Apache Kafka

for Java Developers

Consuming Records

Boris Fresow, Markus Günther

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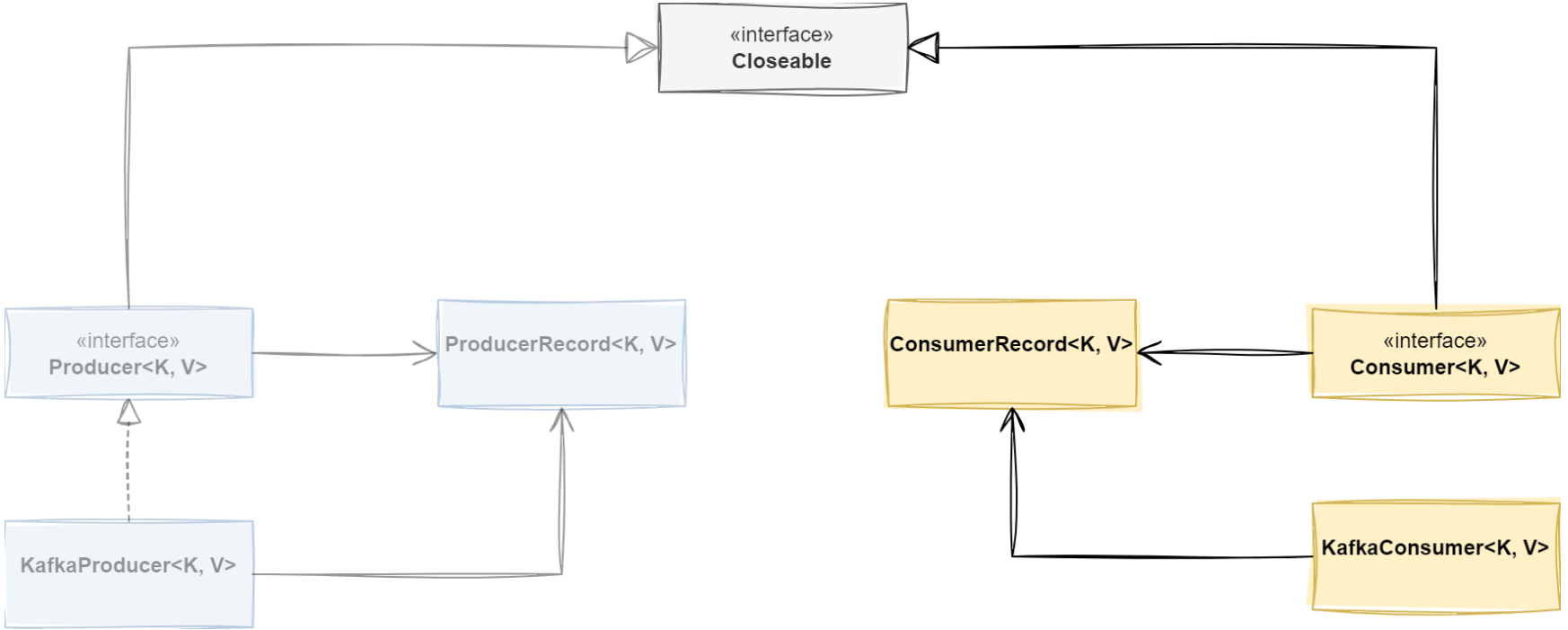
The Apache Kafka Clients SDK

A Consumer's Perspective

We are able to write a basic consumer by using just these few classes on the right.



A Consumer<K,V> offers methods for managing subscriptions and consuming records.

```
public interface Consumer<K, V> extends Closeable {
  // subscription management
  void subscribe(Collection<String> topics);
  void subscribe(Collection<String> topics, ConsumerRebalanceListener callback);
  void subscribe(Pattern pattern);
  void subscribe(Pattern pattern, ConsumerRebalanceListener callback);
  void unsubscribe();
  void assign(Collection<TopicPartition> partitions);
  Set<TopicPartition> assignment();
  Set<String> subscription();

  // record consumption
  ConsumerRecords<K, V> poll(long timeout);
  ConsumerRecords<K, V> poll(Duration timeout);

  // offset committing (not showing overloaded methods)
  void commitSync();
  void commitAsync();

  // manage consumption order (not showing overloaded methods)
  void seek(TopicPartition partition, long offset);
  void seekToBeginning(Collection<TopicPartition> partitions);
  void seekToEnd(Collection<TopicPartition> partitions);
  // ... and a lot more ...
}
```

