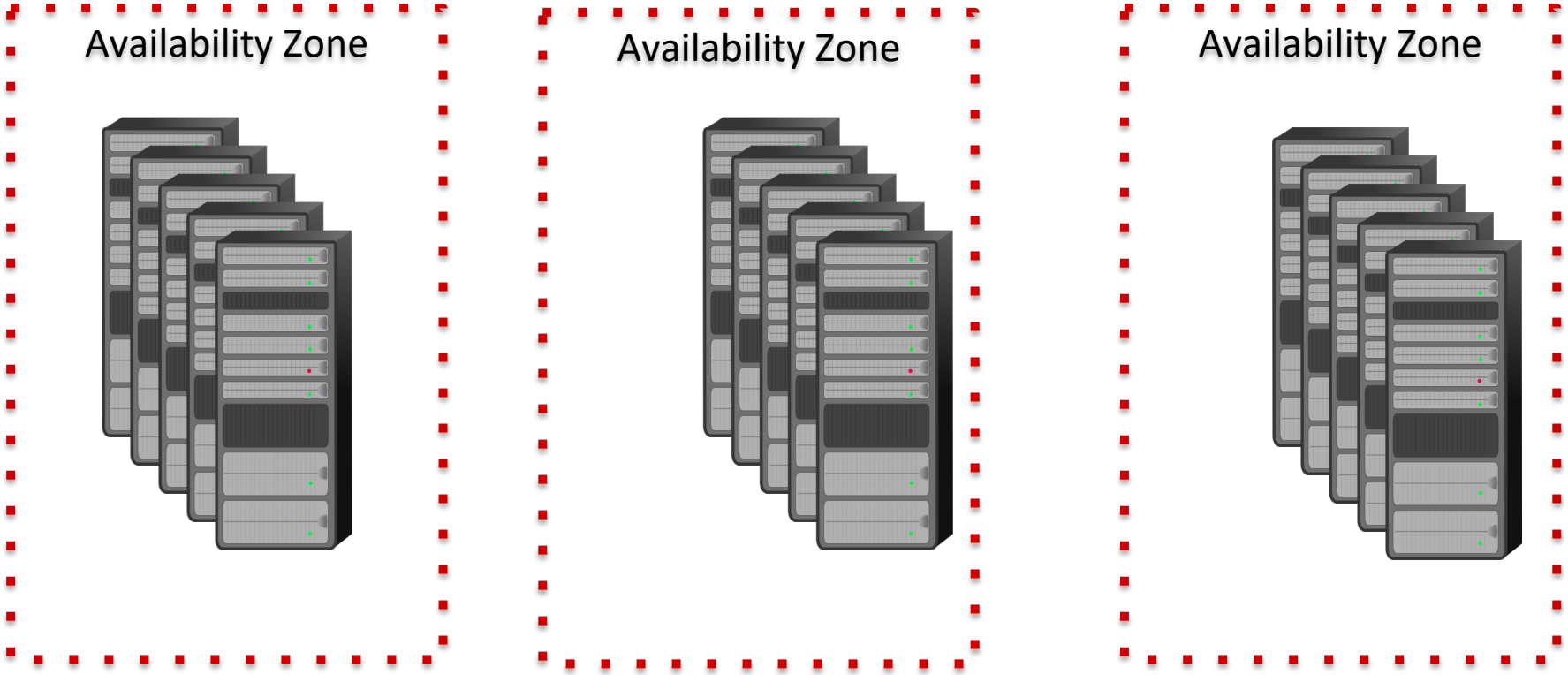
Kafka Main Concepts: Cluster



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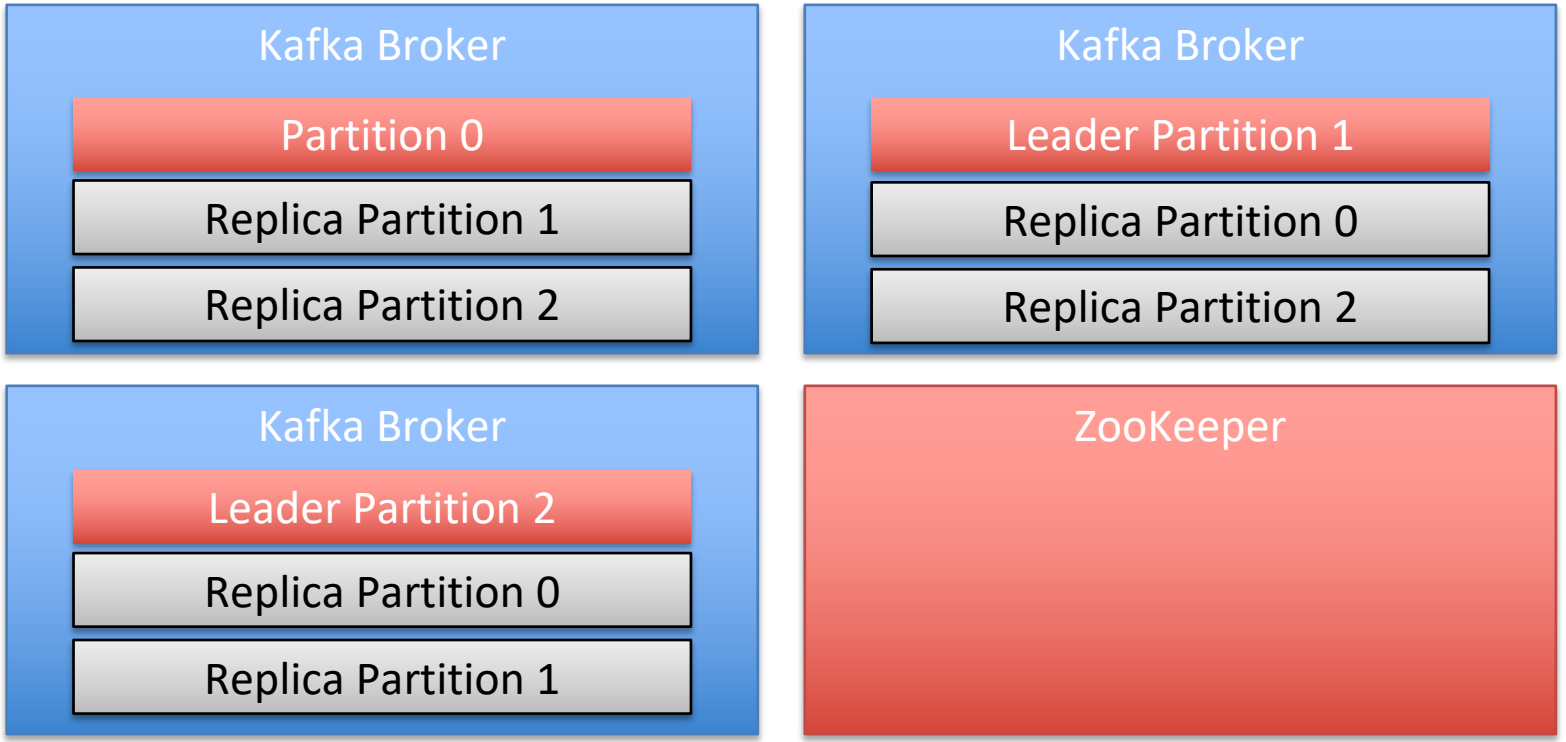
Kafka Main Concepts: Partitions and Clusters



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Summary

- Apache Kafka is an open source, distributed, partitioned, and replicated commit-log based publish-subscribe messaging system
  - Scalable
  - High Performance
  - Multiple Consumers
  - Multiple Producers
  - Disk-based Retention

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Start of Exercise

- Do you have Docker installed?

- We will be using Docker to run Kafka
- If you have not done so already, please install Docker
  - https://docs.docker.com/engine/installation/

- Check if Docker works by running

Check installation of Docker

```
$ docker -v
Docker version 1.13.0, build 49bf474
$ docker run hello-world
Unable to find image 'hello-world:latest' locally
latest: Pulling from library/hello-world
78445dd45222: Already exists
Digest: sha256:c5515758d4c5e1e838e9cd307f6c6a0d620b5e07e6f927b07d05f6d12a1ac8d7
Status: Downloaded newer image for hello-world:latest

Hello from Docker!
This message shows that your installation appears to be working correctly.

To generate this message, Docker took the following steps:
 1. The Docker client contacted the Docker daemon.
 2. The Docker daemon pulled the "hello-world" image from the Docker Hub.
 3. The Docker daemon created a new container from that image which runs the
    executable that produces the output you are currently reading.
 4. The Docker daemon streamed that output to the Docker client, which sent it
    to your terminal.

To try something more ambitious, you can run an Ubuntu container with:
 $ docker run -it ubuntu bash

Share images, automate workflows, and more with a free Docker ID:
 https://cloud.docker.com/

For more examples and ideas, visit:
 https://docs.docker.com/engine/userguide/
```

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docker-compose.yml

```
version: '2'
services:
        zookeeper:
                image: zookeeper:XXX
        kafka:
                image: wurstmeister/kafka:XXX
                environment:
                        HOSTNAME_COMMAND: "echo
$HOSTNAME"
                        KAFKA_ADVERTISED_PORT: 9092
                        KAFKA_ZOOKEEPER_CONNECT:
zookeeper:2181
```

Run Zookeeper

Run Kafka

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Essential Kafka CLI Commands (used in exercise)

- Kafka can be configured via the command
- Key commands
  - kafka-topics.sh
    - Allows us to manipulate and view topics
  - kafka-console-producer.sh
    - Allows us to produce data from using stdin
  - kafka-console-consumer.sh
    - Allows us to consume messages from the console
- We're running all tools in docker, so we have to 'reach into' the docker instance, hence our commands look like this:
  - docker-compose exec kafka /opt/kafka/bin/CMD
  - You may want to alias these commands to reduce typing or simply run a bash shell inside the docker image
    - docker-compose exec kafka /bin/bash

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Lab

- In this lab we'll simply ensure that we can run Kafka
- We'll run Kafka using Docker
  - Easy configuration
  - Runs Kafka and Zookeeper
  - Flexible setup that allows us to setup a cluster of machines for later exercises
- The lab simply:
  1. Starts the docker images using docker-compose
  2. Runs a simple producer
  3. Runs a simple consumer
  4. Allows you to type messages in the producer and see them consumed by the consumer

Lab/Demo

The lab description can be found on GitHub in the directory **labs/01-Verify-Installation/hello-world-kafka.md**

Goals of the lab:

- **Make sure your docker environment is working properly**
- **Make sure you can run the Kafka installation in Docker**
- **Show some of the tools to create topics, publish records, and consume records**

Producers and Consumers

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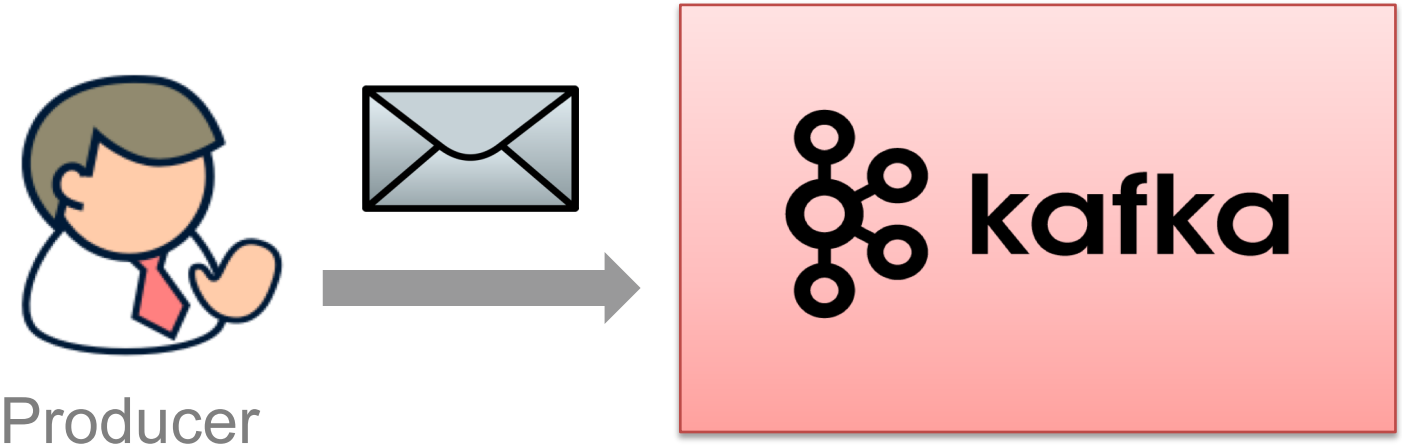
Outline

- Producers
  - What is a producer?
  - The producer API
- What is a Consumer?
  - What is a consumer and a consumer group?
  - The consumer API
- Anatomy of messages

What is a Producer?



- Producer

- Producers produces the data sent to the Kafka clusters
  - Sent via topics
  - Directly involved in load-balancing
  - Controls the resiliency of messages

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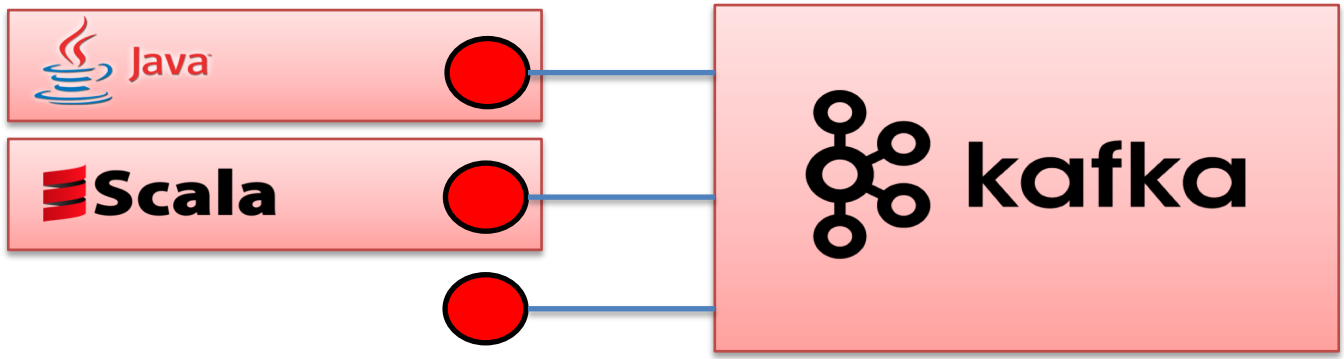
Kafka APIs



- Kafka ships with built in client APIs for developers to use with applications
  - Kafka ships with a Java client that is recommended
  - Legacy Scala clients are still included
  - Kafka also includes a **binary wire protocol**
  - Many tools in other languages that implement this wire protocol

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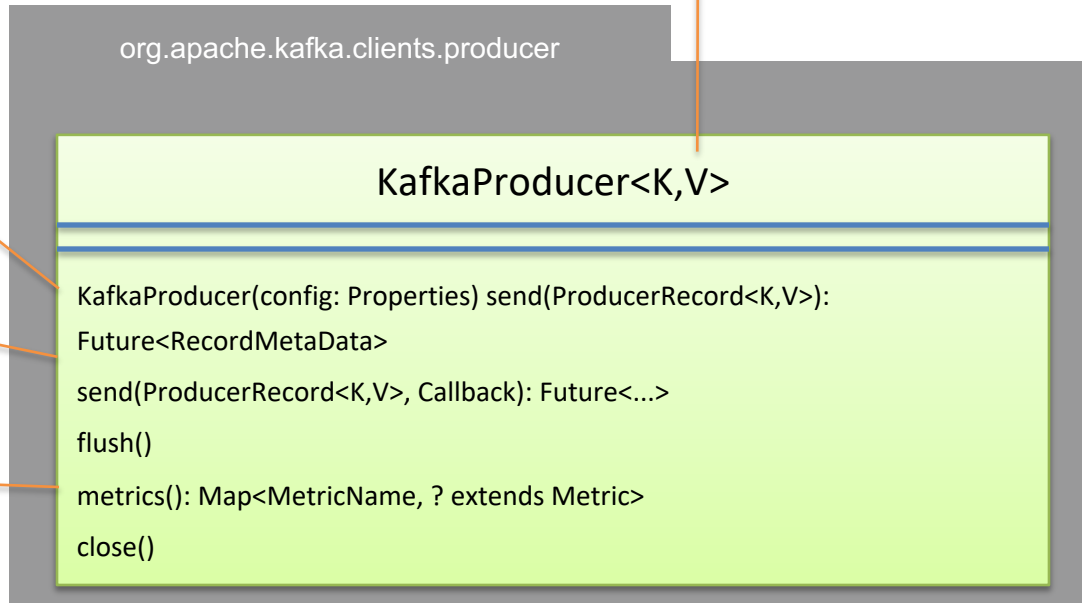
The Java API

Generic sender where:
K = Type of key
V = Type of message

Constructor takes a configuration (mostly a hashmap of options)

Send a messages (with or without callbacks)

Get metrics for this producer



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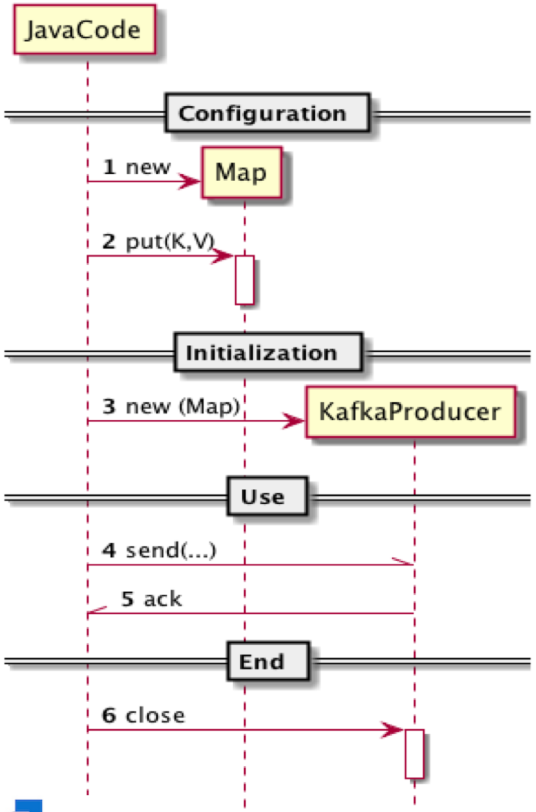
Java API Behavior




```
// Configuration
Properties kp = new Properties();
kp.put("bootstrap.servers",
                "mybroker1:9092,mybroker2:9092");
kp.put("key.serializer", "...");



// Initialization
KafkaProducer<String, String> producer =
                new KafkaProducer<String, String>(kp);

// Use
Future<...> f = producer.send(...);
... f.get(); // when acked


// End
producer.close();
```

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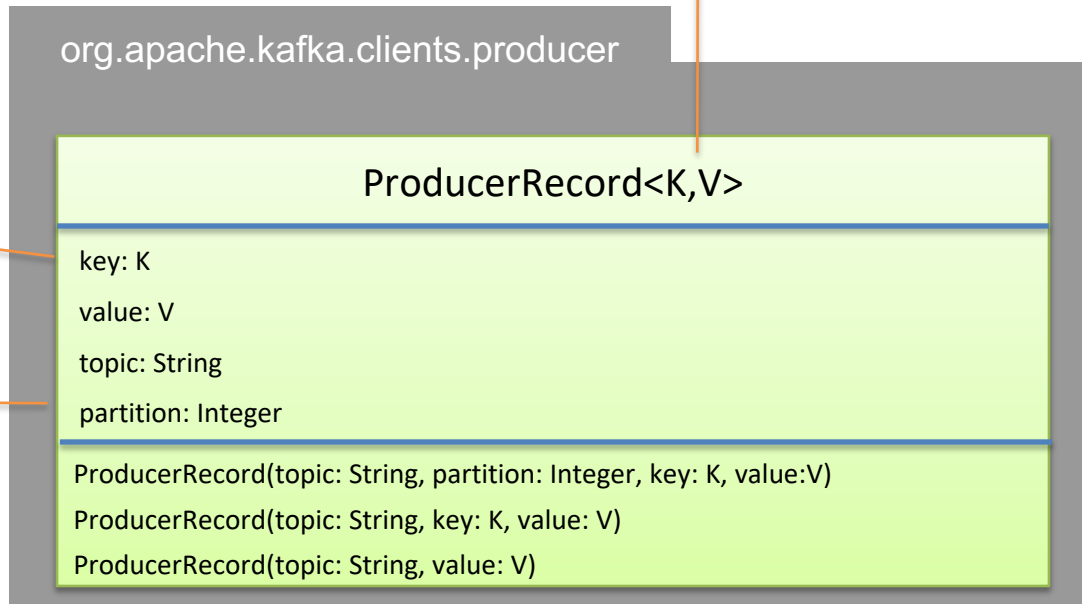
Creating a Kafka Producer

