POLITECNICO
MILANO 1863

Apache Kafka

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Communication semantics

Communication semantics

- In theory, message delivery can be provided with different guarantees
  1. At most once semantics: no duplicates, but messages can be lost
  2. At least once semantics: messages can be delivered more than once, but they are not lost
  3. Exactly once semantics: the system behaves as if each message was delivered once and exactly once

Communication semantics

- Exactly once semantics is theoretically impossible to guarantee in the presence of failures
  - It is equivalent to a distributed consensus problem
  - Possible in practice under some reasonable assumptions

- Consider a communication between a sender and a receiver
  - The receiver fails …
  - … but is re-instantiated later in time

- The receiver acknowledges messages …
- … and the sender does not receive an acknowledgement
  - It can send the message again
    - But if the message was received before the failure, it might be duplicated
    - At least once semantics
  - It can avoid sending the message
    - But if the message was not received before the failure, it is lost
    - At most once semantics

Communication semantics

- Which guarantees does Kafka offer?

- In Kafka, communication takes place in two steps
  - From producers to brokers
  - From brokers to consumers

- In recent versions, Kafka offers exactly once semantics (EOS) for both steps

EOS on the producer

- The producer can be configured to be idempotent
  - An idempotent operation can be performed many times without causing any different effect than being performed once
  - This removes the possibility of duplicate messages being delivered to a topic

- Implementation
  - The producer waits for an ack from the broker
  - If it does not receive the ack, after a timeout it sends the message again (possible duplication of messages)
  - The producer attaches sequence numbers to messages …
  - … that the broker can use to discard duplicates

EOS on the consumer

- A consumer repeatedly performs three actions
  - Reads a message
  - Processes the message
  - Produces some results

- EOS requires that the results are produced once and only once

EOS on the consumer

- Kafka provides EOS in the consumer under the following assumptions
  - Results are written to a Kafka topic
  - Kafka topics are reliable (achieve through replication)

- Implementation using transactional writes
  - Possibility to write multiple messages as part of a transaction
    - Either all or none of the messages are written
  - The consumer can write the results and advance the offsets of consumed messages within a transaction
    - If the offset is updated, the results are written
    - If the results are not written, the offset is not updated

End-to-end EOS

- This solution enables end-to-end exactly once semantics
  - In the case of many intermediate processing steps …
  - … if each step writes its results in Kafka topics …
  - … each step guarantees exactly once semantics …
  - … resulting in exactly once semantics being guaranteed end-to-end!

- Useful for services that require multiple processing steps
  - Used to implement Kafka Streams

Transactions

- EOS relies on transactional (atomic) updates of offsets
- Transactions are implemented using a transaction coordinator
  - Writes metadata about transactions in a special Kafka log
  - Same guarantees as other logs
    - Ordered, idempotent, fault-tolerant
- Consumers can choose between two different isolation levels
  - Read committed: read only writes that have been committed as part of a transaction
  - Read uncommitted: read also writes that have not been yet committed

Log compaction

- To achieve EOS, consumers need to store any state/result in Kafka
  - Kafka has no control on state that is outside the system (e.g., in memory or in external databases)
- In many cases, new events have update semantics
  - Their effect is to update/overwrite the previous state of a consumer
- Kafka offers a special message storage configuration to deal with this specific (and frequent) situation

Log compaction

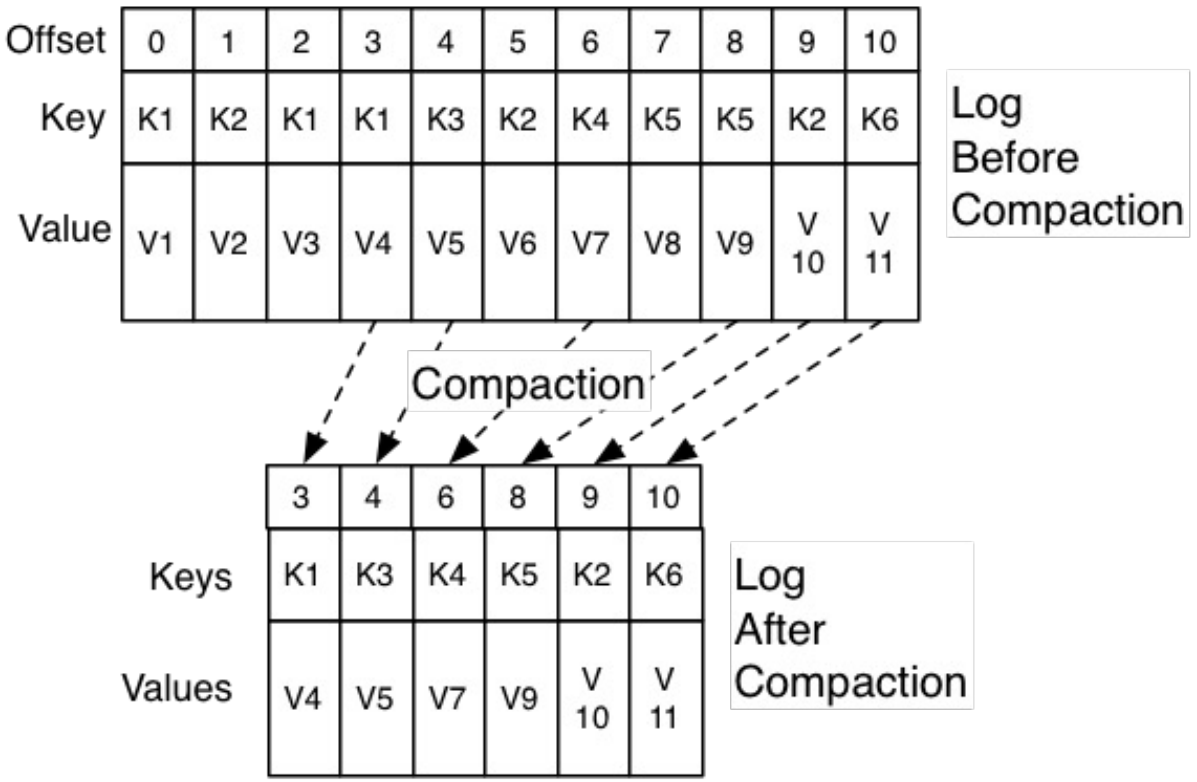
- By default, all messages are stored in Kafka topics for a configurable retention time
  - This is reasonable for all those scenarios where we want to store the history of messages
  - However, it is not optimal when old messages become irrelevant with the arrival of new messages

Log compaction

- To support scenarios where we are only interested in the most recent state, Kafka introduces log compaction
  - A specific retention policy
  - Configurable per topic
  - Allows Kafka to only keep the last value for each key
  - Preserves the offset and order of messages
    - Simply deletes messages when a more recent one with the same key becomes available

Log compaction

discard old messages --> here it discards the o



Log compaction

- Log compaction is not performed as soon as new messages are received
  - Log is split in two parts (head and tail)
  - Messages are marked for deletion only in the tail
  - Actual removal of messages triggered periodically