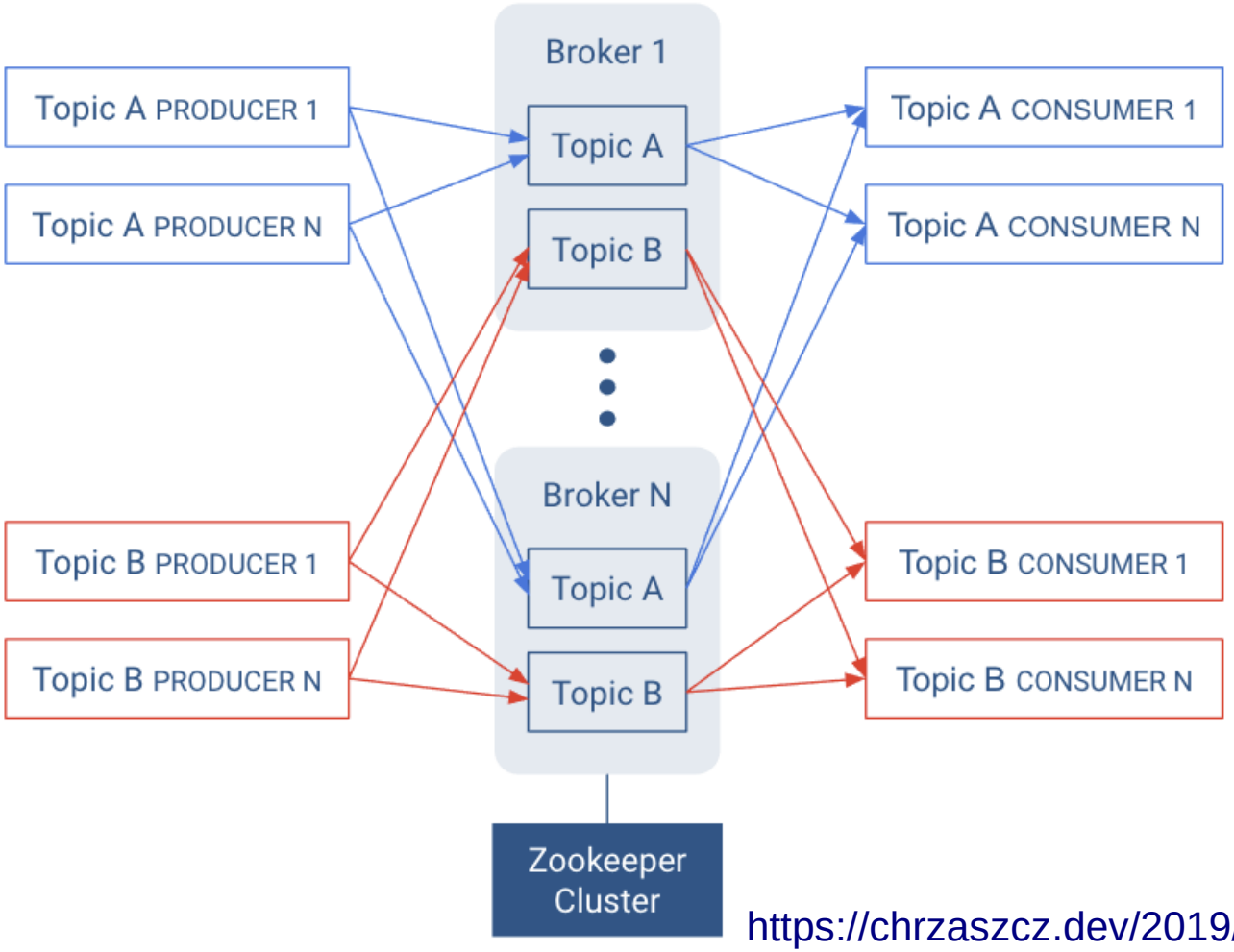
Apache Kafka

Kafka 101

- Kafka is a distributed system, which allows you to construct asynchronous processing of events, publish-subscribe mechanism, or distribute work evenly among worker servvices.



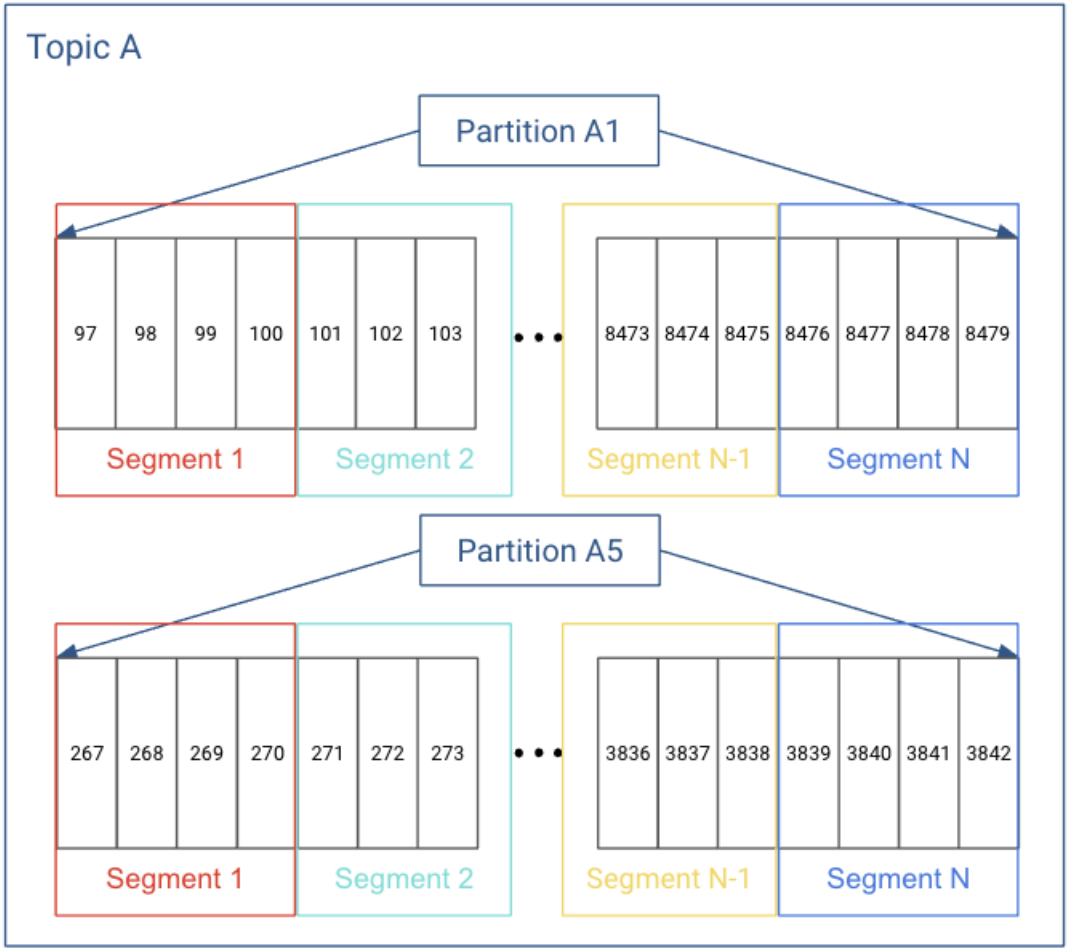
https://chrzaszcz.dev/2019/05/26/kafka-101/

Basic concepts

- Broker
  - server (onprem, virtual, container), on which runs Kafka process
- Message (Event)
  - Message contains a pair (key – value)
    - Key and value can have any (even different) data type – scalar value or even more complex object like JSON.
    - Key isn’t something like primary key in relational database, but for example name of sensor, ID / name of business operation etc. It can be NULL, but for various reasons it’s a good idea if it’s present.
    - Message is immutable

Basic concepts

- Topic
  - Messages are stored to „topic“ (something like log)
- Partition
  - Topic consists of „partitions“
    - Order of messages is guaranteed only within one partition!
      - Each partition has offsets numbered from zero!
- Segment
  - Data aren’t stored into one big file, but are stored in log segments (physically segments are files on disc)



Nice overview where exactly Kafka stores data:
https://rohithsankepally.github.io/Kafka-Storage-Internals/

Basic concepts

- When key == null, then messages are stored into partitions using round robin algorithm. If messages have key, then it’s guaranteed, that messages with the same key will be in the same partition and will be ordered.
  - Internally key is transformed to hash and based on it’s value the message is stored to appropriate partition. The Producer is responsible for hashing and storing to partition.
- Topic is append only, can only seek by offset. Topics are durable, retention is configurable.
  - Default retention is time retention (7 days) and is configurable. Retention also can be based on Topics size:
    - https://medium.com/@sunny_81705/kafka-log-retention-and-cleanup-policies-c8d9cb7e09f8
- Replication
  - One partition is lead replica, others are follow replicas. Replication factor specifies number of replicas, default value is 1 (meaning that replication is by default disabled, data are only in lead replica)

Cluster

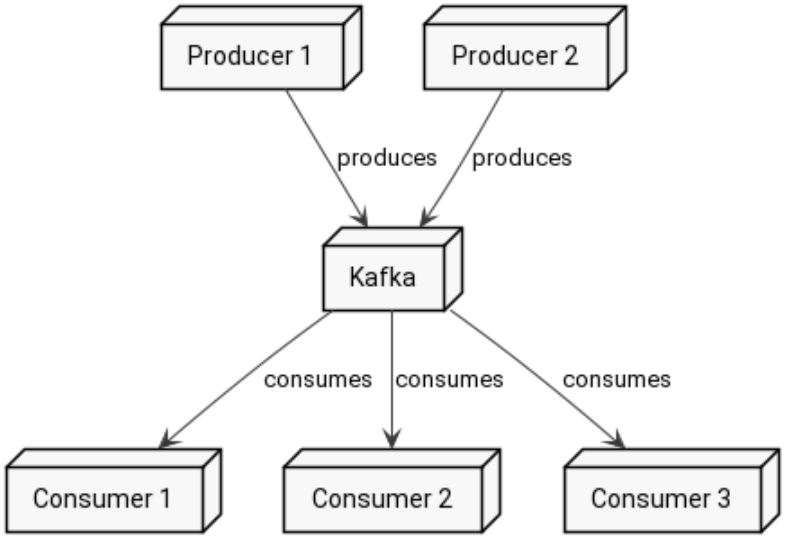
- Kafka uses Apache Zookeeper to keep list of Brokers, which are currently members of cluster. Each Broker has unique ID, which if not specified is automatically generated during Broker startup.
- How to get list of all active brokers in cluster:
  - zookeeper-shell localhost:2181 ls /brokers/ids
- Information about broker with KAFKA_BROKER_ID = 10 in cluster:
  - zookeeper-shell localhost:2181 get /brokers/ids/10
- https://www.baeldung.com/ops/kafka-list-active-brokers-in-cluster
- Controller
  - The first of the Kafka Brokers to join the cluster is co-called Controller and is in charge of allocating partition leaders. When Controller stops working, another working Broker is set as Controller.

Replication

- There are two kinds of replicas:
  - Leader replica
    - Every partition has one replica, which is leader replica. All requests of all Producers and Consumers go through leader for data consistency.
  - Follower replica
    - All other replicas are followers. Followers only job is to replicate messages from leader and to keep up-to-date with state of leader. When leader replica crashes, one of the follower replicas will become the new leader.
- Leader replica has one more role and that’s to control whether follower replicas are in-sync. Replicas don’t have to be in-sync for example due to networking issue, or when broker crashes and data aren’t yet replicated to other brokers.
- Kafka guarantees that every replica is on different broker, thus maximum value of replication factor is equal to number of brokers.

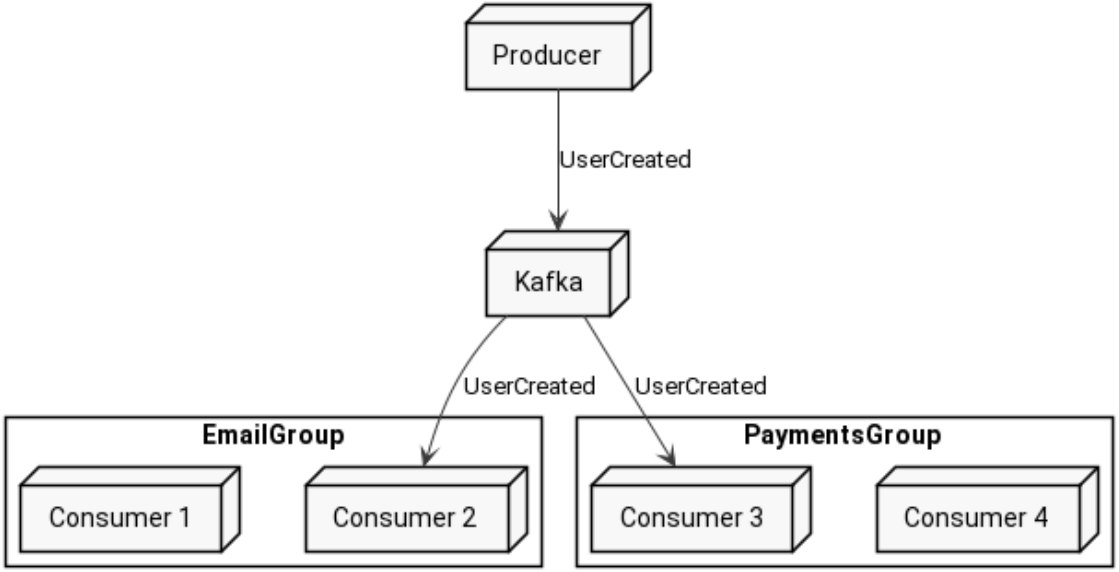
Producer & Consumer

- Producer
  - Producer produces messages to topics
- Consumer
  - Consumer consumes messages from topics
    - Consumers can be grouped to groups (using group.id).
    - Consumer doesn’t remove message from topic (big difference from message-queue), but it keeps offset by which it knows what message to read from.
      - Offsets are stored in topic __consumer_offsets



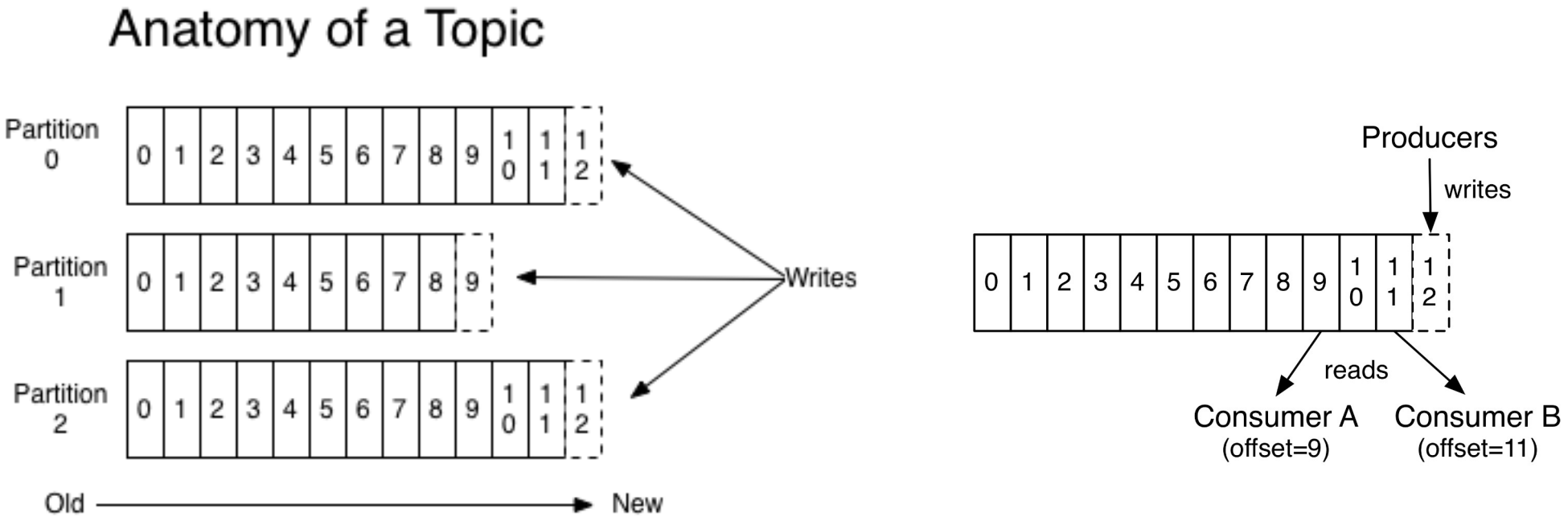
Consumer Group

- Consumer Group
  - There can be more Consumers, which have same group.id (that is known as Consumer Group) and thus works horizontal scaling of consumers. Kafka will automatically distribute load between these consumers. It’s not possible to have more active Consumers than number of partitions, but from a single topic can read any number of consumers with different group.id.
    - Each message will be sent to every Consumer group, but inside that group it will be consumed by just one Consumer.



