How We Built an Event-Time Merge of Two Kafka-Streams with Spark Streaming

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Agenda

- Who are we?
- Our Setup
- The Problem
- Our Approach
- Requirements
- Advanced Requirements
- Lessons learned

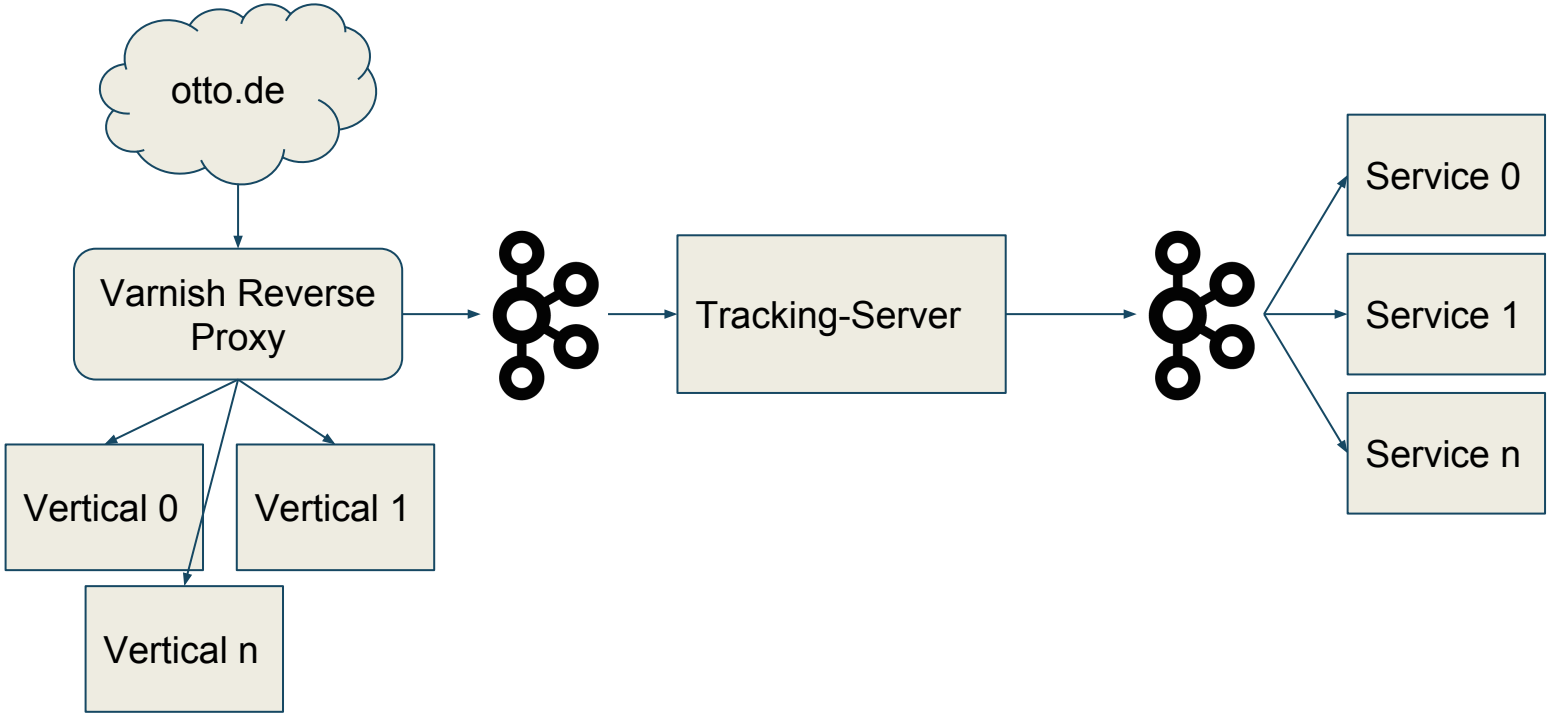
Who are we?

- Ralf
  - Technical Designer Team Tracking
  - Cycling, Surfing
  - Twitter: @sistar_hh
- Sebastian
  - Developer Team Tracking
  - Taekwondo, Cycling
  - Twitter: @Sebasti0n

Who are we working for?

- 2nd largest ecommerce company in Germany
- more than 1 million visitors every day
- our blog: https://dev.otto.de
- our jobs: www.otto.de/jobs

