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08.04.2024

Stream processing part III (real-time data architecture)

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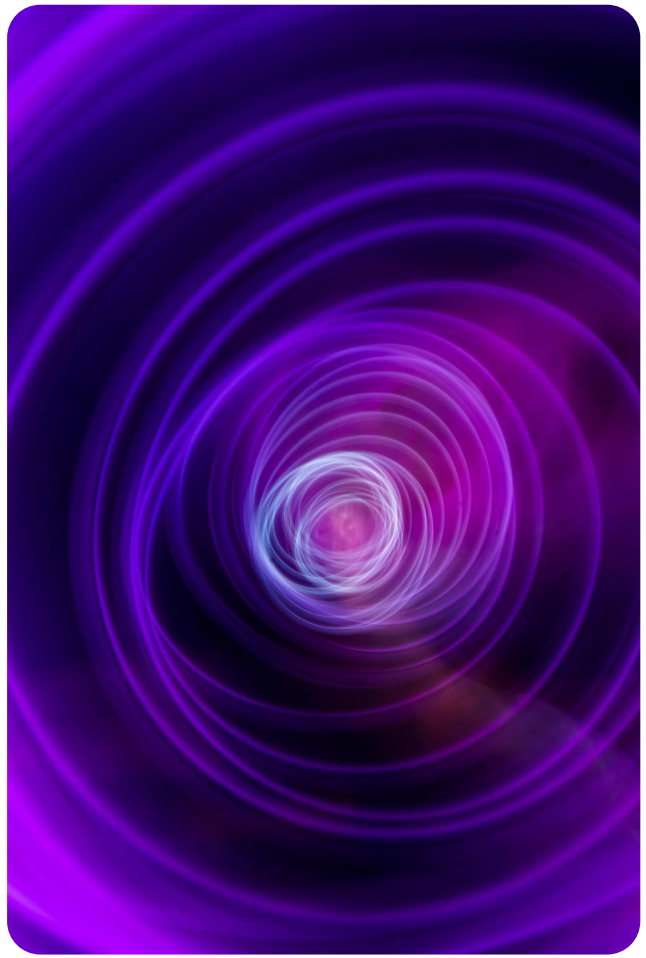
RTB HOUSE

What will this lecture be about?

Goal

- show an example of real-time data architecture at RTB House (different approaches and use cases, design decisions)

- dig deep into data processing frameworks (Apache Storm, Kafka Streams, Kafka Workers etc.)



The context: RTB platform

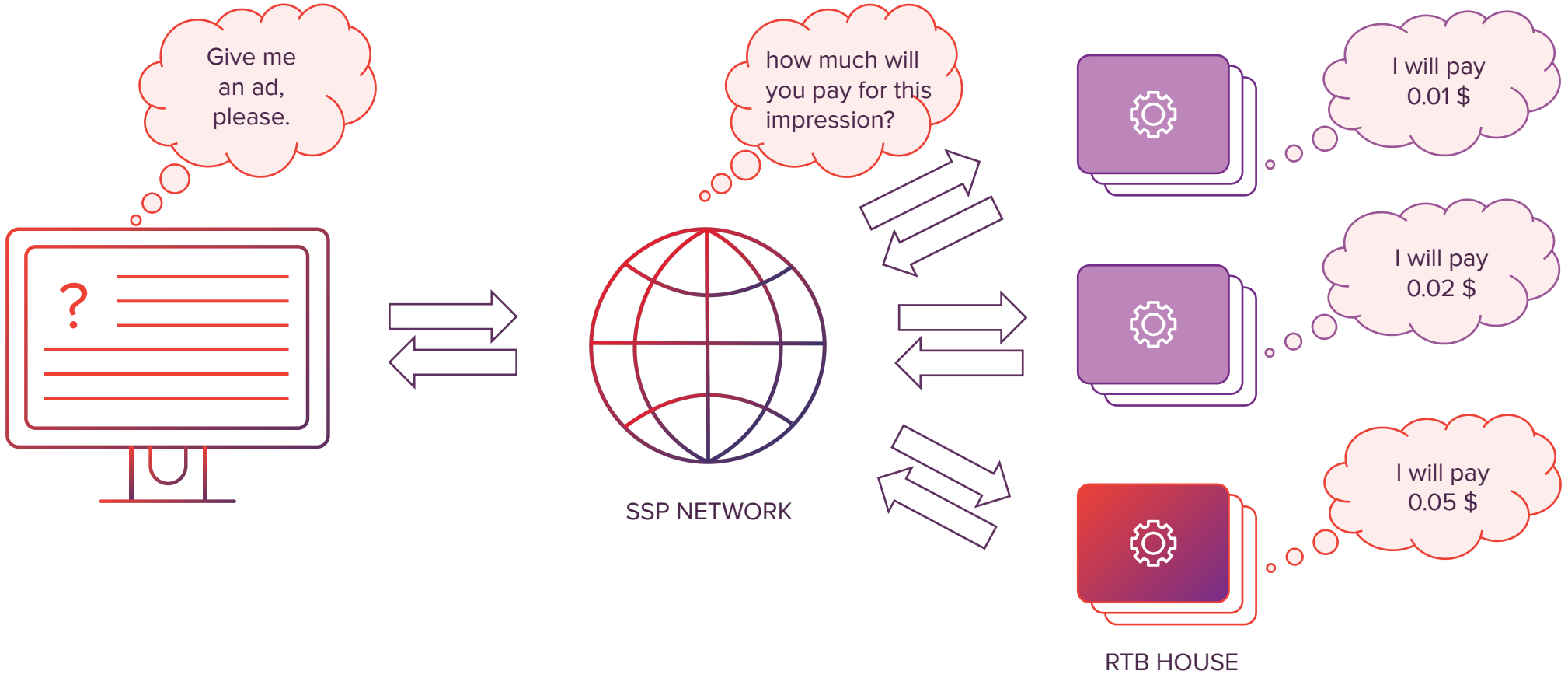
Our platform:

- takes part in auctions, purchases and emits advertisements in the RTB model
- processes 10M+ bid requests per second and generates 500K events per second (300TB data every day)

Data processing:

- requirements: machine learning, system monitoring (alerting, ad hoc debugging) and financial settlements (reports, budget limits)
- use cases: filtering, synchronizing, joining, aggregating, storing events and statistics in Hadoop, GCS, BigQuery, Postgres or Elasticsearch

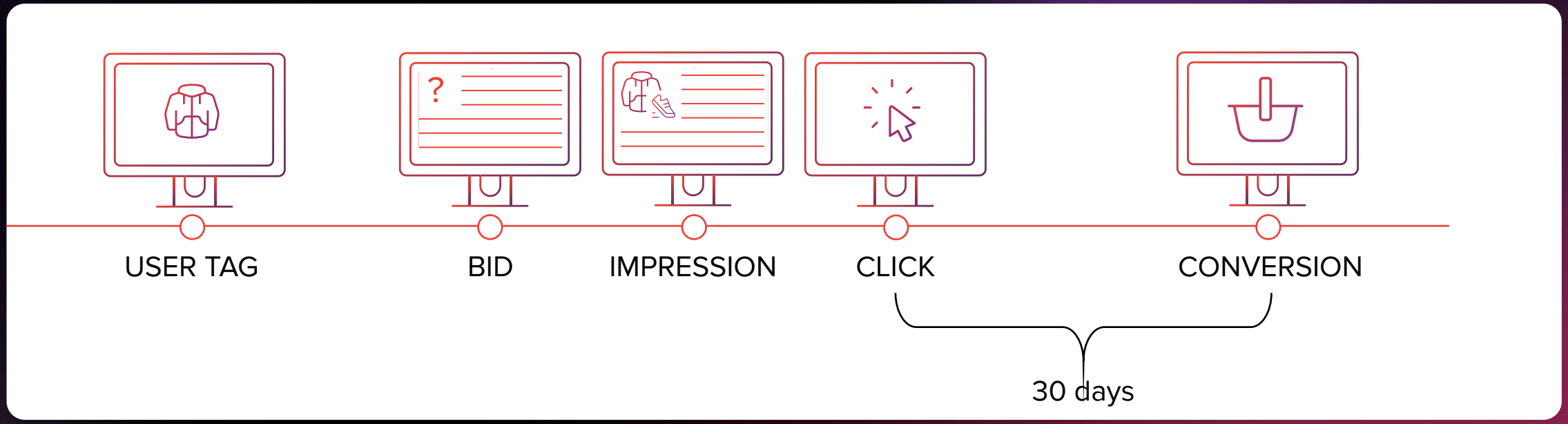
The context: RTB platform



The context: RTB platform

Our platform consists of two types of servlets:

- bidders process bid requests
- adservlets process user requests (tags, impressions, clicks and conversions)



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The context: RTB platform

To be able to buy advertising space effectively, we needed to store and process data (user info, historical impressions)

We were able to use this data for estimating:

CTR
probability of a click (click-through rate)

CR
conditional probability of a conversion given that an impression was clicked (conversion rate)

CV
conversion value

These estimated values are used for bid pricing:

bid_value = (1-margin) * CTR * CR * CV * rate (impression_value)

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Iterations

We have been improving our solution by many iterations:

- at first: end-of-day batch jobs, single-DC, inconsistent data-flows
- finally: real-time data processing, delay reduced from 1 day to 15 seconds, multi-DC architecture, end-to-end exactly-once processing

It was essential to:

- separate data-flow from the core platform
- provide immutable streams of events and data synchronization between DCs
- dig deep into open-source streaming technologies and if needed replace them by better, custom-built components

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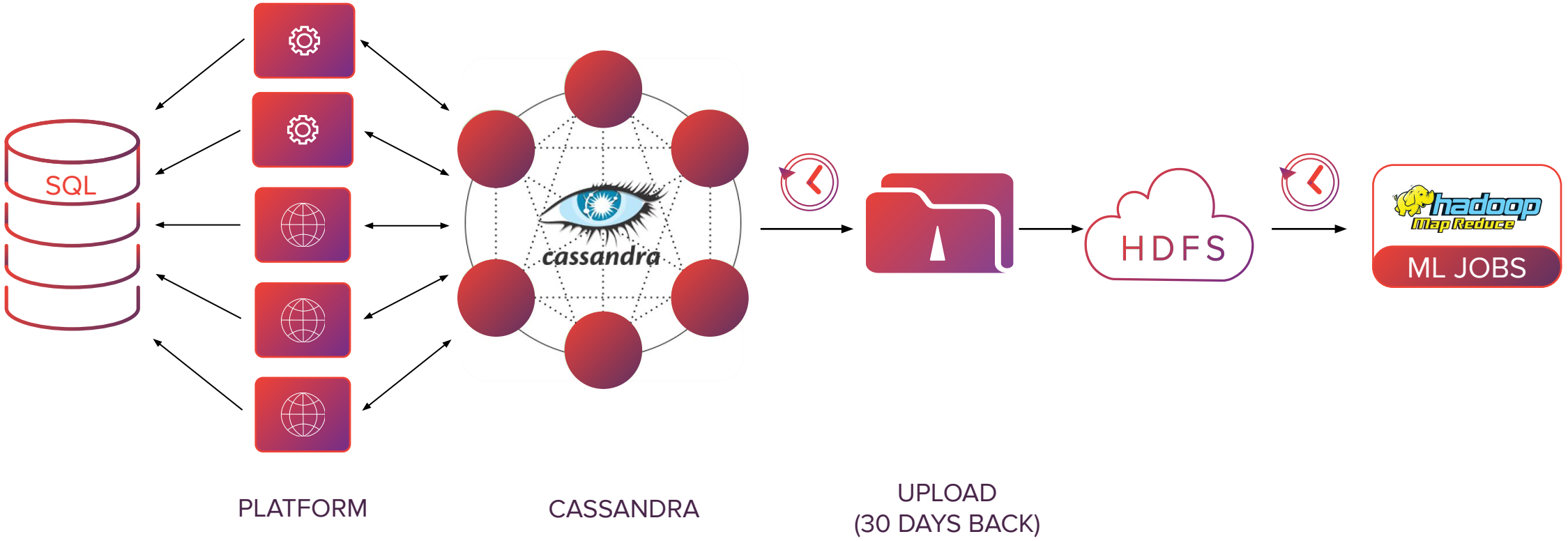
The 1st iteration: mutable impressions

```
{ IMPRESSION:
      IMPRESSION_HASH,
      TIME,
      COOKIE,
      ADVERTISER_ID,
      ...
      CLICKS,
      CONVERSIONS
}
```

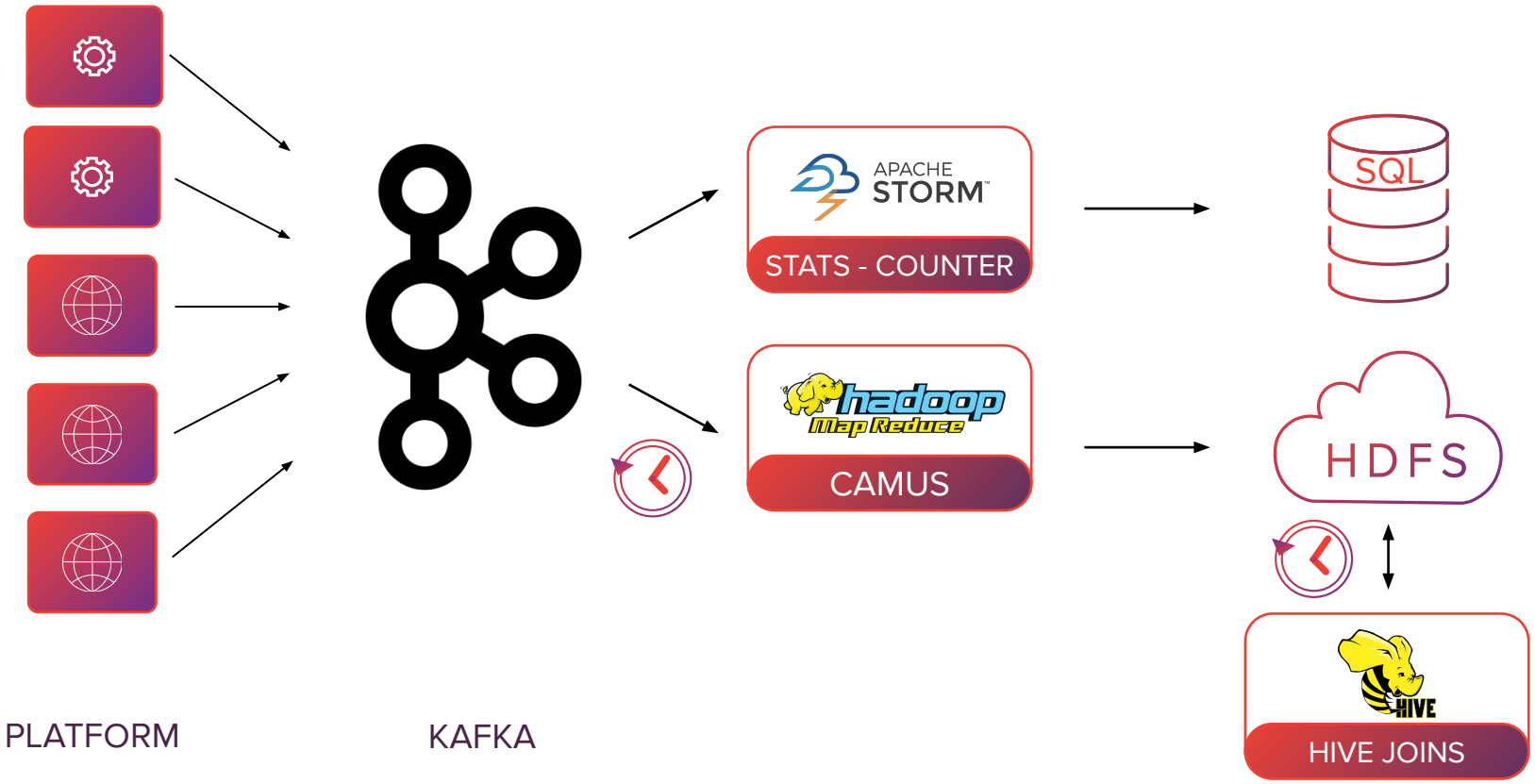
```
{ CLICK:
      CLICK_HASH,
      TIME,
      COOKIE,
      ADVERTISER_ID,
      IMPRESSION_HASH
      ...
}
```

```
{ CONVERSION:
      CONVERSION_HASH,
      TIME,
      COOKIE,
      ADVERTISER_ID,
      ...
}
```

