Apache Kafka for Java Developers

Producing Records

Boris Fresow, Markus Günther

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The Apache Kafka Clients SDK

A Producer's Perspective

Clients for Apache Kafka come in different sizes and shapes.

- Built-in CLI
- Java-based clients
  - Apache Kafka Client library
  - Apache Kafka for Spring
  - SmallRye Reactive Messaging with Kafka
- `librdkafka`-based clients
  - C, Python, ...

The official Apache Kafka Client library is only a single dependency away.

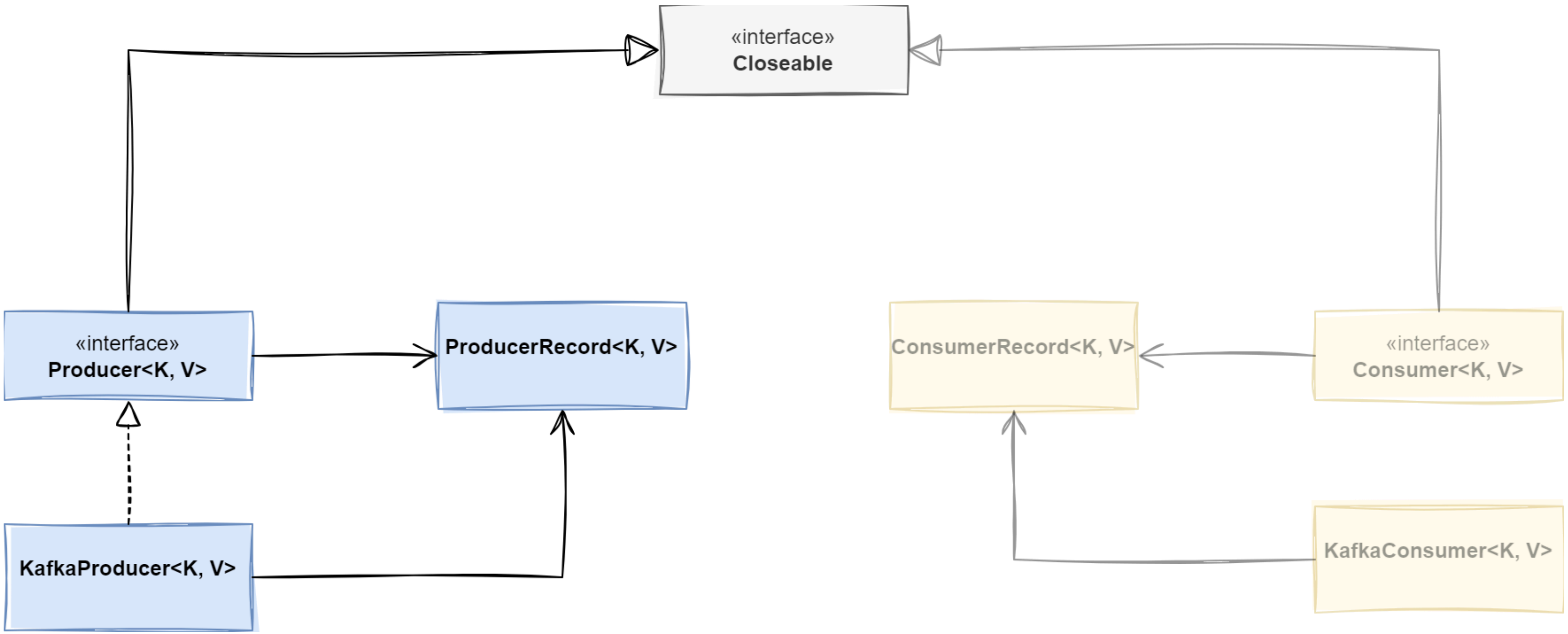
Maven

```xml
<dependency>
  <groupId>org.apache.kafka</groupId>
  <artifactId>kafka-clients</groupId>
  <version>3.6.1</version>
</dependency>
```

Gradle

```groovy
dependencies {
  implementation "org.apache.kafka:kafka-clients:3.6.1"
}
```

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



- `Producer<K,V>`: This is the public interface of the producer client. It comprises the necessary methods for publishing records and using transactions.
- `KafkaProducer<K,V>`: This is the implementation of the `Producer` interface. Whereas the interface is barely documented, the implementation class offers rich documentation for the class itself as well as for every method of its public API.
- `ProducerRecord<K,V>`: This is a data structure that comprises all attributes of a Kafka record as perceived by a producer. To be more precise, this is the representation of a record **before** it has been published to a partition. It contains topic name, partition number, an optional set of headers, key, value, and a timestamp.

The parametric types `K` and `V` stand for the key resp. the value of of the record.

A Producer<K, V> has methods for publishing records and managing transactions.

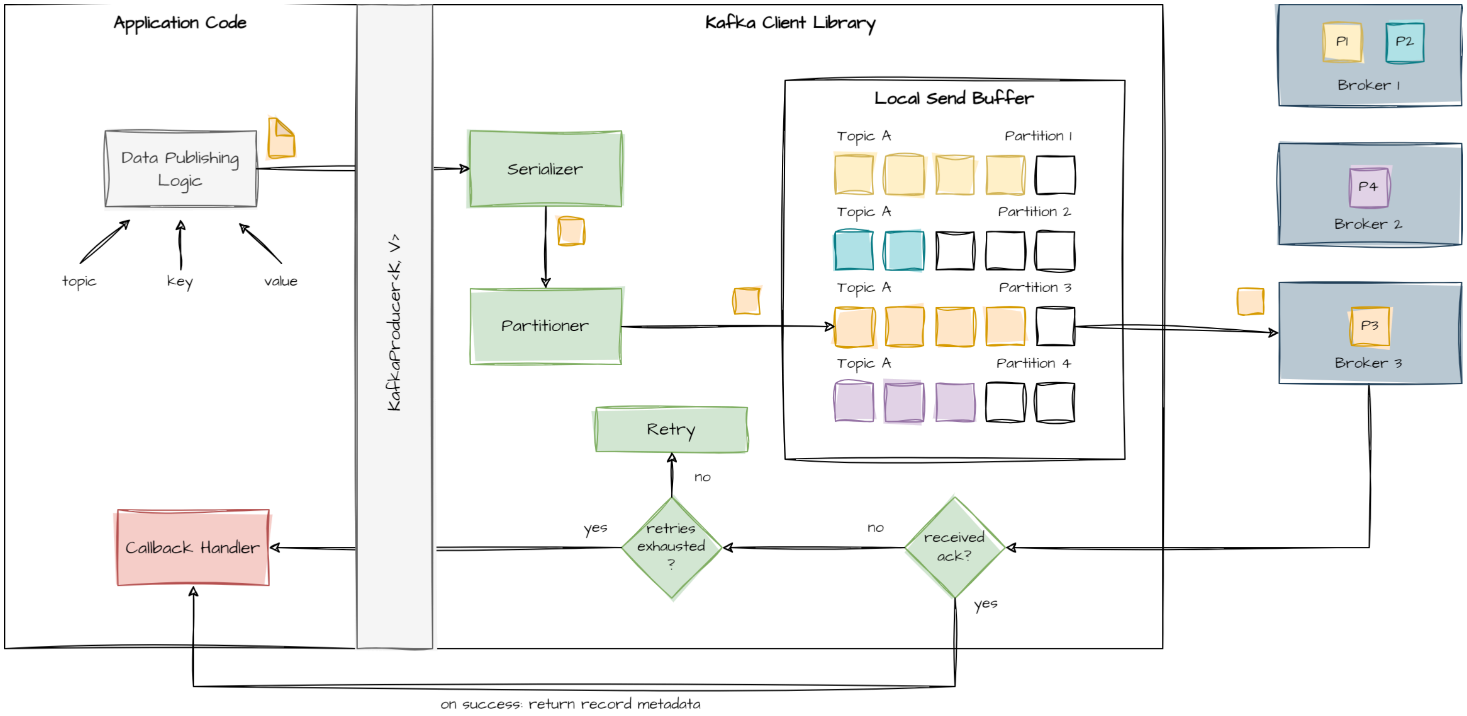
```java
public interface Producer<K, V> extends Closeable {

  // methods for publishing records
  Future<RecordMetadata> send(ProducerRecord<K, V> record);

  Future<RecordMetadata> send(ProducerRecord<K, V> record, Callback callback);

  // methods for managing transactional publishing
  void initTransactions();

  void beginTransaction() throws ProducerFencedException;

  void commitTransaction() throws ProducerFencedException;

  void abortTransaction() throws ProducerFencedException;

  // ... a couple of more methods omitted for brevity ...
}
```

