Apache Kafka

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About Me...

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Testing in Scala (Book)
Beginning Scala Programming (Video)
Scala Beyond the Basics (Video)

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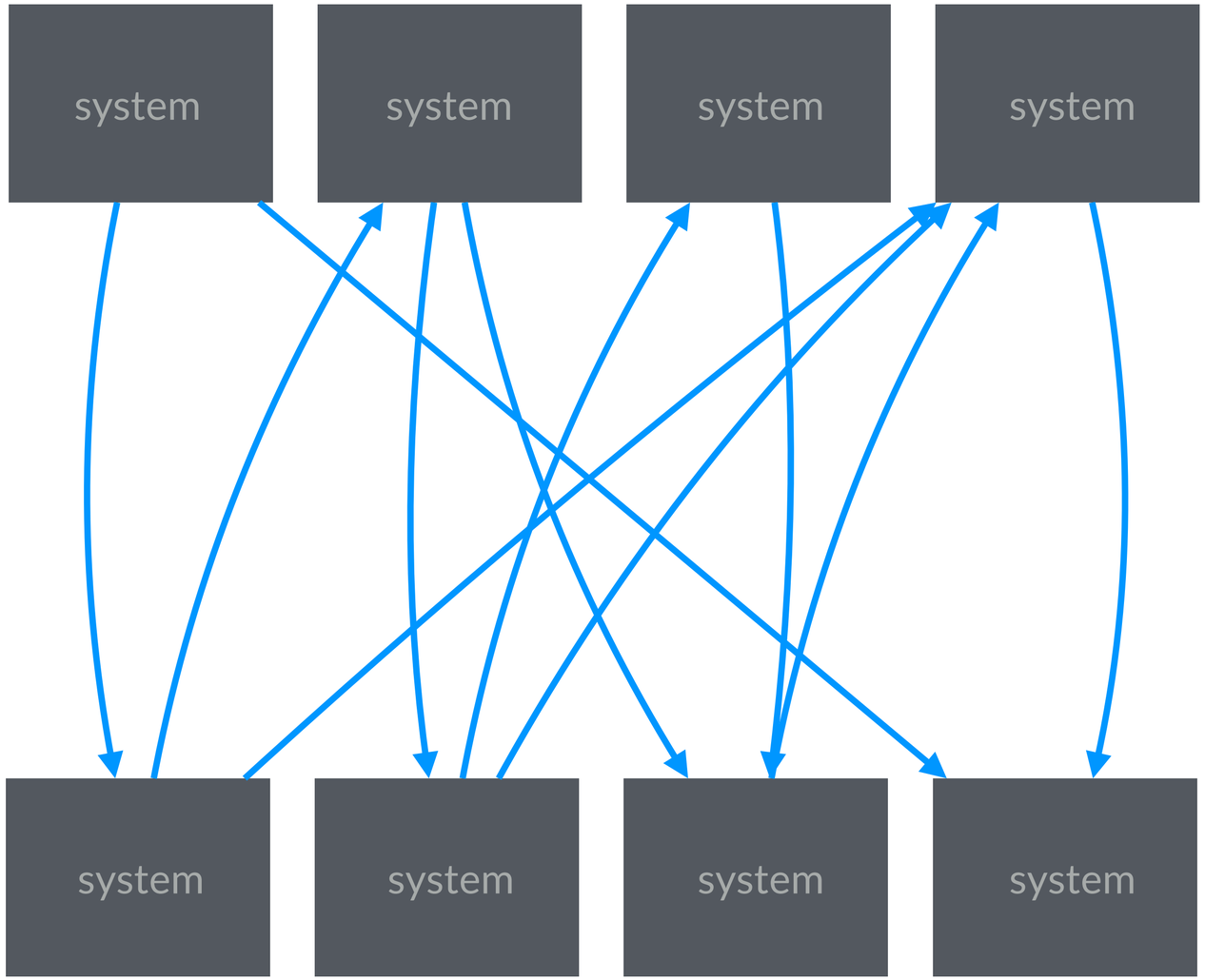
Agenda

Agenda

- ⭐Understand Kafka
- ⭐Understand Producer
- ⭐Understand Consumer
- ⭐Understand Rebalancing
- ⭐Understand Streaming
- ⭐Understand Tables
- ⭐Understand KSQL

Kafka Introduction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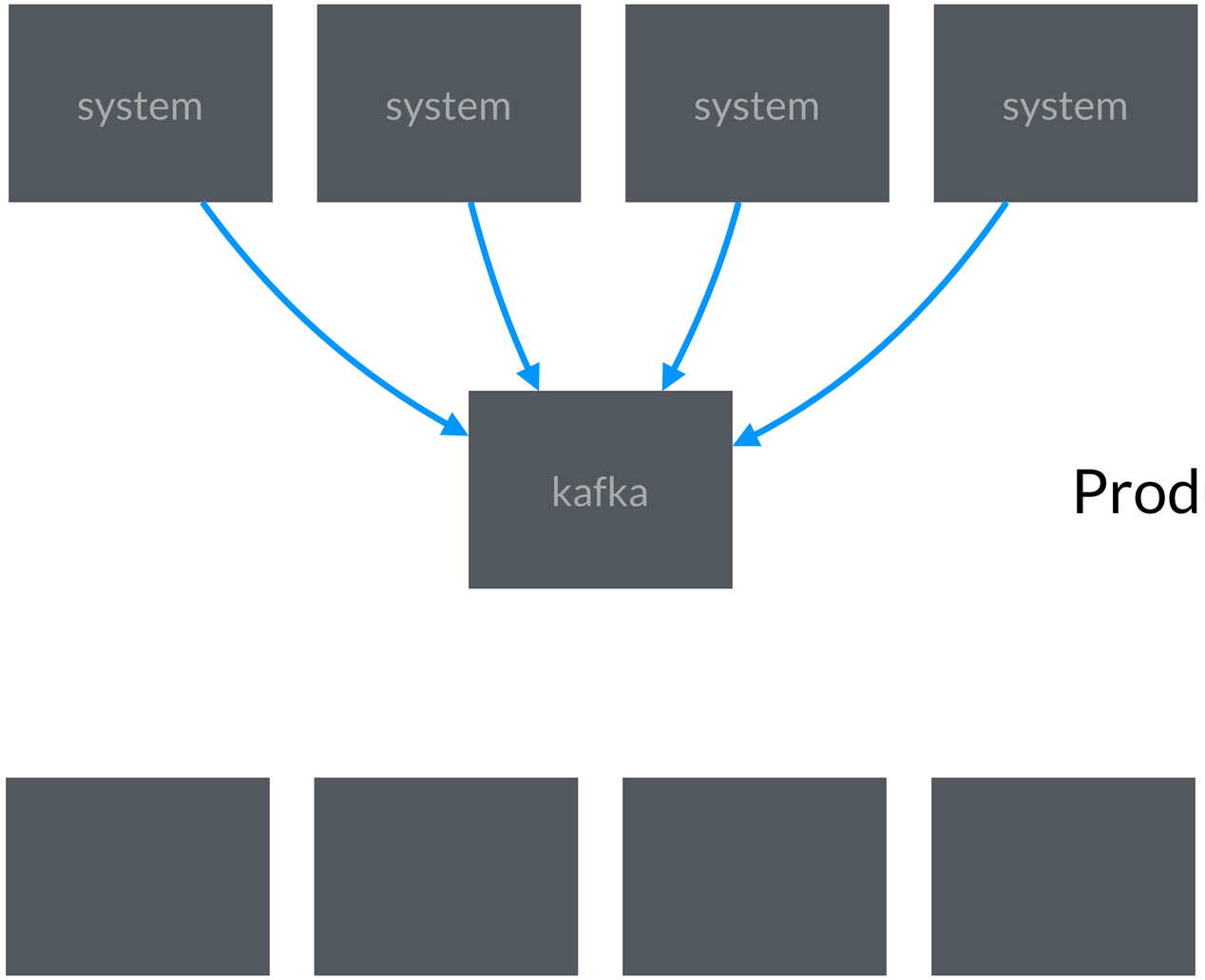
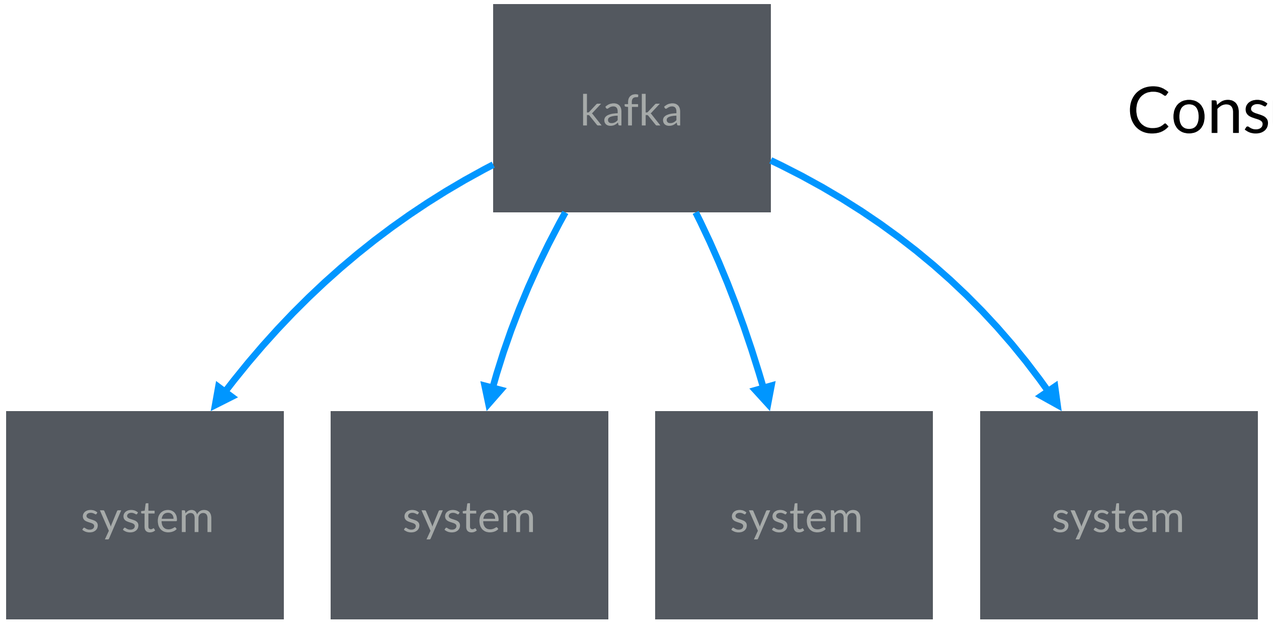
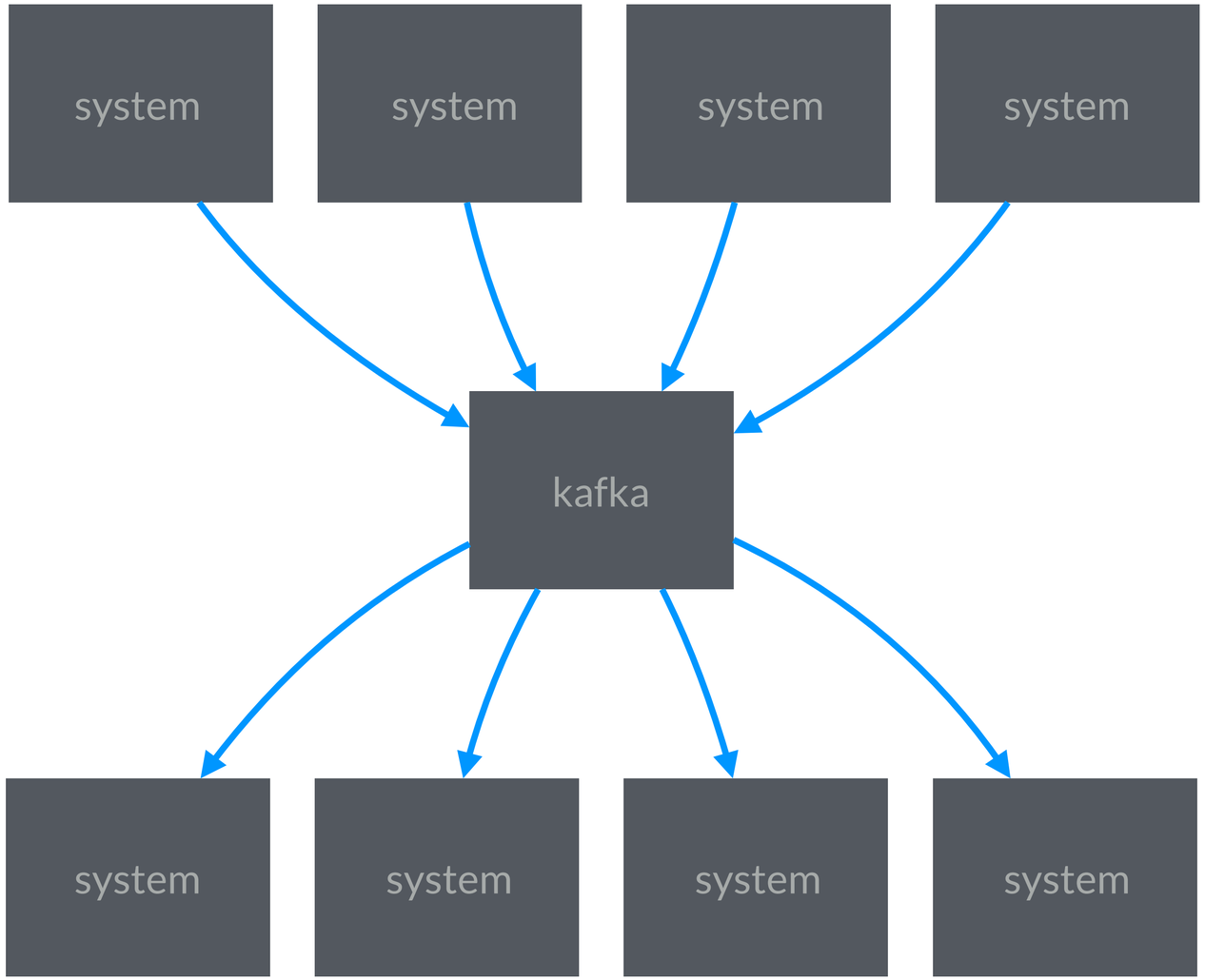


Producers



Consumers


system
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kafka
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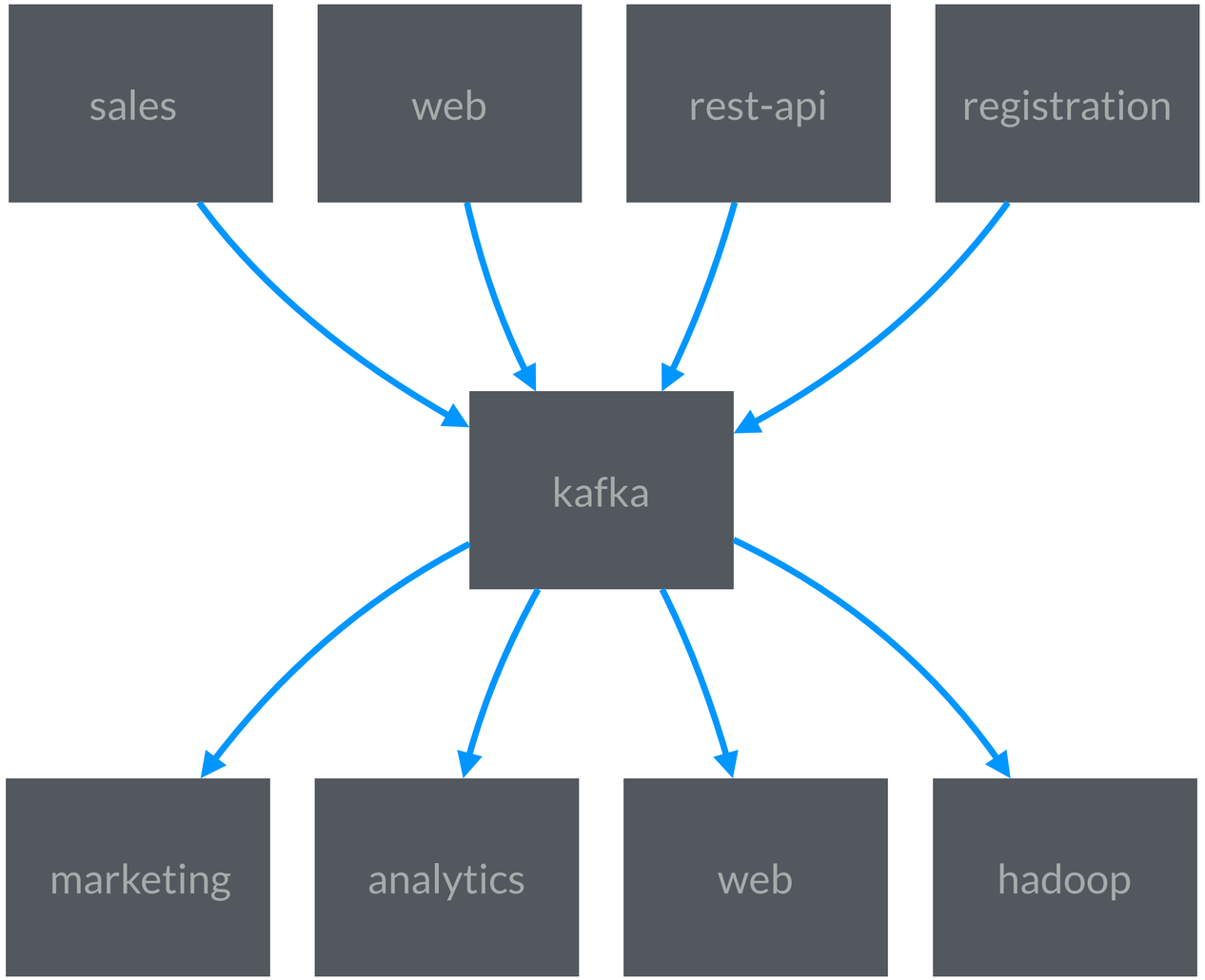


