Systems and Architectures for Big Data AY 2017/2018
University of Rome Tor Vergata

Data stream processing for social network data with Apache Flink, Storm and Kafka Streams on Google Cloud Platform

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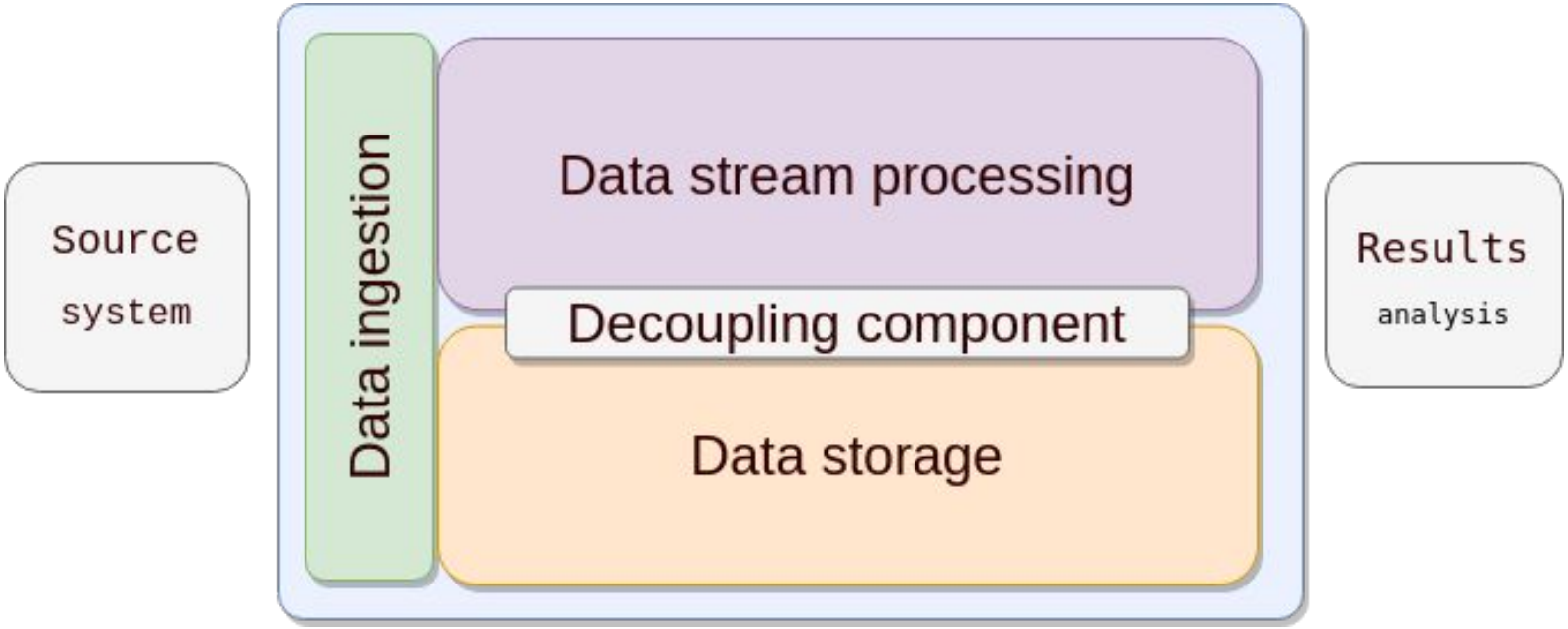
1.