The 1st iteration: mutable impressions



The 1st iteration: mutable impressions



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The 3rd iteration: immutable streams of events

```
{ IMPRESSION:
      IMPRESSION_HASH,
      TIME,
      COOKIE,
      ADVERTISER_ID,
      ...
      CLICKS,
      CONVERSIONS
}
```

```
{ CLICK:
      CLICK_HASH,
      TIME,
      COOKIE,
      ADVERTISER_ID,
      IMPRESSION_HASH
      ...
}
```

```
{ CONVERSION:
      CONVERSION_HASH,
      TIME,
      COOKIE,
      ADVERTISER_ID,
      ...
}
```

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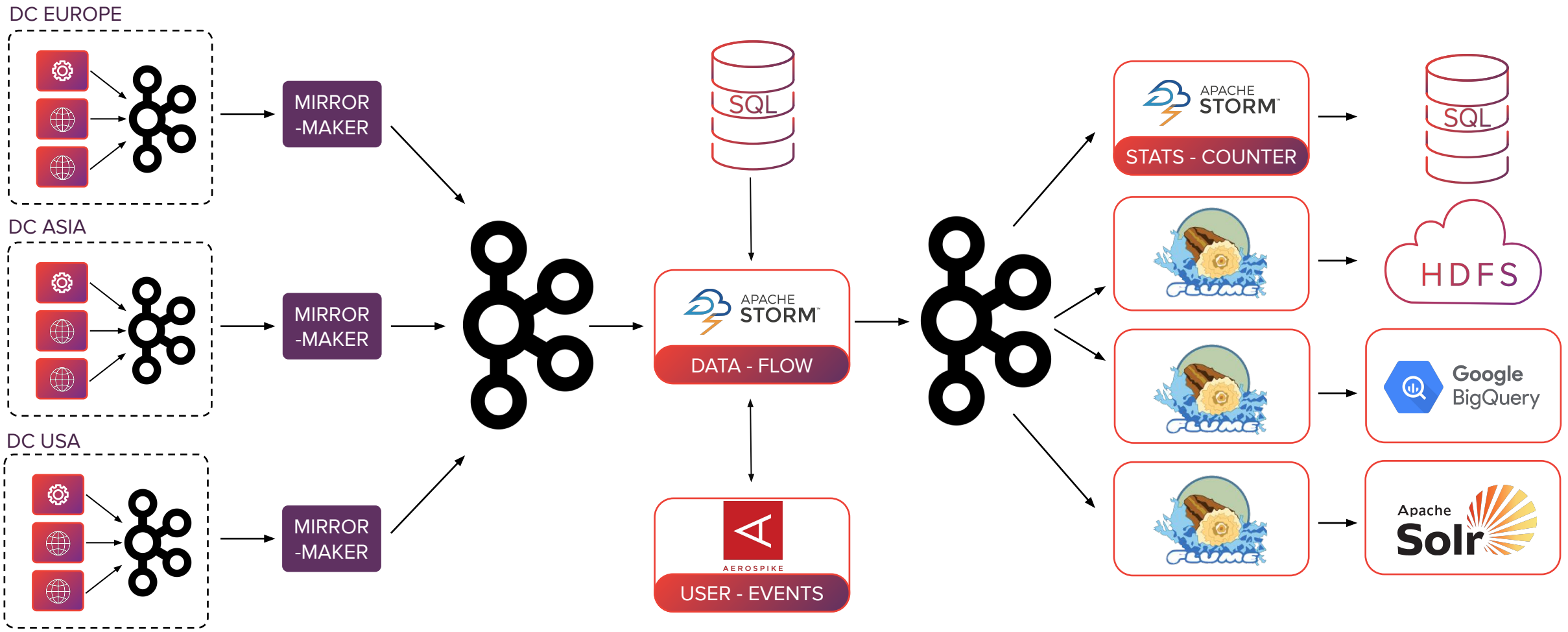
The 3rd iteration: immutable streams of events

```
{ IMPRESSION:
      IMPRESSION_HASH,
      TIME,
      COOKIE,
      ADVERTISER_ID,
      ...
      ~~CLICKS~~,
      ~~CONVERSIONS~~
}
```

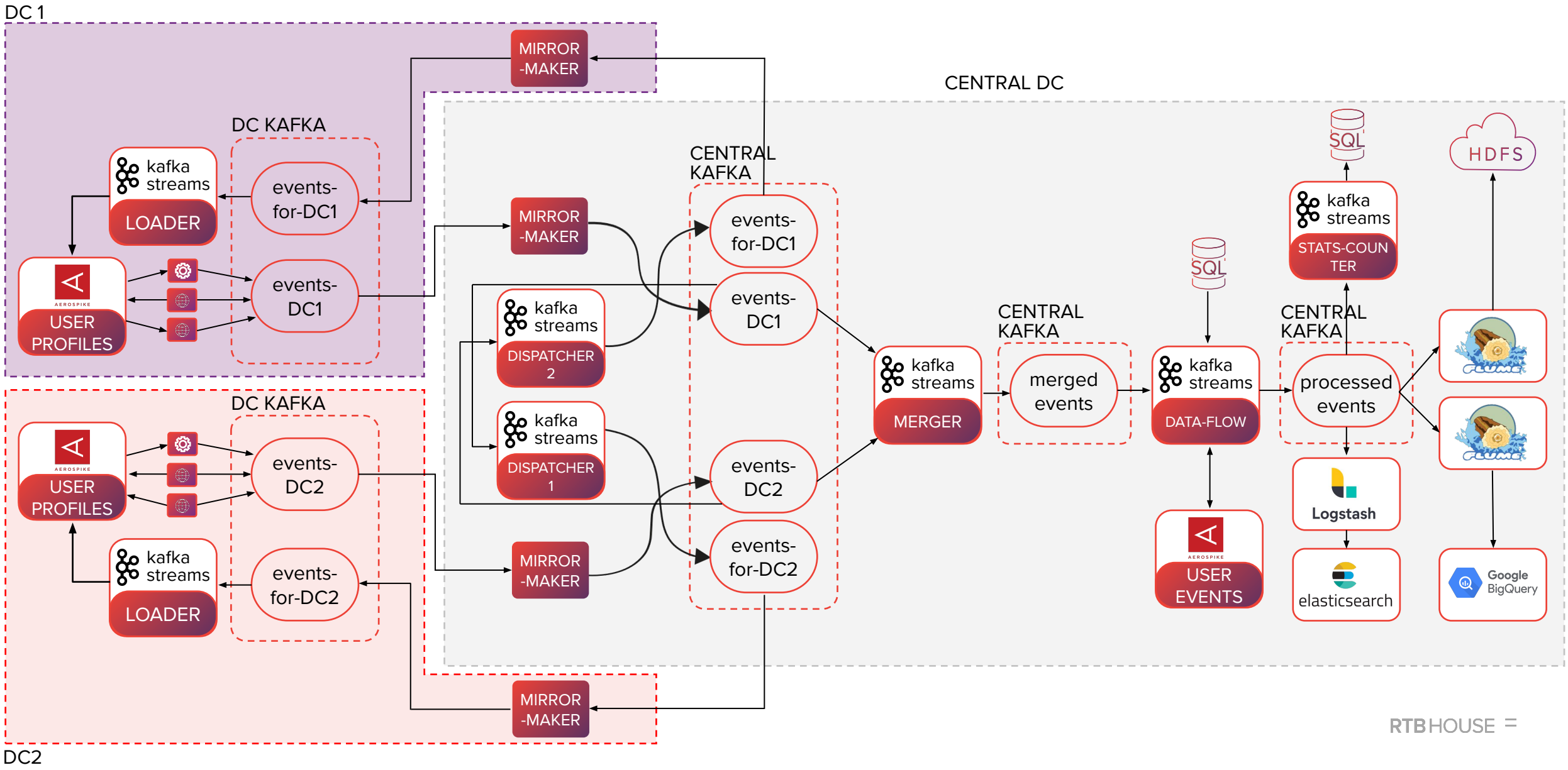
```
{ CLICK:
      CLICK_HASH,
      TIME,
      COOKIE,
      ADVERTISER_ID,
      ~~IMPRESSION_HASH~~
      ...
      IMPRESSION
}
```

```
{ CONVERSION:
      CONVERSION_HASH,
      TIME,
      COOKIE,
      ADVERTISER_ID,
      ...
      IMPRESSION,
      CLICK
}
```

The 3rd iteration: immutable streams of events



The 4th iteration: multi-dc architecture



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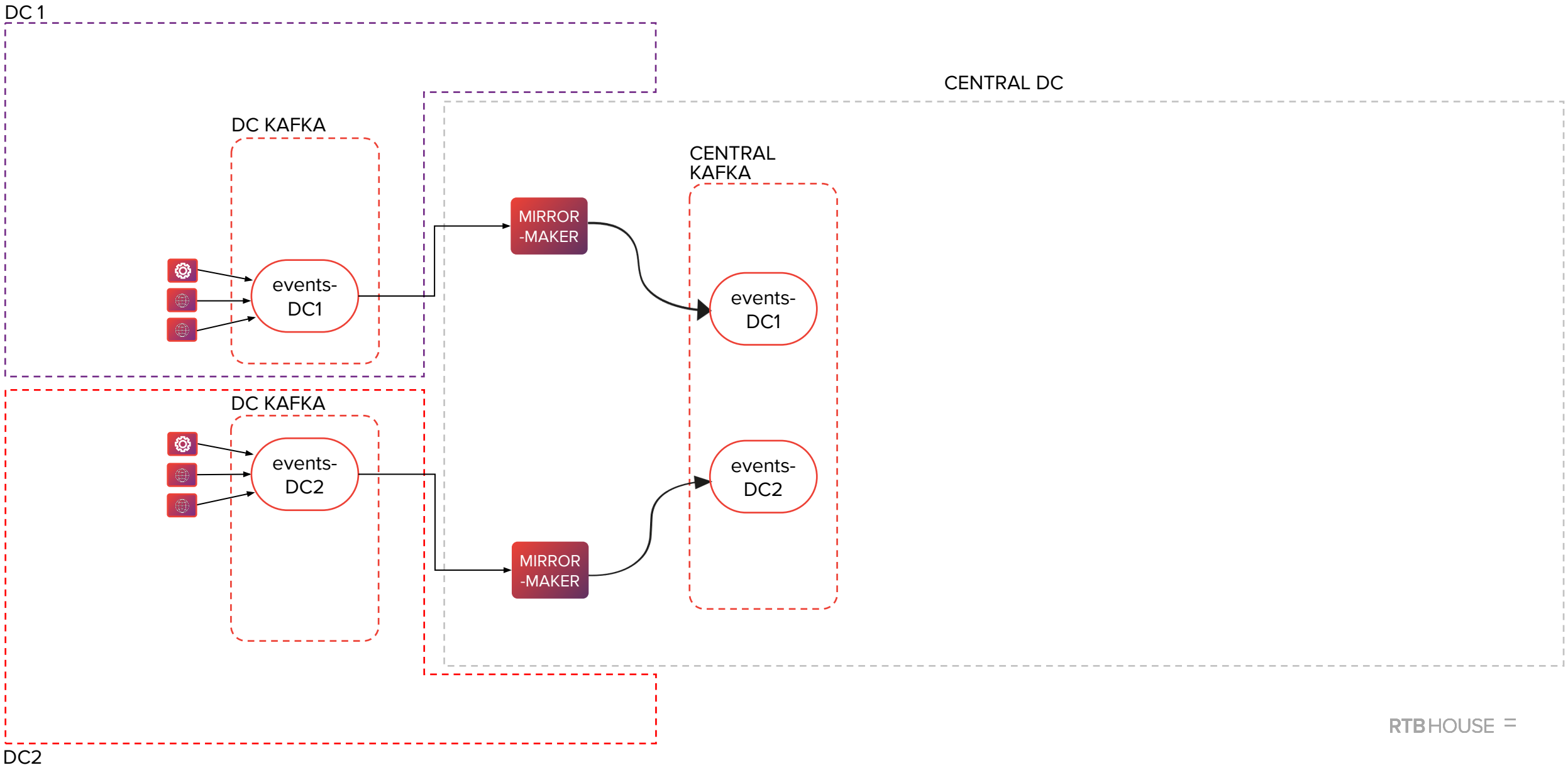
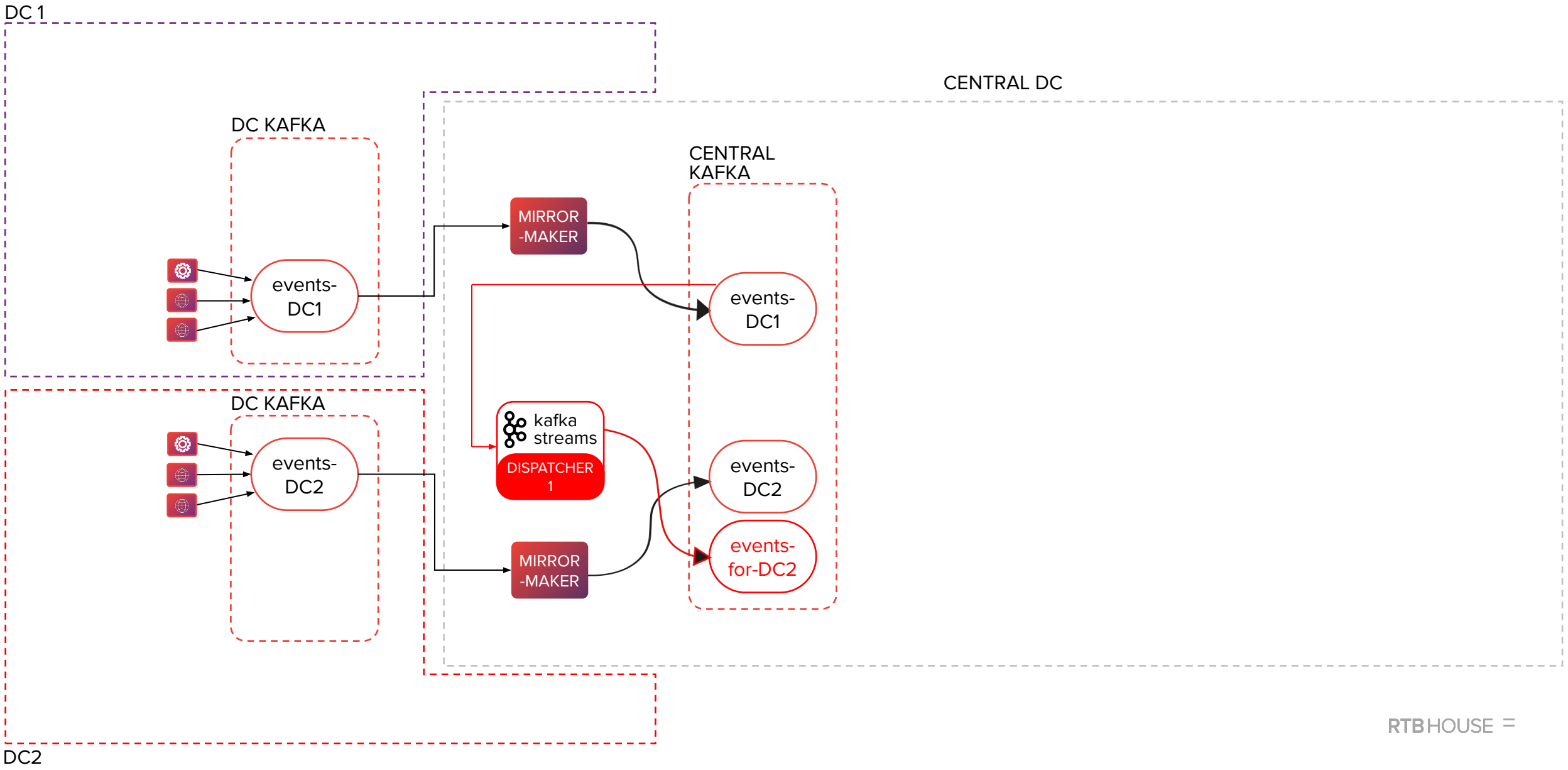
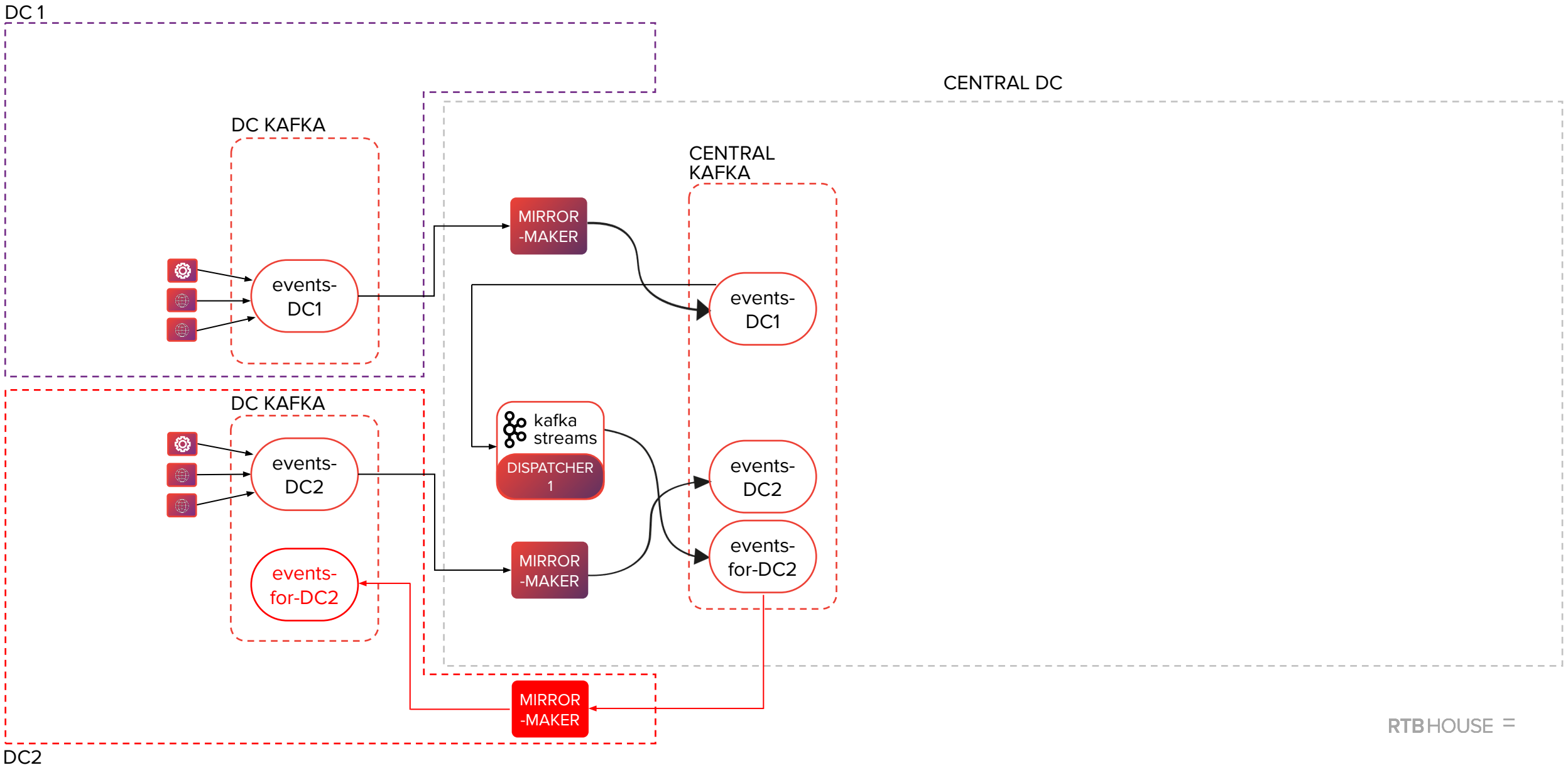
The 4th iteration: multi-dc architecture



