Apache Kafka - The must know Pub-Sub

Daniel Hinojosa

About Me...

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

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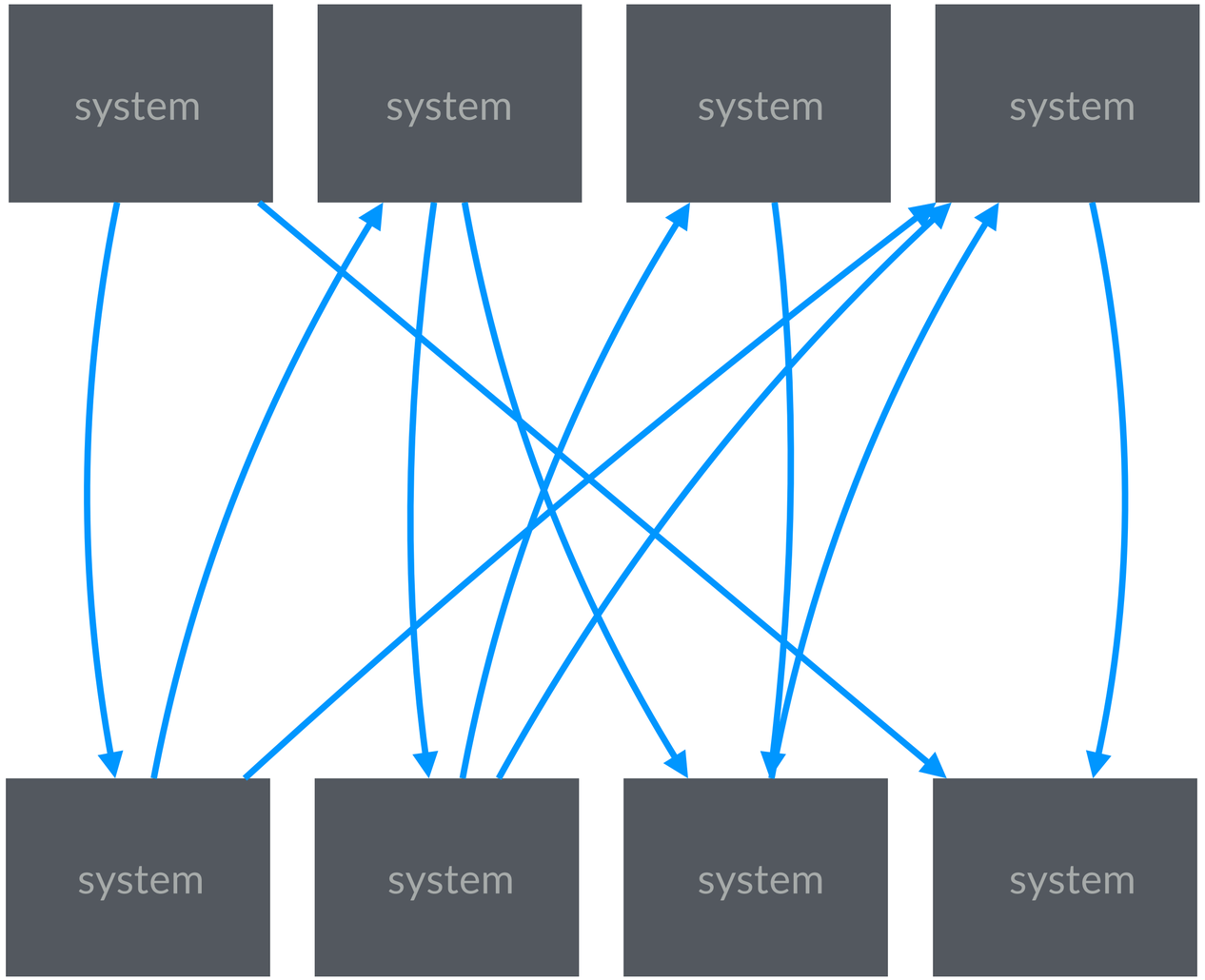
Agenda

Agenda

- ⭐Understand Kafka
- ⭐Understand Producer
- ⭐Understand Consumer
- ⭐Understand Rebalancing

Kafka Introduction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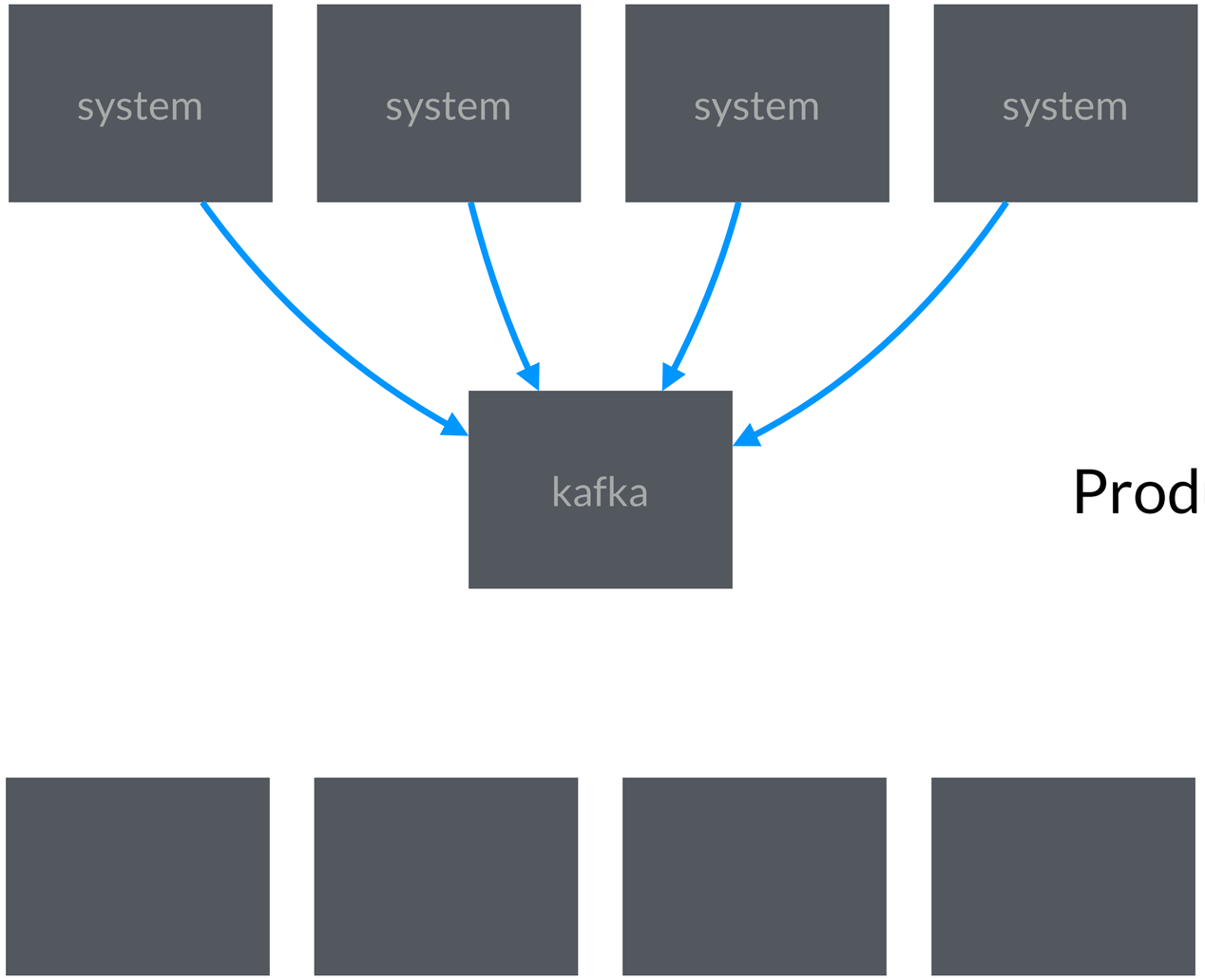
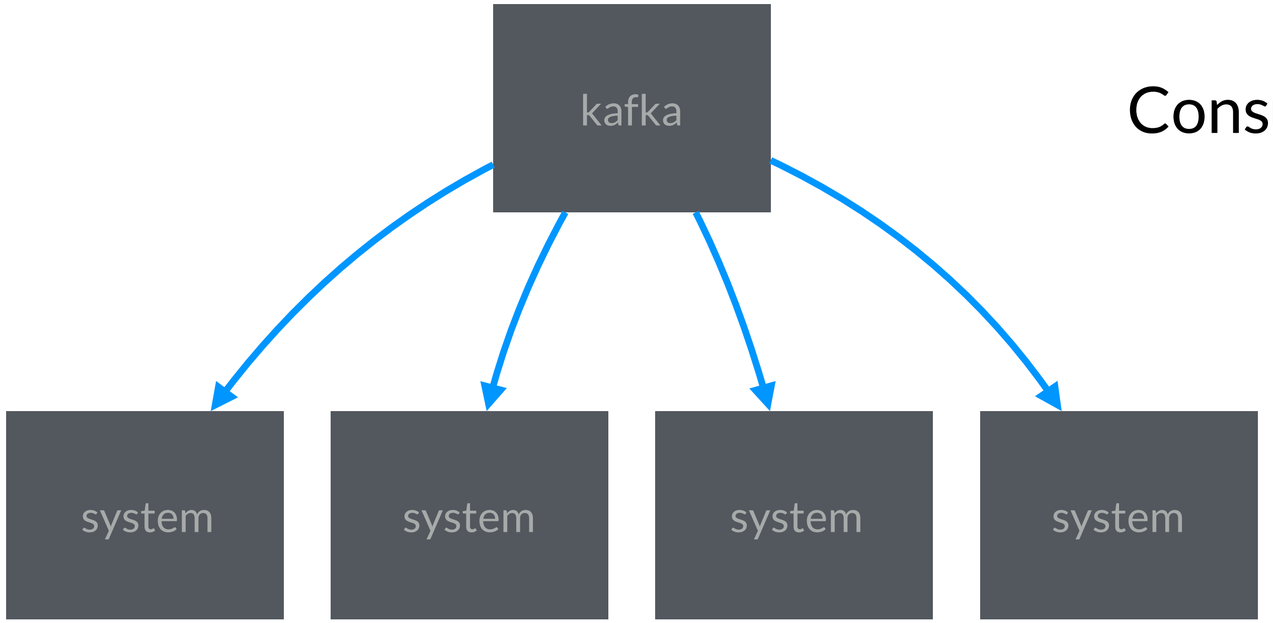
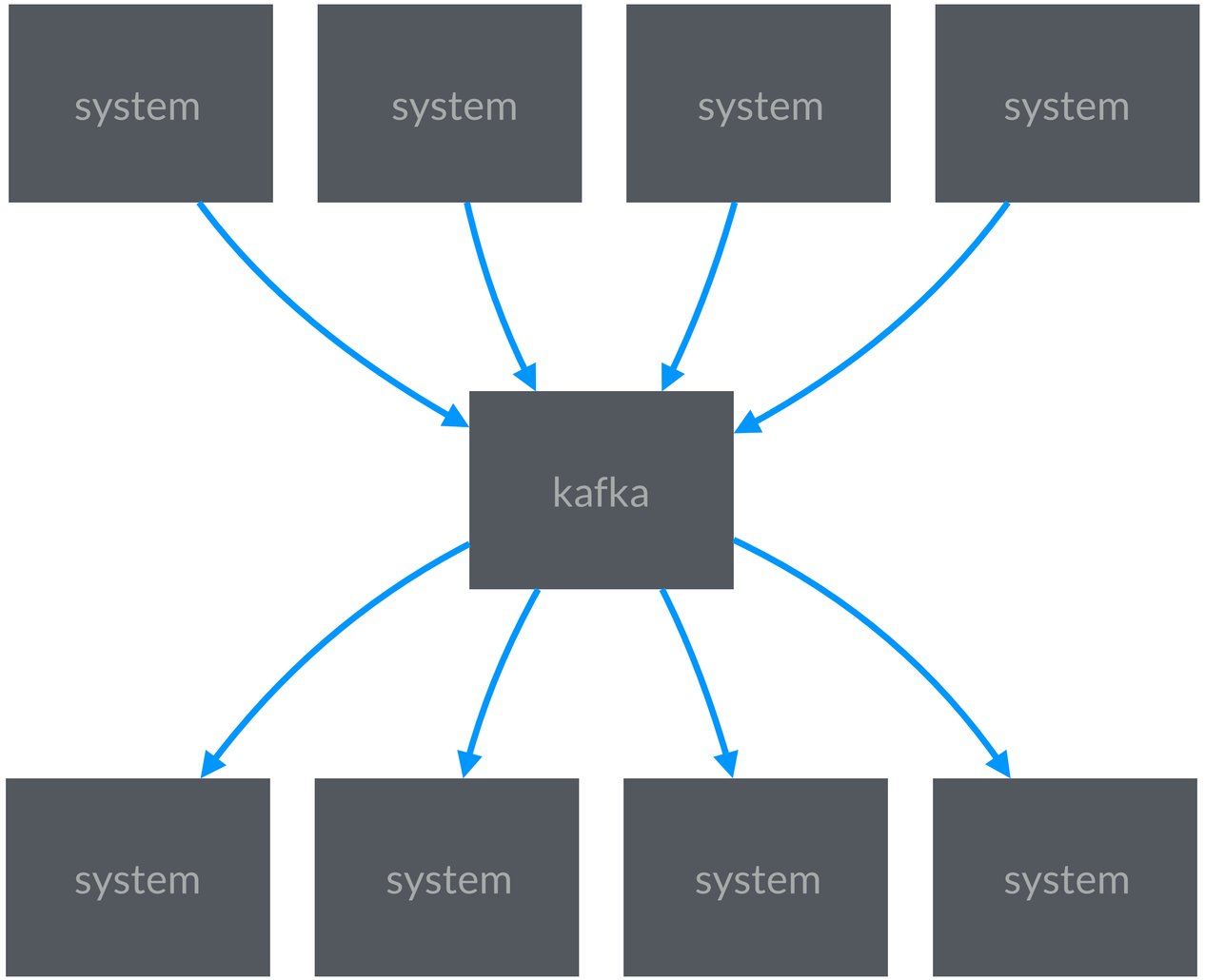