Offset

- Every message when stored to Partition will have allocated an offset. Offset of the first message is 0, second message 1 etc.
- Every message can be uniquely identified by this combination: (topic_name, partition_number, offset)
- Consumer uses offset to specify position in log. There are two kinds of offsets. First is stored in Kafka (commited offset), second is local and is used by consumer for polling (consumer position).



Commited Offset vs. Consumer Position

- Commited Offset
  - Stored to Kafka when Consumer performs commit.
  - Used when Consumer crashes.
  - Example:
    - Consumer C1 just started consuming new topic. It performed fetch of 10 messages from offset 0. After their processing it wants to give information to Kafka that they’re processed. This process is called „commit“. So it performs a commit, then Consumer C1 crashes. Afterwards starts up Consumer C2, which looks to Kafka what has been processed so far and starts processing messages from 10th message.

Commited Offset vs. Consumer Position

- Consumer Position
  - Consumer normally does polling (that’s what it does). During pollingu is not automatically performed commit. That’s performed either peridocally during Xth call of poll method, or mannually calling commit method.
  - In the background, during polling Consumer remembers the current offset of the last processed message in something called Consumer Position.
  - Consumer Position can be changed by calling one of these methods:
    - consumer.seek(somePartition, newOffset)
    - consumer.seekToBeginning(somePartitions)
    - consumer.seekToEnd(somePartitions)

Initial Offset

- When a brand new Consumer Group is added, it has no commited offset. What is the default? We have to choose:
  - Earliest
    - Smallest (oldest) available offset
    - In Consumeru you need to set auto.offset.reset=earliest
  - Latest
    - Largest (newest) available offset
    - This is default
  - None
    - We have to manually specify concrete offset.
- Warning! In Broker is property offsets.retention.minutes (default 24h), which means, that when Consumer Group drops out for more than 24h and is setup latest offset, then will be processed items, which were delivered after Consumer startup Consumera (initial offset will be created), therefore data will be lost.
  - https://dzone.com/articles/apache-kafka-consumer-group-offset-retention

Kafka vs. RabbitMQ

- Traditionally, RabbitMQ is a message broker that delivers messages (like postman), while Kafka is a distributed log. Today, however, it offers more or less the same thing (especially since the release of RabbitMQ 3.9, which contains new data structure: Streams).
- Today I would see main differences especially in ecosystem around these two products (Kafka has Kafka Streams, Kafka Connect and Debezium, ksqlDB etc.).
- From performance perspective Kafka has higher throughput, while RabbitMQ has lower message delivery latency.
- https://qr.ae/pG0g2J
- https://tanzu.vmware.com/developer/blog/understanding-the-differences-between-rabbitmq-vs-kafka/

Hello World Kafka (landoop)

- Apache Kafka startup:

```
docker run --rm -it -p 2181:2181 -p 3030:3030 \
-p 8081:8081 -p 8082:8082 -p 8083:8083 -p 9092:9092 \
-e ADV_HOST=127.0.0.1 landoop/fast-data-dev
```

- How to get to command line tools:

```
docker run --rm -it --net=host landoop/fast-data-dev bash
```

- Dashboard:
  - http://localhost:3030/

Hello World Kafka (confluent)

- Apache Kafka startup:

```
git clone https://github.com/confluentinc/cp-all-in-one

cd cp-all-in-one/cp-all-in-one

docker compose up -d
```

- How to get to command line tools:

```
docker run -it --rm --net=host \
confluentinc/cp-zookeeper:5.0.0-beta30 bash
```

- Dashboard:
  - http://localhost:9021

- https://docs.confluent.io/platform/current/quickstart/ce-docker-quickstart.html

kafka-topics

- Create topic:

```
kafka-topics --zookeeper localhost:2181 --create \
--topic first_topic --partitions 3 --replication-factor 1
```

- Display list of topics:

```
kafka-topics --zookeeper localhost:2181 --list
```

- More detailed information about some topic:

```
kafka-topics --zookeeper localhost:2181 --describe --topic first_topic
```

- Delete topic:

```
kafka-topics --zookeeper localhost:2181 --delete --topic first_topic
```

Kafka Broker Configuration

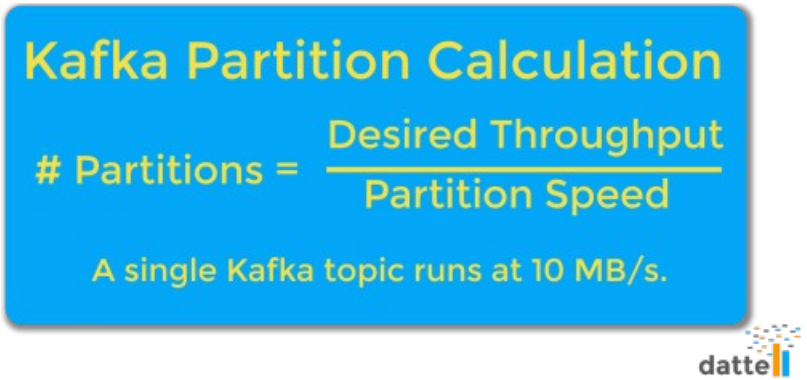
- Kafka Broker defaults to reconsider:
  - auto.create.topics.enable (default: true)
    - It’s not a best practice for an application to automatically create a Topic the first time it is used, especially since each Topic may have a different configuration:
    - log.retention.hours (default: 7 dní): Log retention in Kafka
    - min.insync.replicas (default: 1): When Producer has acks = all, min.insync.replicas specifies minimum number of replicas, that return information that they successfully wrote the message. Correct value is (replication-factor – 1)
    - replication.factor (default: 1): Number of topic replicas. Depends on how many replicas we want to have and number of Brokers, because you cannot have more replikas than brokers.
    - num.partitions (default: 1): Number of partitions. This value determines parallelism.
  - offsets.retention.minutes (default: 24 hodin): After how long unused Consumer offsets in Kafka will be deleted.
- https://www.javierholguera.com/2018/06/13/kafka-defaults-that-you-should-re-consider-i/

Partitions: Throughput

- Topic Partition is a unit of parallelization in Kafka. Both Producer and Consumer can work with different partitions in a fully parallel way. Kafka will send data from one partition only to single Consumer (within one Consumer Group). Thus degree of parallelization(withing one Consumer Group) is limited by number of partitions. Generally, the greater the number of partitions, the greater the throughput.
- https://www.confluent.io/blog/how-choose-number-topics-partitions-kafka-cluster/
- Maximal number of partitions in Kafka:
  - Broker: 4 000 partitions
  - Cluster: 200 000 partitions
    - https://blogs.apache.org/kafka/entry/apache-kafka-supports-more-partitions

Number of Partitions

- How many partitions?
  - There are different opinions on this. I like this the most: 10 partitions, or dependding on what is required throughput computed by this formula:



    - https://dattell.com/data-architecture-blog/kafka-optimization-how-many-partitions-are-needed/
  - Consequences of a bad setup:
    - https://docs.cloudera.com/runtime/7.2.10/kafka-performance-tuning/topics/kafka-tune-sizing-partition-number.html

Kafka REST Proxy

- Kafka REST Proxy offers a REST interface for controlling Kafka, which can do:
  - CRUD operations on Topics
  - Simple Producer & Consumer
- https://github.com/confluentinc/kafka-rest
- List of topics:
  - http://localhost:8082/topics

Kafka UI

https://towardsdatascience.com/overview-of-ui-tools-for-monitoring-and-management-of-apache-kafka-clusters-8c383f897e80

- kafdrop:
  - https://hub.docker.com/r/obsidiandynamics/kafdrop
- kowl
  - https://github.com/cloudhut/kowl
- akhq
  - https://github.com/tchiotludo/akhq
- kafka-ui
  - https://github.com/provectus/kafka-ui

Programmatic access to topic

- You can programmatically create / delete / … topics using AdminClient:
  - https://stackoverflow.com/a/45122955/894643
- How to get list of topics:
  - KafkaConsumer#listTopics()
  - OR:
  - AdminClient#listTopics()

kafka-console-producer

- Easily add messages to a topic from console:

```
kafka-console-producer --broker-list localhost:9092 --topic first_topic
```

- Notes:
  - 1 line = 1 message
  - End: CTRL + C
  - Messages go to random partition (because key is not specified)
  - When we add message to non-existent topic, new topic is automatically created (if this feature is not disabled)
  - How to specify key:

```
kafka-console-producer --broker-list localhost:9092 --topic first_topic \
--property "parse.key=true" --property "key.separator=:"
```

kafka-console-consumer

- Easily read messages from topic (output is to console):

```
kafka-console-consumer --bootstrap-server localhost:9092 \
--topic first_topic

kafka-console-consumer --bootstrap-server localhost:9092 \
--topic first_topic --from-beginning

kafka-console-consumer --bootstrap-server localhost:9092 \
--topic first_topic --from-beginning --partition 0
```

- Other useful parameters:

`--from-beginning` (reads messages from oldest offset)

`--partition X` (reads messages from partition X)

`--offset Y` (reads messages from offset Y)

`--consumer-property group.id=mygroup1` (sets group.id)

Custom Deserializer

- Kafka-console-consumer (and other tools) can work only with some data formats (kafka-console-consumer can practically work only with Strings). If you use different formats, it may be needed to add custom deserializer. For example when values are in Double:

```
kafka-console-consumer --bootstrap-server kafka:9092 \
  --group ConsoleConsumer --from-beginning --topic TODO_TOPIC_NAME \
  --property \
    value.deserializer=org.apache.kafka.common.serialization.DoubleDeserializer
```

- https://stackoverflow.com/questions/44530773/kafka-stream-giving-weird-output

kafkacat

- Kafkacat is an alternative to kafka-console-producer/consumer tools:
  - https://docs.confluent.io/platform/current/app-development/kafkacat-usage.html
- Examples:
  - List of topics:
    - `docker run --rm --tty --network kafka_net confluentinc/cp-kafkacat kafkacat -b kafka:9092 -L`
  - Kafkacat acting as a consumer of topic „first_topic“:
    - `docker run --rm --tty --network kafka_net confluentinc/cp-kafkacat kafkacat -b kafka:9092 -t first_topic`
  - Kafkacat acting as a producer to topic „first_topic“:
    - `docker run --rm --tty --network kafka_net confluentinc/cp-kafkacat kafkacat -b kafka:9092 -t first_topic -P`
      - Input should be confirmed by CTRL+D, but for some reason it doesn’t work for me :-(

pom.xml

```
<dependencies>
    <dependency>
        <groupId>org.apache.kafka</groupId>
        <artifactId>kafka-clients</artifactId>
        <version>3.1.0</version>
    </dependency>
</dependencies>

<build>
    <plugins>
        <plugin>
            <groupId>org.apache.maven.plugins</groupId>
            <artifactId>maven-compiler-plugin</artifactId>
            <configuration>
                <source>1.8</source>
                <target>1.8</target>
            </configuration>
        </plugin>
    </plugins>
</build>
```

MyProducer

acks values: 0, 1, -1 (all)

```java
public class MyProducer {

    public static void main(String[] args) {
        Properties properties = new Properties();
        properties.setProperty(ProducerConfig.BOOTSTRAP_SERVERS_CONFIG, "localhost:9092");
        properties.setProperty(ProducerConfig.KEY_SERIALIZER_CLASS_CONFIG, StringSerializer.class.getName());
        properties.setProperty(ProducerConfig.VALUE_SERIALIZER_CLASS_CONFIG, StringSerializer.class.getName());
        properties.setProperty(ProducerConfig.ACKS_CONFIG, "1");
        properties.setProperty(ProducerConfig.RETRIES_CONFIG, "3");

        try(Producer<String, String> producer = new KafkaProducer<>(properties)) {
            ProducerRecord<String, String> producerRecord
               = new ProducerRecord<>("first_topic", "mykey", "myvalue");
            producer.send(producerRecord);
            producer.flush(); // can be replaced with properties.setProperty("linger.ms", "1");
        }
    }

}
```

How Producer works

1) Producer establishes a connection with one of the bootstrap servers (Kafka Broker), the best practice is to set up at least two bootstrap servers in the Producer's configuration.
2) The Bootstrap server returns a list of all brokers in the cluster and metadata such as topics, partitions, replication factors etc.
3) Based on this Producer identifies the leader broker, which has the leader partition and writes messages to this partition.

- https://dzone.com/articles/kafka-producer-overview
- Producer performs all these operations in thread kafka-producer-network-thread (Sender), which is daemon thread:
  - https://jaceklaskowski.gitbooks.io/apache-kafka/content/kafka-producer-internals-Sender.html
- Producer IS thread safe!!!
  - https://stackoverflow.com/questions/36191933/using-kafka-producer-by-different-threads

Producer Configuration I.

- acks
  - The number of acknowledgments the producer requires the leader to have received before considering a request complete. This controls the durability of records that are sent.
  - The default value is „all“. This setting refers to the min.insync.replicas setting (in Topicu), which sets the number of brokers which must log a message before an „acknowledge“ is sent to the client. The default value of min.insync.replicas is 1. The correct settings depends on „replication factor“. If the replication factor is 3, then the correct value of min.insync.replicas is 2.
  - https://docs.confluent.io/platform/current/installation/configuration/producer-configs.html#producerconfigs_acks
- https://strimzi.io/blog/2020/10/15/producer-tuning/
- https://www.javierholguera.com/2018/06/13/kafka-defaults-that-you-should-re-consider-i/

Producer Configuration II.

- retries
  - How many times the Producer will try to deliver the message to Kafka broker. The default value is 0. When retries is set to a higher value than 0, then max.in.flight.requests.per.connection = 1 should be set, otherwise the message that is sent in retry mode could be delivered in wrong order.
    - https://docs.confluent.io/platform/current/installation/configuration/producer-configs.html#producerconfigs_retries
- compression.type
  - Compression is useful for increasing throughput and reducing storage, but may not be suitable for low-latency applications, because compression and decompression will inevitably increase latenci.
  - Supported types: gzip, snappy, lz4, zstd

Producer Configuration III.

- Batching of messages will increase throughput. Important settings:
  - batch.size
    - Maximum batch size
  - linger.ms
    - Maximum time until the batch is sent
  - Messages will be sent if one of these two parameters is reached
- buffer.memory:
  - When Kafka Producer cannot send data to the Broker (for example due to a Broker outage), it will store messages up to buffer.memory. Once the buffer.memory is full (default value: 32 MB), it will wait max.block.ms (default: 60s) if the buffer was empties. If this time elaspes and the buffer is not emptied, then an exception is thrown.