Note: A Producer can be a Consumer

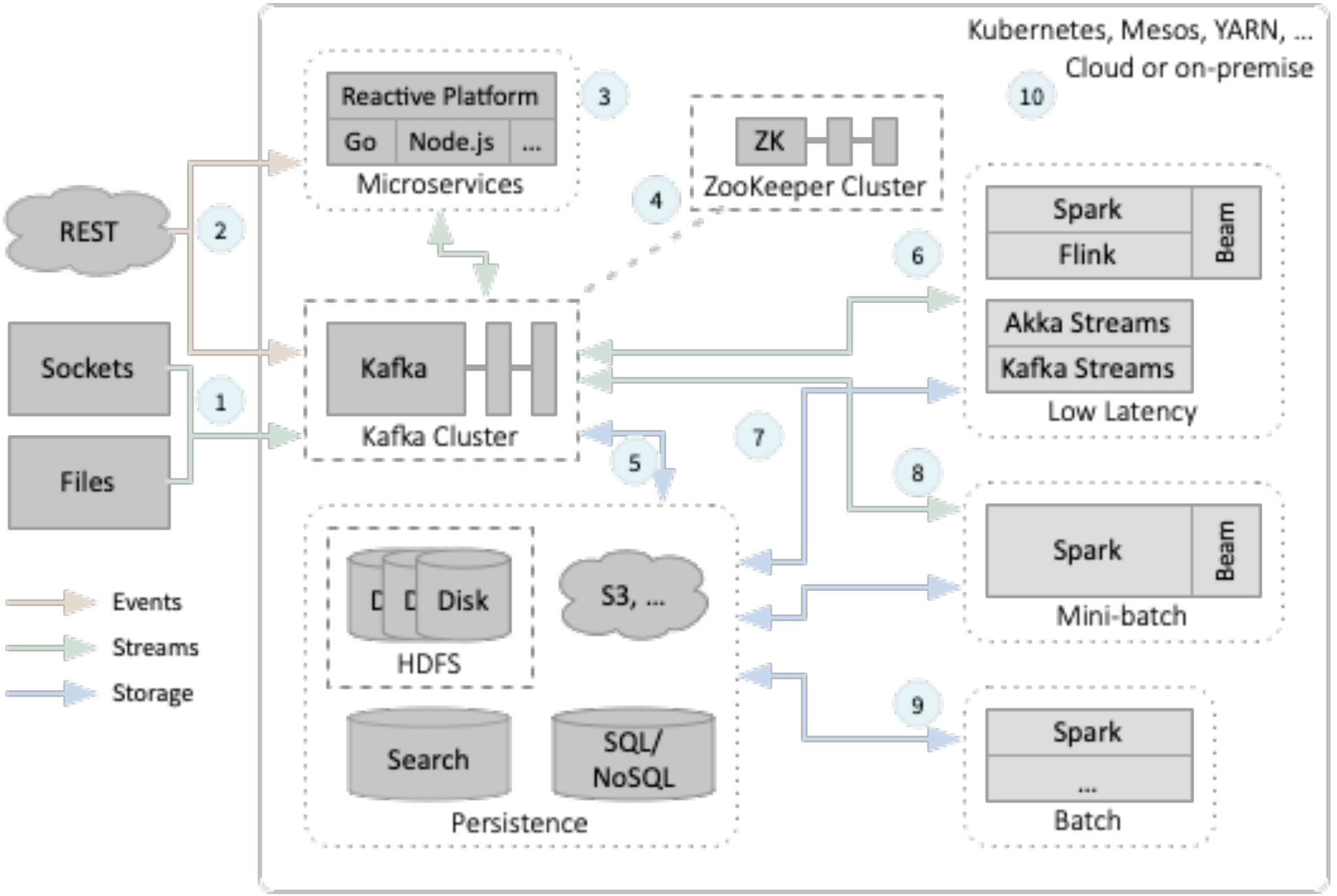
About Kafka

- Handles millions of messages per second, high throughput, high volume
- Distributed and Replicated Commit-log
- Real Time Data Processing
- Stream processing

Kafka Use-Cases

- Activity Tracking
- Page Views
- Click Tracking
- Advertising Patronage
- Feed Artificial Intelligence
- Internet of Things

Dean Wampler Architecture


Kubernetes, Mesos, YARN, ...
Cloud or on-premise
Reactive Platform
Go
Node.js
...
Microservices
3
ZK
ZooKeeper Cluster
10
4
REST
2
Sockets
1
Files
Kafka
Kafka Cluster
5
6
Spark
Flink
Beam
Akka Streams
Kafka Streams
Low Latency
7
8
Spark
Beam
Mini-batch
Disk
HDFS
S3, ...
Search
SQL/
NoSQL
Persistence
9
Spark
...
Batch
Events
Streams
Storage

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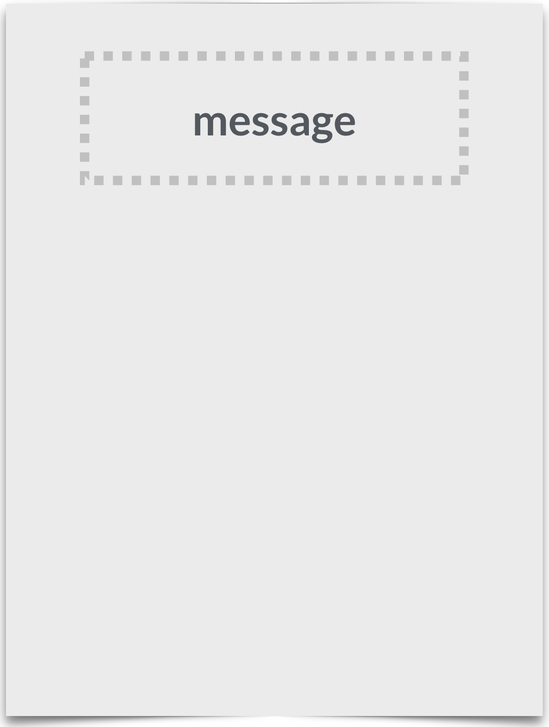
Kafka Messages

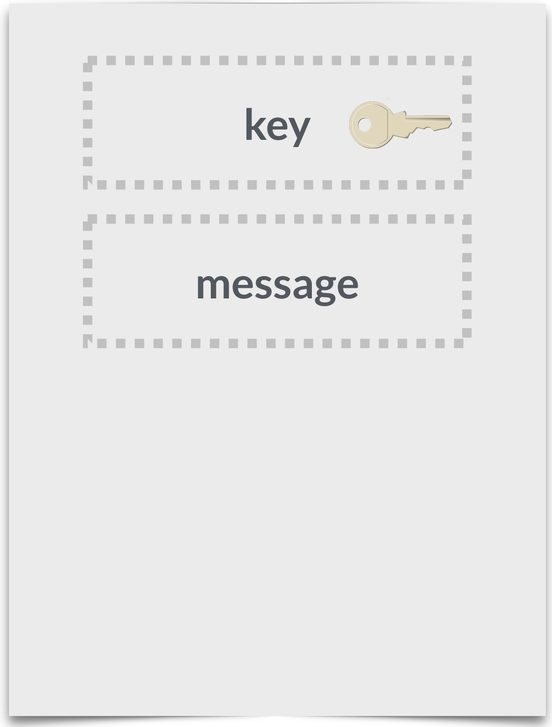
A Kafka Message

- Similar to a *row* or a *record*
- Message is an array of bytes
- No special serialization, that is done at the producer or consumer

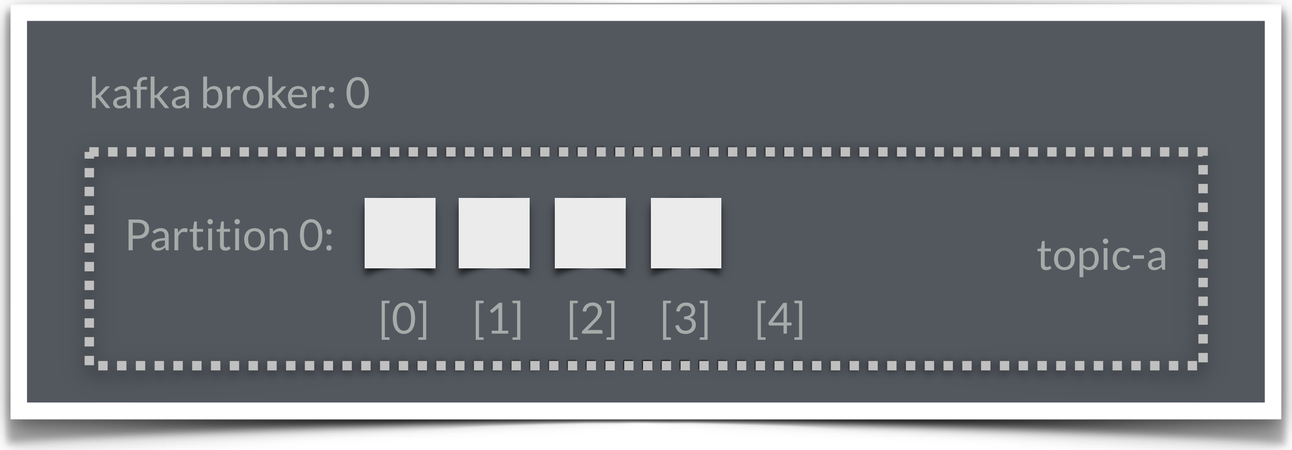


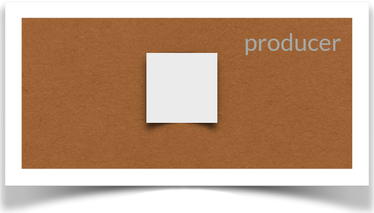
A Kafka Message Key

- Message may contain a *key* for better distribution to partitions
- The *key* is also an array of bytes
- If a *key* is provided, a partitioner will hash the key and map it to a single partition
- Therefore it is the only time that something is guaranteed to be in order



Kafka Producers

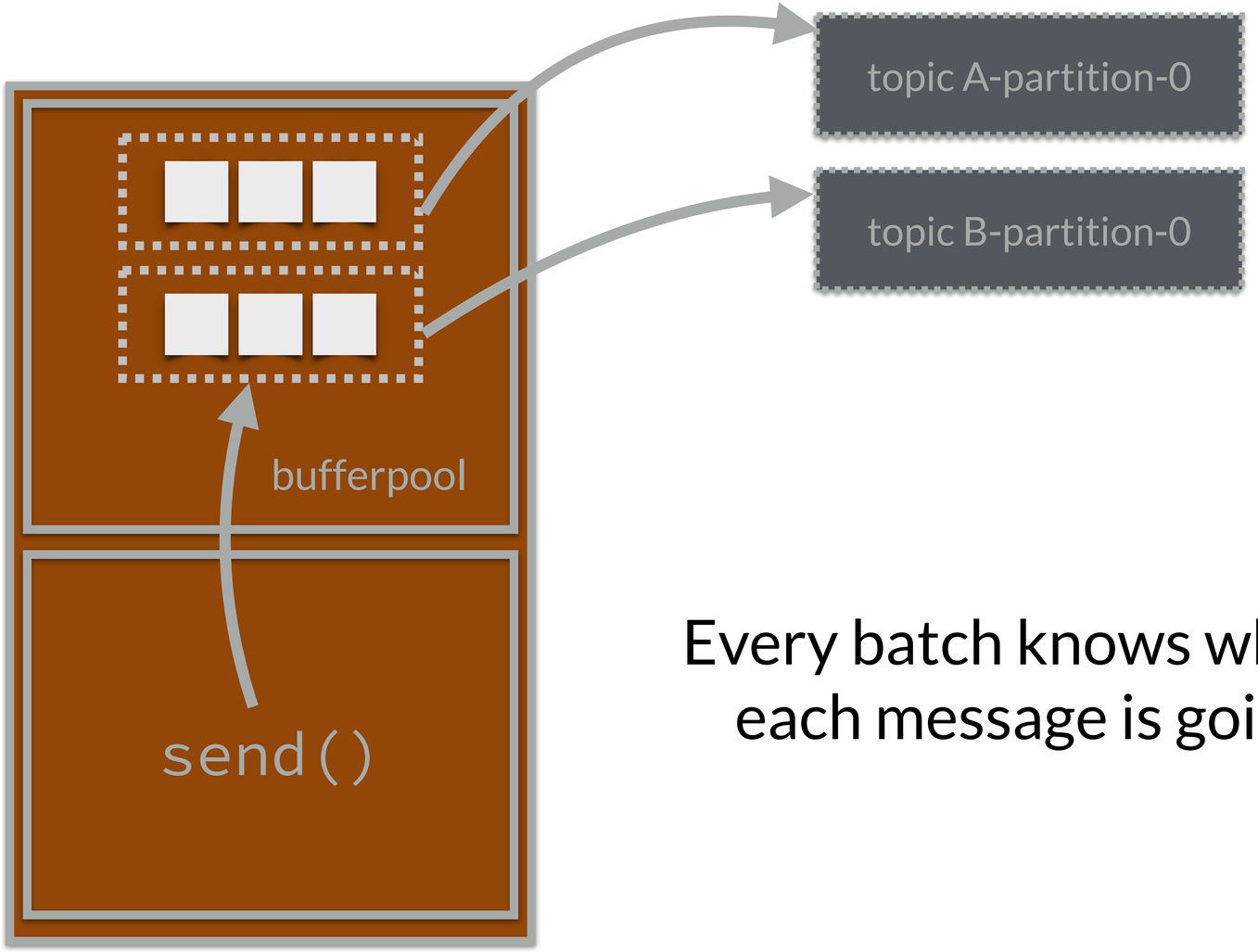

kafka broker: 0
Partition 0:
topic-a
[0]
[1]
[2]
[3]
[4]


producer

Retention: The **data is temporary**

Kafka Batch

- A collection of messages, that is sent, configured in *bytes*
- Sent to the same *topic* and the same *partition*
- *Avoids overhead of sending multiple message over the wire*



Every batch knows where each message is going

```
murmur2(bytes) % number partitions
```

This could be changed with custom partitioner

~~murmur2(bytes) % number partitions~~

```
if (key == "CSCO") {
  else return 0;
} else {
  (murmur2(bytes) % number partitions - 1) + 1
}
```