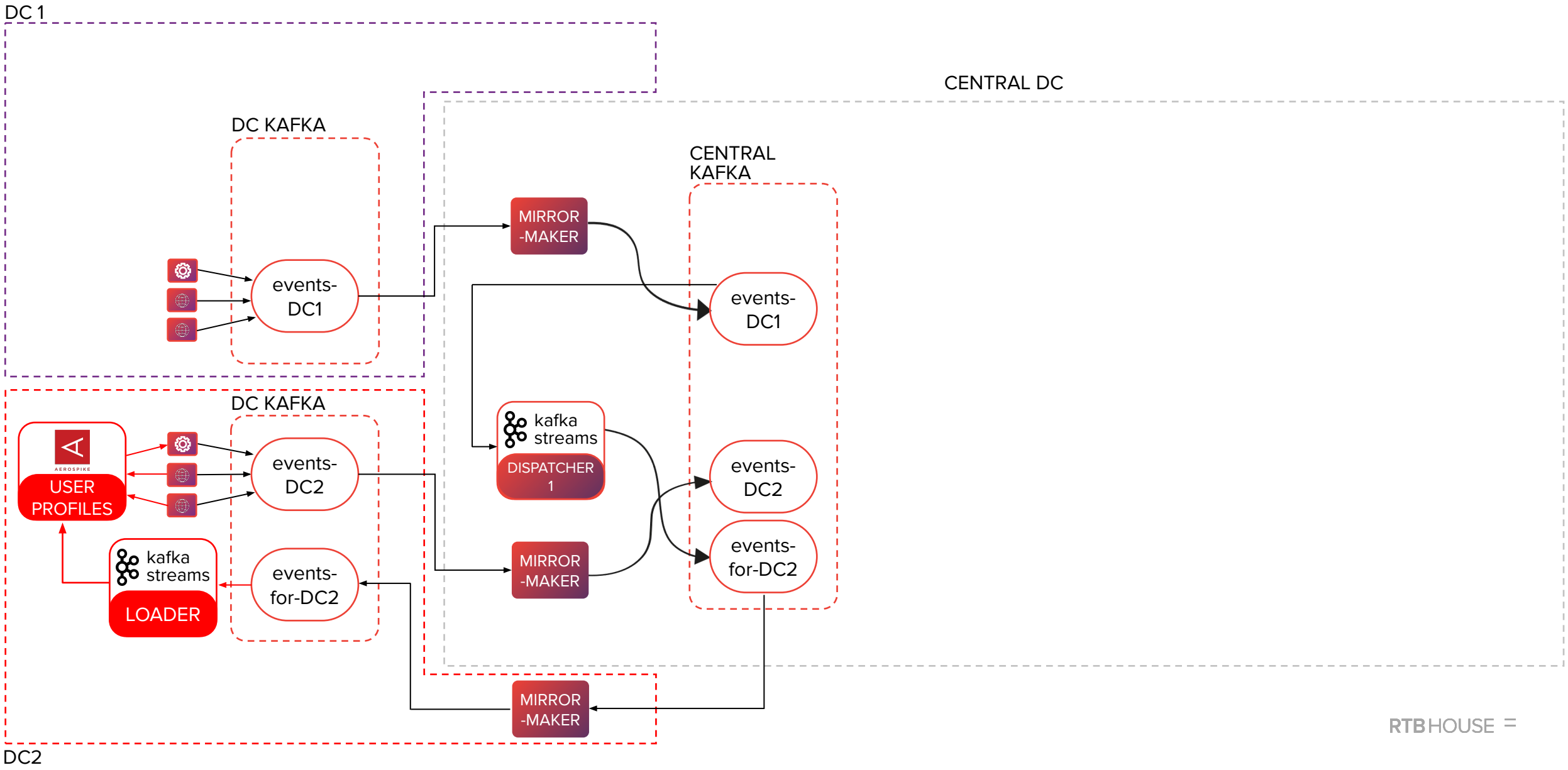
The 4th iteration: multi-dc architecture



The 4th iteration: multi-dc architecture



The 4th iteration: multi-dc architecture



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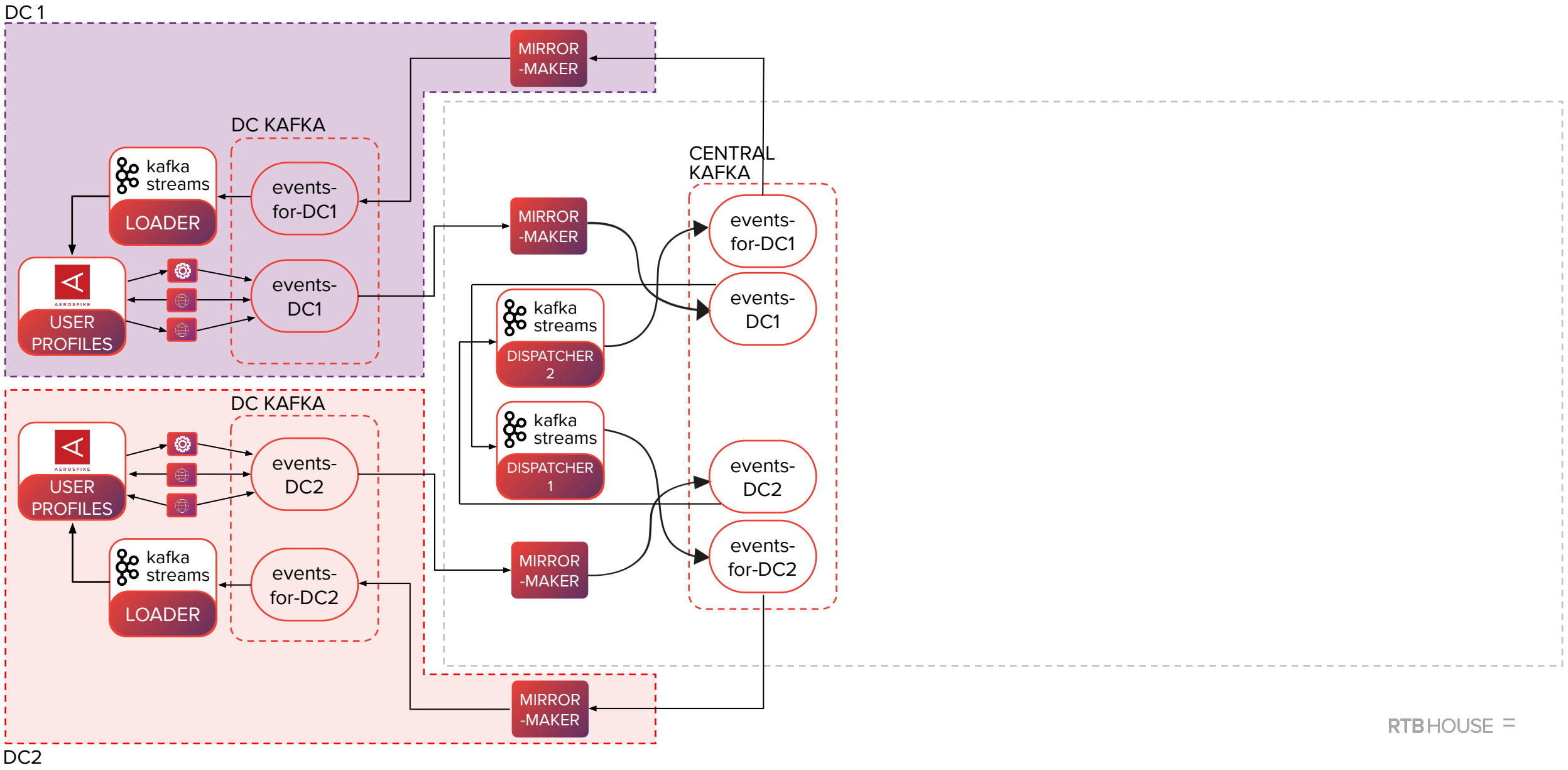

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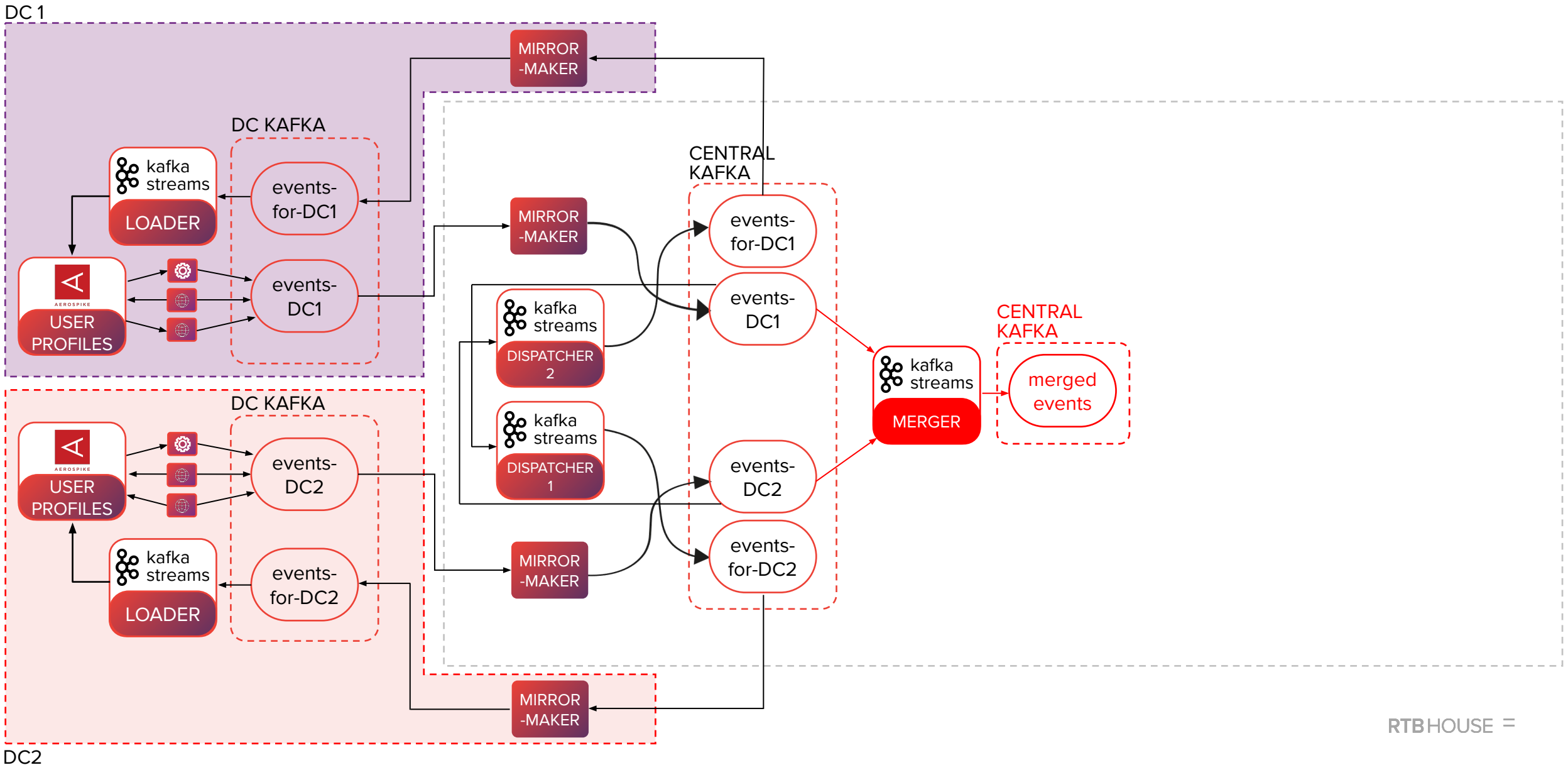
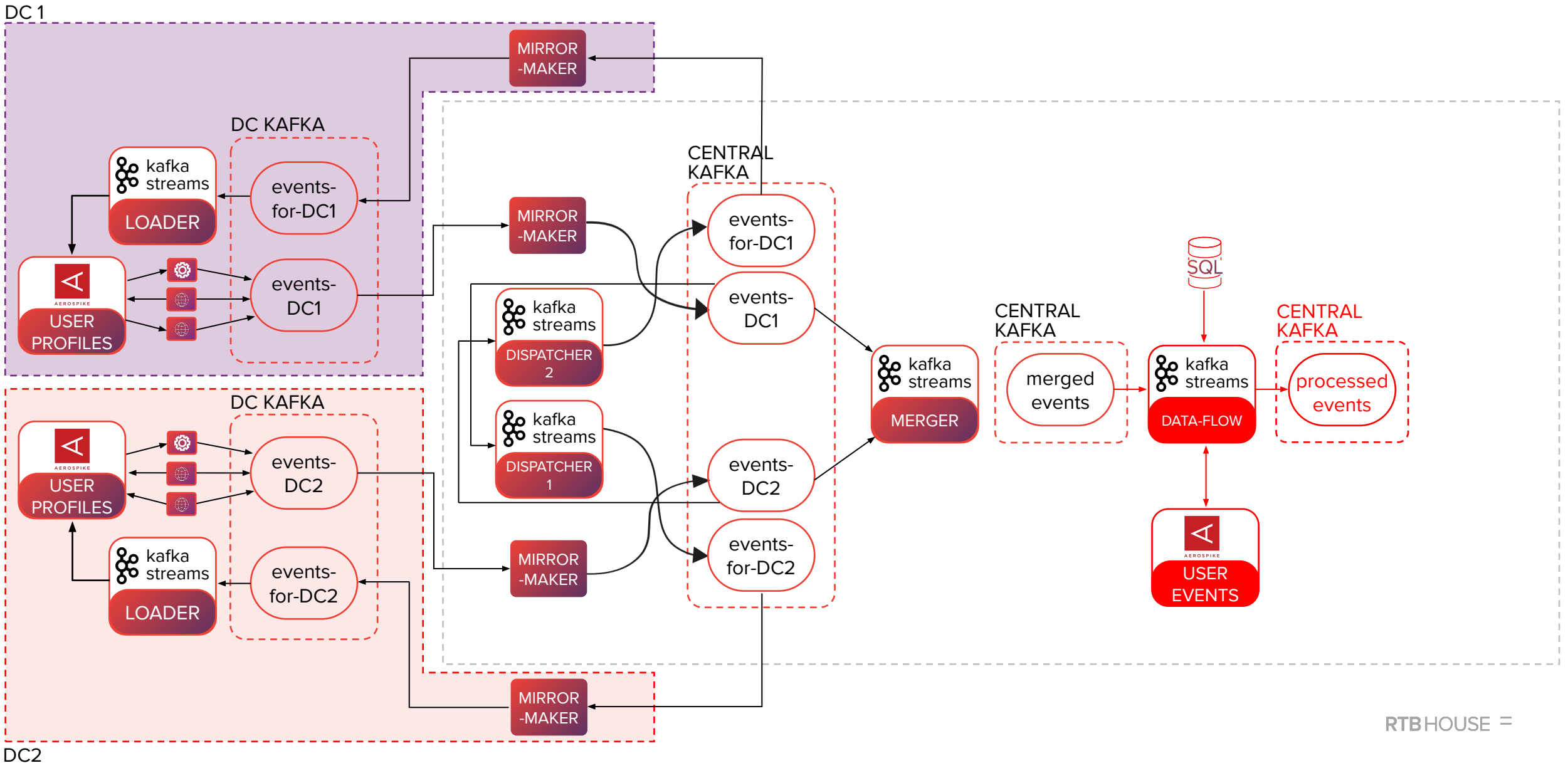