With this knowledge in mind, we are able to write a first, yet simple, consumer!

```
public class BasicConsumer {
  public static void main(String[] args) {
    var topic = "getting-started";
    Map<String, Object> config = Map.of(
      ConsumerConfig.BOOTSTRAP_SERVERS_CONFIG, "localhost:9092",
      ConsumerConfig.KEY_DESERIALIZER_CONFIG, StringDeserializer.class.getName(),
      ConsumerConfig.VALUE_DESERIALIZER_CONFIG, StringDeserializer.class.getName(),
      ConsumerConfig.GROUP_ID_CONFIG, "basic-consumer-group",
      ConsumerConfig.AUTO_OFFSET_RESET_CONFIG, "earliest",
      ConsumerConfig.ENABLE_AUTO_COMMIT_CONFIG, false);
    try (var consumer = new KafkaConsumer<String, String>(config)) {
      consumer.subscribe(Set.of(topic));
      while (true) {
        var records = consumer.poll(Duration.ofMillis(100));
        for (var record : records) {
          System.out.println("Received record with value %s%n", record.value());
        }
        consumer.commitAsync();
      }
    }
  }
}
```

Subscribing and Consuming

A `KafkaConsumer<K,V>` offers two ways for subscribing to the topics.

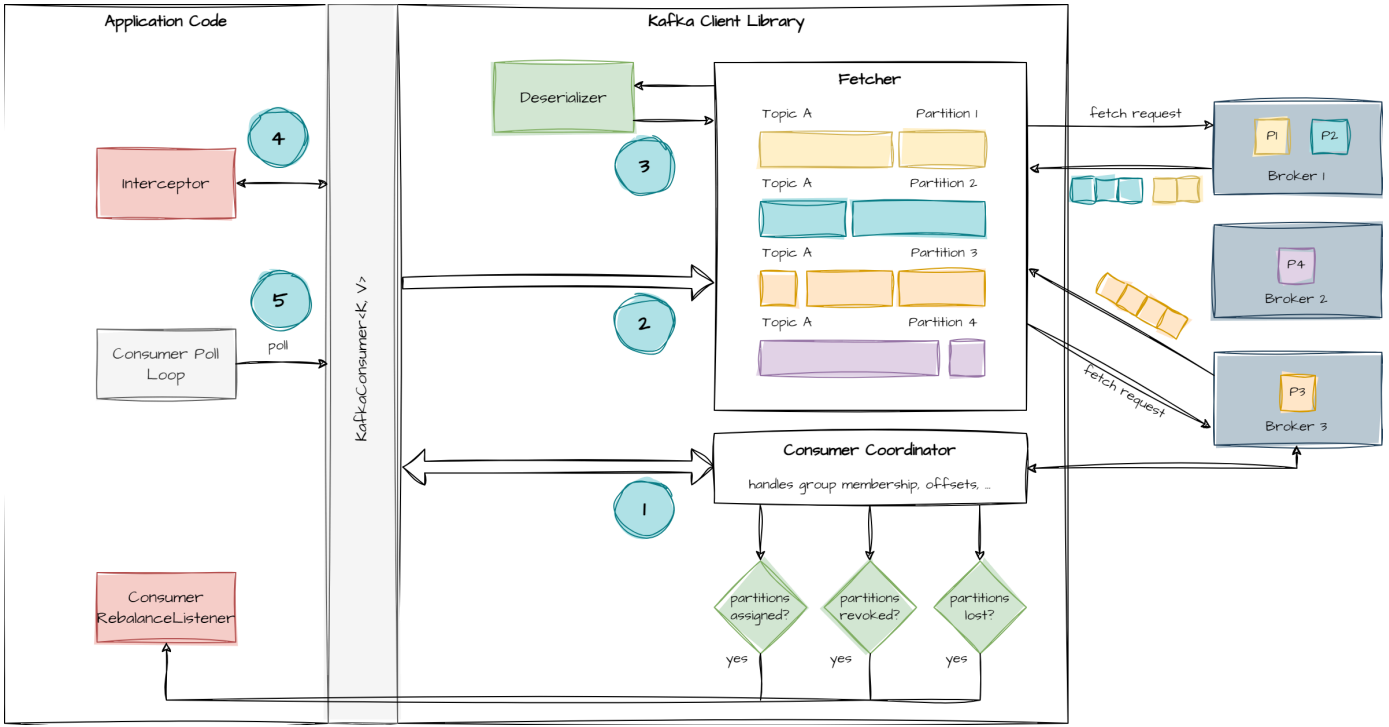
via `subscribe`

- subscribe to list of topics (regexp possible)
- group membership with failure detection
  - client-side
  - server-side
- dynamic partition assignment
- automatic or manual offsets management
- single consumer per partition