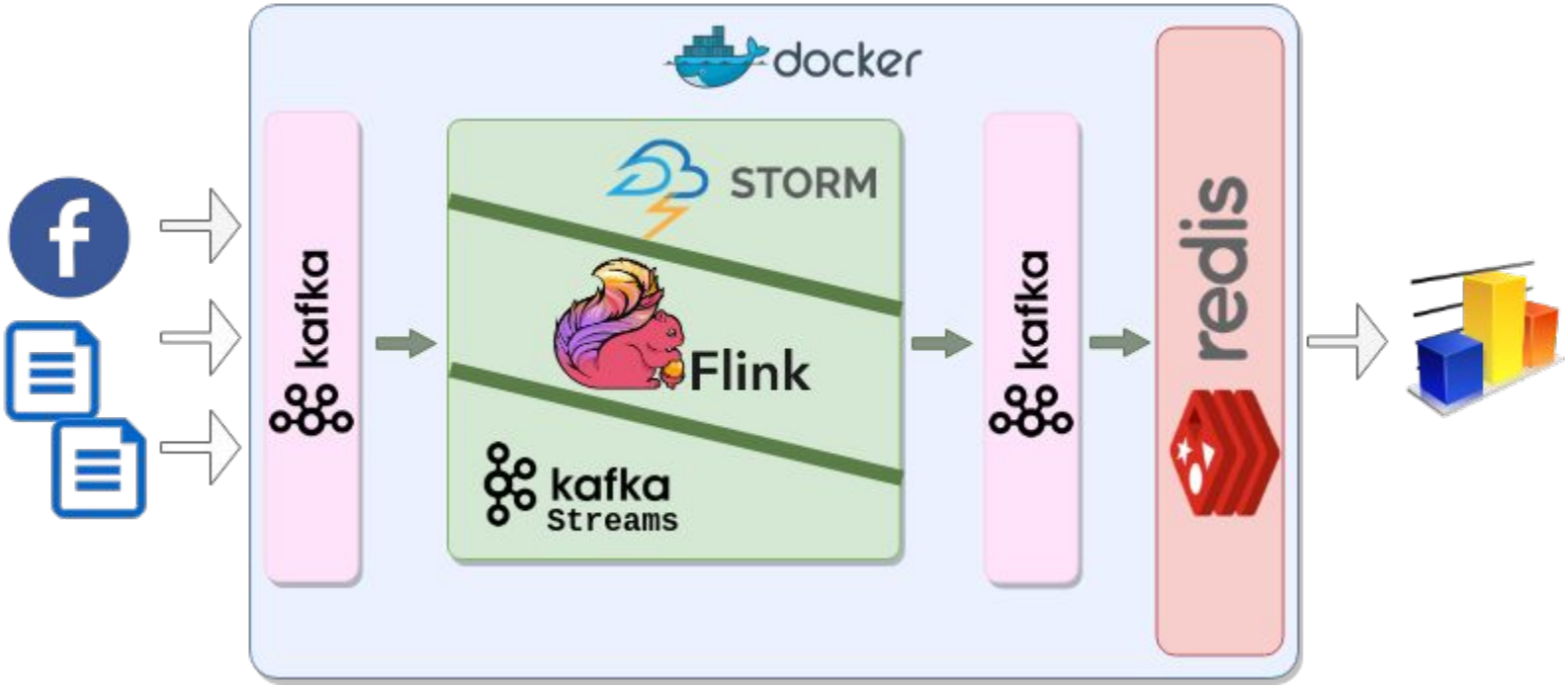
System Architecture

High Level Overview

System Layers



System Layers



Data Processing Layer

- Flink DataStream API
- Kafka Streams DSL API & Processor API
- Storm API
- Topologies composes a multistage stream computation

Data Ingestion & Decoupling

- Inject data from external sources to Kafka input topics
- Results stream published on Kafka output topics

Data Producer

- Read from local file
- Parametrized emission frequency proportional to the real one
- Apache Avro as serialization format

Data Storage

redis

- Redis is an in-memory NoSQL key-value database
- Stream results consumed from Kafka
- Results grouped in Sorted Sets keyed by Avro schema name sorted by statistics timestamp