Our Setup



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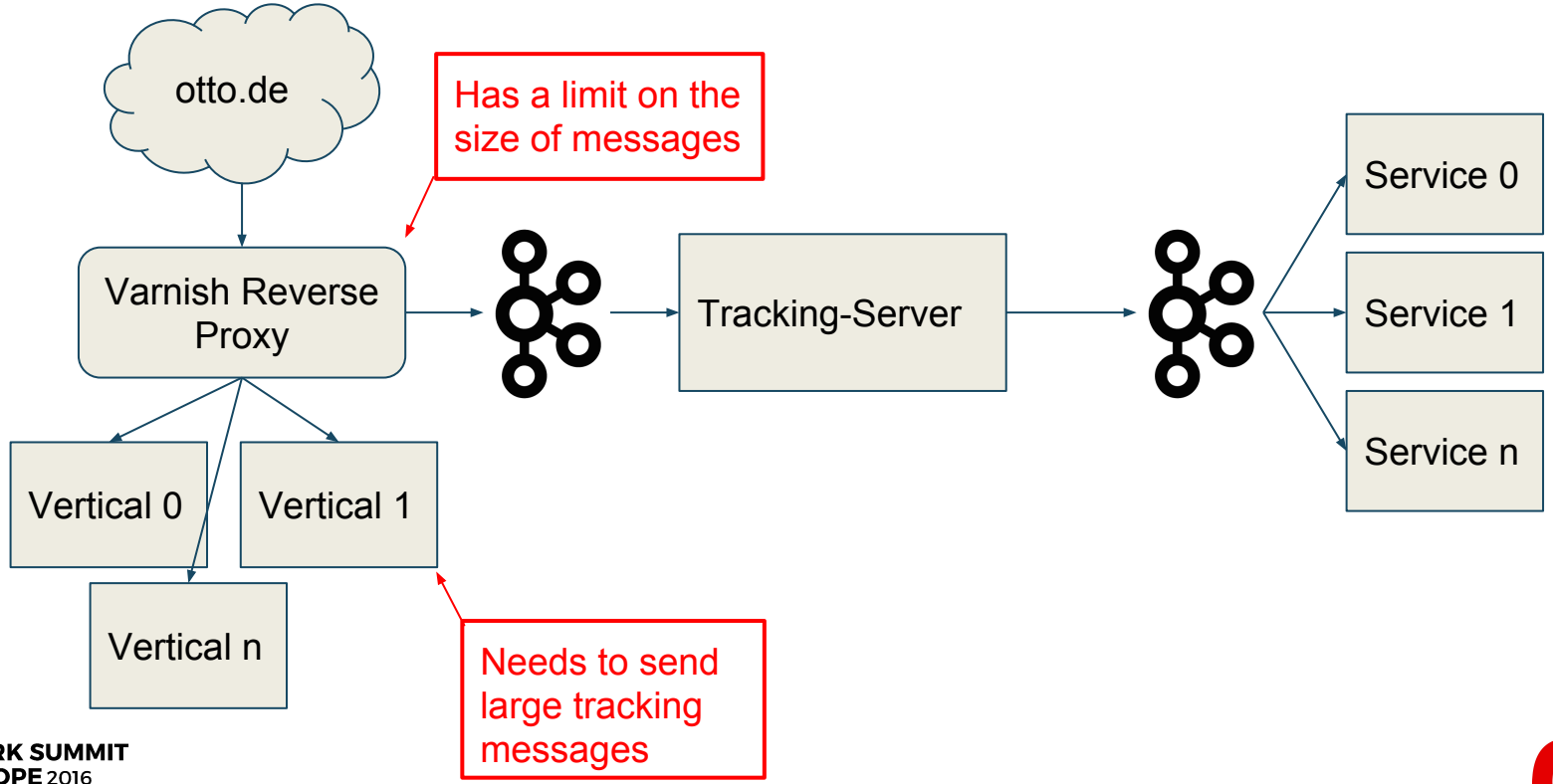
The Problem



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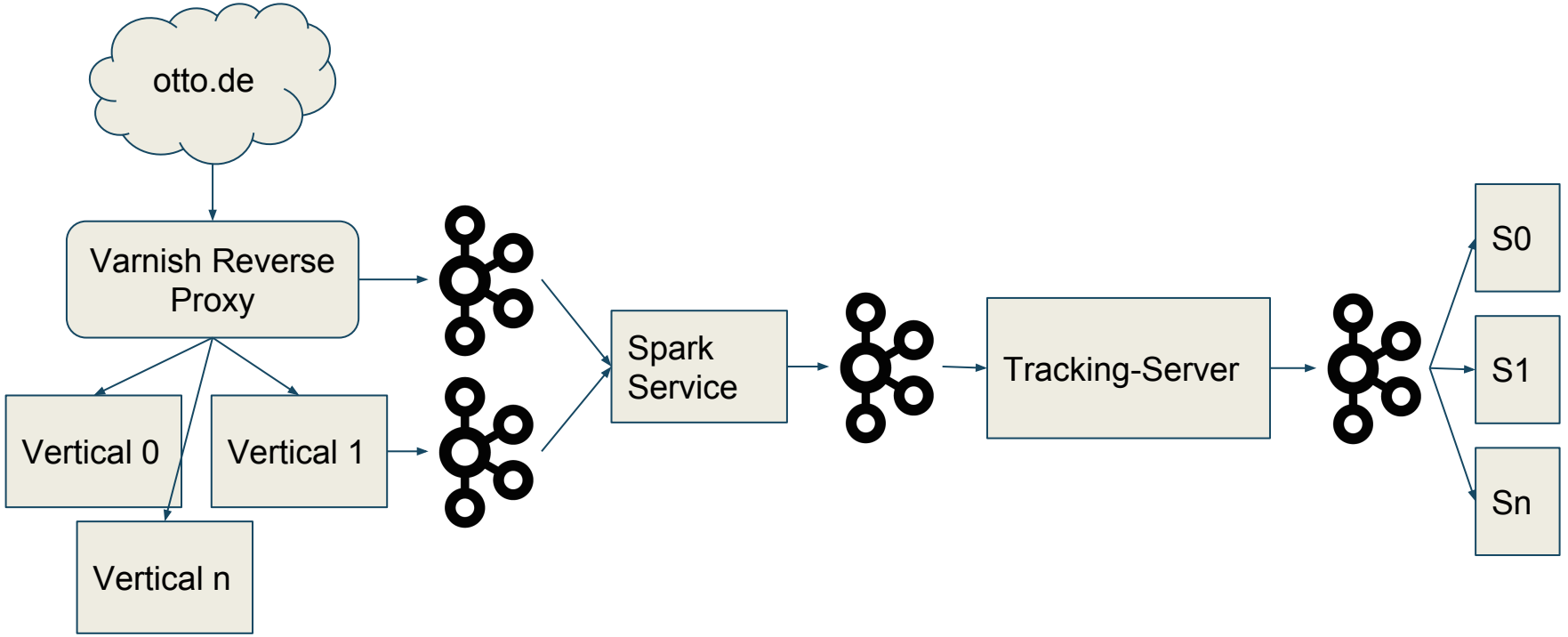
Our Approach