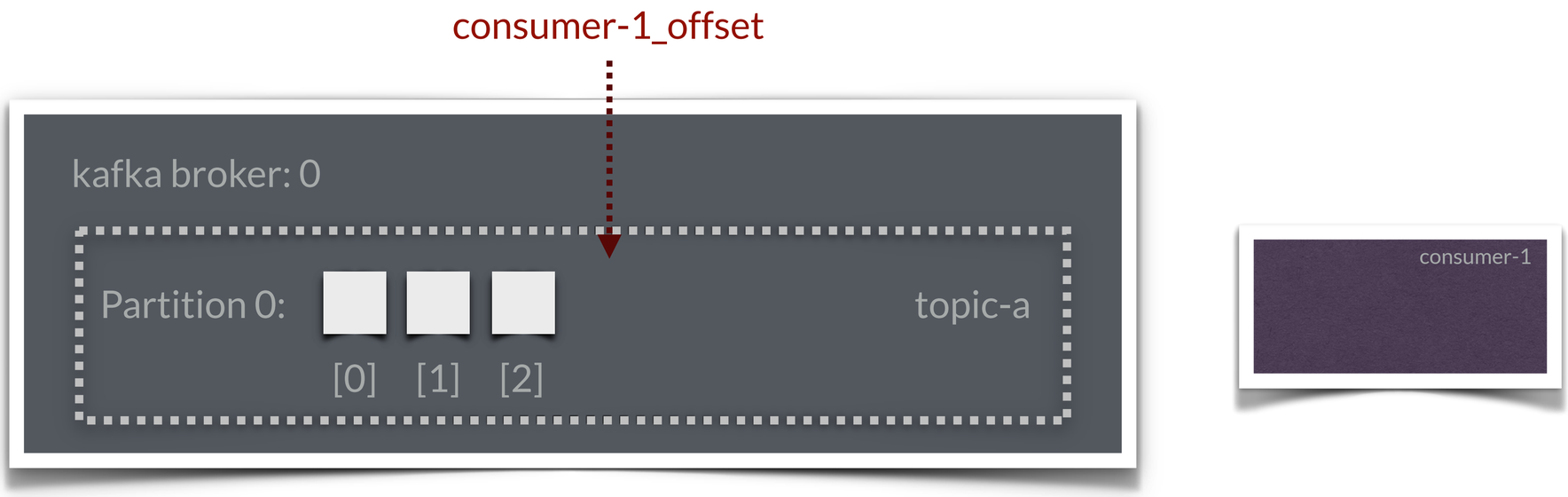
A-E

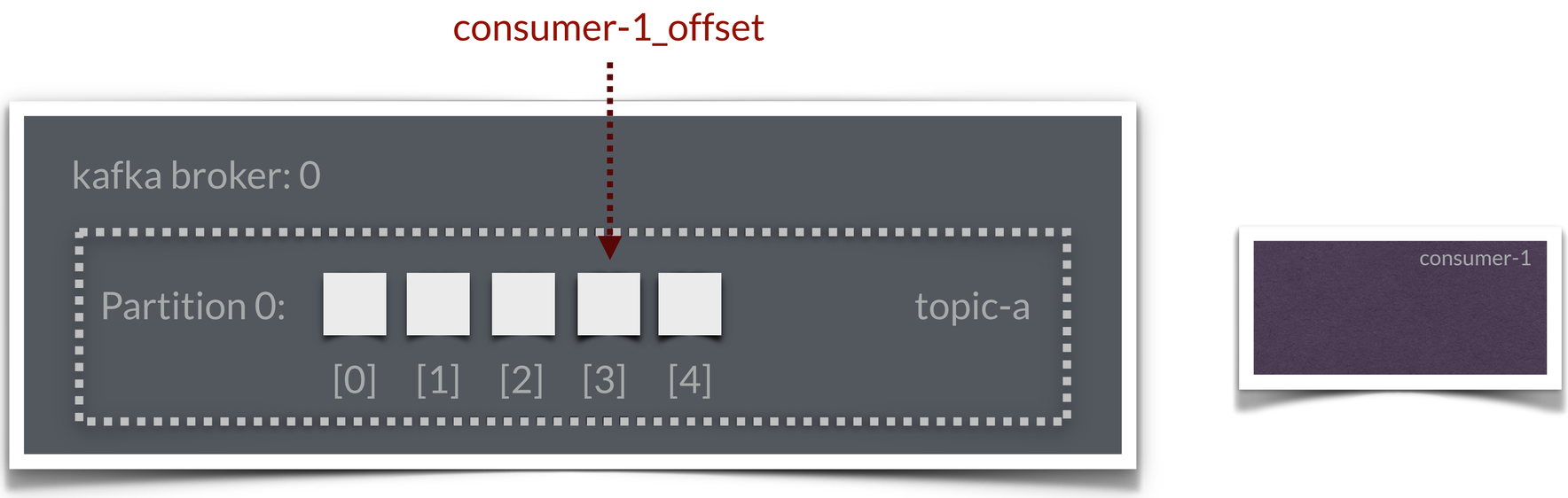
F-K

L-S

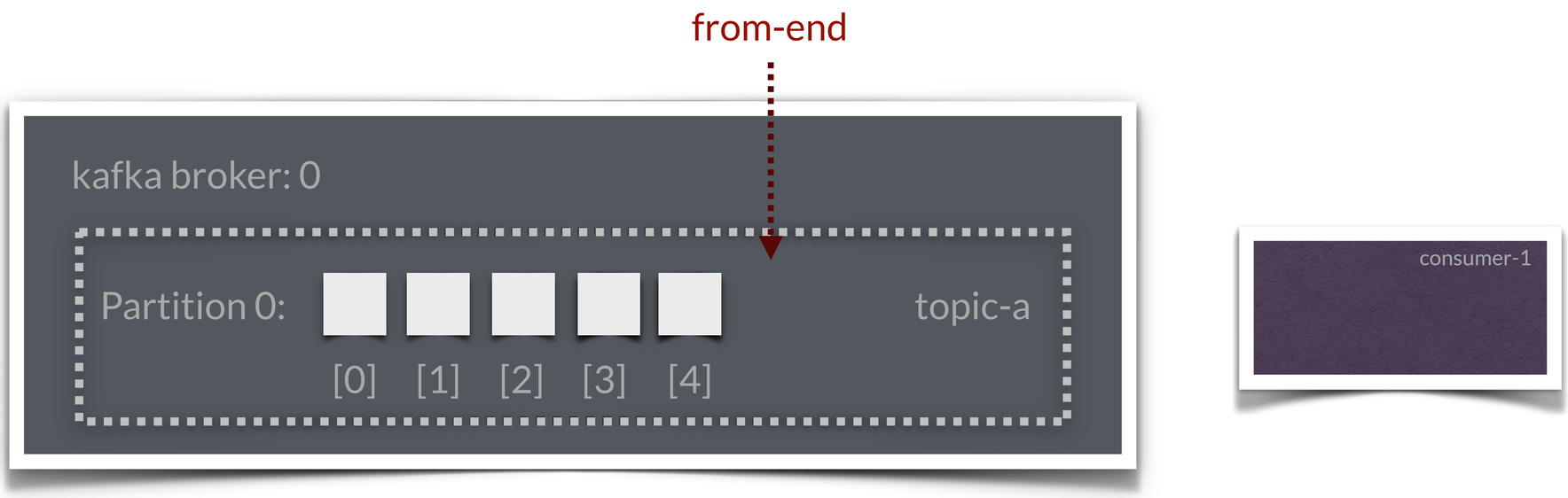
T-Z

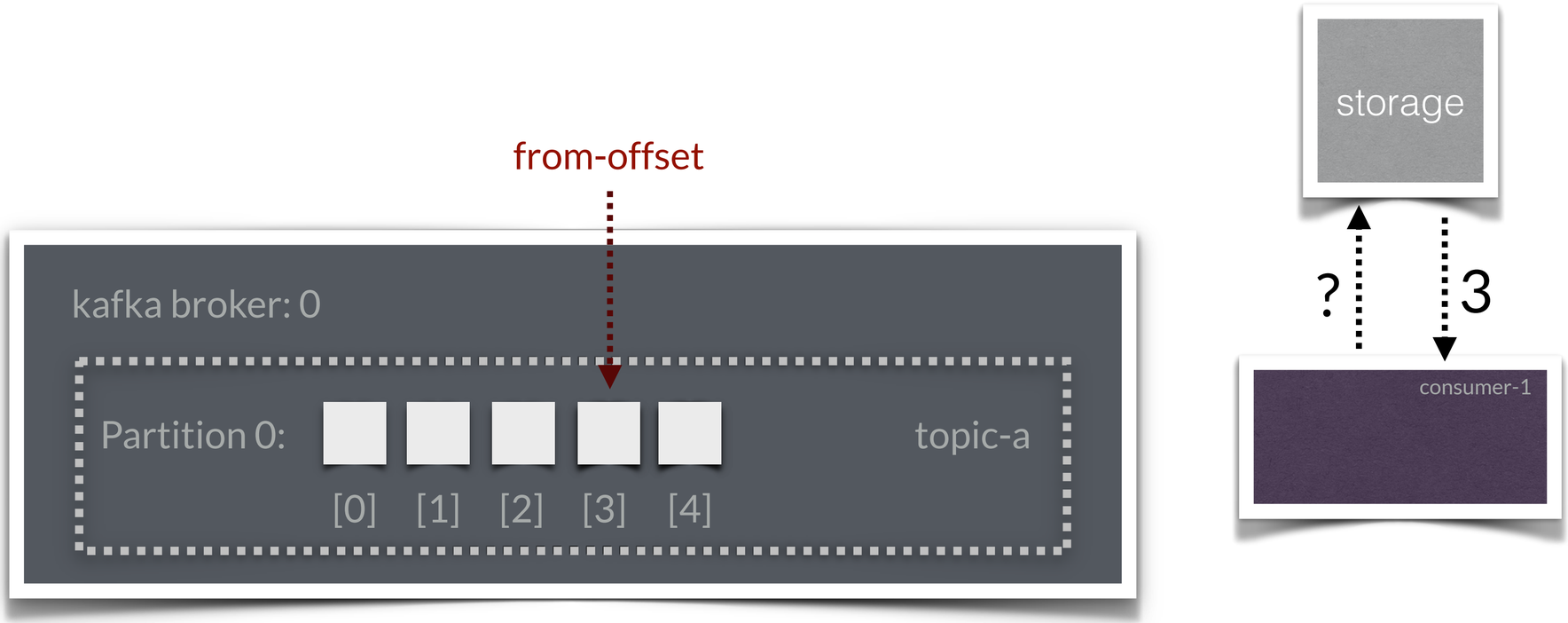
Kafka Consumers


consumer-1_offset
kafka broker: 0
Partition 0:
[0]
[1]
[2]
topic-a
consumer-1

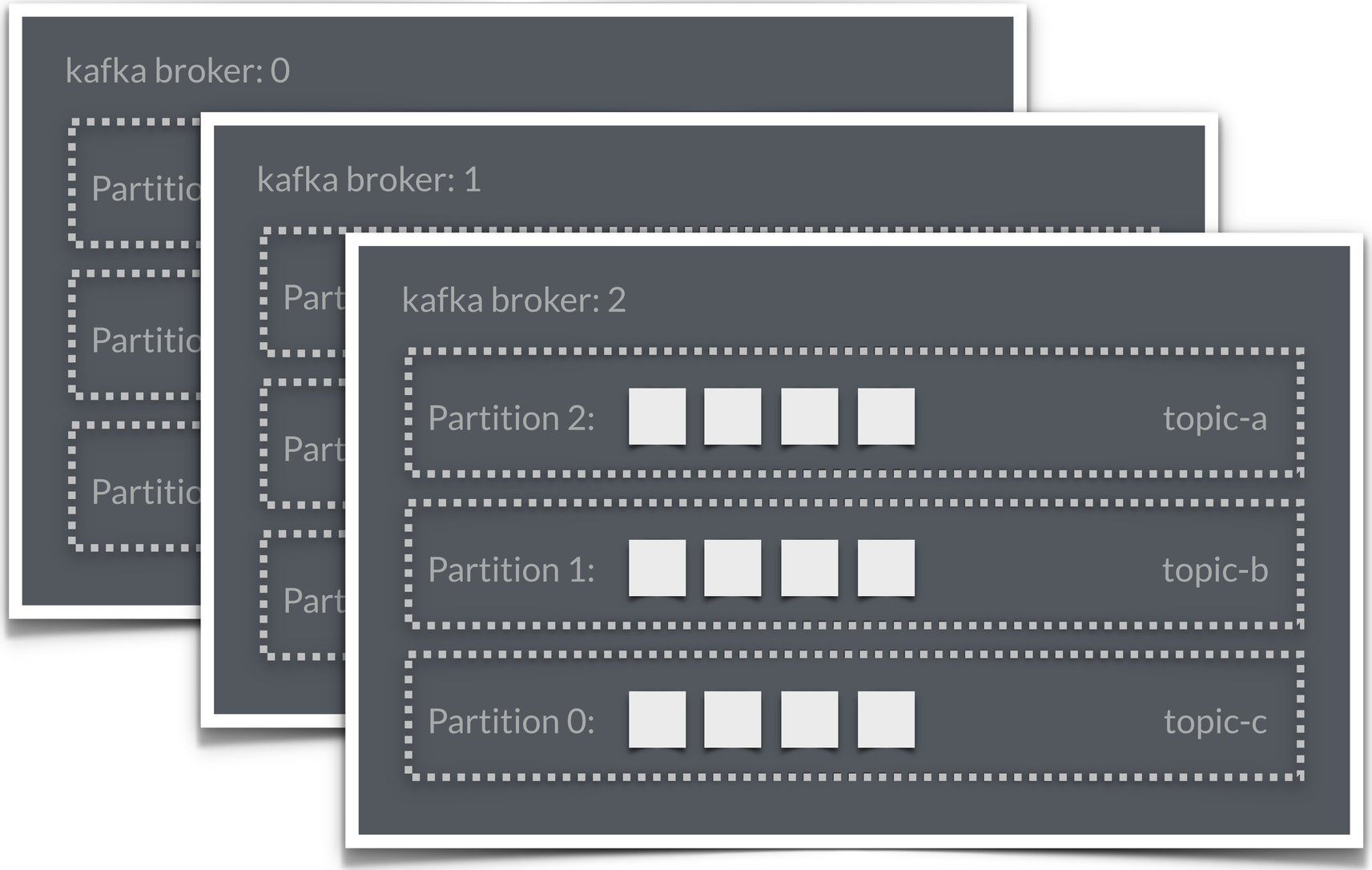

consumer-1_offset
kafka broker: 0
Partition 0:
topic-a
[0]
[1]
[2]
[3]
[4]
consumer-1


from-beginning
kafka broker: 0
Partition 0:
topic-a
[0]
[1]
[2]
[3]
[4]
consumer-1

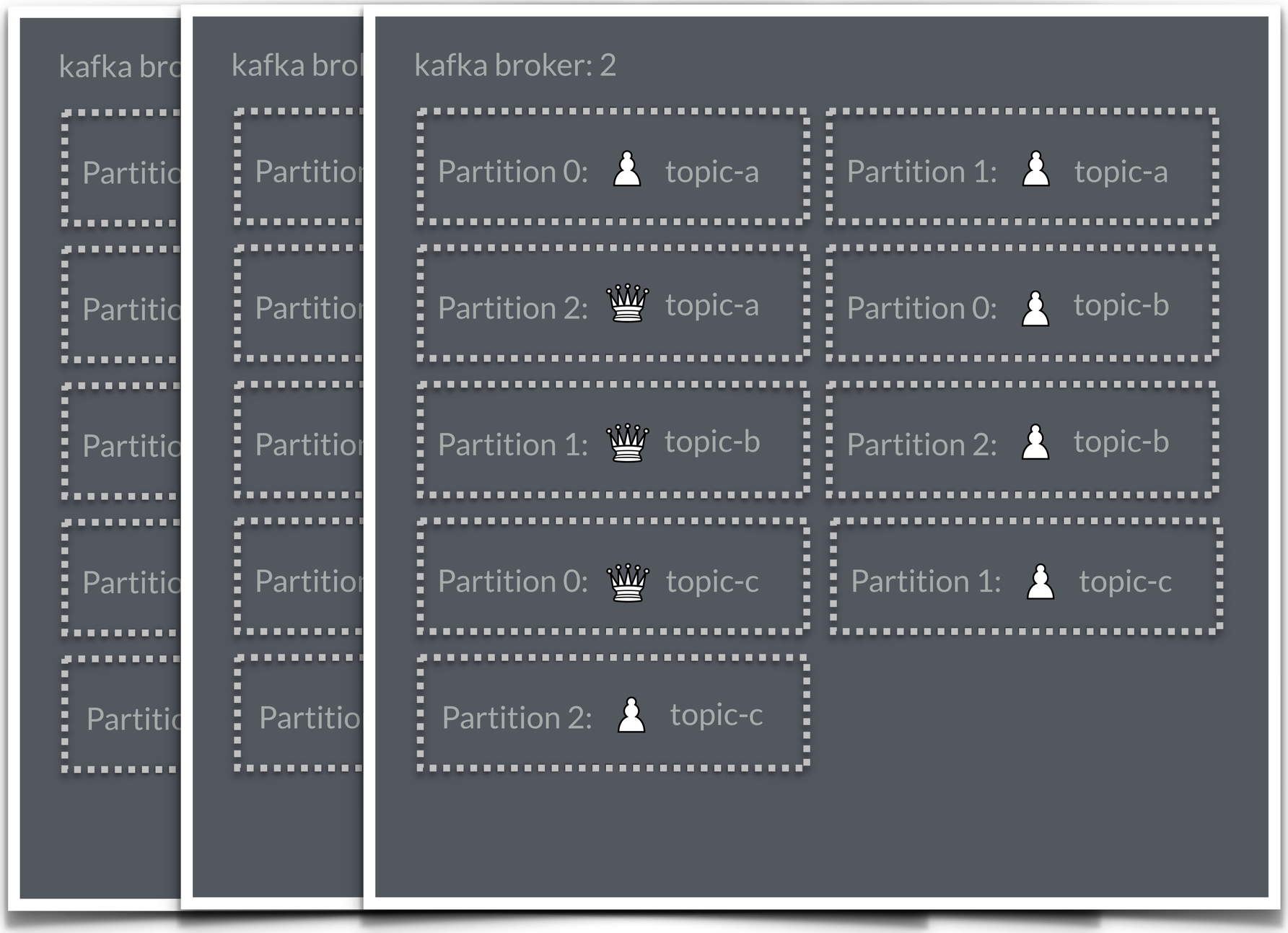

from-end
kafka broker: 0
Partition 0:
[0]
[1]
[2]
[3]
[4]
topic-a
consumer-1


from-offset
kafka broker: 0
Partition 0:
[0]
[1]
[2]
[3]
[4]
topic-a
storage
?
3
consumer-1

Kafka Partitions



Each partition is on a different broker,
therefore a single topic is scaled


kafka broker: 2
Partition 0: topic-a
Partition 1: topic-a
Partition 2: topic-a
Partition 0: topic-b
Partition 1: topic-b
Partition 2: topic-b
Partition 0: topic-c
Partition 1: topic-c
Partition 2: topic-c

A-E

F-K

L-S

T-Z

Kafka Pub/Sub Comparisons

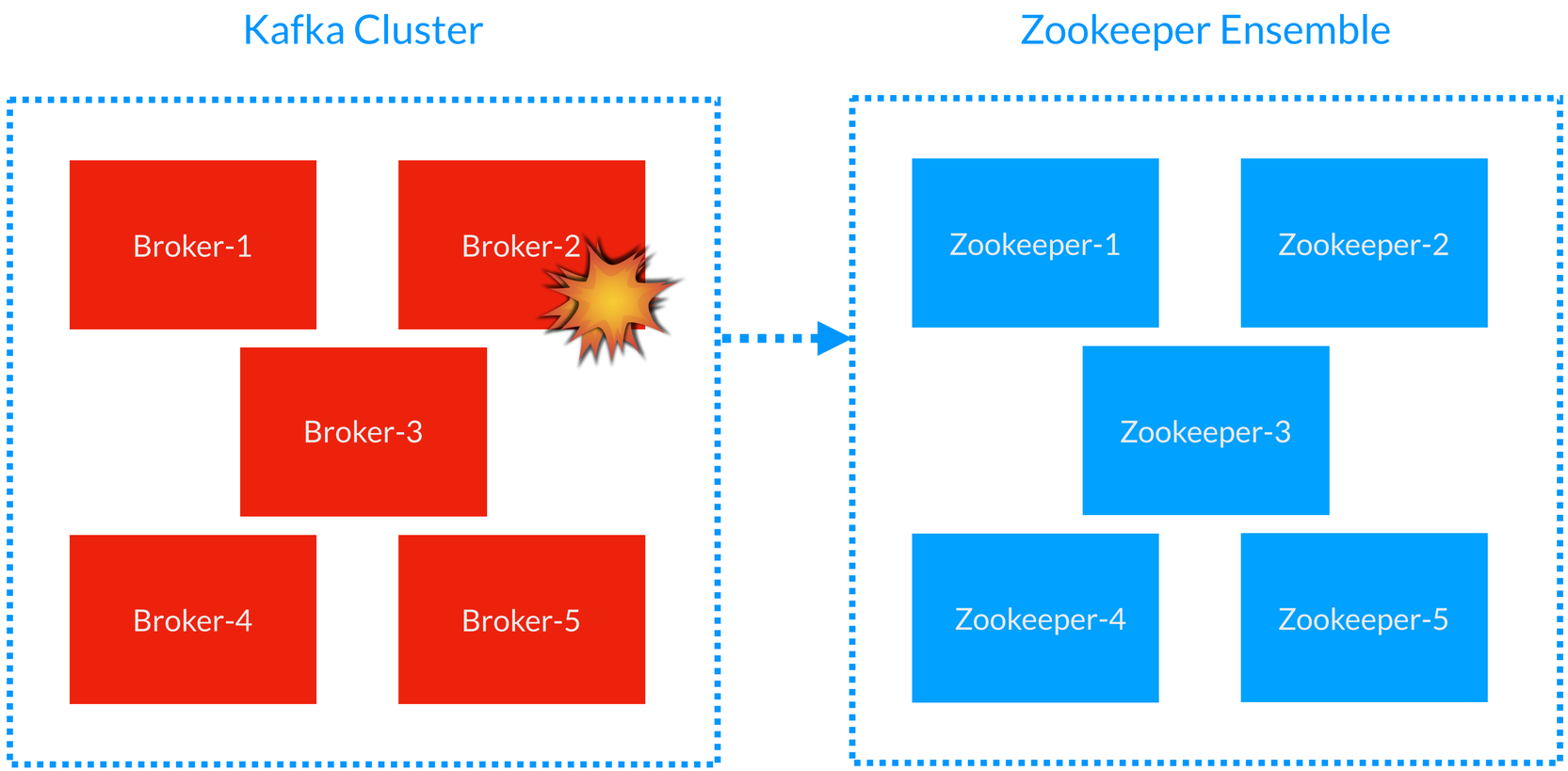
Comparison Pub/Sub

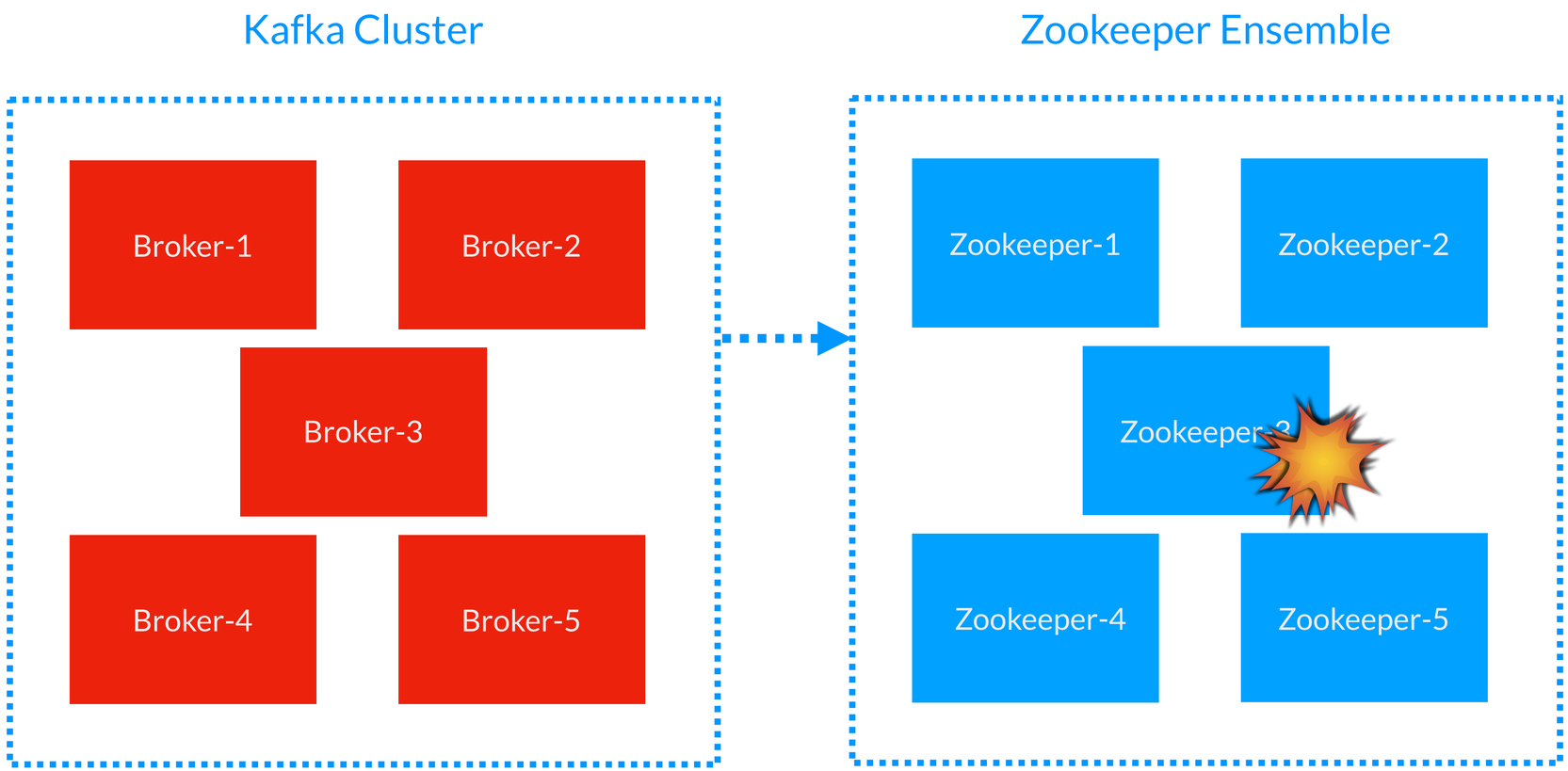
- Kafka as the distributed "git log"
- Ability to replayed in a consistent manner
- Kafka is also stored durable, in order, and deterministic, if key is available
- Data can also be distributed for resiliency
- Scalable and Elastic

Zookeeper

Zookeeper Essence

- Centralized Coordination Service
- Maintains:
  - Metadata
  - Naming
  - Configuration


Kafka Cluster
Zookeeper Ensemble
Broker-1
Broker-2
Broker-3
Broker-4
Broker-5
Zookeeper-1
Zookeeper-2
Zookeeper-3
Zookeeper-4
Zookeeper-5


Kafka Cluster
Broker-1
Broker-2
Broker-3
Broker-4
Broker-5
Zookeeper Ensemble
Zookeeper-1
Zookeeper-2
Zookeeper-3
Zookeeper-4
Zookeeper-5

Requirements

Hardware Requirements

- Do not co-locate other applications due to memory page cache pollution and will degrade performance
- Performant drive is required
- Storage capacity will need to be calculated by the expected messages per day and retention
- Slower networks can degrade the rate in which messages are produced

Cloud Requirements

- Analyze by data retention
- Analyze performance need by the producers
- If low latency is required, SSD should be considered
- Ephemeral Storage may be required (Elastic Block Storage)

Kafka Guarantees

Kafka Guarantees

- Messages sent by a producer to a particular topic partition will be appended in the order they are sent.
- A consumer instance sees records in the order they are stored in the 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.