The `send()` methods operate asynchronously, meaning they complete immediately after the record is serialized and placed into a local buffer. The process of actually transmitting the record occurs in the background, managed by a dedicated I/O thread. If the application needs to wait for the outcome, it should call the `get()` method on the `Future` object provided.

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

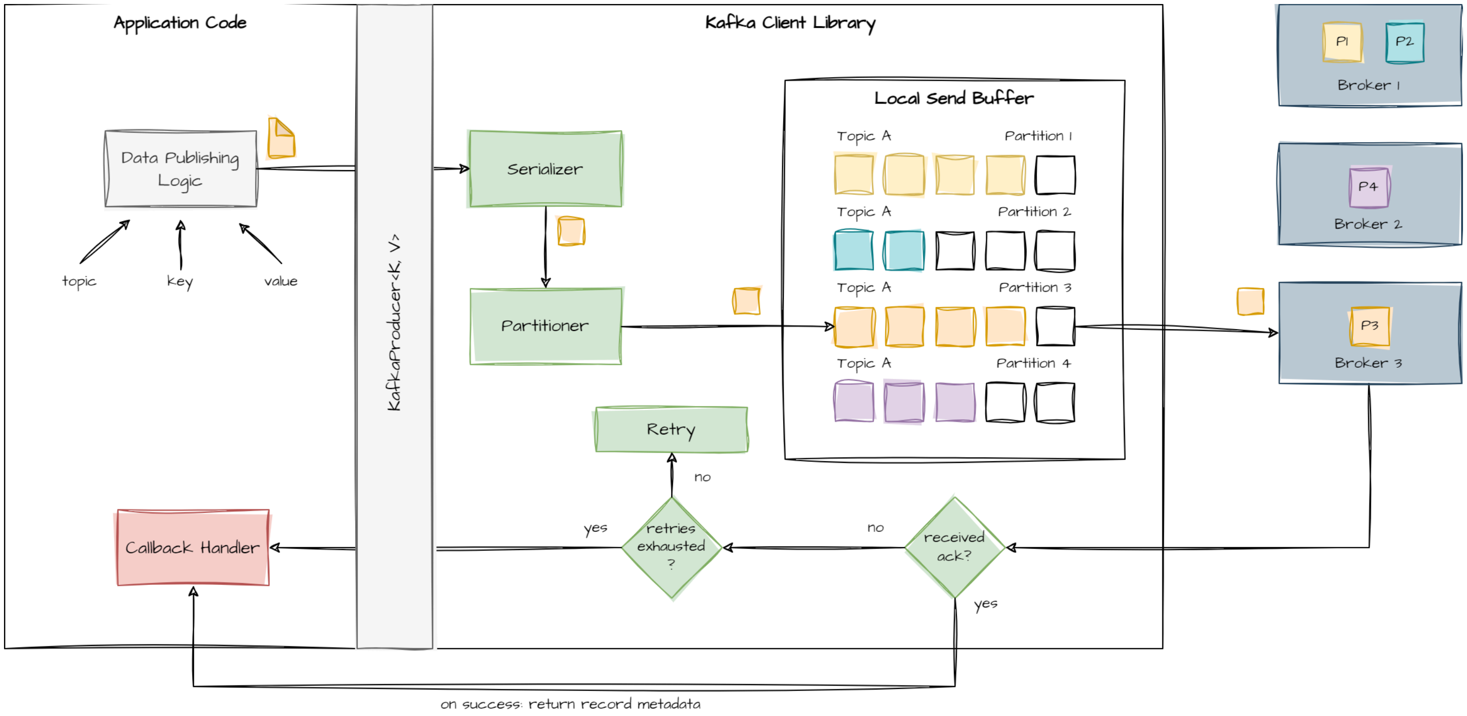
```java
public class BasicProducer {
  public static void main(String[] args) throws Exception {
    var topic = "getting-started";
    Map<String, Object> config = Map.of(
      ProducerConfig.BOOTSTRAP_SERVERS_CONFIG, "localhost:9092",
      ProducerConfig.KEY_SERIALIZER_CLASS_CONFIG, StringSerializer.class.getName(),
      ProducerConfig.VALUE_SERIALIZER_CLASS_CONFIG, StringSerializer.class.getName()
    );
    try (var producer = new KafkaProducer<String, String>(config)) {
      var key = "my-key";
      var value = new Date().toString();
      Callback callback = (metadata, exception) -> {
        System.out.println("Published with metadata: %s, error: %s%n",
          metadata, exception);
      };
      producer.send(new ProducerRecord<>(topic, key, value), callback);
    }
  }
}
```

But what happens after we call `producer.send`?



Serialization

A `Serializer` encodes data of type T into `byte[]`.