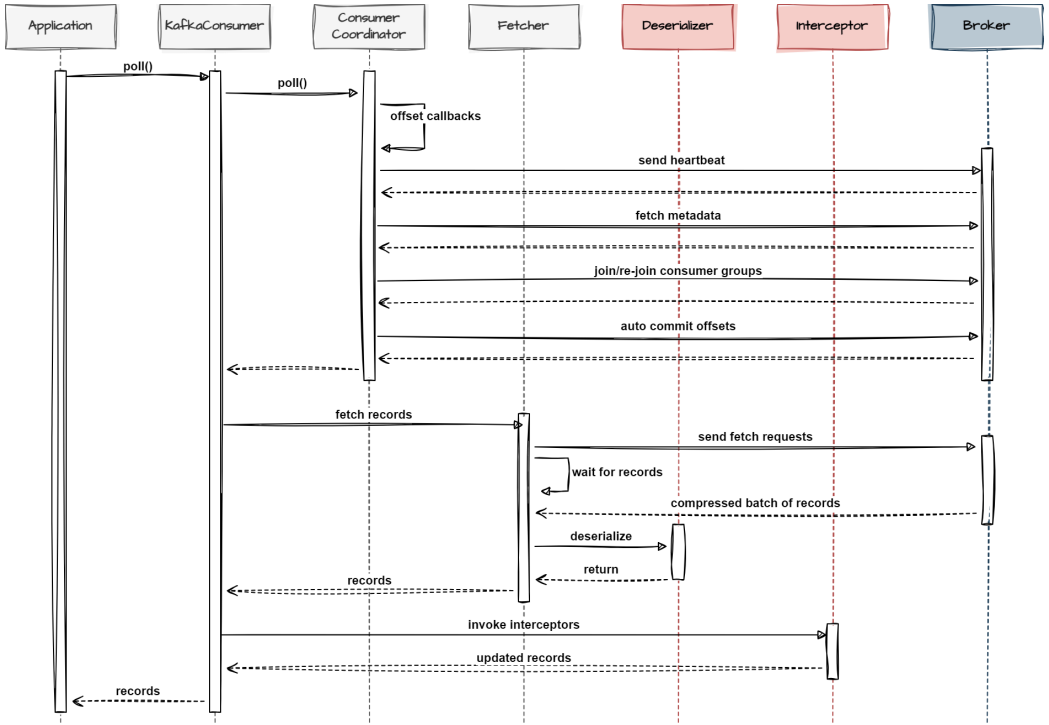
via `assign`

- finer control with topic-partition subscription
- automatic or manual offsets management
- supports multiple consumers per partition

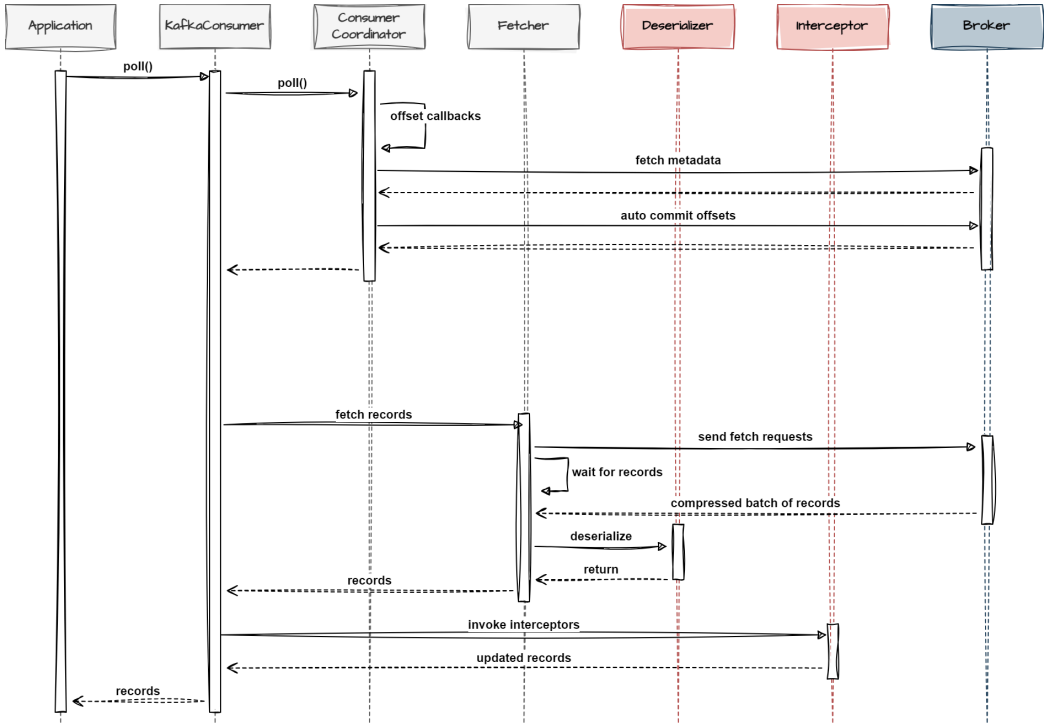
But what happens after subscribing and entering the poll-loop?