Producers



Consumers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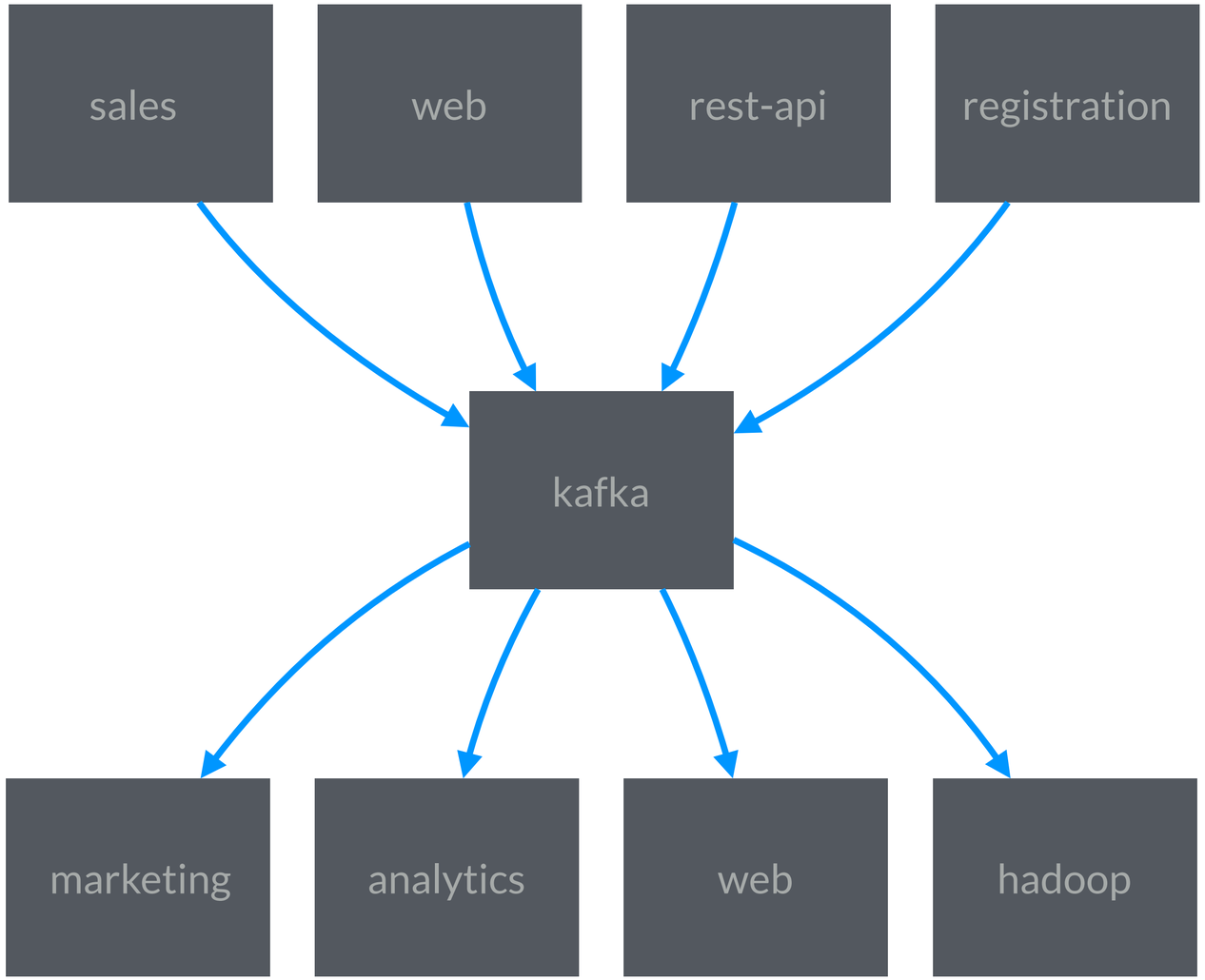
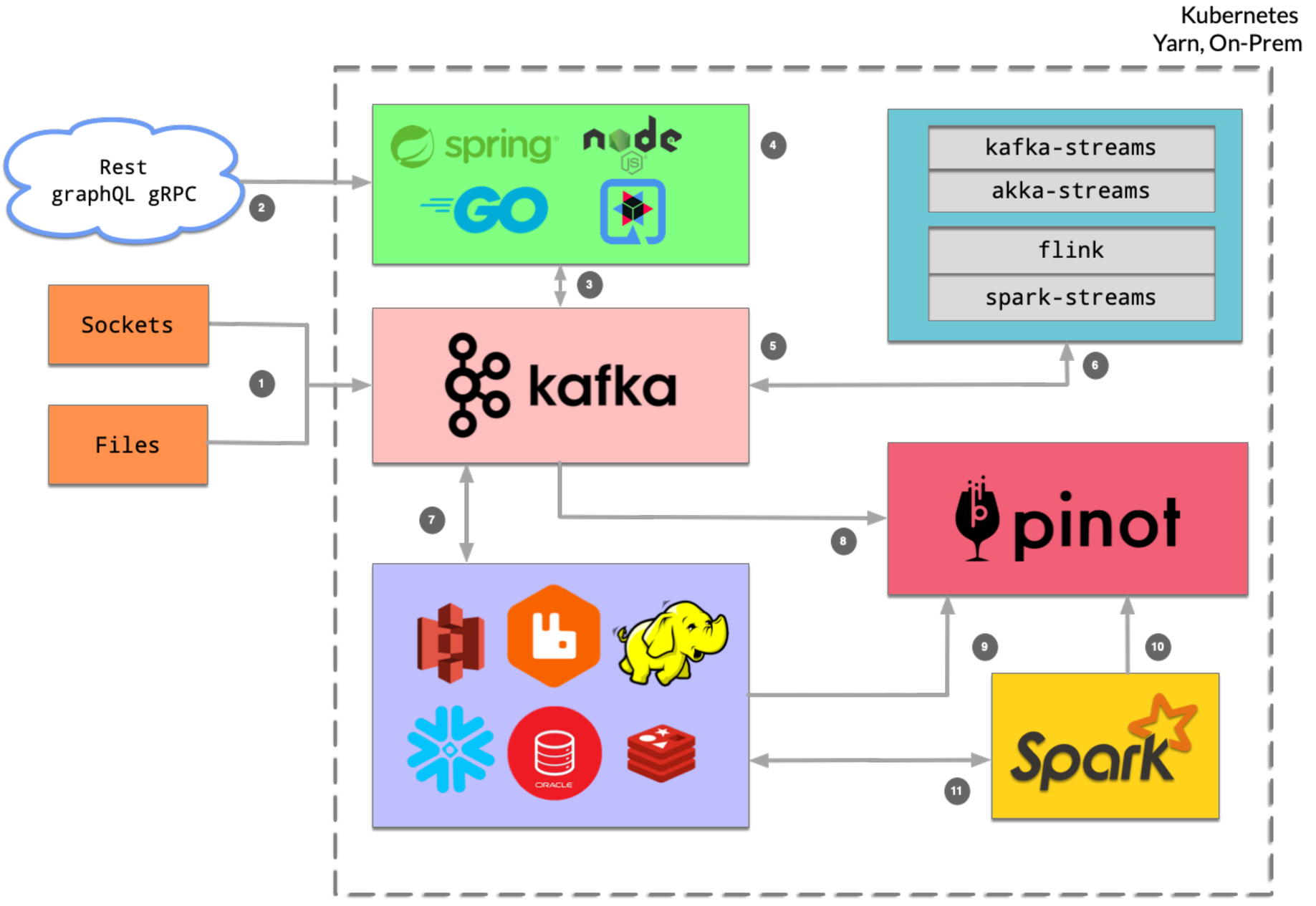