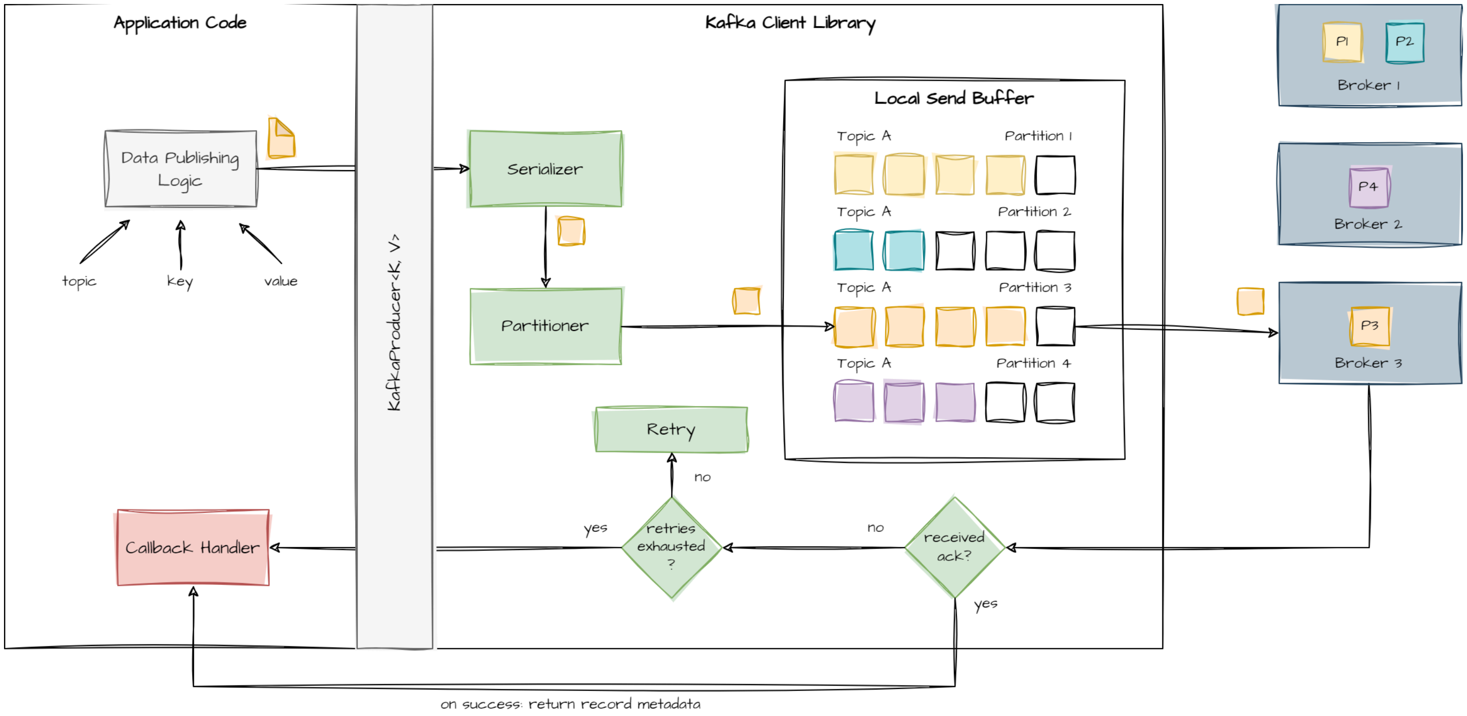
A Serializer encodes data of type T into byte[]. (cont.)

```java
public interface Serializer<T> extends Closeable {

  byte[] serialize(String topic, T data);

  default byte[] serialize(String topic, Headers headers, T data) {
    return serialize(topic, data);
  }

  default void configure(Map<String, ?> configs, boolean isKey) {
    // intentionally left blank
  }

  @Override
  default void close() {
    // intentionally left blank
  }
}
```

A `Serializer` encodes the given data into `byte[]`. This is the target format for Apache Kafka. Kafka does not interpret the payload of a record. It only deals with `byte[]`. Thus, serialization is a concern of the application.

Partition Assignment

After serialization, a partitioner sorts data into buffers for their resp. topic-partition.



Partition assignment factors in different strategies.

1. Use the partition of the `ProducerRecord<K,V>` (if assigned)
2. Use a custom `Partitioner` (if configured)
3. Try to calculate the partition based on record key (if not null)
    1. uses a hash function over the key
    2. default for Java-based clients is `murmur2`
    3. default for `librdkafka` is `crc32`
4. If there is no key or key should be ignored, use built-in partitioning logic

The `murmur2`-hash is calculated like this:

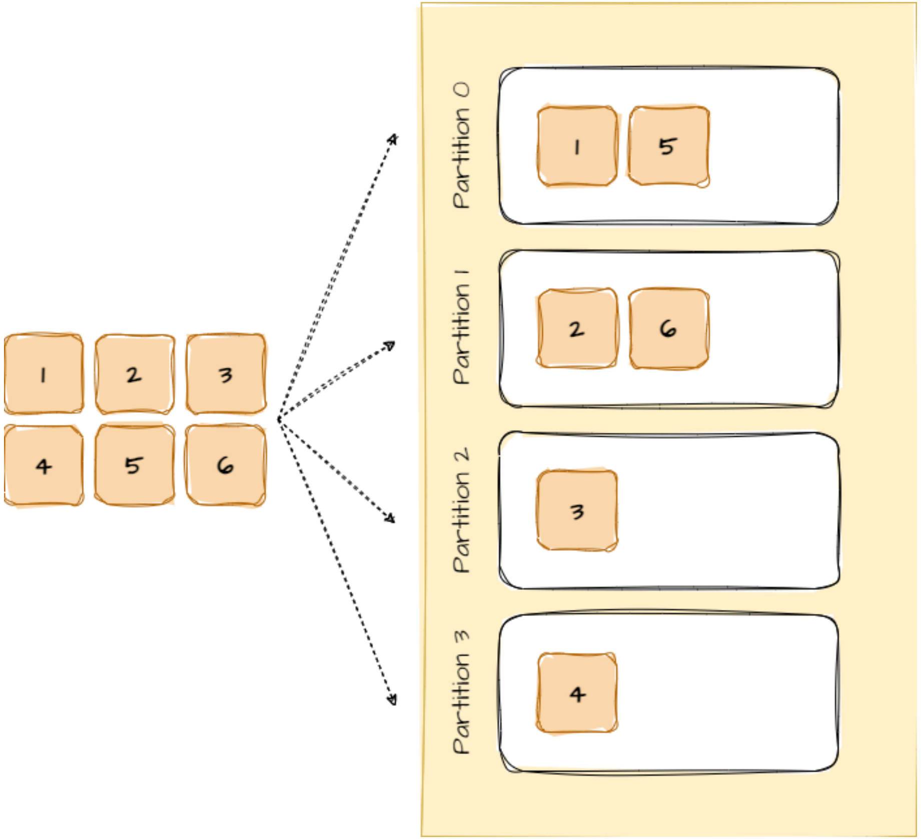
```
int targetPartition = Math.abs(Utils.murmur2(keyBytes)) % (numPartitions - 1);
```

Moving to the **Sticky Partitioner** is not just about the fact that the previously used round-robin strategy led to an imbalanced workload between topic-partitions (cf. KAFKA-9965), but also results in a significant increase in performance (cf. KIP-480: Sticky Partitioner).