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Requirements

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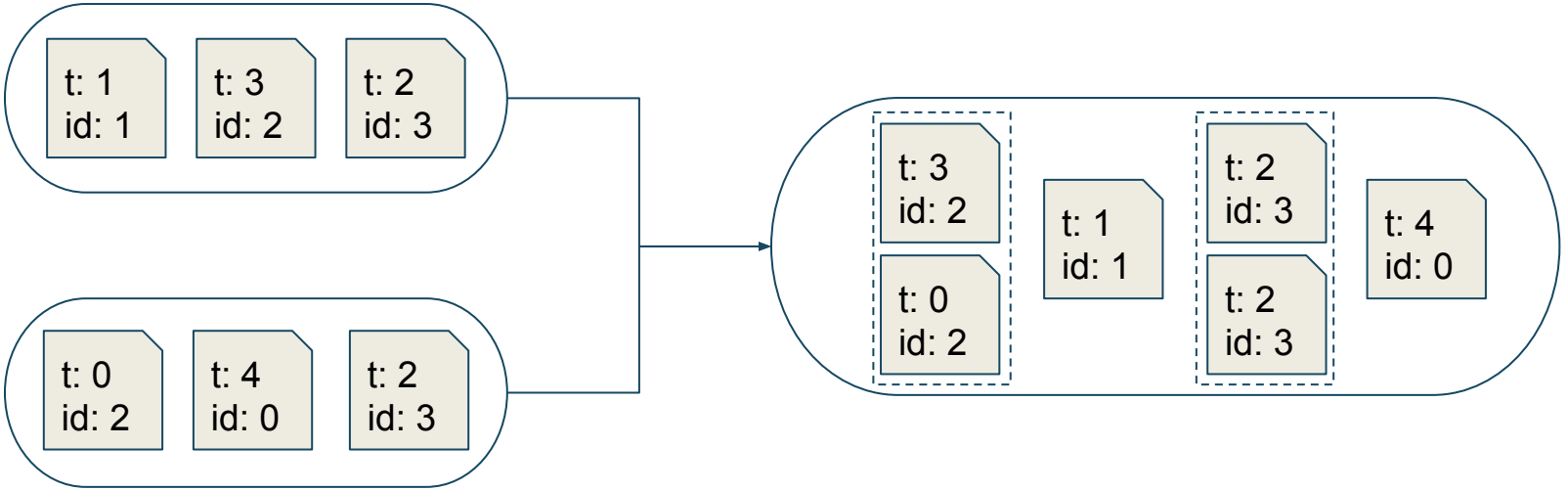
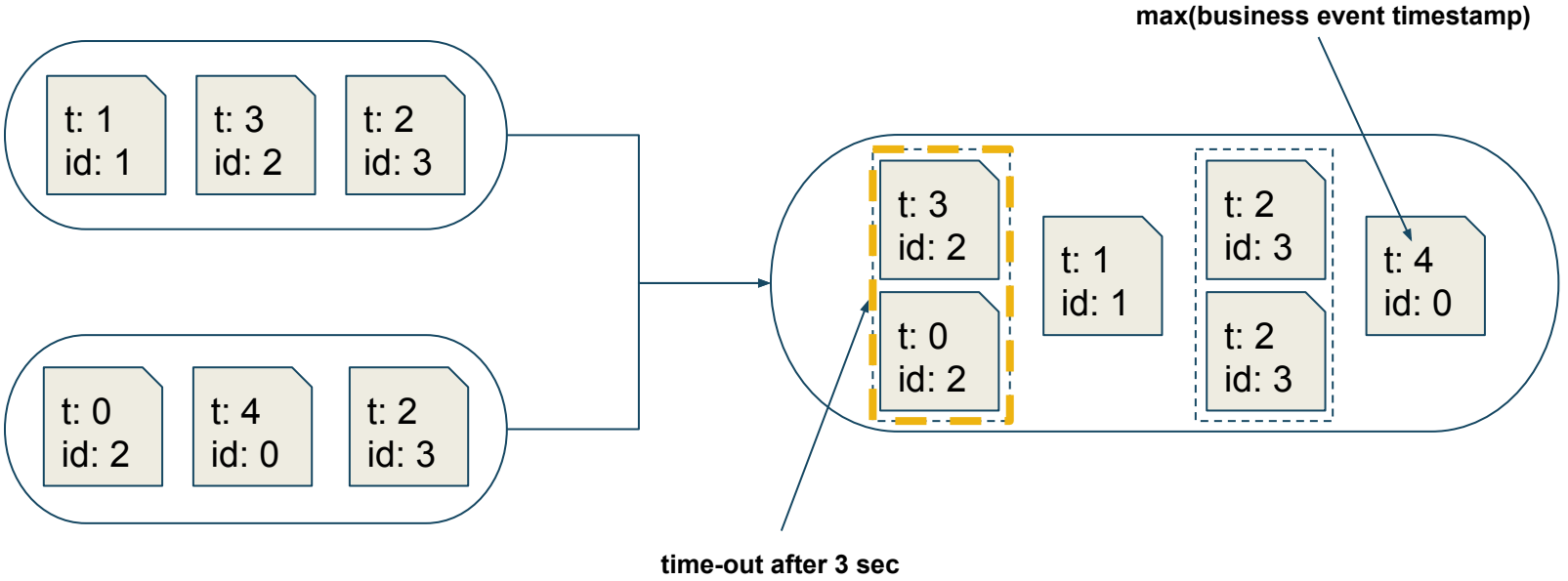
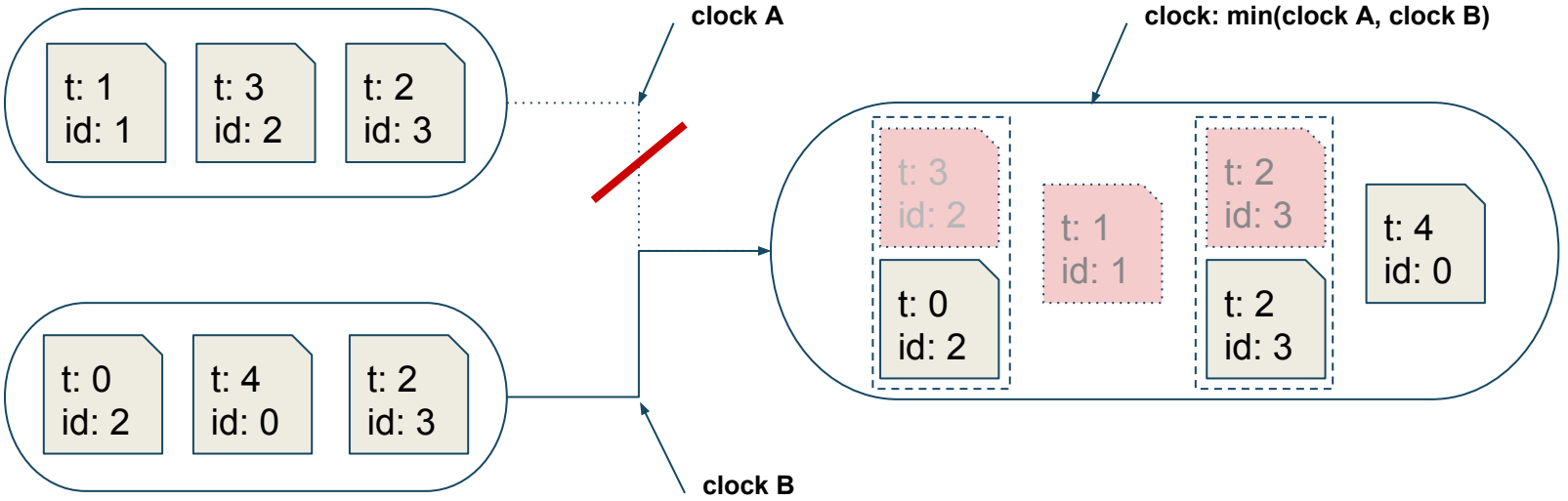
Messages with the same key are merged