Note: A Producer can be a Consumer

About Kafka

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

A Kafkaesque Architecture


Kubernetes
Yarn, On-Prem
Rest
graphQL gRPC
Sockets
Files
spring
node
GO
kafka-streams
akka-streams
flink
spark-streams
kafka
pinot
ORACLE
Spark
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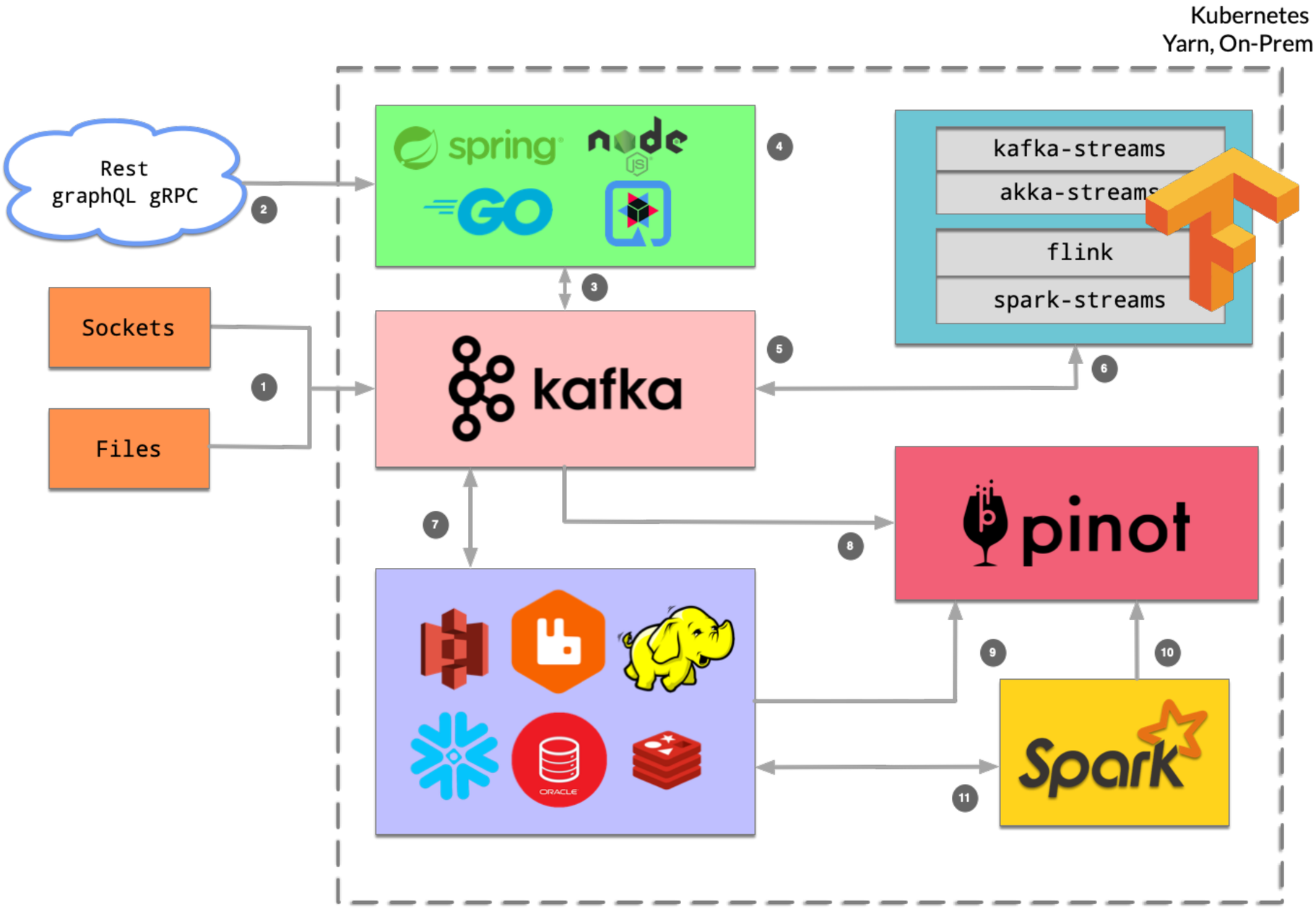
11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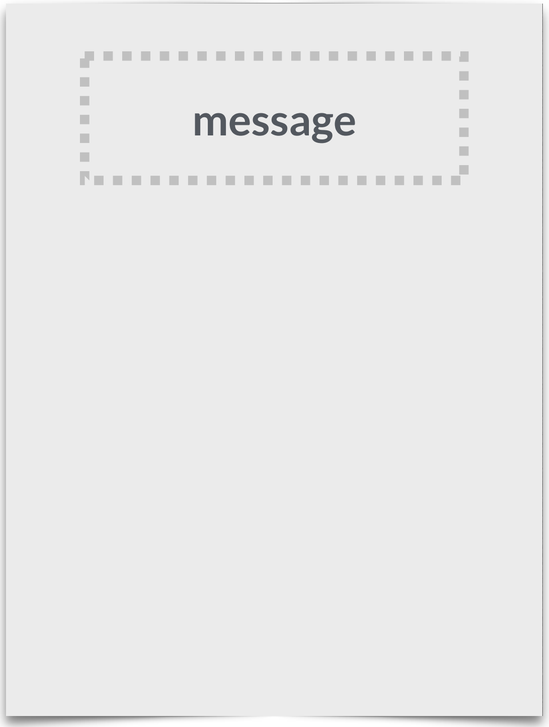
Kafka Messages

A Kafka Message

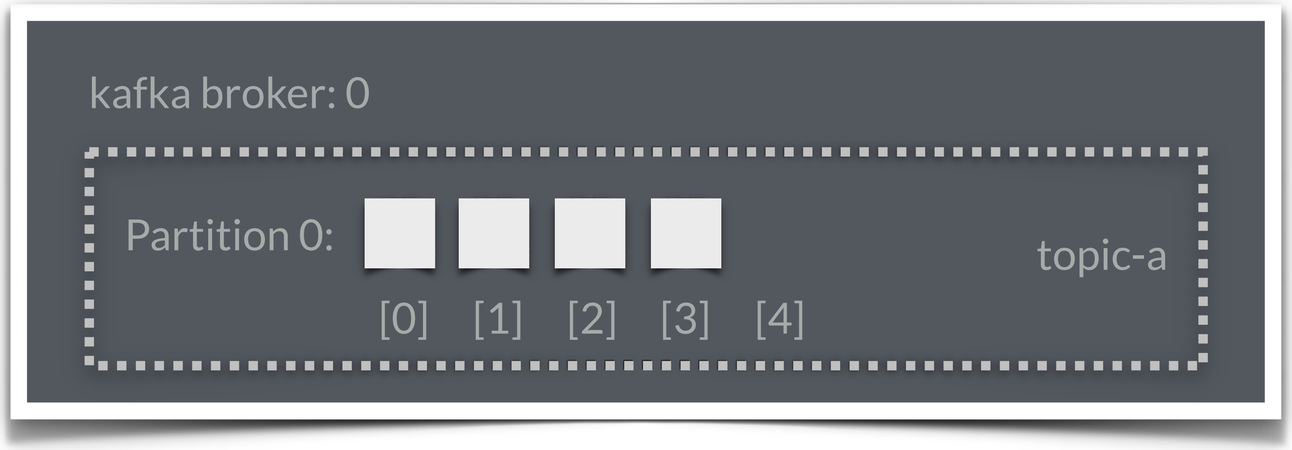
- Similar to a *row* or a *record*
- Message is an array of bytes
- No special serialization, that is done at the producer or consumer

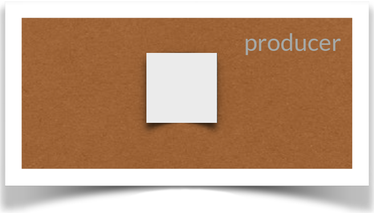


A Kafka Message Key

- 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

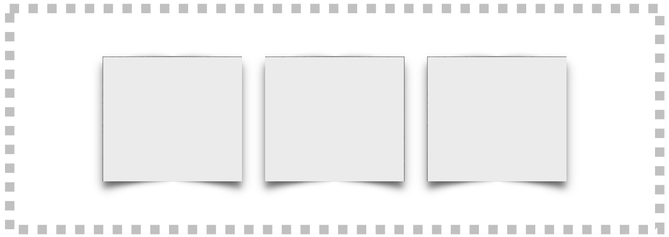

kafka broker: 0
Partition 0:
topic-a
[0]
[1]
[2]
[3]
[4]