- Constructing a Kafka producer requires 3 mandatory properties
  - bootstrap.servers – list of host:port pairs of Kafka brokers. This doesn't have to include all brokers in the cluster as the producer will query about additional brokers. It is recommended to include at least 2 in case one broker goes down
  - key.serializer – should be set to a class that implements the Serializer interface that will be used to serialize **keys**
  - value.serializer - should be set to a class that implements the Serializer interface that will be used to serialize **values**

The ProducerRecord

Generic record where:
K = message key
V = Type of message



Message Key is optional

Partition Key is optional

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Sending a Message

```
ProducerRecord<String,String> record =
  new ProducerRecord<String,String>(
    "someTopic", "someKey, "someValue");

producer.send(record,  new Callback() {
   public void onCompletion(
      RecordMetadata metadata, Exception e) {
         if(e != null) e.printStackTrace();
         System.out.println(
           "Offset: " + metadata.offset());
      }
});
```

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Producer Controls Message Guarantees

- As a producer you can determine what guarantees you want Kafka to give you when sending a message
  - Controlled by acknowledgement
- Different use cases requires different guarantees
  - Web page clicks log:
    - Don't care if I lose a few messages
  - Credit card payment
    - I want best possible guarantee
- Kafka provides options
  - The better guarantee, the higher the latency

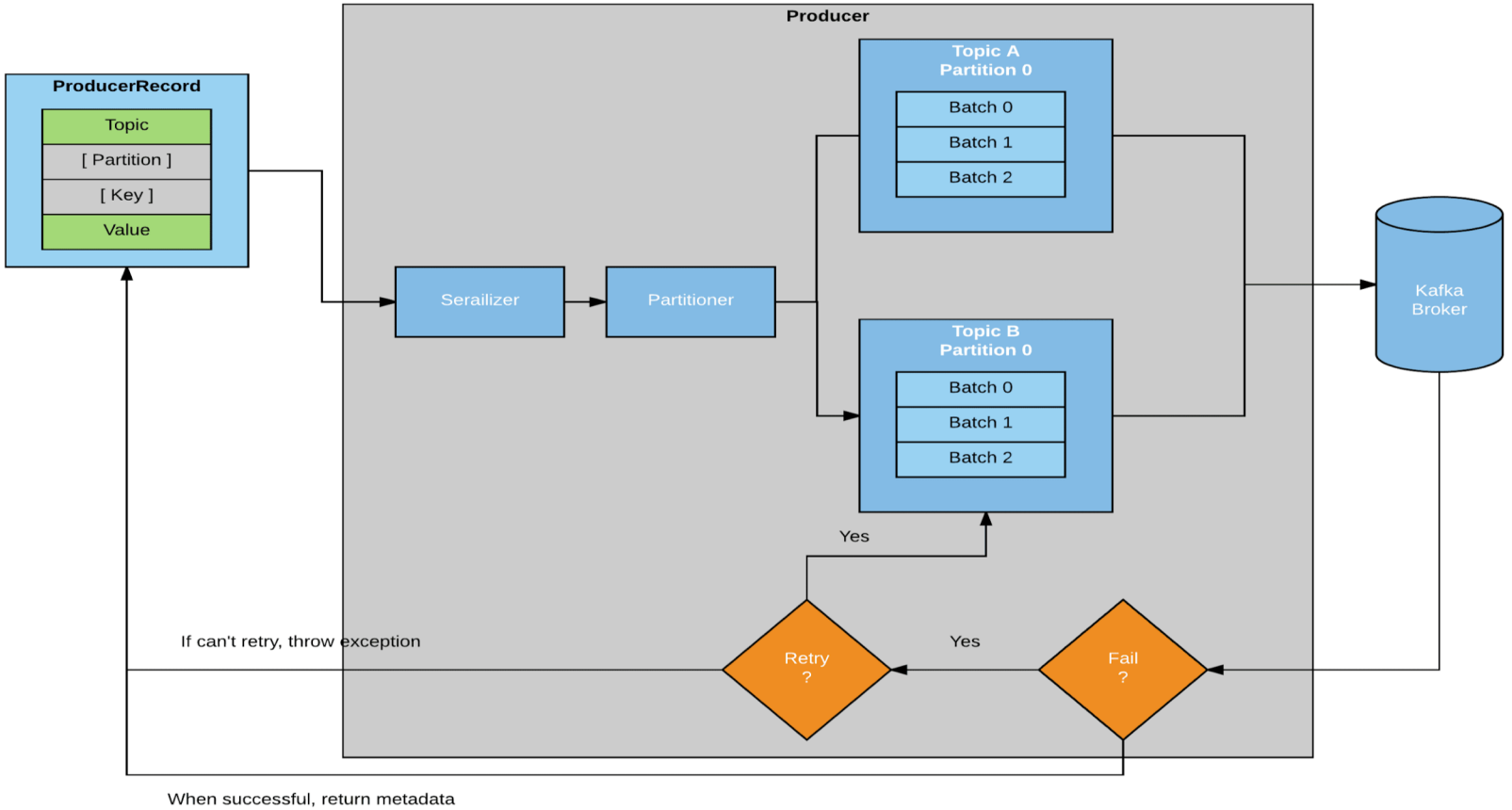
Producer API

- Different use case requirements will influence the way the producer API is used to write messages to Kafka and its configuration
- Three primary ways of sending messages
  - Fire-and-forget – send a message and don't really care if it arrived successfully or not. Most of the time it will arrive successfully but it's possible that some messages will get lost
  - Synchronous send – message is sent and a Future object is returned which can be used to see if the send() was successful
  - Asynchronous send – the send() method has a callback function which is triggered when a response is received from the Kafka broker

Acknowledgement of Messages

- No ack (0)
  - Kafka will most likely receive the message
  - Producer will not wait for any reply from the broker before assuming the message was sent successfully
  - If something goes wrong, producer will not know and message is lost
  - Because producer is not waiting for a response, high throughput can be achieved
- Ack from N replicas (1..N)
  - A message is not considered consumed by the Kafka cluster unless N replicas holding the message has acknowledged
- Ack from all replicas (-1)
  - Every replica must acknowledge the message

Producer Overview



Serialization

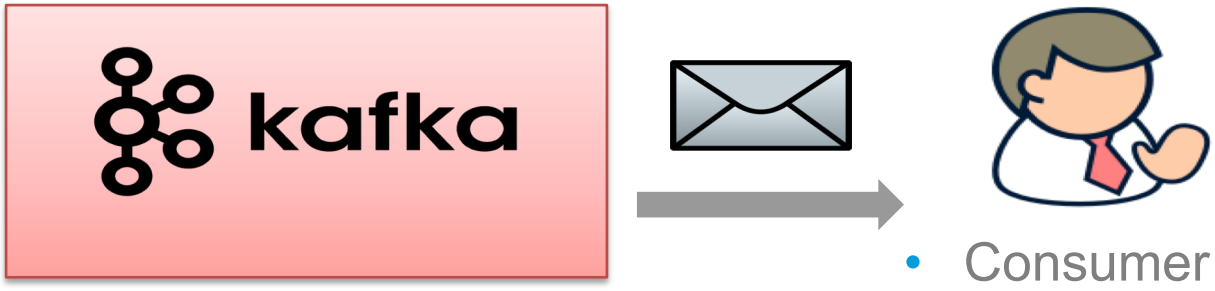
- Kafka messages are byte arrays (to Kafka)
  - Key → Array of bytes
  - Value → Array of bytes
- The Java API allows you to pass any object as key or value
  - Makes the code readable, but...
  - ... requires serializes and deserializes

- Kafka includes an interface for this
  org.apache.kafka.common.serialization.Serializer

Built-in Serializers

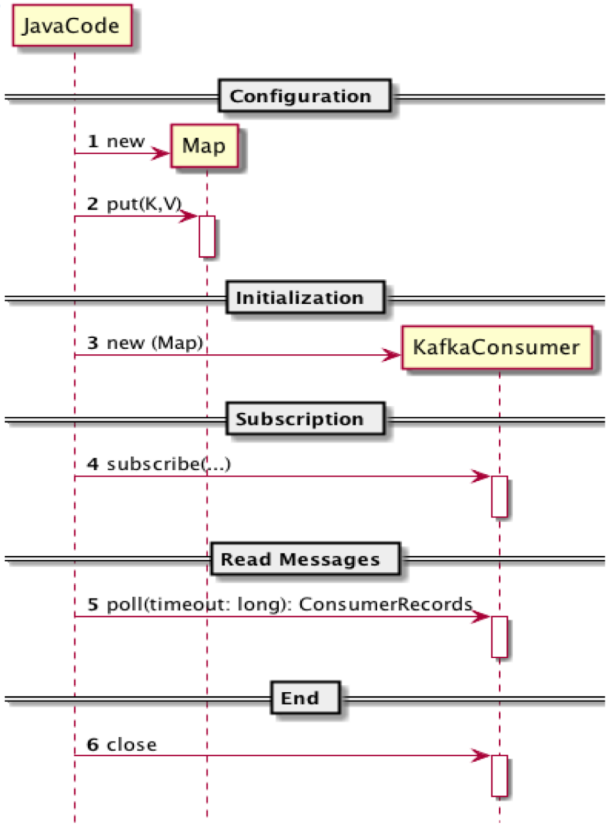
- Kafka includes serializes for common types:
  - ByteArraySerializer
  - StringSerializer
  - IntegerSerializer
  - …
- Most organizations settle on some standard serialization strategy
  - JSON, XML, Apache Avro, Protobuf

Consumers and Consumer Groups



- Applications that read data from Kafka are consumers
  - Subscribes to topics
  - Use KafkaConsumer to read messages from these topics
  - Kafka consumers are usually part of a *consumer group*
  - **The main way consumption of data from a Kafka topic is scaled is by adding more consumers to a consumer group**

Java API Behavior




```
// Configuration
Properties kp = new Properties();
kp.put("bootstrap.servers",
                "mybroker1:9092,mybroker2:9092");
kp.put("key.deserializer", "...");


// Initialization
KafkaConsumer<...> consumer=
                new KafkaConsumer<...>(kp);


// Subscription
consumer.subscribe("interesting.*");


// Read messages
ConsumerRecords<...> records = consumer.poll(100);
for (ConsumerRecord<...> cr : records) {
                // cr.value(); cr.key(); cr.offset();
}

// End
consumer.close()
```

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The Java API

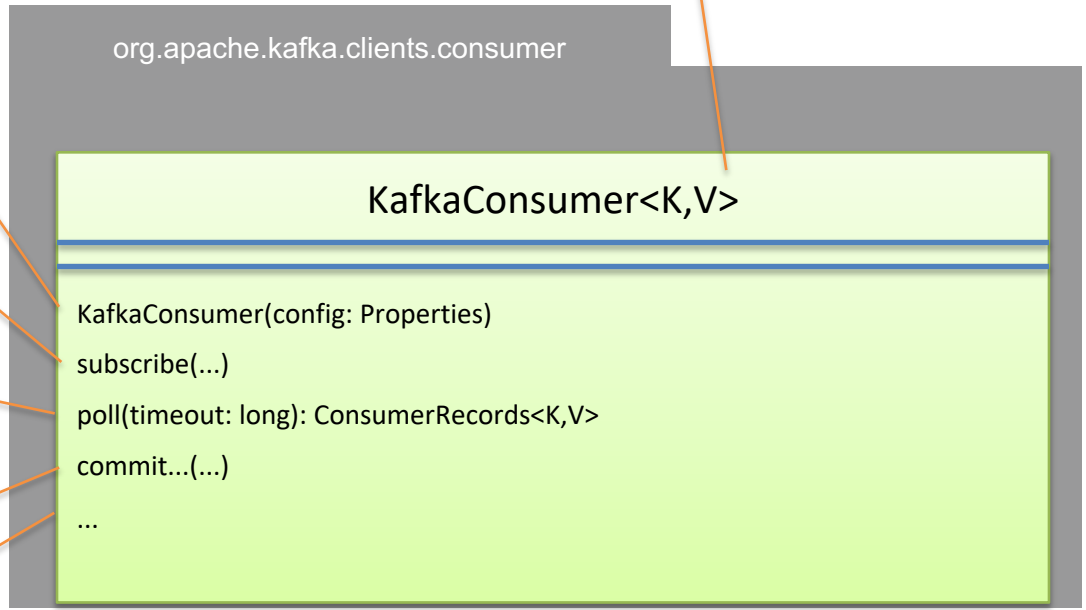
Generic sender where:
K = Type of key
V = Type of message

Constructor takes a configuration (mostly a hashmap of options)

Multiple ways to subscribe. Subscribe by list, wildcard, etc.

Read messages from Kafka

Multiple (sync/async) ways to confirm reception to consumer groups



A set of other methods such as: metrics(), pause(...), assign(...), close(), etc

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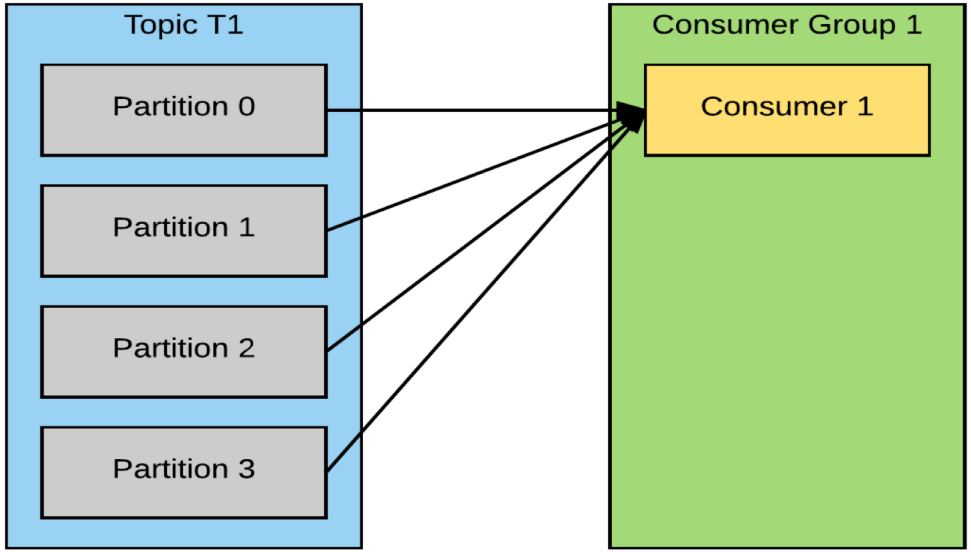
How to Use the API?

- The ***org.apache.kafka.clients.consumer.KafkaConsumer*** acts as a proxy for the consumer

- Some key issues to to resolve
  - Setup of consumer groups
  - Which topics to subscribe to
  - Which partitions to subscribe to (optional)
  - Manual or automatic offset management
  - Multi-threaded or single-threaded consumption

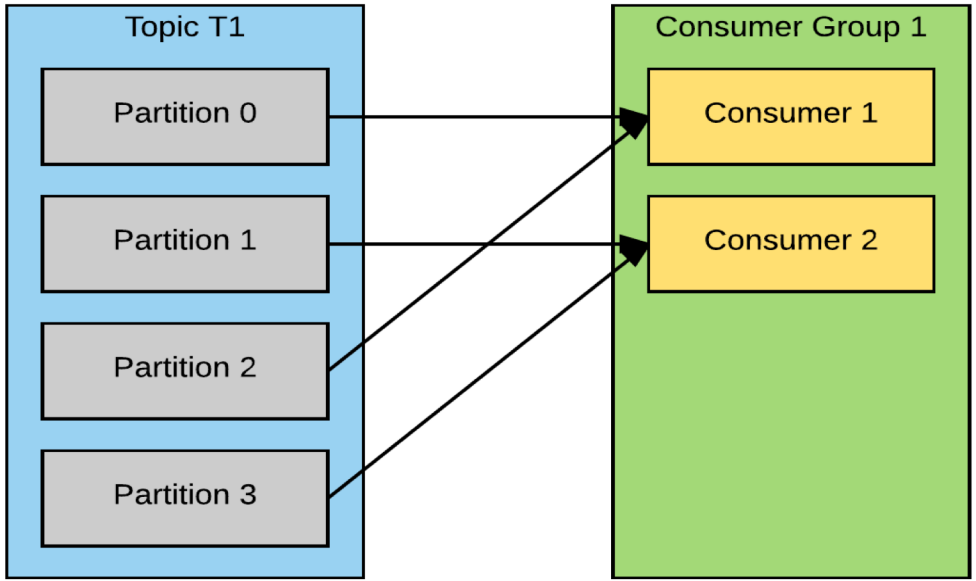
Consumer Group

- The consumer will receive all messages from all four partitions



Consumer Group

- Each consumer will only get messages from two partitions



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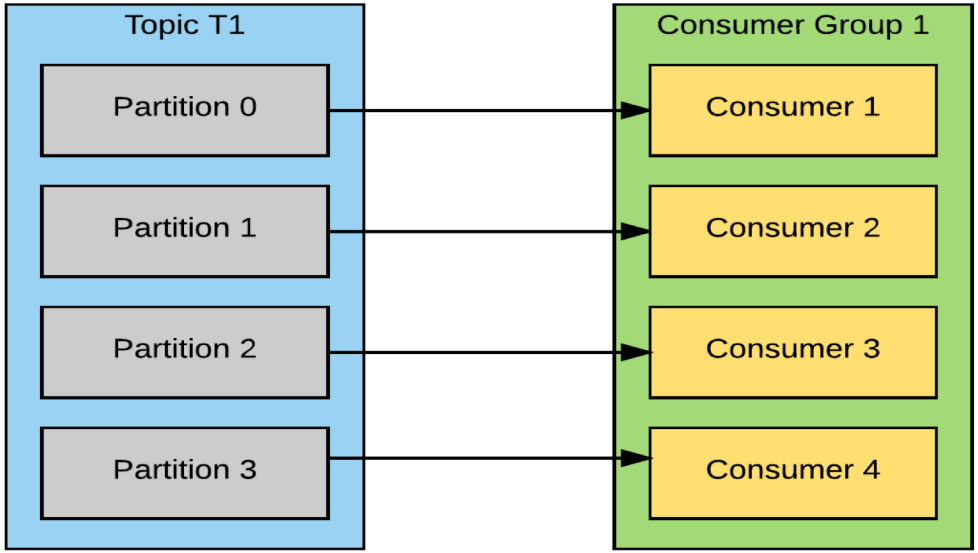
Consumer Group

- If the consumer group has the same number of consumers as partitions, each will read messages from a single partition



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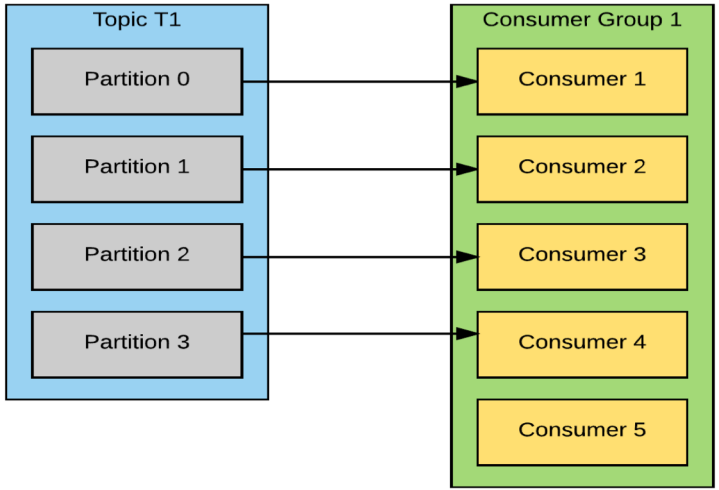
Consumer Group

- If there are more consumers than partitions for a topic, some consumers will be idle and receive no messages
- Create topics with a large number of partitions to allow adding more consumers when load increases