Results Collector

redis

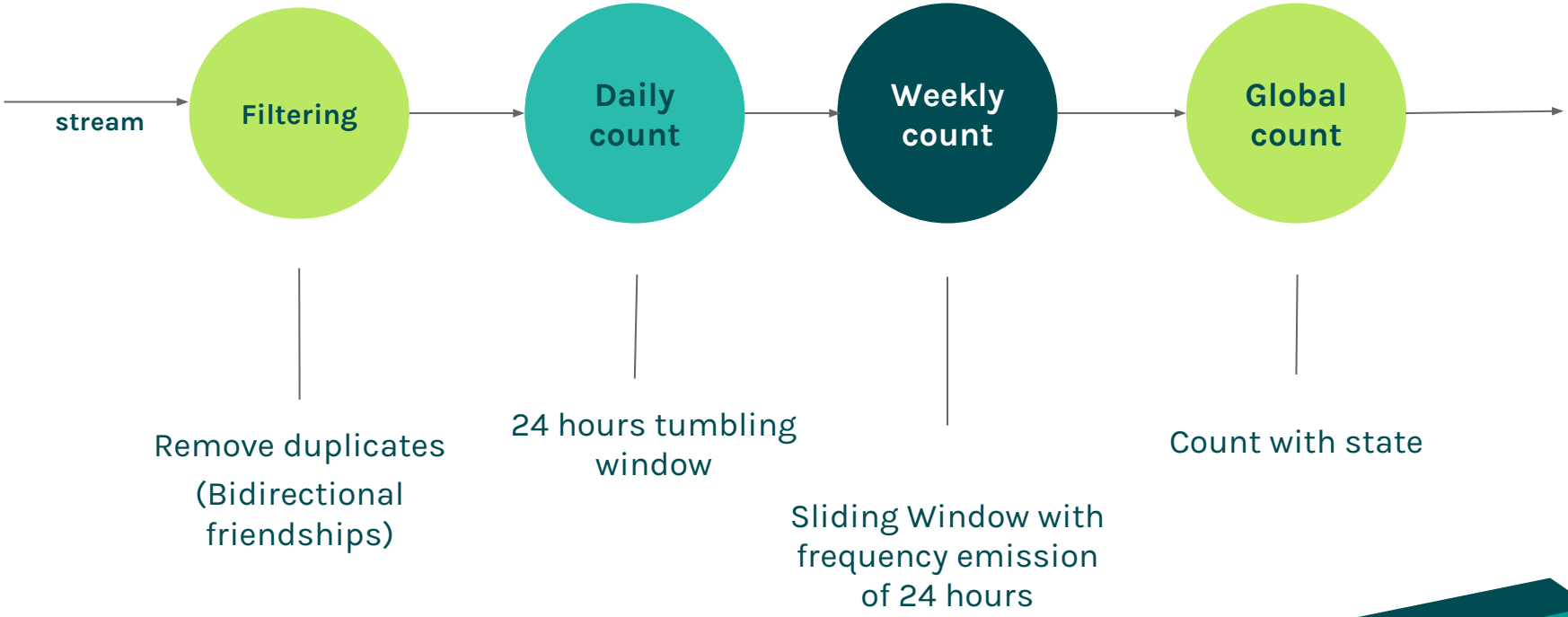
- Consume all new results published on output topics
- Write asynchronously records into Redis

2.