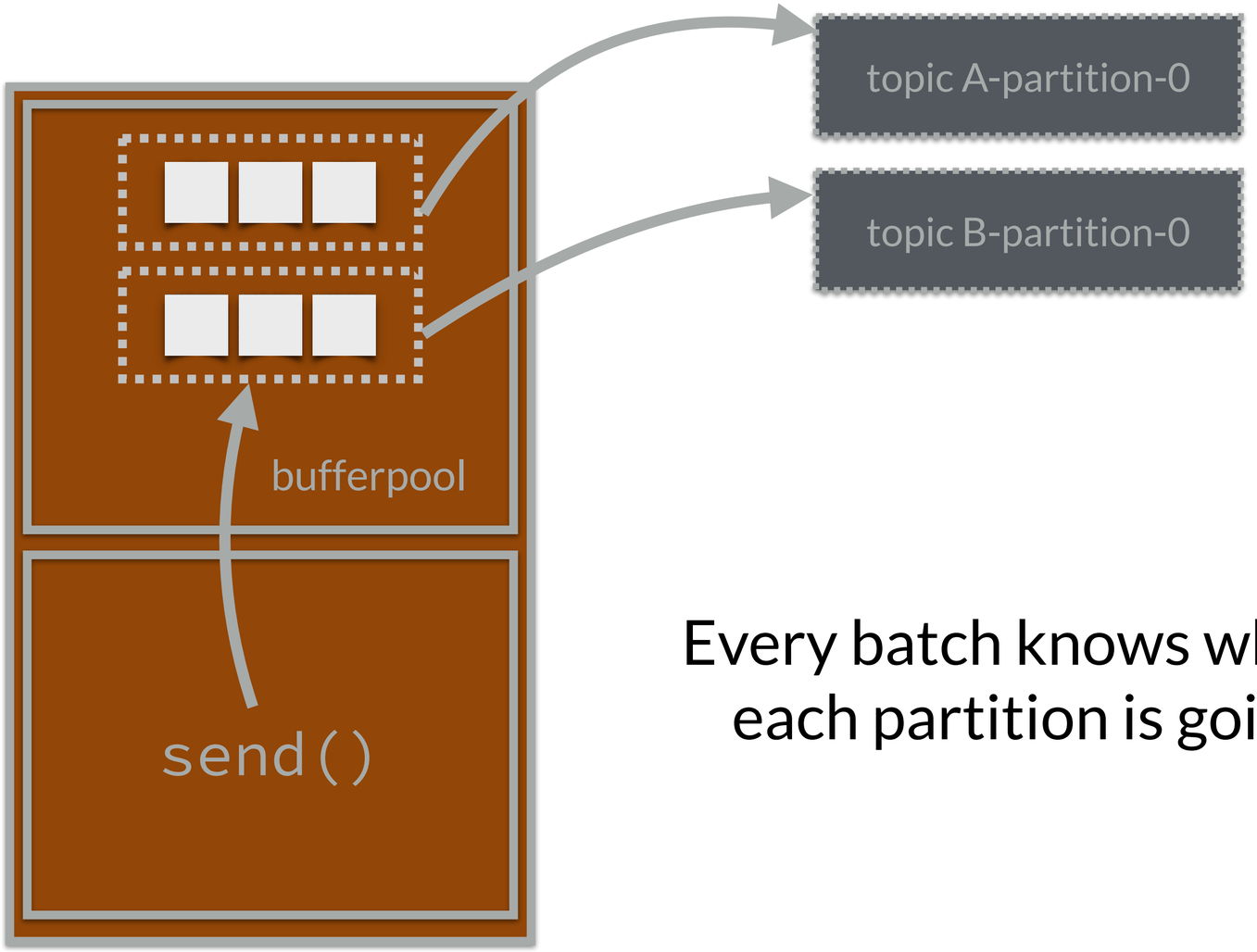

producer

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 partition is going

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

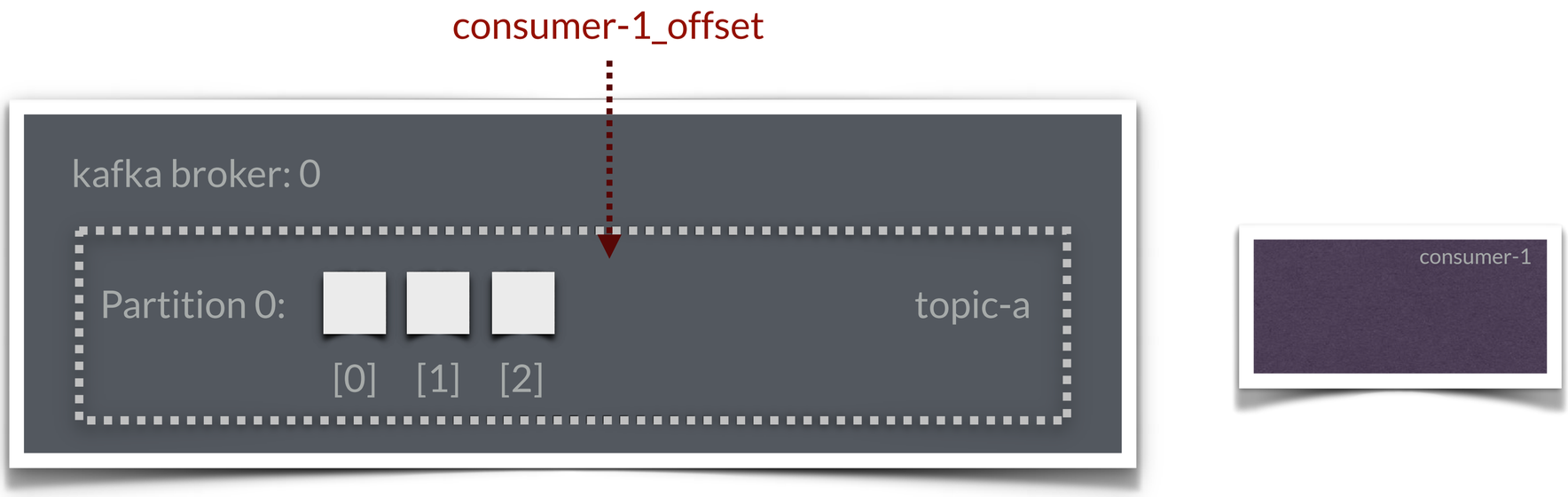
A-E

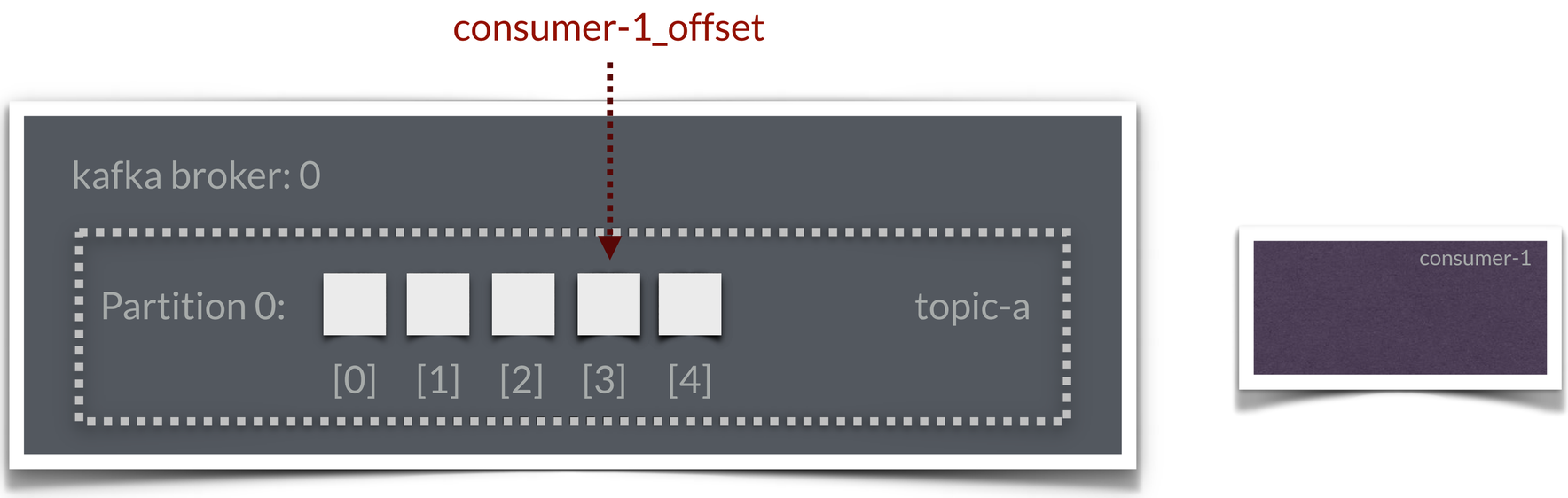
F-K

L-S