Messages have to be timed out



Event Streams might get stuck



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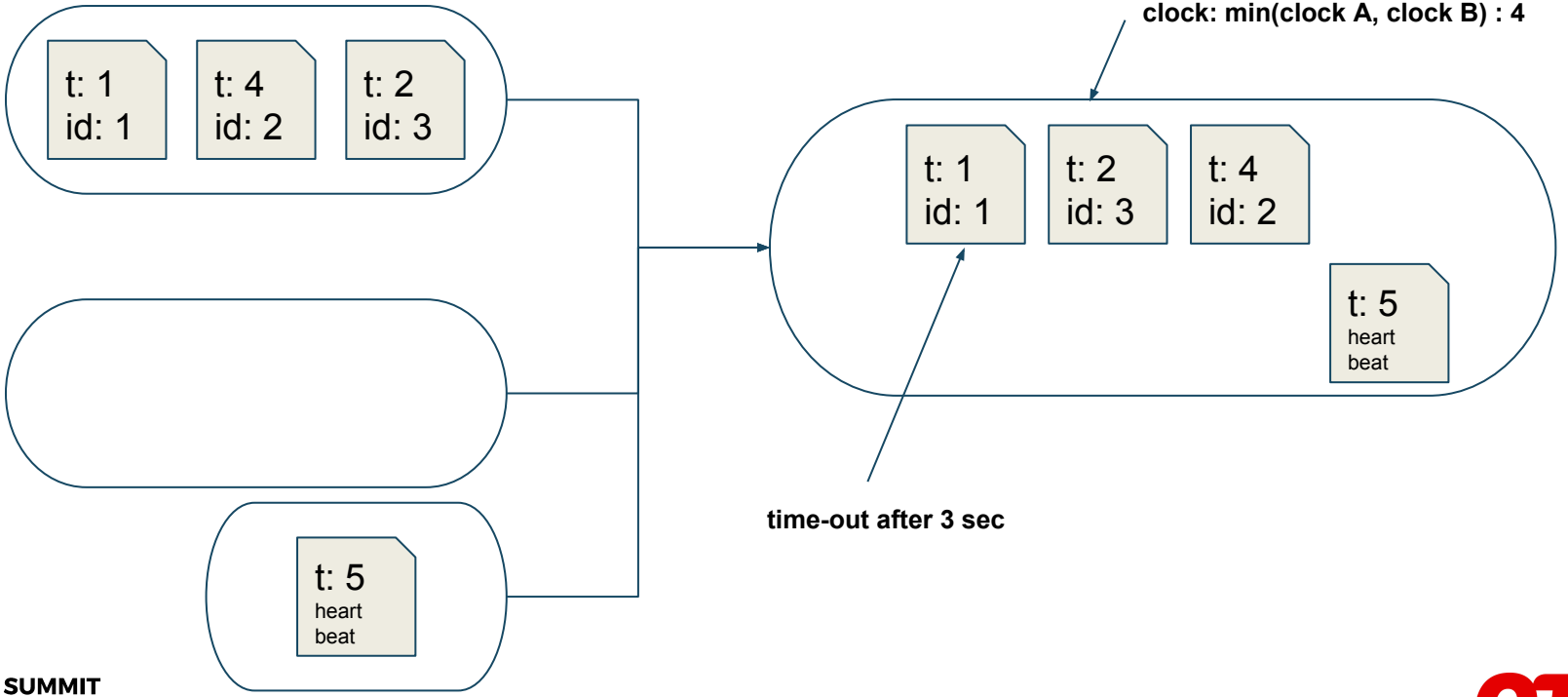
There might be no messages