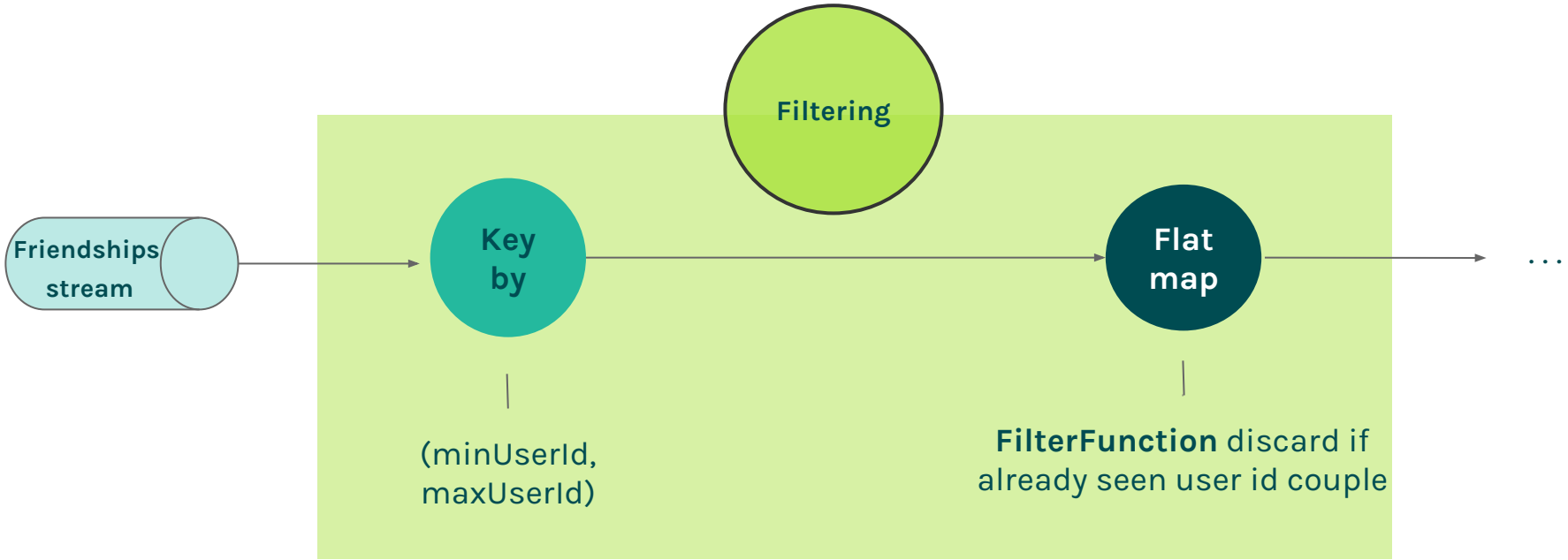
Queries

Detailed queries description

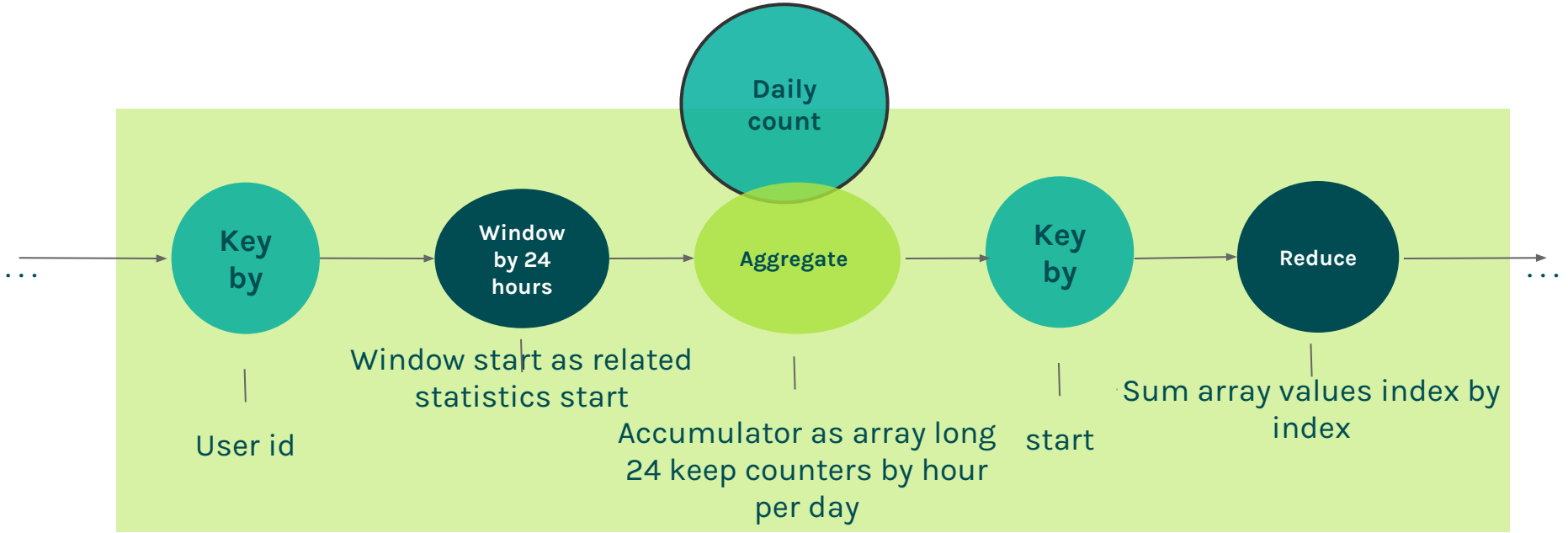
Query 1


stream
Filtering
Daily count
Weekly count
Global count
Remove duplicates (Bidirectional friendships)
24 hours tumbling window
Sliding Window with frequency emission of 24 hours
Count with state