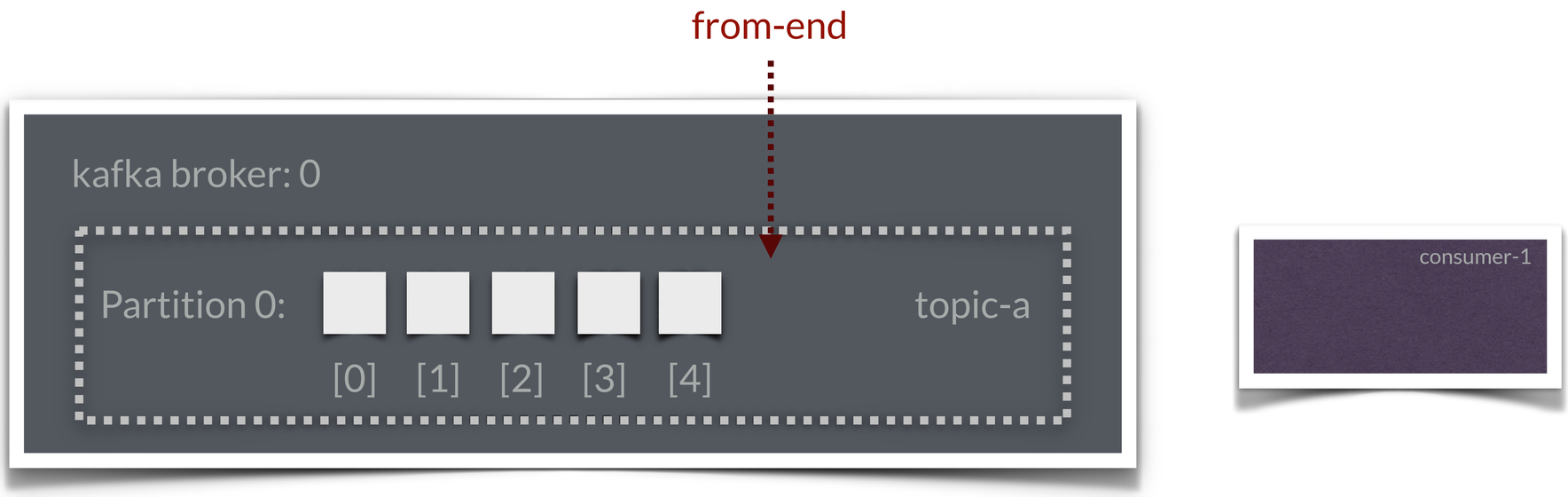
T-Z

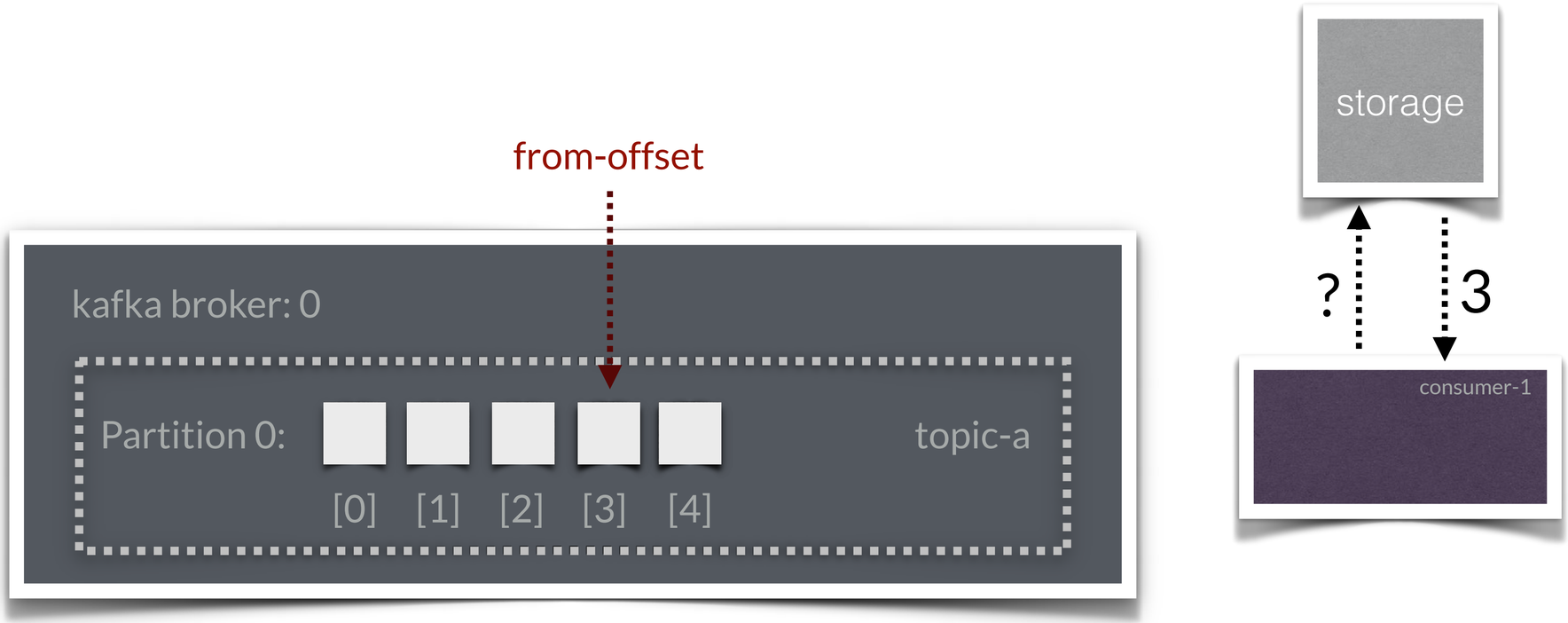
Kafka Consumers


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

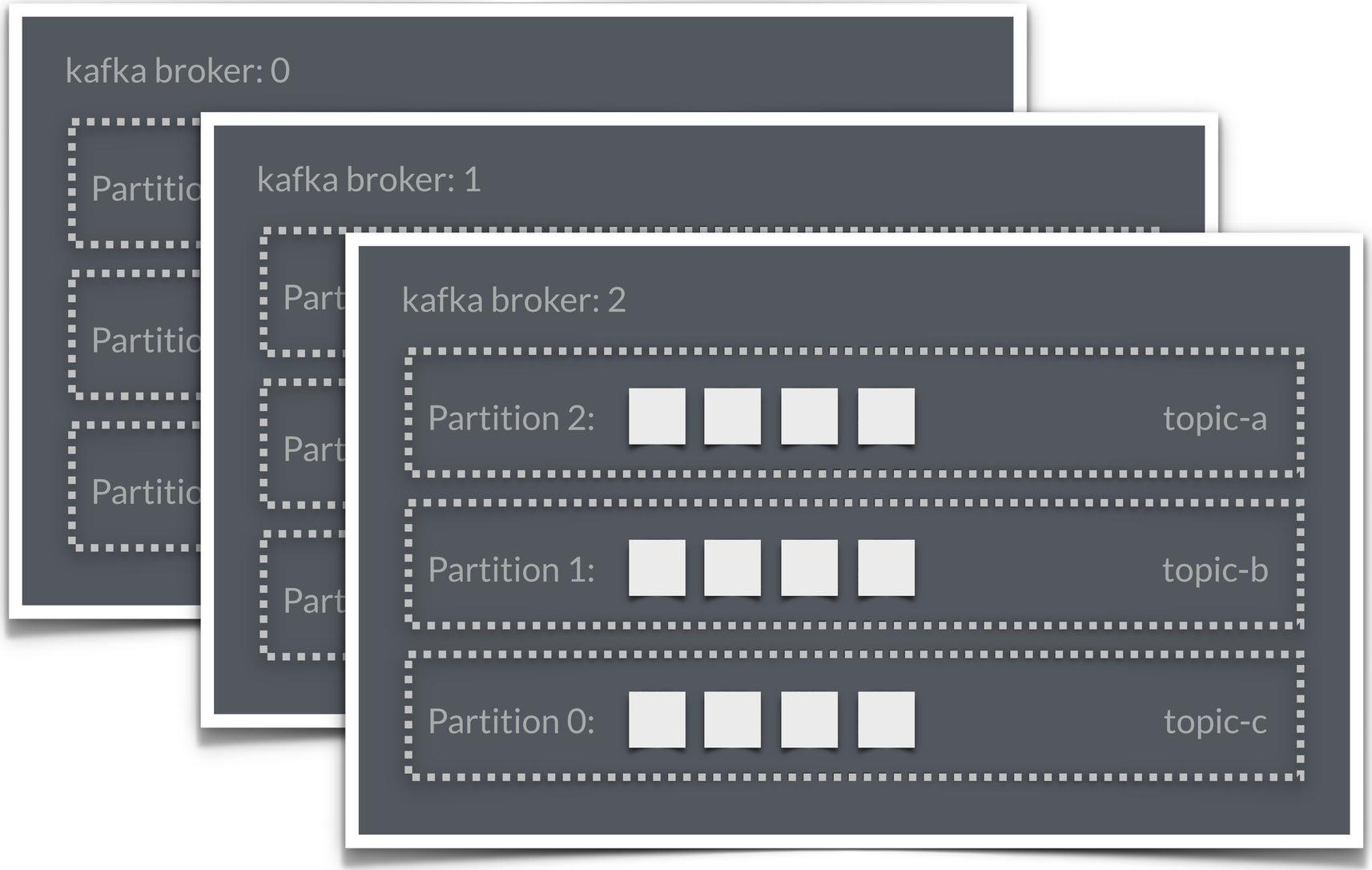

consumer-1_offset
kafka broker: 0
Partition 0:
topic-a
[0]
[1]
[2]
[3]
[4]
consumer-1