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Requirements Summary

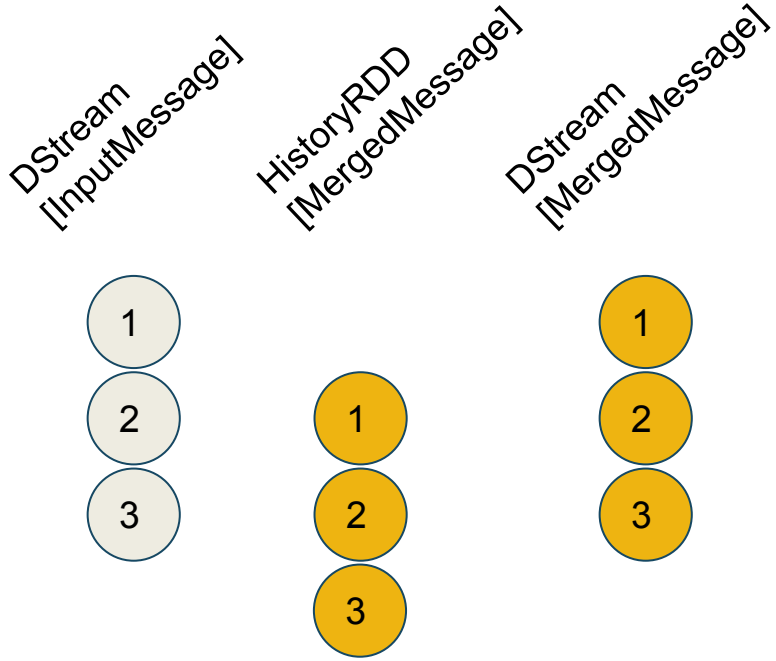
- Messages with the same key are merged
- Messages are timed out by the combined event time of both source topics
- Timed out messages are sorted by event time

Solution

Merge messages with the same Id

- UpdateStateByKey, which is defined on pairwise RDDs
- It applies a function to all new messages and existing state for a given key
- Returns a StateDStream with the resulting messages

UpdateStateByKey



UpdateFunction:
(Seq[InputMessage], Option[MergedMessage]) =>
Option[MergedMessage]

OTTO

Merge messages with the same Id

```
val merge: (DStream[InputMessage]) => DStream[(String, MergedMessage)] =
  (input) => {
    input
      .map(msg => (msg.ssid, msg))
      .updateStateByKey(updateState(_, _))
  }
```