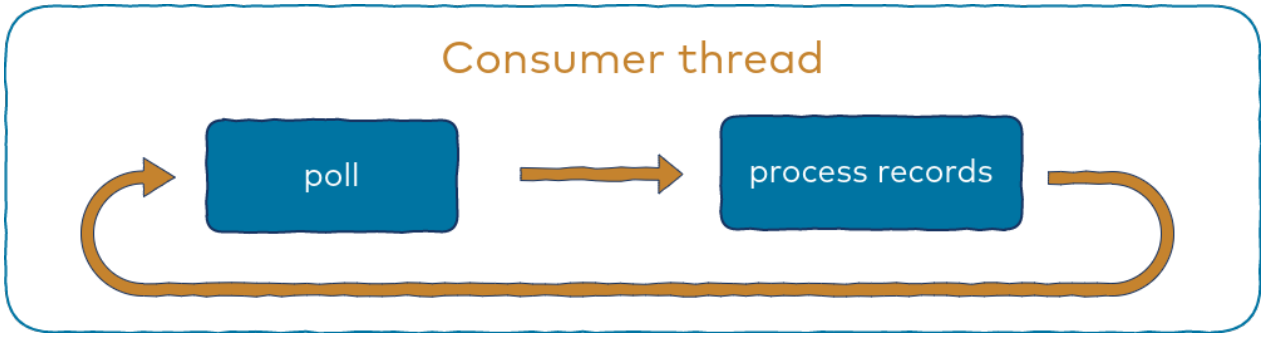
MyConsumer

```java
public class MyConsumer {

    public static void main(String[] args) {
        Properties properties = new Properties();
        properties.setProperty(ConsumerConfig.BOOTSTRAP_SERVERS_CONFIG, "localhost:9092");
        properties.setProperty(ConsumerConfig.KEY_DESERIALIZER_CLASS_CONFIG, StringSerializer.class.getName());
        properties.setProperty(ConsumerConfig.VALUE_DESERIALIZER_CLASS_CONFIG, StringSerializer.class.getName());
        properties.setProperty(ConsumerConfig.GROUP_ID_CONFIG, "test");
        properties.setProperty(ConsumerConfig.ENABLE_AUTO_COMMIT_CONFIG, "true");
        properties.setProperty(ConsumerConfig.AUTO_COMMIT_INTERVAL_MS_CONFIG, "1000");
        properties.setProperty(ConsumerConfig.AUTO_OFFSET_RESET_CONFIG, "earliest");

        KafkaConsumer<String, String> consumer = new KafkaConsumer<>(properties);
        consumer.subscribe(Arrays.asList("first_topic"));
        while(true) {
            ConsumerRecords<String, String> records = consumer.poll(Duration.ofSeconds(1));
            records.forEach(record -> {
                System.out.println(record.key() + ":" + record.value());
            });
        }
    }

}
```

Alternative to:
`consumer.commitSync();`

How Consumer Works I.

- Consumer performs polling:



- By default, Consumer stores offsets in Kafka. You can use `auto.commit.interval.ms` to change commit frequency. Offsets are not commited in separate thread, but are commited in the same thread in which the polling is performed. Only offsets that were processed in the previous call of poll method are commited. Because processing of messages is done between calls of poll methods, offsets of unprocessed messages will never be processed. This guarantees at-least-once delivery.
- Because messages are retrieved and processed in the same thread, they are processed in the same order in which they were written to the partition. This guarantees the order of processing.
- Consumer IS NOT thread safe!!! https://chrzaszcz.dev/2019/06/16/kafka-consumer-poll/
  - https://www.confluent.io/blog/kafka-consumer-multi-threaded-messaging/

How Consumer Works II.

- An interesting configuration of Consumer is `max.poll.records` (default: 500 messages), which sets the maximum number of messages returned in a single poll() metod call. If zou increase this value or your messages in Kafka are larger, then this setting is also important: `max.partition.fetch.bytes` (default: 1 MB). This specifies maximum number of bytes that the server will return per partition.
  - Why these restrictions? In order to protect the Consumer against a situation where are a large number of record in Kafka, or those records have large size.
- Another configuration: `fetch.min.bytes`, which sets minimum number of bytes that Kafka should have in Topic in order to return some data to client (default: 1 byte). This settings increases throughput, but also increases latency. When using it, it may also make sense to set up `fetch.max.wait.ms`, thanks to which Kafka doesn’t wait only for min.bytes, but after wait.ms time has elapsed, the Broker will send data to the client (default: 500 ms).

How Consumer Works III.

- Only records that have been written to all in-sync replicas are sent to the Consumer. This is for data consistency and thanks to this setting there cannot be a situation, where the leader would receive the message, the client would read it, the leader would crash before it could replicate the message to replicas, some replica is promoted to leader and suddenly there wouldn’t be message in Topic, but it would be consumed by client.
  - This also means, that if for some reason data replication between brokers is slow, then it will také longer for messages to reach clients (because first broker waits for them to be replicated to another brokers before it sends them to the clients).

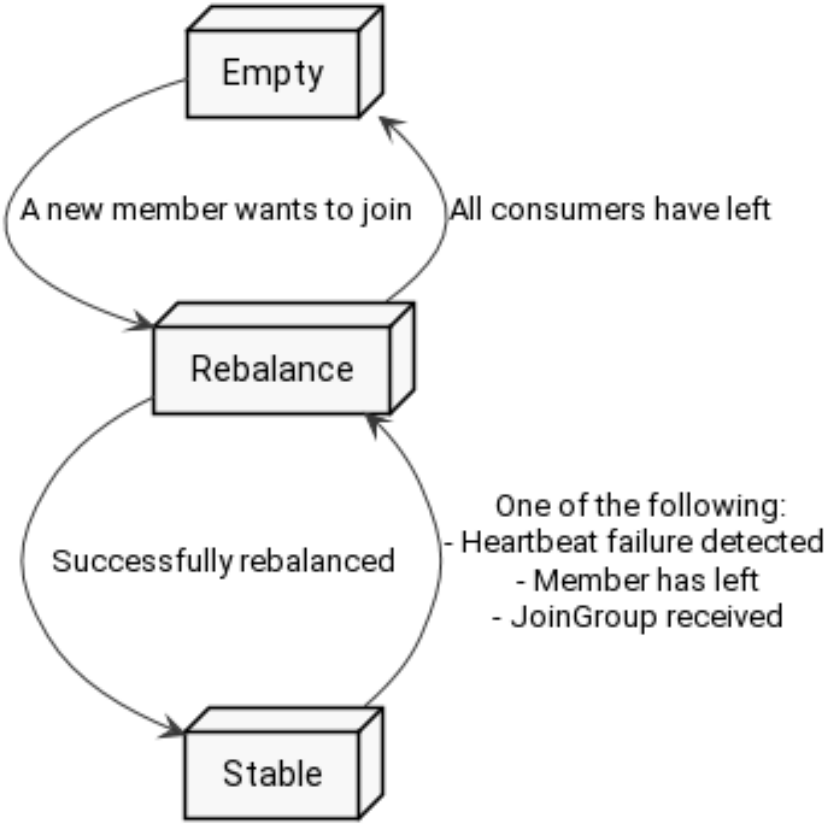
Consumer: Group Leader vs. Followers

- Group Leader is one of the Consumers (in practice the first Consumer to join the group), which functions as a normal Consumer and normally consumes data from Kafka, but in addition, when rebalancing, it decides which Consumer will consume which partition.
- Partition assignment can be changed using property partition.assignment.strategy:
  - https://medium.com/streamthoughts/understanding-kafka-partition-assignment-strategies-and-how-to-write-your-own-custom-assignor-ebeda1fc06f3
- Kafka has 3 build-in strategies:
  - Range (default)
  - RoundRobin
  - StickyAssignor
- If you change the default strategy, then it is important that all Consumers in the Consumer Group must have the same strategy!

How Consumer Works: Group Rebalancing I.

- When new Consumer joins a Consumer Group, an existing Consumer leaves the group, or a partition is added to one of the subscribed topics, „Group Rebalancing“ is started.
- Consumer Group can be in one of these states:
  - Empty: Consumer Group exists, but is empty
  - Stable: Rebalancing has taken place and Consumers and consuming messages
  - Preparing Rebalance & Completing Rebalance
  - Dead

Simplified graph of states and transitions between them:

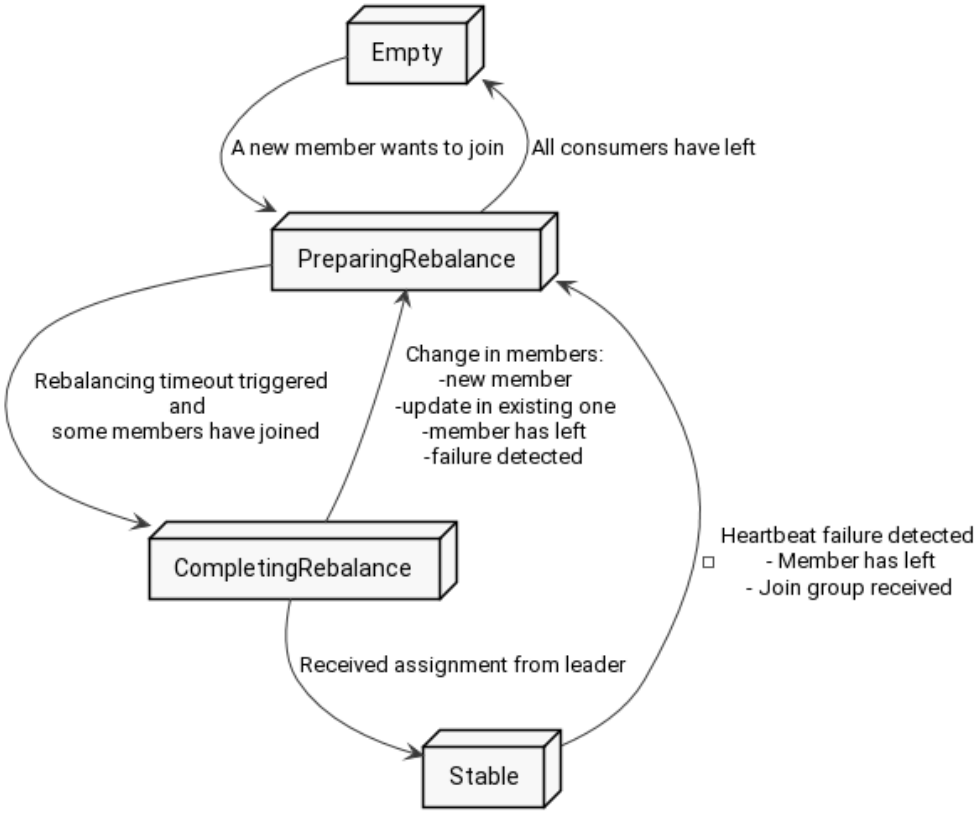


- https://chrzaszcz.dev/2019/06/kafka-rebalancing/

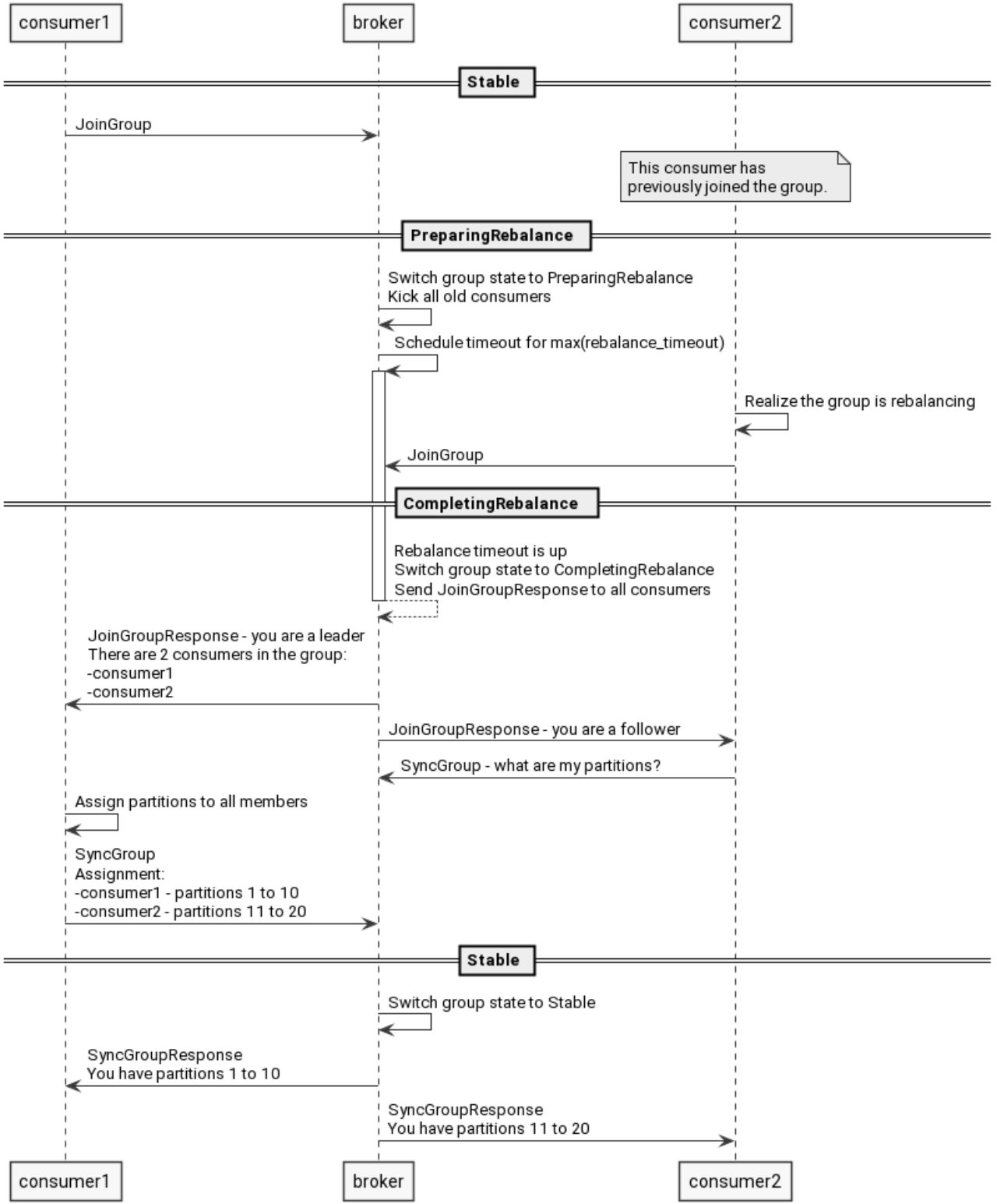
https://www.confluent.io/blog/kafka-consumer-multi-threaded-messaging/#group-rebalancing

How Consumer Works: Group Rebalancing II.