For Kafka 2.3 and below, the default partitioner uses a round-robin strategy.

Round Robin Partitioner

- one batch per partition
  - more batches
  - smaller batches
- leads to
  - more requests
  - higher latency
- bug: leads to uneven distribution (2.4+)

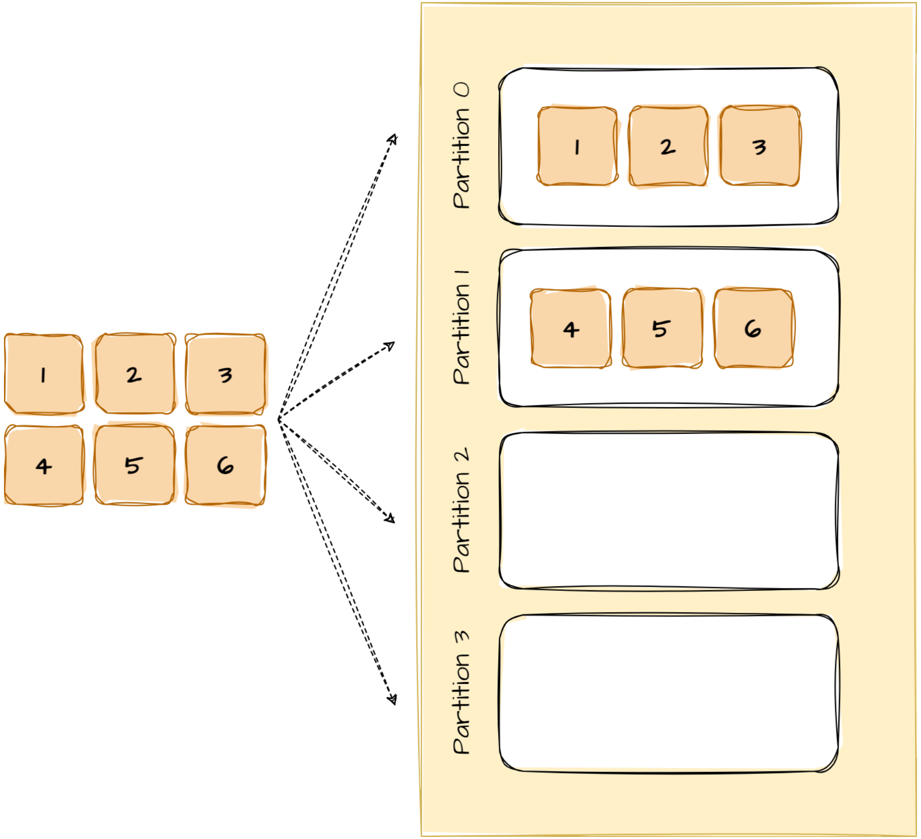


There is an bug that leads to an uneven distribution if the `RoundRobinPartitioner` is used in Kafka 2.4+. See https://issues.apache.org/jira/browse/KAFKA-9965 for details.

For Kafka 2.4. and up to Kafka 3.2, the default partitioner uses batch stickiness.

Sticky Partitioner

- stick to a partition
  - until batch is full
  - `linger.ms` has elapsed
- leads to
  - larger batches
  - reduced latency
- bug: uneven distribution (slow brokers)



This will lead to larger batches and reduced latency (due to larger requests, `batch.size` is more likely to be reached). Over time, the records are still spread *almost evenly* across partitions, so the balance of the cluster is not affected.

For Kafka 3.3 and higher, there are two new strategies available.

Uniform Sticky Batch Size

- don't switch unless `batch.size` bytes got produced to partition
- uniform throughput and data distribution
  - adapts well to higher latency brokers
- might slow down producer rate due to filling local buffer if brokers are constantly lagging behind

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Uniform Sticky Batch Size

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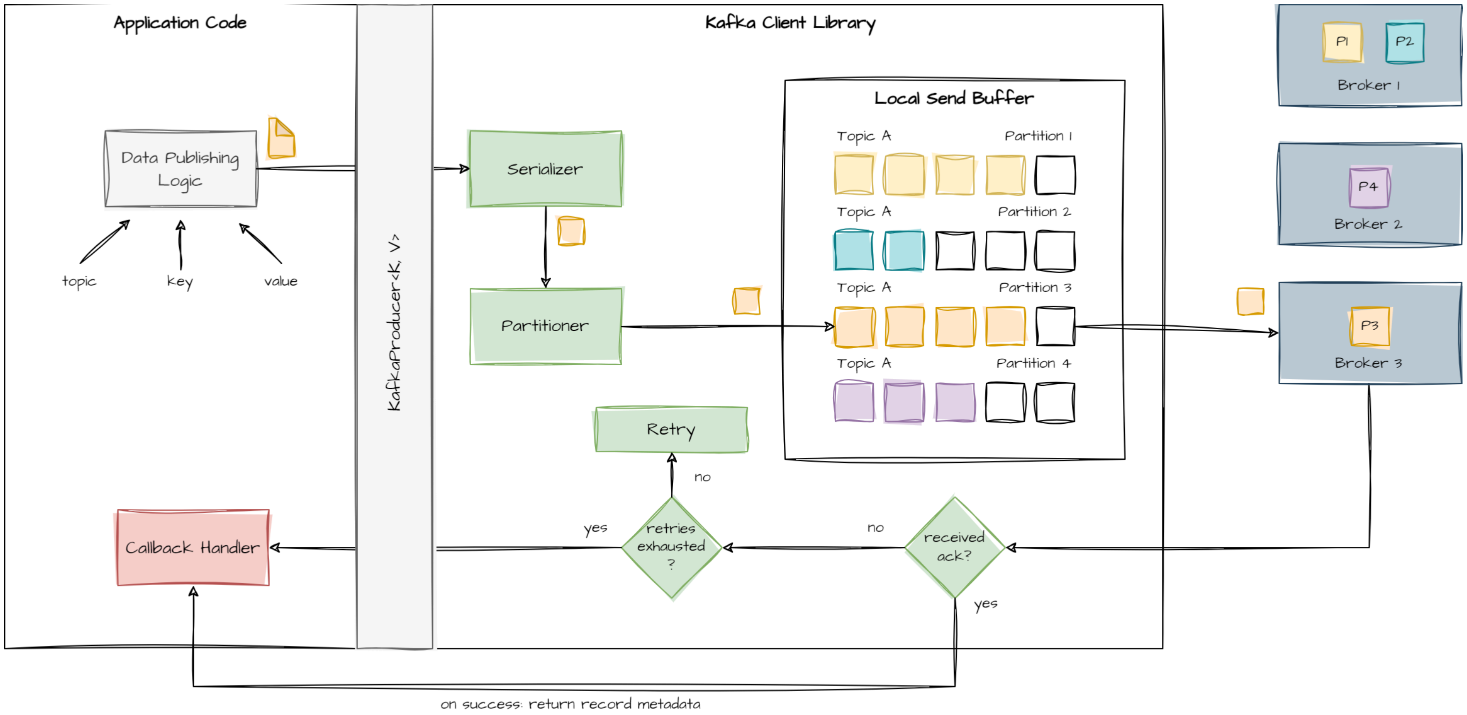
Adaptive Partition Switching (default)