Kafka CLI

Creating a Topic

Creating the topic `orders` with replication factor 2 and 4 partitions

```
$ /usr/bin/kafka-topics --create --zookeeper zoo:2181 \
  --replication-factor 2 --partitions 4 --topic orders
```

Listing Topics

List the topics using one of the zookeeper nodes

```
$ /usr/bin/kafka-topics --zookeeper <zookeeper>:2181 --list
```

Sending a Message

Send a message to list of brokers for a particular topic

```
$ /usr/local/kafka/bin/kafka-console-producer.sh \
  --broker-list <kafka-broker>:9092 --topic <topic>
> Hello
> I
> am
> sending
> six
> messages
```

Receiving a Message

Receiving the messages from the topic that was posted by the CLI producer

```
$ /usr/local/kafka/bin/kafka-console-consumer.sh \
 --bootstrap-server <kafka-broker>:9092 \
 --topic <topic> \
 --from-beginning

> Hello
> I
> am
> sending
> six
> messages
```

Showing Distributed Partitions

Showing how partitions are distributed

```
$ /usr/local/kafka/bin/kafka-topics.sh --describe \
   --topic <topic-name> \
   --zookeeper <zookeeper>:2181
```

Lab: Command-Line

Kafka Programming
Producers

Establishing Properties

- Construct a `java.util.Properties` object
- Provide two or more locations where the bootstrap servers are located
- Provide a Serializer for the key
- Provide a Serializer for the value

```
Properties properties = new Properties();
properties.put(ProducerConfig.BOOTSTRAP_SERVERS_CONFIG,
    "localhost:9092");
properties.put(ProducerConfig.KEY_SERIALIZER_CLASS_CONFIG,
    StringSerializer.class);
properties.put(ProducerConfig.VALUE_SERIALIZER_CLASS_CONFIG,
    IntegerSerializer.class);
```

Create a Producer Object

- Construct a `org.apache.kafka.clients.producer.KafkaProducer` object
- A Kafka Producer is thread-safe
- Inject the `Properties` into the `Producer` object

```
KafkaProducer<String, Integer> producer = new KafkaProducer<>(properties);
```

Creating a Record/Message

- Create a `org.apache.kafka.clients.producer.ProducerRecord`
- Accepts many parameters but the main ones are:
  - Topic
  - Key (if applicable)
  - Value

```
ProducerRecord<String, Integer> producerRecord =
    new ProducerRecord<>("my_orders", state, amount);
```

Sending a message

- Send the record by calling `send` on the `Producer`
- Returns a `Future` object to process the results on another Thread.
- The `Future` will contain `RecordMetadata`, an object that has information about your send.

```
Future<RecordMetadata> send = producer.send(producerRecord);
```

RecordMetadata

Contains information about your send including the messages

```
if (metadata.hasOffset()) {
    System.out.format("offset: %d\n",
        metadata.offset());
}
System.out.format("partition: %d\n",
    metadata.partition());
System.out.format("timestamp: %d\n",
    metadata.timestamp());
System.out.format("topic: %s\n", metadata.topic());
System.out.format("toString: %s\n",
    metadata.toString());
```

Sending with a Callback

- Alternately, you can send with a `Callback` (lambda)
- `Callback` is an interface, can be use as a lambda
- If `RecordMetadata` is null there was an error, if `Exception` is `null` the send was successful

```
producer.send(producerRecord, new Callback() {
    @Override
    public void onCompletion(RecordMetadata metadata,
                             Exception e) {
        ...
    }
}
```

Using a Closure to capture Key and Value

- RecordMetadata does not have information on key and value
- Using a closure you can obtain that in the block of your lambda

```
producer.send(producerRecord, (metadata, e) -> {
    if (metadata != null) {
        System.out.println(producerRecord.key());
        System.out.println(producerRecord.value());
    }
}
```

Be a good citizen, close your resources

- When you need to terminate, flush messages from the bufferpool
- Close the Producer

```
producer.flush();
producer.close();
```

Closing Resources in a Shutdown Hook

- Runtime.getRuntime().addShutdownHook(...) will listen for SIGTERM (CTRL+C)
- This would make an excellent place to flush and close, and close any loops that you may have created

```
Runtime.getRuntime().addShutdownHook(new Thread(() -> {
    done.set(true);
    producer.flush();
    producer.close();
}));
```

Lab: Writing a Producer

Acknowledgements & Retries

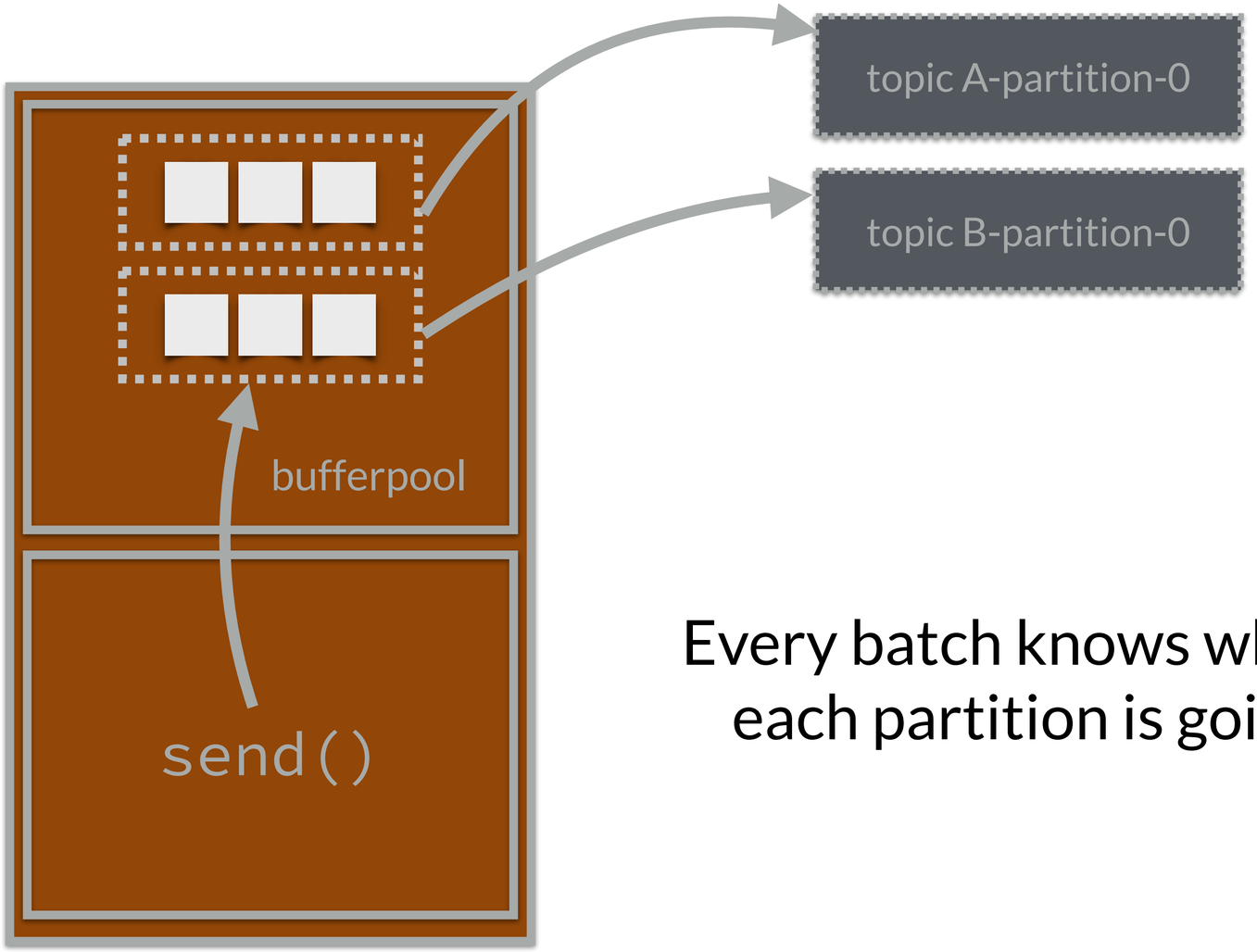
Acks

acks controls how many partition replicas must receive the record before the write is considered a success.

```
Properties properties = new Properties();
properties.put(ProducerConfig.BOOTSTRAP_SERVERS_CONFIG,
    "localhost:9092");
properties.put(ProducerConfig.KEY_SERIALIZER_CLASS_CONFIG,
    StringSerializer.class);
properties.put(ProducerConfig.VALUE_SERIALIZER_CLASS_CONFIG,
    IntegerSerializer.class);
properties.put(ProducerConfig.ACKS_CONFIG, "all");
properties.put(ProducerConfig.RETRIES_CONFIG, 20);
properties.put(ProducerConfig.RETRY_BACKOFF_MS_CONFIG, 3000);
```

Acks

acks	description
0	No acknowledgment, assume all is well
1	At least one replica will Producer will receive a success response, error if unsuccessful, up to client to hand
all	All replicas must acknowledge. Higher latency, safest



Every batch knows where each partition is going

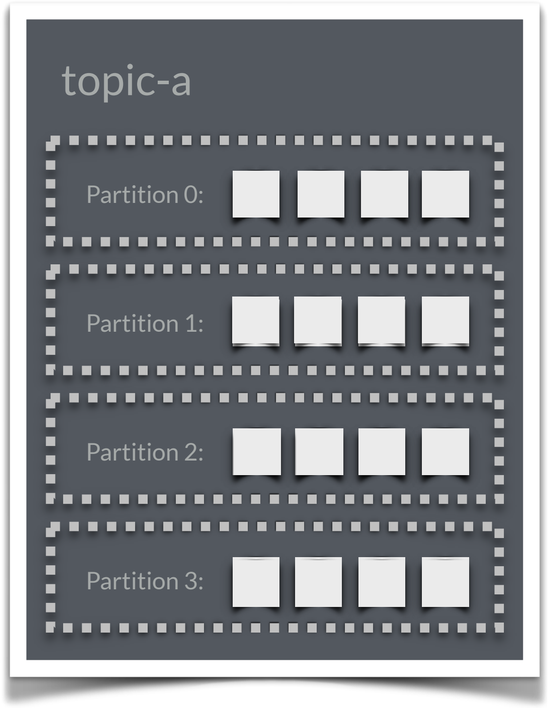
```
murmur2(bytes) % number partitions
```

Lab: Acks

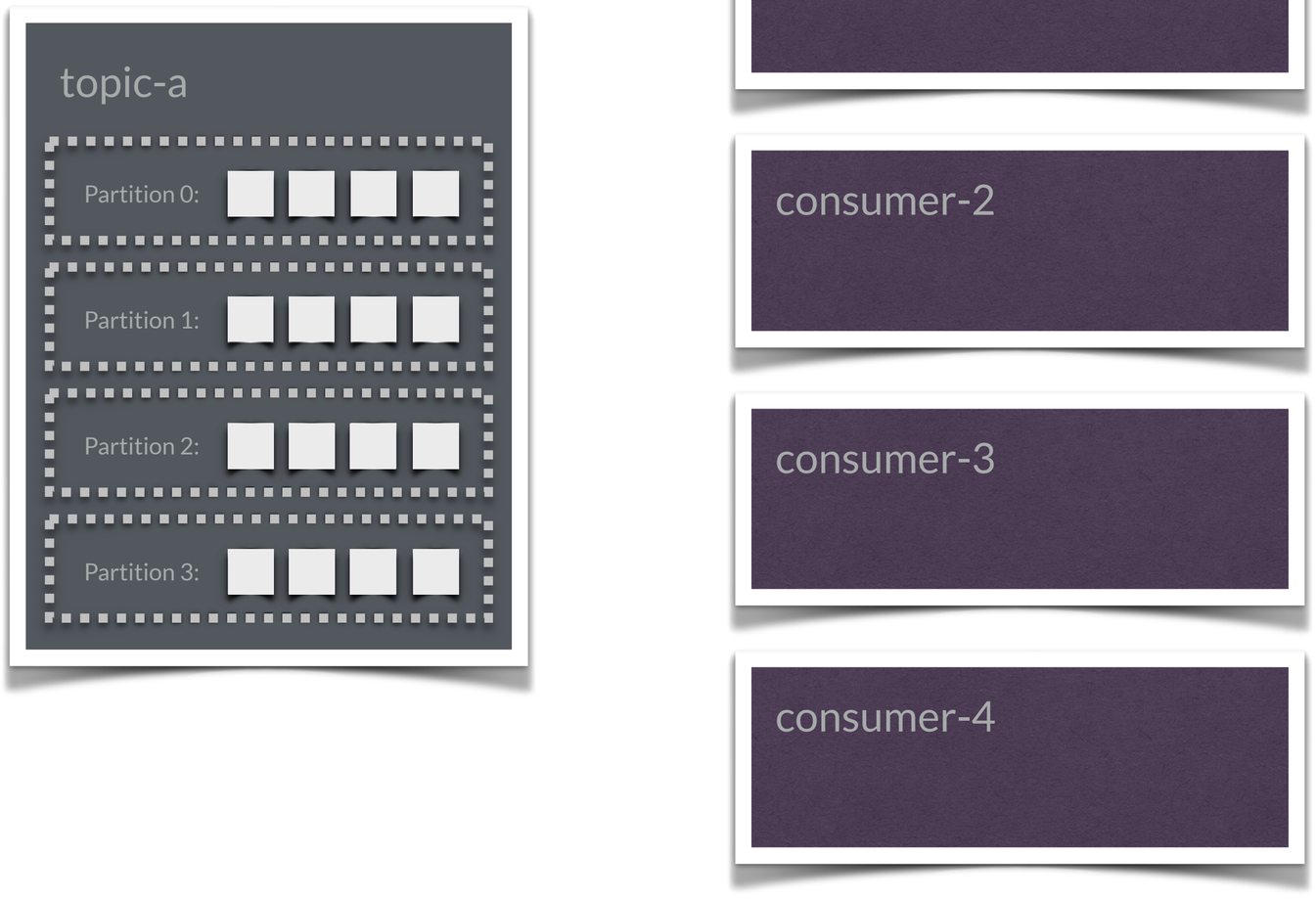
Kafka Programming
Consumers & Groups

Kafka Consumer Groups

- Consumers are typically done as a group
- A single consumer will end up inefficient with large amounts of data
- A consumer may never catch up
- **Every consumer should be on it's own machine, instance, pod**


topic-a
Partition 0:
Partition 1:
Partition 2:
Partition 3:


consumer-1


topic-a
Partition 0:
Partition 1:
Partition 2:
Partition 3:
consumer-1
consumer-2
consumer-3
consumer-4

Kafka’s Goal

Kafka scales to large amount of different consumers without affecting performance

Kafka Consumer Threading

- There are no multiple consumers that belong to the same group in one thread. **One consumer per one thread.**
- There are not multiple threads running one consumer, **One consumer per one thread.**

`__consumer_offsets`

- Topic on Kafka brokers that contain information about consumer and their offsets, stored in Kafka’s data directory

Establishing Properties

- Construct a `java.util.Properties` object
- Provide two or more locations where the bootstrap servers are located
- Provide a "Team Name", officially called a `group.id`
- Provide a DeSerializer for the key
- Provide a DeSerializer for the value

```
Properties properties = new Properties();
properties.put(ConsumerConfig.BOOTSTRAP_SERVERS_CONFIG,
        "localhost:9092");
properties.put(ConsumerConfig.GROUP_ID_CONFIG, "my_group");
properties.put(ConsumerConfig.KEY_DESERIALIZER_CLASS_CONFIG,
        "org.apache.kafka.common.serialization.StringDeserializer");
properties.put(ConsumerConfig.VALUE_DESERIALIZER_CLASS_CONFIG,
        "org.apache.kafka.common.serialization.IntegerDeserializer");
```

Create a Consumer Object

- Construct a `org.apache.kafka.clients.consumer.KafkaConsumer` object
- A Kafka Consumer is **not thread-safe**
- Inject the `Properties` into the `Consumer` object

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

Processing Messages

- Use the consumer that you have constructed, and call `poll` with pulse time
- The poll is a max sleep time, if a message is ready it will download a batch, `ConsumerRecords`
- Iterate through each record in the batch with a for-loop, process the message

```
while (!done.get()) {
    ConsumerRecords<String, String> records =
        consumer.poll(Duration.of(500, ChronoUnit.MILLIS));
    for (ConsumerRecord<String, String> record : records) {
        System.out.format("offset: %d\n", record.offset());
        System.out.format("partition: %d\n", record.partition());
        System.out.format("timestamp: %d\n", record.timestamp());
        System.out.format("timeStampType: %s\n", record.timestampType());
        System.out.format("topic: %s\n", record.topic());
        System.out.format("key: %s\n", record.key());
        System.out.format("value: %s\n", record.value());
    }
}
```

Be a good citizen, close your resources

- When you need to terminate, let the *Kafka group coordinator* know you are done
- Close the Consumer

```
consumer.close();
```

Consumer Offset Reset

Consumer Offset Reset

- When a consumer is assigned it must determine what offset for the partition to start
- Position is set according to your consumer's reset policy, either `earliest` or `latest`
- This is only applicable if there is no valid offset in the `__consumer_offset__` topic

```
Properties properties = new Properties();
...
properties.put(ConsumerConfig.AUTO_OFFSET_RESET_CONFIG, "earliest");

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

Manual Commits

Manual Commits

- Consumers will commit automatically every 5 seconds
- If your consumer fails within those 5 seconds another consumer may get those messages
- Might be too long before commit, in such case you may want to handle commits yourself
- Turn off your auto-commit by setting `ENABLE_AUTO_COMMIT_CONFIG` to `false`

```
Properties properties = new Properties();
...
properties.put(ConsumerConfig.ENABLE_AUTO_COMMIT_CONFIG, false);
KafkaConsumer<String, String> consumer = new KafkaConsumer<>(properties);
```

Synchronous Commit

- After turning off auto-commit
- Committing and blocking synchronously yourself
- Synchronous commits will block

Synchronous Commit

- After turning off auto-commit
- Committing and blocking synchronously yourself
- Synchronous commits will block

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

...

consumer.commitSync(); //Block
```

Asynchronous Commit

- After turning off auto-commit
- Committing and and letting it commit asynchronously
- Advantage: Speed, Higher throughput
- Disadvantage: You will get error reports asynchronously

```
consumer.commitAsync((offsets, exception) -> {
    //offsets
    //exception
});
```