- Rebalancing (from high-level perspective):
  - New Consumer sends a request to one of the bootstrap servers that it wants to join the Consumer Group.
  - Kafka changes state of group to PreparingRebalancing, disconnects all current members and waits until they reconnect.
  - Kafka:
    - Selects one Consumer as Group Leader
    - Sends all Consumers info that they successfully joined group
    - To Leader sends list of followers
  - Followers send request to partitions, which will be processing
  - Leader decides which partitions will be sent to whom and sends this information to Kafka
  - Kafka receives list of partitions from leader and sends to leader and follower which partitions they should process

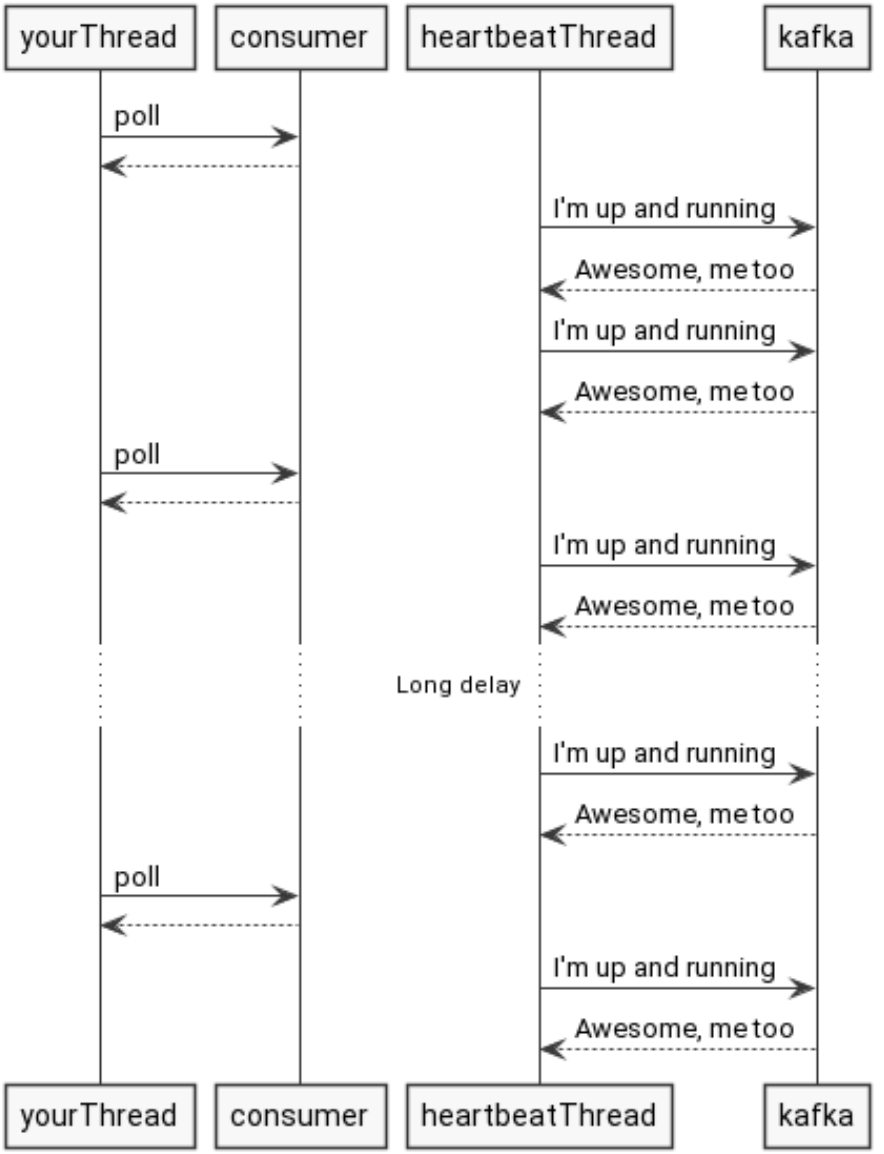


https://chrzaszcz.dev/2019/06/kafka-rebalancing/


consumer1
broker
consumer2
Stable
JoinGroup
This consumer has previously joined the group.
PreparingRebalance
Switch group state to PreparingRebalance
Kick all old consumers
Schedule timeout for max(rebalance_timeout)
Realize the group is rebalancing
JoinGroup
CompletingRebalance
Rebalance timeout is up
Switch group state to CompletingRebalance
Send JoinGroupResponse to all consumers
JoinGroupResponse - you are a leader
There are 2 consumers in the group:
-consumer1
-consumer2
JoinGroupResponse - you are a follower
SyncGroup - what are my partitions?
Assign partitions to all members
SyncGroup
Assignment:
-consumer1 - partitions 1 to 10
-consumer2 - partitions 11 to 20
Stable
Switch group state to Stable
SyncGroupResponse
You have partitions 1 to 10
SyncGroupResponse
You have partitions 11 to 20
consumer1
broker
consumer2

How Consumer Works: Heartbeat

- Consumer has thread kafka-coordinator-heartbeat-thread, which determines if the connection to Kafka works.
  - https://chrzaszcz.dev/2019/06/kafka-heartbeat-thread/
- Heartbeat configuration parameters:
  - `heartbeat.interval.ms`: Frekvency of sending heartbeat requests, default: 3s
  - `session.timeout.ms`: Time interval, in which the Broker must obtain at least one request from Consumer, otherwise it considers Consumer dead, default: 10s
- https://stackoverflow.com/questions/43881877/difference-between-heartbeat-interval-ms-and-session-timeout-ms-in-kafka-consume



How Consumer Works: Heartbeat

- Another significant konfiguration: `max.poll.interval.ms` (default: 5 minut). If data processing takes longer than this setting, then the Broker considers Consumer dead, kicks him out of the Consumer Group and performs rebalancing.

Spring + Kafka

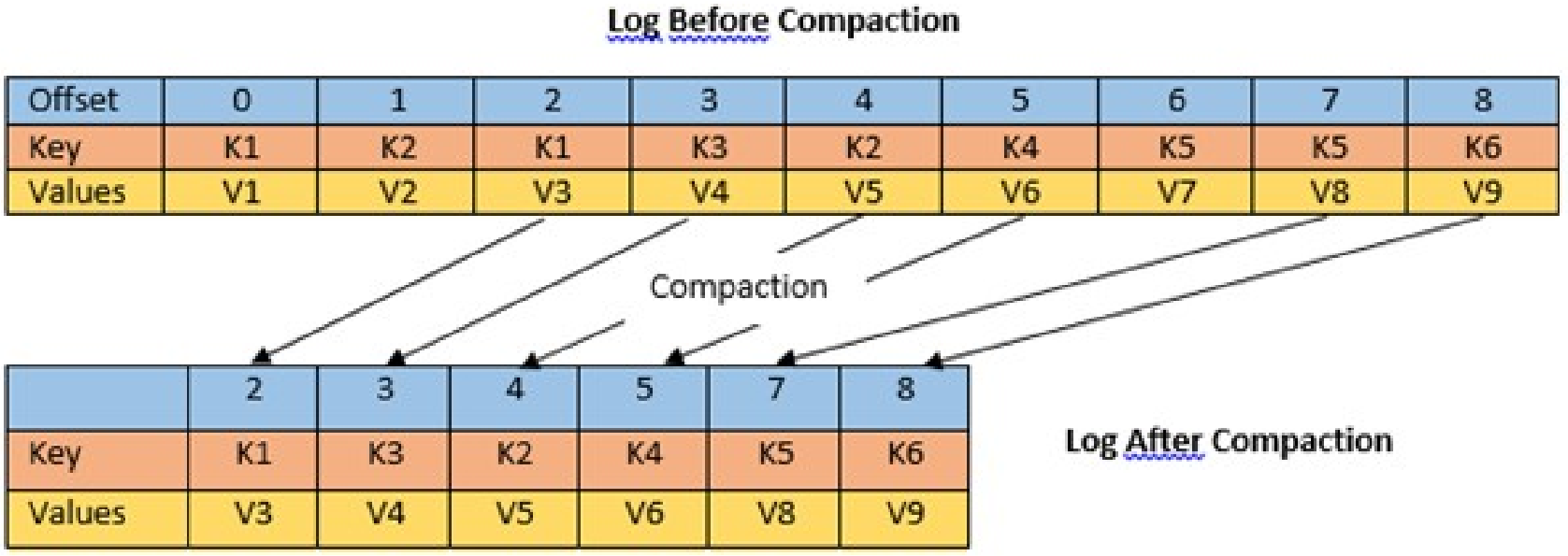
- Documentation:
  - https://spring.io/projects/spring-kafka
- KafkaTemplate IS thread-safe!
- Working project:
  - https://memorynotfound.com/spring-kafka-json-serializer-deserializer-example/
- Spring + Avro:
  - https://www.codenotfound.com/spring-kafka-avro-bijection-example.html

Spring Cloud Streams

- Even greater abstraction than Spring Kafka.
- https://piotrminkowski.com/2021/11/11/kafka-streams-with-spring-cloud-stream/
- https://medium.com/geekculture/spring-cloud-streams-with-functional-programming-model-93d49696584c
- https://www.baeldung.com/spring-cloud-stream-kafka-avro-confluent

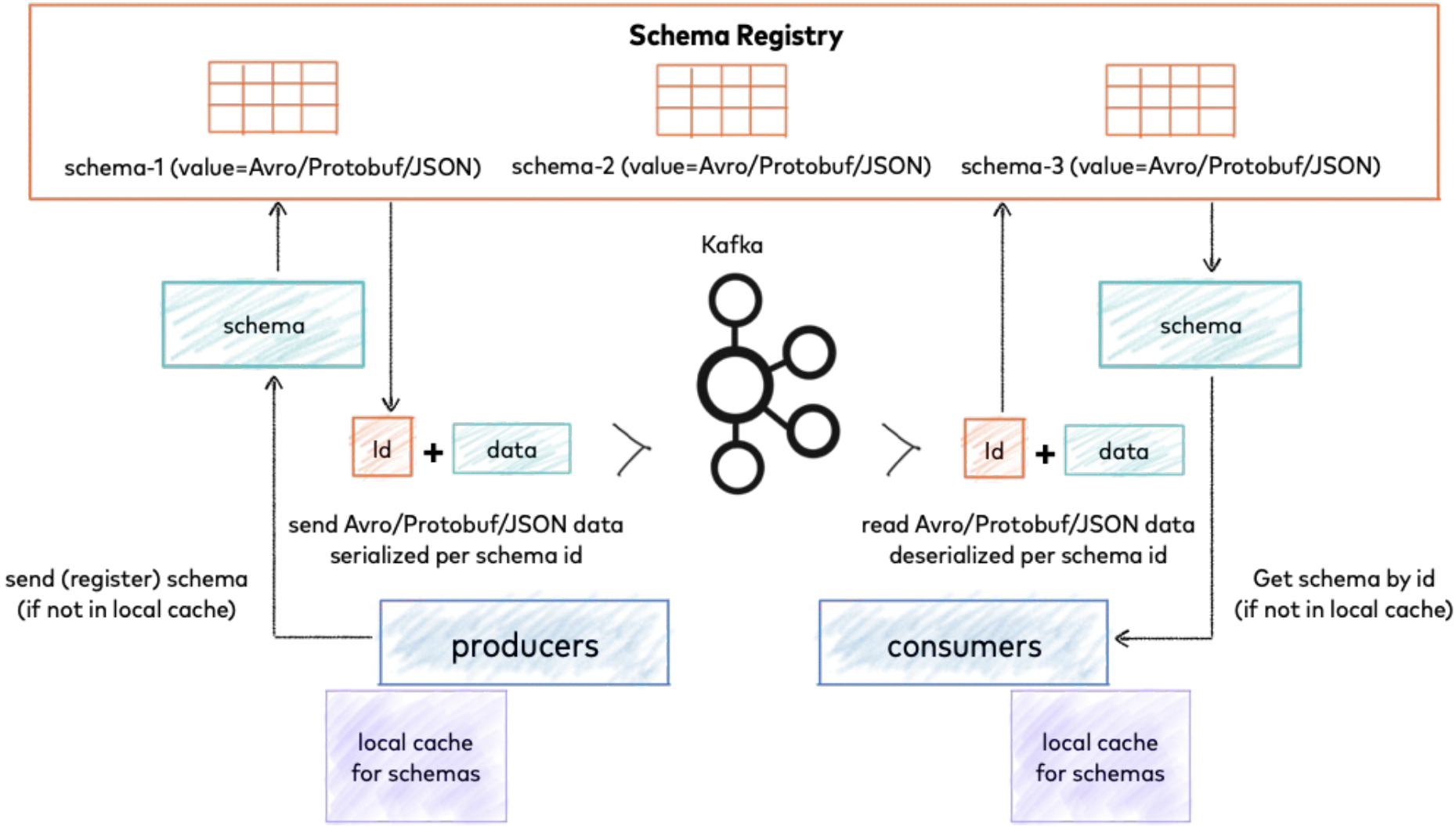
Log Compaction

- Sometimes you may want to use Topic Log Compaction:
  - https://medium.com/swlh/introduction-to-topic-log-compaction-in-apache-kafka-3e4d4afd2262
- It is a mechanism, that selectively deletes old records for which there are newer records with the same key. Beware! If you don't use key (it is NULL), then you cannot use Log Compaction!



Schema Registry + Avro

Schema Registry



Avro + Schema Registry II.

- V případě, že chceme použít jako formát dat Avro, pak musíme specifikovat schéma. Schémata se nachází ve Schema Registry:
  - Landoop: http://localhost:3030/api/schema-registry/
  - Confluent: http://localhost:8081
- Konfigurace:
  - https://docs.confluent.io/platform/current/schema-registry/index.html
    - Schémata jsou uložena v Kafce v topicu `_schemas`
    - Názvy schémat mají následující formát: `<topic>-key, <topic>-value`
- Schema Registry obsahuje REST API, pomocí kterého se s ním dá pracovat:
  - https://github.com/confluentinc/schema-registry
- Nebo přes Maven:
  - https://docs.confluent.io/platform/current/schema-registry/develop/maven-plugin.html
- Seznam všech schémat:
  - http://localhost:8081/schemas

Poznámka: Schéma v registry se nazývá „subject“, tohle vrátí jejich seznam: http://localhost:8081/subjects

Avro + Schema Registry I.

- Message in Kafka can have any format (String, JSON, XML, binary). Kafka is agnostic to the serialization format. For Kafka key and value are just an array of bytes. However, this has the disadvantage, that we must ensure that Producer a Consumer understand each other.
- The solution to this problem is a schema. Default schema in Kafka is Avro. Supported are also JSON Schema and Protobuf. Another advantage of schema is that data can be stored more efficiently in Kafka. Specifically, when using Afro schema, attribute names are not stored internally in the data, it has a binary format and thus is more compact than for example JSON.
  - https://www.baeldung.com/java-apache-avro
  - https://www.confluent.io/blog/avro-kafka-data/
  - http://avro.apache.org/docs/current/
    - There is also Maven plugin, which generates Java classes from .avsc files.
  - https://medium.com/slalom-technology/introduction-to-schema-registry-in-kafka-915ccf06b902

Schema Compatibility

- Schema can have one of the compatibility types:
  - NONE
  - FORWARD
  - BACKWARDS (default)
  - FULL
- For default BACKWARDS compatibility, these changes cause a breaking change:
  - Adding or removing field without a default value
  - Change of name or type of a field
  - Change of enum values if there’s not default enum symbol
- Notes:
  - Compatibility can be set globally, or per schema
  - Change of schema is done using REST API

kafka-avro-console-producer/consumer

```
kafka-avro-console-producer --broker-list localhost:9092 --topic first_topic_avro \
  --property parse.key=true \
  --property key.schema='{"type":"string"}' \
  --property value.schema='{"type":"record","name":"myrecord","fields":[{"name" : "name",
"type" : "string"}, {"name" : "age", "type" : "int"}]}'
```

```
Messages:

"jirka"<TAB>{ "name" : "Jirka Pinkas", "age" : 40 }
```