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

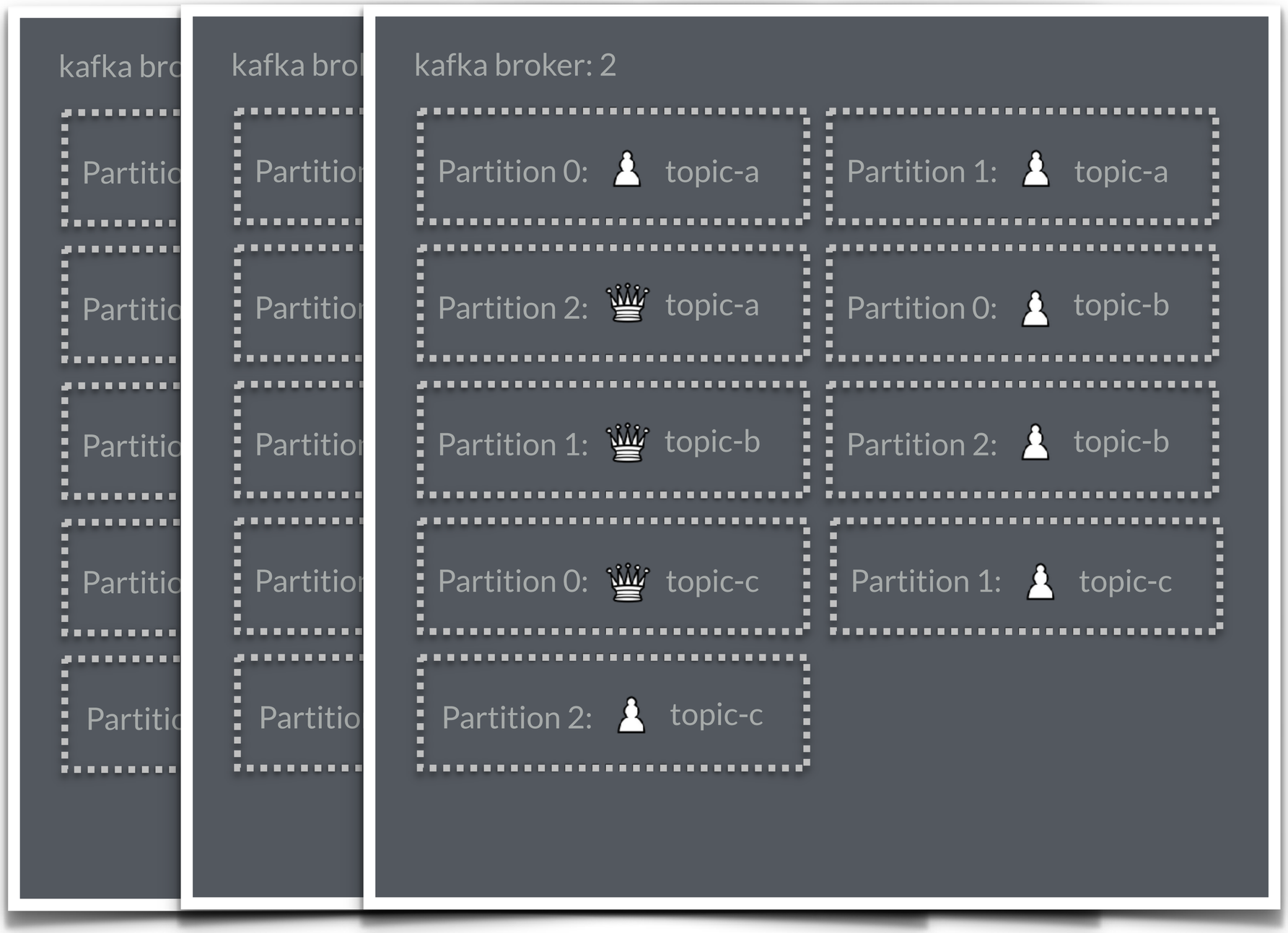

from-end
kafka broker: 0
Partition 0:
[0]
[1]
[2]
[3]
[4]
topic-a
consumer-1


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

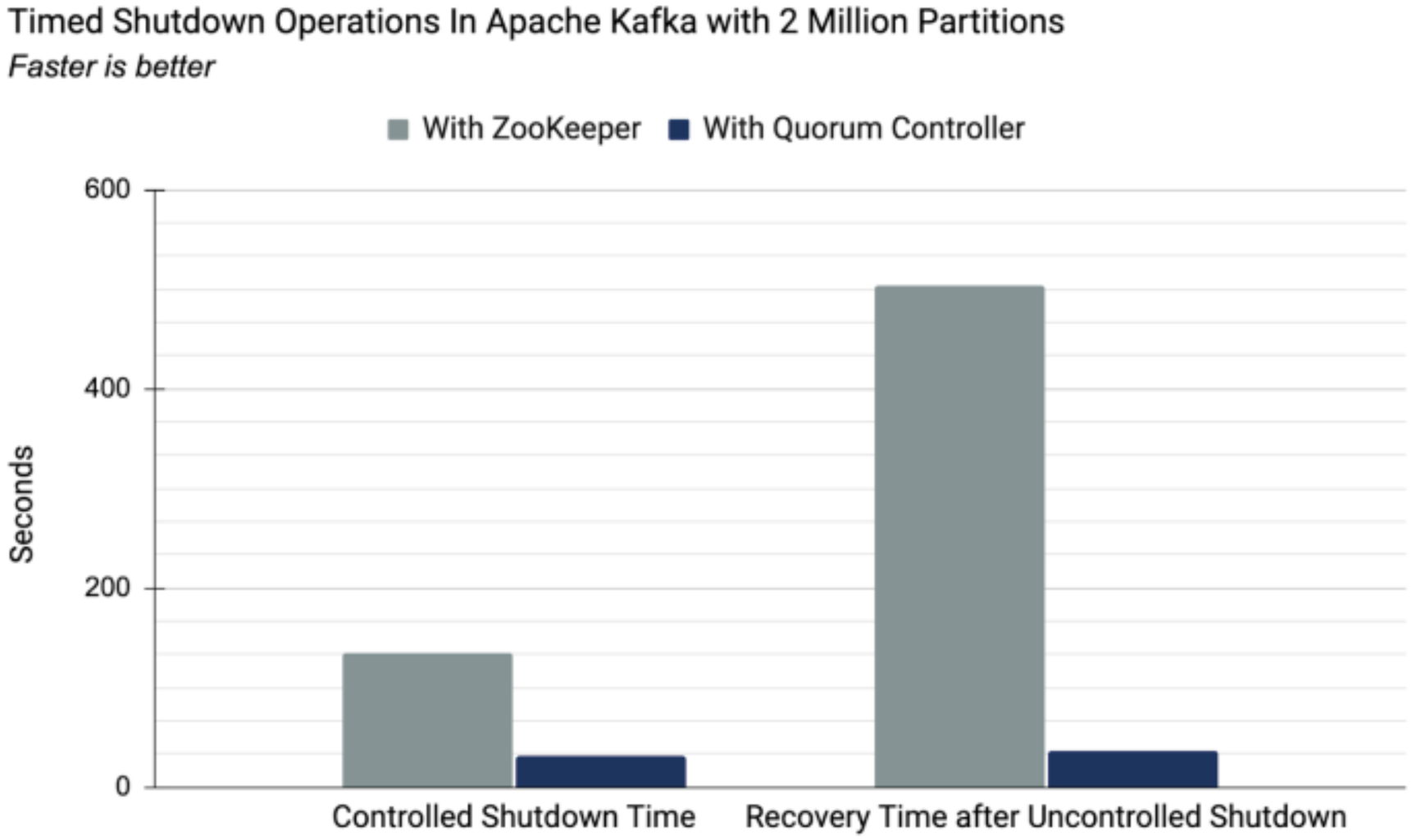
Comparison Pub/Sub

- 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

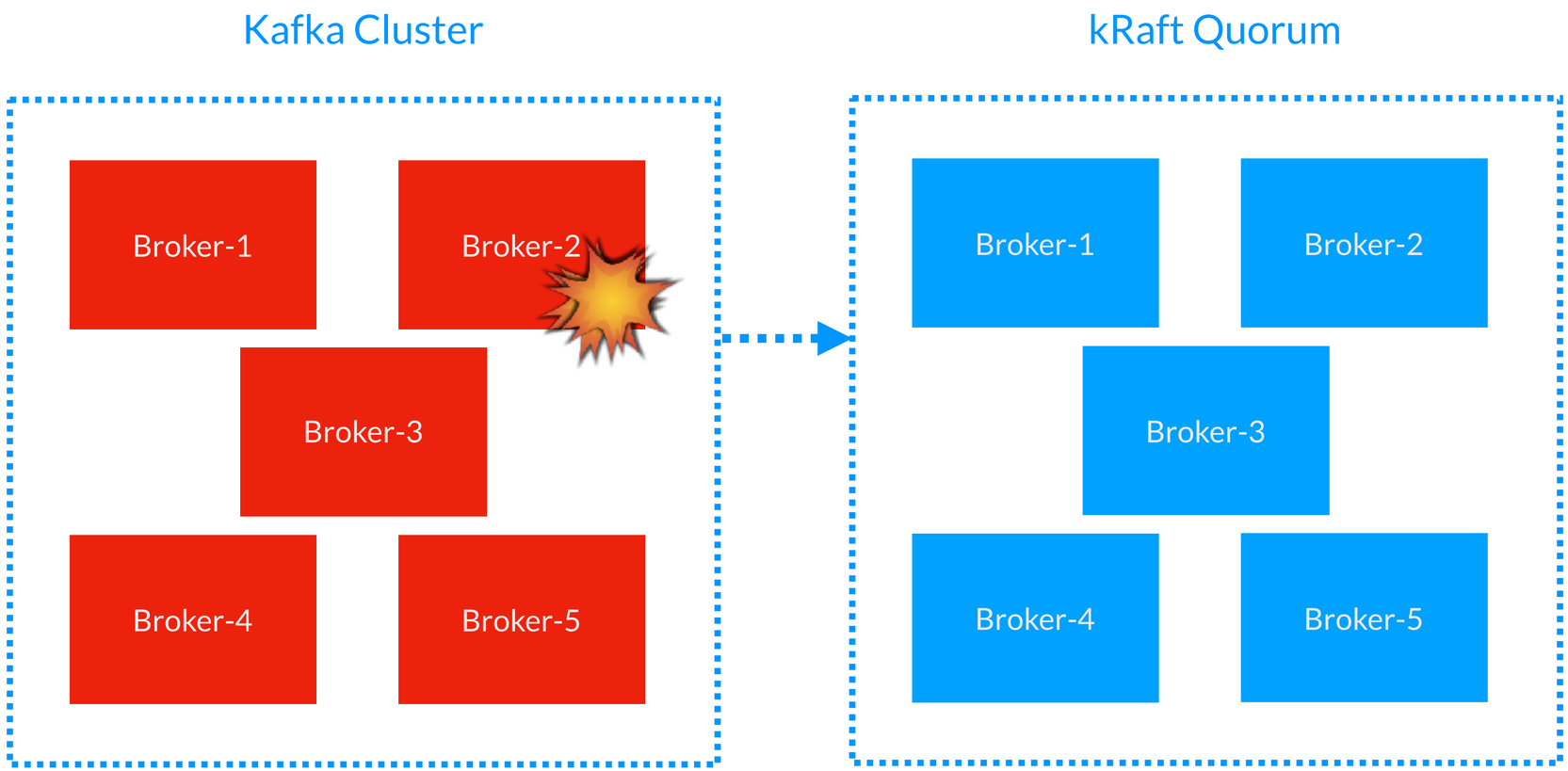
kRaft

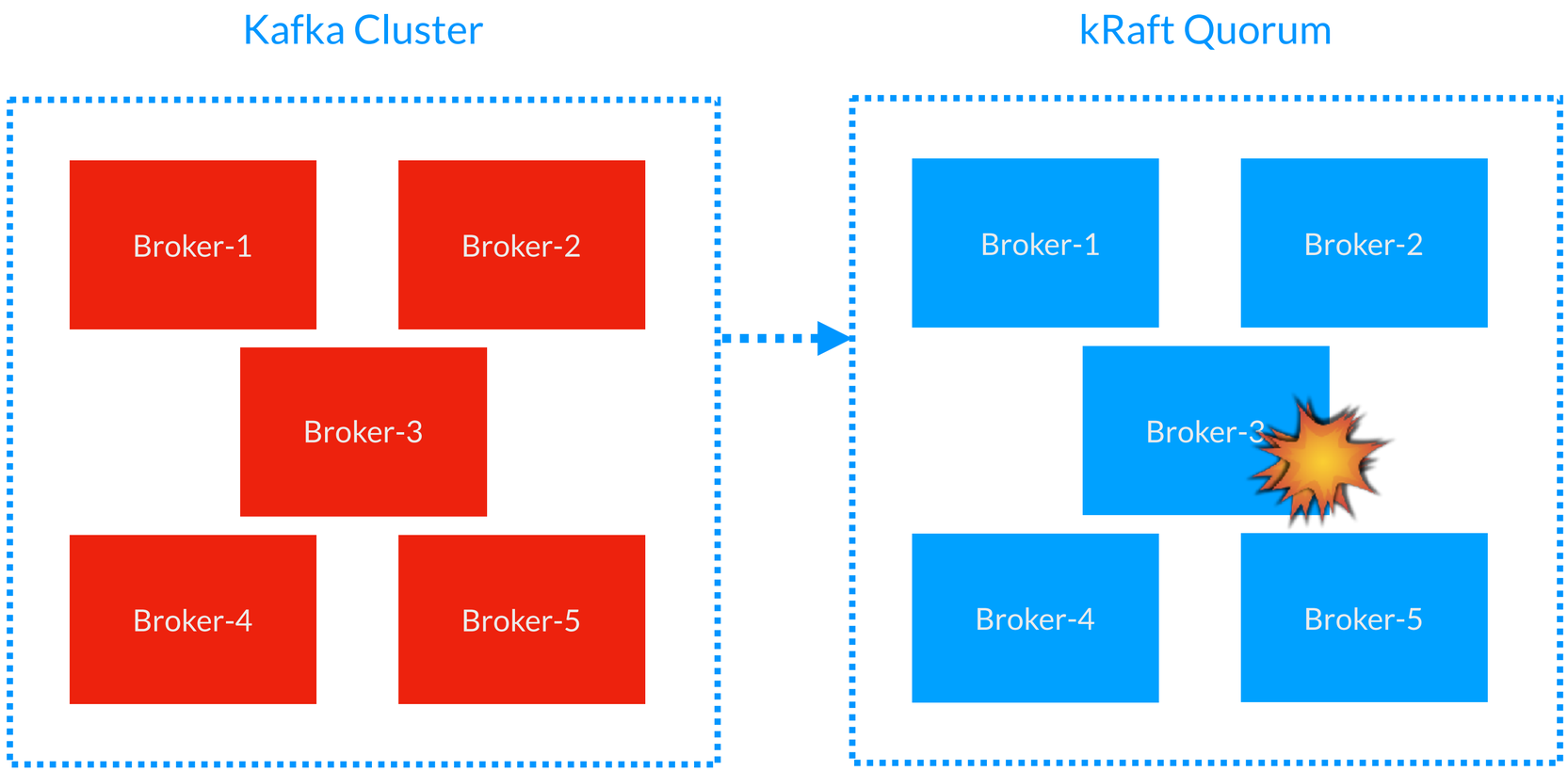
kRaft

- Consensus Protocol, introduced in KIP-500.
- Used to replace Zookeeper with its own management.
- kRaft mode makes use of a new quorum controller service in Kafka which replaces the previous controller.
- Makes use of an event-based variant of the Raft consensus protocol.
- Combined mode, used for development is a Kafka node acts as a broker and also a kRaft controller



https://developer.confluent.io/learn/kraft/


Kafka Cluster
Broker-1
Broker-2
Broker-3
Broker-4
Broker-5
kRaft Quorum
Broker-1
Broker-2
Broker-3
Broker-4
Broker-5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Broker-2
Broker-3
Broker-4
Broker-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 --bootstrap-server localhost:9092 \
  --replication-factor 2 --partitions 4 --topic orders
```

Listing Topics

List the topics using one of the zookeeper nodes

```
$ /usr/bin/kafka-topics --bootstrap-server localhost:9092 --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> \
   --bootstrap-server localhost:9092
```

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();
}));
```