With `subscribe`, the consumer won't read records until it joins the consumer group.



With `assign`, the consumer won't invoke group membership functionality.



Offset Management

Partition offsets are part of the local consumer state, unless shared with the Kafka cluster.

- Use consumer offsets as **resumption point**
- Upon re-assigning a consumer, we need to know where to continue
- Skip over any records that have already been processed

Persisting the consumer state to the Kafka cluster is called committing an offset.

- Commit `offset of last record + 1`
  1. New consumer joins the consumer group and takes over.
  2. Starts off at the offset of the **last record** that has not been read
  3. This is `offset of last record + 1`

- Kafka employs a **recursive strategy** when managing offsets
  - Utilizes itself to persist and track offsets
  - cf. topic `__consumer_offsets`

Controlling when an offset is committed provides flexibility wrt. delivery guarantees.

- Move between *at-most-once* to *at-least-once* simply
  - by committing offsets **before** record processing (at-most-once)
  - by committing offsets **after** record processing completes (at-least-once)

> *A committed offset implies that the record **one below that offset** and **all prior records** have been processed by the consumer.*

- Last offset of a batch of records acknowledges the whole batch
- Built your error handling strategy around that fact

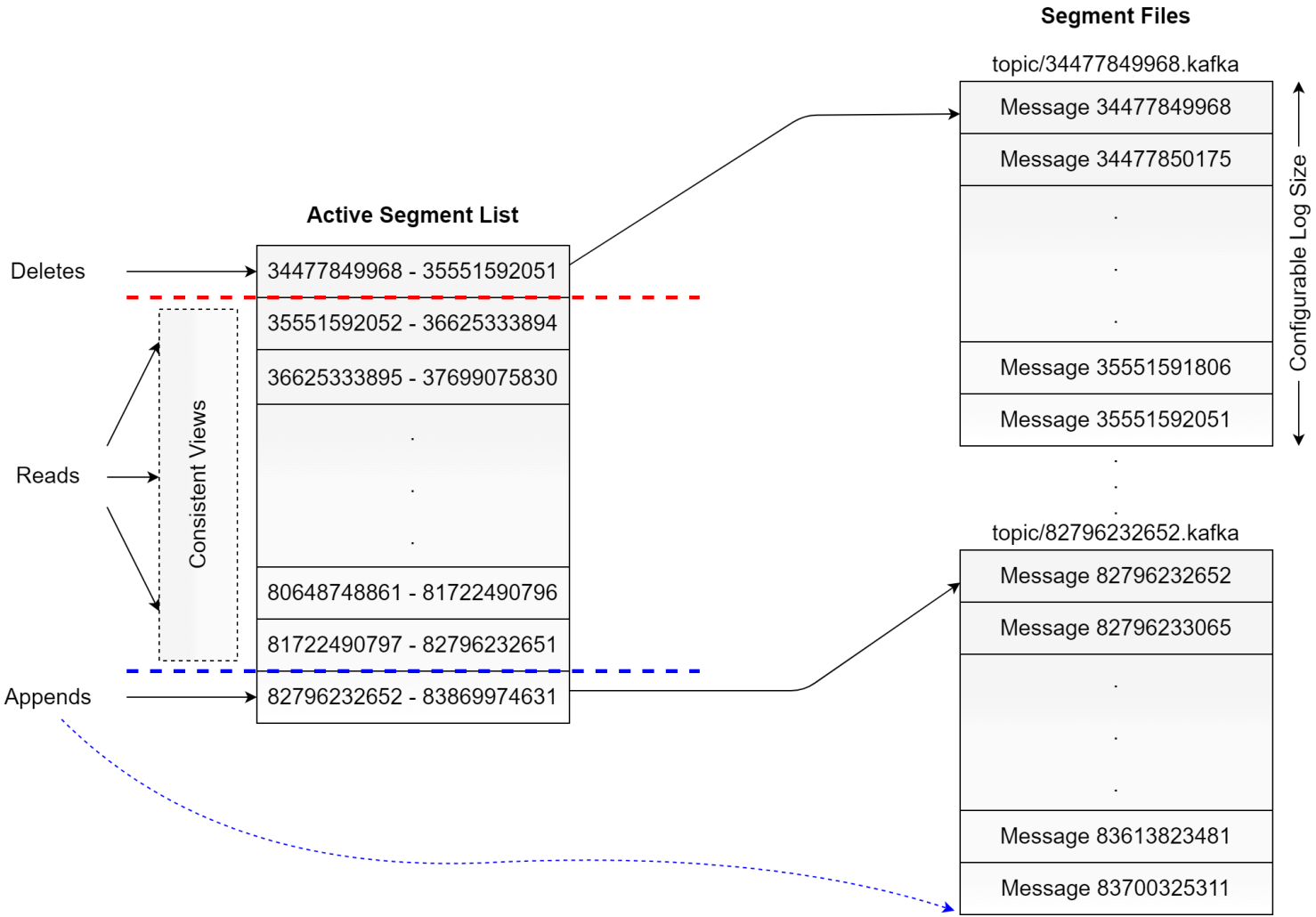
By default, a Kafka consumer will automatically commit offsets every five seconds.