- adapts to broker load
  - queue size of unsent batches is indicator
  - probability of choosing a partition is proportional to the inverse queue size
  - partitions with longer queues are less likely to be chosen
- `partitioner.availability.timeout.ms` > 0 to indicate a failed batch if the producer is unable to produce data within timeout

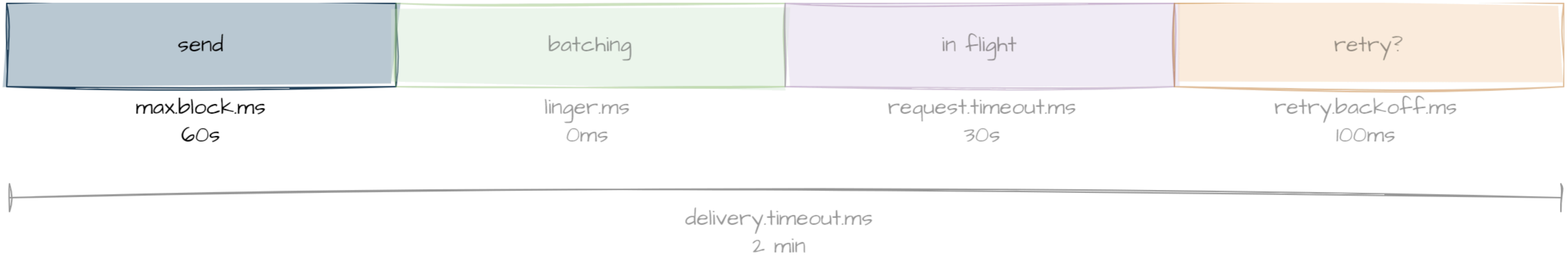
Set `partitioner.adaptive.partitioning.enable` to `false` to use **Uniform Sticky Batch Size**. If set to `true` (default), **Adaptive Partition Switching** is used.

Timeouts

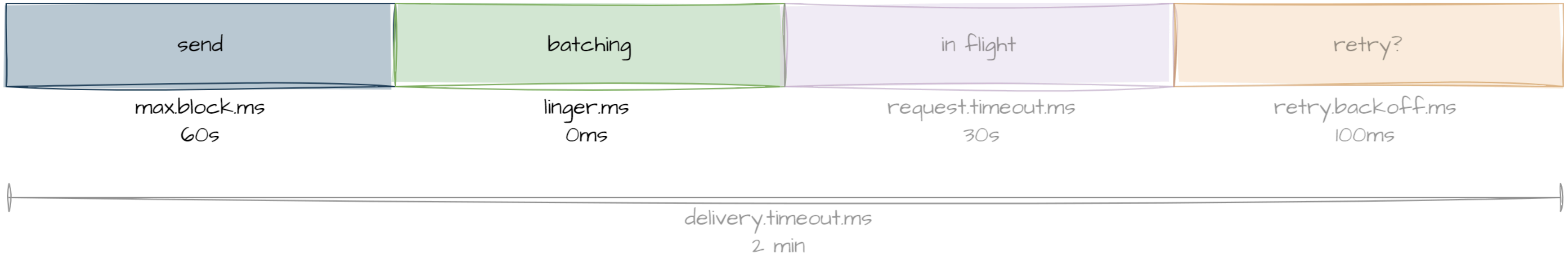
After partitioning, data is moved into a local buffer for the target topic-partition.



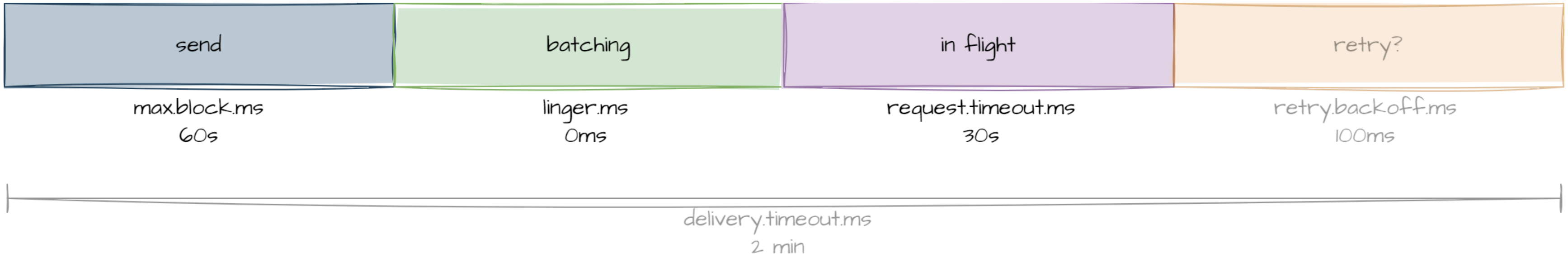
The `send` method of the producer waits a maximum of `max.block.ms`.



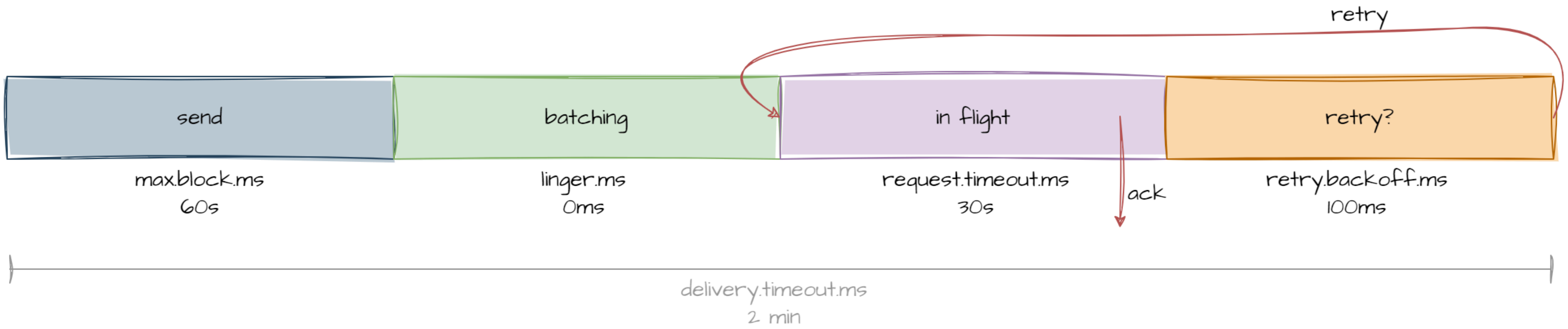
The producer waits a maximum of `linger.ms` for messages to include into a batch.