Using both kinds of commits

- You can commit asynchronously within the loop
- Then commit synchronously outside the loop
- Reason, if you are out of the loop, likely you want to shut down

```
Runtime.getRuntime().addShutdownHook(new Thread(() -> done.set(true)));

while (!done.get()) {
    ConsumerRecords<String, String> records = consumer.poll(Duration.of(500, ChronoUnit.MILLIS));
    for (ConsumerRecord<String, String> record : records) {
       ...
    }
    consumer.commitAsync((offsets, exception) -> {
        //offsets
        //exception
    });
}
consumer.commitSync(); //Block
consumer.close();
```

Consumer Rebalancing

Partition Rebalance

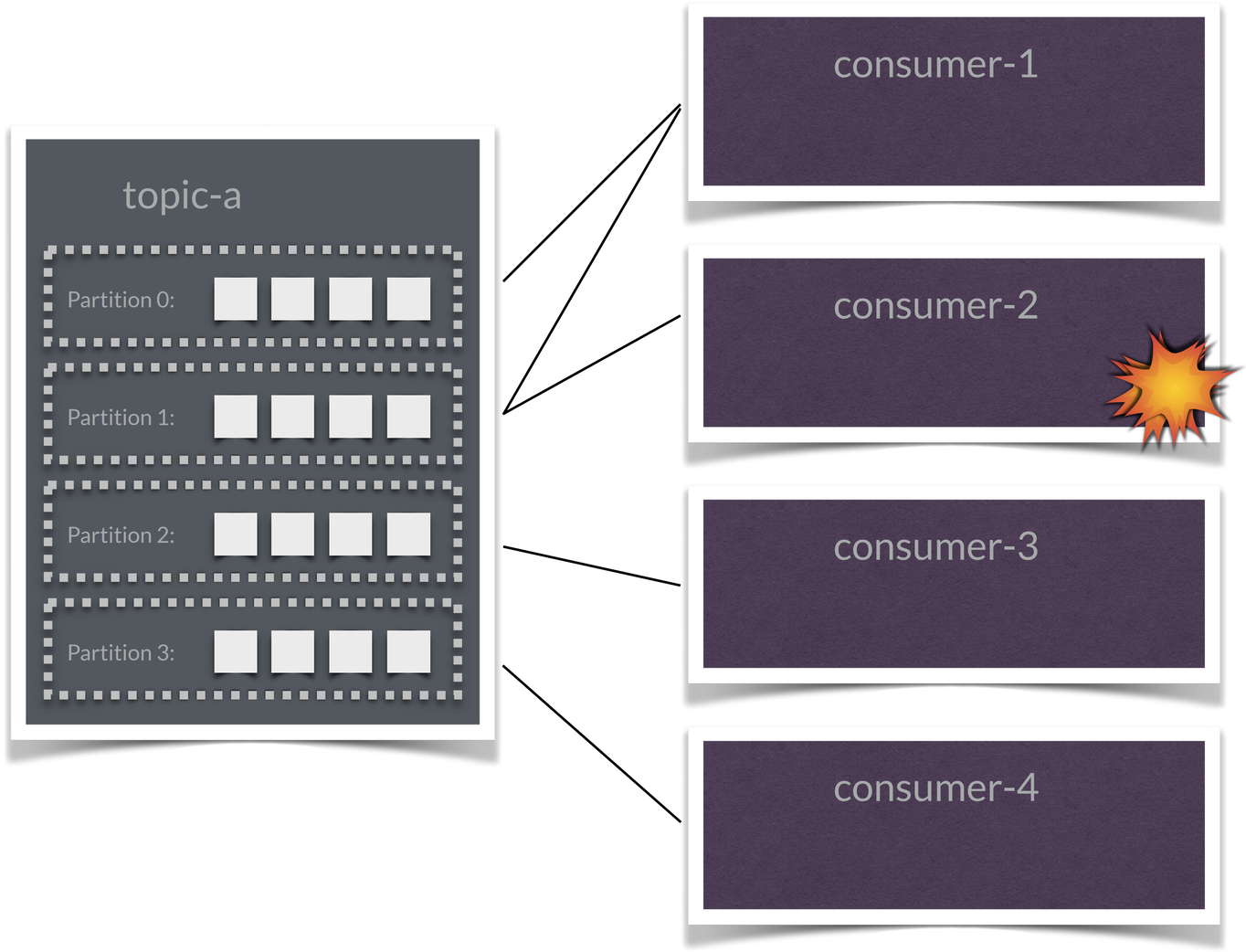
- When one partition is moved from one consumer to another, this is known as a *rebalance*.
- A way to mitigate when either consumers go down, or when consumers are added.
- Although unavoidable, this will cause an unfortunate pause, and it ***will lose state***.

Groups and Heartbeats

- At regular intervals, consumers will send heartbeats to the broker, to let it know it is alive and still reading data
- Heartbeats are sent to a Kafka broker called the *group coordinator*
- They are sent when the consumer **poll**s and consumes a record

Leaving the Group

- When a consumer leaves the group, it lets the *group coordinator* know it is done
- The Kafka broker then triggers a rebalance of the group.


topic-a
Partition 0:
Partition 1:
Partition 2:
Partition 3:
consumer-1
consumer-2
consumer-3
consumer-4

Consumer Rebalance Listener

- You can implement a ConsumerRebalanceListener and be alerted when a rebalance has occurred
- The rebalance listener requires that you implement `onPartitionsRevoked`, and `onPartitionsAssigned`

```
consumer.subscribe(Collections.singletonList("my_orders"),
        new ConsumerRebalanceListener() {
            @Override
            public void onPartitionsRevoked(Collection<TopicPartition> collection) {
                System.out.println("Partition revoked:" +
                        collectionTopicPartitionToString(collection));
                consumer.commitAsync();
            }

            @Override
            public void onPartitionsAssigned(Collection<TopicPartition> collection) {
                System.out.println("Partition assigned:" +
                        collectionTopicPartitionToString(collection));
            }
        });
```

Lab: Consumer

Retention Settings

Retention

- Durable Storage over a Period of Time
- Can either be configured in time or size
- Once reached messages are expunged

Retention Formula

Who administers Kafka can update the default retention time or size

```
log.retention.hours = 120
log.retention.bytes = 3221225472
```

Default Hours are set to (168 hours) or one week

You may also use **log.retention.minutes** or **log.retention.ms**, whichever is smallest wins.

You can also configure retention per topic, like the following

```
bin/kafka-configs --zookeeper localhost:2181 --entity-type topics --entity-name my-topic --alter --add-config retention.ms=128000
```

Retention Evaluation

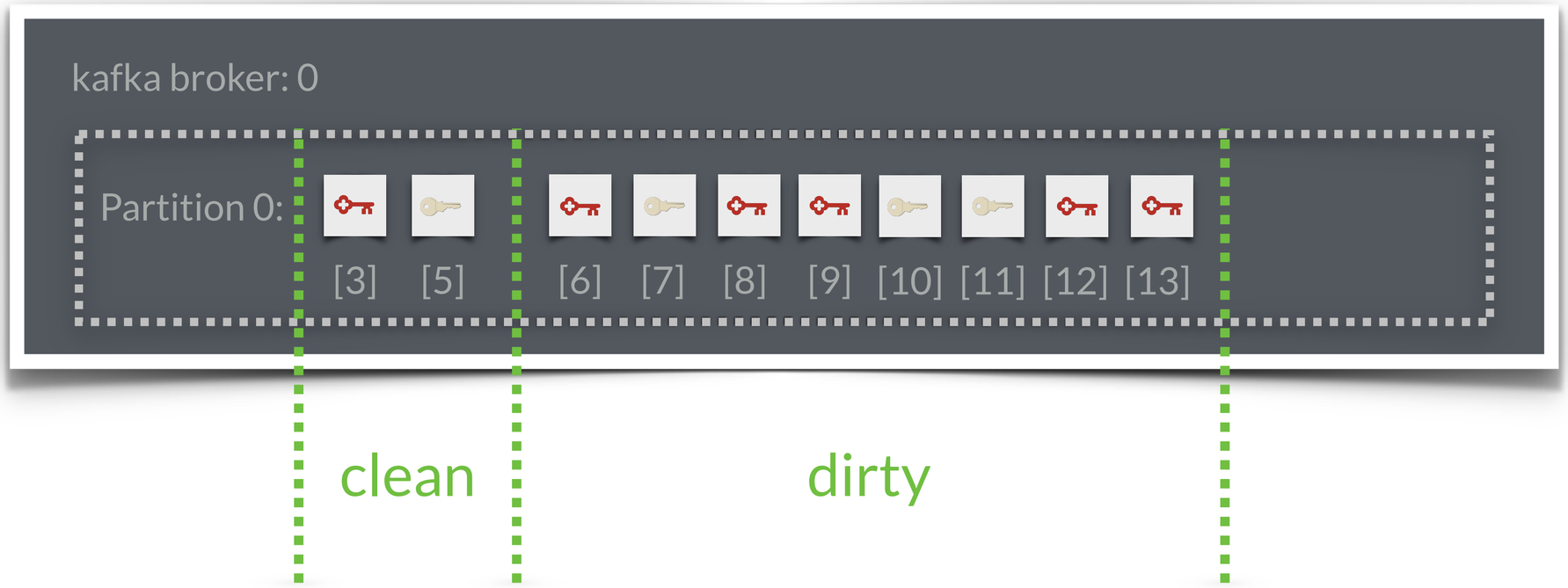
- Durable Storage over a Period of Time
- Can either be configured in time or size
- Once reached messages are expunged

Compaction

Compaction

- A form of retention where messages of the same key where only the latest message will be retained.
- Compaction is performed by a *cleaner thread*


kafka broker: 0
Partition 0:
[0]
[1]
[2]
[3]
[4]
[5]
kafka broker: 0
Partition 0:
[3]
[5]



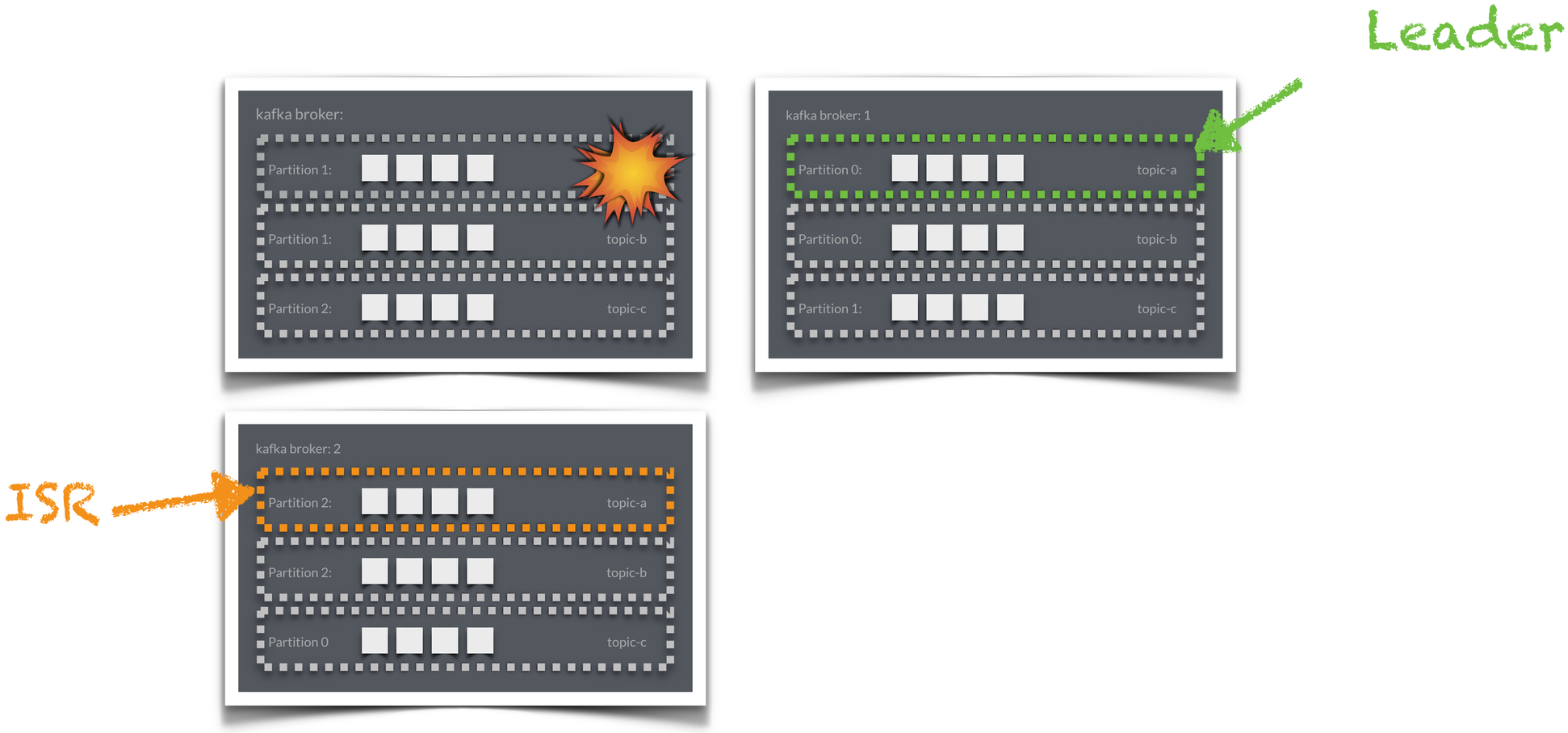
Kafka will start compacting when 50% of the topic contains dirty records

Resiliency

ISR (In sync replicas)

- Given a leader partition, an in sync replica is one that has been kept up to date within the last 10 seconds
- This is configurable
- During a crash, the closes ISR will retain control for failover


Leader
ISR
kafka broker:
Partition 1:
Partition 1:
topic-b
Partition 2:
topic-c
kafka broker: 1
Partition 0:
topic-a
Partition 0:
topic-b
Partition 1:
topic-c
ISR
kafka broker: 2
Partition 2:
topic-a
Partition 2:
topic-b
Partition 0
topic-c


Leader
kafka broker:
Partition 1:
Partition 1:
topic-b
Partition 2:
topic-c
kafka broker: 1
Partition 0:
topic-a
Partition 0:
topic-b
Partition 1:
topic-c
ISR
kafka broker: 2
Partition 2:
topic-a
Partition 2:
topic-b
Partition 0
topic-c

Exactly Once Semantics

Mathias Verraes
@mathiasverraes

Follow

There are only two hard problems in distributed systems: 2. Exactly-once delivery 1. Guaranteed order of messages 2. Exactly-once delivery

RETWEETS 6,775 LIKES 4,727

10:40 AM - 14 Aug 2015

69 6.8K 4.7K

Exactly Once Semantics

- If a stream processing application consumes message *A* and produces message *B* such that *B = F(A)*
- *E*xactly once processing means that *A* is considered consumed if and only if *B* is successfully produced, and vice versa.

How Exactly Once Processing is Lost (1)

- The `producer.send()` could result in duplicate writes of message *B* due to internal retries.
- This is addressed by the idempotent producer
- *E*xactly once processing means that *A* is considered consumed if and only if *B* is successfully produced, and vice versa.

How Exactly Once Processing is Lost (2)

- We may reprocess the input message *A*, resulting in duplicate *B* messages being written to the output
- Reprocessing may happen if the stream processing application crashes after writing *B* but before marking *A* as consumed.
- Thus when it resumes, it will consume *A* again and write *B* again, causing a duplicate.

How Exactly Once Processing is Lost (3)

- Finally, in distributed environments, applications will crash or—worse!—temporarily lose connectivity to the rest of the system.
- Typically, new instances are automatically started (like Kubernetes) to replace the ones which were deemed lost.
- Through this process, we may have multiple instances processing the same input topics and writing to the same output topics, causing duplicate outputs and violating the exactly once processing semantics.
- We call this the problem of “zombie instances.”

Requirements for EOS

- Transaction API
  - All of the messages included in the transaction will be successfully written or none of them will be.
- Zombie Fencing
  - We solve the problem of zombie instances by requiring that each transactional producer be assigned a unique identifier called the `transactional.id`.

`transaction.id` and epochs

- Producers register the Producer's transaction.id
- Identifies producer with a unique identifier across process restarts
- Registers transaction.id with broker
- Kafka broker checks for open transactions with the given transactional.id and completes them
- Increments an epoch associated with the transactional.id
- Any producers with same transactional.id and an older epoch are considered zombies and are fenced off, ie. future transactional writes from those producers are rejected.

Consumers and transactions

- Guarantees with consumers fall short
- Consumers will
  - not know whether these messages were written as part of a transaction
  - not know when transactions start or end
  - not guaranteed to be subscribed to all partitions which are part of a transaction
- **Kafka guarantees that a consumer will eventually deliver only non-transactional messages or committed transactional messages**

Transactions in the Producer

To "turn on" transactions in the Producer

- Add transaction id to identify the producer
- Initialize the transaction

```
Properties properties = new Properties();
properties.put(ProducerConfig.BOOTSTRAP_SERVERS_CONFIG,
    "localhost:9092");
properties.put(ProducerConfig.KEY_SERIALIZER_CLASS_CONFIG,
    StringSerializer.class);
properties.put(ProducerConfig.VALUE_SERIALIZER_CLASS_CONFIG,
    IntegerSerializer.class);
properties.put(ProducerConfig.TRANSACTIONAL_ID_CONFIG, "my-transaction-id");


producer.initTransactions();
```

Sending Transactionally

```
producer.initTransactions();

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

Using transactions:

- Beginning Transaction with `beginTransaction`
- Send records as normal
- `commit` the Transaction
- If fenced, close it, nothing more we can do
- Other Exceptions, abort that transaction

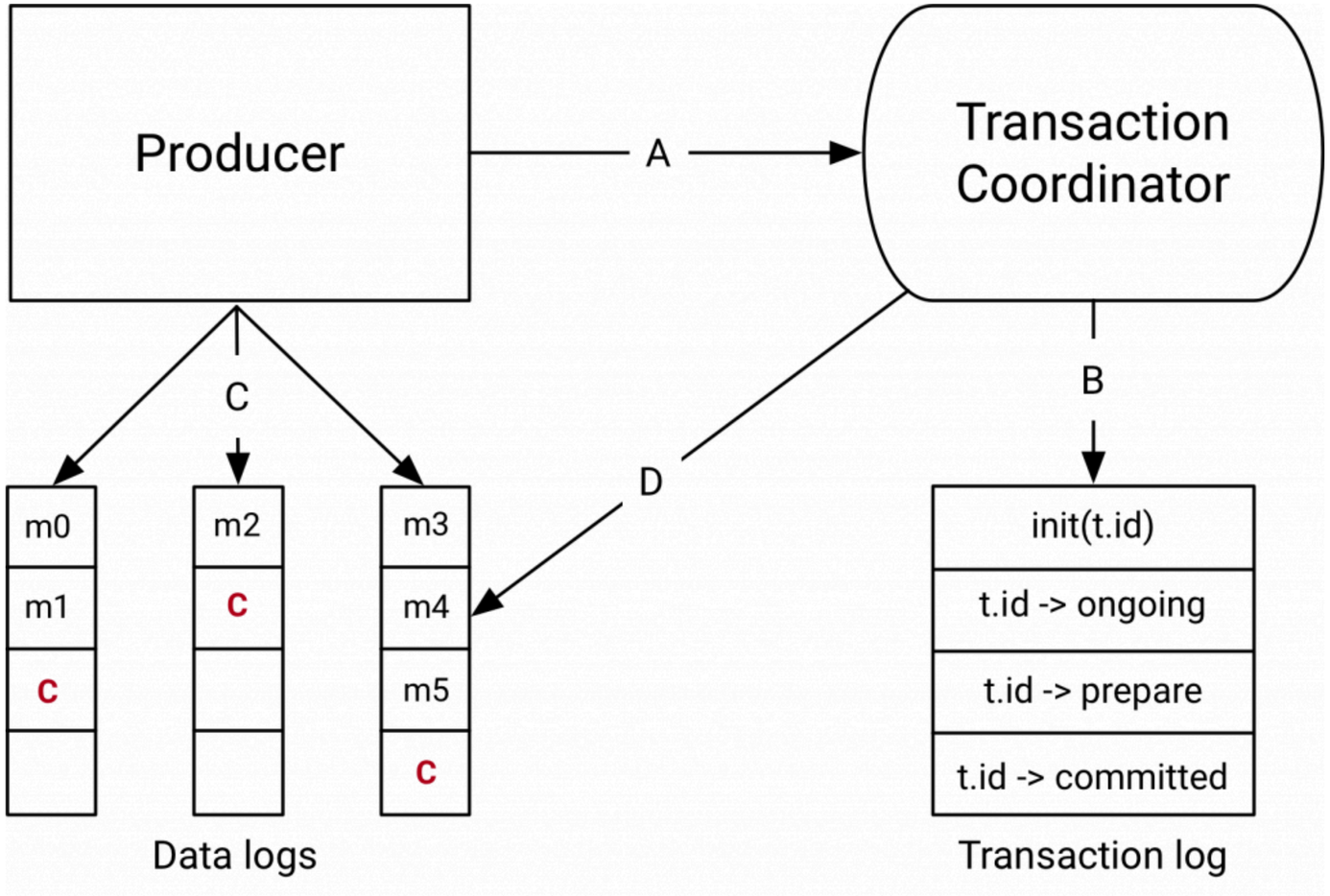
What about the consumer?

For the consumer, we will need to establish:

- `read_committed` - In addition to reading messages that are not part of a transaction, you can also read ones that are, after the transaction is committed
- `read_uncommited` - Read all messages in offset order without waiting for transactions to be committed. This option is similar to the current semantics of a Kafka consumer.