The 4th iteration: multi-dc architecture



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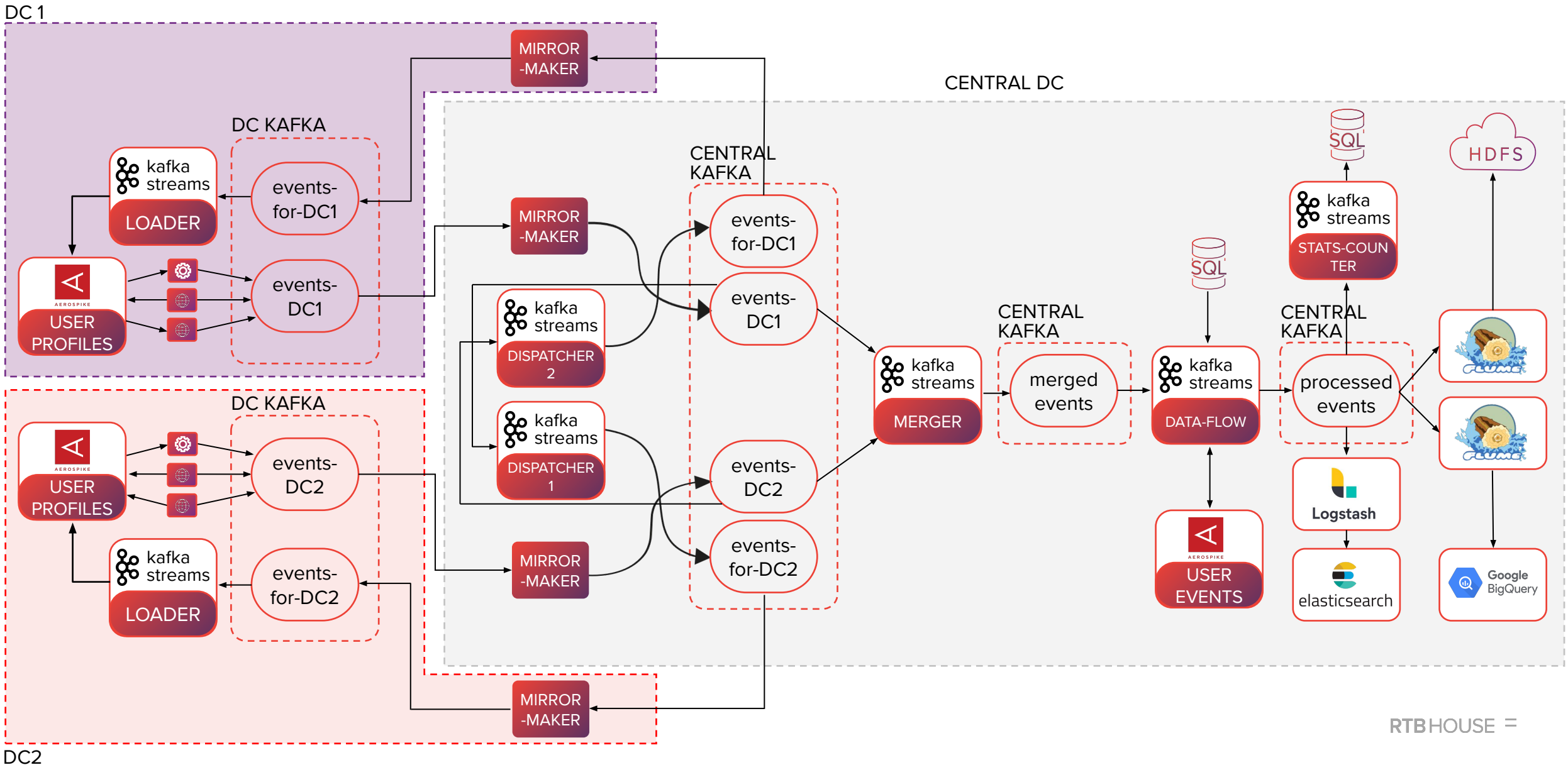
The 4th iteration: multi-dc architecture



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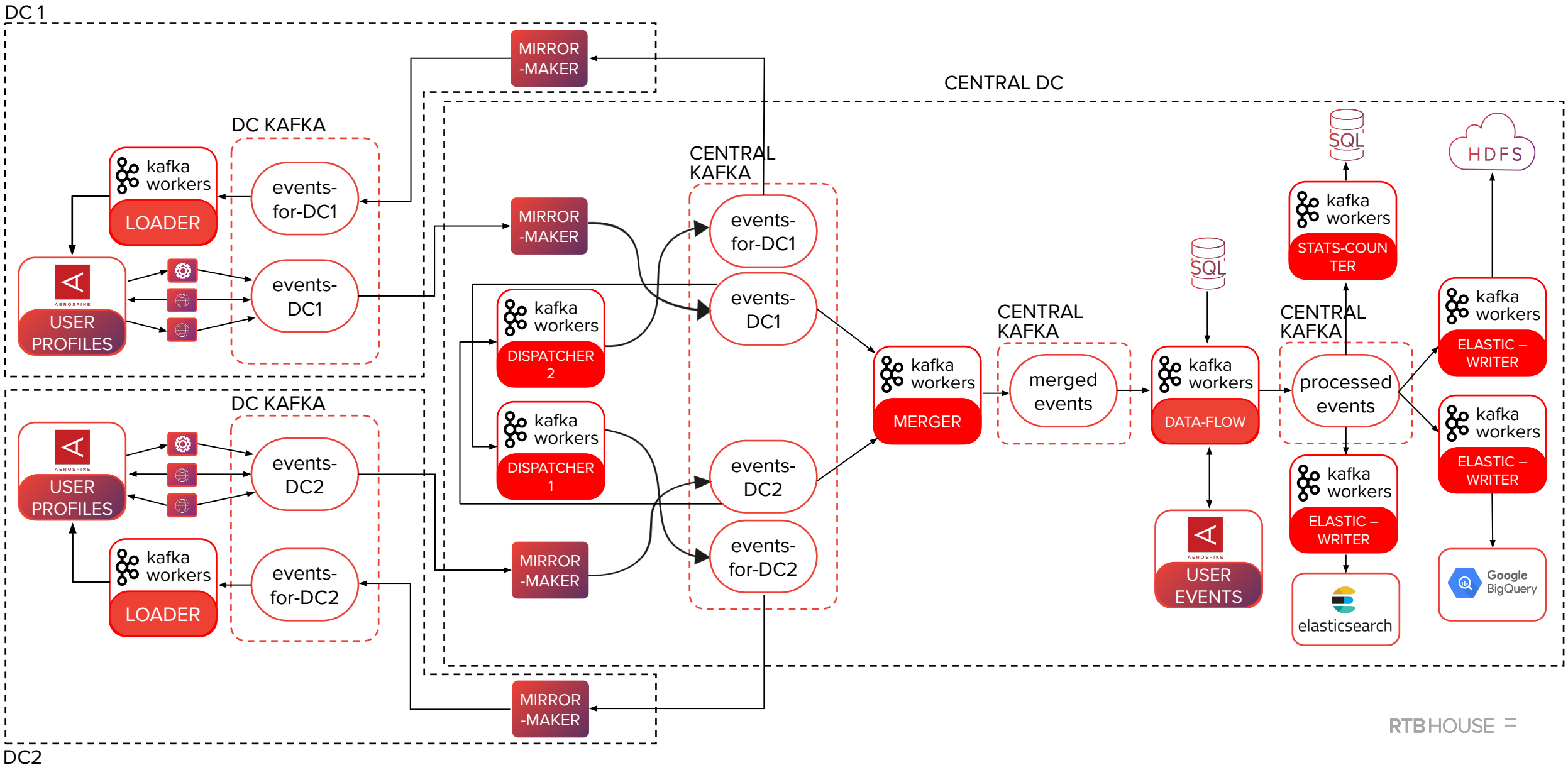
The 5th iteration: Kafka Workers



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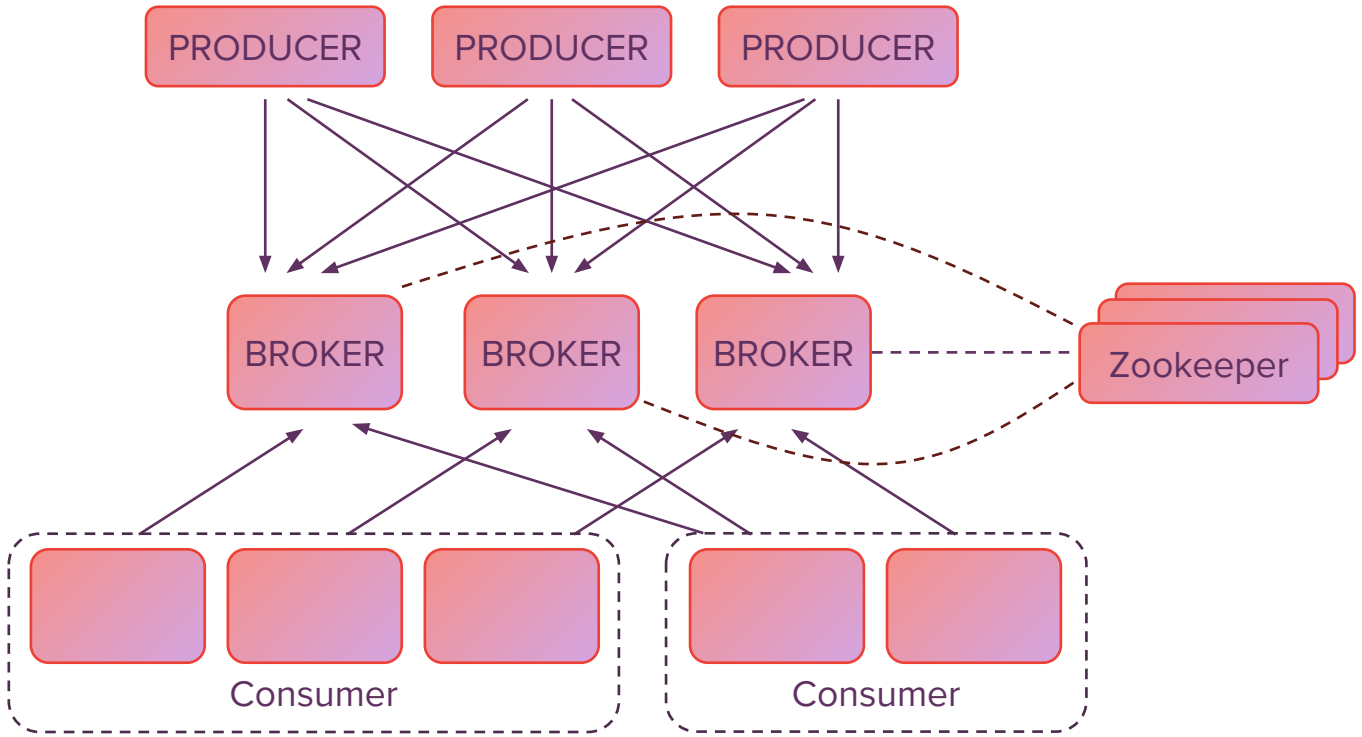
Apache Kafka

Why Kafka:

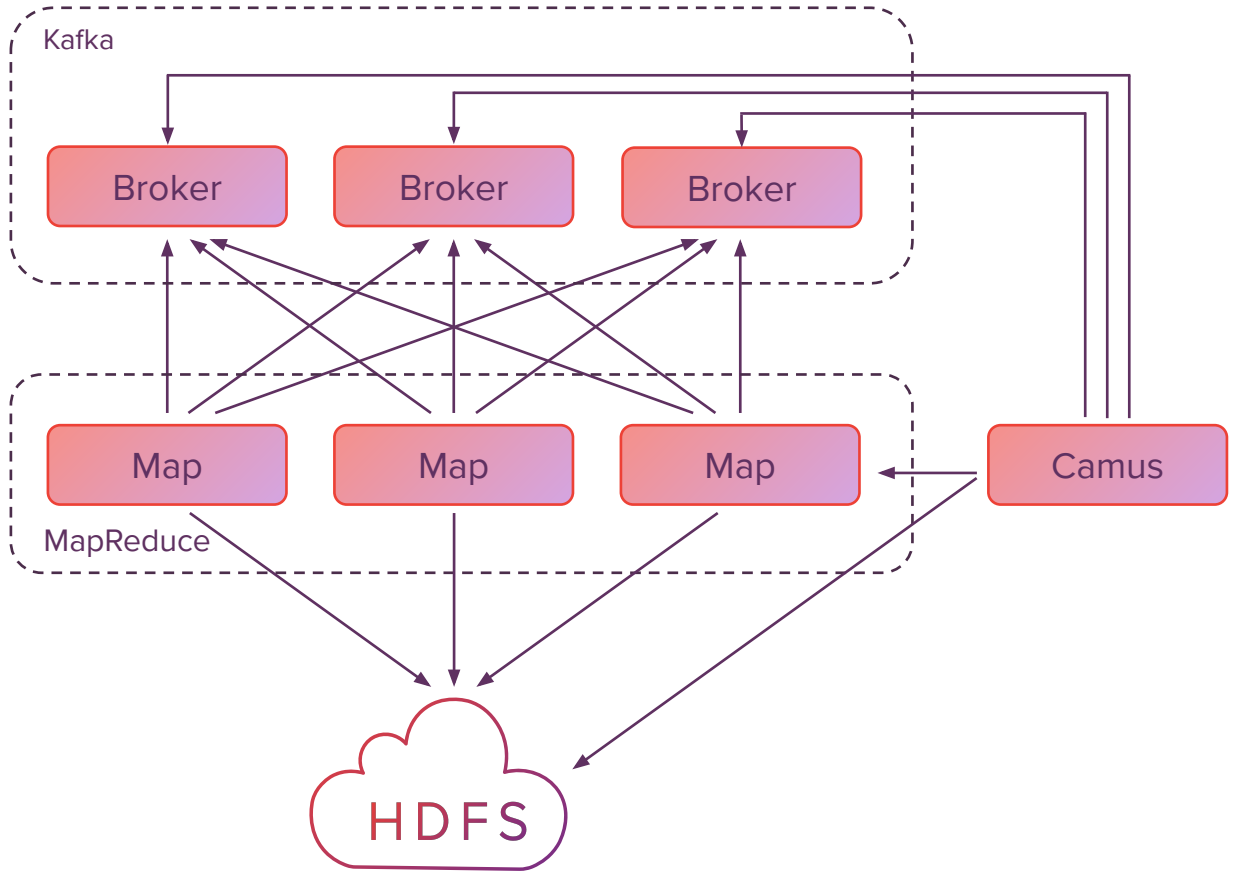
- event streaming platform (**distributed log**)
- producer-consumer separation
- fault-tolerance (**replication**)
- scalability and distribution (**topics partitioning**)
- log retention, statelessness
- efficient data consumption