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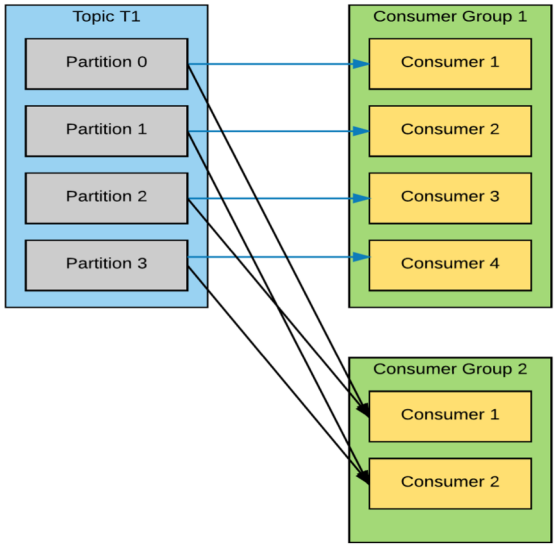
Multiple Consumer Groups

- One of the main design goals of Kafka was to allow multiple applications the ability to read data from the same topic
- Make sure each application has its own consumer group for this purpose



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Partition Rebalance

- Consumers in a consumer group share ownership of the partitions in the topics they subscribe to
- When a new consumer is **added** to the group, it consumes messages from partitions which were previously consumed by another consumer
- When a consumer **leaves** the group (shuts down, crashes, etc), the partitions it used to consume will be consumed by one of the remaining consumers
- Reassignment of partitions to consumers can also happen when topics are modified – an administrator adds new partitions, for example

Partition Rebalance

- The event in which partition ownership is moved from one consumer to another is called a *rebalance*
- During a rebalance, consumers can't consume messages!
- Steps can be taken to safely handle rebalances and avoid unnecessary rebalances

Creating a Kafka Consumer

- Creating a KafkaConsumer is similar to creating a KafkaProducer
- Like the producer, you must specify bootstrap.servers, key.deserializer, and value.deserializer in a Properties object
- You must also specify a group.id which specifies the consumer group for which the KafkaConsumer instance belongs to

Setup of KafkaConsumer Example

```
private Properties kafkaProps = new Properties();
kafkaProps.put("bootstrap.servers", "mybroker1:9092,mybroker2:9092");

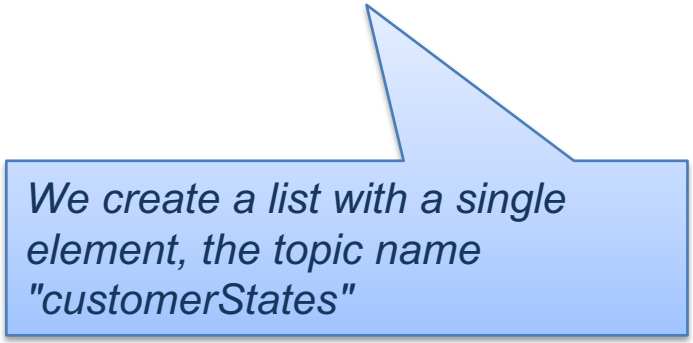
kakfaProps.put("key.serializer", "org.apache.kafka.common.serialization.StringSerializer");
kakfaProps.put("value.serializer", "org.apache.kafka.common.serialization.StringSerializer");
kafkaProps.put("group.id", "StateCounter");

KafkaConsumer<String, String> consumer = new KafkaConsumer<String, String>(kafkaProps);
```

Subscribing to Topics

- Once a consumer is created, you can subscribe to one or more topics

```
consumer.subscribe(Collections.singletonList("customerStates"));
```



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Subscribing with Regular Expressions

- You can also subscribe to topics using regular expressions
- The expression can match multiple topic names
- If a new topic is created with a name that matches, a rebalance will happen and consumers will start consuming from the new topic
- Useful for applications that need to consume from multiple topics
- Example: subscribe to all test topics
  - consumer.subscribe("test.*");

Consumer Poll Loop

- Once a consumer subscribes to topics, a loop polls the server for more data

```
KafkaConsumer<String, String> consumer = new KafkaConsumer<>(props);
consumer.subscribe(Arrays.asList("foo", "bar"));
while (true) {
  ConsumerRecords<String, String> records = consumer.poll(100);

  for (ConsumerRecord<String, String> record : records)
    System.out.printf("offset = %d, key = %s, value = %s", record.offset(), record.key(), record.value());
} finally {
  consumer.close();
}
```

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Consumer Poll Loop

- Once a consumer subscribes to topics, a loop polls the server for more data

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    System.out.printf("offset = %d, key = %s, value = %s", record.offset(), re                cord.value());
} finally {
  consumer.close();
}
```

Consumers must keep polling Kafka or they will be considered dead and the partitions they are consuming will be handed to another consumer in the group

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Poll Method

- poll() returns a list of records that contain:
  - Topic and partition the record came from
  - Offset of the record within the partition
  - Key and value of the record

- Takes a timeout parameter that specifies how long it will take to return, with or without data
  - *How fast do you want to return control to the thread that does the polling?*

Multithreading Considerations

- **One consumer per thread**
- To run multiple consumers in the same group in one application, each must run in its own thread
- You can wrap the consumer logic in its own object and then use Java's ExecutorService to start multiple threads each with its own consumer

Commits

- Unlike other JMS queues, Kafka does not track acknowledgements from consumers
- When poll() is called, it returns records that consumers in the group have not yet read

- The records that have been read by a consumer of the group are tracked by their position (offset) in each partition

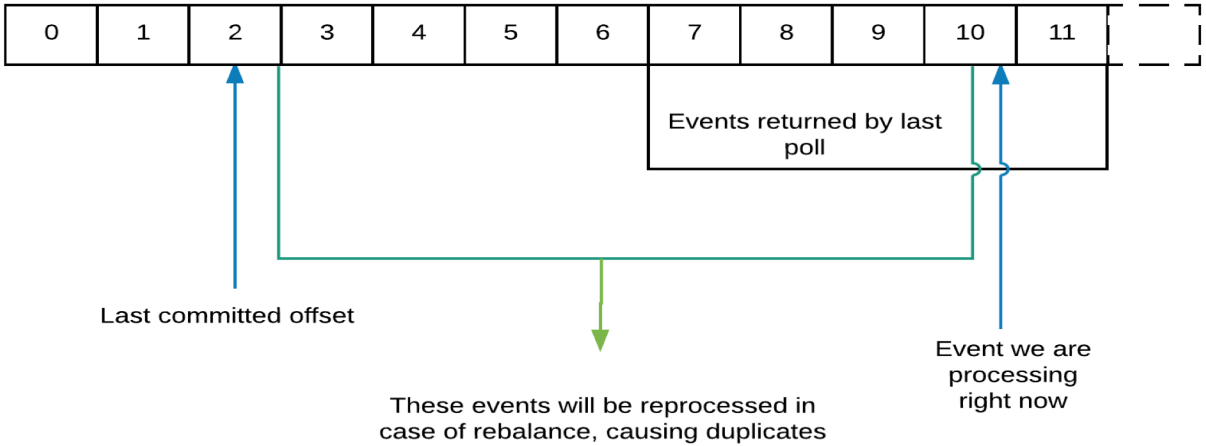
- When the current position in the partition is updated, it is known as a *commit*

Consumers Commit Offsets

- Consumers send a message to Kafka to a reserved topic with the committed offset for each partition
- If a consumer crashes or a new consumer joins the consumer group, a rebalance is triggered
- After a rebalance, a consumer may be assigned a new set of partitions and must read the latest committed offset of each partition and continue from there

Messages Processed Twice

- If the committed offset is smaller than the offset of the last message the client processed, the messages between the last processed offset and the committed offset will be processed twice



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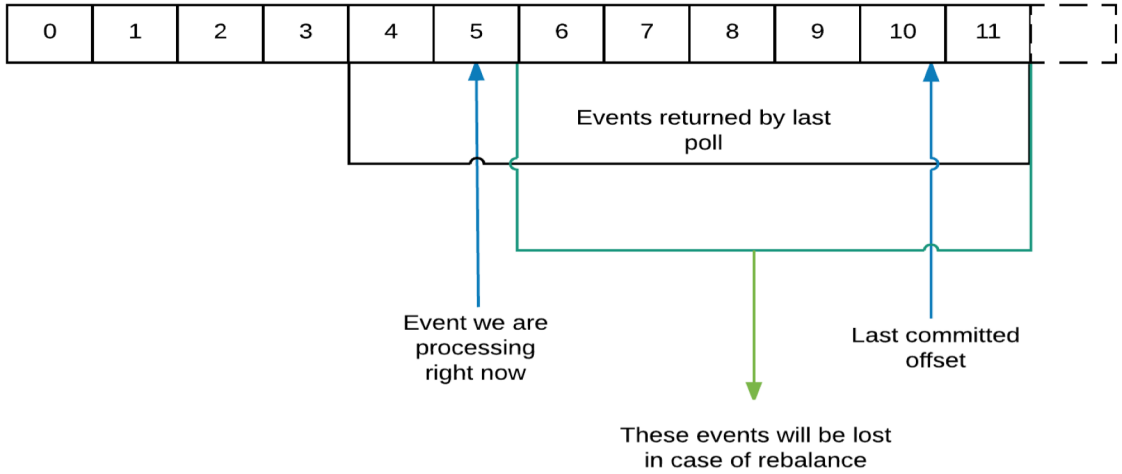
Messages Missed

- If the committed offset is larger than the offset of the last message the client processed, messages between the last processed and the committed offset will be missed by the consumer group



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Automatic Commit

- If you configure enable.auto.commit=true, the consumer will commit the largest offset your client received from poll() every 5 seconds by default
- Whenever there is a poll, the consumer checks if its time to commit and if so, will commit the offsets it returned in the last poll

- Convenient but don't give developers enough control to avoid duplicate messages

Commit Current Offset

- Developers usually want to exercise control over the time offsets are committed to eliminate possibility of missing messages **and** reduce the number of duplicate messages during rebalancing

- Setting `auto.commit.offset=false` means that offsets will only be committed explicitly

- Consumer has a `commitSync()` API to commit the latest offset returned by `poll()`

commitSync Example

```
while (true) {
  ConsumerRecords<String, String> records = consumer.poll(100);

  for (ConsumerRecord<String, String> record : records)
    System.out.printf("offset = %d, key = %s, value = %s", record.offset(), record.key(), record.value());

  try {
    consumer.commitSync();
  } catch (CommitFailedException e) {
    log.error("commit failed", e);
  }

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

Once we are done processing all records in the current batch, commitSync is called before polling for more

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Asynchronous Commit

- The application is blocked until the broker responds to the commit request with commitSync() limiting throughput
- An alternative is to use commitAsync() which commits the last offsets and continues

```
while (true) {
  ConsumerRecords<String, String> records = consumer.poll(100);

  for (ConsumerRecord<String, String> record : records)
    System.out.printf("offset = %d, key = %s, value = %s", record.offset(), record.key(), record.value());

  consumer.commitAsync();
}
```

You can also pass a callback which is invoked by the consumer when the commit finishes (either successfully or not)

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Summary

- Producers
  - API
  - Sending messages
  - Serialization
- Consumers
  - API
  - Subscribing
  - Consumer groups
  - Rebalance

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Lab/Demo

- In this lab we'll use the Java API to consume and produce messages
- Two projects
  - Producer
  - Consumer
- Required tools:
  - Java
  - Maven
  - Docker (as before)
- Maven can be run stand alone or using a docker-container

Designs of Topics and Partitions

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Topic Design

- Name
- Schema
- Payload (Data)
- Key
- Number of partitions
- Number of replicas

The Short Story

- DevOps concerns
  - Bandwidth consumption: Size of messages, `serdes`, etc.
  - Fault tolerance and availability: Size of cluster, replication factor, etc.
  - Performance: Partitions, message size, cost of serialization, etc.
- Producer concerns
  - Ease of production: Clear schema, cost of serialization, delivery guarantees, etc.
- Consumer concerns
  - Can I subscribe to only what I need: Topics and partitions
  - Latency: Cluster size, performance, etc.

How Topics and Partitions Influence Concerns?

- Topic topology
  - Schema (structure, format, etc.)
  - Temporal constraints (frequency, triggers, etc.)
  - Do you use topics to allow for fine grain subscriptions?
- Partitions
  - Determines throughput (but not without cost)
  - Can be used for fine-grained subscription (requires use of low level API)
- Recommendation
  - Use topics to convey semantics
  - Use partition to control throughput

Name

- Descriptive name
- Evaluate use of hierarchy in naming
- Rule of thumb:
  - Use a longer name that is easy to understand

Schema

- JSON
  - Common choice
  - Not the most efficient

- Apache Avro
  - Binary format
  - Compression
  - Schema evolution
  - Dynamic typing (no code generation needed for serialization)

Partitions and Throughput

- Unit of parallelism: topic partition
- Writes to different partitions done in parallel
- Consumer: one thread get a single partitions data
- Consumer parallelism: bounded by the number of consumed partitions
- Throughput on a producer is a function of:
  - Batching size
  - Compression codec
  - Acknowledgement type
  - Replication factor
- Consumer throughput is a function of the message processing logic

Overpartitioning

- Problem: Increasing the number of partition and message ordering
  - If messages have keys, increasing the number of partitions may cause problems
  - Kafka maps a message to a partition based on the hash of the key
  - Messages with the same key go to the same partition
  - If we increase the number of partitions, this does not hold
    - Messages with the same key may for the retention period appear in multiple partitions
- Therefore:
  - Overpartition for a situation you expect in future

Too Many Partitions

- Each partition maps to a directory in the broker
  - 2 files: index, actual data
- You may need to configure the open file handle limit
  - Configuration
  - Seen in production > 30K open file handles / broker

Partitions and Availability

- Intra-cluster replication
- A partition can have multiple replicas, each on a different broker
- Clean broker shutdown: the controller moves the leaders off the broker that is shutting down
  - Takes a couple of ms
- Unclean shutdown: the loss of availability is dependent on the number of partitions
  - All replicas become unavailable at the same time
  - A new leader must be elected
  - Potential unavailability in seconds

Partitions and Client Memory

- A producer can set the amount of memory for buffering messages
  - Messages are buffered per partition
  - When buffer is full, messages are sent to the broker
- More partitions: more message buffering in the producer
- If out of memory, producer will block or drop new messages
  - Reconfigure
- Allocate at least a few tens of KB per partition

Summary

- Design topics based on your application semantics
  - Message types
  - Consumer concerns
  - Subscription granularity
- Decide on the number of partitions based on throughput
  - The more partitions, the higher theoretical throughput
  - Not without penalty
    - File handlers, consumer memory, latency, etc
  - Evaluate to overpartition to accommodate future growth

Lab: Design

- Let's assume you'll have to collect information from devices installed to keep track of the vitals of a set of patients
  - The patients are being treated from their home
  - You may assume that the patients produce 10 messages per second on average
  - You may have up to 1 million patients being tracked at the same time
- Multiple stakeholders
  - Nurse: Keeps track of a number of patients
  - Service technician: Need to know when a device goes down
  - Billing: Keeps track of events that are billable
  - ...

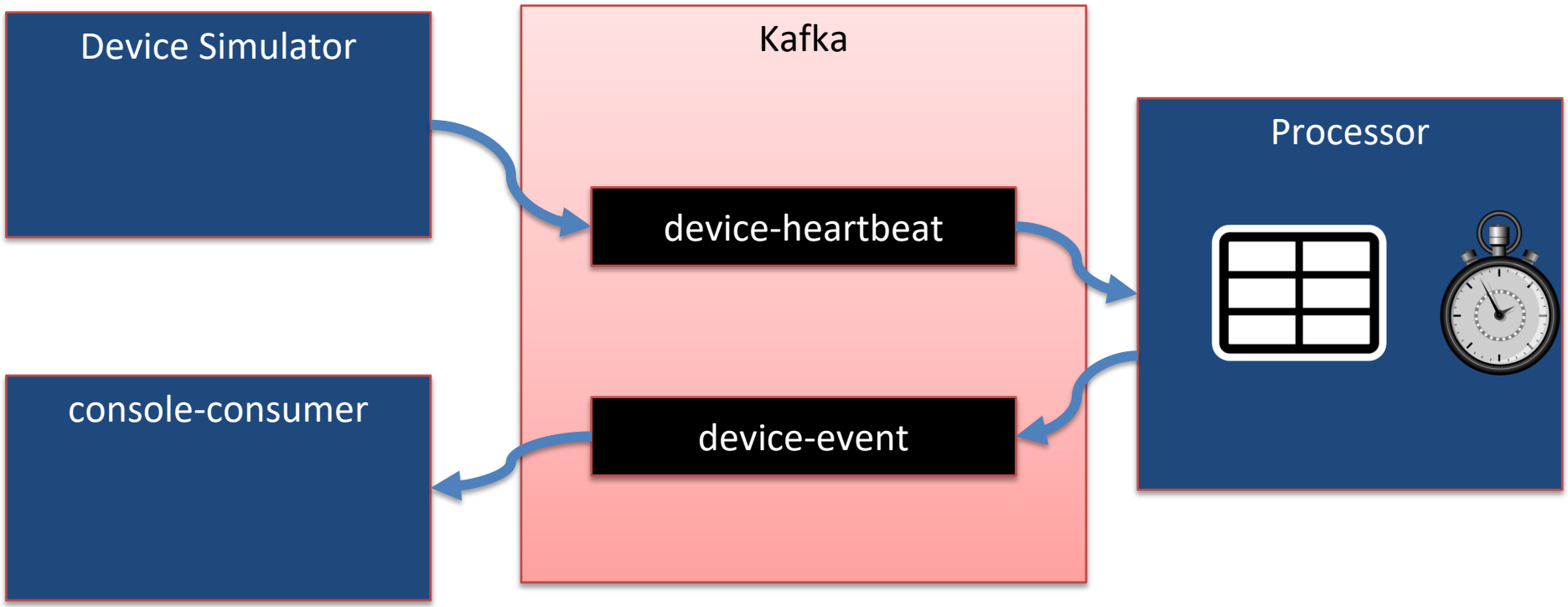
Lab: Design... The Question

- What would be the topics for such a system?
- How do we decide how many partitions per topic?