```
Properties properties = new Properties();
properties.put(ConsumerConfig.BOOTSTRAP_SERVERS_CONFIG,
        "localhost:9092");
properties.put(ConsumerConfig.GROUP_ID_CONFIG, "sf_giants");
...
properties.put(ConsumerConfig.ISOLATION_LEVEL_CONFIG, "read_committed");
```

How Transactions Work



Enable Idempotence

- We talk about transactions which is a part of ensuring EOS
- We also need to ensure that we handle idempotence
  - *Idempotence* - denoting an element of a set which is unchanged in value when multiplied or otherwise operated on by itself
  - Each batch of messages sent to Kafka will contain a sequence number that the broker will use to dedupe any duplicate send
  - Turn it on in the Producer with `enable.idempotence=true`

```
properties.put(ProducerConfig.ENABLE_IDEMPOTENCE_CONFIG, true);
```

Avro

Avro

- Created by Doug Cutting; Creator of Hadoop
- Serialization is defined by schema
- Schemas are JSON Based
- Codegen available at command line
- Codegen available by Maven, Gradle, SBT Plugin
- Supports the following languages:
  - C, C++, Java, Perl, Python, Ruby, PHP
- Named after WWI, WWII Aircraft Company, A.V. Roe

Types of Avro Serialization

- Generic
  - Develop code that reflects your schema
- Specific
  - Code generate your class from a schema, an `.avsc` file
  - This is the most common form
- Reflection
  - Auto-create schema from an existing class

Avro Primitive Types

Avro Type	Java Type
`null`	null
`double`	`double`
`float`	`float`
`int`	`int`
`long`	`long`
`bool`	`bool`
`string`	Unicode `CharSequence`
`bytes`	Sequence of 8-bit unsigned bytes

Avro Complex Types

```
{
  "namespace": "com.xyzcorp",
  "type": "record",
  "doc" : "An music album",
  "name": "Album",
  "fields": [
    {
      "name": "name",
      "type": "string"
    },
    {
      "name": "yearReleased",
      "type": [
        "int",
        "null"
      ]
    }
  ]
}
```

Avro Field Options

Avro Field	Description
`name`	Name of the Field
`doc`	Documentation
`type`	Type of the Field
`default`	Default Value
`order`	What order does this impact record
`aliases`	Any other names

Avro Array

List of Strings, but can be any type for items

```
{"type": "array", "items": "string"}
```

Avro Map

All keys in an Avro map are `string`

```
{"type": "map", "values": "long"}
```

Avro Enum

When autogen in Java, `RainbowColors` will be an `enum`

```
{ "type" : "enum",
  "name" : "RainbowColors",
  "doc" : "Colors of the Rainbow",
  "symbols" : ["RED", "ORANGE", "YELLOW",
               "GREEN", "BLUE", "INDIGO",
               "VIOLET"]}
```

Full Specification for Avro

- Read more about Avro, https://avro.apache.org/docs/current/spec.html
- Includes other types and feature:
  - UUID
  - Timestamp
  - Date/Time
  - Sorting
  - Codecs

Running Avro Tools

Avro Tools is a jar file that can executed to generate Java from schema

```
java -jar avro-tools-1.8.2.jar compile schema <schema file> <destination>
```

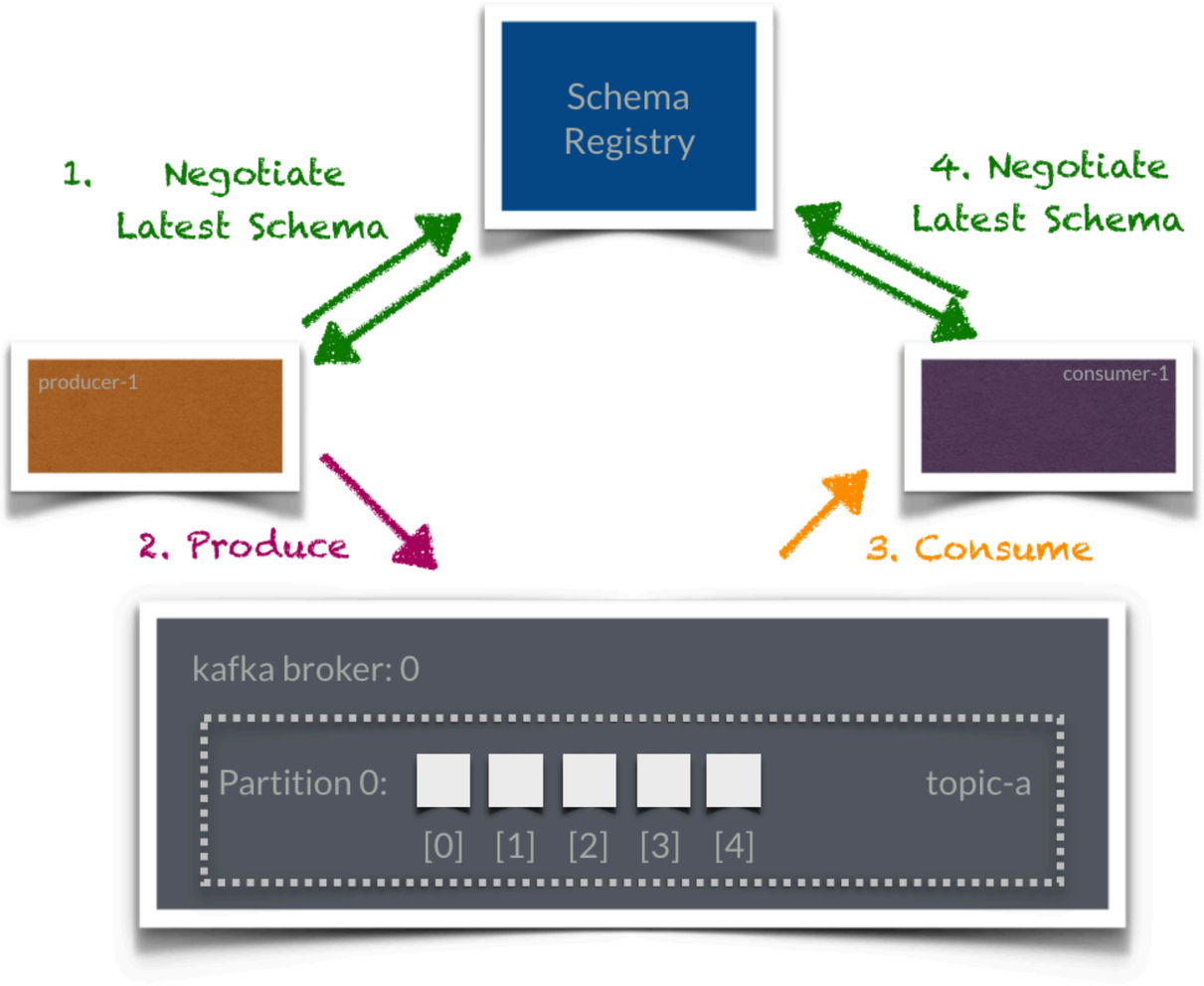
Avro Tools is available for most IDEs like Maven, and Gradle

Schema Registry

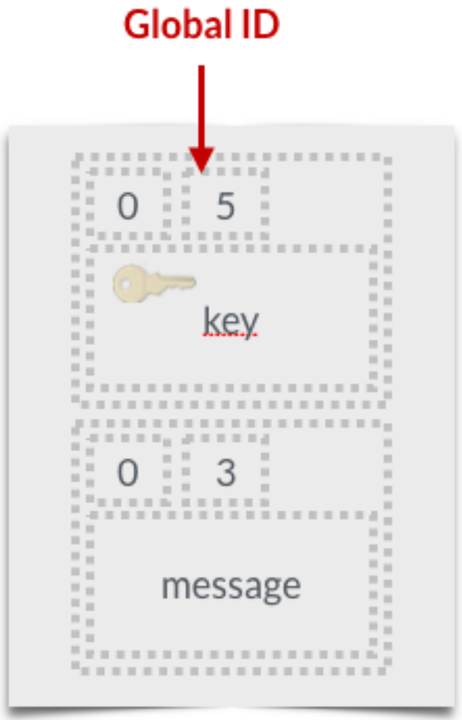
Schema Registry

- Service that contrains and typechecks messages before sending
- Stores schemas in registry for and assigns a global ID
- Ensures *backward* and *forward* compatibility
- Does so through Serializers and Deserializers
- Automatically done through Java Kafka Client API

Schema Registry



Schema Registry Message Format



- The first byte is a zero byte
- The second byte is the global identifier of the Schema that registered in the Schema Registry
- The Global ID is used to as a means of communicating which Schema to use with messages

Registering a New Schema Manually

```
POST /subjects/my_topic-key/versions HTTP/1.1
Host: schemaregistry.example.com
Accept: application/vnd.schemaregistry.v1+json,
        application/vnd.schemaregistry+json,
        application/json

{
  "schema":
    "{
       \"type\": \"record\",
       \"name\": \"test\",
       \"fields\":
         [
           {
             \"type\": \"string\",
             \"name\": \"field1\"
           },
           {
             \"type\": \"int\",
             \"name\": \"field2\"
           }
         ]
     }"
}
```

- Posts to a subject
- A subject is combination of
  - Topic
  - `-key` or `-value`
- Example of a subject
  - `stocks-key`
  - `sales-value`

Note: We aren't going manually do this we just wanted to show what an avro producer will do

Getting Response from the Registry

```
HTTP/1.1 200 OK
Content-Type: application/vnd.schemaregistry.v1+json

{"id":1}
```

The `{"id":1}` is the global id, this is used as reference to this schema

Schema Registry Java Producer

```
Properties properties = new Properties();
properties.put(ProducerConfig.BOOTSTRAP_SERVERS_CONFIG,
        "localhost:9092");
properties.put(ProducerConfig.KEY_SERIALIZER_CLASS_CONFIG,
        StringSerializer.class);
properties.put(ProducerConfig.VALUE_SERIALIZER_CLASS_CONFIG,
        io.confluent.kafka.serializers.KafkaAvroSerializer.class);
properties.setProperty("schema.registry.url", "http://localhost:8081");
```

- What makes schema registry work is the Serializer
- You must add `schema.registry.url` and specify the location of the registry

Example of Sending Custom Avro Object

```
Album album = new Album("Purple Rain", "Prince", 1984,
   Arrays.asList("Purple Rain", "Let's go crazy"));

ProducerRecord<String, Album> producerRecord =
    new ProducerRecord<>("music_albums", "Prince", album);

producer.send(producerRecord);
```

- The ProducerRecord's value is accepting an actual Java Object
- We can just send the object just like any other type

Schema Registry Consumer

```
Properties properties = new Properties();
properties.put(ConsumerConfig.BOOTSTRAP_SERVERS_CONFIG, "localhost:9092");
properties.put(ConsumerConfig.GROUP_ID_CONFIG, "my_group");
properties.put(ConsumerConfig.KEY_DESERIALIZER_CLASS_CONFIG,
        "org.apache.kafka.common.serialization.StringDeserializer");
properties.put(ConsumerConfig.VALUE_DESERIALIZER_CLASS_CONFIG,
        io.confluent.kafka.serializers.KafkaAvroDeserializer.class);
properties.setProperty("schema.registry.url", "http://localhost:8081");
properties.setProperty("specific.avro.reader", "true");
```

- What makes schema registry work is the `Deserializer`
- You must add `schema.registry.url` and specify the location of the registry
- You must add `specific.avro.reader` and specify that you used specific avro mode

Receiving a Custom Object from Kafka

```
while (true) {
  ConsumerRecords<String, Album> records =
          consumer.poll(Duration.of(500, ChronoUnit.MILLIS));
  for (ConsumerRecord<String, Album> record : records) {
      System.out.format("offset: %d\n", record.offset());
      System.out.format("partition: %d\n", record.partition());
      System.out.format("timestamp: %d\n", record.timestamp());
      System.out.format("timeStampType: %s\n",
              record.timestampType());
      System.out.format("topic: %s\n", record.topic());
      System.out.format("key: %s\n", record.key());
      Album a = record.value();
      System.out.format("value: %s\n", a.getTitle());
      System.out.format("value: %s\n", a.getArtist());
  }
}
```

Lab: Using Avro

Streaming Concepts


TK45
115m
ÚNIK.C.

Stream Processing

Endless supply of data

“Replayable"

Real Time Processing for Fraud Detection, High End Sales Detection, Internet of Things, and More.

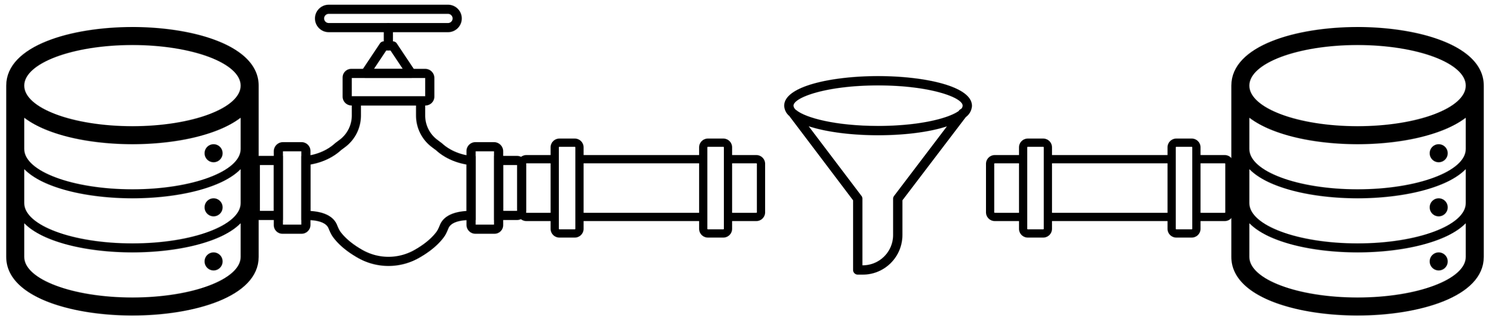
Will require built-in accumulator table to perform real time data processing, like counting, and grouping


NY
100.00

Filtering

NY

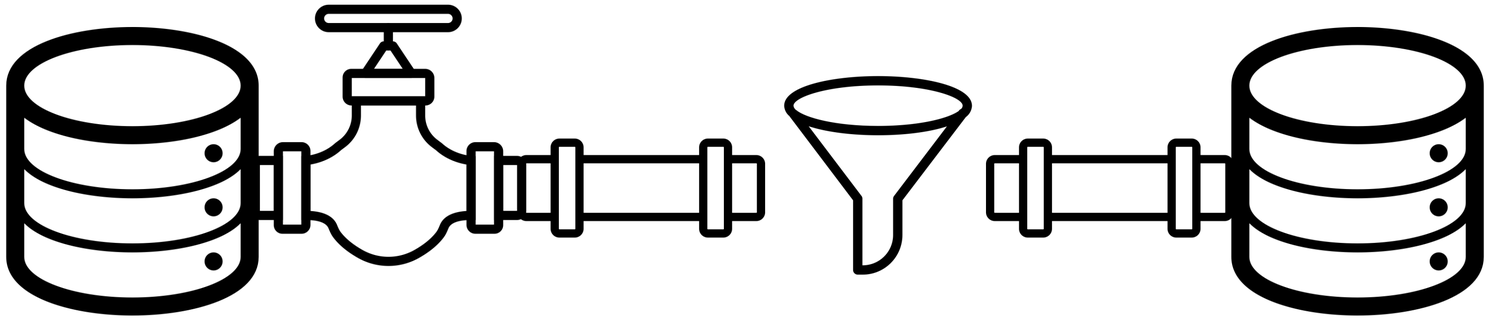
100.00