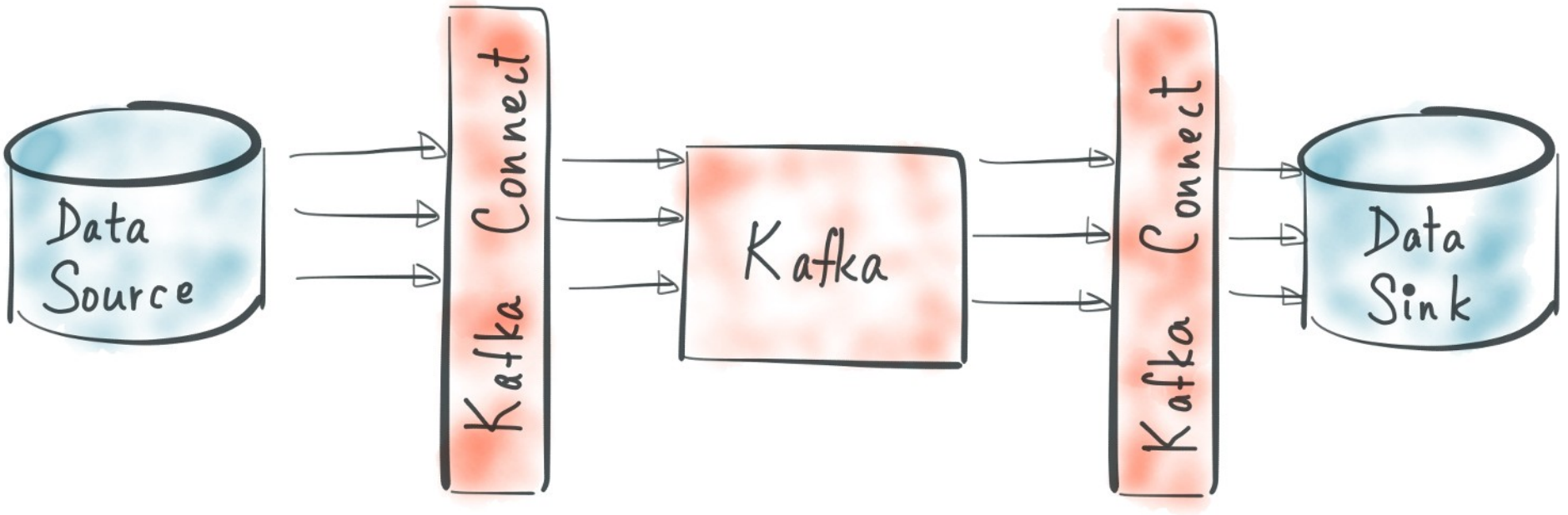
Press TAB, because key is separated from value with tabulator

```
kafka-avro-console-consumer --topic first_topic_avro --bootstrap-server localhost:9092
```

Note: kafka-avro-console-producer will create two schemas:
- first_topic_avro**-key**
- first_topic_avro**-value**

http://localhost:3030/schema-registry-ui/

Kafka Connect


Data Source
Kafka Connect
Kafka
Kafka Connect
Data Sink

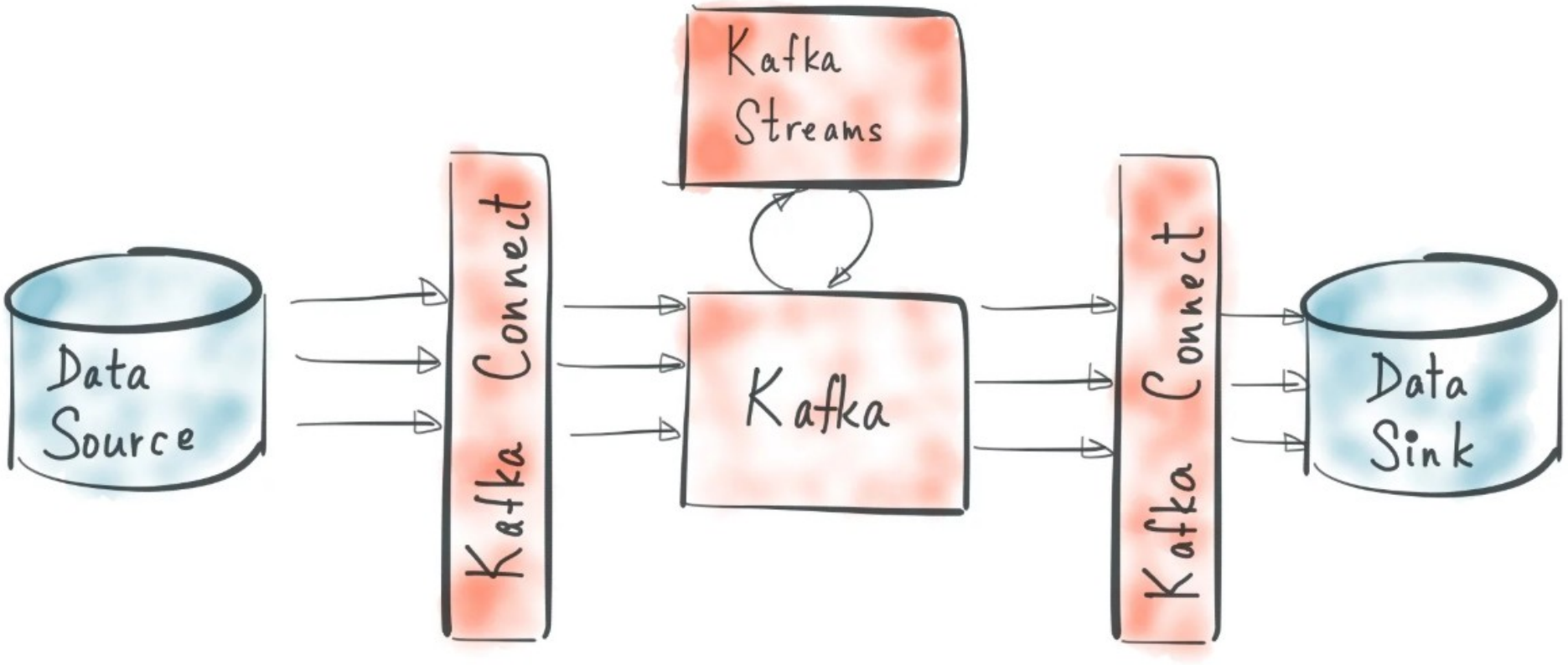
Basic concepts

- Source => Kafka = Kafka Connect Source
- Kafka => Sink = Kafka Connect Sink
- Kafka Connect contains Connectors
- Connectors + Configuration => Tasks
- Tasks are performed by processes called „Workers“ (servers):
  - Worker = Java process
  - Worker can be:
    - Standalone – one (only for testing, state of the worker is stored locally)
    - Distributed – whole cluster (ideally everywhere, not only for production, but also for testing, because configuration of Standalone worker is different than configuration of Distributed worker. State of the worker is stored in Kafka topic)

Debezium

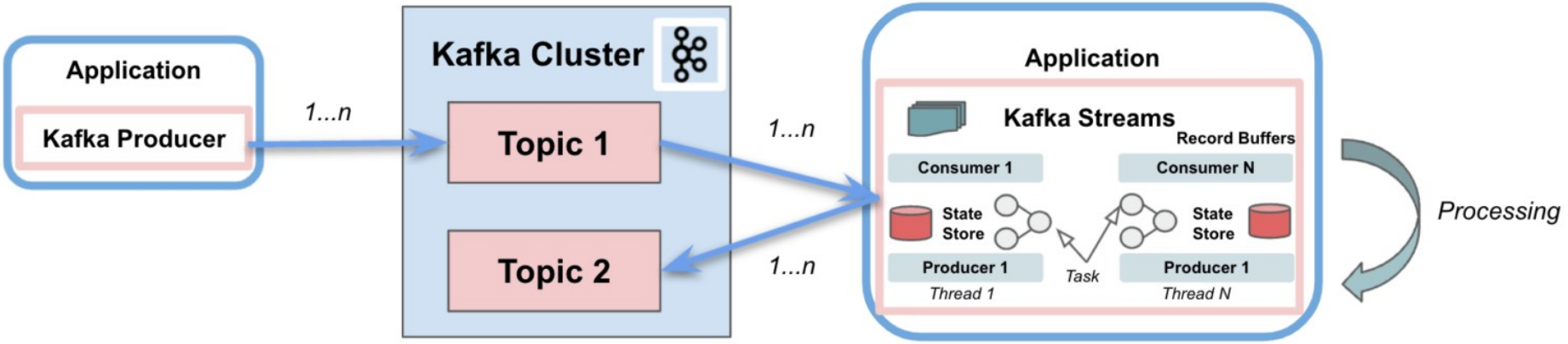
- Debezium is a project build on Kafka Connect and implements CDC (Change Data Capture)

Kafka Streams


Kafka
Streams
Data
Source
Kafka Connect
Kafka
Kafka Connect
Data
Sink

Kafka Streams

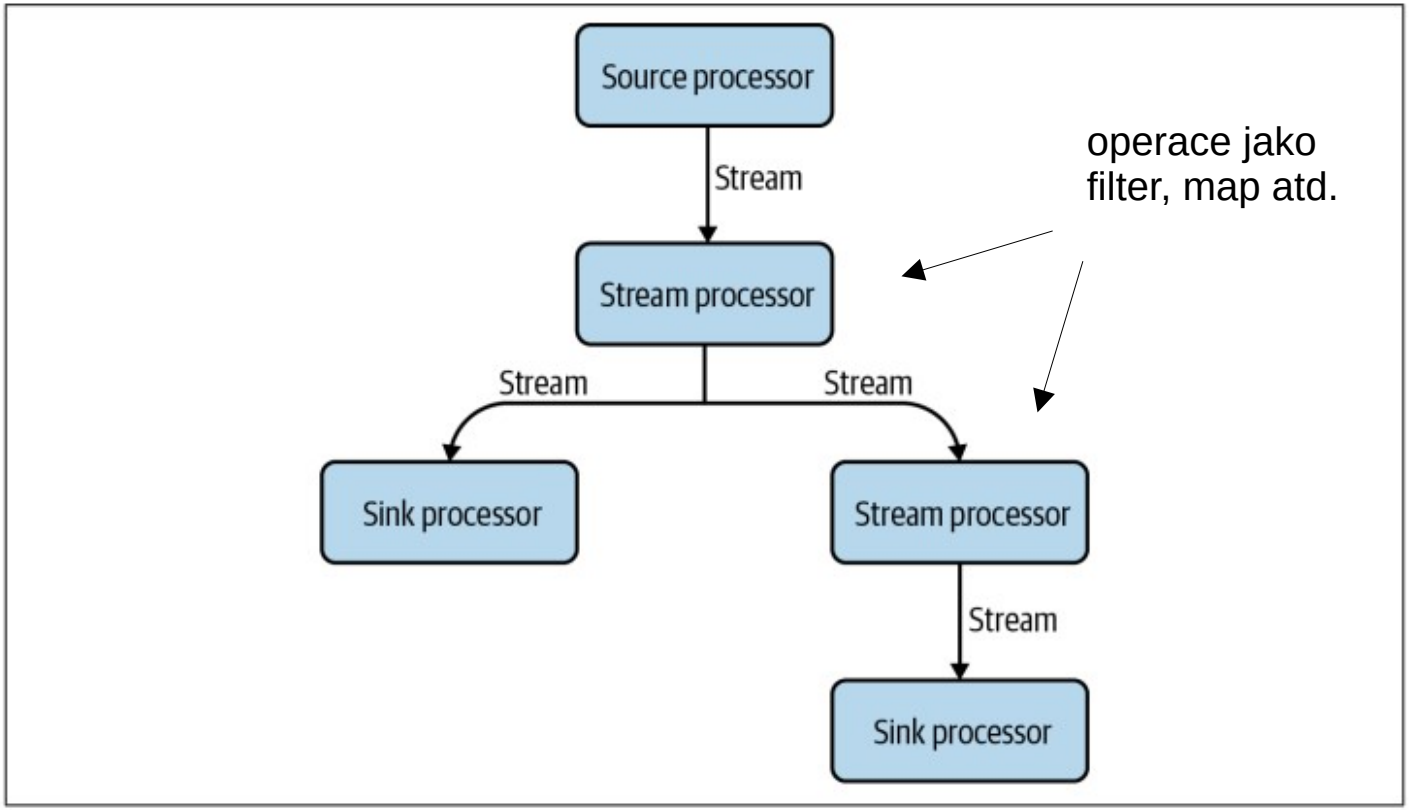
- Kafka Streams is a library that is used to obtain to data from Kafka Topic, their subsequent transformation and storage into another Kafka Topic.
- Kafka Streams are built on Kafka client libraries (Kafka Consumer & Producer) and nowadays it is tyically Spring Boot console application which usually runs in our Kubernetes cluster:



- https://www.baeldung.com/java-kafka-streams-vs-kafka-consumer
- Kafka Consumer API vs. Streams API:
  - https://stackoverflow.com/questions/44014975/kafka-consumer-api-vs-streams-api

Processor Topology

- Kafka Streams application is structured as directed acyclic graph (DAG). The node is a „processing step“ and the end nodes are either input from the topic (source), or output (sink):



pom.xml

```
<dependencies>
    <dependency>
        <groupId>org.apache.kafka</groupId>
        <artifactId>kafka-streams</artifactId>
        <version>2.0.0</version>
    </dependency>
</dependencies>

<build>
    <plugins>
        <plugin>
            <groupId>org.apache.maven.plugins</groupId>
            <artifactId>maven-compiler-plugin</artifactId>
            <configuration>
                <source>1.8</source>
                <target>1.8</target>
            </configuration>
        </plugin>
    </plugins>
</build>
```

Hello World

This is something like Consumer group.id

Messages are read from last offset (or 0)

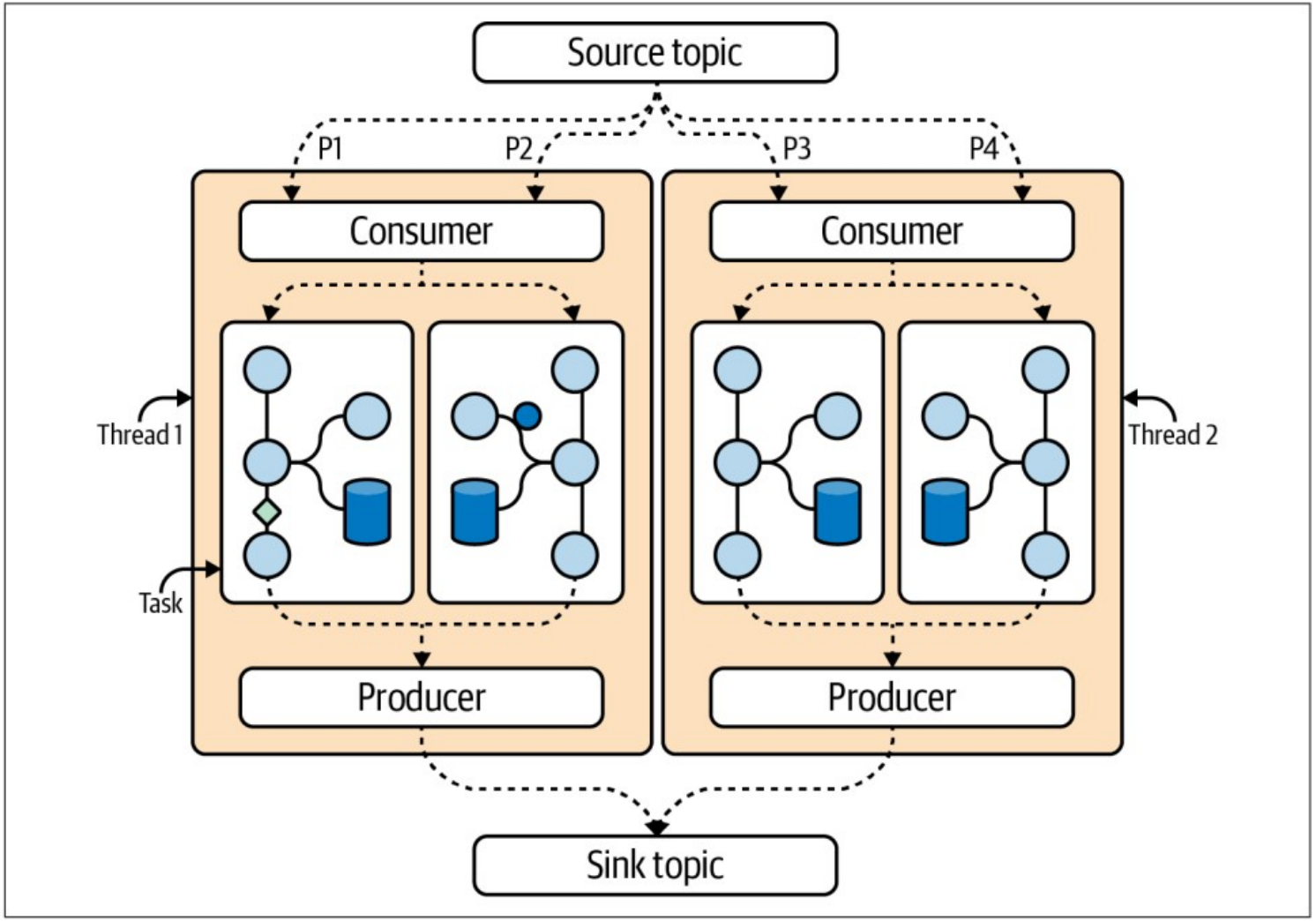
```java
public class Main {

    public static void main(String[] args) {
        Properties properties = new Properties();
        properties.put(StreamsConfig.APPLICATION_ID_CONFIG, "kafka-streams-app");
        properties.put(StreamsConfig.BOOTSTRAP_SERVERS_CONFIG, "localhost:9092");
        properties.put(ConsumerConfig.AUTO_OFFSET_RESET_CONFIG, "earliest");
        properties.put(StreamsConfig.DEFAULT_KEY_SERDE_CLASS_CONFIG, Serdes.String().getClass());
        properties.put(StreamsConfig.DEFAULT_VALUE_SERDE_CLASS_CONFIG, Serdes.String().getClass());

        StreamsBuilder builder = new StreamsBuilder();
        KStream<String, String> stream = builder.stream("first_topic");
        stream
                .mapValues(s -> s.toLowerCase())
                .to("first_topic_lowercase");

        KafkaStreams streams = new KafkaStreams(builder.build(), properties);
        streams.start();
        Runtime.getRuntime().addShutdownHook(new Thread(streams::close));
    }
}
```