Lab: Implementation

- We'll take a look at a small sleeve of the problem
- Service technician's view:
  - Assuming all devices send a heartbeat
  - We want to know if the devices go offline and when they come back online
- We'll implement a processor that listens to the incoming heartbeats and decides if the device is online or offline

What We'll Run



Lab/Demo

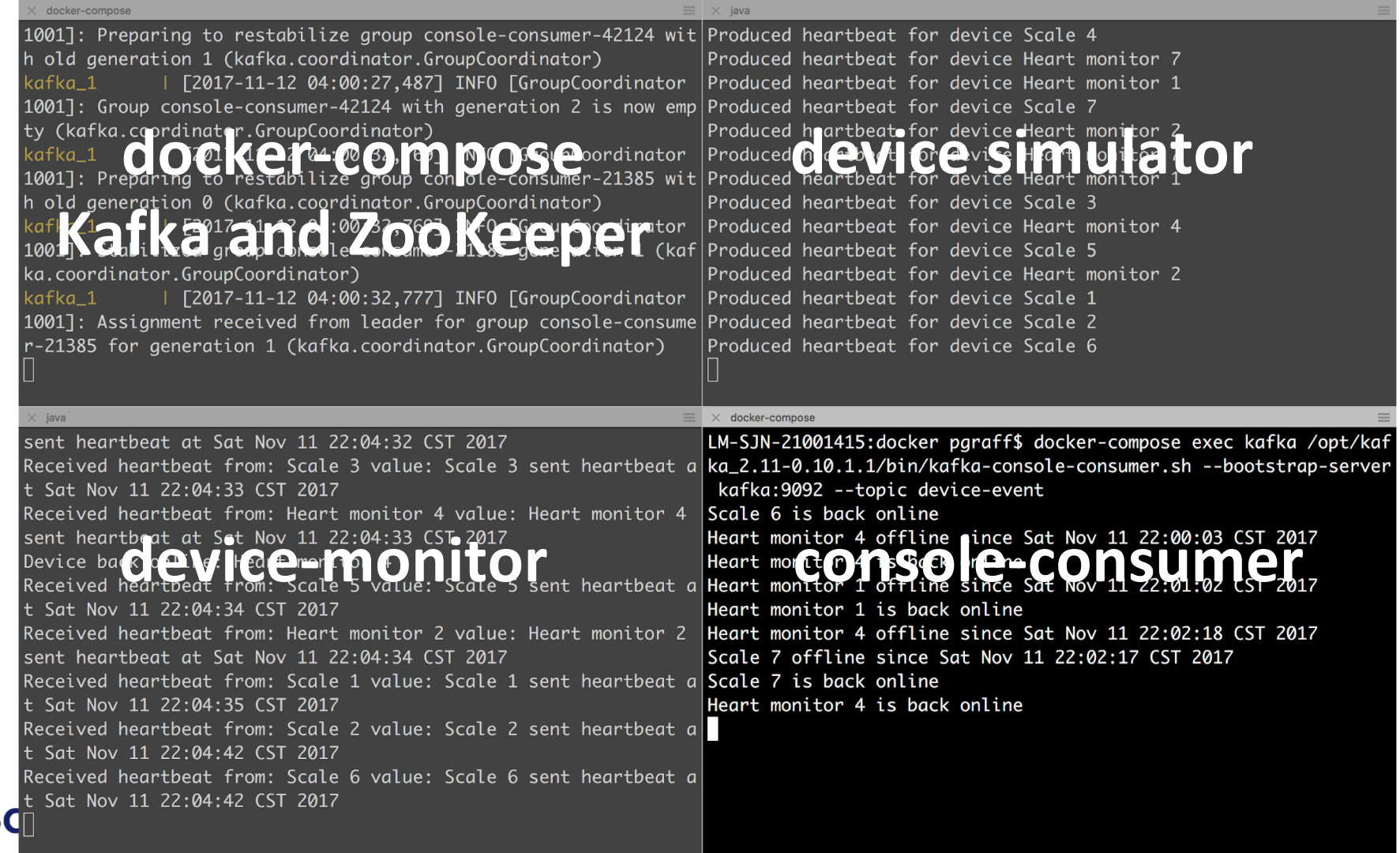
- Setup Kafka
  - Two topics
    - device-heartbeat
    - device-event
- Start the consumer(s)
  - At minimum, the listener to the device-event
- Build and run the processing daemon for the heart beats
  - Build in Java with Maven
- Build and run a simulator (simulating the devices)
  - Built in Java with Maven
- Observe the behavior of the application(s)

The Critical Code of DeviceSim

```
14   public DeviceSim(final String deviceId, final KafkaProducer<String, String> producer) {
15     timer.scheduleAtFixedRate(new TimerTask() {
16
17       @Override
18       public void run() {
19         if (r.nextBoolean()) {
20           System.out.println("Produced heartbeat for device " + deviceId);
21           producer.send(
22               new ProducerRecord<String, String> (
23                   "device-heartbeat",
24                   deviceId,
25                   deviceId + " sent heartbeat at " + new Date().toString()
26                   ));
27         }
28       }
29     }, r.nextInt(10000)+10000, 15*1000);
30   }
```

Interesting Code inside the Device Monitor

```
32      while (true) {
33        final ConsumerRecords<String, String> records = consumer.poll(1000);
34        for (ConsumerRecord<String, String> record : records) {
35          final String key = record.key();
36          lastSeenMap.put(record.key(), new Date());
37          System.out.println("Received heartbeat from: " + key + " value: " + record.value());
38          if (offlineDevices.contains(key)) {
39            offlineDevices.remove(key);
40            System.out.println("Device back online: " + key);
41            producer.send(createOnlineMessage(key));
42          }
43
44        }
45      }
```


docker-compose
Kafka and ZooKeeper
device simulator
device-monitor
console-consumer
1001]: Preparing to restabilize group console-consumer-42124 wit
h old generation 1 (kafka.coordinator.GroupCoordinator)
kafka_1 | [2017-11-12 04:00:27,487] INFO [GroupCoordinator
1001]: Group console-consumer-42124 with generation 2 is now emp
ty (kafka.coordinator.GroupCoordinator)
1001]: Preparing to restabilize group console-consumer-21385 wit
h old generation 0 (kafka.coordinator.GroupCoordinator)
ka.coordinator.GroupCoordinator)
kafka_1 | [2017-11-12 04:00:32,777] INFO [GroupCoordinator
1001]: Assignment received from leader for group console-consume
r-21385 for generation 1 (kafka.coordinator.GroupCoordinator)
Produced heartbeat for device Scale 4
Produced heartbeat for device Heart monitor 7
Produced heartbeat for device Heart monitor 1
Produced heartbeat for device Scale 7
Produced heartbeat for device Heart monitor 2
Produced heartbeat for device Heart monitor 1
Produced heartbeat for device Scale 3
Produced heartbeat for device Heart monitor 4
Produced heartbeat for device Scale 5
Produced heartbeat for device Heart monitor 2
Produced heartbeat for device Scale 1
Produced heartbeat for device Scale 2
Produced heartbeat for device Scale 6
sent heartbeat at Sat Nov 11 22:04:32 CST 2017
Received heartbeat from: Scale 3 value: Scale 3 sent heartbeat a
t Sat Nov 11 22:04:33 CST 2017
Received heartbeat from: Heart monitor 4 value: Heart monitor 4
sent heartbeat at Sat Nov 11 22:04:33 CST 2017
Received heartbeat from: Scale 5 value: Scale 5 sent heartbeat a
t Sat Nov 11 22:04:34 CST 2017
Received heartbeat from: Heart monitor 2 value: Heart monitor 2
sent heartbeat at Sat Nov 11 22:04:34 CST 2017
Received heartbeat from: Scale 1 value: Scale 1 sent heartbeat a
t Sat Nov 11 22:04:35 CST 2017
Received heartbeat from: Scale 2 value: Scale 2 sent heartbeat a
t Sat Nov 11 22:04:42 CST 2017
Received heartbeat from: Scale 6 value: Scale 6 sent heartbeat a
t Sat Nov 11 22:04:42 CST 2017
LM-SJN-21001415:docker pgraff$ docker-compose exec kafka /opt/kaf
ka_2.11-0.10.1.1/bin/kafka-console-consumer.sh --bootstrap-server
kafka:9092 --topic device-event
Scale 6 is back online
Heart monitor 4 offline since Sat Nov 11 22:00:03 CST 2017
Heart monitor 1 offline since Sat Nov 11 22:01:02 CST 2017
Heart monitor 1 is back online
Heart monitor 4 offline since Sat Nov 11 22:02:18 CST 2017
Scale 7 offline since Sat Nov 11 22:02:17 CST 2017
Scale 7 is back online
Heart monitor 4 is back online

Scaling Kafka

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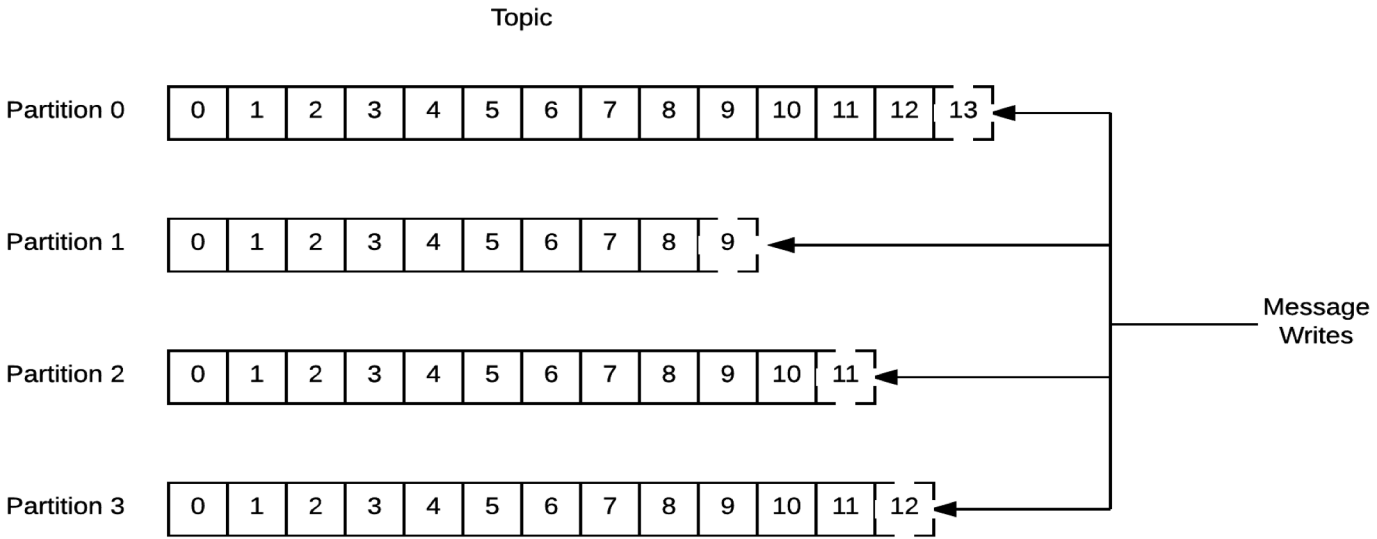
Topics and Partitions

- Messages in Kafka are categorized into *topics*
- Think of a topic as a database table or folder in a filesystem
- Topics are broken down into a number of *partitions*
- A topic generally has multiple partitions

Topics and Partitions



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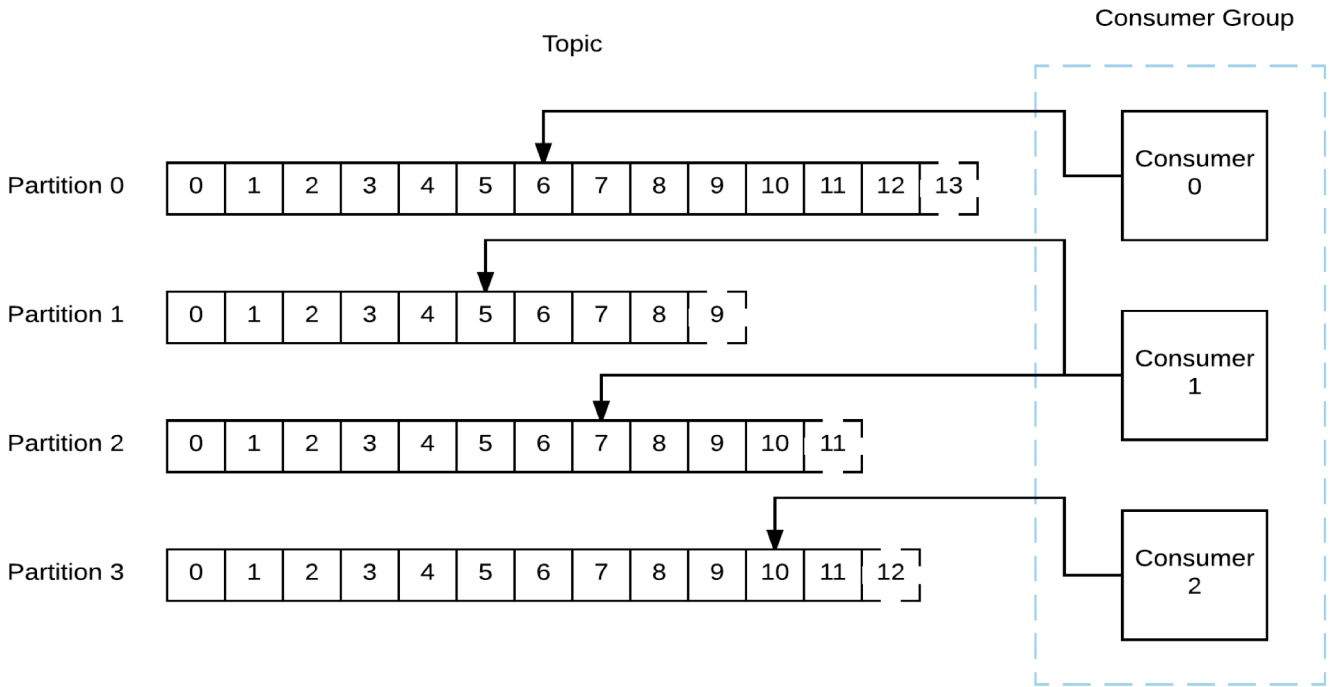
Consumer Groups

- Consumers work as part of a *consumer group*
- One or more consumers that work together to consume a topic
- Group assures that each partition is only consumed by one member
- Mapping of a consumer to a partition is called *ownership* of the partition by the consumer

Consumer Group Illustrated



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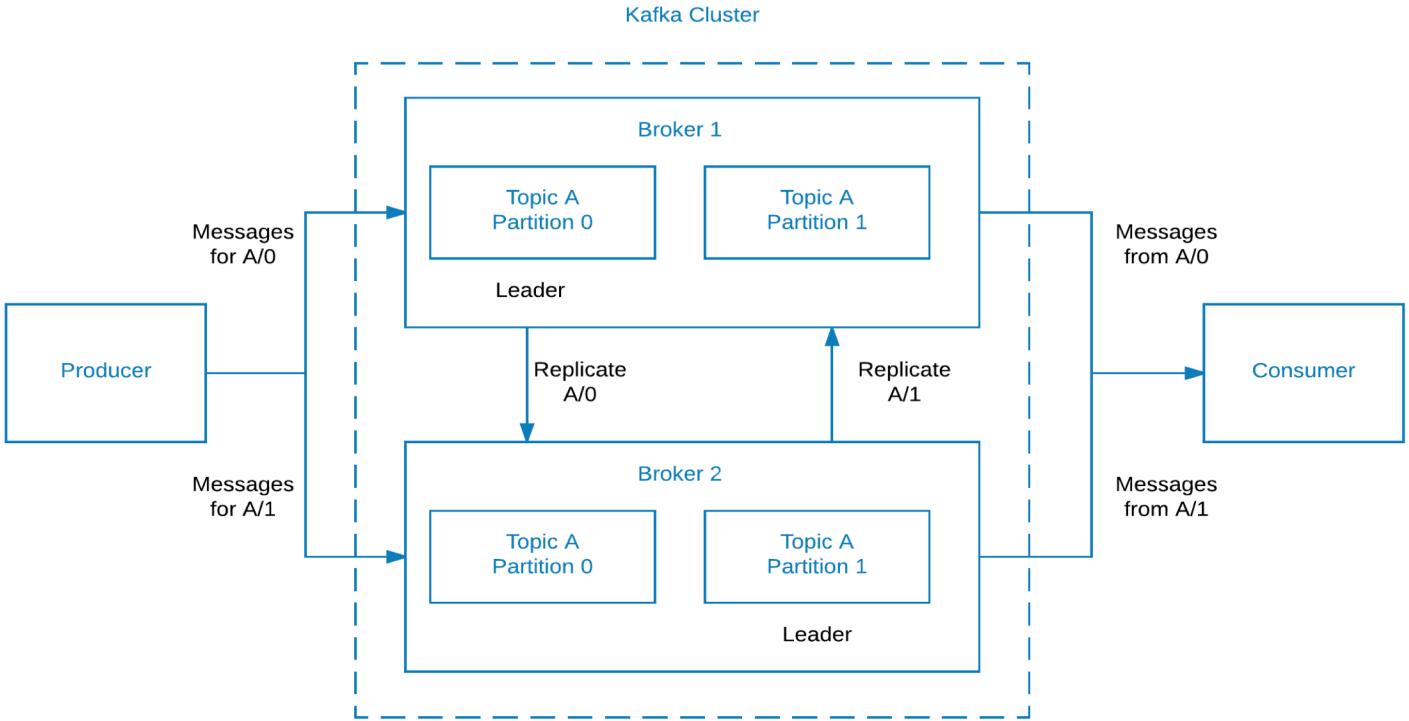
Brokers

- A single Kafka server is called a *broker*
- The broker receives messages from producers, assigns offsets to them, and commits the messages to storage on disk
- Responds to consumer fetch requests with the messages in the requested partition
- **A single broker can handle thousands of partitions and millions of messages per second**

Clusters

- Kafka brokers operate as part of a cluster
- Within a cluster of brokers, one broker acts as the ***cluster controller***
- The controller handles administrative operations such as assigning partitions to brokers and monitoring for broker failures
- A partition is owned by a single broker in the cluster known as the ***leader*** for the partition
- Another broker can take over leadership if there is a broker failure
- All consumers and producers on that partition must connect to the leader

Replication of Partitions in a Cluster



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Retention

- Kafka brokers are configured with a default retention setting for topics either retaining messages for some period of time or until the topic reaches a certain size in bytes
- When limits are reached, messages are expired and deleted
- Topics can be configured with their own retention settings
  - Application metrics may only be useful for a few hours
  - Tracking topics may be useful for several days
- Topics can be *log compacted* – Kafka only retains the last message produced with a specific key
  - For example, changelog data where only the last update is useful

Compression

- In some of the largest Kafka deployments, hundreds of billions of messages per day are processed amounting to **moving hundreds of terabytes of data**

- Enabling compression allows you to reduce network utilization which can be a bottleneck when sending messages to Kafka

- Compression is an optional configuration setting in the broker and producer

Supported Compression Algorithms

- snappy
  - Created by Google
  - Provides good compression ratio with low CPU overhead
  - Recommended when both performance and bandwidth are a concern
- gzip
  - Uses more CPU and time but results in better compression ratios
  - Recommended where network bandwidth is more restricted
- lz4
  - Newest algorithm to Kafka
  - Faster than gzip and smaller than snappy

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Compression Overview

- Multiple messages are bundled and compressed
- The compressed messages are then appended to Kafka's log file
- Compression works on a batch of messages rather than individual to take advantage of the fact that compressors work more efficiently with bigger data

Multiple Clusters

- As your Kafka deployment grows, it can be advantageous to have multiple clusters:
  - Segregation of types of data
  - Isolation for security requirements
  - Multiple datacenters (disaster recovery)

- With multiple datacenters, messages must be copied between them

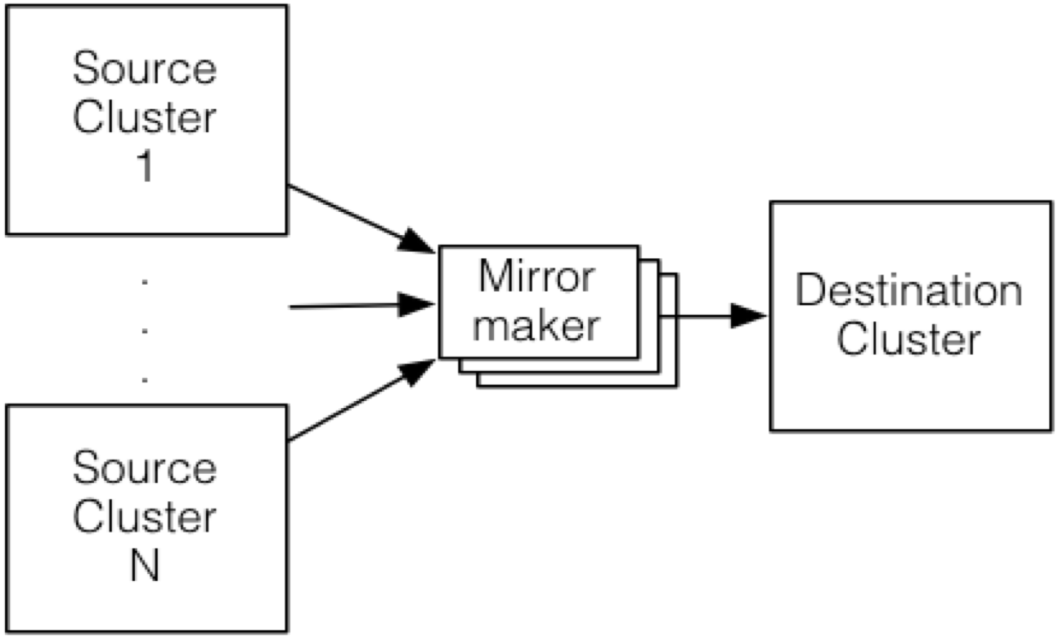
- Replication within a Kafka cluster only works within a single cluster, not between multiple clusters

Cluster Mirroring

- Kafka includes a tool called *Mirror Maker* to mirror a source Kafka cluster into a target (mirror) cluster

- Uses a Kafka consumer to consume messages from the source cluster and re-publishes the messages to the local (target) cluster using an embedded Kafka producer

Mirror Maker Illustrated



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Scaling with MirrorMaker

- Designate clusters into two categories
- **Mission critical,** production
  - E.g. supporting microservices
- **Non-mission critical**
  - Consumers which are not mission critical read from another cluster
  - E.g. run analytics, feed real-time analytics and dashboards
- Mission critical cluster is not affected by readers

Multiple MirrorMakers

- Production cluster
- Analytics cluster
- Backup cluster

- Mirrormakers:
  - Production → MirrorMaker1 → Analytics
  - Production → MirrorMaker2 → Backup

Summary

- Topics and Partitions
- Producers and Consumers
- Consumer Groups
- Brokers
- Clusters
- Retention
- Compression
- Mirror Maker

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Kafka Streaming

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Introduction

- Kafka Streaming: An alternative for streaming to and from Kafka
  - Part of the Apache Kafka
  - Powerful
    - Highly scalable, fault-tolerant
    - Rich feature set with support for both stateless and stateful processing
    - Support for fault-tolerant local state
  - Lightweight
    - Just a library integrated in Kafka (no external dependencies)
    - No need for dedicated clusters
  - Near real-time
    - Millisecond processing latency
- Kafka and Spark / Flink

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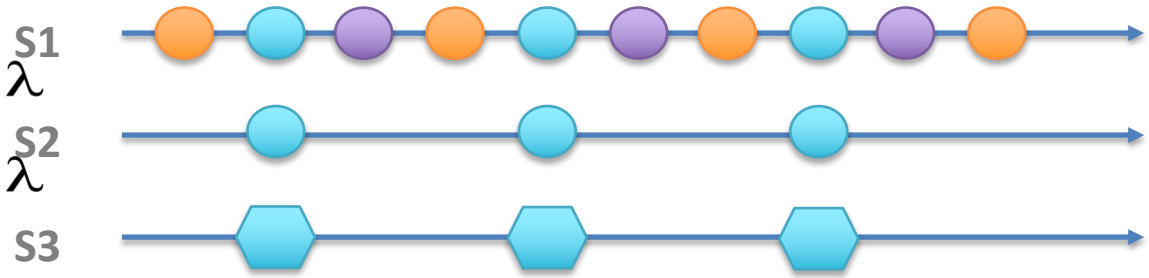
Two API's

- Kafka supports a low level API that can be used to manipulate streams

- We'll focus on the Kafka Stream `DSL`
  - Higher level
  - Closer to other streaming ideas
    - Brining in some of the functional programming paradigms

What is Stream Processing?