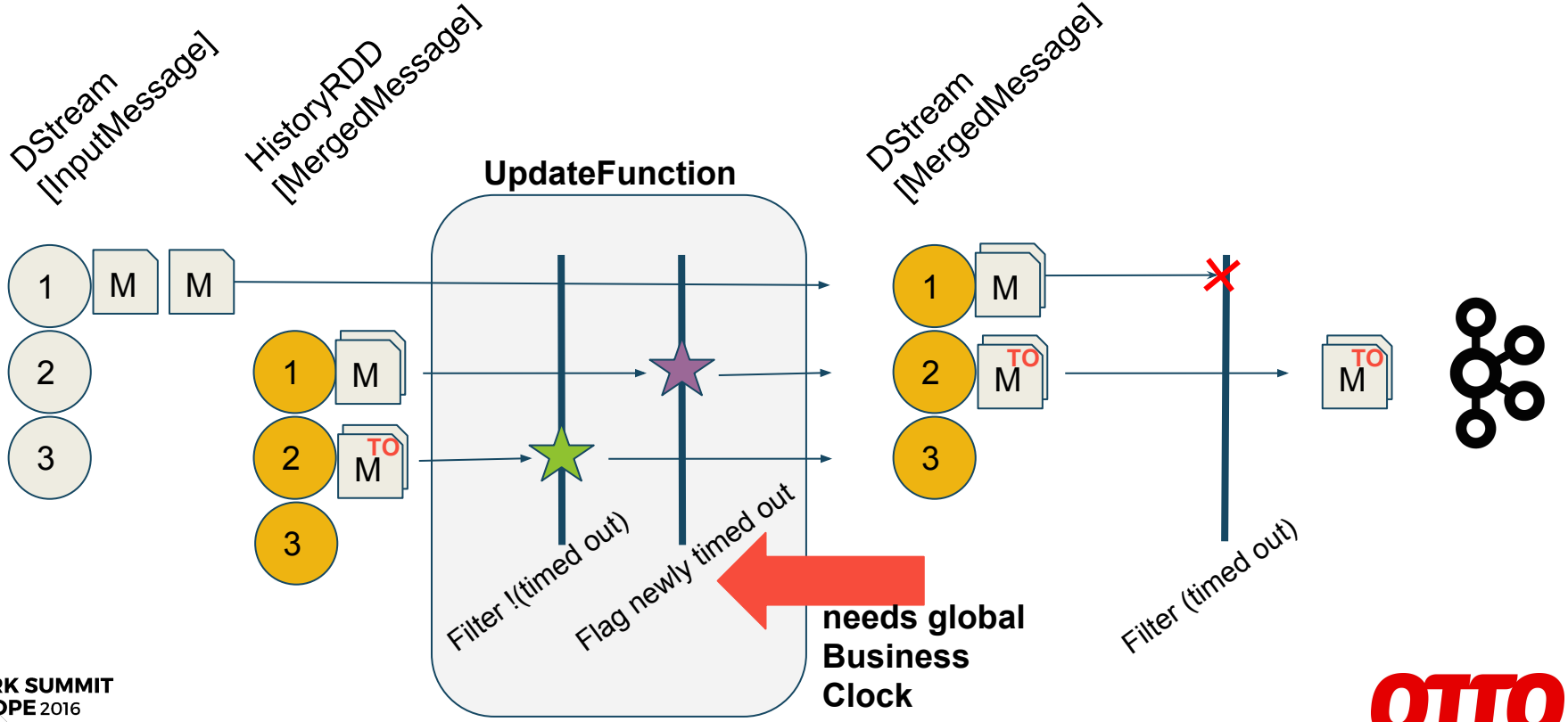
Merge messages with the same Id

```
@tailrec
def updateState(inputMessages: Seq[InputMessage],
                history: Option[MergedMessage]): Option[MergedMessage] = {

  def combine(mm: MergedMessage, im: InputMessage): MergedMessage = {...}

  (inputMessages, history) match {
    case (seq, _) if seq.isEmpty => // no input messages
      history
    case (seq, None) => // no history (state), new input message(s)
      updateState(seq.tail, Some(MergedMessage.fromInputMessage(seq.head)))
    case (seq, Some(h)) => // existing history (state), new input messages
      updateState(seq.tail, Some(combine(h, seq.head)))
  }
}
```

Flag And Remove Timed Out Msgs



OTTO

Messages are timed out by event time

- We need access to all messages from the current micro batch and the history (state) => Custom StateDStream
- Compute the maximum event time of both topics and supply it to the updateStateByKey function

Messages are timed out by event time

```
val merge: (DStream[InputMessage]) => DStream[(String, MergedMessage)] =
  (input) => {
    input
      .map(msg => (msg.ssid, msg))
      .updateStateByKeyMerge(createUpdateStateFunction(_, _))
  }
```

Messages are timed out by event time

```
def createUpdateStateFun(inputMsgs: Option[RDD[(String, InputMessage)]],
                         historyMsgs: Option[RDD[(String, MergedMessage)]]):
(Seq[InputMessage], Option[MergedMessage]) => Option[MergedMessage] = {

  val minBusinessClockPerPartition = calculateMbc(inputMsgs, historyMsgs)
  val minOffsetPerPartition = calculateMinOffset(inputMsgs, historyMsgs)

  updateState(minBusinessClockPerPartition, minOffsetPerPartition)
}
```

Messages are timed out by event time

```
def updateState(minBusinessClocks: Map[Int, Long],
                minSourceTopicOffsets: Map[Int, MinSourceTopicOffsets])
               (inputMsgs: Seq[InputMessage], history: Option[MergedMessage]):
Option[MergedMessage] = {

  def flagIfTimedOut(mergedMessage: MergedMessage): MergedMessage = {...}

  inputMsgs
    .filterNot(isHeartbeatMessage)
    .mergeWith(history)
    .filterNot(_.meta.timedOut)
    .map(flagIfTimedOut)
}
```

Messages are timed out by event time

```
def flagIfTimedOut(mergedMessage: MergedMessage): MergedMessage = {
  val isTimedOut = minBusinessClocks
    .get(mergedMessage.meta.partition)
    .exists(mbc => mergedMessage.timestamp < (mbc - TimeoutPeriod))

  if (isTimedOut) {
    mergedMessage.asTimedOut(minSourceTopicOffsets.
      get(mergedMessage.meta.partition))
  } else {
    mergedMessage
  }
}
```