Graceful shutdown

Note: If you want something like --from-beginning, then you must:
- change application id
- or before streams.start() call streams.cleanUp()

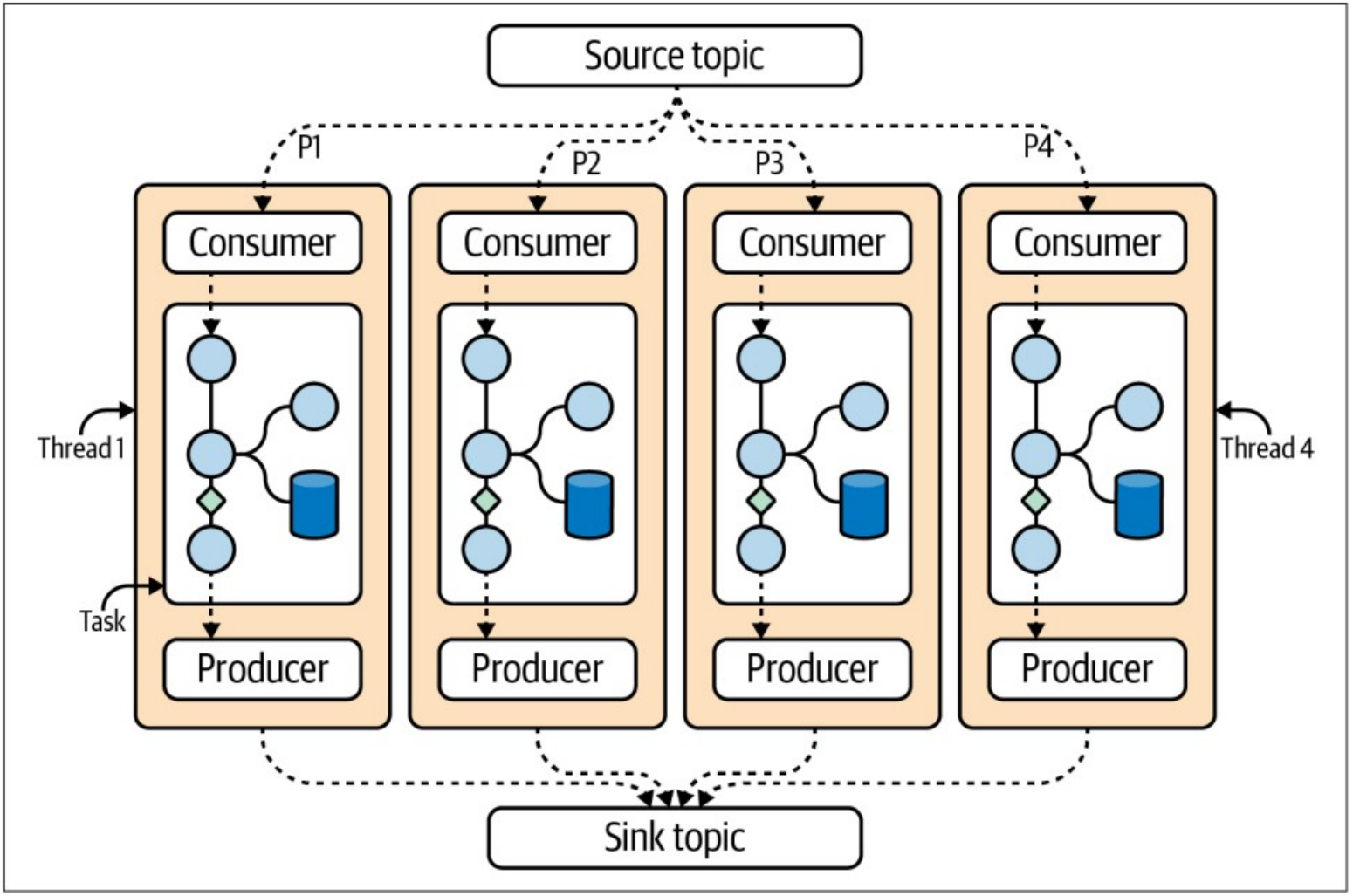
Kafka Streams Internals

- 4 Kafka Streams tasks running in 2 threads:



Kafka Streams Internals

- 4 Kafka Streams tasks running in 4 threads:



Tasks

- Task = the smallest „unit of work“ of Kafka Streams application. The number of tasks is derived from the number of input partitions. If we have Kafka Streams application, which uses only one input topic, then the number of tasks is equal to the number of partitions of that topic. If the application uses more input topics, then the number of tasks is equal to the maximum number of partitions that any of the topics has.
- Tasks are assigned to the StreamThread, that executes them. By default, there is one StreamThread in the application. If you have 5 tasks, then their logic is executed sequentially. If you have 5 threads (or 5 instances of the application with the same application.id), then the tasks will be executed in parallel.
- https://developer.confluent.io/learn-kafka/kafka-streams/internals/

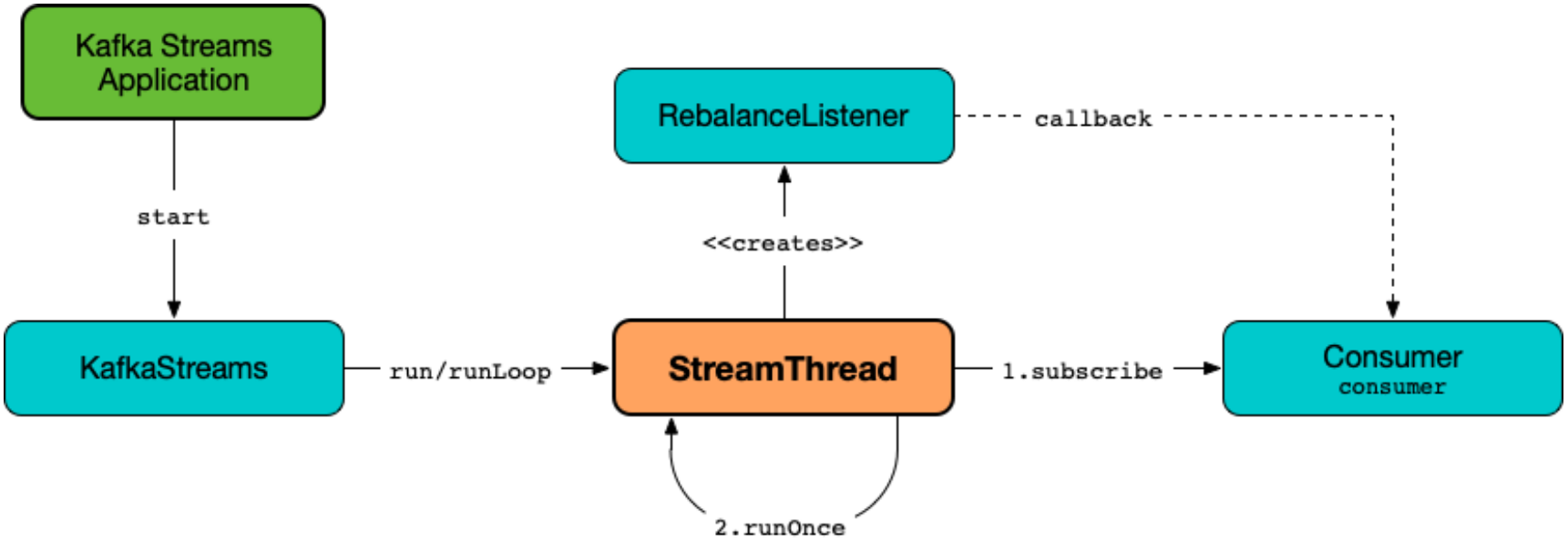
Stream & Threading

- Method KafkaStreams#start() starts Kafka Stream, which contains these threads:
  - Note: Number of these threads can be changed by property num.stream.threads (default 1 thread):
    - ClientId-StreamThread
      - The main thread, that subscribes to Consumer. If we want exactly X threads to get data from input topic, then the topic must have X exactly partitions!
    - kafka-coordinator-heartbeat-thread
      - Consumer heartbeat thread
    - kafka-producer-network-thread
      - Kafka Producer thread
  - ClientId-CleanupThread
    - Used for cleaning StateDirectory
  - kafka-admin-client-thread
    - This thread uses Kafka AdminClient and creates StreamThread

StreamThread

- StreamThread
  - https://medium.com/@andy.bryant/kafka-streams-work-allocation-4f31c24753cc
- How to get number of running Consumers:

```
kafka-consumer-groups --bootstrap-server kafka:9092 --describe --group STREAM_APPLICATION_ID
```



Stream Threads

- There is no shared state between threads. From a Kafka Streams perspective, it doesn’t matter if we achieve parallelism by increasing num.stream.threads, or by running more instances of a Kafka Streams application with the same application.id.
- Personally, however, I would prefer to scale by using multiple instances for the following reasons:
  - Higher throughput
  - Better resource utilization
  - Better resilience to individual instance failures

Depth first processing

- When Stream starts processing a message from the input topic, that message must go through the whole topology in order for another message to be processed. The advantage is that the behaviour of the stream is easy to understand. The disadvantage is that when a processing operation is slow, it will block the processing of other messages.
  - **Note!!!** This is also true for sub-topology, but for each sub-topology separately and each must be performed in a dedicated thread. When there are 2 sub-topologies, there must be at least either 1 instance of the Streams application with num.stream.threads=2, or 2 instances with num.stream.threads=1
    - Sub-topology is when withing a topology data are stored to sink processor and then are read by another source processor.
    - How to get Topology Description:

```
Topology topology = streamsBuilder.build();
log.info("Topology description {}", topology.describe());
```

    - Topology vizualizer:
      - https://zz85.github.io/kafka-streams-viz/
  - https://medium.com/@andy.bryant/kafka-streams-work-allocation-4f31c24753cc

Stateless operations

- Stateless Kafka Streams applications are the simplest streams. They do not require any knowledge of previous events, do not store any state, they just také input data, perform processing and store the result to output topics.

mapValues(), map()

- mapValues()
  - Transforms every value in stream.
- map()
  - Transforms not only values, but also keys.
- If it is not necessary to perform a key transformation, then we should always prefer mapValues() operation, because it does not trigger re-partitioning.
- Similar operations are transformValues() and transform(), which use the low-level Processor API:
  - https://docs.confluent.io/platform/current/streams/developer-guide/processor-api.html

filter(), filterNot()

- filter()
  - Filters messages from stream
  - Doesn’t make changes in keys / values
- filterNot()
  - filter() negation

foreach(), peek(), print()

- foreach() is classical foreach cycle :-), it is a terminal operation
- peek() does basically the same as foreach, but it’s an intermediate operation. Peek MUST be idempotent (cannot have side-effects)!
- print() is only for debugging and to print every message in stream, it is a terminal operation

branch(), merge()

- branch() splits stream based on 1 .. N predicates to array of streams.
- From Kafka 2.8.0 it’s used in conjunction with the split() operation
- We would achieve a similar result by applying multiple filter() operations.
- The opposite operation is merge(), which combines messages from two streams together

selectKey()

- selectKey() performs a transformation of a key to a new value.

flatMapValues(), flatMap()

- Input is one message, output is 0, 1 or N messages.
- flatMapValues()
  - Doesn’t make changes in keys
  - Only for KStream
- flatMap()
  - Allows changes in keys
  - Only for KStream

to(), through(), repartition()

- KStream or KTable output can be saved to any topic using the following methods:
  - to(): terminal operation – writes data to topic and ends stream
  - through(): writes data to topic and returns new KStream or Ktable. From Kafka 2.6 deprecated.
    - repartition(): newer replacement of through()
    - Both through() and repartition() is a short version of KStream#to() followed by StreamsBuilder#stream()
      - Why use through() / repartition()? As the data are written to the topic, one topology is divided to two sub-topologies, thus increasing the parallelism of the Kafka Streams application.
      - With through() you had to manually create topic, to which you would store data. With repartition() the topic is created automatically, it is named KSTREAM-REPARTITION-XXXXX-repartition and in Kafka Streams application you can easily set up number of partitions of this topic.

Stateful operations

- Use-cases:
  - Joining data
  - Aggregating data
  - Windowing Data
- The state is stored in the „state store“. Kafka Streams application may contain multiple state stores. State store is fyzically in Kafka Streams application, not in Kafka. Default implementation is RocksDB.
- To ensure failover, the state is also in a Kafka topic called:
  - <application.id>-<storeName>-changelog

RocksDB

- RocksDB is key-value store in Kafka Streams application.
- https://www.confluent.io/blog/how-to-tune-rocksdb-kafka-streams-state-stores-performance/

KStream vs. KTable vs. GlobalKTable

- Kstream is like a log, it goes message after message.
  - Example: we have 2 messages in stream:
    - (KEY, VALUE): (alice, 1), (alice, 3).
    - When you perform SUM operation, the result will be : (alice, 4)
  - KStream is stateless
- KTable takes into account only the last value of message with a specific key:
  - In the previous example would SUM operation return (alice, 3)
  - KTable is stateful, internally is KTable implemented using RocksDB and a topic in Kafka. RocksDB contains the current table data and is stored on the Kafka Streams application disc. RocksDB is not fault-tolerant, so the data are also stored in the Kafka topic.
    - https://stackoverflow.com/questions/52488070/difference-between-ktable-and-local-store
  - Note! Unlike KStream, KTable does not get real-time data from topic, but loads the last state (key-value) into the cache and by default, after 30 seconds is performed flush of the cache and current state is read (property commit.interval.ms). Or if the cache is full (default 10 mb: property cache.max.bytes.buffering).
- GlobalKTable is like KTable, but data are read from all partitions.

join, left join, outer join

Operator	Description
`join`	Inner join. The join is triggered when the input records on both sides of the join share the same key.
`leftJoin`	Left join. The join semantics are different depending on the type of join: • For stream-table joins: a join is triggered when a record on the *left side* of the join is received. If there is no record with the same key on the right side of the join, then the right value is set to null. • For stream-stream and table-table joins: same semantics as a stream-stream left join, except an input on the right side of the join can also trigger a lookup. If the right side triggers the join and there is no matching key on the left side, then the join will not produce a result.
`outerJoin`	Outer join. The join is triggered when a record on *either side* of the join is received. If there is no matching record with the same key on the opposite side of the join, then the corresponding value is set to null.