- Programming with streams of data (even unbounded streams)
- Typical traits
  - Functional
    - Apply a dataflow or a sequence of functions to the streams
    - Combining functions provides a powerful expression language (lambda expression)
  - Reactive
    - Process incoming stream data immediately upon receipt



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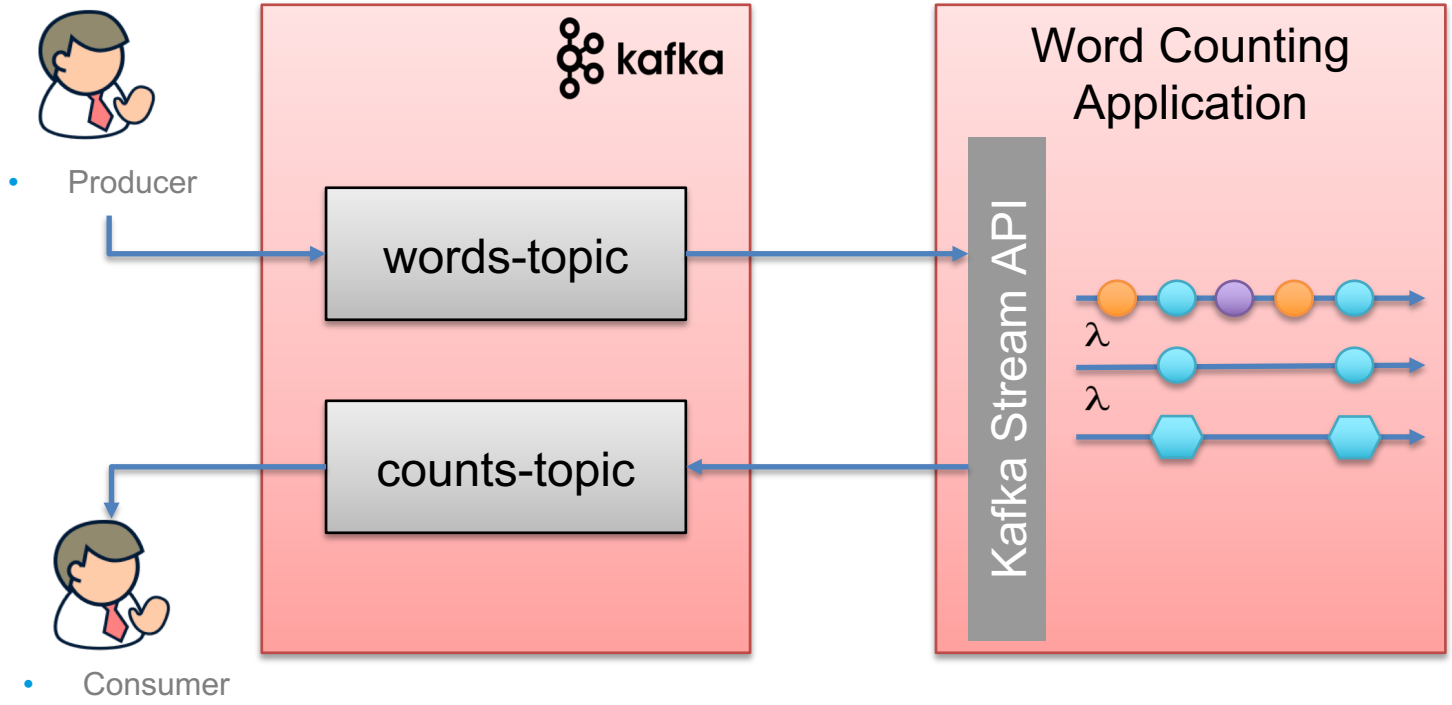
The Obligatory Word Count Example



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Kafka Stream Classes

- StreamsConfig
  - A wrapper around a map used for configuration
- KStreamBuilder
  - The key class for setting up the stream processing
  - Based on the GoF Builder Pattern
    - Fluent API
    - Constructs the processing dataflow
- KafkaStreams
  - A wrapper of the actual stream

Enable Kafka Stream (Using Maven)

- Kafka Streams are distributed as a simple jar file
- Simply include the jar file in your program and you'll be able to use the streaming library

```
<dependency>
        <groupId>org.apache.kafka</groupId>
        <artifactId>kafka-streams</artifactId>
        <version>1.1.0</version>
</dependency>
```

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Programming to Stream

```
// Configure
Properties props = new Properties();
pros.put(StreamsConfig.CLIENT_ID_CONFIG, "...")
...
StreamsConfig config = new StreamsConfig(props);

// Serialization/deserialization
Serde<String> serDeser = Serdes.String();

// Create the data processing pipeline
KStreamBuilder bld = new KStreamBuilder();
bld.stream(serDeser, serDeser, "topic")
.map(...) ...

// Create stream
KafkaStreams sp = new KafkaStreams(bld, config);

// Start stream
kafkaStreams.start();
```

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Word Count Streaming

```
StreamsConfig config = new StreamsConfig(props);
Serde<String> serde = Serdes.String();

KStreamBuilder bld = new KStreamBuilder();
bld.stream(serde, serde, "words-topic")
  .flatMapValues(text -> asList(text.split(" ")))
  .map((key, word) -> new KeyValue<>(word, word))
  .countByKey(serde, "Counts")
  .toStream()
  .map((word, count) ->
               new KeyValue<>(word, word + ":" + count))
  .to(serde, serde, "counts-topic");

KafkaStreams s= new KafkaStreams(bld, config);
s.start();
```

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kafkacat – A Useful Tool

- kafkacat is a tool created by Magnus Edenhill
  - https://github.com/edenhill/kafkacat
  - Doesn't require JVM
  - Similar to 'netcat'
  - Can act as a Producer and consumer
  - Useful also to query metadata from Kafka
- To provide the word list to the application, we could simply use kafkacat instead of writing new producers and consumers
- Use as a producer
  - kafkacat –P –b myBroker –t topic1
- Use as a consumer
  - kafkacat –b myBroker –G mygroup topic1 topic 2

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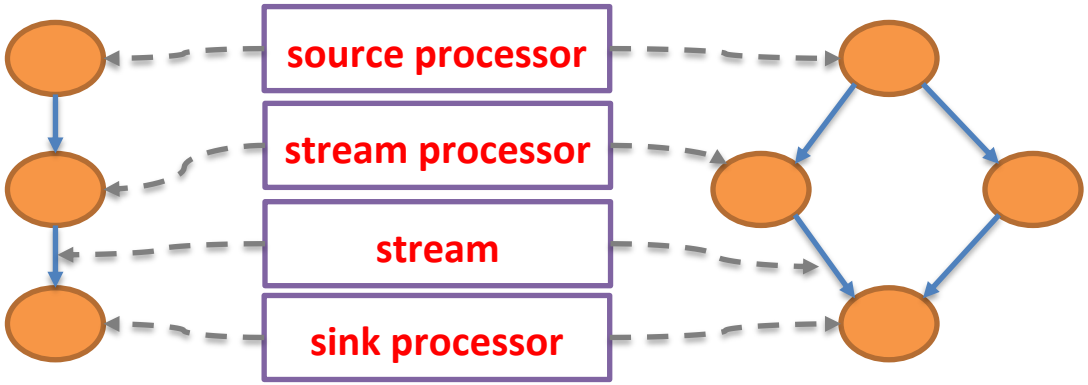
Installing kafkacat

- The installation of kafkacat is trivial on Mac most Linux distributions
  - Mac
    - brew install kafkacat
  - Ubuntu or Debian
    - [sudo] apt-get install kafkacat

- Our Kafka docker image is using Alpine distribution so if you want to run it in the docker image you'll have to:
  - apk add --update alpine-sdk bash python cmake
  - curl https://codeload.github.com/edenhill/kafkacat/tar.gz/master | tar xzf - && cd kafkacat-* && bash ./bootstrap.sh

Processor Topology



- The topology defines the computational logic of the data processing pipeline
- The topology typically forms a chain, but more advanced computation may be defined as a graph

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Processing and Time

- In streaming time is an important design consideration
  - When working with concepts such as windowing, it is essential to establish which time to use
- Event-time
  - The point in time when an event or data record was created by the source
- Processing-time
  - The point in time when an event was processed by the stream processor
- Ingestion-time
  - The point in time when an event was stored in a topic partition by one of the Kafka brokers

Stateful Stream Processing

- Typically we try to make our stream processing stateless
- However, for some use cases, stateful streaming may be essential
- The Kafka Stream DSL provides support for stateful processing

Stream vs. Table

- Kafka streams introduces the concept of tables, where
  - A stream can be viewed as a table: KStream → KTable
  - A table can be viewed as a stream: KTable → KStream
  - (called stream-table duality)
- Streams as tables
  - A stream can be considered a changelog of a table
  - One can convert the stream into a table by replaying the event stream
- Table as streams
  - A table can be be converted into a stream by iterating over each key-value entry

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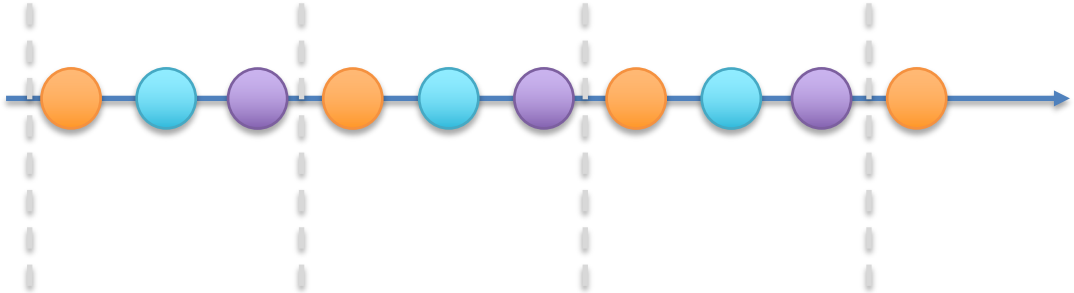
Windowing

- We may have to process data in time buckets, called windows
- Typically as part of some form of aggregation
- Windowing operations are available in the Kafka Stream DSL
- A window has a retention period to handle possible late arriving events



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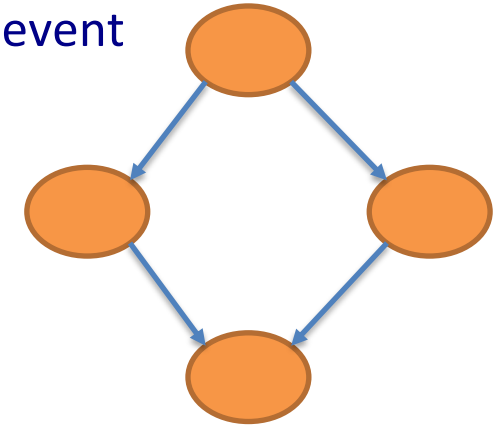
Parallel Stream Processing Pipelines

- The Kafka Stream DSL supports ways to parallelize and rendezvous processing steps
- Join
  - This operation merges two streams into a single stream
- Aggregation
  - Takes one input stream and yields a new stream by combining multiple input events into a single output event



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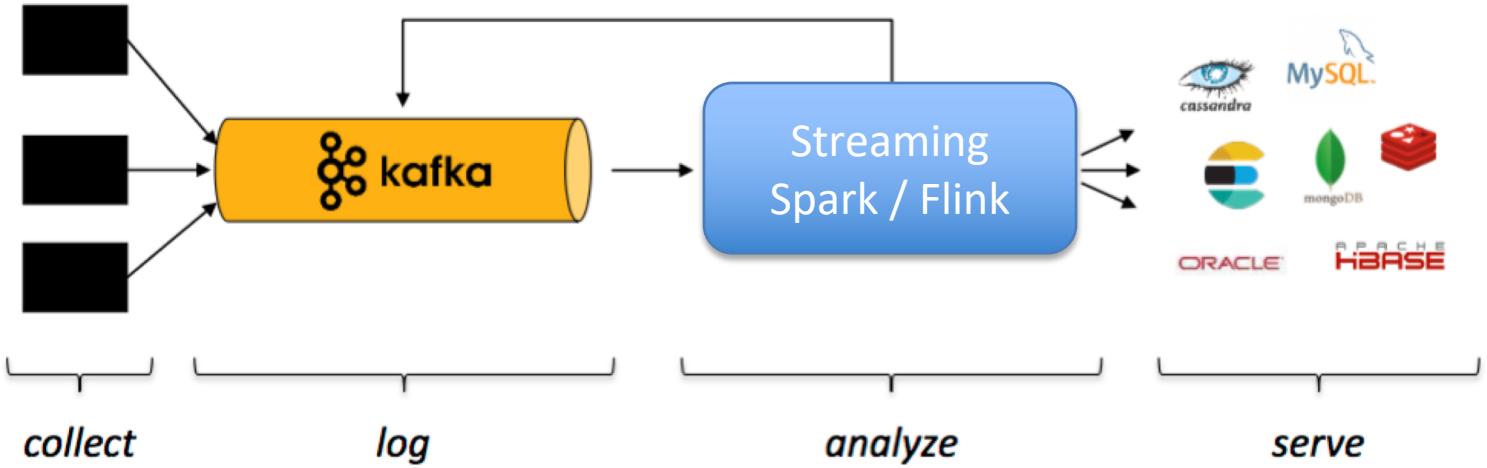
Backpressure

- Kafka Streams don't need a back pressure mechanism
- Kafka uses a depth-first processing strategy
  - Each event consumed from Kafka goes through the complete processor topology before the next message is processed

Kafka with Spark or Flink



- Gather and backup streams
- Offer streams for consumption
- Provide stream recovery

- Analyze and correlate streams
- Create derived streams and state
- Provide these to downstream systems

Spark Streaming and Kafka

- We can set up Spark to use Kafka stream as the source of events

- Code structure:
  - A bit of configuration for Spark Streaming
  - A bit of configuration for Kafka parameters
  - Create stream from Kafka

- At this point, we have a DStream and we can do the normal Spark Streaming processing on it

Spark Streaming with Kafka – Spark Configuration

```
// Consume command line parameters
val Array(brokers, topics, interval) = args

// Create Spark configuration
val sparkConf = new SparkConf().setAppName("SparkKafka")

// Create streaming context, with batch duration in ms
val ssc = new StreamingContext(sparkConf, Duration(interval.toLong))
ssc.checkpoint("./output")
```

Spark Streaming with Kafka – Kafka Configuration

```
// Create a set of topics from a string
val topicsSet = topics.split(",").toSet

// Define Kafka parameters
val kafkaParams = Map[String, Object](
  "bootstrap.servers" -> brokers,
  "key.deserializer" -> classOf[StringDeserializer],
  "value.deserializer" -> classOf[StringDeserializer],
  "group.id" -> "use_a_separate_group_id_for_each_stream",
  "auto.offset.reset" -> "latest",
  "enable.auto.commit" -> (false: java.lang.Boolean))
```

Create a Kafka Stream in Spark and Use It

```
// Create a Kafka stream
val stream = KafkaUtils.createDirectStream[String, String](
  ssc, PreferConsistent, Subscribe[String, String](topicsSet,kafkaParams))
// Get messages - lines of text from Kafka
val lines = stream.map(consumerRecord => consumerRecord.value)
// Split lines into words
val words = lines.flatMap(_.split(" "))
// Map every word to a tuple
val wordMap = words.map(word => (word, 1))
// Count occurrences of each word
val wordCount = wordMap.reduceByKey(_ + _)
//Print the word count
wordCount.print()
```

Summary

- Kafka provides a stream processing library
- Two APIs
  - Low level API
  - Kafka Stream DSL
- The Kafka Stream DSL enables the definition of processing topologies
- Kafka streams support stateful stream processing
- Kafka has a reach support of functions and features
  - Windowing
  - Aggregation
  - Join
  - Functions (map, flatMap, etc.)
- Integration with other streaming systems: Spark, Flink, …

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Lab/Demo

- We have 4 examples for streaming
- 1: Word count using Kafka Streams (We'll show this example)
  - I will show this in slides
- 2: Word count in Spark
  - I'll leave that for you to do after the class
- 3: IoT example in Spark
  - I'll walk you through the code
- 4: IoT example implemented in Kafka Streams (We'll show if we have time)
  - I'll walk you through the code

Lab/Demo: Hello World with Kafka Streams

- The hello-world of distributed computing is a simple word count!
  - We have a stream of text coming in on a topic
  - We want to count the number of times a word appear in the stream
  - We'll use a continuous count
  - We want to make sure that if the Kafka clients goes down, they can continue from the last point of processing
  - We want to make sure that the solution works even though we run multiple consumers
- We'll use the "kafka-console" tools to produce the input and consume the output
- The processor is written in Java and built with Maven

One New Parameter (print.key)

- When we run the kafka-console-consumer, you'll notice one additiona parameter

```
docker-compose exec kafka
/opt/kafka_2.11-0.10.1.1/bin/kafka-console-
consumer.sh
--bootstrap-server localhost:9092
--topic stream-output
--from-beginning
--property print.key=true
```