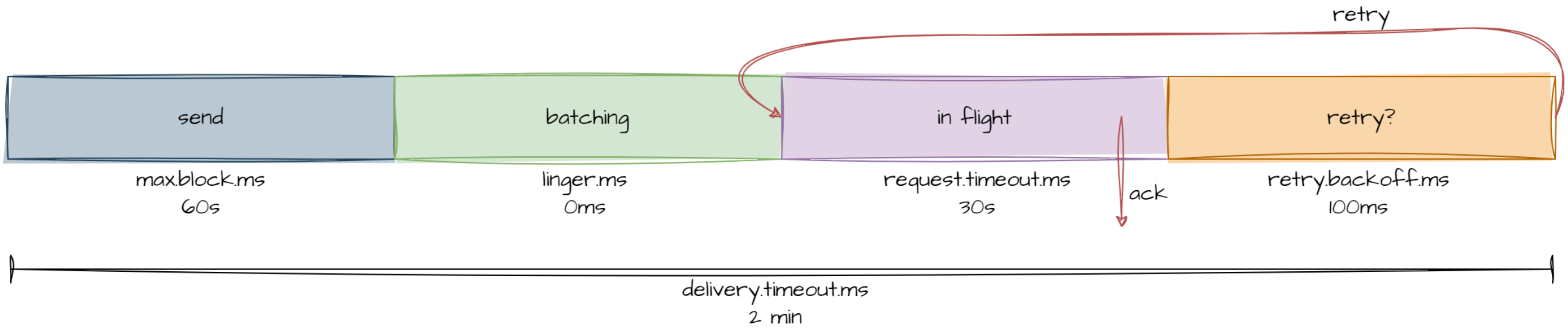
The producer waits for `request.timeout.ms` for an acknowledgement.



If the producer receives no ack within a certain time, its retry mechanism fires.



After a maximum of `delivery.timeout.ms` the attempt to publish will be aborted.



Acknowledgements

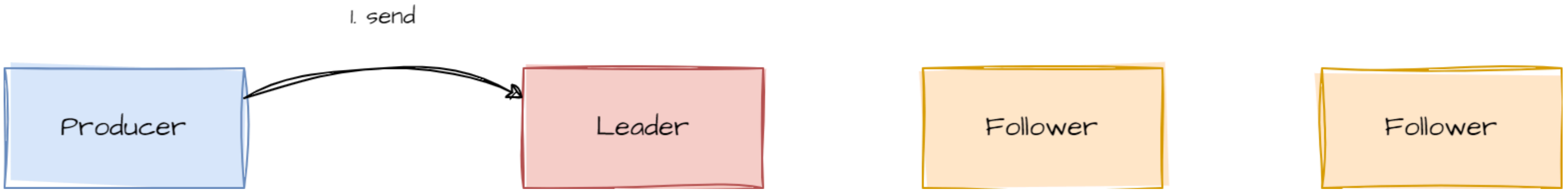
Depending on your acks setting, the producer waits for an acknowledgment (or not).

General

- Producer is able to submit data anew in case of missing ack
- If the error is persistent, the producer will generate an exception

> ***Acknowledgements*** *are not only used to signal that data has been received, but also play a part in Kafka's* ***replication strategy****.*

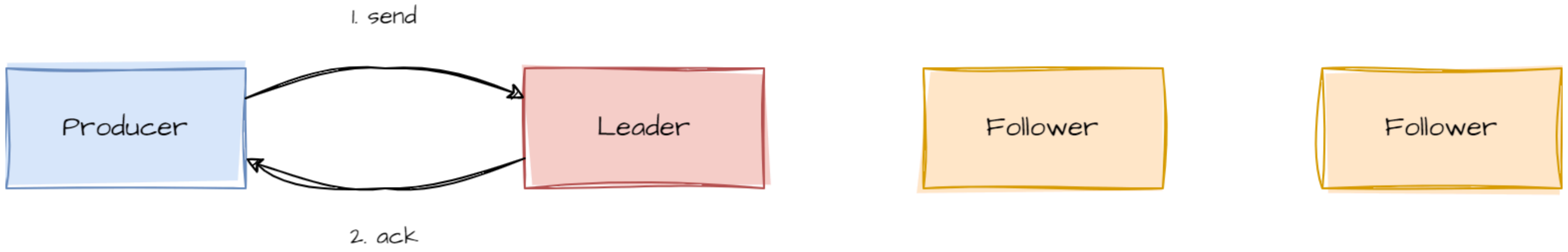
The producer does not wait for an acknowledgment if `acks=0`.



Traits

- Fire-and-forget
- Networking analogy: UDP
- Best performance, if data loss is tolerable

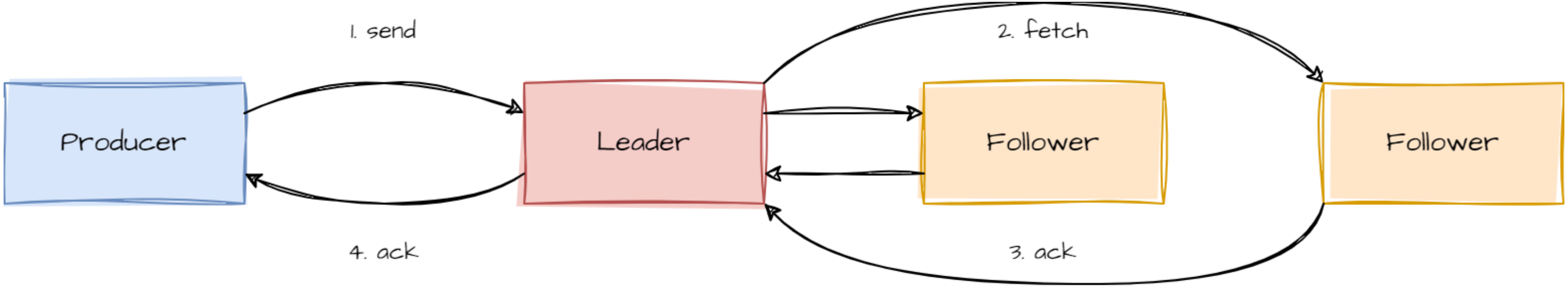
The leader acknowledges directly after receiving the record if `acks=1`.



Traits

- Does not wait for the replication result to followers
- Networking analogy: TCP
- Default configuration up until Apache Kafka 3.0

The leader replicates to all followers before it sends the acknowledgment if `acks=all`.