Apache Camus

Why Camus:

- **MapReduce** job that incrementally **loads data from Kafka into HDFS**
- fetches topics from Zookeeper and latest offsets from Kafka
- **partitions the output** based on the timestamp of each record
- **stores offsets** in log files in HDFS



Apache Avro

Why Apache Avro:

- data serialization framework
- stores data in a compact, efficient binary format
- schema (JSON) could define rich data structures using various complex types
- schema is stored with data in one Avro file (self-describing container files)
- supports schema changes (old schema could be deserialized by a new program)

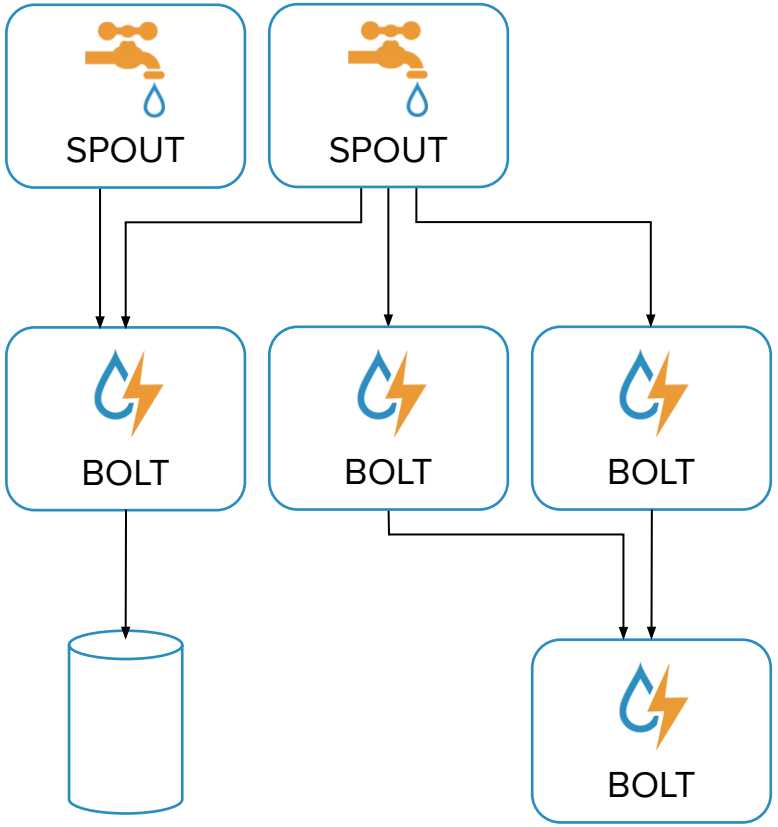
Our approach:

- Kafka's messages and HDFS files
- schema registry, historical schemas for Avro deserialization
- avro-fastserde (github.com/RTBHOUSE/avro-fastserde)

Apache Storm

Why Apache Storm:

- real-time computation system
- processes **streams** of **tuples** and runs user-defined **topologies** with processing nodes:
  - **spouts** emit new tuples
  - **bolts** receive tuples, do processing and generate tuples (**states** persist information)
- guarantees that every spout tuple will be fully processed (fault-tolerance)
- executes spouts and bolts as individual **tasks** that run in parallel on multiple machines



Apache Storm

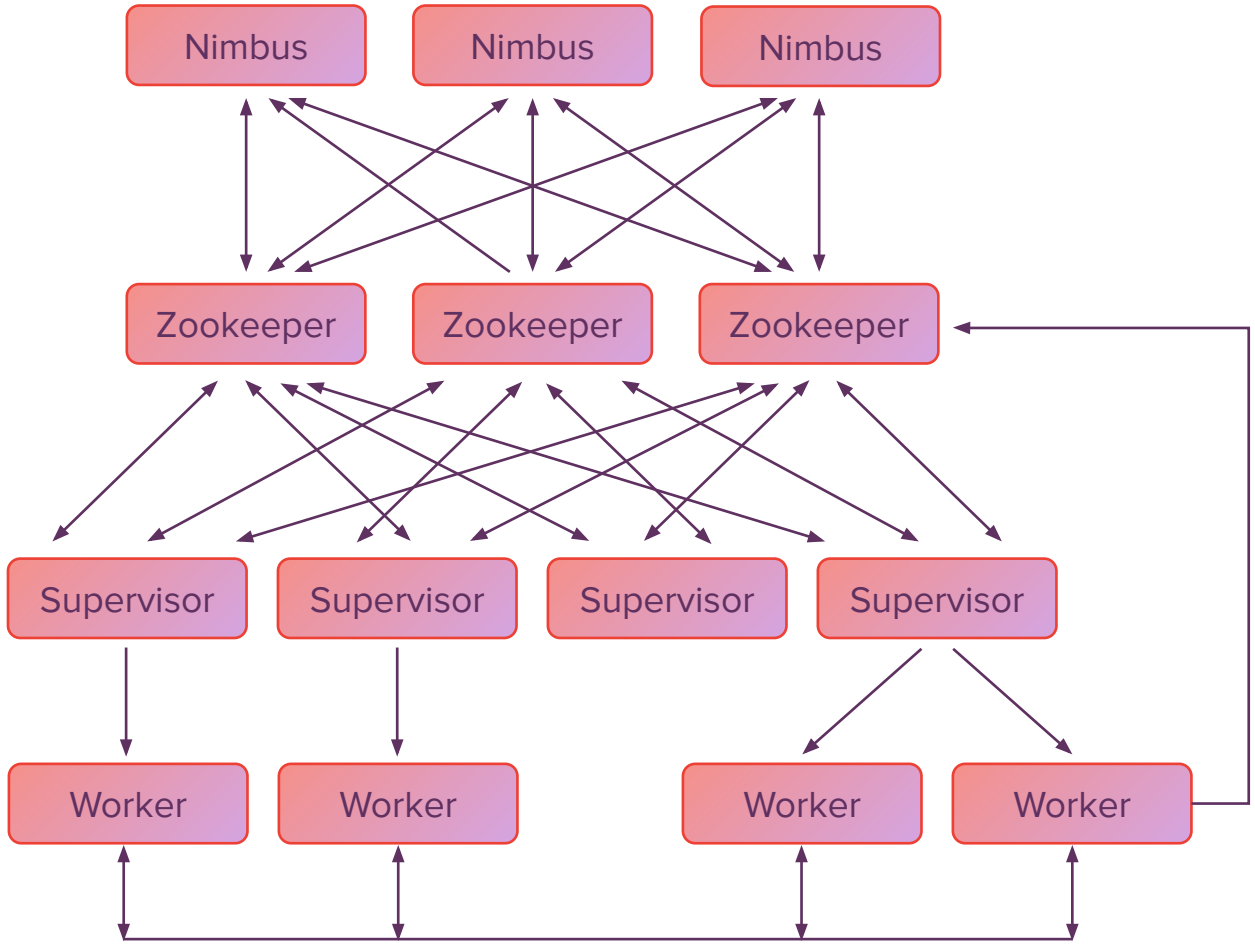
Master runs a daemon – **Nimbus:**

- responsible for distributing code around the cluster, assigning tasks to machines, and monitoring

Worker runs a daemon - **Supervisor**:

- listens for work assigned to its machine and starts and stops worker processes

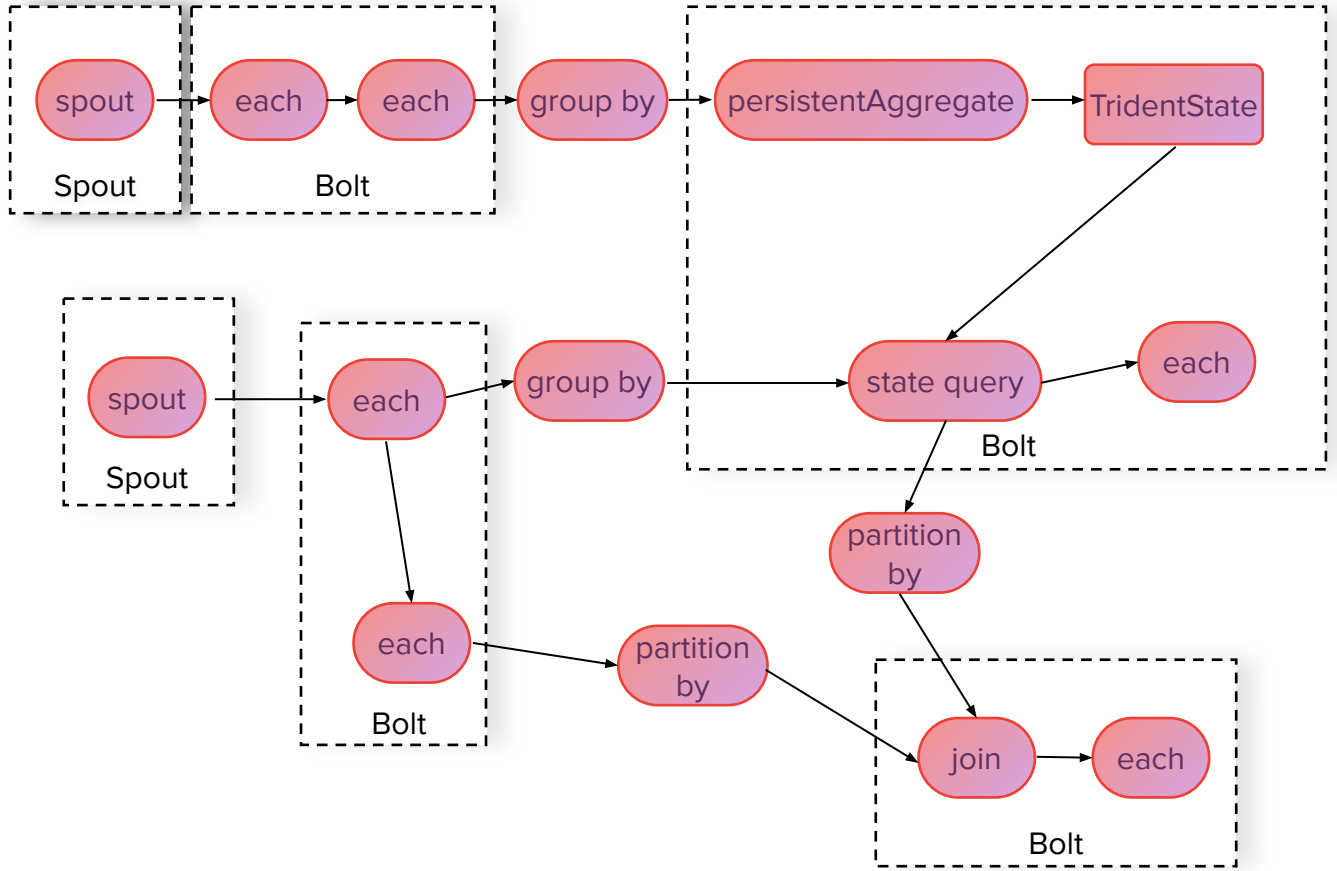
Each **worker process** is a physical JVM and executes a subset of all the tasks for the topology



Apache Storm Trident API

Why Trident:

- high-level declarative API
- provides **functions, filters, joins, groupings, and aggregations**
- supports stateful, incremental processing on top of persistence stores
- processes **microbatches** (transactions) and supports exactly-once processing



Source: storm.apache.org

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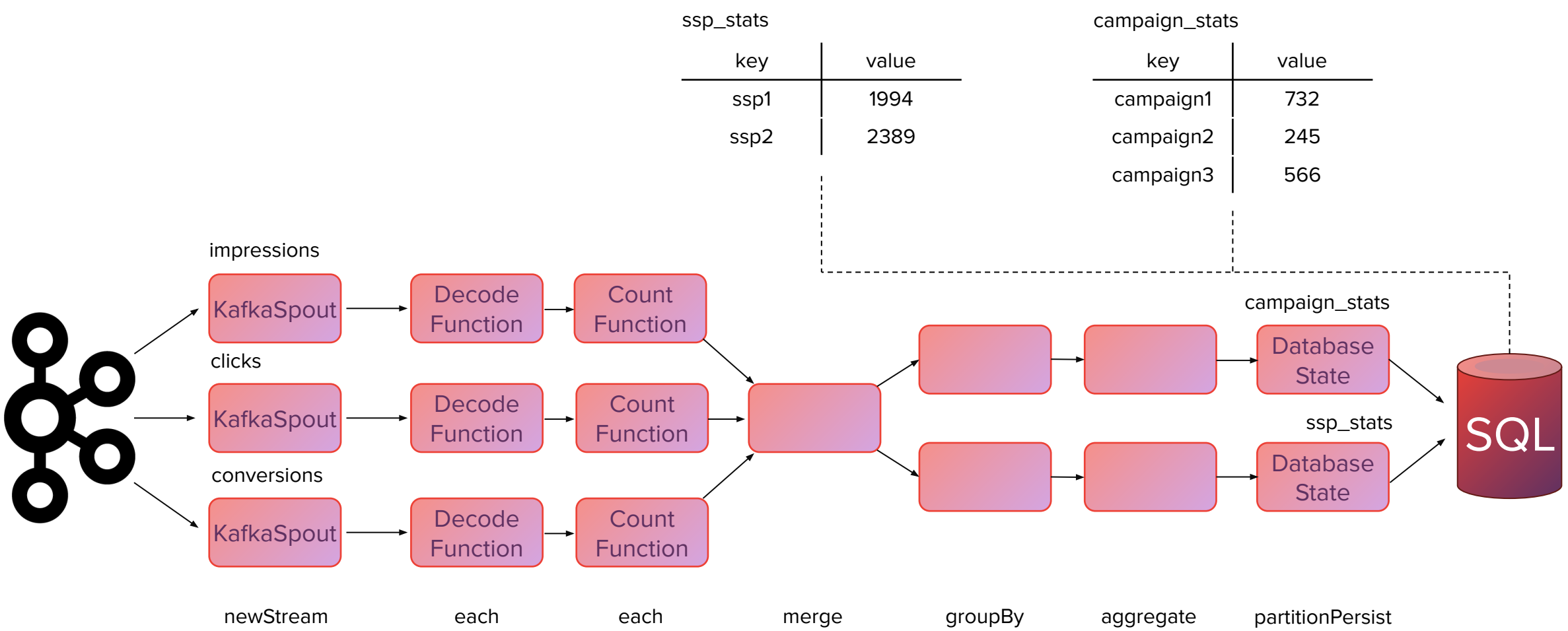
Use case: stats-counter