Prints the key as well as the value of each message

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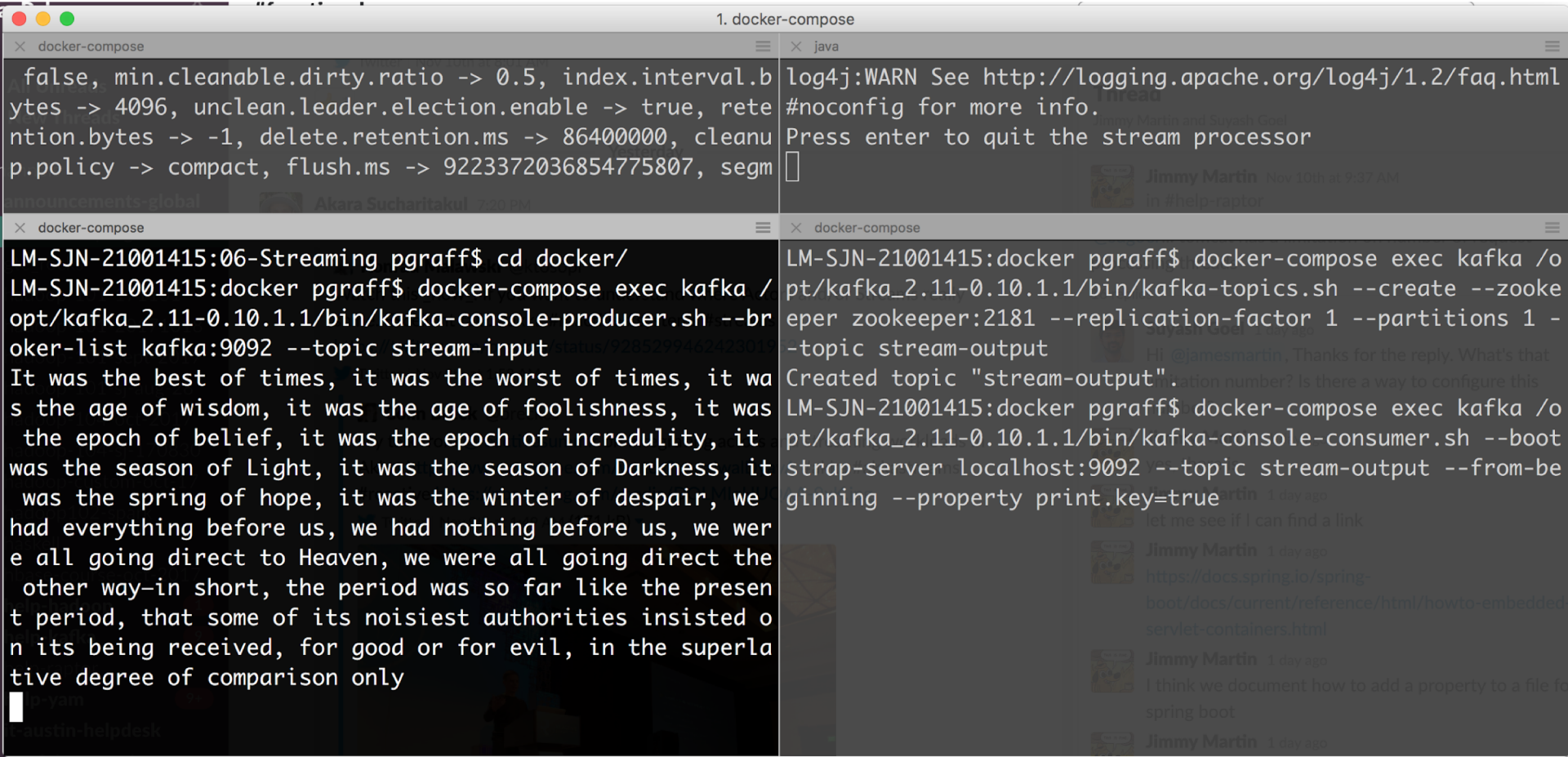
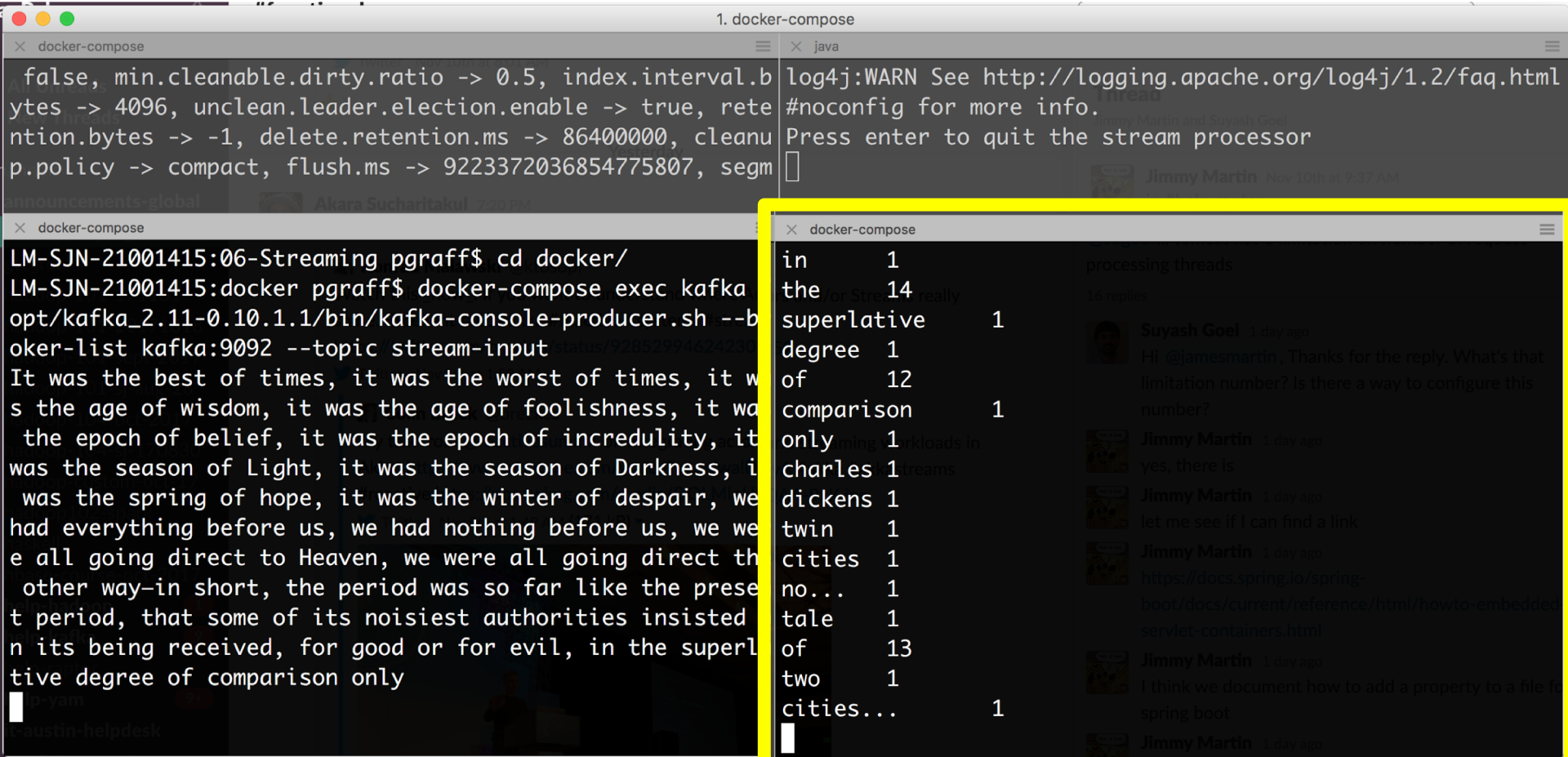
Expected Delay…



After some time...



Demo/Lab: Asset Management System

We'll show a real-time example from a product that we built for a client some time ago:

- We are tracking a set of vehicles (500,000 vehicles)
- The vehicle has a tracker that yields its location at regular intervals
- The vehicle is being tracked in case it needs to be repossessed
- What if the vehicle tracker is broken (or deliberately uninstalled)?
- How can we find the vehicle?
- Idea:
  - Let's look at its past behavior and figure out where it has been parked
  - Let's figure out it's most frequent parking spots

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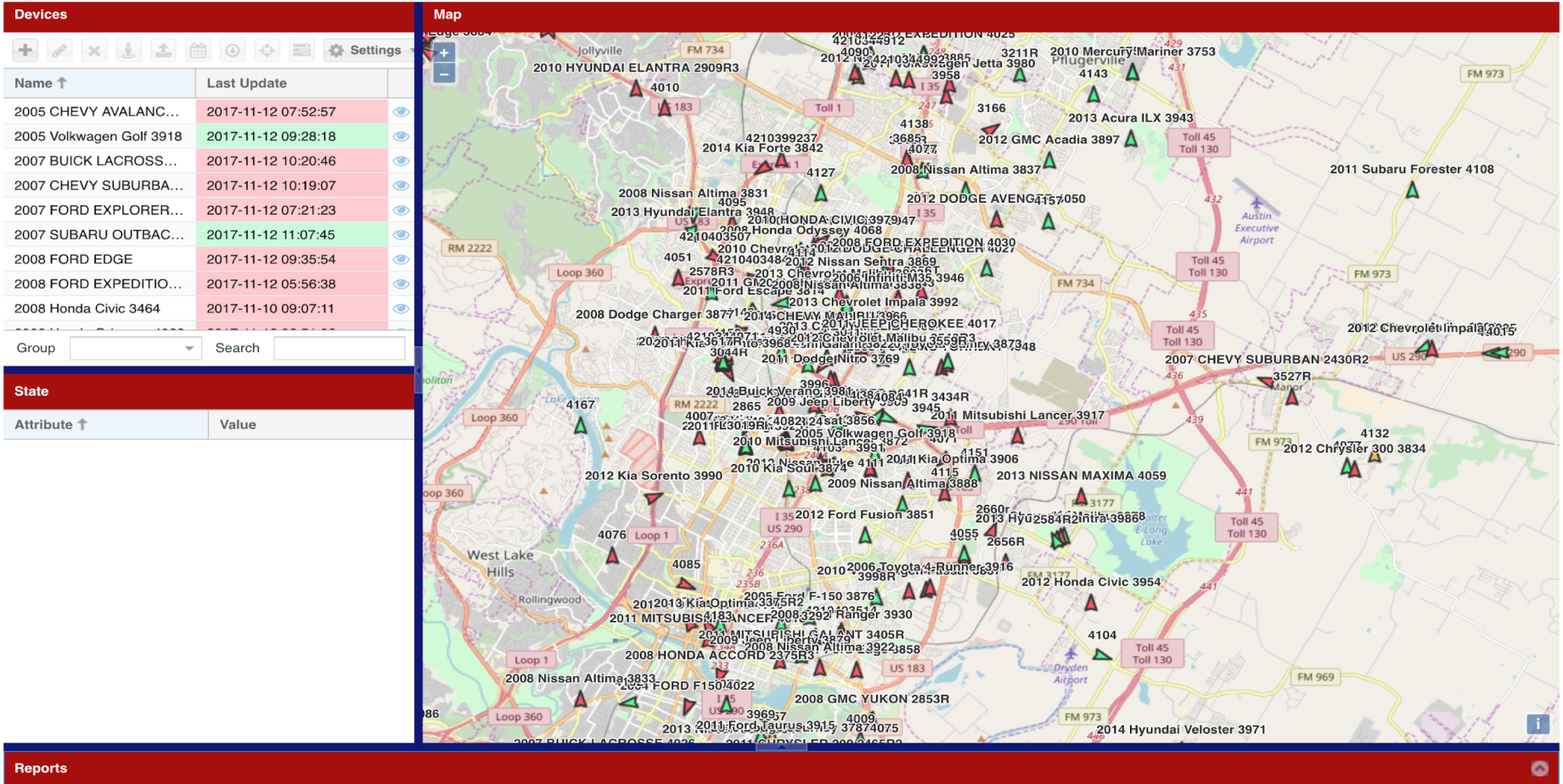
The Tracking Solution



Devices

Settings

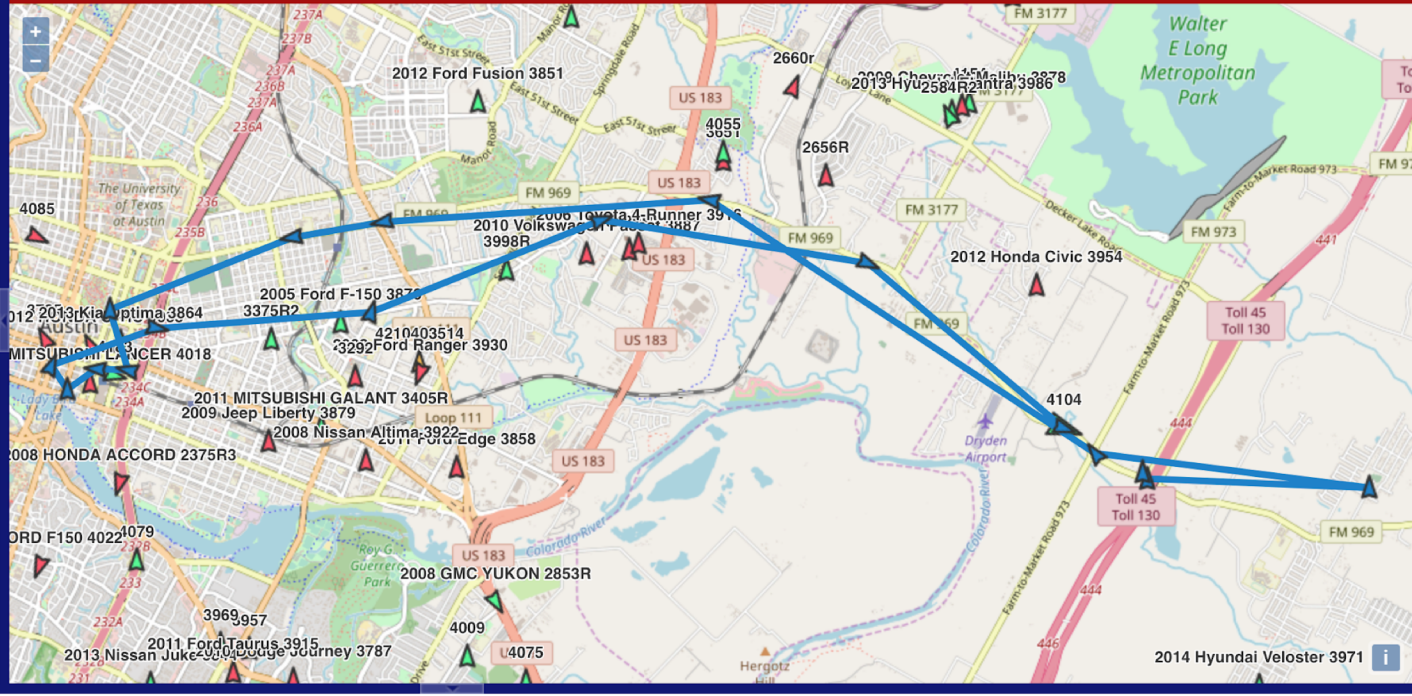
Name	Last Update
2005 CHEVY AVALANC…	2017-11-12 07:52:57
2005 Volkwagen Golf 3918	2017-11-12 09:28:18
2007 BUICK LACROSS…	2017-11-12 10:20:46
2007 CHEVY SUBURBA…	2017-11-12 10:19:07
2007 FORD EXPLORER…	2017-11-12 07:21:23

Group Search

State

Attribute	Value
Address	display
Battery	No
Color	BLACK
Course	E
Ignition	Yes
Ip	80.65.250.116
Latitude	30.259717
Longitude	-97.615567

Map



Device 4104 From 2017-11-12 00:00 To 2017-11-12 23:59 Show Clear

Event	Time	Latitude	Longitude	Speed	Address
.. moving	2017-11-12 01:22:00	30.259717	-97.615567	50.6 mph	display
.. moving	2017-11-12 01:17:00	30.278067	-97.640783	51.8 mph	display
.. moving	2017-11-12 01:12:00	30.282883	-97.675117	31.1 mph	display
.. moving	2017-11-12 01:07:00	30.272633	-97.704783	12.7 mph	display
.. moving	2017-11-12 01:02:00	30.270833	-97.732417	16.1 mph	display
.. moving	2017-11-12 00:57:00	30.266733	-97.745950	20.7 mph	display
.. moving	2017-11-12 00:52:00	30.264017	-97.743933	2.3 mph	display

Example Description

- We get a stream of vehicle locations
- Each location contains:
  - Vehicle ID
  - Data of observation
  - Speed
  - Direction
  - Latitude
  - Longitude

Problem and Plan

- We want to know where the vehicle is most likely to be parked
- Our plan
  1. Parse the vehicle data from an input stream
  2. Filter out the only those locates where the vehicle was at rest
  3. Convert the vehicle locate into keys that we can accumulate. The key would be based on
     - Vehicle ID
     - Geo location
  4. Group the locates together by key and count them
  5. Stream the frequent parking count to another stream

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Input File: vehicle_1_to_1000.tsv

```
678  120 2016-08-16 16:31:21 30  162 -97.79678333333334  30.466516666666667
679  120 2016-08-16 16:31:31 5 159 -97.79646666666666  30.465716666666665
680  113 2016-08-16 16:31:37 5 159 -97.79645 30.465733333333333
681  120 2016-08-16 16:31:41 5 159 -97.79646666666666  30.465716666666665
682  120 2016-08-16 16:31:51 5 159 -97.79646666666666  30.465716666666665
683  120 2016-08-16 16:32:01 14  154 -97.79638333333334  30.465566666666668
684  120 2016-08-16 16:32:11 22  163 -97.79596666666667  30.464583333333334
685  120 2016-08-16 16:32:17 28.4  159 -97.795695  30.463865
686  120 2016-08-16 16:32:21 26  159 -97.79548333333334  30.463366666666666
687  107 2016-08-16 16:32:29 25  159 -97.79508333333334  30.4624
688  120 2016-08-16 16:32:31 24  157 -97.795 30.462216666666666
689  120 2016-08-16 16:32:41 7 160 -97.79466666666667  30.4615
690  120 2016-08-16 16:32:51 2 158 -97.79463333333334  30.461433333333332
691  113 2016-08-16 16:32:52 2.1 160 -97.79464166666666  30.461433333333332
692  120 2016-08-16 16:33:01 2 158 -97.79463333333334  30.461433333333332
693  111 2016-08-16 16:33:08 2 161 -97.79468333333334  30.46145
```

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Message Pump: Simulator

- We've created a message pump application to simulate the vehicle input
- You can find this implementation in the directory:
  `kafka-lab/labs/06-Streaming/iot-kafka/gps-pump`
- The implementation reads the TSV file and produces messages into a topic called:
  `gps-locations`
- In the real world, we would have to write some edge servers that receives the data from the vehicles and publish the topic into the topic

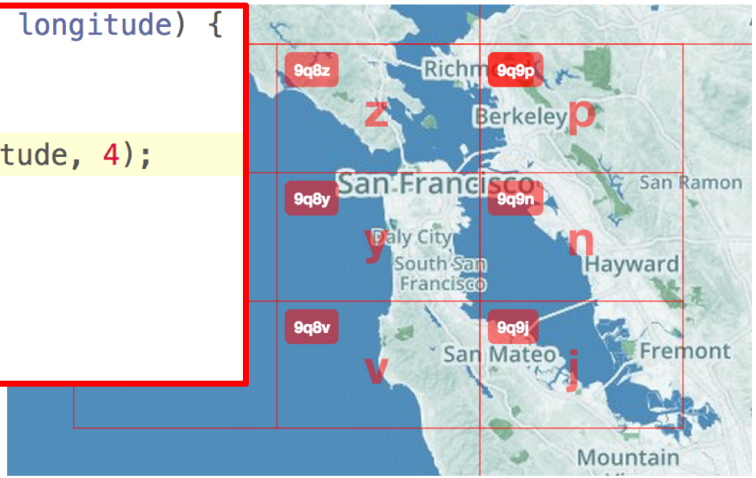
Event Processor

- We've created an event processor based on kafka-streaming (and another on Spark that we'll look at later)
- You can find this implementation in the directory: **`kafka-lab/labs/06-Streaming/iot-kafka/gps-monitor`**
- This processor uses kafka-streams to read the events from the topic **`gps-locations`** and produces messages on the topic **`frequent-parking`**
  - The messages produced:
    - Key: Vehicle and location key based on GeoHash
    - Value: parking count

GeoHash

- We build a key based on the vehicle id and a GeoHash
- GeoHash allows us to focus on an area instead of absolute locates

```
 9    public LocationKey(String id, double latitude, double longitude) {
10      this.objectId = id;
11      try {
12        this.geoHash = GeoHash.encodeHash(longitude, latitude, 4);
13      }
14      catch (Exception e) {
15        System.out.println(e.getMessage());
16      }
17    }
```



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Kafka Stream Solution

```
1  source
2    .map( (key,value) -> new KeyValue<>(key, value.split("\t")))
3    .filter((key,value)-> value.length > 5 && Double.parseDouble(value[2]) == 0)
4    .map((key,value) ->
5        new KeyValue<>(
6          new LocationKey(value[0],
7            Double.parseDouble(value[4]),
8            Double.parseDouble(value[5])).toString(),
9            value[0]))
10   .groupByKey()
11   .count("parking")
12   .mapValues((value) -> Long.toString(value))
13   .to("frequent-parking");
```