Traits

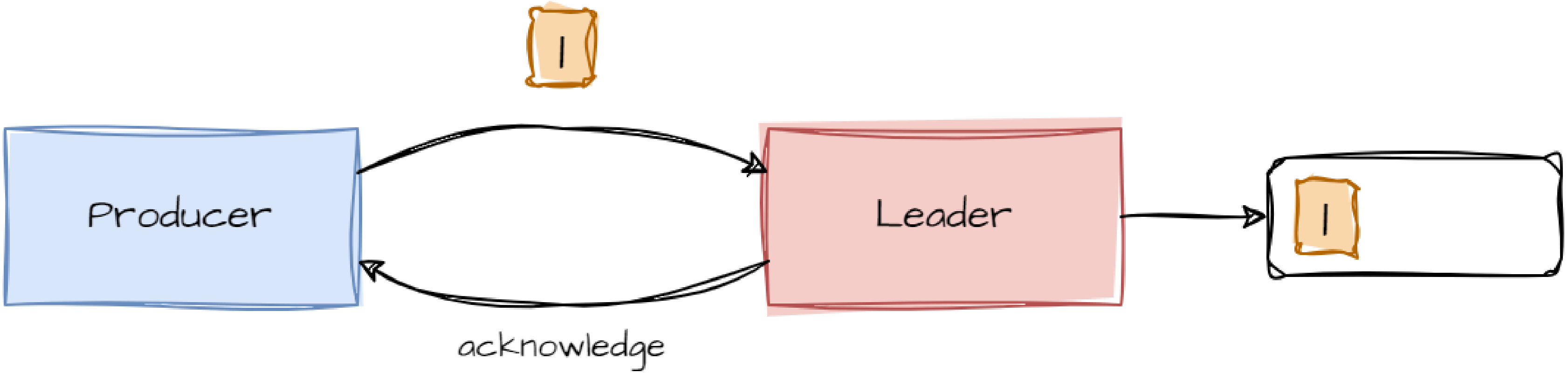
- Replicas are considered in-sync if they received latest data within 30 s
- Best consistency guarantees
- `min.insync.replicas` controls how many brokers must be in-sync

- Best consistency guarantees, but for the lack of a higher throughput

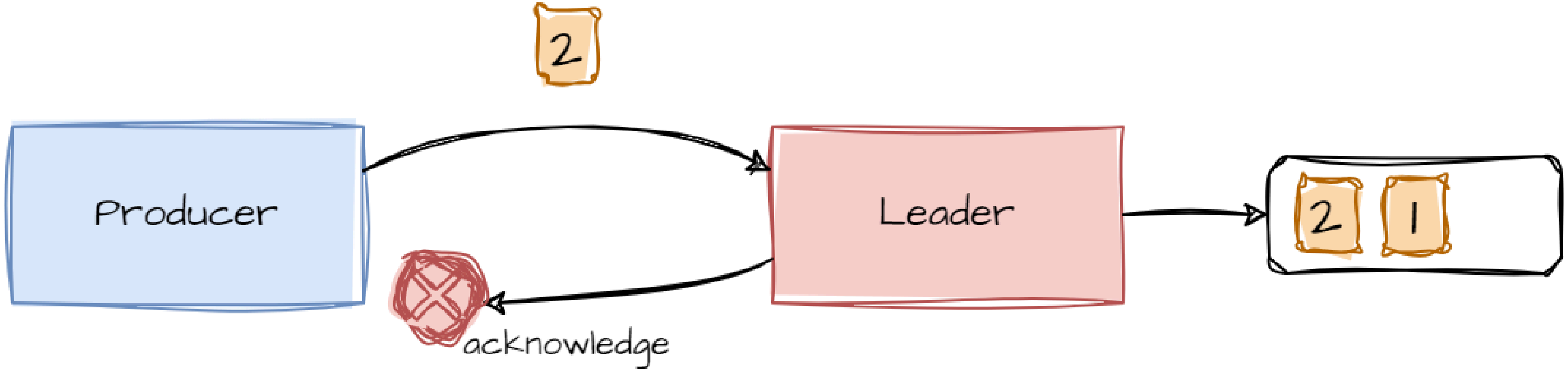
- If there are not enough `min.insync.replicas`, the broker sends an error back to the producer, which will raise a `NotEnoughReplicasException`

Delivery Guarantees

Lost acknowledgments may lead to duplicated records in the log.



Lost acknowledgments may lead to duplicated records in the log. (cont.)