```
value > 10000
```

OH

20000

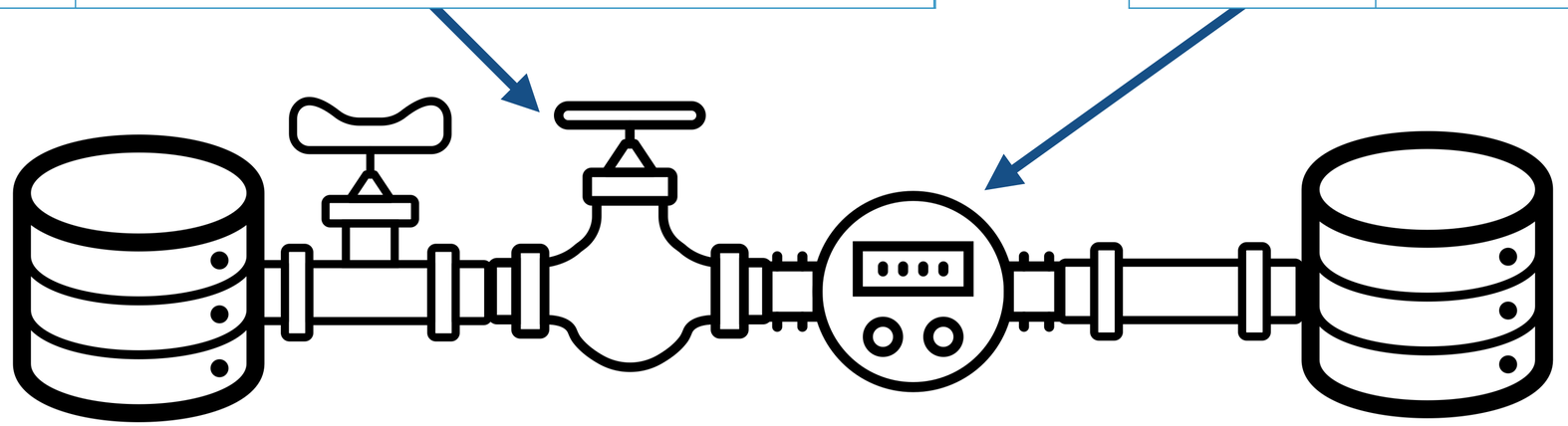


```
value > 10000
```

Aggregating

Key	Value
OH	100.0

Key	Value
OH	100.0



OH

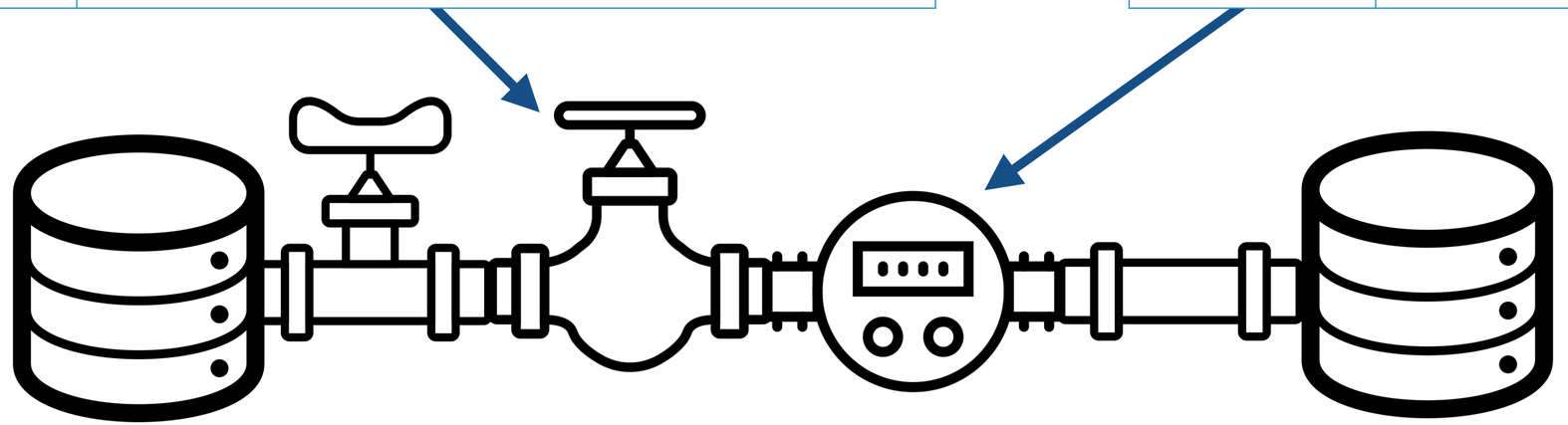
100.00

OH

100.00

Key	Value
OH	100.0
NY	20.0

Key	Value
OH	100.0
NY	20.0



NY

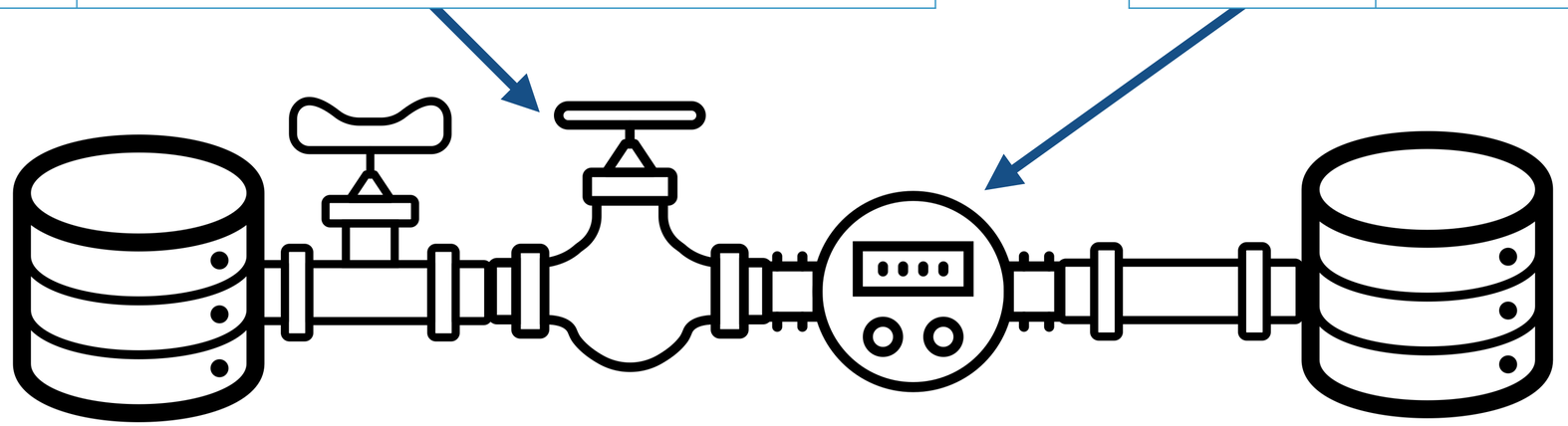
20

NY

20

Key	Value
OH	100.0
NY	20.0, 60.0

Key	Value
OH	100.0
NY	80.0

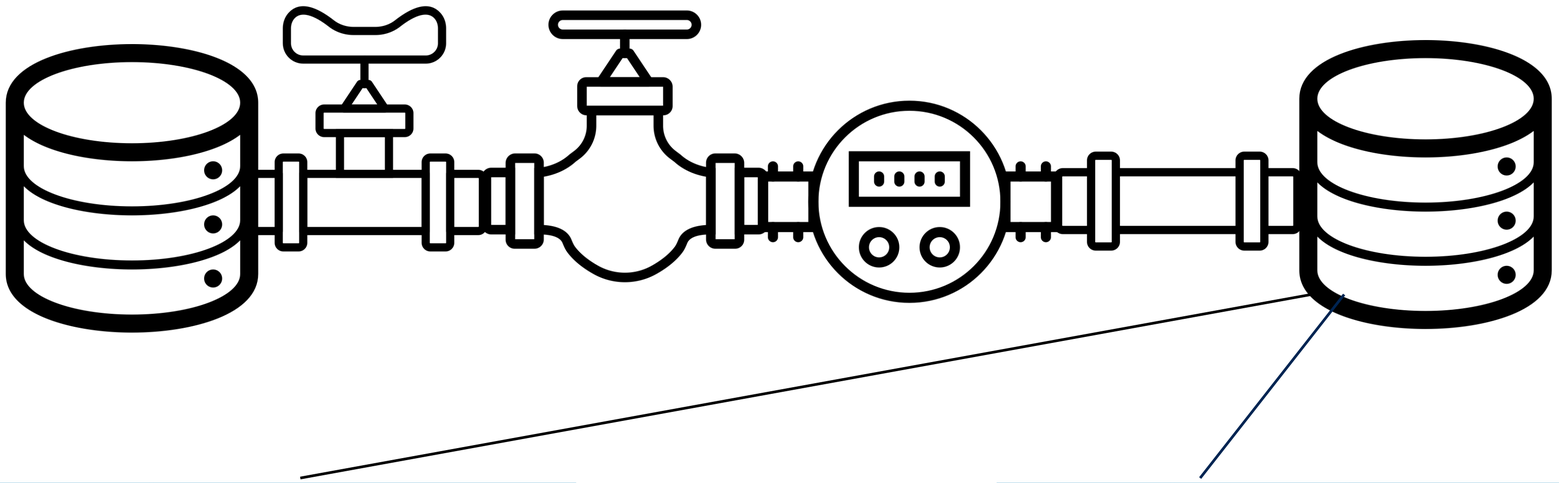


NY

60

NY

80.0

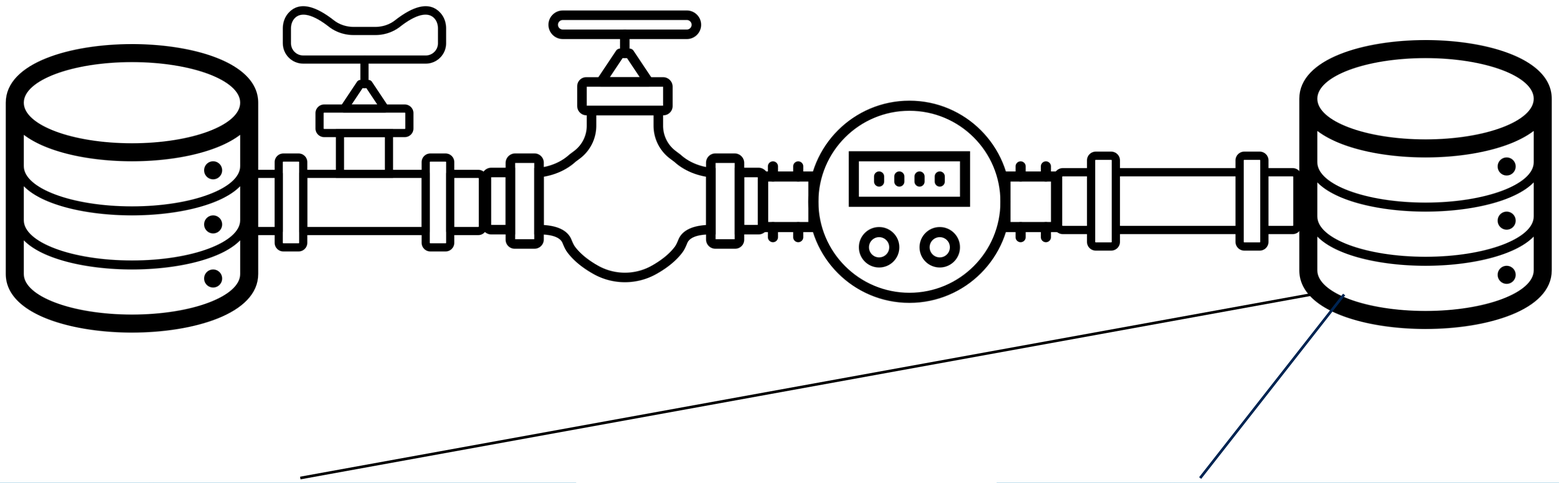


Offset	Key	Value
0	**OH**	100.0

Partition 0

Offset	Key	Value
0	**NY**	20.0
1	**NY**	80.0

Partition 1



Offset	Key	Value
0	**OH**	100.0

Partition 0

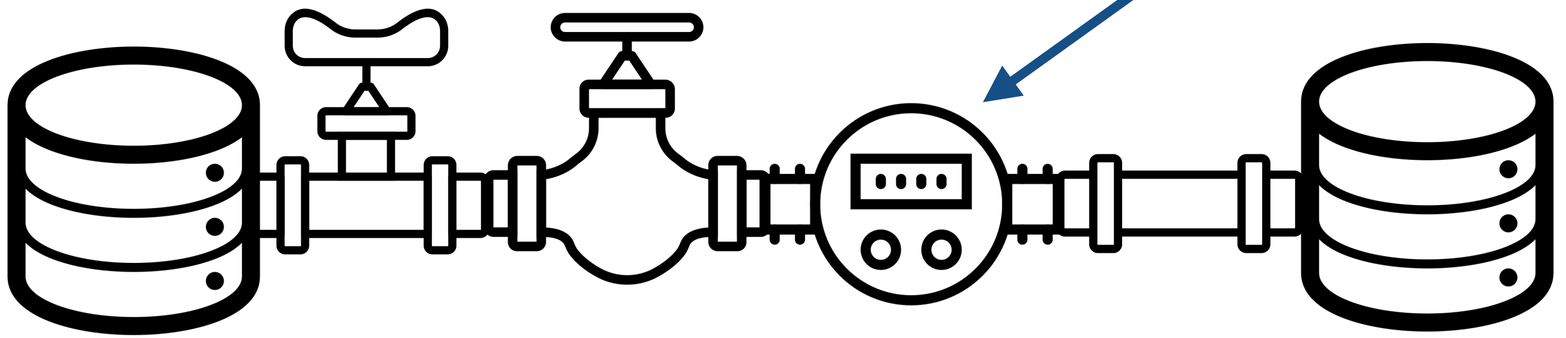
Offset	Key	Value
1	**NY**	80.0

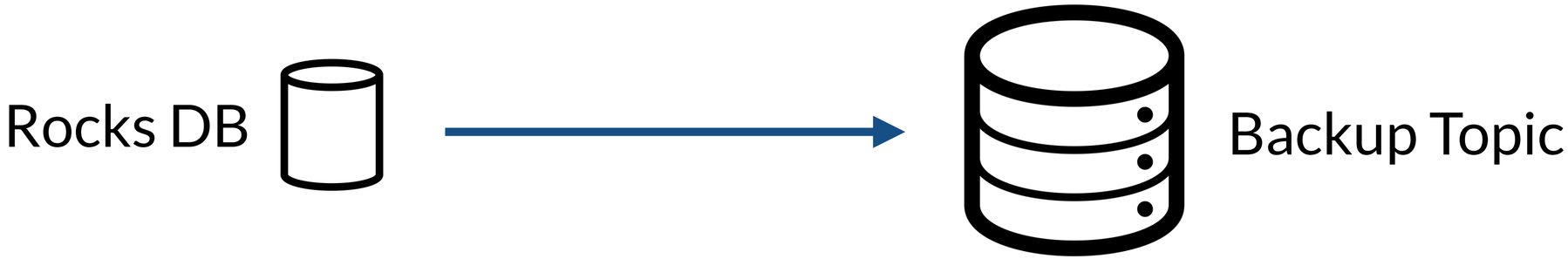
Partition 1

After Compaction

Rocks DB

Key	Value
OH	100.0
NY	80.0




Rocks DB
Backup Topic

Windowing

Tumbling Window

Hopping Window

Session Window

Session Window

the last element has a occurred; now we wait

Session Window

waited 5 minutes = make it a window

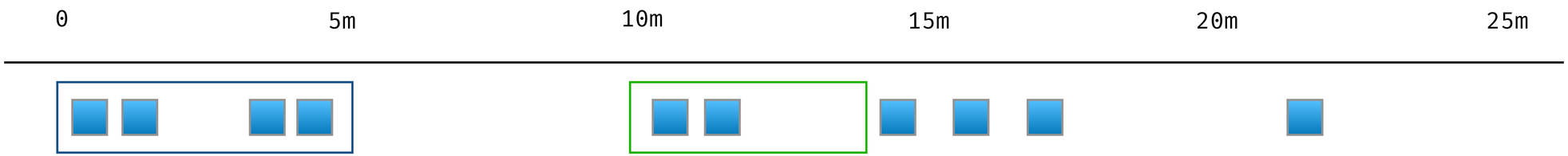
Session Window

we have a new element; we start a new window

Session Window

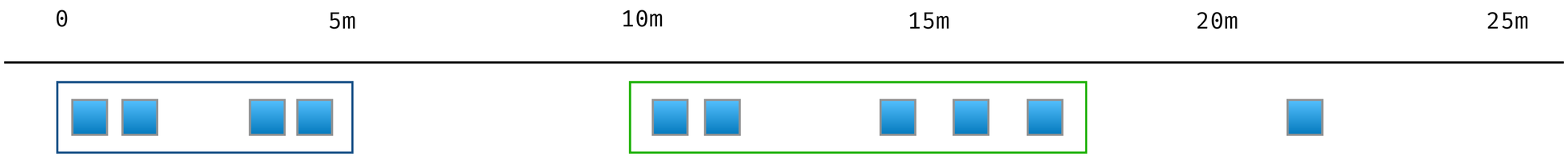
we wait for 5 minutes

Session Window



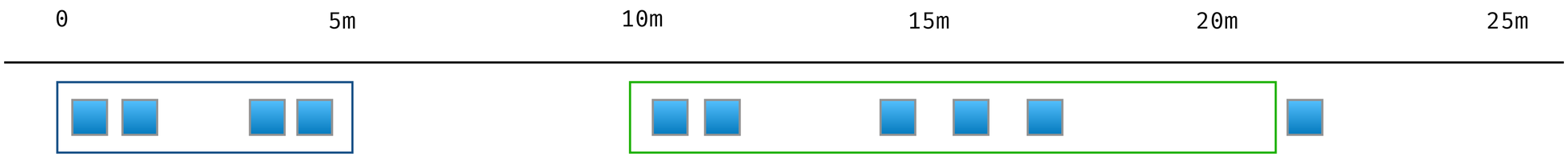
2 minutes elapsed; no windowing yet

Session Window



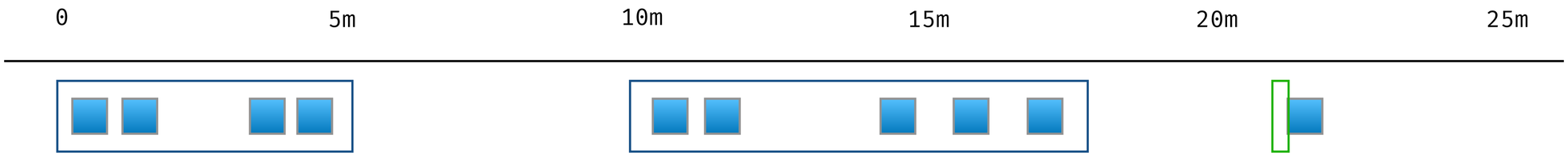
we wait five minutes

Session Window



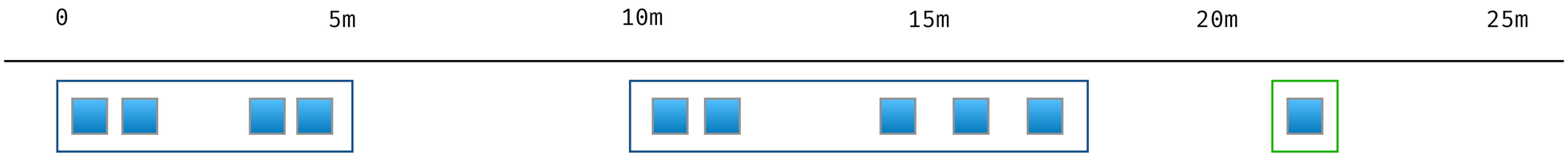
no new elements; we make it a window

Session Window



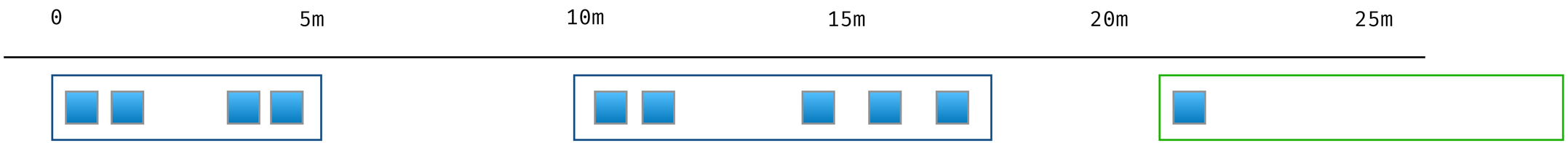
we see something new

Session Window



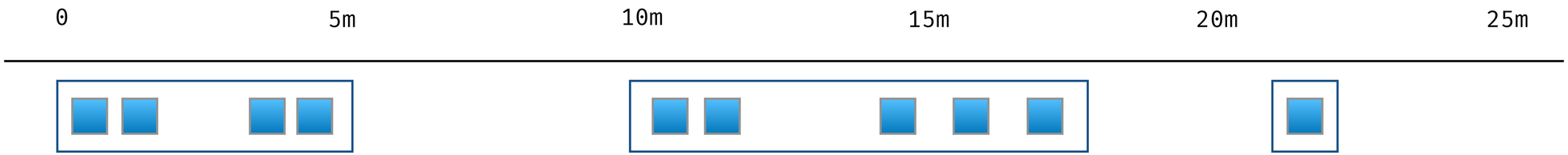
last element; we wait five minutes

Session Window



nothing else; we wait 5 minutes

Session Window



that's a new window

Stream API

Establishing Properties

- Create an `application.id` that represents your application group or "team"
- Serde is combination of Serializer/Deserializer
- Every stream application and KSQL app (later) is a consumer-producer

```
Properties props = new Properties();
props.put(StreamsConfig.APPLICATION_ID_CONFIG, "my_stream_app");
props.put(StreamsConfig.BOOTSTRAP_SERVERS_CONFIG, "localhost:9092");
props.put(StreamsConfig.DEFAULT_KEY_SERDE_CLASS_CONFIG, Serdes.String().getClass());
props.put(StreamsConfig.DEFAULT_VALUE_SERDE_CLASS_CONFIG, Serdes.Integer().getClass());
```

Create a Stream Builder

- Always start with a `StreamBuilder` object
- This is the GoF builder pattern, where we will create a Topology object that represents our data pipeline

```
StreamsBuilder builder = new StreamsBuilder();
```

Read from a Topic

- Recall there are two representations of how to ingest data from a topic
  - Stream - Flow of data
  - Table - An aggregation; Or a database
- How do you read the topic is up to you
- Result is either a `stream` or `table` object that can take functional programming DSL.