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Output

java

```
Calculating geohash for 88(-97.40266666666666,27.
Calculating geohash for 88(-97.40266666666666,27.
Calculating geohash for 88(-97.40266666666666,27.
Calculating geohash for 88(-97.40266666666666,27.
Calculating geohash for 22(-97.89346666666667,30.
Calculating geohash for 22(-97.89346666666667,30.
Calculating geohash for 22(-97.9058,30.37845)
Calculating geohash for 22(-97.9058,30.3784166666
Calculating geohash for 88(-97.40265,27.765433333
Calculating geohash for 88(-97.40266333333334,27.
Calculating geohash for 88(-97.40263333333333,27.
Calculating geohash for 88(-97.40264833333333,27.
Calculating geohash for 88(-97.4027,27.7654)
Calculating geohash for 88(-97.402715,27.76541)
Calculating geohash for 88(-97.40266666666666,27.
Calculating geohash for 88(-97.40267333333334,27.
Calculating geohash for 88(-97.40267333333334,27.
```

docker-compose

```
120@9v6m        5934
111@9v6m        1035
107@9v6m        2208
13@9v6m 1575
22@9v6m 1903
22@9v6k 4588
88@9v6m 2464
22@9v6e 146
88@9uft 4587
114@9v6m        144
110@9v6m        144
88@9ufq 648
113@9v6m        2016
88@9ufw 360
120@9v6m        6192
111@9v6m        1080
107@9v6m        2304
13@9v6m 1638
22@9v6m 1981
22@9v6k 4773
```

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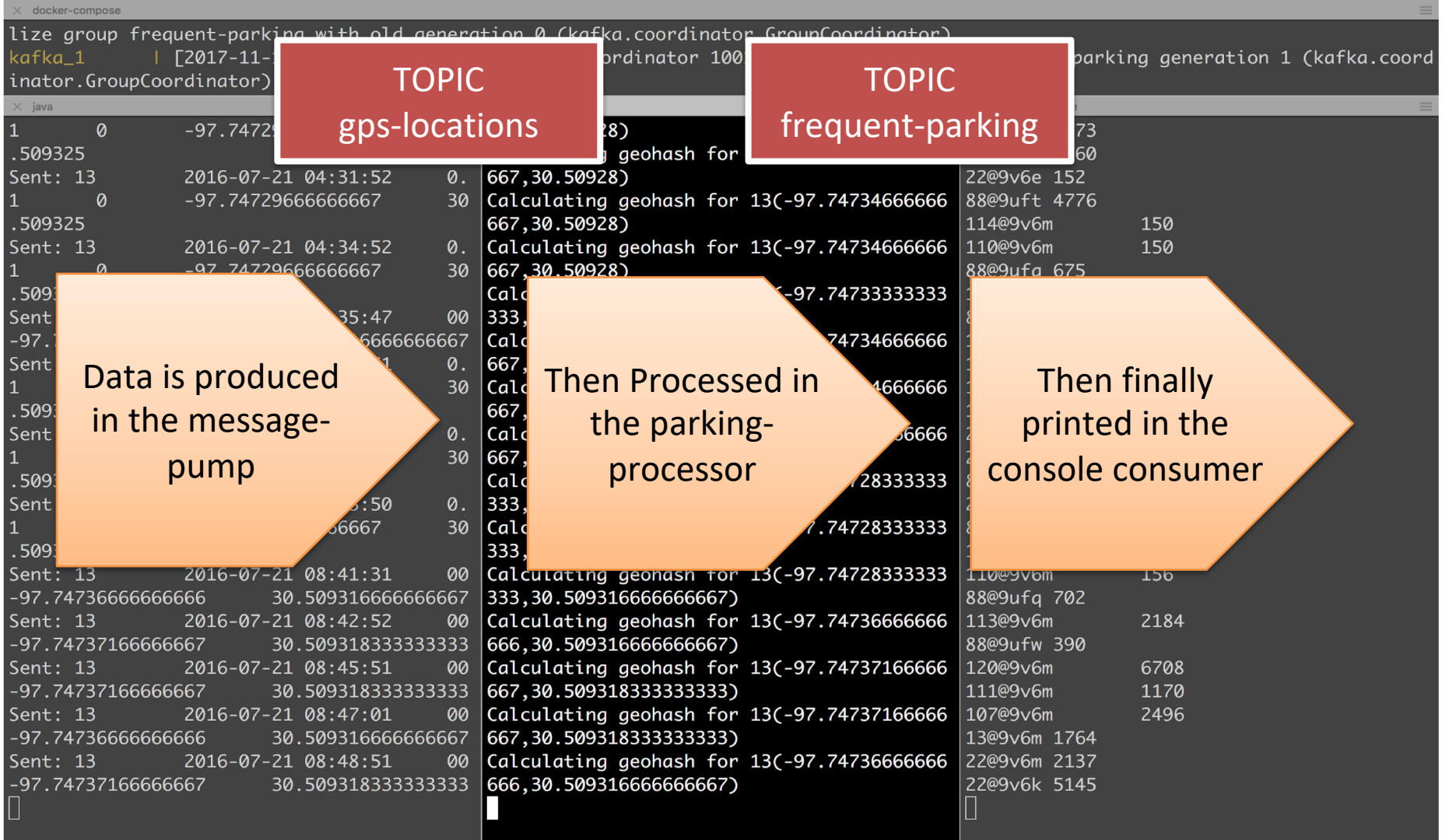
TOPIC
gps-locations
TOPIC
frequent-parking
Data is produced in the message-pump
Then Processed in the parking-processor
Then finally printed in the console consumer

Kafka Administration and Integration

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TECHNOLOGY GROUP

Kafka Integration with Hadoop

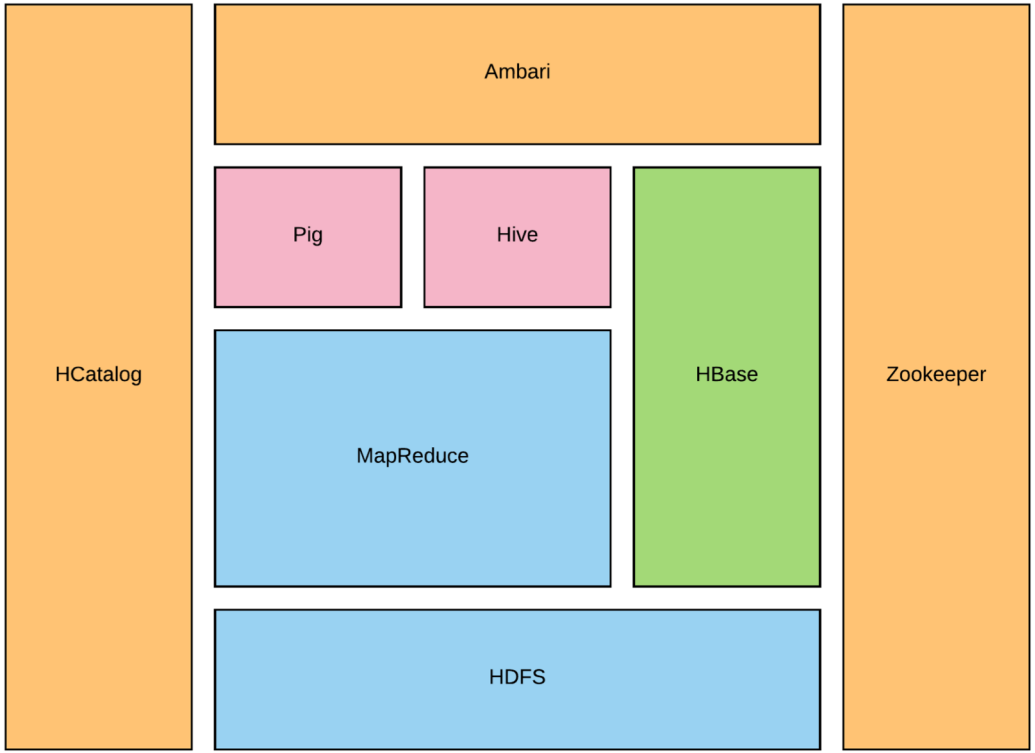
- Another common use case is consuming Kafka data directly into **Hadoop**
- **Hadoop** is a large scale distributed batch processing framework which parallelizes data processing across many servers
- Its strength is in the ability to scale across thousands of commodity servers that don't share memory or disk space

Major Functional Components

- **Hadoop** can be thought of as an ecosystem comprised of many different components that work together to create a single platform

- Two key functional components:
  - **HDFS** – a scalable file system that distributes and stores data across all machines in Hadoop cluster
  - **MapReduce** – the system used to efficiently process the large amount of data stored in HDFS. Large data is divided into smaller and smaller tasks in a pipeline.

Hadoop Cluster Components



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Kafka Integration with Hadoop

- In earlier versions of Kafka (0.8), integration with Hadoop could be achieved with an extension directly in the Kafka code base

- This was great news for Hadoop users but a lot of code would need to be written for other integrations
  - S3
  - HBase
  - JDBC
  - Cassandra

Kafka Connect and Confluent

- **Confluent** is a startup that was founded in 2014 by the creators of Kafka
- **Kafka Connect** is a feature in Apache Kafka 0.9+ developed by **Confluent** that makes building and managing stream data pipelines easier
- **Kafka Connect** abstracts away common problems that every connector to Kafka needs to solve such as
  - fault tolerance
  - partitioning
  - offset management
  - monitoring

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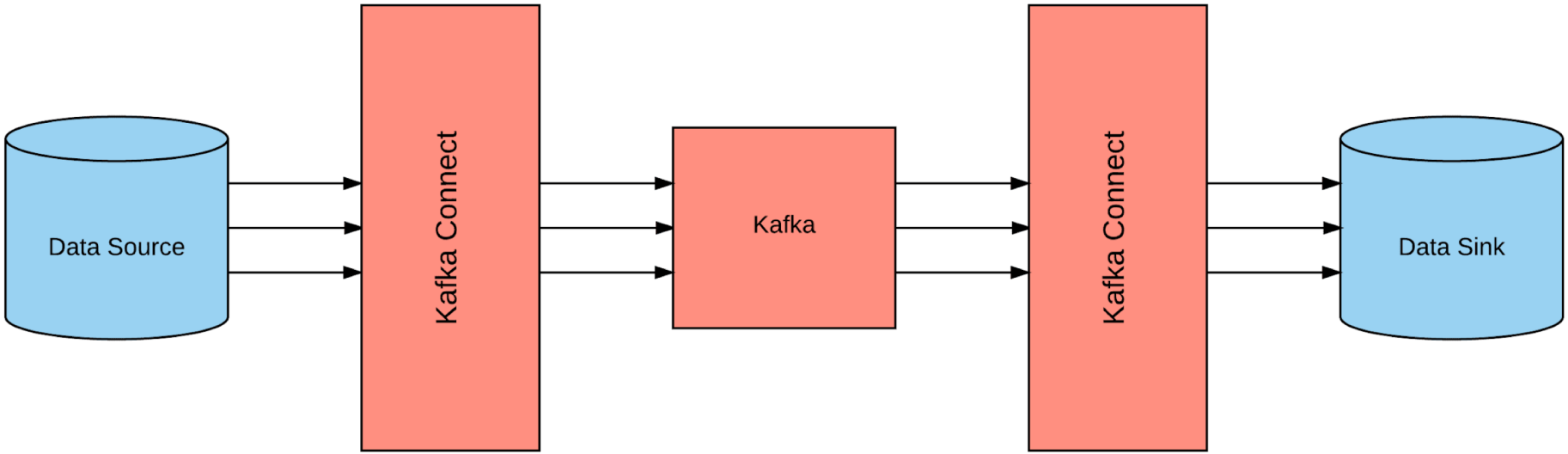
High Level Look at Kafka Connect



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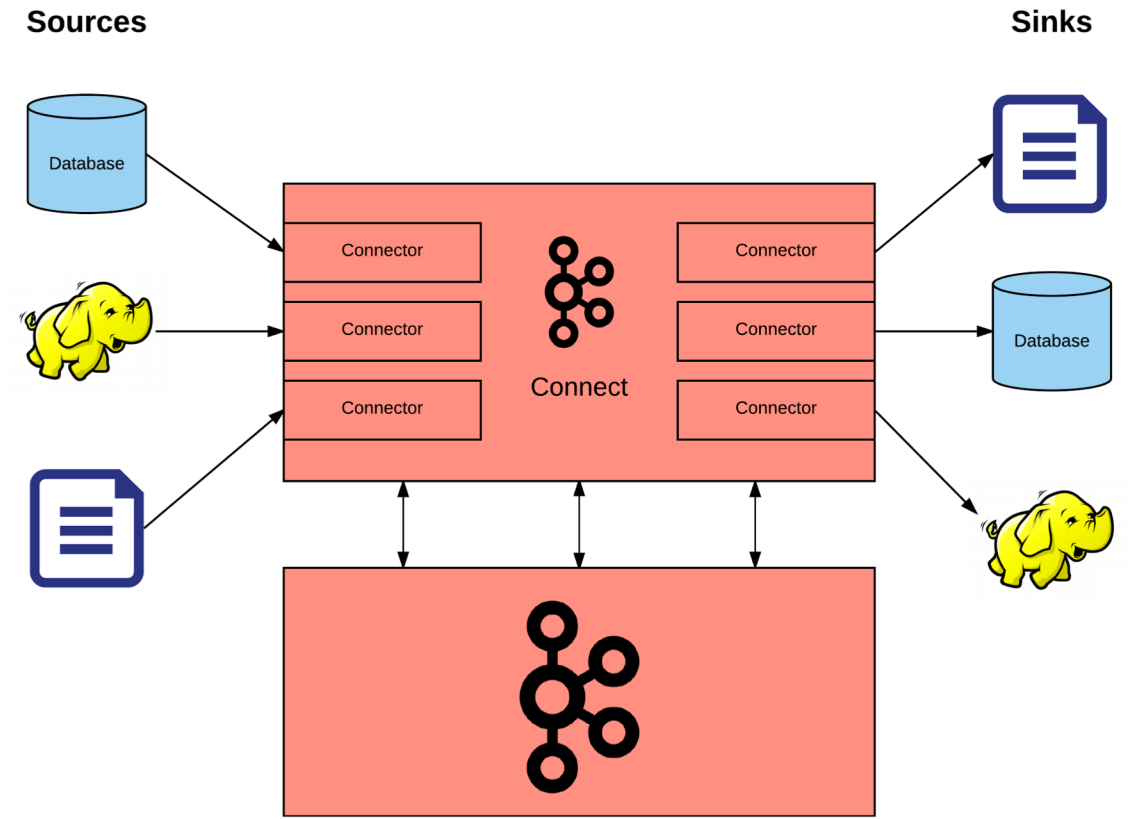
Certified Connectors

- Confluent maintains the **HDFS (Sink) connector** using the Kafka Connect framework
- Other certified connectors from Confluent include
  - JDBC (Source)
  - Elastic Search (Sink)
  - Attunity (Source)
  - Couchbase (Source)
  - GoldenGate (Source)
  - JustOne (Sink)
  - Syncsort DMX (Source)
  - Syncsort DMX (Sink)
  - Vertica (Source)
  - Vertica (Sink)

Additional Community Connectors

- Other notable community connectors utilizing Kafka Connect
  - Cassandra (Source and Sink)
  - Elastic Search (Sink)
  - FTP (Source)
  - HBase (Sink)
  - InfluxDB (Sink)
  - Bloomberg Ticker (Source)
  - MongoDB (Source)
  - Mixpanel (Source)
  - MQTT (Source)
  - Solr (Sink and Source)
  - And more!

Another Kafka Connect View



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Kafka Administration

- There are a number of useful operations that are not automated and must be triggered using one of the tools that ship with Kafka
  - Adding/deleting topics
  - Modifying topics
  - Graceful shutdown
  - Balancing leadership
  - Checking consumer position
  - Mirroring data between clusters
  - Expanding a cluster
  - Decommissioning brokers
  - Increasing replication factor

Adding and Deleting Topics

- Topics can be added manually or you can have them be created automatically when data is first published to a non-existent topic

- Topics are added and removed with the topic tool
  - kafka-topics.sh --zookeeper zk_host:port --create --topic my_topic_name --partitions 20 --replication-factor 3 --config x=y
  - kafka-topics.sh --zookeeper zk_host:port --delete --topic my_topic_name

Modifying Topics

- Changing the configuration or partitioning of a topics can be done with the same topic tool
  - kafka-topics.sh --zookeeper zk_host:port/chroot --alter --topic my_topic_name --partitions 40

- The partition count controls how many logs the topic will be sharded into

Graceful Shutdown

- A Kafka cluster will automatically detect any broker shutdown or failure and elect new leaders for the partitions on that machine
- When a broker is brought down intentionally for configuration changes, Kafka supports a more graceful shutdown that comes with two optimizations
  - All logs are synced to disk to avoid needing to validate checksums when restarting. This speeds up intentional restarts
  - Partitions the server is the leader for will be migrated to other replicas prior to shutting down. This will make leadership transfer faster and minimize the time each partition is unavailable to a few milliseconds

Graceful Shutdown Continued

- To take advantage of this graceful shutdown, the following setting is required
  - controlled.shutdown.enable=true

Checking Consumer Position

- The following command will show the position of all consumers in a consumer group and how far behind the end of the log they are
  - kafka-run-class.sh kafka.tools.ConsumerOffsetChecker --zookeeper localhost:2181 --group test

Mirroring Data Between Clusters

- Replicating data *between* Kafka clusters is known as **mirroring** which is not to be confused with the replication that happens amongst the nodes in single cluster
- Kafka comes with a tool for this purpose called kafka-mirror-maker
- A common use case is to provide a replica in another datacenter

Expanding a Cluster

- To add servers to a Kafka cluster, just assign them a unique broker id and start
- The new servers will not automatically be assigned any data partitions so unless partitions are moved to them they won't be doing any work until new topics are created
- Most of the time when you add machines to the cluster you will migrate some existing data with the kafka-reassign-partitions tool
- Check out the documentation for examples and usage!

Decommissioning Brokers

- The partition reassignment tool cannot automatically generate a reassignment plan for decommissioning brokers
- The admin must come up with a plan to move the replica for all partitions hosted on the broker to be decommissioned to the rest of the brokers
  - Can be **tedious**!
- Tooling support for this task is planned in the future

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Increasing Replication Factor

- To increase the replication factor of an existing partition, the extra replicas must be specified in a JSON file

- The following example increases the replication factor of partition 0 of topic test from 1 to 3
  - increase-replication-factor.json:

```
{"version":1,"partitions":[{"topic":"test","partition":0,
"replicas":[5,6,7]}]}
```

  - kafka-reassign-partitions.sh --zookeeper localhost:2181 --reassignment-json-file increase-replication-factor.json --execute

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Monitoring

- Kafka uses **Yammer Metrics** for metrics reporting in both the server and client

- You can use jconsole and attach to a running Kafka client or server to see all the metrics available with JMX

Security

- In release 0.9, Kafka added a number of security related features to Kafka
  - Authentication of connection to brokers from clients using SSL or SASL (Kerberos)
  - Authentication of connections from brokers to Zookeeper
  - Encryption of data transferred between brokers and clients, between brokers, or between brokers and tools using SSL
  - Authorization of read/write operations by clients
  - Authorization is pluggable and can be integrated with external authorization services

Summary

- Kafka Integrations
  - Apache Hadoop
- Kafka Connect
- Administration
  - Command line tools for modifying topics, graceful shutdown, mirroring data, checking consumer position, etc.
  - Monitoring
  - Security

Kafka Delivery Guarantees

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Introduction

- Kafka's delivery model leaves potential gaps in typical enterprise deployment scenarios
- Naïve programming may lead to
  - Messages being processed multiple times
  - Messages not being processed

- We will look at a few different scenarios where such failures may occur
- We'll also look at some technique that can be used to minimize or avoid the failures
  - Idempotent services
  - Kafka's new exactly once processing guarantee

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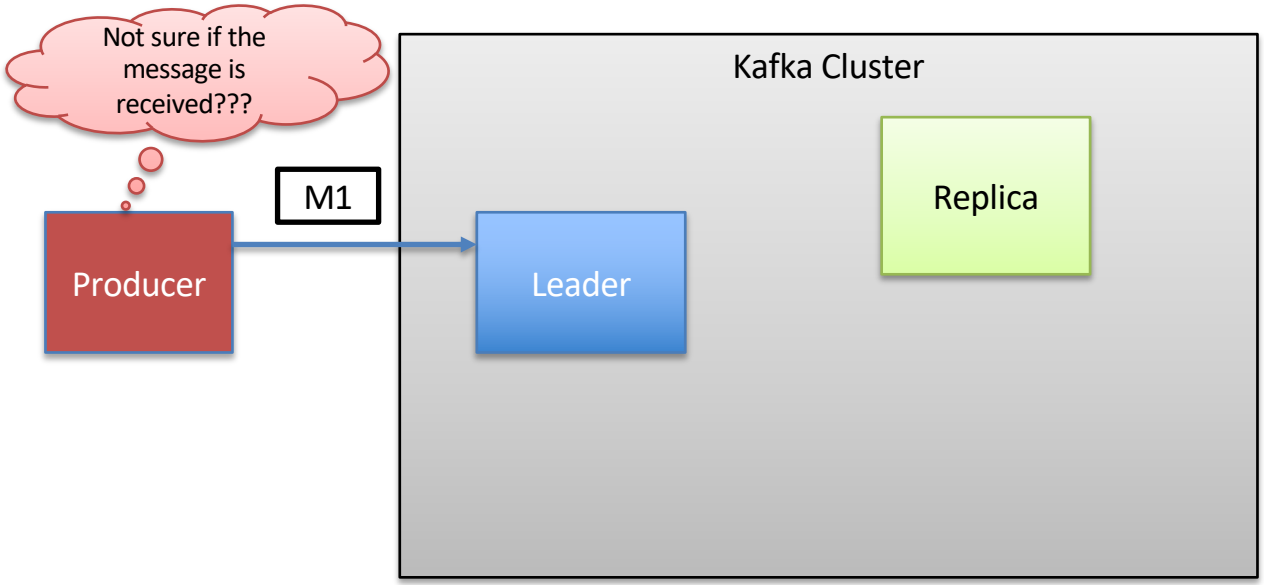
Message Duplication: 1. Send the message