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Use case: stats-counter (exactly-once state)

zookeeper

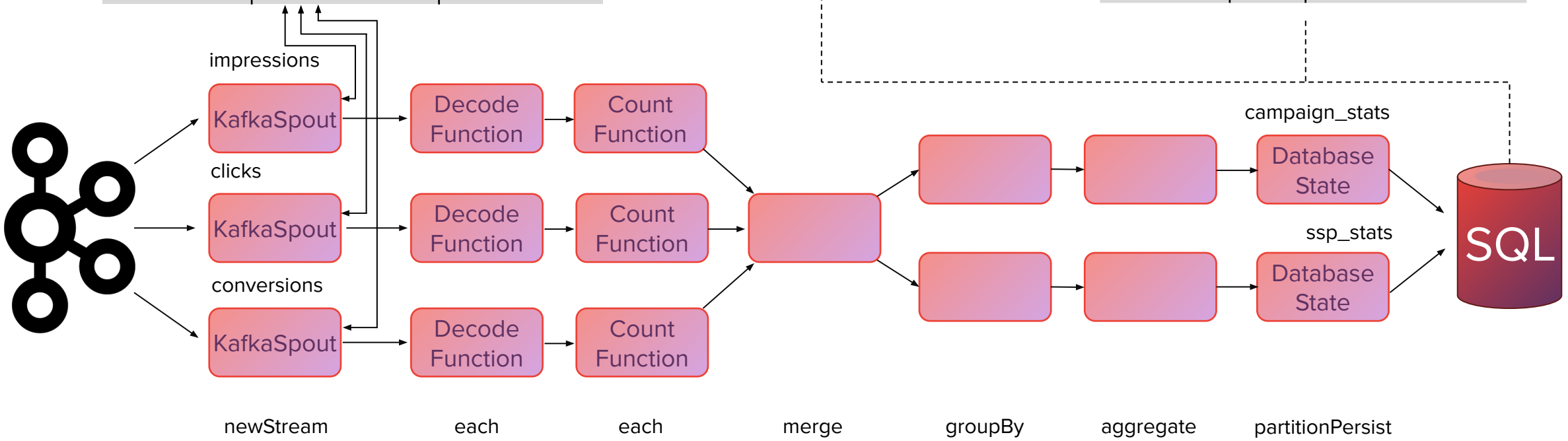
key	<offset1, offset2>	transaction_id
impressions	<5831, 5917>	19
clicks	<623, 680>	19
conversions	<423, 442>	19

ssp_stats

key	value	last_transaction_id
ssp1	1994	17
ssp2	2389	18

campaign_stats

key	value	last_transaction_id
campaign1	732	18
campaign2	245	17
campaign3	566	18



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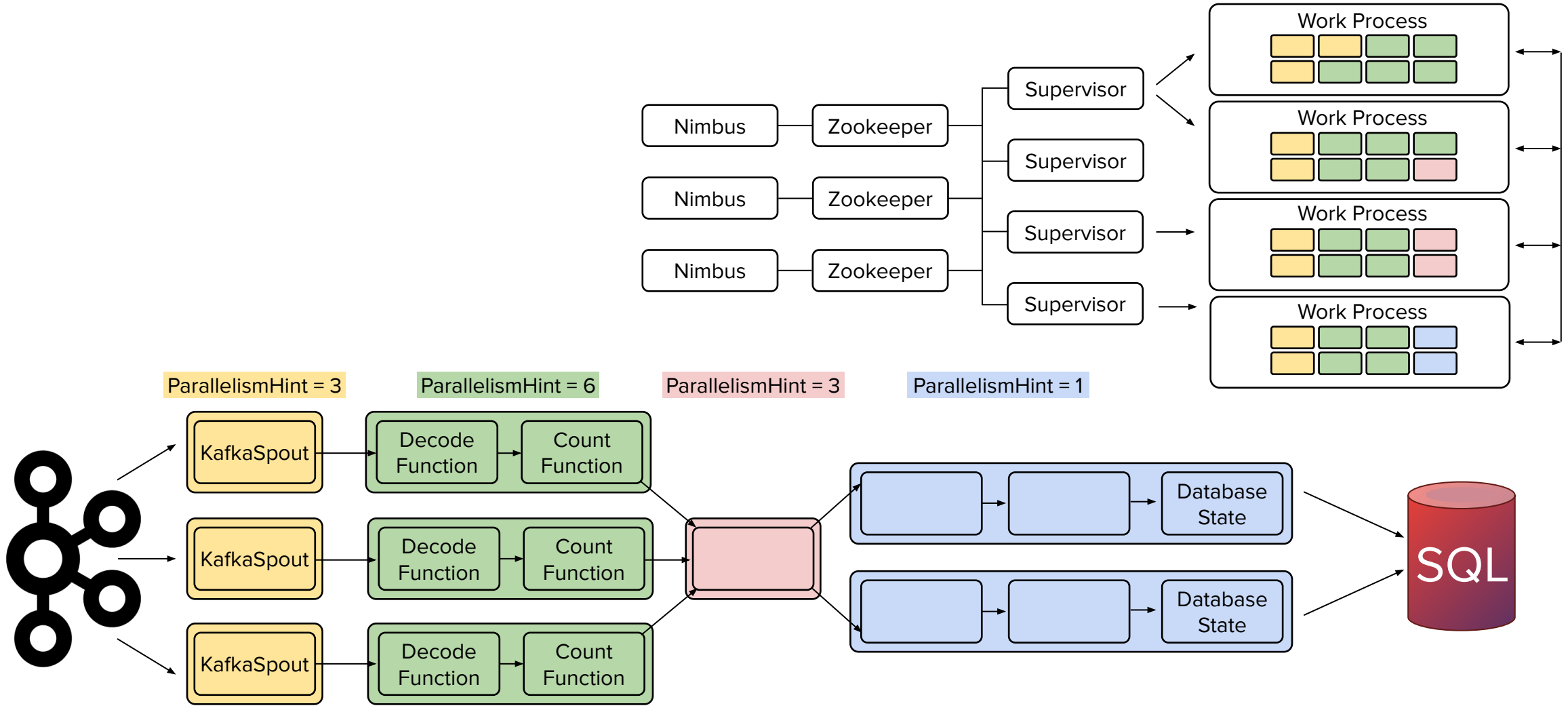
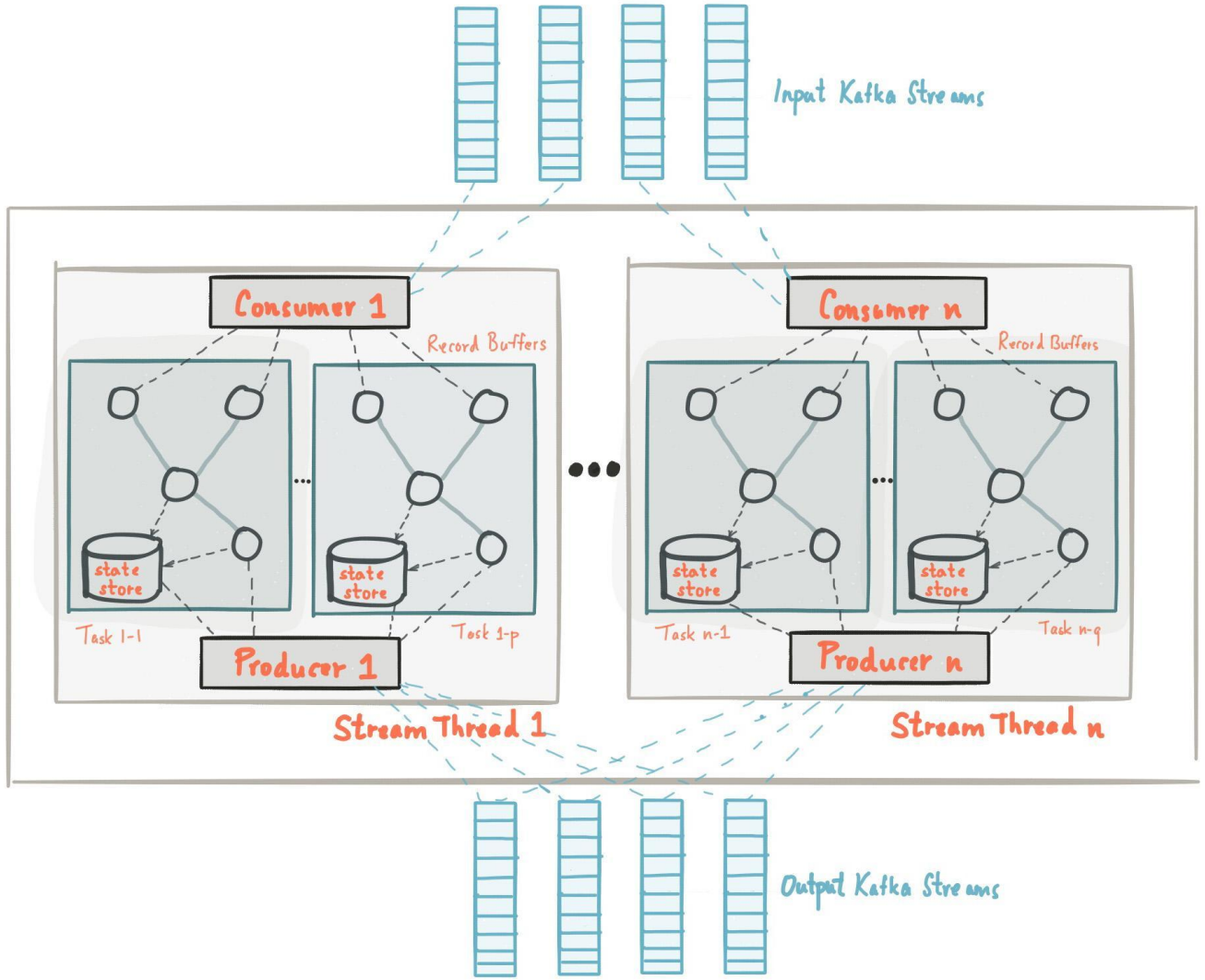
Use case: stats-counter (parallelism)



Kafka Streams

Why Kafka Streams:

- Java library (based on Kafka **producer and consumer APIs**) run as a standard application
- **no processing cluster** and no external dependencies
- uses Kafka's **parallelism model** and group membership mechanism (scalability and fault-tolerance)
- does **event-at-a-time** processing (no batching)
- supports **exactly-once** processing



Source: kafka.apache.org

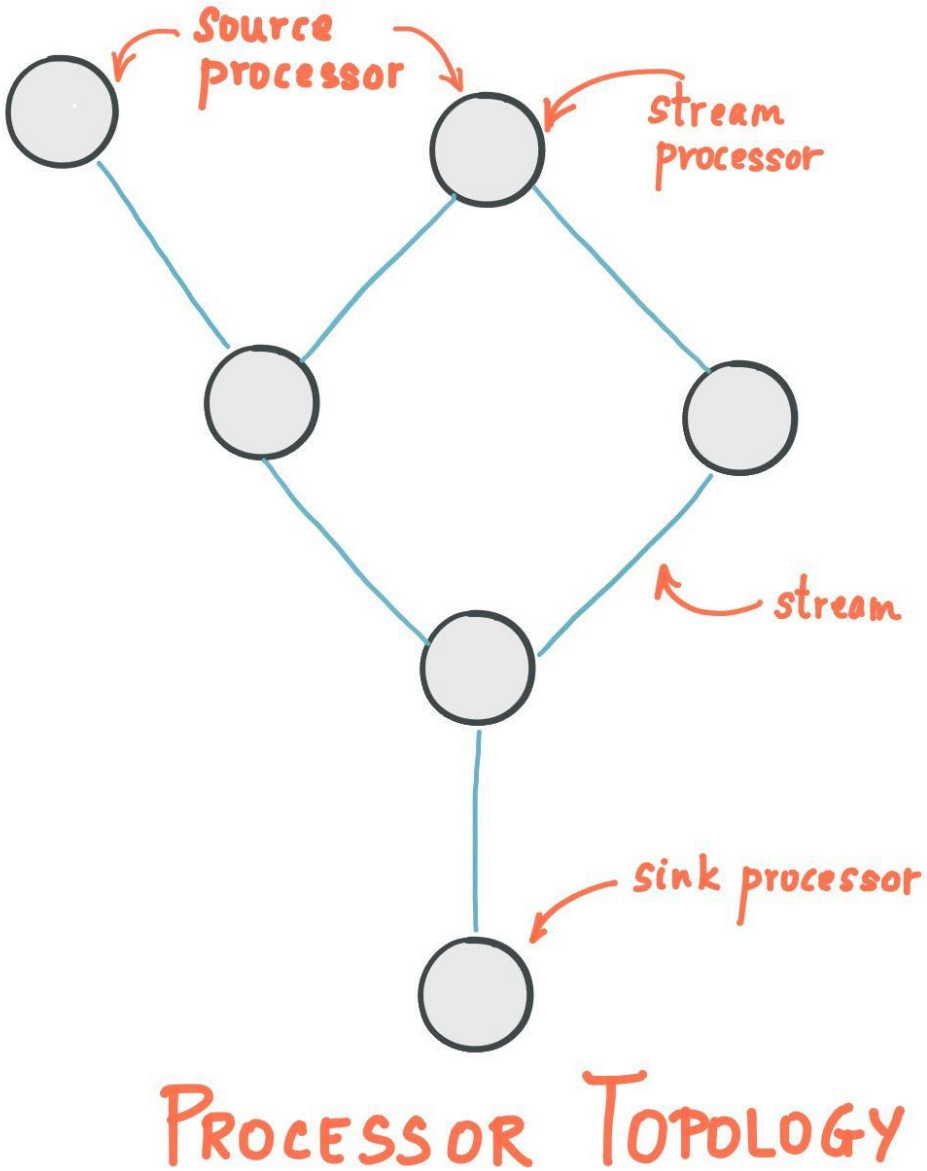
Kafka Streams: topology

Topology is a graph of **stream processors** that are connected by **streams**:

- consumes records from one or more input Kafka topics (source processors)
- sends records to output Kafka topic (sink processors)

Kafka Streams uses Kafka concepts:

- **data record** - Kafka message
- **stream partition** - Kafka topic partition
- **keys** determine the partitioning