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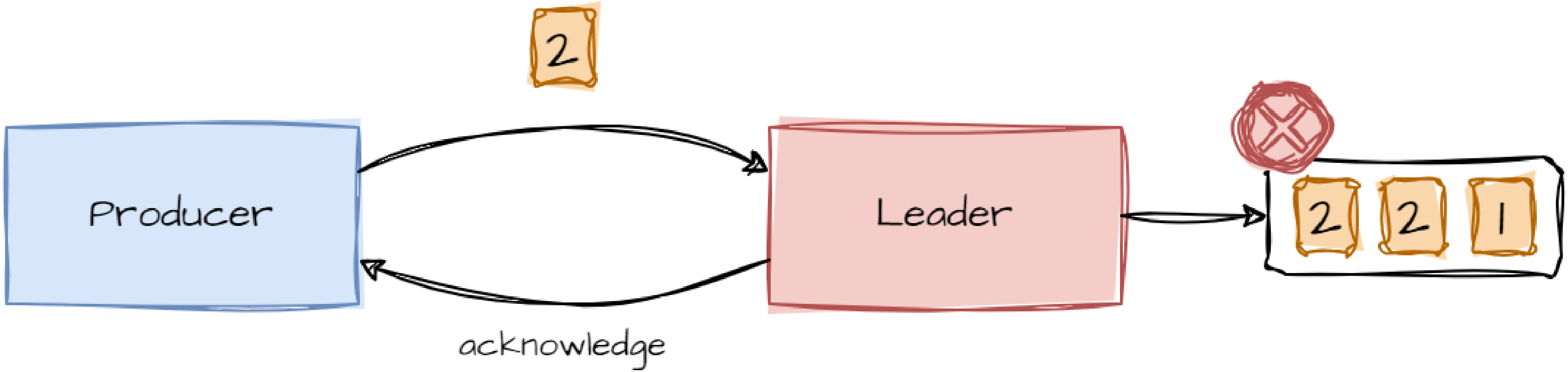
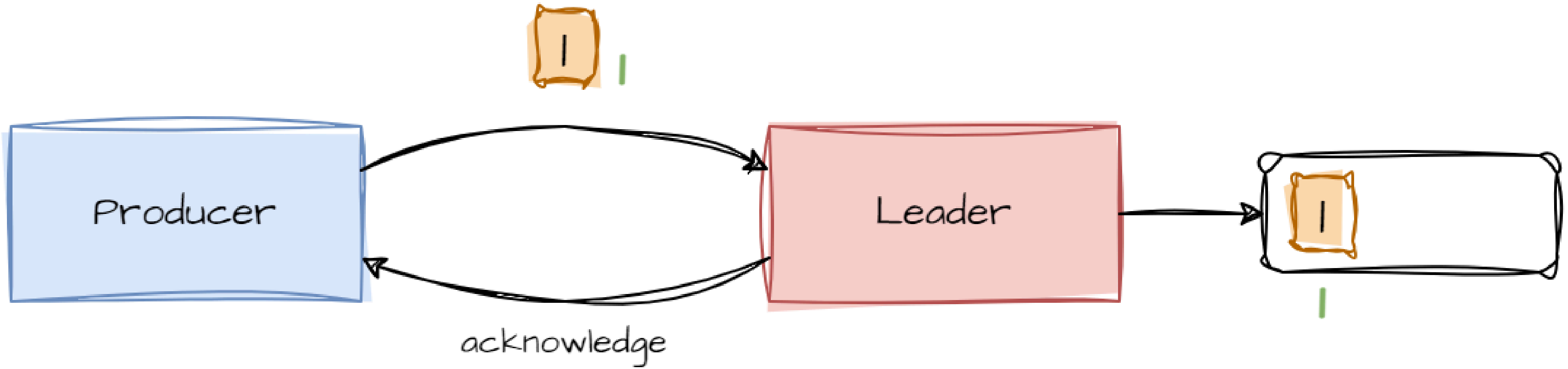
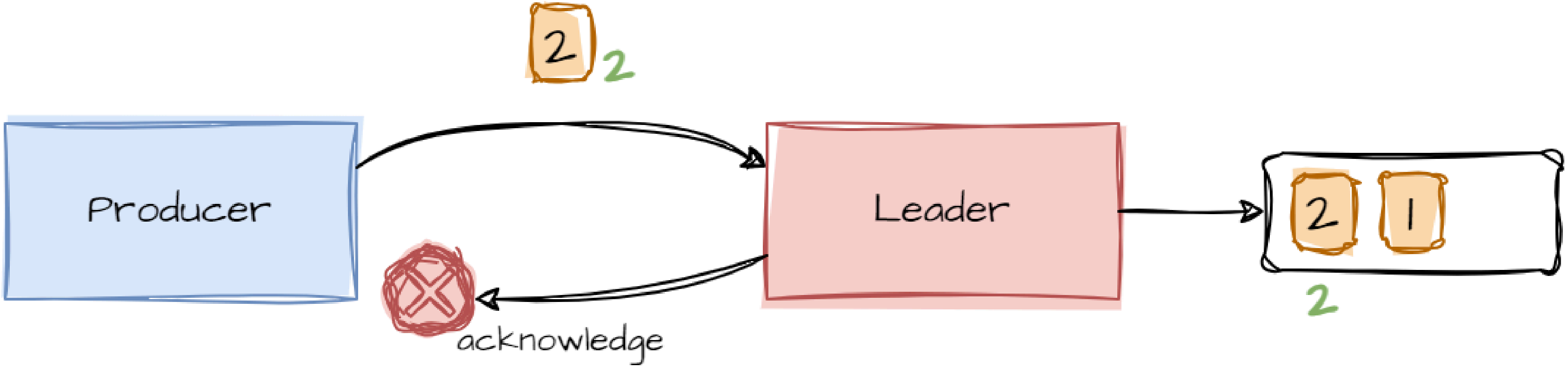


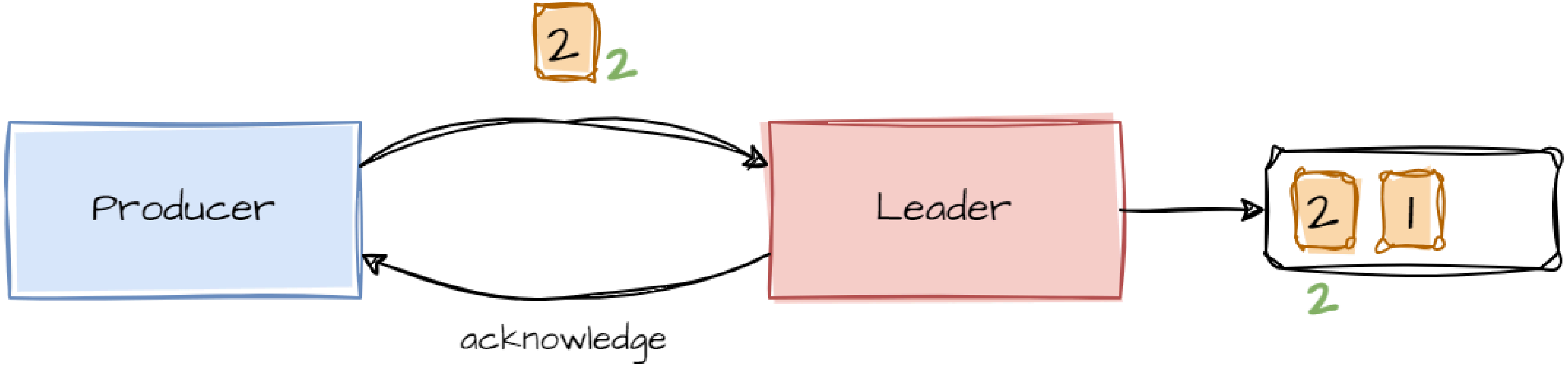
Setting `acks=all` and `enable.idempotence=true` prevents duplicates.



Setting `acks=all` and `enable.idempotence=true` prevents duplicates. (cont.)



Setting `acks=all` and `enable.idempotence=true` prevents duplicates. (cont.)



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We distinguish between three different delivery guarantees.

At-most-once

> *Guarantees that a record will be delivered **at most one time**. There can be **no duplicates**. There is **no guarantee** that the record will be received from the broker.*

- This is the case for `acks=0`

We distinguish between three different delivery guarantees. (cont.)

At-least-once

> *Guarantees that a record* ***will be received*** *by the broker, but* ***possibly multiple times****. Hence, there* ***may be duplicates****.*

- This the case for
  - `acks=all`
  - `min.insync.replicas` to a sensible value

We distinguish between three different delivery guarantees. (cont.)

Exactly-once

> *Guarantees that a record **will be written to the log** exactly **one time** (idempotency).*

- This is the case for
  - `acks=all`
  - `enable.idempotence=true`
- Default setting since Apache Kafka 3.0

Summary

What did we learn?

- Client SDK Essentials
- Partition Assignment
- Timeouts
- Retries
- Error Handling
- Acknowledgements
- Delivery Guarantees

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- Client SDK Essentials
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What's to follow?

- *Serialization*
- Interceptors
- Broker Internals
- Producer Designs
- Transactions

Questions?