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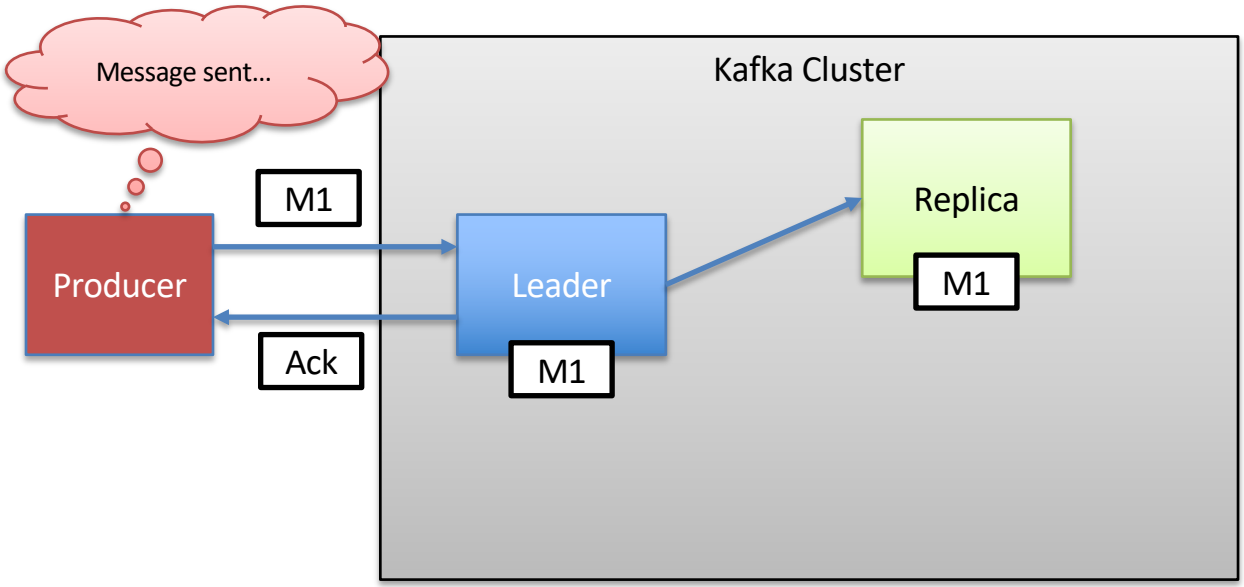
Message Duplication: 2. Message ack



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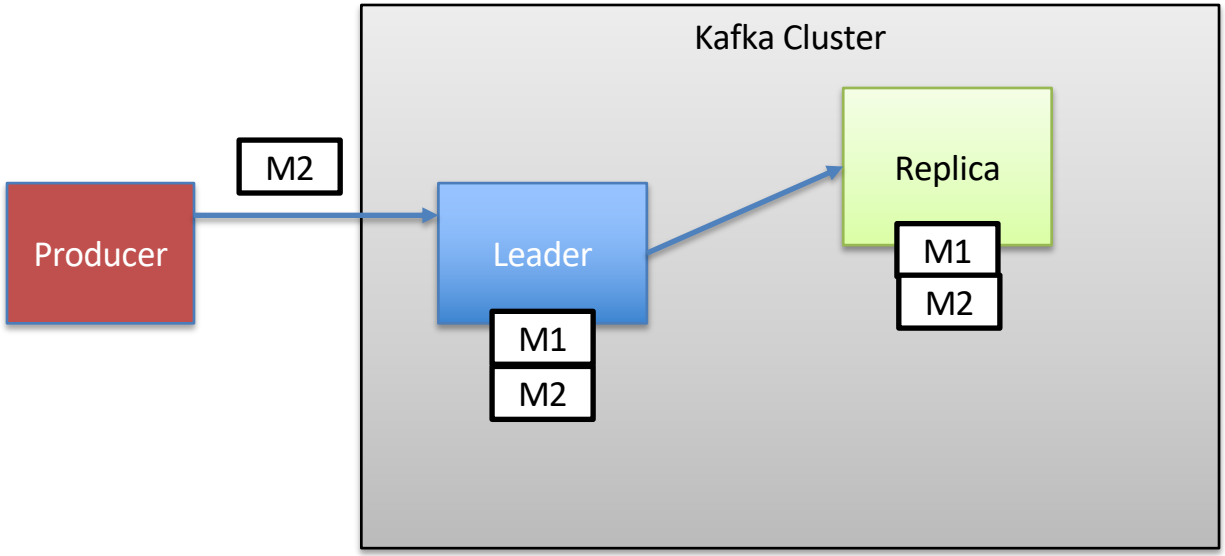
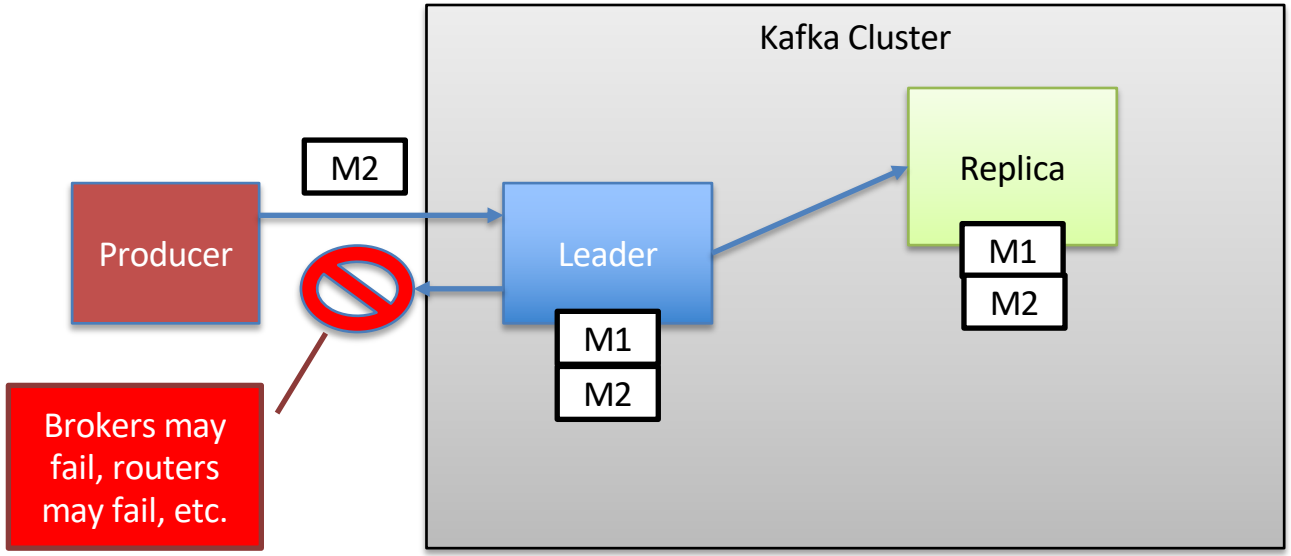
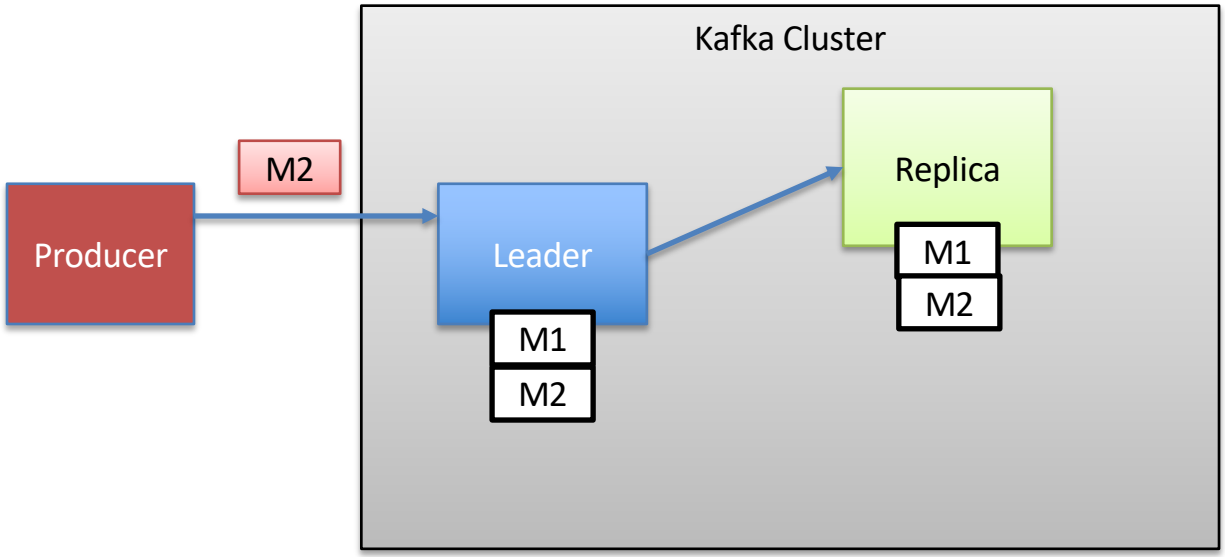
Message Duplication: 3. M2 being sent



Message Duplication: 4. Message never ack-ed



Message Duplication: 5. M2 is resent



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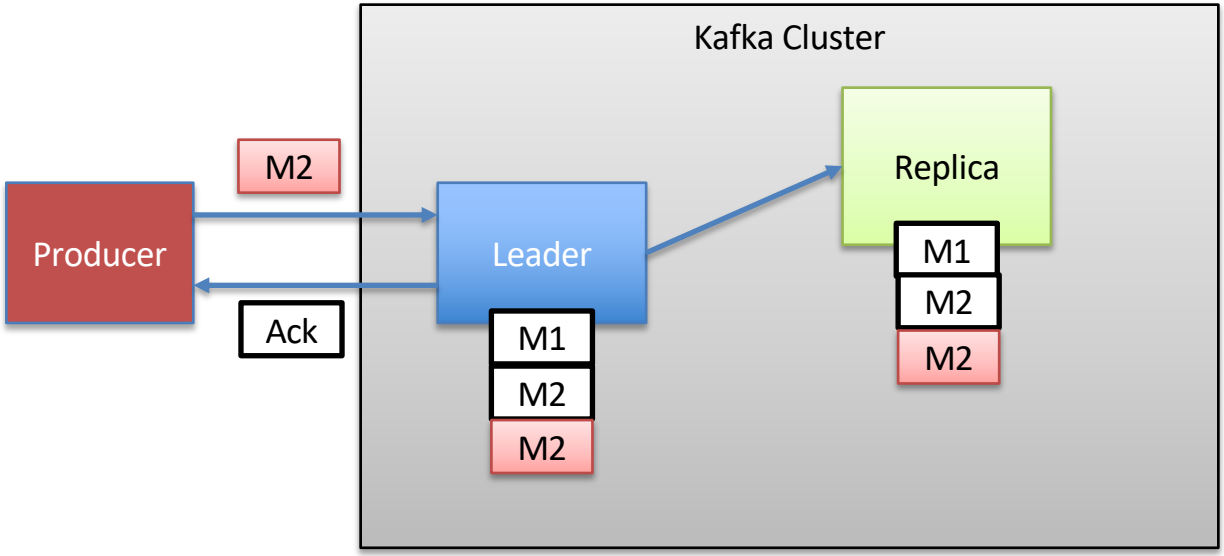
Message Duplication: 5. M2 is resent and stored again



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Kafka Exactly Once Producer Solution

- Idempotent producer (per partition)
  - Exactly once
  - In order
- Transactions
  - Atomic writes across partitions

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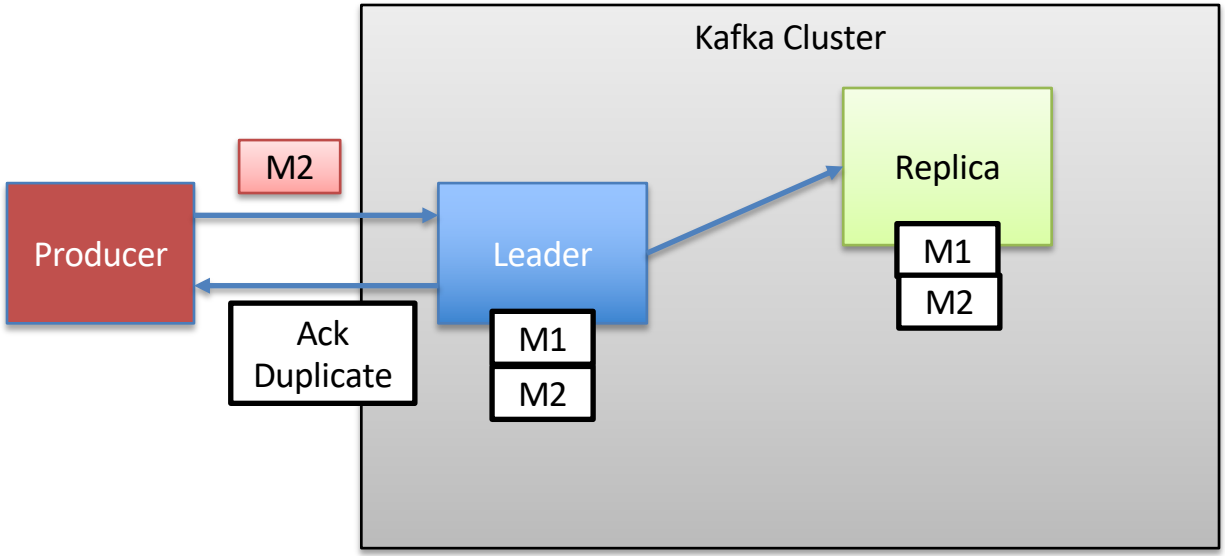
Idempotent Producer



Transaction API

- Atomic writes across multiple partitions
- Either all records are visible, or none

```
producer.initTransaction();
try {
        producer.beginTransaction();
        producer.send(record1);
        producer.send(record2);
        …
        producer.commitTransaction();
}
catch (KafkaException e) {
        producer.abortTransaction();
}
```

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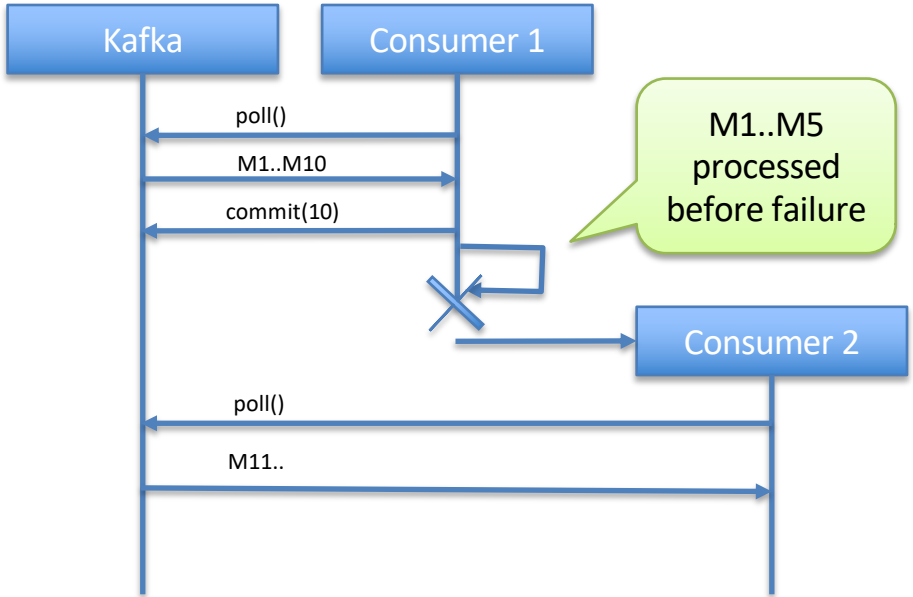
Consumer Problems

- Messages missed
  - Offset is committed prior to processing the messages
  - No or only partial processing of incoming messages
  - Consumer failure
- Messages double processed
  - Processing of messages prior to commit
  - Consumer failure before commit
- There is now real failsafe way to ensure that messages are processed exactly once
  - Requires distributed transaction

Consumer Message Loss

1. Messages received (M1…M10)
2. Offset committed (M10)
3. Processing M1..M5
4. Consumer crashes
5. Consumer resumes
6. Message M11.. is delivered



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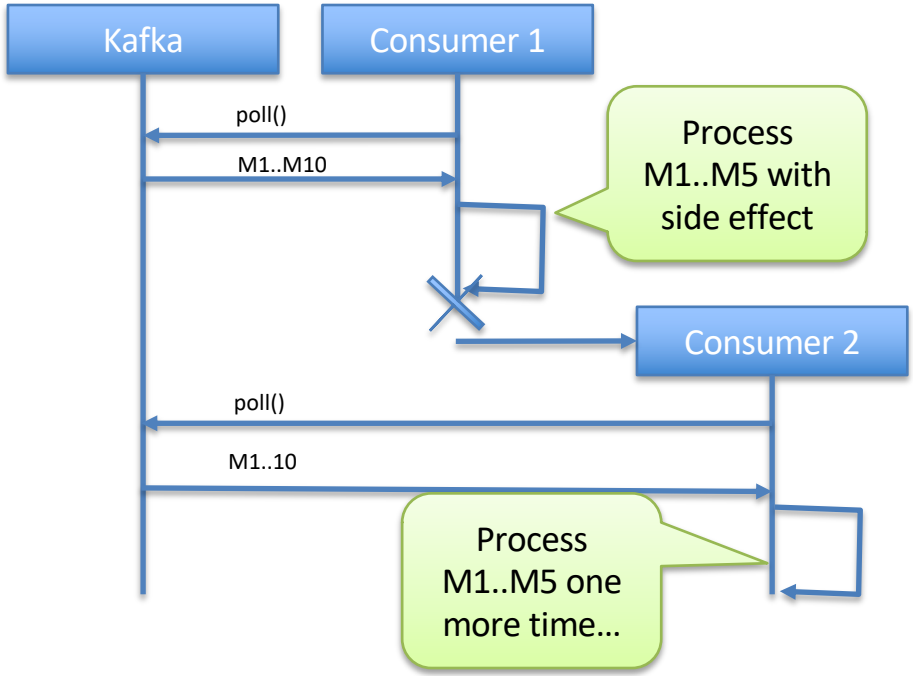
Consumer Double Processing

1. Messages received (M1…M10)
2. Processing M1..M5
3. Consumer crashes
4. Consumer resumes
5. Message M11.. is delivered



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Kafka Exactly Once Stream Processing

- Kafka provides an exactly once guarantee for stream processing
- Important to understand the guarantee
  - The effect on the Kafka stream state is AS IF each message was processed exactly once
    - The message may actually be processed multiple times
    - However, the offset is moved with the state changes
- This means:
  - If the processing have side effect OUTSIDE KAFKA this side effect may have to be idempotent!

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Configuration of Exactly Once

Producer Configuration

- enable.idempotence=true
- **Also recommended**
  - max.inflight.requests.per.connection=1
  - acks="all"
  - retries= MAX_INT

Consumer Configuration

- isolation.level = read_committed
  or
- isolation.level = read_uncommitted
- processing.mode = "exactly_once"

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Summary

- Kafka supports an exactly once message delivery guarantee

- Solved with
  - Idempotent producer
  - Transactions
  - Stream processing

- It’s important to know that the exactly once guarantee on the consumer is only guaranteed within the context of Kafka!