Source: kafka.apache.org

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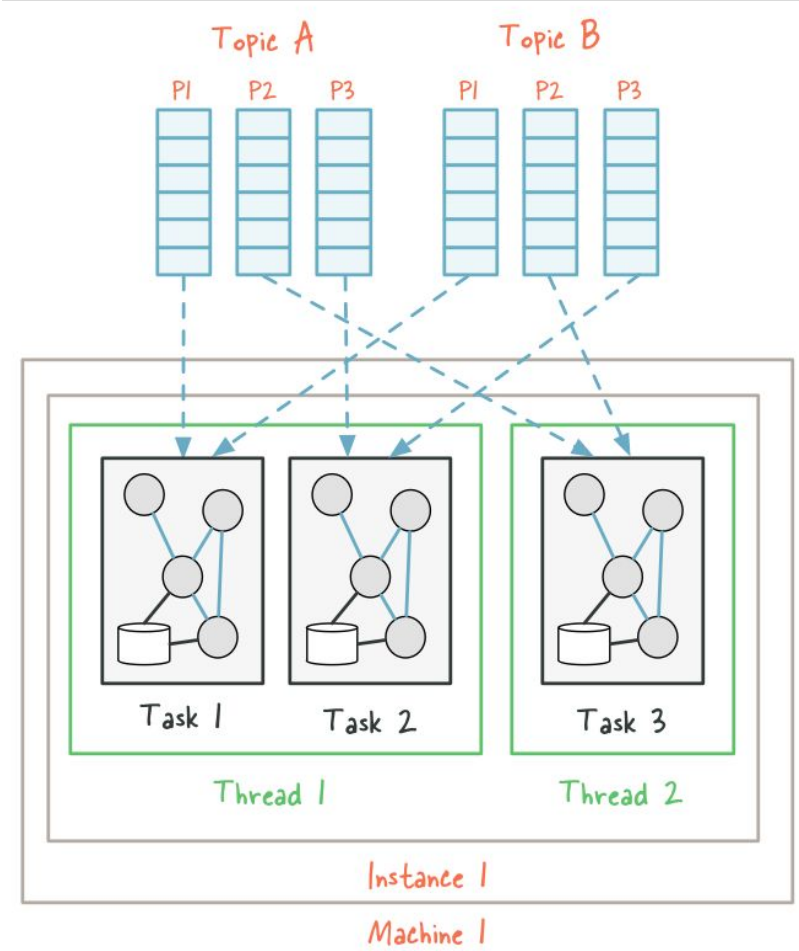
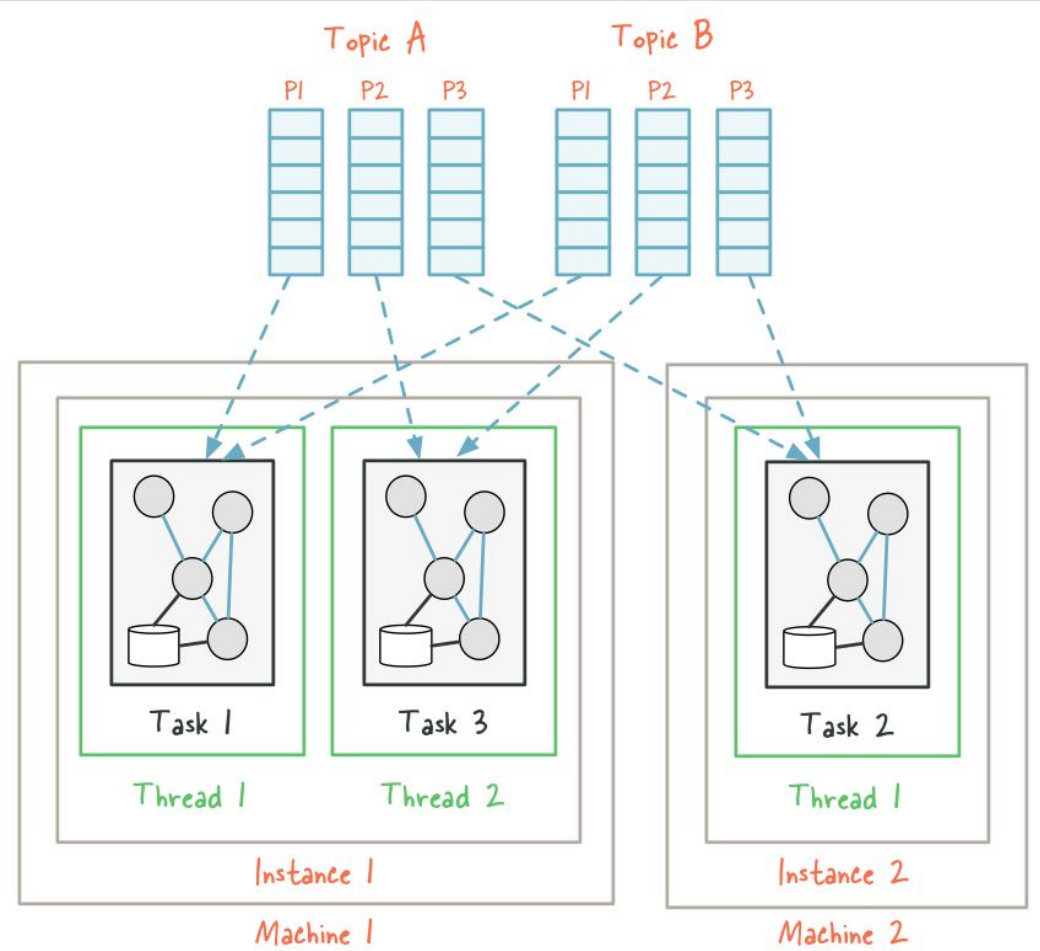
Kafka Streams: threading model





Source: kafka.apache.org

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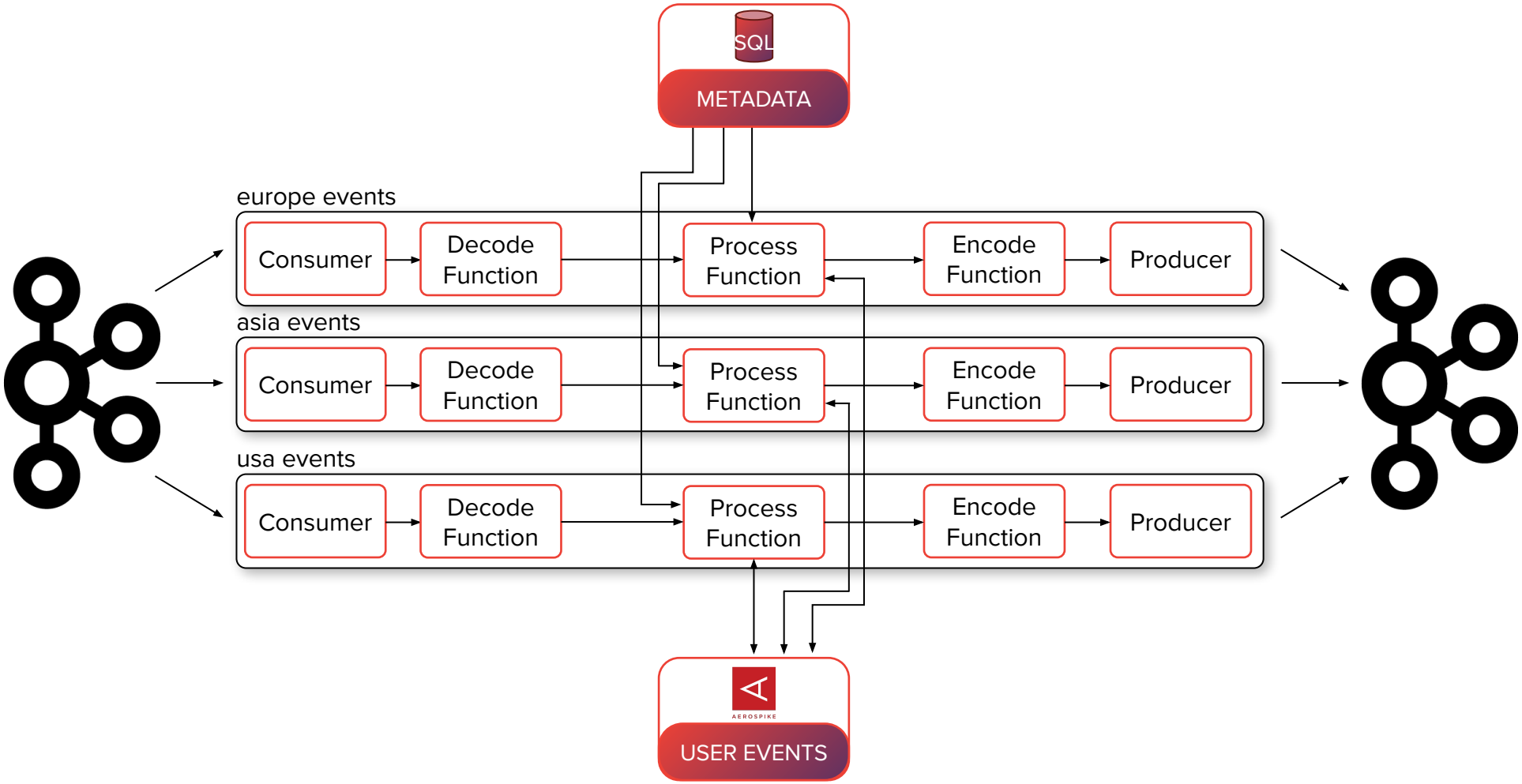
Use case: data-flow



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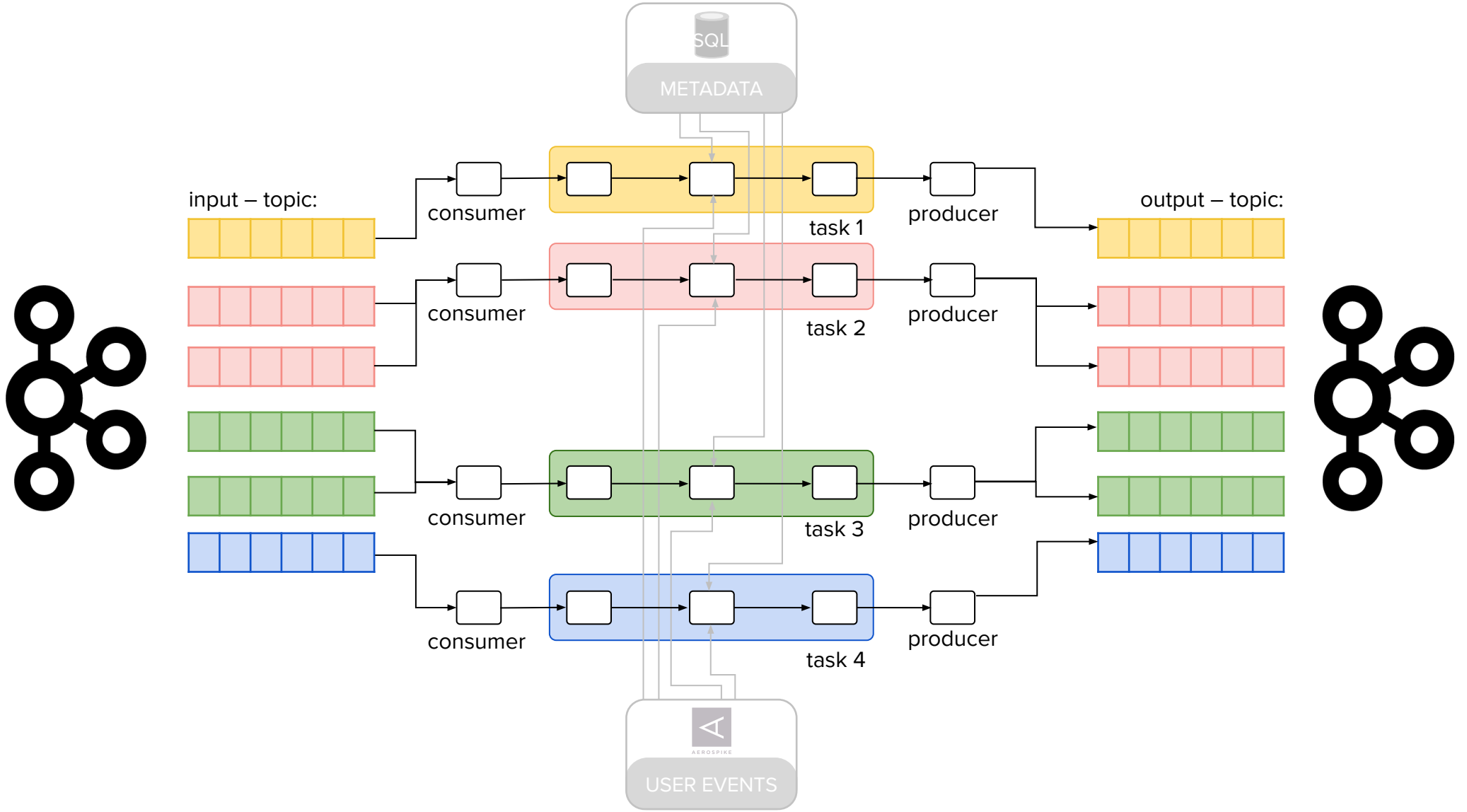
Use case: data-flow (parallelism)