Type	Windowed	Operators	Co-partitioning required
`KStream-KStream`	Yes[a]	• `join` • `leftJoin` • `outerJoin`	Yes
`KTable-KTable`	No	• `join` • `leftJoin` • `outerJoin`	Yes
`KStream-KTable`	No	• `join` • `leftJoin`	Yes
`KStream-GlobalKTable`	No	• `join` • `leftJoin`	No

co-partitioning

- When performing join operations, input topics must be co-partitioned.
- What is co-partitioning?
  - Input topic left and right must have the same number of partitions.
  - Input topics must use the same partitioning strategy (luckily out-of-the-box they do).
- Why is co-partitioning required? Because joins are performed based on keys (left and right key must be „paired“) and based on key value Kafka decides in which partition the message will be put.
- GlobalKTable doesn’t require co-partitioning.

groupByKey, groupBy

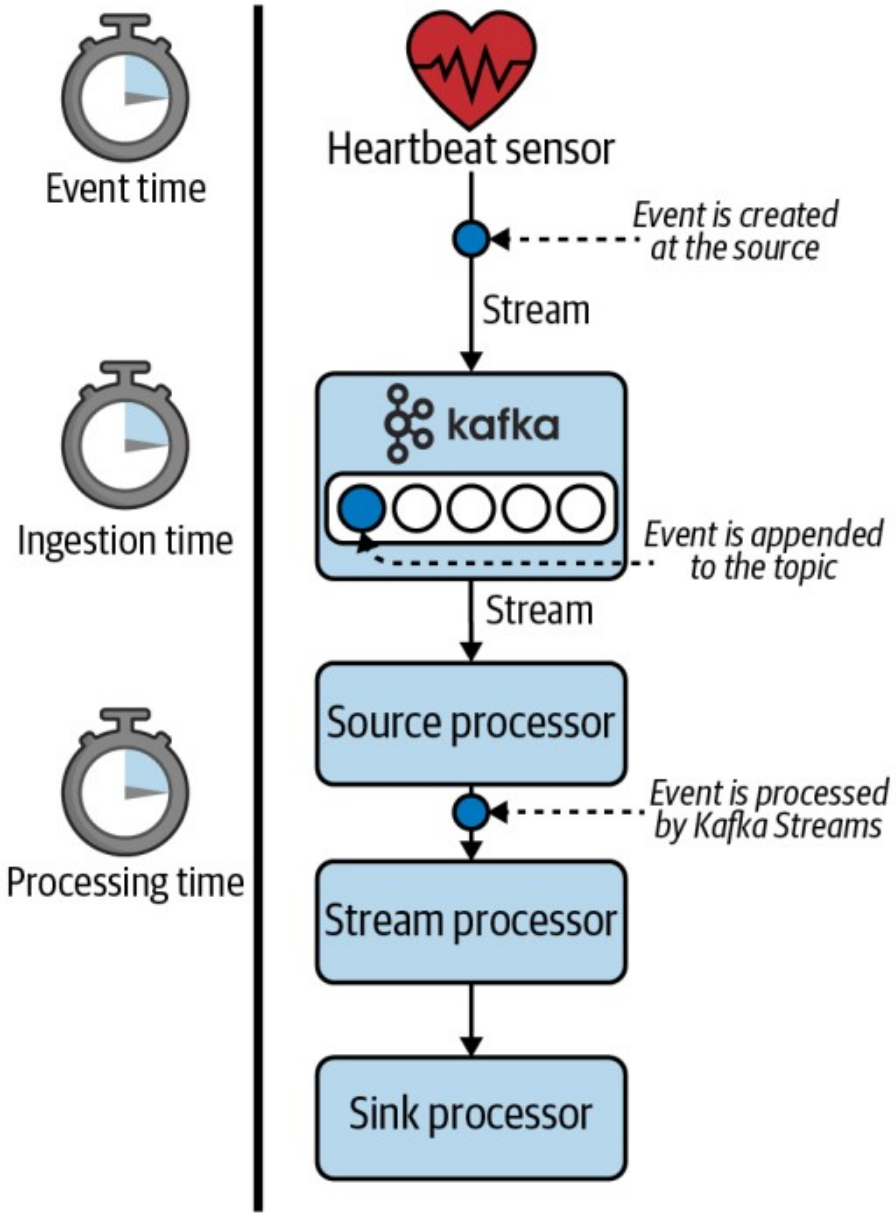
- Before calling aggreation operations, it is necessary to group KTable or KStream:
  - groupByKey performs grouping without key transformation
    - Efficient, doesn’t perform repartitioning
    - Only for KStream
  - groupBy performs key mapping and then grouping
    - Performs repartitioning
    - For KStream and KTable

Aggregations

- Operations:
  - count
    - Count operation
  - reduce
    - Reduce algorithm, compared to aggregate differs in that the resulting type must be the same as input type.
    - With reduce you can implement min, max, sum.
  - aggregate
    - You can implement the same operations as with reduce operations, but it’s more advanced. Plus it’s possible to implement average.
- https://mail-narayank.medium.com/stream-aggregation-in-kafka-e57aff20d8ad

Timestamp

- By default, when Producer sends a record to Kafka, it is assigned a timestamp (that time is set by the Producer and it's called „Event time").
- Whey you create ProducerRecord, you can specify that time (it's Long value):
  - `new ProducerRecord<>(TOPIC, null, TIMESTAMP, KEY, VALUE);`
- It is also possible to set up, that this time isn't created by the Producer, but that it's the time of storing the record to topic (than it would be „Ingestion time"):
  - https://kafka.apache.org/documentation/#log.message.timestamp.type



TimestampExtractor

- Out-of-the-box when working with time is used default timestamp which was discussed in previous slide. In case you want to use another (for example defined in message), then it's necessary to implement TimestampExtractor, which can then be used:
  - Globaly in Kafka Streams configuration:
    - `streamsConfiguration.put(StreamsConfig.DEFAULT_TIMESTAMP_EXTRACTOR_CLASS_CONFIG, MyTimestampExtractor.class);`
  - Or ad-hoc:
    - `Consumed.with(Serdes.String(), temperatureValueSerde)`
      `.withTimestampExtractor(new MyTimestampExtractor());`

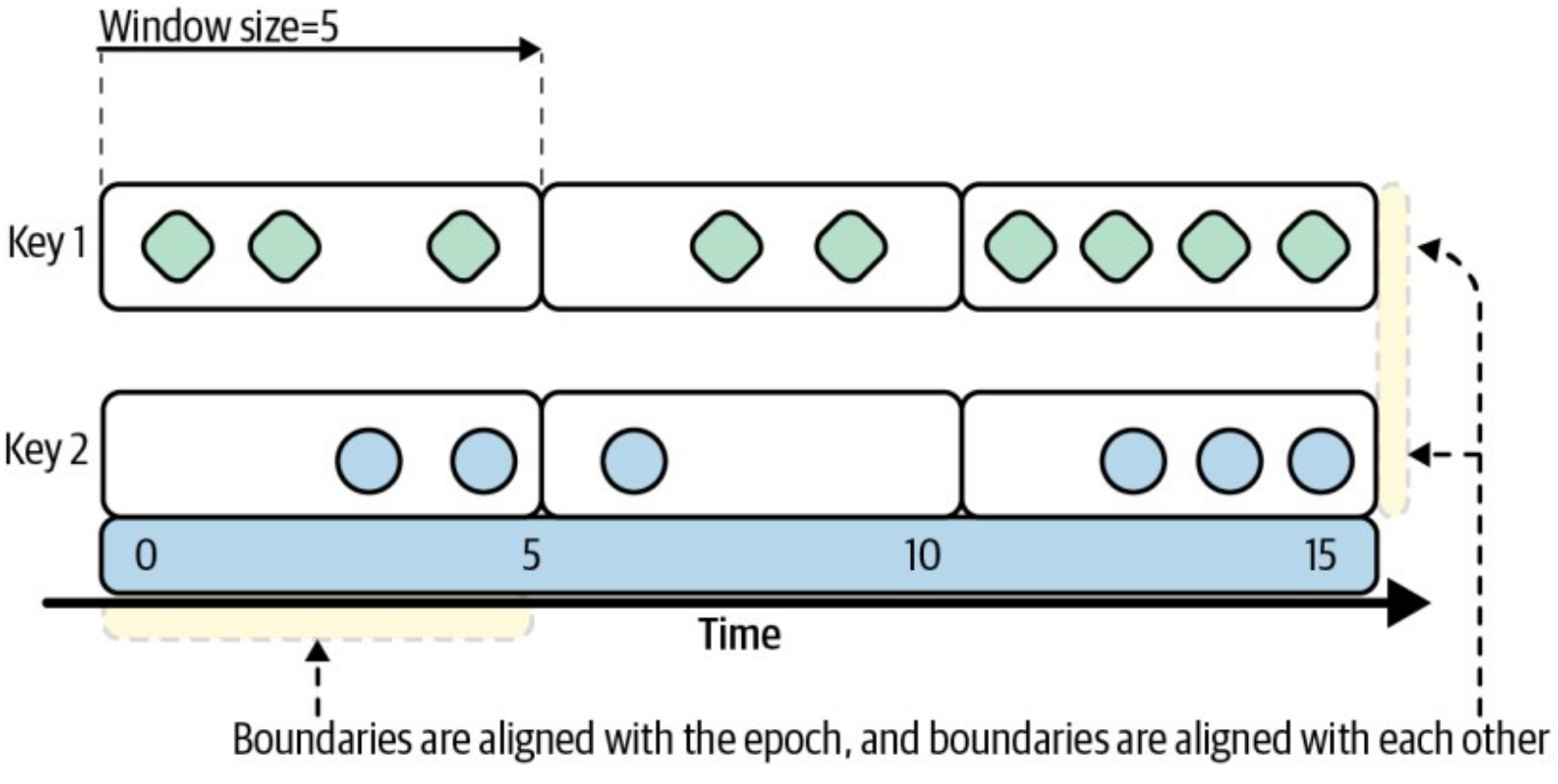
Windowing Streams

- Aggregation or join operations work on all records. But often we want result over a period of time. For this is used Windows concept. TimeWindow object is aligned with epoch time (that means, that window of size 60 000 ms will have bounds [0, 60 000), [60 000, 120 000) …
  - Note: [= inclusive,) = exclusive
- Grace period
  - A very important concept of how long to wait for records for some window, even if that window is no longer valid. If the record arrives after the end of grace period, then it will be discarded and will no longer be processed in the given window.
- Supress
  - Another very important concept. By default, KTable is commited every 30 seconds. To avoid intermediate results in KTable, it is possible to use supress() operation. Note! This operation doesn’t use state store, but buffers records in RAM.

Tumbling Window

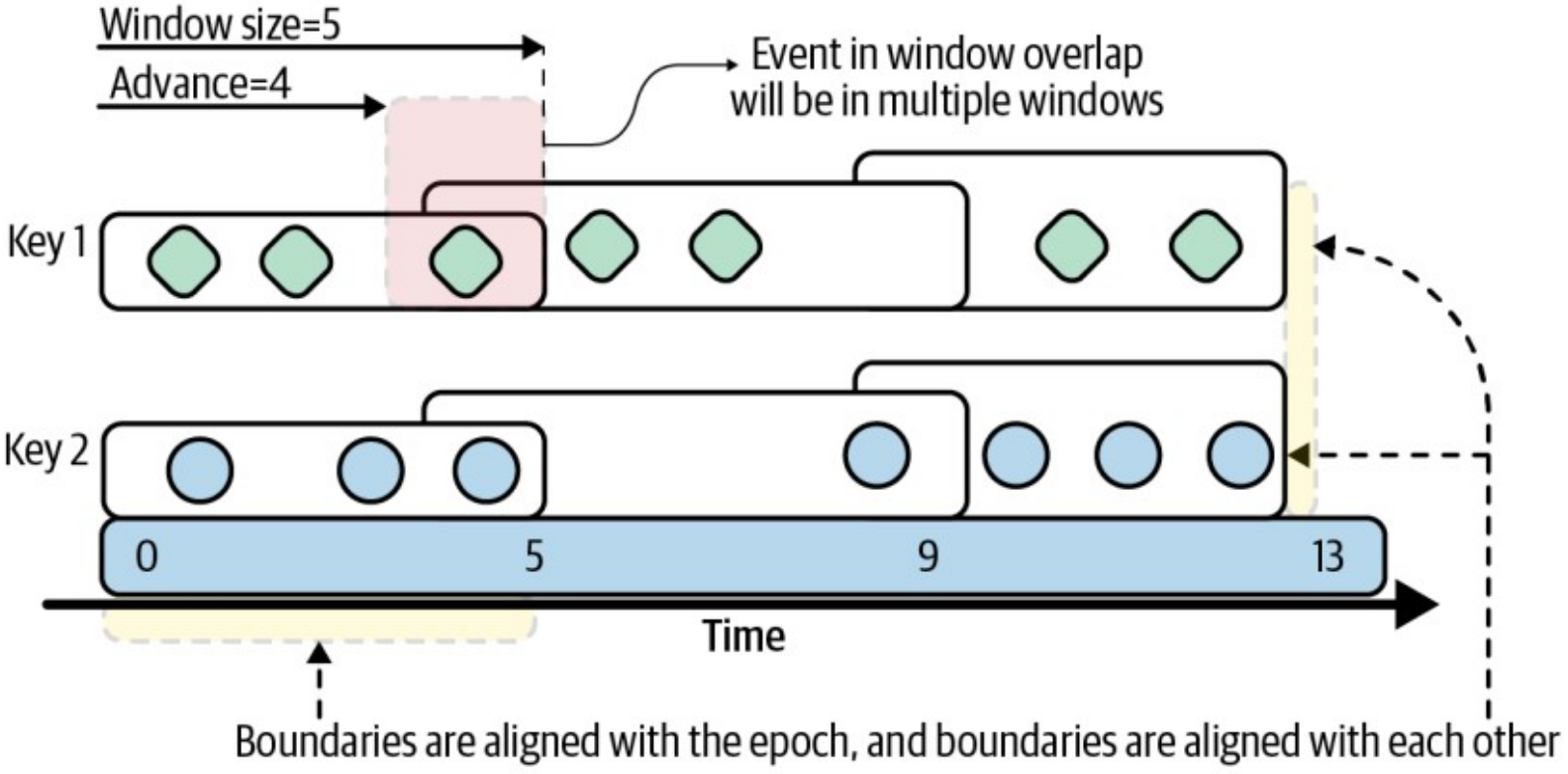
- Windows, that never overlap and are defined using a single property: window size.
  - `TimeWindows tumblingWindow =`