- Adjusting frequency is done by setting `auto.commit.interval.ms`
- Setting `enable.auto.commit` to `false` disables this behavior
- API offers **synchronous** and **asynchronous** commit operations

```
public interface Consumer<K,V> {
  // only showing commit* methods
  // synchronous commits
  void commitSync();
  void commitSync(Duration timeout);
  void commitSync(Map<TopicPartition, OffsetAndMetadata> offsets);
  void commitSync(Map<TopicPartition, OffsetAndMetadata> offsets, Duration timeout);
  // asynchronous commits
  void commitAsync();
  void commitAsync(OffsetCommitCallback callback);
  void commitAsync(Map<TopicPartition, OffsetAndMetadata> offsets, OffsetCommitCallback callback);
}
```

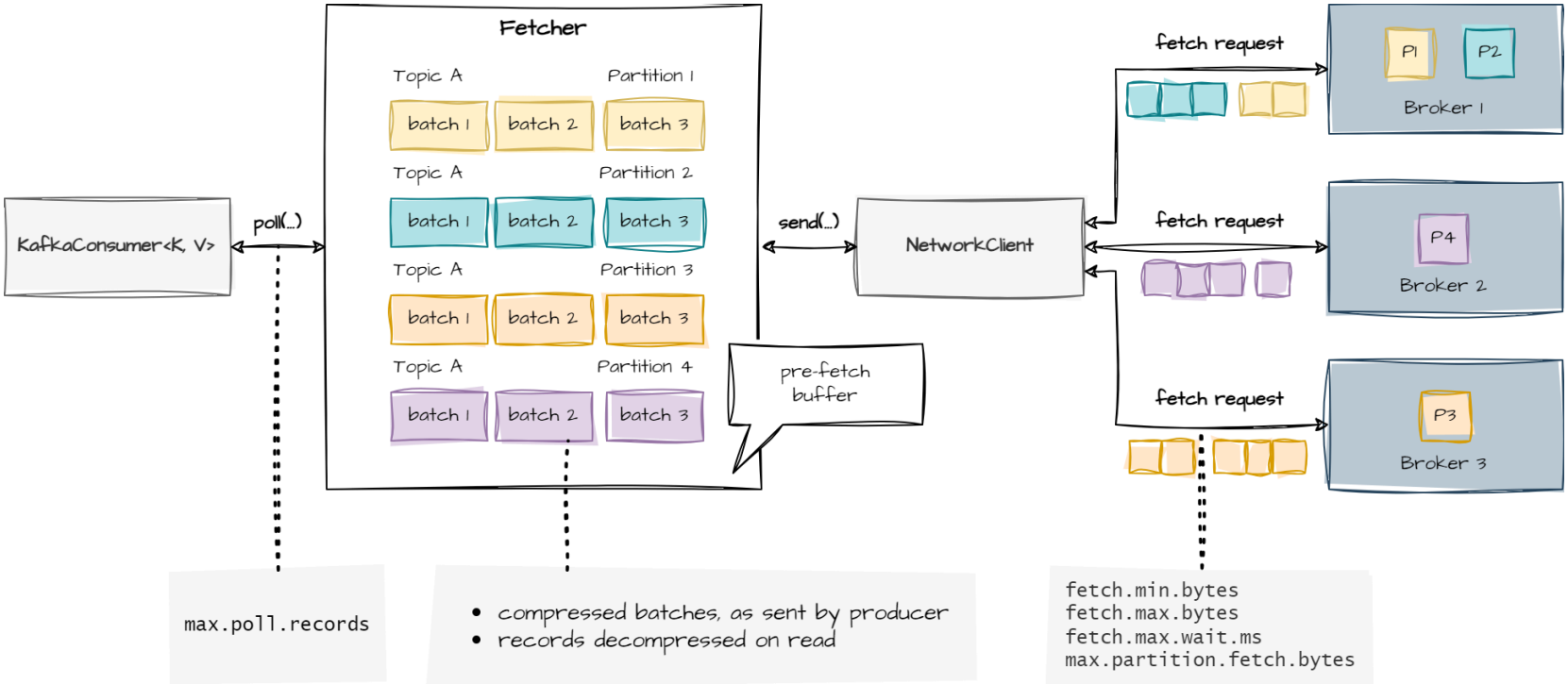
In case of no persisted offsets, `auto.offset.reset` controls where the consumer starts.