Acknowledgements & Retries

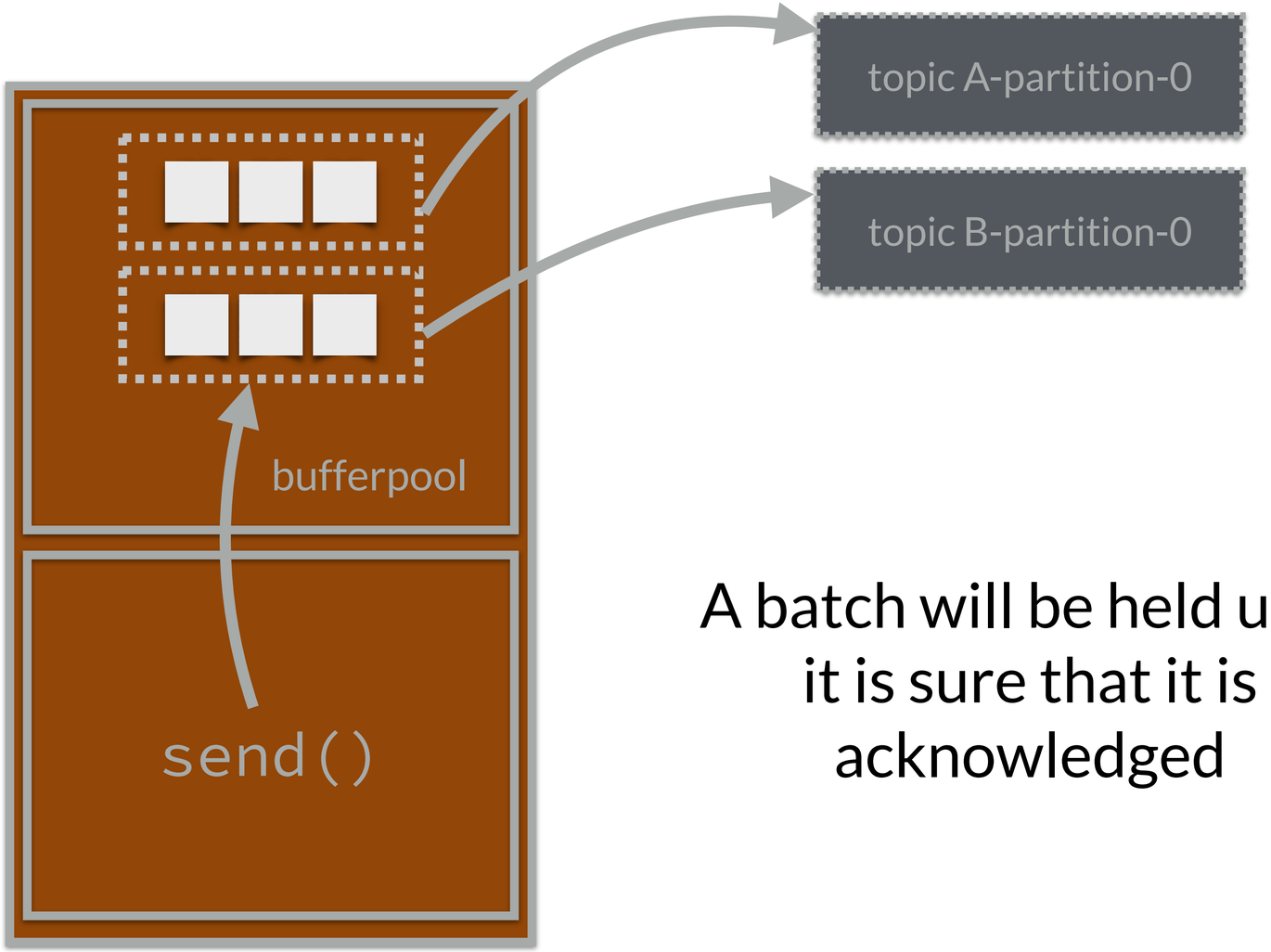
Acks

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);
```

Acks

acks	description
0	No acknowledgment, assume all is well
1	Leader will acknowledge, Not the replicas
all	All replicas must acknowledge. Higher latency, safest



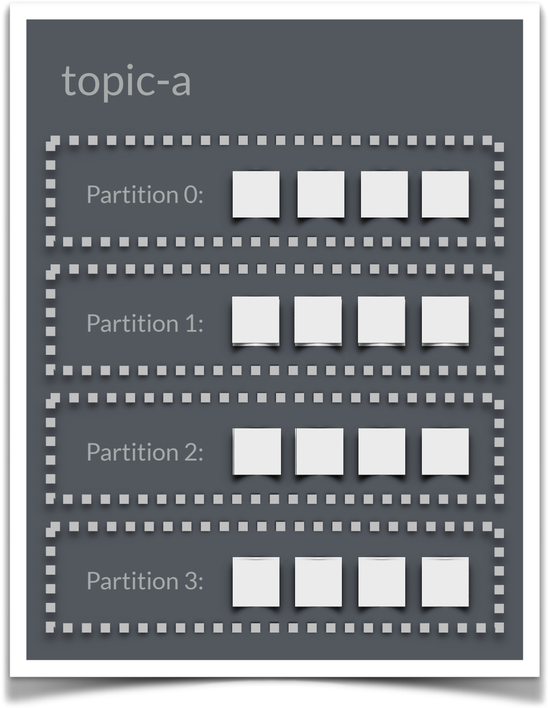
A batch will be held until it is sure that it is acknowledged

Demo: Producers

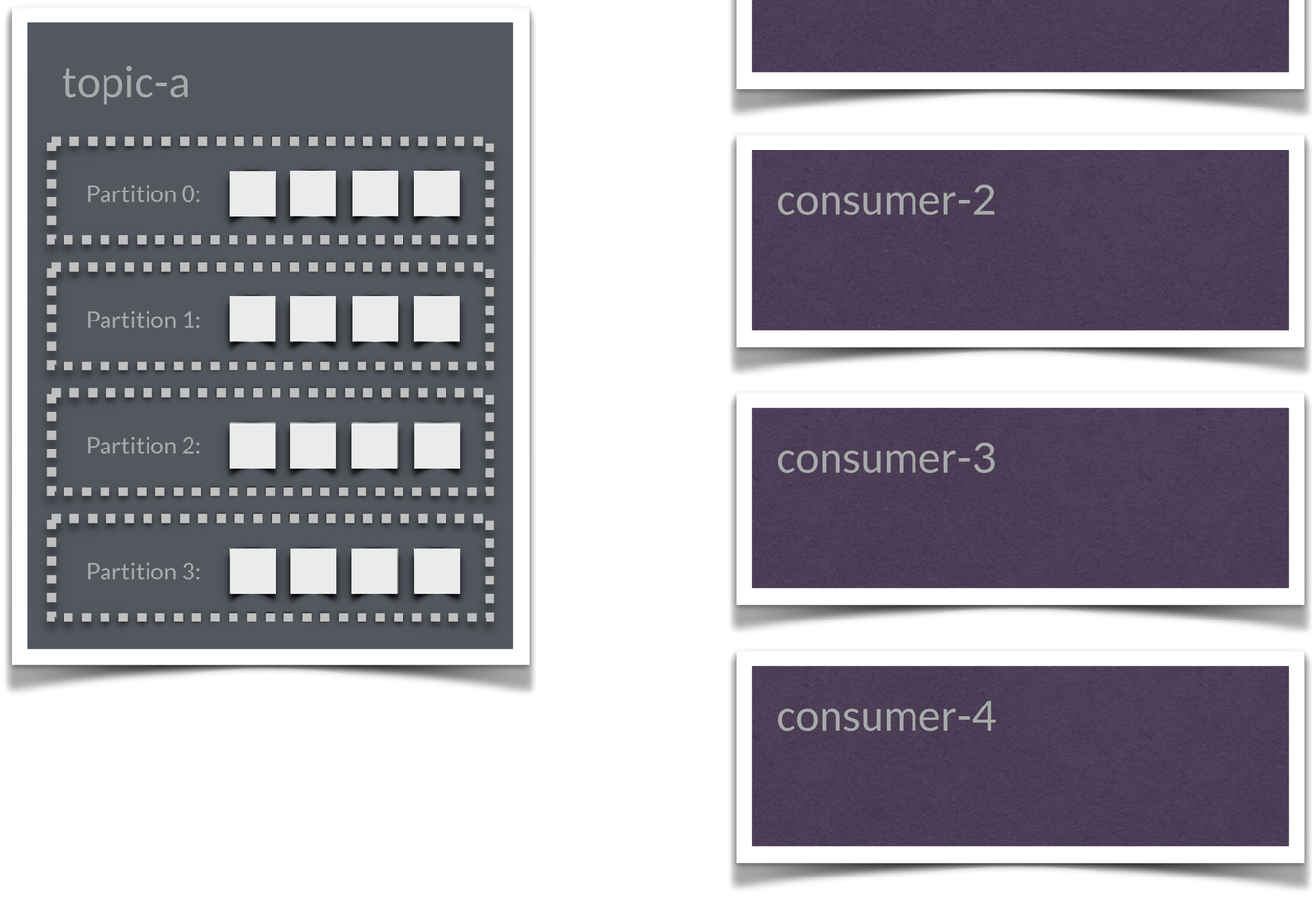
Kafka Programming
Consumers & Groups

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, Integer> 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, Integer> 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 at minimum for 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 reposts 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

Consumer Rebalance

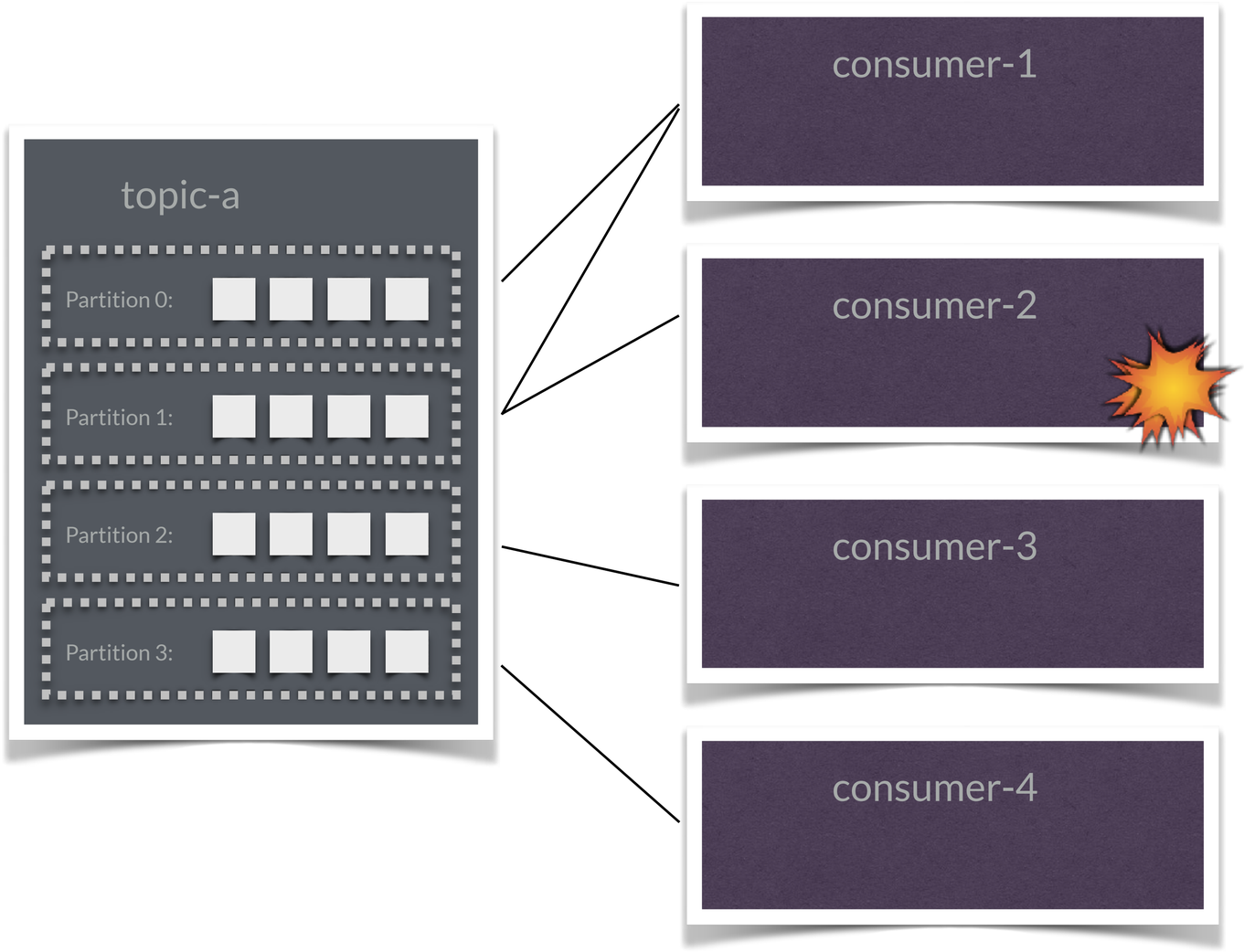
- When one partition is moved from one consumer to another, this is known as a *rebalance*.
- A way to mitigate when either consumers go down or when consumers are added.
- Although unavoidable, this will cause an unfortunate pause, and it ***will lose state***.

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 in a separate band, aka it’s own thread.

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

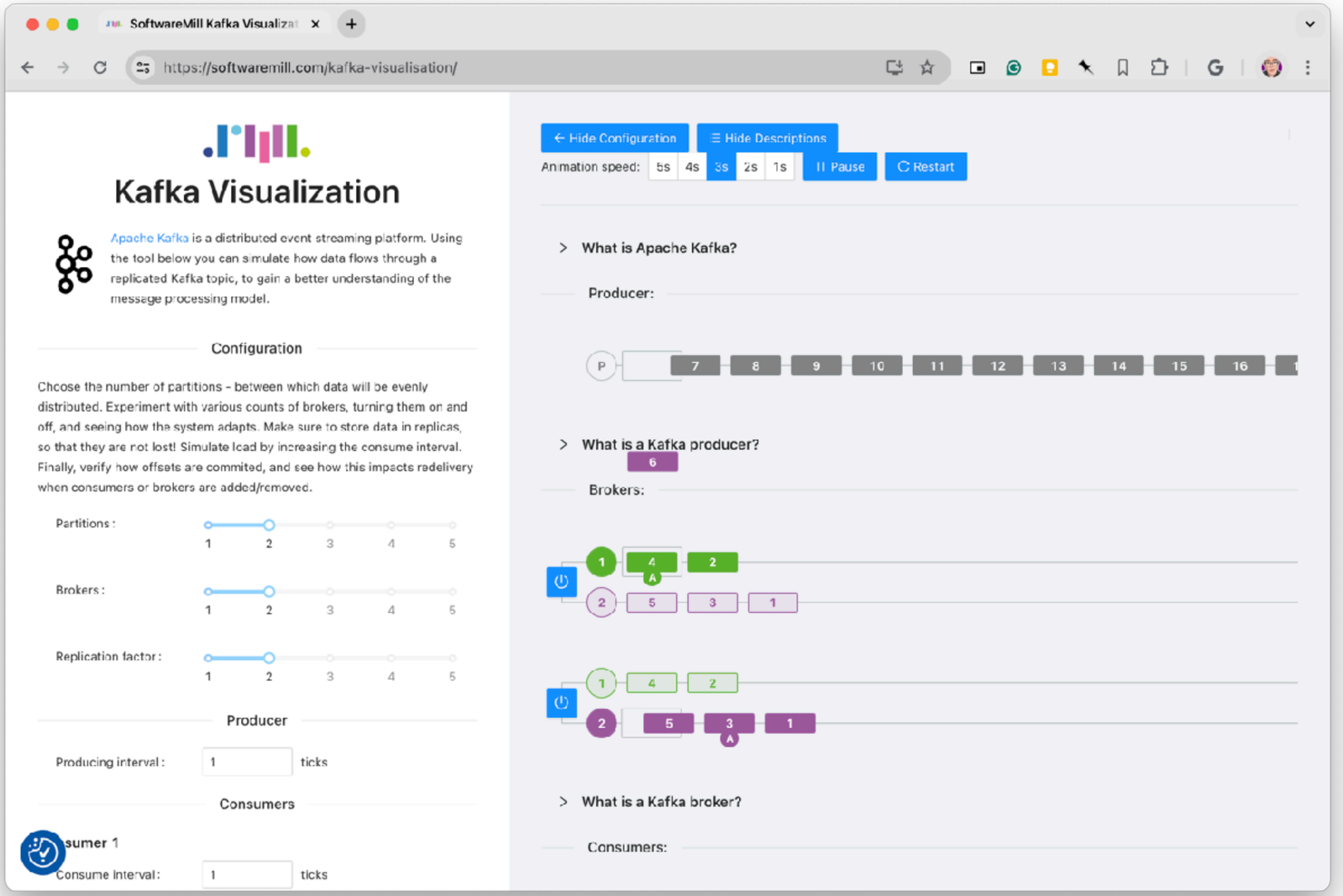
- You can implement a ConsumerRebalanceListener and be alerted when a rebalance has occurred
- The rebalance listener requires that you implement `onPartitionsRevoked`, and `onPartitionsAssigned`