    `TimeWindows.ofSizeWithNoGrace(Duration.ofSeconds(5));`



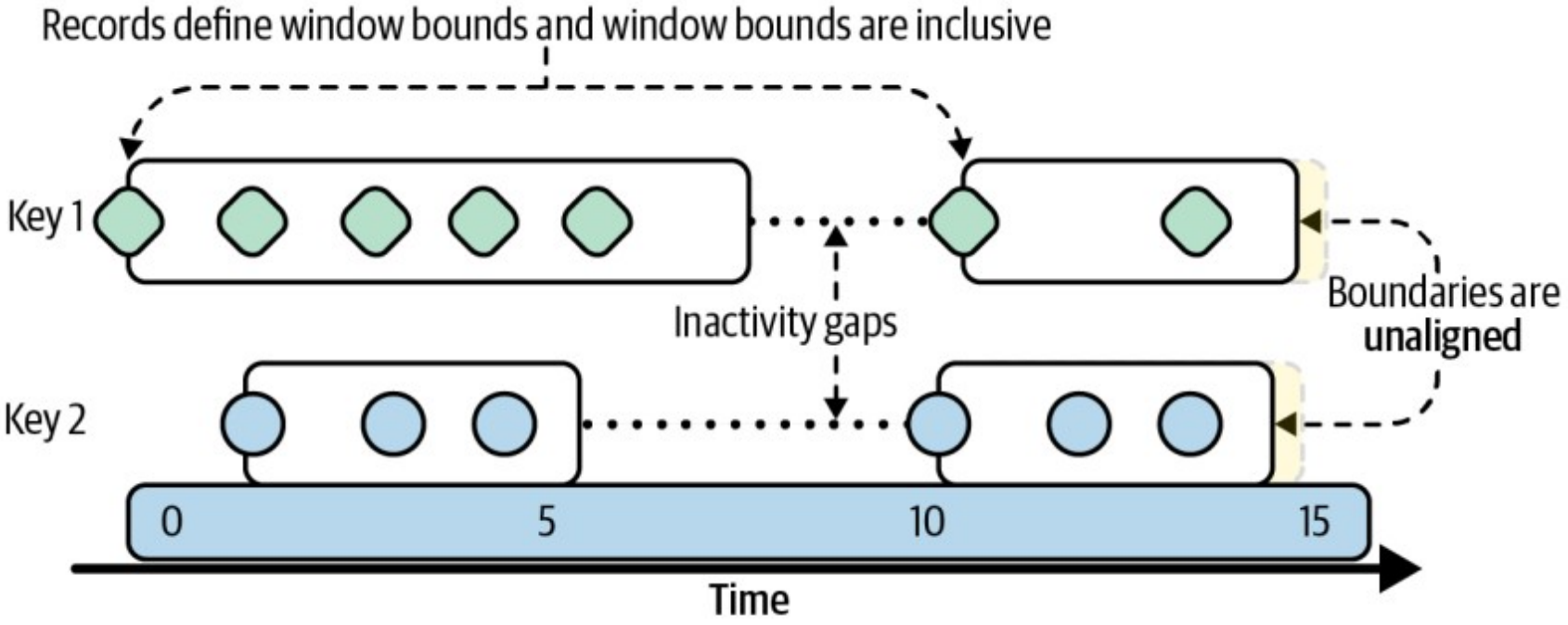
Hopping Window

- Windows that are fixed-size and can overlap.
  - `TimeWindows hoppingWindow =`
    `TimeWindows.ofSizeWithNoGrace(Duration.ofSeconds(5))`
    `.advanceBy(Duration.ofSeconds(4));`



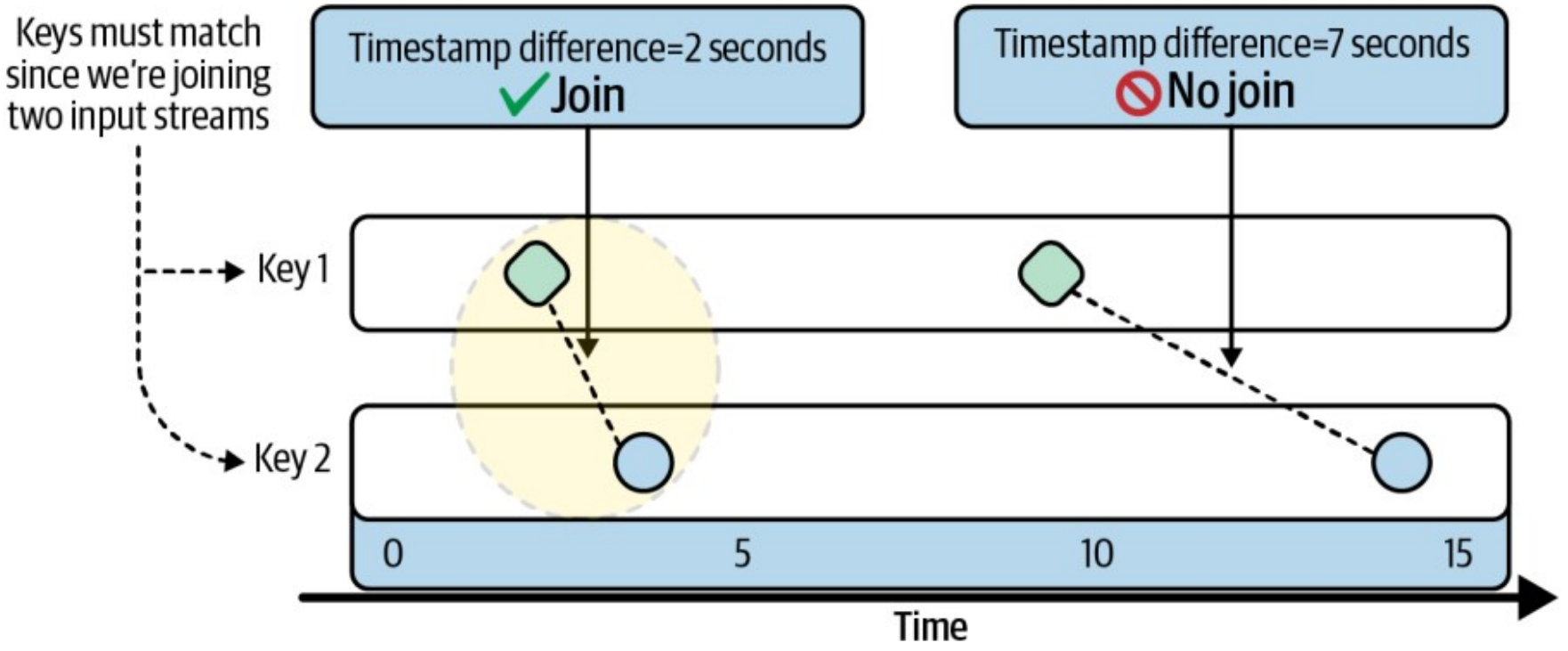
Session Window

- In Session Window is specified „inactivity gap“. When this situation occurs (no messages are received during this time), then the existing session window closes and new session window begins when a new message arrives.
  - `SessionWindows.ofInactivityGapWithNoGrace(Duration.ofSeconds(5))`



Join Window

- Two records will be merged when the difference between their timestamp values is less than or equal to the window size.
  - `JoinWindows.of(Duration.ofSeconds(5));`
- For aggregations, it is possible to use SlidingWindow, which is not linked to epoch, but to the timestamp of the record, similar to JoinWindow:
  - `SlidingWindows.ofTimeDifferenceWithNoGrace(Duration.ofSeconds(5));`



Guarantees

- Kafka streams out-of-the box guarantee at_least_once Stream processing. This can be changed to „exactly once“, which guarantees atomicity of the whole stream:

```
properties.put(StreamsConfig.PROCESSING_GUARANTEE_CONFIG, "exactly_once_v2");
```

  - https://docs.confluent.io/platform/current/streams/developer-guide/config-streams.html#processing-guarantee
  - Note: Exactly once requires cluster with at least 3 brokers!

Stream Exception Handling

- Kafka Streams currently allows the following exception handling:
  - Deserialization Exception Handler allows you to catch exceptions that can occur when deserializing a record.
  - Streams Uncaught Exception Handler handles exceptions that may occur during stream processing.
  - Production Exception Handler allows you to catch exceptions that may occur when communicating with the broker.

    - https://developer.confluent.io/learn-kafka/kafka-streams/error-handling/
    - https://developer.confluent.io/learn-kafka/kafka-streams/hands-on-error-handling/

Interactive Queries

- The State store used so far can only be used if there is only one instance of the Kafka Streams application. If we have a large number of instances in cluster, we must either obtain data from the local state store, or call another Kafka Streams application via REST, which will return data from its local state store.
- To do this, Kafka Streams makes it easier for us to find an instance that contains a state store with we're looking for (so it provides discovery). To do this, you must set property application.server. However that's all that Kafka Streams helps us, the rest we must implement on our own (publishing REST endpoint and communication with it).
- https://kafka.apache.org/20/documentation/streams/developer-guide/interactive-queries.html
- https://github.com/confluentinc/kafka-streams-examples/tree/7.0.0-post/src/main/java/io/confluent/examples/streams/interactivequeries

State Store & Performance I.

- From a performance point of view, rebalancing is problematic, especially when an instance of the Kafka Streams application fails. Subsequently, the state store must be re-created from the Kafka Streams topic and especially when the state store is large, a longer downtime may occure. To mitigate this problem is used:
  - Standby Replicas
    - The state of State store will be replicated to more instances of Kafka Streams aplikace. This can be affected by property property num.standby.replicas (default is 0, value 1 means one replica)
      - https://medium.com/transferwise-engineering/achieving-high-availability-with-stateful-kafka-streams-applications-cba429ca7238

State Store & Performance II.

- Rebalancing will sooneer or later still occure. How to mitigate it’s effects In particular, so that there is as little data as possible in the state store using::
  - Tombstones: When it is no longer necessary to have a value in the state store, it is set to null.
  - Window retention: For windowed stores, it is possible to set data retention
  - Agressive topic compaction: KTable has compaction enabeled, but data on disc may také up more space. Why? The data on disc are physically in segments. There is always an active segment, into which data are written. Over some time active segment will change to inactive (whtn it exceeds its size or some time elapses). Only inactive segment can be cleaned. These parameters affect the cleaning speed of the segments:
    - segment.bytes (default: 1GB): Segment maximum size
    - segment.ms (default: 7 dnů): Maximum time when a new segment will be created even if segment.bytes has not been filled
    - min.cleanable.dirty.ratio (default: 0.5): How often the log will be cleaned. By default, the log will not be cleaned when more than 50% of the log is compacted

Testing

- https://chrzaszcz.dev/2020/08/kafka-testing/
- https://www.baeldung.com/spring-boot-kafka-testing
- https://docs.confluent.io/platform/current/streams/developer-guide/test-streams.html
- https://blog.jdriven.com/2019/12/kafka-streams-topologytestdriver-with-avro/

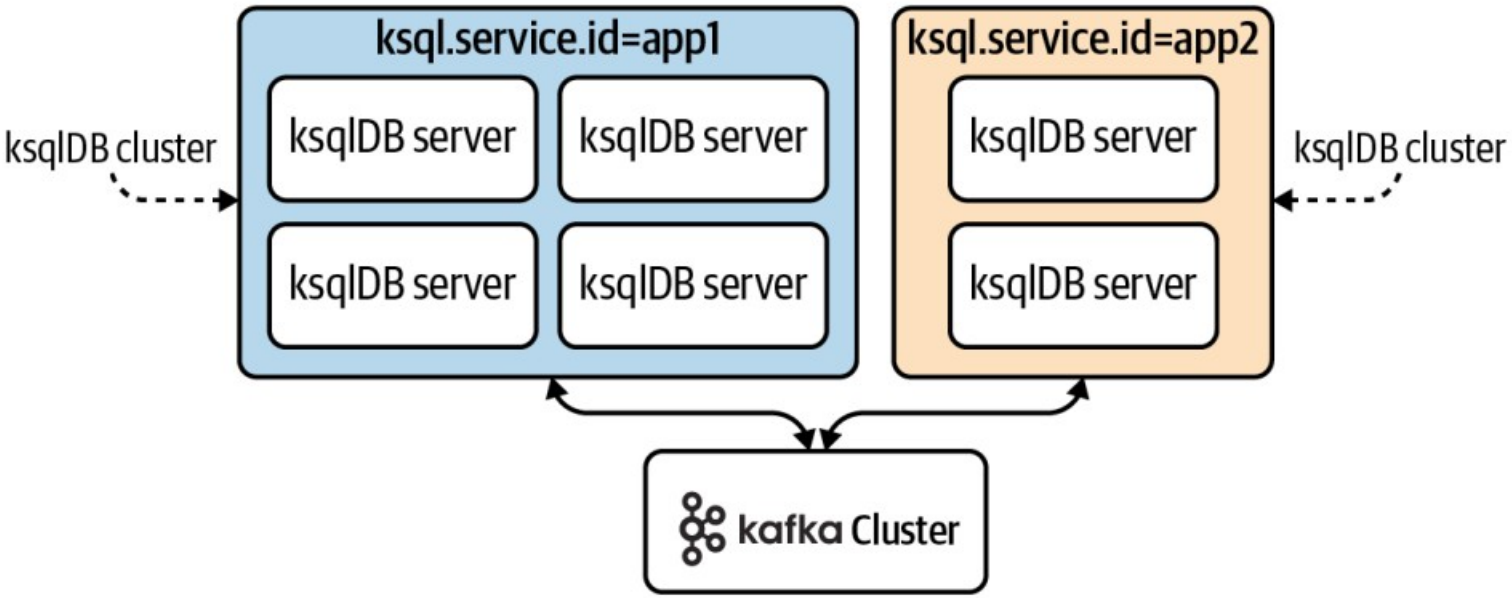
Kafka Streams Examples

- More examples from Confluent:
  - https://github.com/confluentinc/kafka-streams-examples/tree/7.0.0-post/src/main/java/io/confluent/examples/streams

ksqlDB

ksqlDB

- ksqlDB is an extension of Kafka Streams and Kafka Connect. Each instance of ksqlDB acts like one Kafka Streams microservice and when they have the same ksql.service.id, then it’s the same as when multiple Kafka Streams instnaces have the same application.id.



Základní konfigurace

- Interactive vs. headless mode:
  - By default, ksqlDB runs in „interactive mode“, where clients can control ksqlDB usin the REST API. In this mode, all queries are stored to Kafka topic _confluent-ksql-default__command_topic.
  - Alternatively, it can run in headless mode, in which the REST API is disabled and all queries are defined at startup in file, whose location is set using queries.file property.
- Kafka Connect integration also has two modes:
  - External mode: Kafka Connect cluster can be outside the ksqlDB cluster, then it’s location is set using property ksql.connect.url.
  - Embedded mode: In this mode each ksqlDB instance also acts as a Kafka Connect worker. In this case, the ksql.connect.worker.config property is set, which refers to the properties file, in which the worker configuration is located.

ksqlDB CLI & REST API

- ksqlDB CLI is a console application used to control ksqlDB:
  - https://docs.ksqldb.io/en/latest/operate-and-deploy/installation/cli-config/
- It is also possible to use the REST API to control the ksqlDB instance (if it is not running in headless mode):
  - https://docs.ksqldb.io/en/latest/developer-guide/api/index.html

use-cases

- What you can do with ksqlDB?
  - Create Kafka Connect source & sink connectors
  - Create transient (ad-hoc) queries
    - These queries won’t survive restart of the server
  - Create persistent queries (queries, which receive input data, perform transformation and result write to output topic).
    - These queries survive server restart.
  - Queries can be either in format of Stream, or Table.
  - Add records to stream

Books

- Kafka The Definitive Guide 2nd Edition:
  - https://www.oreilly.com/library/view/kafka-the-definitive/9781492043072/
- Kafka streams & ksqlDB:
  - https://www.amazon.com/Mastering-Kafka-Streams-ksqlDB-Real-Time/dp/1492062499
- Free ebooks (from Confluent):
  - https://www.confluent.io/resources/?language=english&assetType=ebook

Kafka & Multiple Datacenters

- https://mbukowicz.github.io/kafka/2020/08/31/kafka-in-multiple-datacenters.html
- https://docs.confluent.io/platform/current/tutorials/examples/multiregion/docs/multiregion.html
- https://cloud.redhat.com/blog/geographically-distributed-stateful-workloads-part-four-kafka