Advanced Requirements

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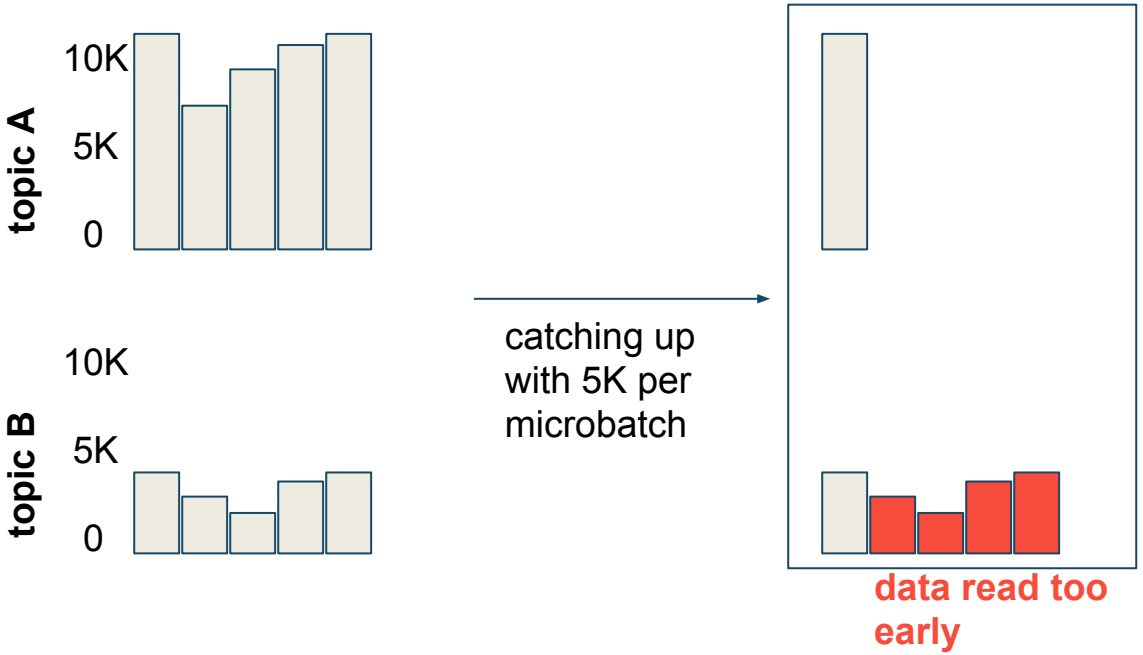
Effect of different request rates in source topics



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Handle different request rates in topics

- Stop reading from one topic if the event time of other topic is too far behind
- Store latest event time of each topic and partition on driver
- Use custom KafkaDStream with clamp method which uses the event time

Handle different request rates in topics

```
private var latestTracking: Map[Int, Long] = Map.empty
private var latestOrder: Map[Int, Long] = Map.empty

def createStreams(ssc: StreamingContext,
                  cProps: Map[String, String],
                  pProps: Map[String, String],
                  readOffsets: Map[TopicAndPartition, Long]):
(DStream[InputMessage], DStream[InputMessage]) = {

  val trackingStream: DStream[InputMessage] = createStream(cProps, pProps,
    readOffsets.filter(_._1.topic == Settings.topic), ssc,
    (raw, p, o) => TrackingMessage(TrackingMessage.Meta(p, o), raw),
    partition => latestTracking.get(partition),
    partition => latestOrder.get(partition))
  val orderStream: DStream[InputMessage] = createStream(...)
```

Handle different request rates in topics

```
  val trackingStream: DStream[InputMessage] = createStream(...)
  val orderStream: DStream[InputMessage] = createStream(...)

  storeLatestTimestamp(trackingStream) { maxTimestamps =>
    latestTracking = latestTracking ++ maxTimestamps }
  storeLatestTimestamp(orderStream) { maxTimestamps =>
    latestOrder = latestOrder ++ maxTimestamps  }

  (trackingStream, orderStream)
}
```