```
KStream<String, Integer> stream = builder.stream("my_topic");
```

```
KTable<String, Integer> table = builder.table("my_topic");
```

Standard Functional Programming

- `map`
- `filter`
- `flatMap`
- `groupBy`
- `reduce`
- `window`
- `join`
- `leftJoin`
- `outerJoin`

Mapping

- Given a Stream

```
(1, "Hello"), (2, "Zoom"), (3, "Fold")
```

- Applying `map`

```
stream.map((key, value) -> new KeyValue<>(key + 1, value + "!"));
```

- Resulting in

```
(2, "Hello!"), (3, "Zoom!"), (4, "Fold!")
```

Filtering

- Given a Stream

```
(1, "Hello"), (2, "Zoom"), (3, "Fold"), (4, "Past")
```

- Applying `filter`

```
stream.filter((key, value) -> key % 2 == 0);
```

- Resulting in

```
(2, "Zoom"), (4, "Past")
```

FlatMap

- Given a Stream

```
(1, "One"), (2, "Two"), (3, "Three"), (4, "Four")
```

- Applying `flatMap`

```
stream.flatMap((key, value) -> Arrays.asList(
new KeyValue(key, value),
new KeyValue(key * 100, value + " Hundred")))
```

- Resulting in

```
(1, "One"), (100, "One Hundred"), (2, "Two"),(200, "Two Hundred"), (3,
"Three"),(300, "Three Hundred"), (4, "Four"),(400, "Four Hundred")
```

Peek

- Peers into the Stream and view what goes through

```
stream1.peek((key, value) ->
  System.out.printf("key: %s, value: %d", key, value));
```

GroupBy

- Given a Stream

```
(1, "One"), (2, "Two"), (3, "Three"), (4, "Four")
```

- Applying `groupBy`

```
stream.groupBy((key, value) -> key % 2 == 0 ? "Even", "Odd")
```

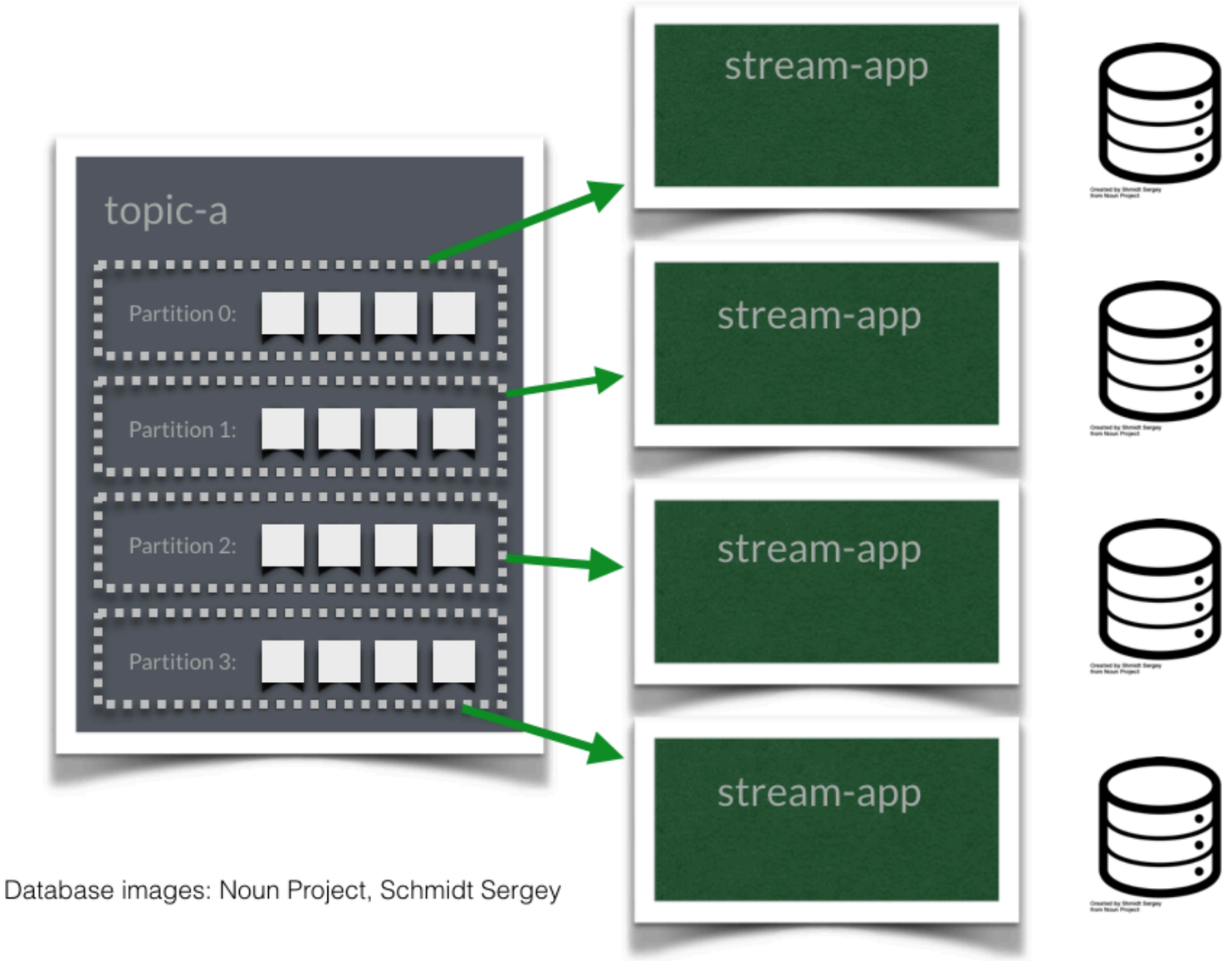
- Resulting in `KGroupedStream`

Once we have `KGroupedStream`

- `groupBy` creates a `KGroupedStream` object
- You have to decide what to do with this group
  - `count`
  - `aggregate`
  - `reduce`
  - `windowBy`
- Once you call any of the above, you have a `KTable`

KTable

- Represents a changelog, where the oldest records are not important
- Ideal for counters, and state
- KTable values are stored at each application’s ephemeral storage
- Most ephemeral storage is backed by Rocks DB
- All streaming is then backed up as a topic for resilience



Database images: Noun Project, Schmidt Sergey

GroupByKey

- Given a Stream

```
(1, "One"), (2, "Two"), (3, "Three"), (4, "Four")
```

- Applying `groupByKey`

```
stream.groupByKey()
```

- Resulting in KGroupedStream
- Is Synonymous with the Following

```
stream.groupBy((key, value) -> key)
```

Count

- Aggregates the count of what has been grouped
- Records with null key or value are ignored
- Returns KTable that represents the latest rolling count
- Will maintain the count in ephemeral storage, (like RocksDB)

Count

- Given a Stream

```
(1, "One"), (2, "Two"), (3, "Three"), (4, "Four")
```

- Applying `groupBy` with `count`

```
stream.groupBy((key, value) -> key % 2 == 0 ? "Even" : "Odd").count();
```

- Will result in the RocksDB ephemeral storage

```
("Even", 2)
("Odd", 2)
```

Reduce

- Given a Stream

```
(1, "One"), (2, "Two"), (3, "Three"), (4, "Four")
```

- Applying `groupBy` with `count`

```
stream.groupBy((key, value) -> key % 2 == 0 ? "Even" : "Odd")
      .reduce((value1, value2) -> value1 + "," + value2);
```

- Will result in the RocksDB ephemeral storage

```
("Even", "Two,Four")
("Odd", "One,Three")
```

Aggregate

- Given a Stream

```
(1, "One"), (2, "Two"), (3, "Three"), (4, "Four")
```

- Applying `groupBy` with `count`

```
groupedStream.aggregate(() -> "0:Zero,",
(nextKey, nextValue, aggString) -> aggString + nextKey + ":" + nextValue ",");
```

- Will result in the RocksDB ephemeral storage

```
("Even", "0:Zero,2:Two,4:Four")
("Odd", "0:Zero,1:One,3:Three")
```

Hopping Windows

- Creating a Time Window

```
import java.util.concurrent.TimeUnit;
import org.apache.kafka.streams.kstream.TimeWindows;

long windowSizeMs = TimeUnit.MINUTES.toMillis(5); // 5 * 60 * 1000L
long advanceMs =    TimeUnit.MINUTES.toMillis(1); // 1 * 60 * 1000L
TimeWindows.of(windowSizeMs).advanceBy(advanceMs);
```

- Applying the Window

```
streams.groupBy(...).windowedBy(TimeWindows.of(windowSizeMs).advanceB
y(advanceMs));
```

Session Windows

- Creating a Time Window

```
import java.util.concurrent.TimeUnit;
import org.apache.kafka.streams.kstream.SessionWindows;

SessionWindows.with(TimeUnit.MINUTES.toMillis(5));
```

- Applying the Window

```
streams.groupBy(...).windowedBy(SessionWindows.with(TimeUnit.MINUTES.
toMillis(5));
```

Dump results to a topic

- Dump the results to a topic using `to`

```
KStream<String, Integer> stream = builder.stream("my_topic");
stream.filter(...).to("new_topic");
```

- Dump the results to a topic using `through` to post to topic and continue:

```
KStream<String, Integer> stream = builder.stream("my_topic");
stream.filter(...).through("new_topic").flatMap(...).to("other_topic")
```

Build the Topology and Stream

- Once you create your stream, you can build a `Topology` object:

```
Topology topology = builder.build();
```

- Create a Kafka Streams object with both Topology and Properties you created earlier

```
KafkaStreams streams = new KafkaStreams(topology, props);
```

- And Run...

```
streams.start();
```

Adding a Shutdown Hook

- As always, be a good citizen, properly shutdown resources

```
Runtime.getRuntime().addShutdownHook(new Thread(streams::close));
```

Lab: Writing a Streams Application

KSQL

KSQL

Open source streaming SQL engine for Apache Kafka

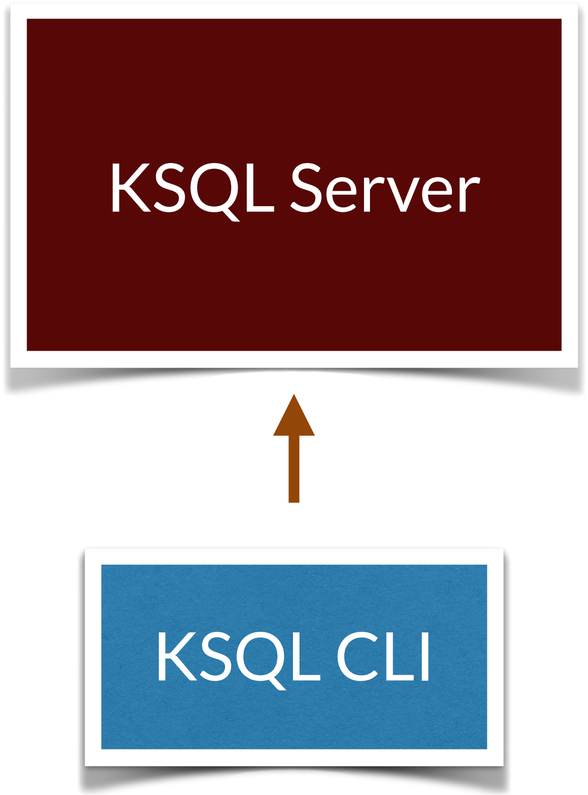
Provides SQL interface for stream processing on Kafka

Scalable, elastic, fault-tolerant, and real-time.

KSQL

Supports a wide range of streaming operations, including:

- Data filtering
- Transformations
- Aggregations
- Joins
- Windowing
- Sessionization


KSQL Server
KSQL CLI

KSQL Architecture

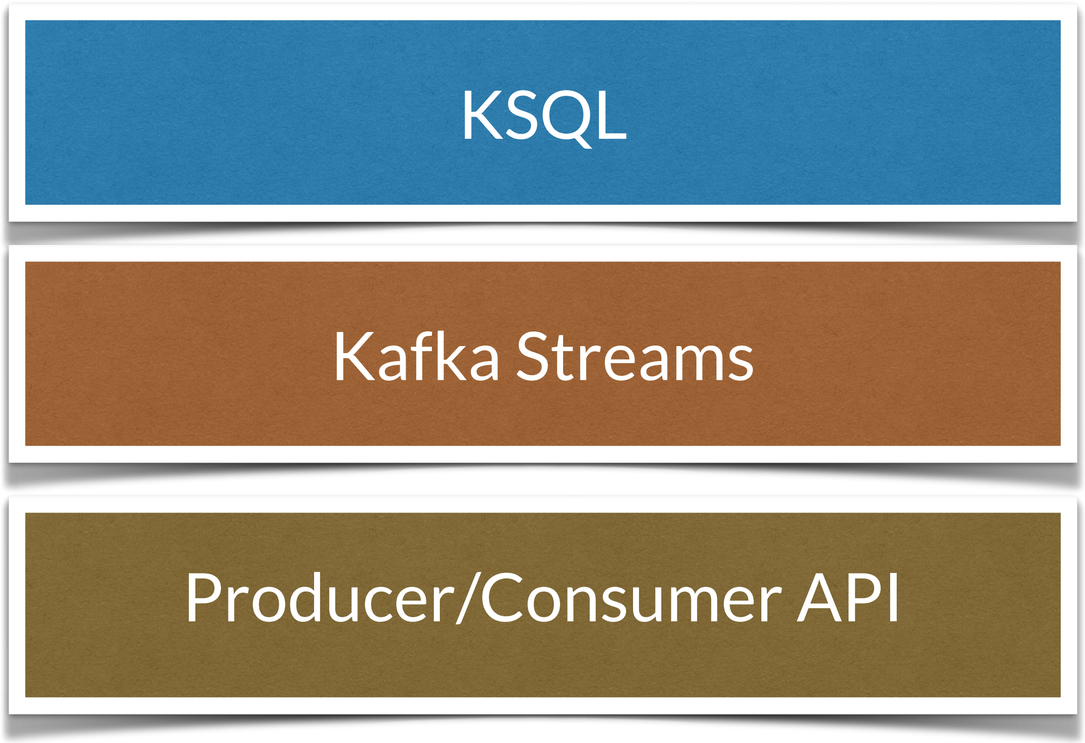
KSQL Server communicates with the broker

KSQL servers are run separately from the KSQL CLI client and Kafka brokers.

You can deploy servers on remote machines, VMs, or containers

KSQL CLI interacts with KSQL Servers via a REST API

KSQL Server runs in two modes: CLI, Headless


KSQL
Kafka Streams
Producer/Consumer API

Starting in CLI Mode

```
/bin/ksql http://localhost:8088
```

Starting in Headless Mode

```
/bin/ksql-start-server \
server_path/etc/ksql/ksql-server.properties \
--queries-file /path/to/queries.sql
```

Tapping a Stream Based Topic

```
CREATE STREAM pageviews \
  (viewtime BIGINT, \
   userid VARCHAR, \
   pageid VARCHAR) \
  WITH (KAFKA_TOPIC='pageviews', \
        VALUE_FORMAT='DELIMITED');
```

Tapping a Table Based Topic

```
CREATE TABLE users \
  (registertime BIGINT, \
   userid VARCHAR, \
   gender VARCHAR, \
   regionid VARCHAR) \
  WITH (KAFKA_TOPIC = 'users', \
        VALUE_FORMAT='JSON', \
        KEY = 'userid');
```

Showing the Streams

```
SHOW STREAMS;

Stream Name | Kafka Topic | Format
-----------------------------------------
PAGEVIEWS   | pageviews   | DELIMITED
-----------------------------------------
```

Showing the Tables

```
SHOW TABLES;

 Table Name   | Kafka Topic | Format
--------------------------------------
 USERS        | users       | JSON
--------------------------------------
```

Supported SQL Types

- `BOOLEAN`
- `INTEGER`
- `BIGINT`
- `DOUBLE`
- `VARCHAR` (or `STRING`)
- `ARRAY<ArrayType>` (JSON and AVRO only. Index starts from 0)
- `MAP<VARCHAR, ValueType>` (JSON and AVRO only)
- `STRUCT<FieldName FieldType, … >` (JSON and AVRO only)

Various Operators

Scalar Operators:

```
ABS, ARRAYCONTAINS, CEIL, CONCAT,
EXTRACTJSONFIELD, FLOOR, GEO_DISTANCE, IFNULL, LC
ASE, LEN, MASK, RANDOM, ROUND,
STRINGTOTIMESTAMP, SUBSTRING, TIMESTAMPTOSTRING,
TRIM, UCASE
```

Aggregator Operators:

```
COUNT, MAX, MIN, SUM, TOPK, TOPKDISTINCT, WINDOWS
TART, WINDOWEND
```

Displays Information

`SHOW TOPICS`	Show all topics
`SHOW <TOPIC>`	Display Topic
`SHOW STREAMS`	Show Streams
`SHOW TABLES`	Show Tables
`SHOW FUNCTIONS`	Show Available Functions
`SHOW QUERIES`	Show Persistent Queries

Describing

`DESCRIBE`	List columns in stream or table
`DESCRIBE EXTENDED`	Describe in detail stream or table; runtime statistics, and queries that populate the stream or table

Persistent Query

```
CREATE TABLE users_female AS \
  SELECT userid, gender, regionid FROM users \
  WHERE gender='FEMALE';
```

What makes this a persistent query is the form
`CREATE (TABLE|STREAM) AS SELECT`
Once executed, it will continuously run, until terminated with `TERMINATE` command

Non-Persistent Query

```
SELECT * FROM pageviews
  WHERE ROWTIME >= 1510923225000
    AND ROWTIME <= 1510923228000;
```

A `LIMIT` can be used to limit the number of rows returned.
Once the limit is reached the query will terminate.

Persistent v. Non Persistent

	Persistent	Non Persistent
Where does data go?	Will store into a topic	Will display on screen
How do I stop it?	Find query id using `SHOW QUERIES` and `TERMINATE <id>`	`CTRL + C`
How to create?	`CREATE STREAM AS SELECT ...`	`SELECT ....`

Selecting Customized Fields

```
CREATE STREAM pageviews_transformed \
  WITH (TIMESTAMP='viewtime', \
        PARTITIONS=5, \
        VALUE_FORMAT='JSON') AS \
  SELECT viewtime, \
         userid, \
         pageid, \
         TIMESTAMPTOSTRING \
           (viewtime, 'yyyy-MM-dd HH:mm:ss.SSS') \
              AS timestring \
  FROM pageviews \
  PARTITION BY userid;
```

Start from the Beginning

```
SET 'auto.offset.reset' = 'earliest';
```

Tumbling Window

```
SELECT item_id, SUM(quantity)
  FROM orders
  WINDOW TUMBLING (SIZE 20 SECONDS)
  GROUP BY item_id;
```

Hopping Window

```
SELECT item_id, SUM(quantity)
  FROM orders
  WINDOW HOPPING (SIZE 20 SECONDS,
     ADVANCE BY 5 SECONDS)
  GROUP BY item_id;
```

Session Window

```
SELECT item_id, SUM(quantity)
  FROM orders
  WINDOW SESSION (20 SECONDS)
  GROUP BY item_id;
```

Please Fill in Survey

https://www.surveymonkey.com/r/5YGVGL2

Lab: Using KSQL

Conclusion

Agenda

- ⭐Understand Kafka
- ⭐Understand Producer
- ⭐Understand Consumer
- ⭐Understand Rebalancing
- ⭐Understand Streaming
- ⭐Understand Tables
- ⭐Understand KSQL