```
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: Consumers

Kafka Visualization



https://softwaremill.com/kafka-visualisation/

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

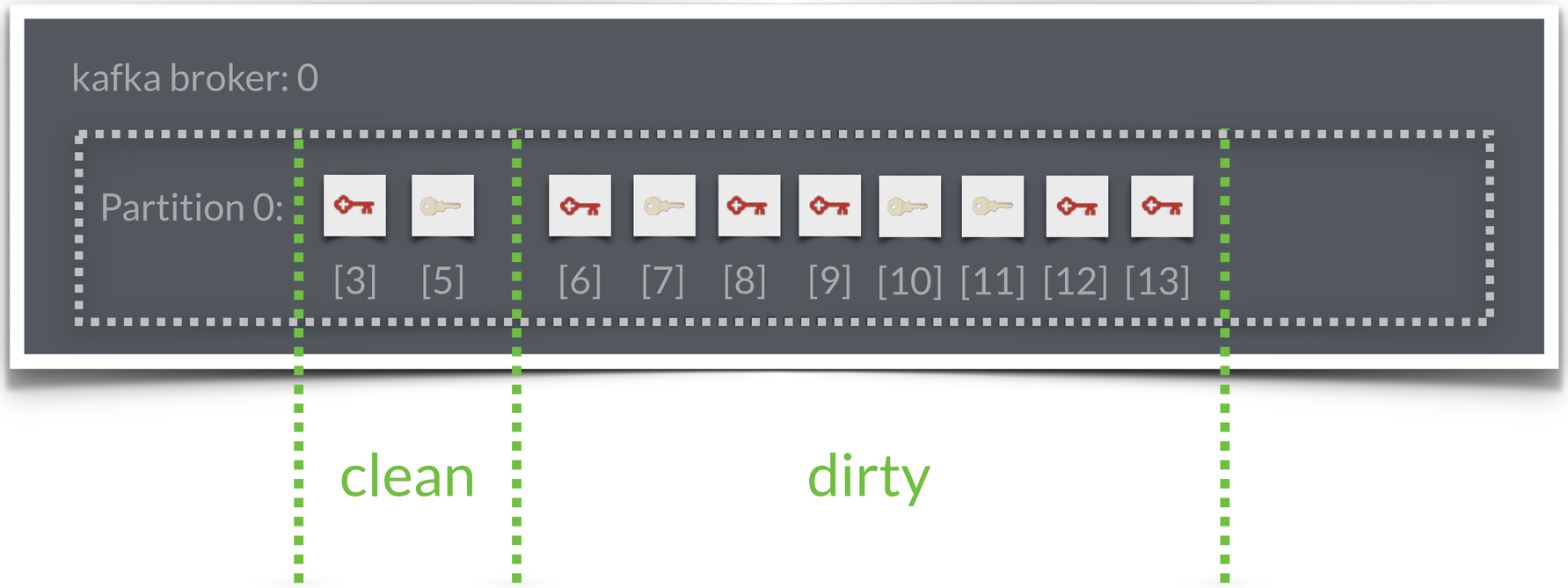
```
bin/kafka-configs --zookeeper localhost:2181 --entity-type topics --entity-name my-topic --alter --add-config retention.ms=128000
```

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

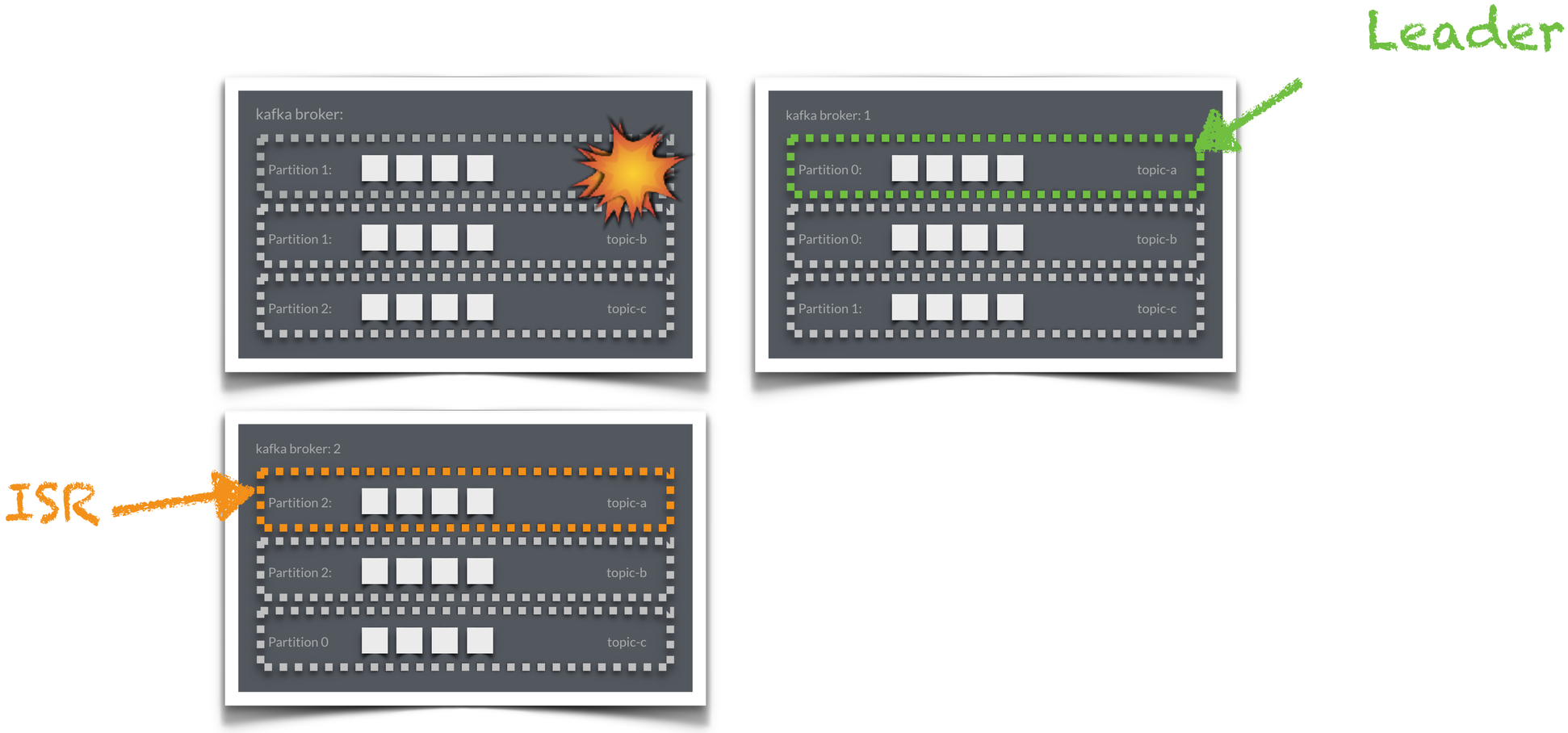
Resiliency

ISR (In sync replicas)

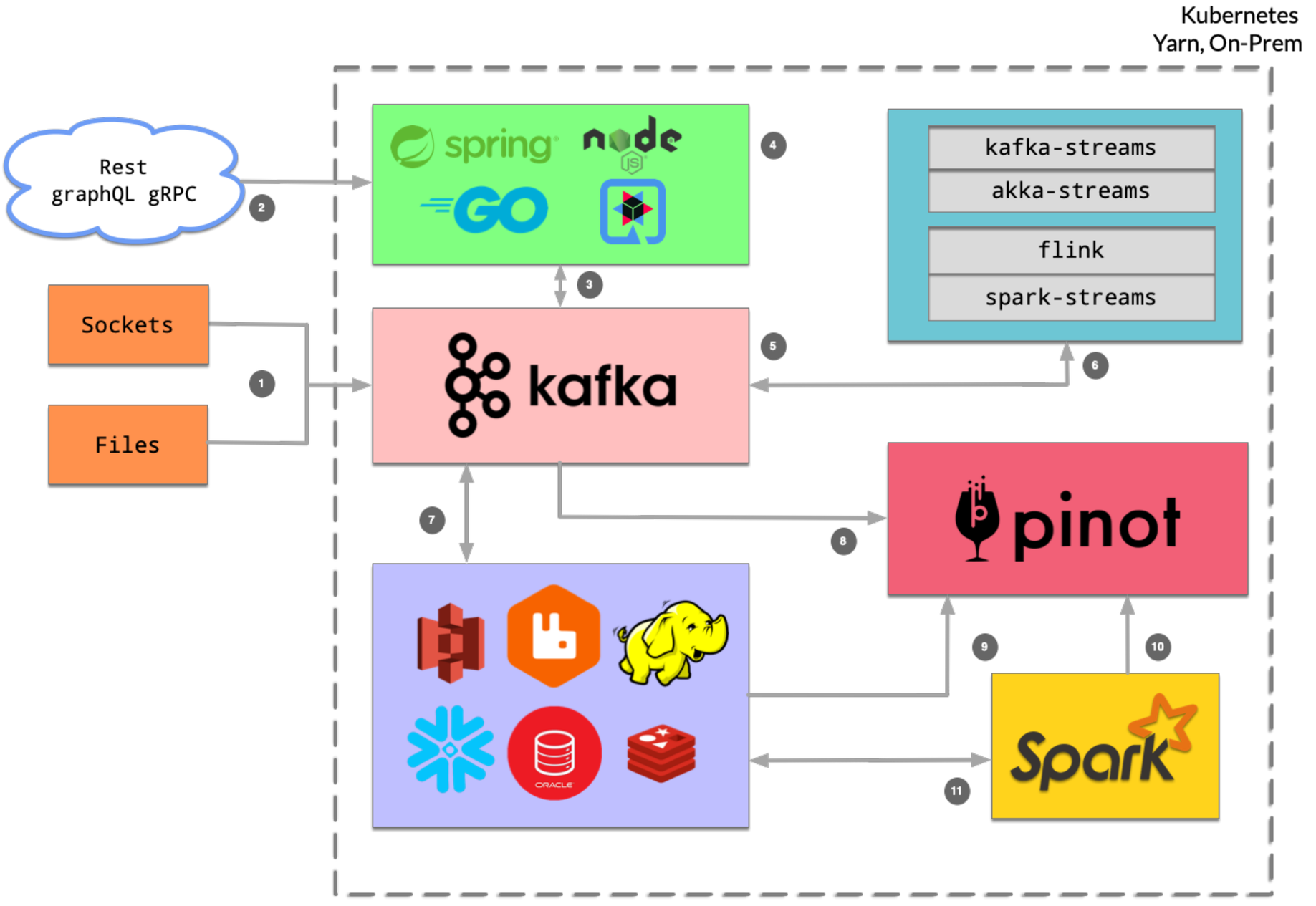
- Given a leader partition, an in sync replica is one that has been kept up to date within the last 10 seconds
- This is configurable
- During a crash, the closest ISR will retain control for failover


Leader
ISR
kafka broker:
Partition 1:
topic-a
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
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

Conclusion


Kubernetes
Yarn, On-Prem
Rest
graphQL gRPC
Sockets
Files
spring
node
GO
kafka-streams
akka-streams
flink
spark-streams
kafka
pinot
ORACLE
Spark
1
2
3
4
5
6
7
8
9
10
11

Agenda

- ⭐Understand Kafka
- ⭐Understand Producer
- ⭐Understand Consumer
- ⭐Understand Rebalancing