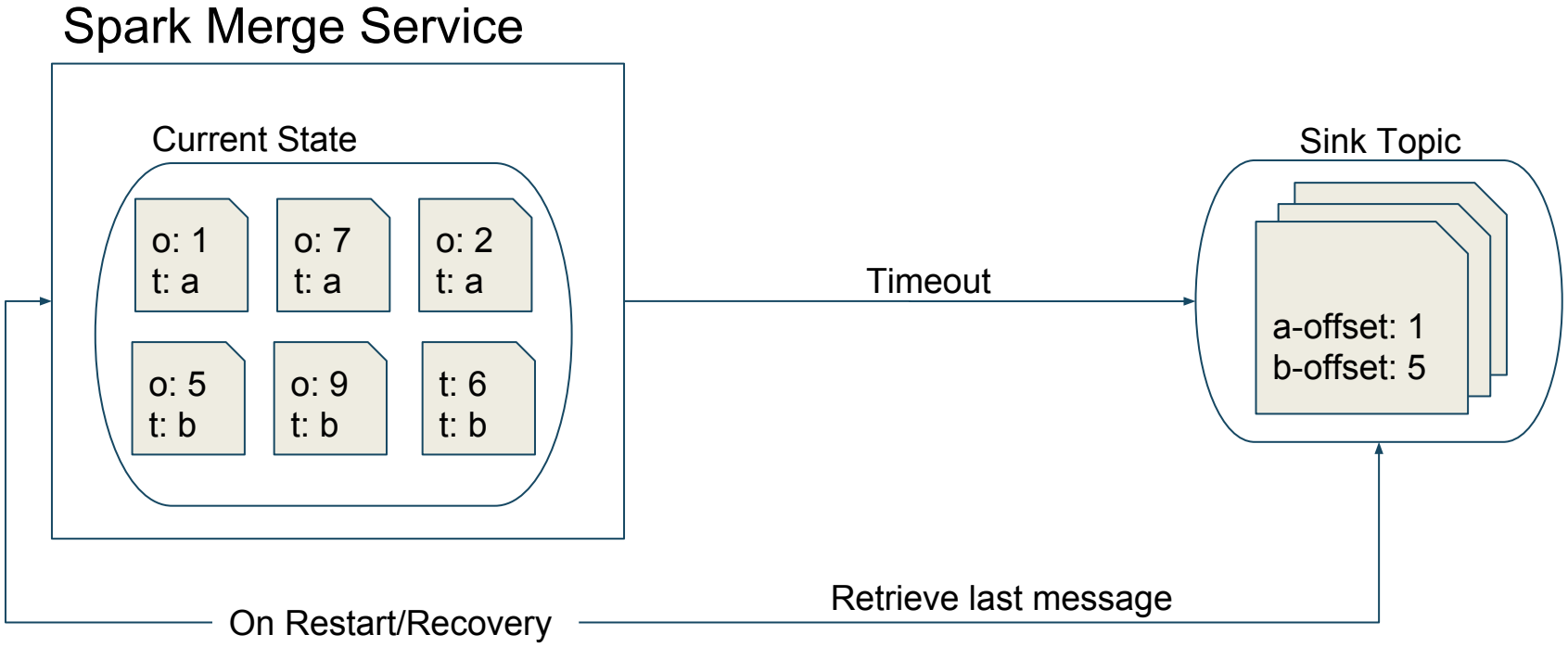
Handle different request rates in topics

```
override def clamp(leaderOffsets: Map[TopicAndPartition, LeaderOffset]):
Map[TopicAndPartition, LeaderOffset] = {

  val ownTimestampValues = for {
    (tp@TopicAndPartition(_, partition), _) <- leaderOffsets
    ownTimestamp <- this.obtainOwnTimestamp(partition)
  } yield (tp, ownTimestamp)

  val otherTimestampValues = for {
    (tp@TopicAndPartition(_, partition), _) <- leaderOffsets
    otherTimestamp <- this.obtainOtherTimestamp(partition)
  } yield (tp, otherTimestamp)
```

Handle different request rates in topics

```
lazy val standardOffsets = super.clamp(leaderOffsets)
leaderOffsets.map { case (tP, leaderOffset) =>
  def stopReading = (tP, leaderOffset.copy(offset = currentOffsets(tP)))
  def continueReading = (tP, standardOffsets(tP))
  (ownTimestampValues.get(tP), otherTimestampValues.get(tP)) match {
    case (None, _) => // no values in this stream yet
      continueReading
    case (_, None) => // stop reading until other stream got values
      stopReading
    case (Some(ownValue), Some(oValue)) if ownValue - oValue > maxLead =>
      stopReading
    case (Some(ownValue), Some(oValue)) =>
      continueReading
  }
}
```

Guarantee at least once semantics



OTTO

Guarantee at least once semantics

```
def lookupOffsets(cProps: Map[String, String]):
Map[TopicAndPartition, Long] = {

  val sourceOffsetsFromSink =
    for {
      (partition, mergedMessage) <- retrieveLastMergedMessage(cProps)
      offsets <- mergedMessage.meta.minSourceTopicOffsets.toList
      (topic, offset) <- List(
        S.topic -> offsets.tracking,
        S.orderTopic -> offsets.order)
    } yield TopicAndPartition(topic, partition) -> offset

  val tPs = retrievePartitions(cProps, Set(S.topic, S.orderTopic))
  val earliestSourceOffsets = retrieveEarliestOffsets(cProps, tPs)
  val latestSourceOffsets = retrieveLatestOffsets(cProps, tPs)
```

Guarantee at least once semantics

```
tPs.map { topicAndPartition =>
  val offset: Long =
    (earliestSourceOffsets.get(topicAndPartition),
      sourceOffsetsFromSink.get(topicAndPartition),
      latestSourceOffsets.get(topicAndPartition)) match {
      case (Some(earliestOffset), Some(offsetFromSink), _)
        if earliestOffset <= offsetFromSink =>
        offsetFromSink
      case (Some(earliestOffset), Some(earliestFromSink), Some(latest)) =>
        earliestOffset //offset already gone in source
      case (_, _, Some(latest)) =>
        latest //min offset could not be retrieved
    }
  topicAndPartition -> offset
}.toMap
```

Everything put together

```
def work(appInfo: AppInfo,
         ssc: StreamingContext,
         cProps: Map[String, String],
         pProps: Map[String, String],
         customReadOffsets: Option[Map[TopicAndPartition, Long]]): Unit = {

  val readOffsets = customReadOffsets.getOrElse(lookupOffsets(cProps))
  val (streamTracking, streamOrder) = createStreams(ssc, cProps, pProps, readOffsets)
  val state = Merger.merge(streamTracking.union(streamOrder))
  val timedOutMessages = state.filter { case (_, message) => message.meta.timedOut }
  val validTimedOutMessages = timedOutMessages.filter(isValid)
  validTimedOutMessages.foreachRDD(MessageSender.send(cProps, pProps))
```

Lessons learned

- Excellent Performance and Scalability
- Extensible via Custom RDDs and Extension to DirectKafka
- No event time windows in Spark Streaming

  See: https://github.com/apache/spark/pull/2633
- Checkpointing cannot be used when deploying new artifact versions
- Driver/executor model is powerful, but also complex

THANK YOU.

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