- Offers three different options
  - `earliest`: reset offset to the earliest offset (low watermark)
  - `latest`: reset offset to latest offset (high watermark)
  - `none`: throw exception if there are no offsets present


Segment Files
topic/34477849968.kafka
Message 34477849968
Message 34477850175
Message 35551591806
Message 35551592051
Configurable Log Size
topic/82796232652.kafka
Message 82796232652
Message 82796233065
Message 83613823481
Message 83700325311
Active Segment List
Deletes
Reads
Appends
Consistent Views
34477849968 - 35551592051
35551592052 - 36625333894
36625333895 - 37699075830
80648748861 - 81722490796
81722490797 - 82796232651
82796232652 - 83869974631

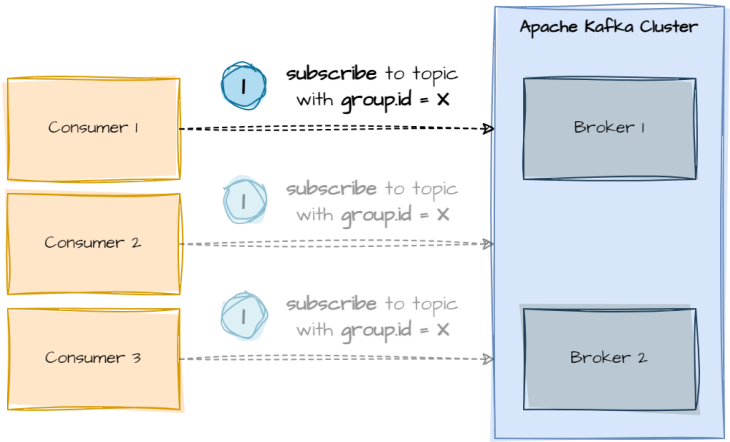
Fetcher

The Kafka consumer uses `Fetcher` as a buffer that retrieves batches from brokers.