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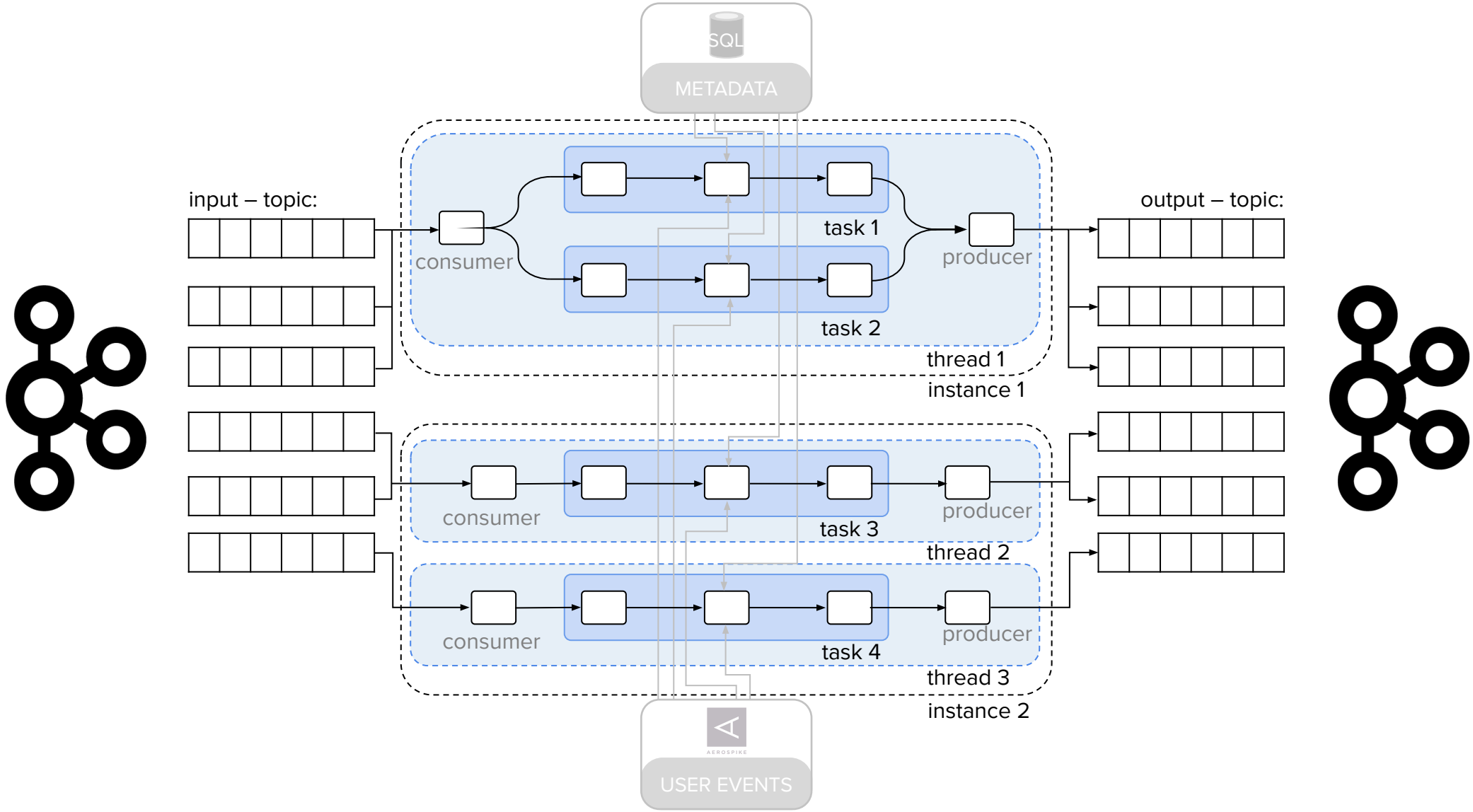
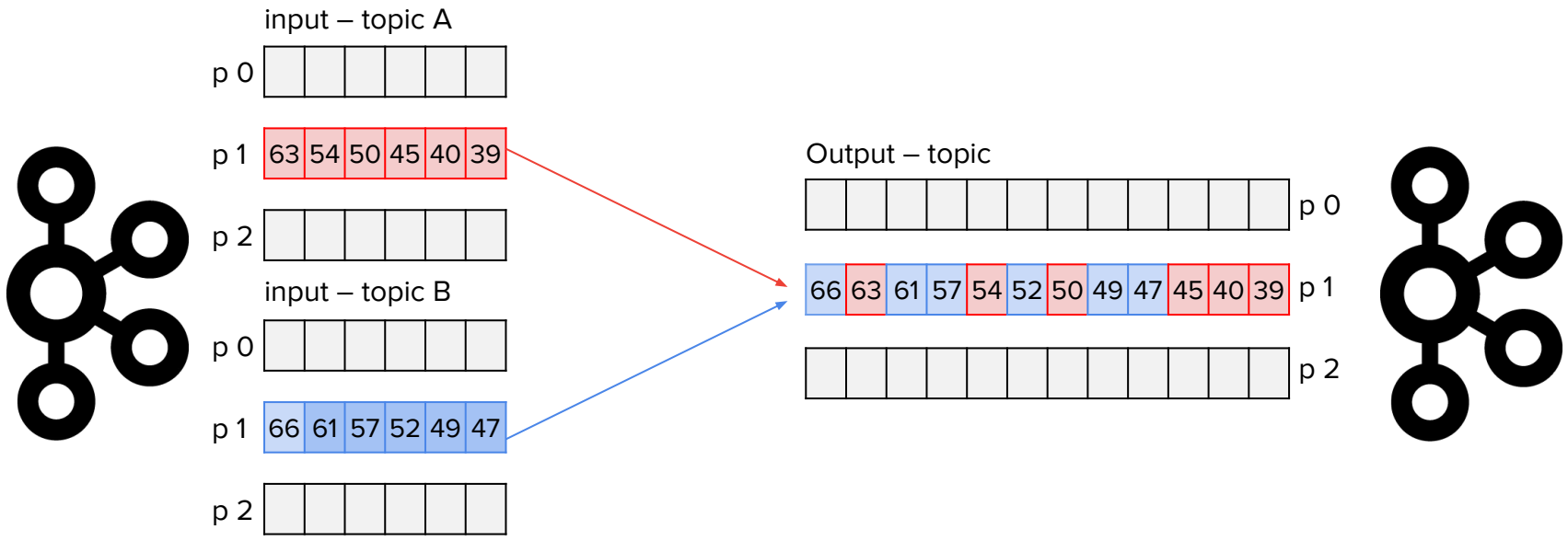
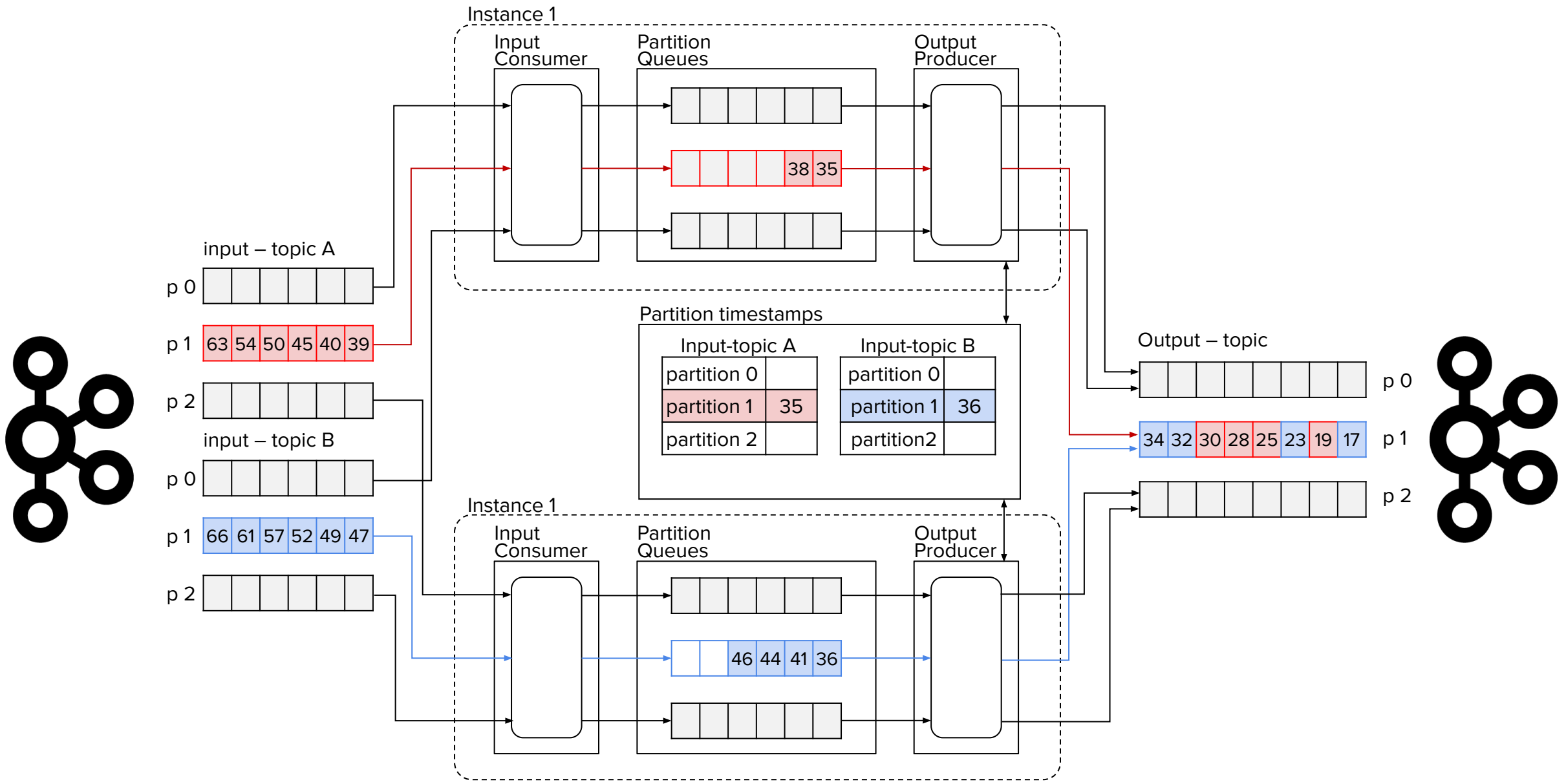
Use case: data-flow (parallelism)



Use case: merger

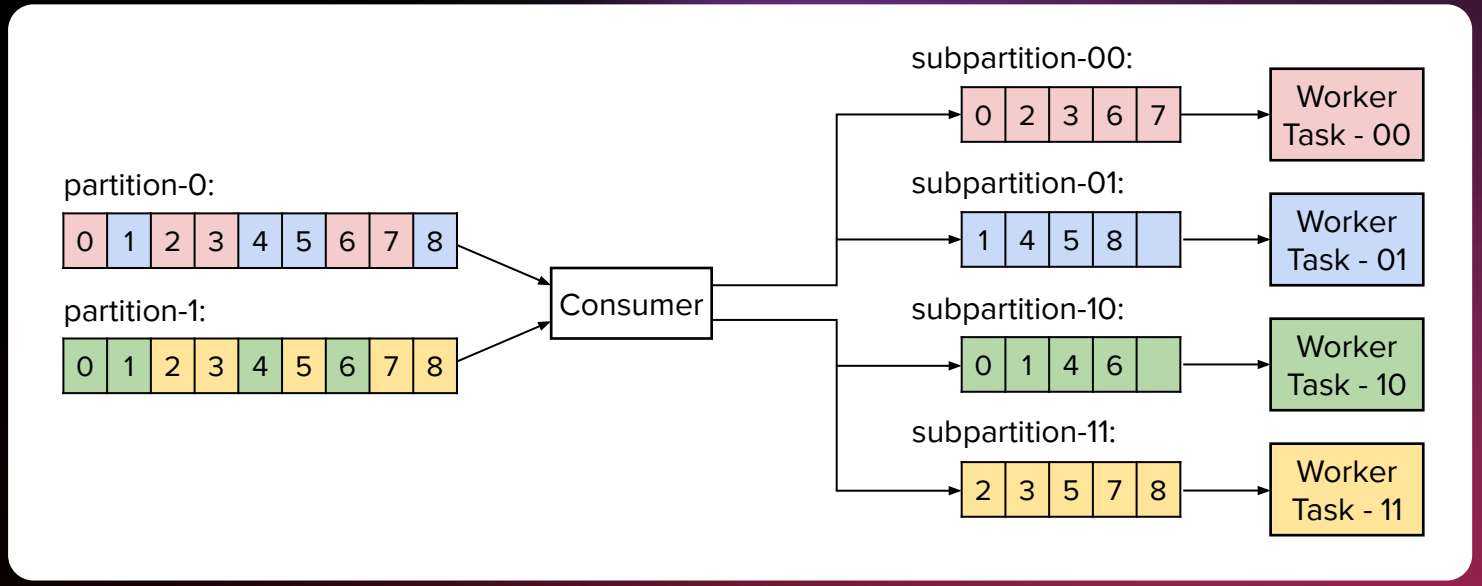



Instance 1
Input Consumer
Partition Queues
Output Producer
38 35
input – topic A
p 0
p 1
63 54 50 45 40 39
p 2
input – topic B
p 0
p 1
66 61 57 52 49 47
p 2
Partition timestamps
Input-topic A
partition 0
partition 1
35
partition 2
Input-topic B
partition 0
partition 1
36
partition2
Instance 1
Input Consumer
Partition Queues
Output Producer
46 44 41 36
Output – topic
p 0
34 32 30 28 25 23 19 17
p 1
p 2

Kafka Workers: main features

Why Kafka Workers (github.com/RTBHOUSE/kafka-workers)

- better threading model with better resources utilization
  - separating processing from consumption
  - higher level of distribution



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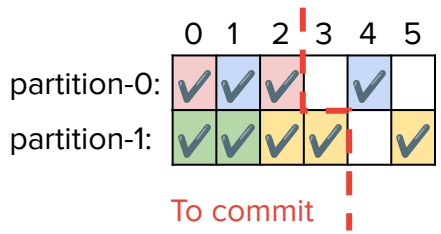
Kafka Workers: main features

Why Kafka Workers
(github.com/RTBHOUSE/kafka-workers)

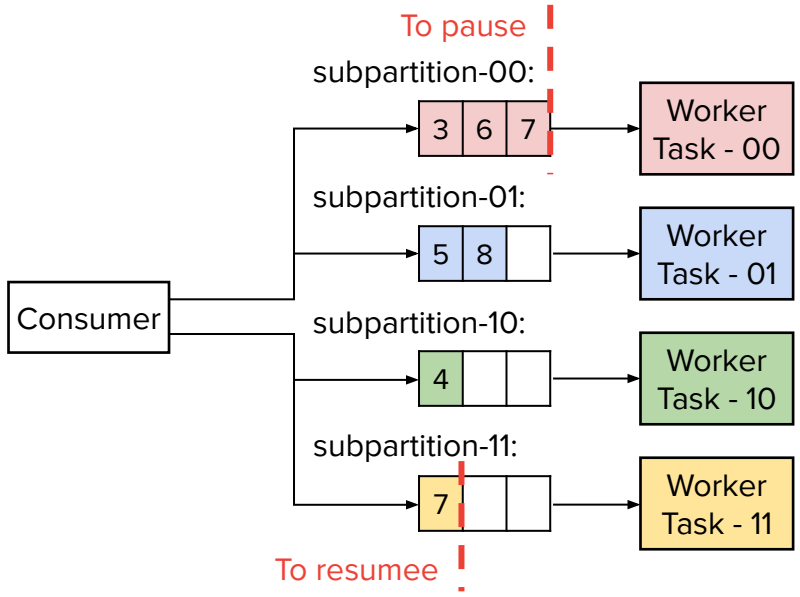
- asynchronous processing
  - processing timeouts
  - tighter control of offset commits



Kafka Workers: main features

Why Kafka Workers
(github.com/RTBHOUSE/kafka-workers)

- backpressure



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Kafka Workers: main features

Why Kafka Workers (github.com/RTBHOUSE/kafka-workers):

- possibility to pause and resume processing for a given partition
- at-least-once semantics
  - handling failures
- simplicity
  - Kafka Consumer API
  - no processing cluster, no external dependencies
  - without translating messages to/from its internal data format
  - no interprocess communication
- kafka-to-kafka, hdfs, bigquery, elasticsearch connectors

Kafka Workers: API (subpartitions)

```
public interface WorkerPartitioner<K, V> {

    int subpartition (ConsumerRecord<K, V> consumerRecord) ;

}
```

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Kafka Workers: API (tasks)

```
public interface WorkerPartitioner<K, V> {

    boolean accept(WorkerRecord<K, V> record);

    void process (WorkerRecord,K, V> record, RecordStatusObserver

observer) :

}
```

```
public interface RecordStatusObserver {

    void onSuccess();

    void onFailure(Exception exception);

}
```

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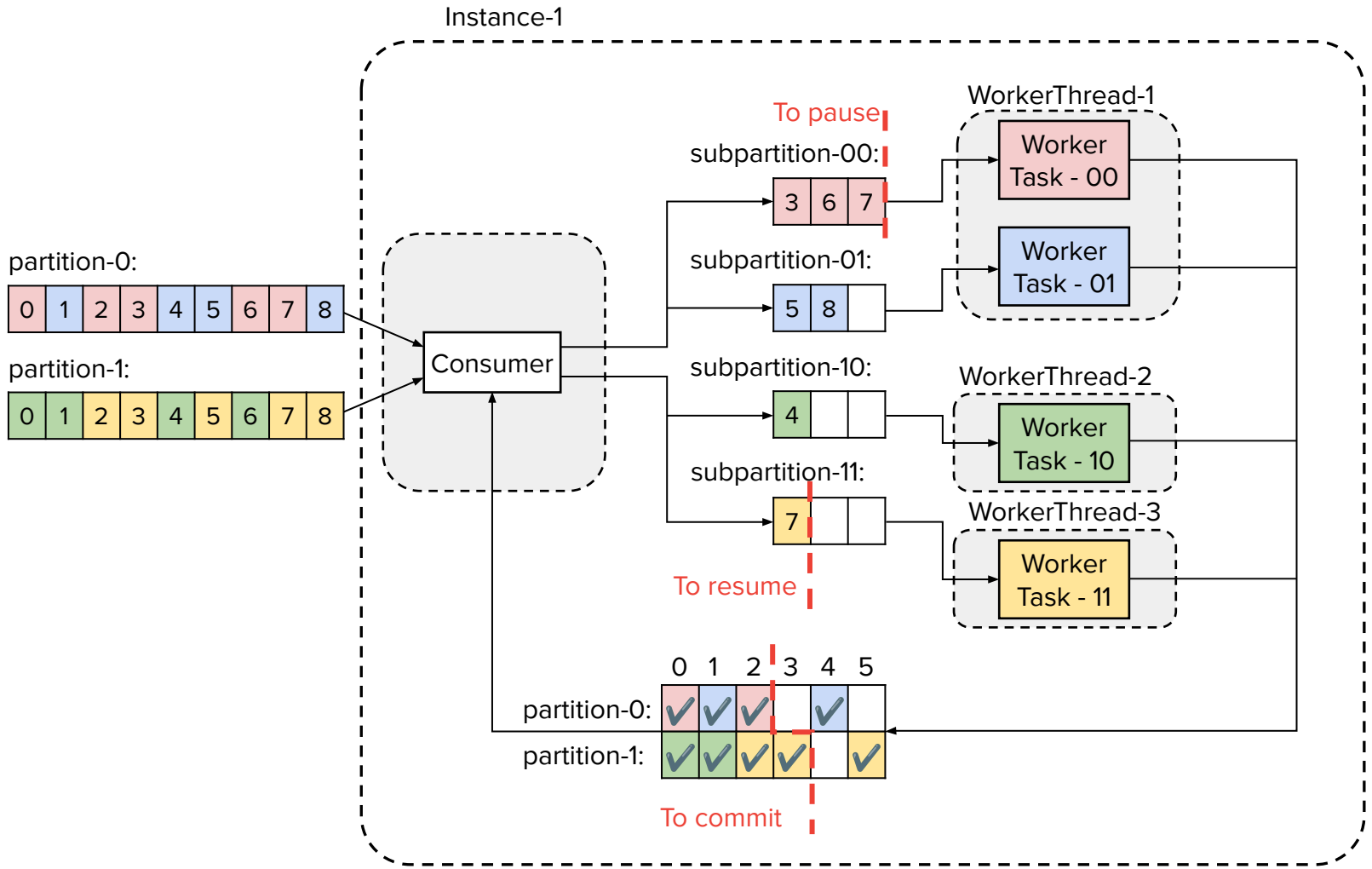
Kafka Workers: threading model



Summary

What we have achieved:

- platform monitoring
- much more stable platform
- higher quality of data processing
- HDFS & BigQuery & Elasticsearch streaming
- multi-DC architecture and data synchronization
- high scalability
- better data-flow monitoring, deployment & maintenance

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Thank you.

Bartosz Łoś