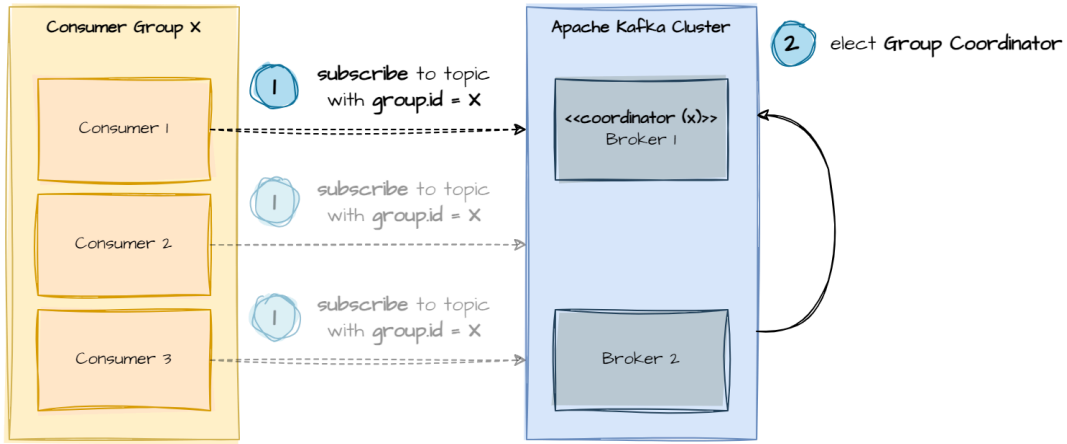


Consumer Groups

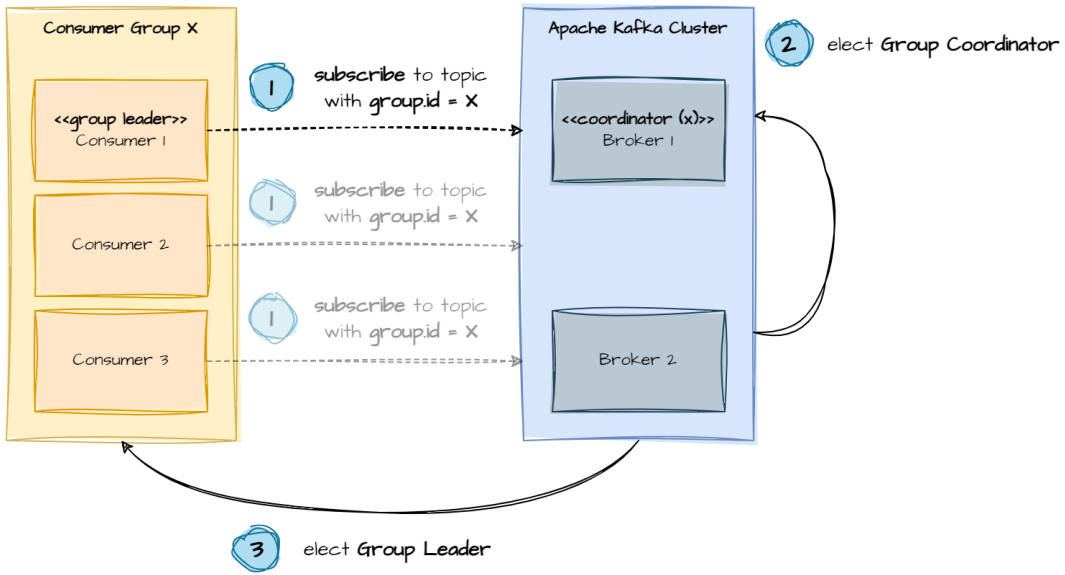
Consumers with the same `group.id` form a consumer group to cooperate.



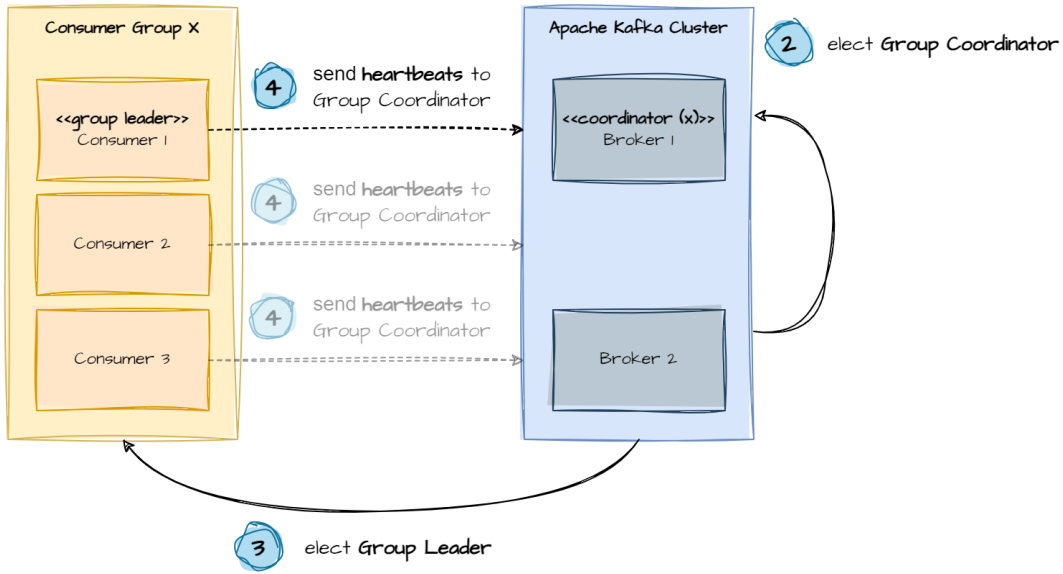
The Kafka cluster elects one of the brokers as *Group Coordinator*.



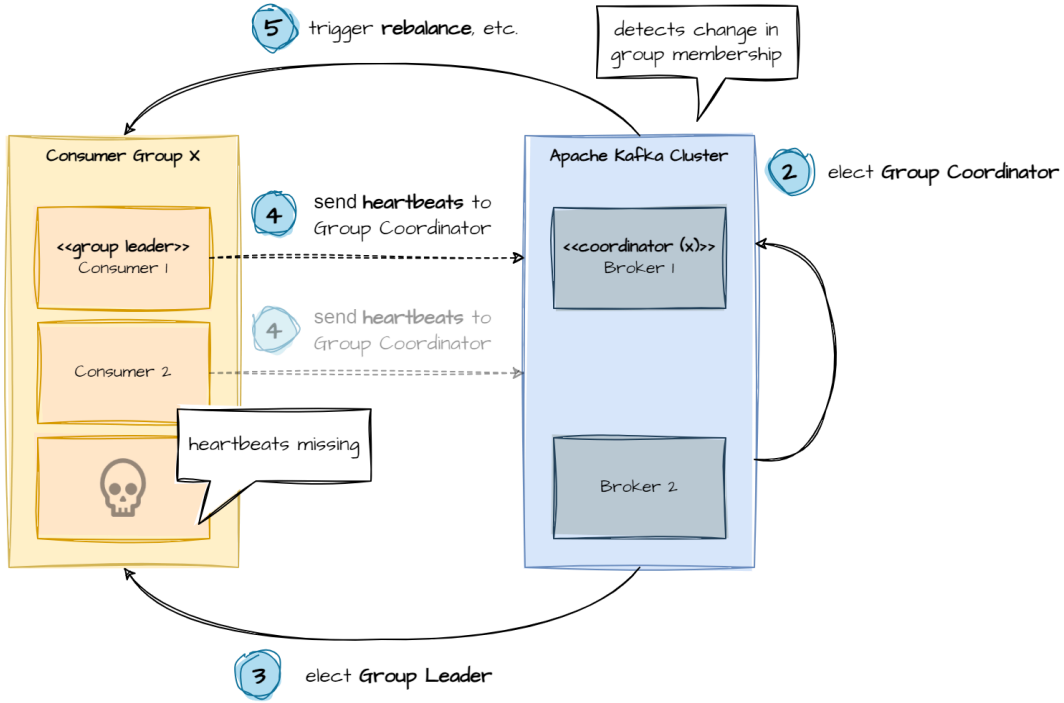
The *Group Coordinator* elects one consumer as *Group Leader*.



Every consumer of the group sends regular heartbeats to the *Group Coordinator*.



The *Group Coordinator* detects a change in membership due to missing heartbeats.



Any change in group membership triggers consumer group rebalances.

Rebalance is triggered when

- consumer joins the group
- consumer leaves the group
- client-side failure detected via `max.poll.interval.ms`
- server-side failure detected via `session.timeout.ms`

There are many probable causes for rebalancing.

- Service is scaling up or down
- `poll()` and long message processing occur in the same thread
- Heartbeats do not reach the *Group Coordinator*
- Long JVM garbage collection pauses (stop-the-world)
- Kubernetes pods become CPU-throttled
- Pod evictions due to Kubernetes cluster upgrades
- Networking issues (latency, packet drop, ...)
- ...

The *Group Leader* uses a configurable partition assignment strategy.

- **Range** (default)
  - stop-the-world strategy
  - works on a per-topic basis
  - can generate imbalanced assignments
- **Round Robin**
  - stop-the-world strategy
  - uniformly distributes partitions

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- **Range** (default)
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- **Round Robin**
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  - uniformly distributes partitions
- **Sticky**
  - stop-the-world strategy
  - initial distribution close to *Round Robin*
  - tries to minimize effect of a rebalance
  - can generate imbalanced assignments
- **Cooperative Sticky** (prefer for newer clusters)
  - incremental rebalance
  - does not stop consumption
  - same logic as *Sticky*

A `ConsumerRebalanceListener` enables us to react on altered partition assignments.

```
public interface ConsumerRebalanceListener {

  void onPartitionsRevoked(Collection<TopicPartition> partitions);

  void onPartitionsAssigned(Collection<TopicPartition> partitions);

  default onPartitionsLost(Collection<TopicPartition> partitions) {
    onPartitionsRevoked(partitions);
  }
}
```

- Use it to save / restore offsets to / from external storage
- Use it to make sure that outstanding offsets are committed
- Instance is passed to `subscribe` when subscribing to a topic
- **Important: Different semantics for eager and incremental assignors!**

Summary

What did we learn?

- Client SDK Essentials
- Subscriptions vs. Assignments
- Offset Management
- The `poll()` loop
- Pre-Fetch Buffer
- Consumer Group
- Partition Assignment & Re-Balancing

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- Client SDK Essentials
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What's to follow?

- *Deserialization*
- Interceptors
- Consumer Coordinator
- Consumer Designs
- Transactions

Questions?

assignment is available at

bit.ly/kafka-workshop-exchanging-records