Query 1 - Flink & Kafka Streams



Query 1 - Flink & Kafka Streams



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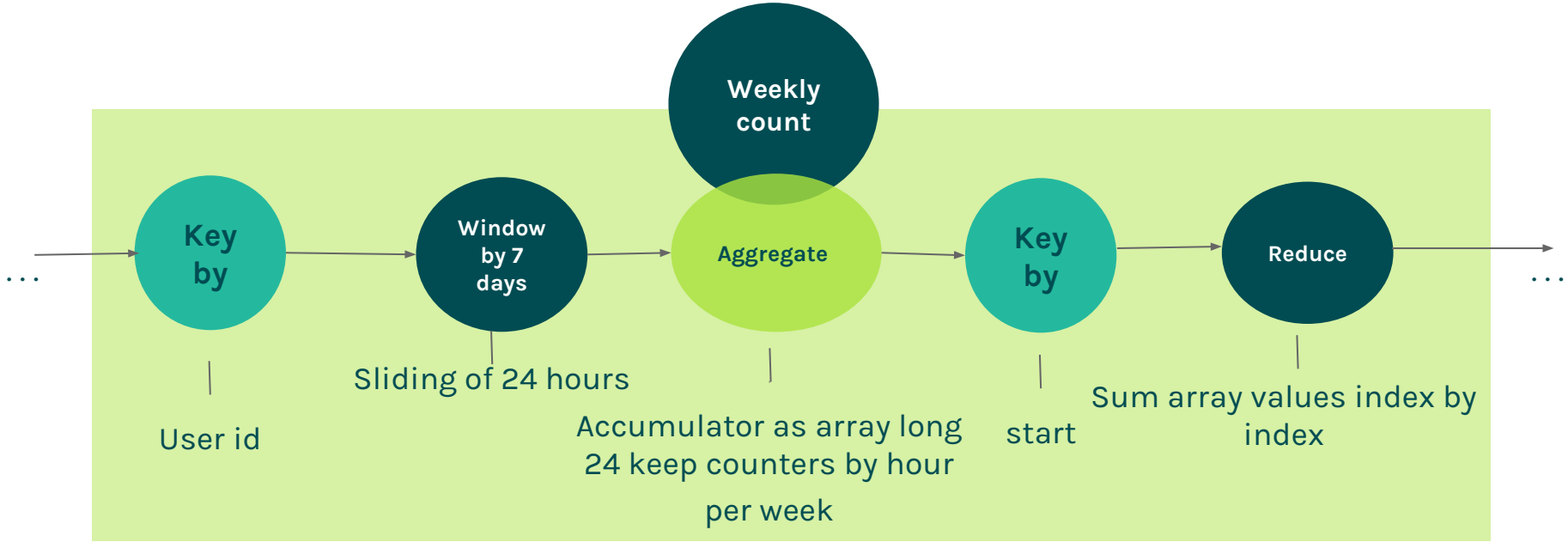
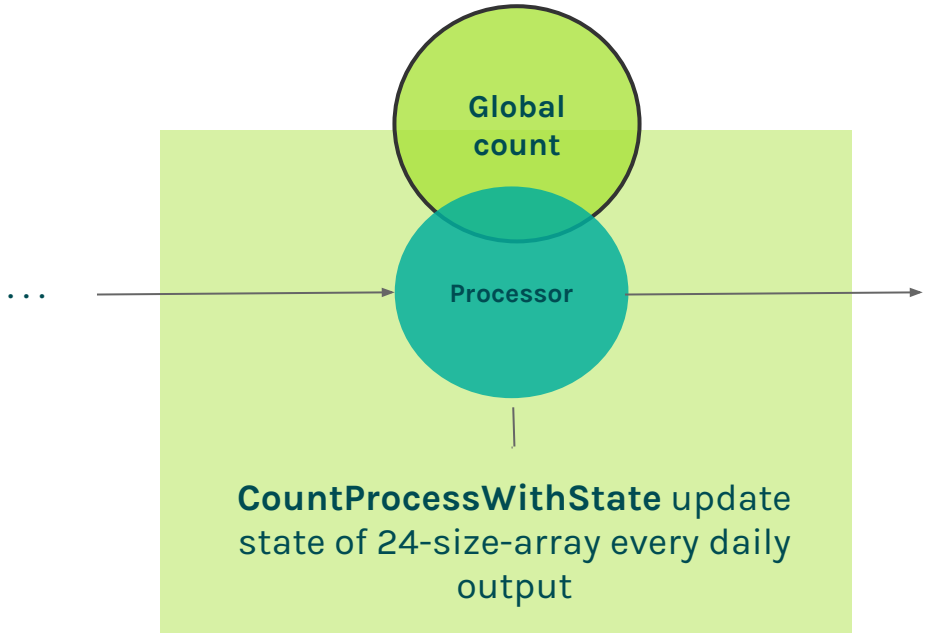
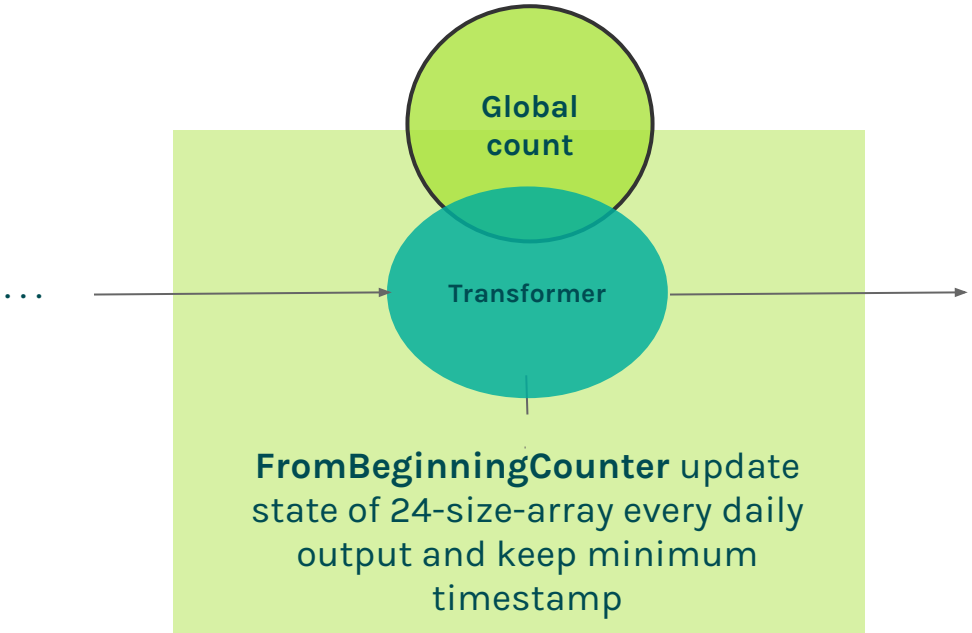


Query 1 - Flink



Query 1 - Kafka Streams



Ranking Queries in Flink

- Goal of Query 2 and 3 is the **Top-10** ranking of most commented posts and most active active user
- Both queries must provide rankings in hourly, daily and weekly event-time windows
- Since they have the same goal, a **general ranking query structure** has been defined and applied to the specific query and related data stream(s)

Ranking Board

- Generic data structure for maintaining the current score of ranked elements (in a *HashMap*)
- Caches and updates the Top-K (implemented with a ListBuffer of size K) so to retrieve it in **constant time**
- Ranked elements are of type *GenericRankElement[A](id: A, score: Score)* where A is data type of ID
- *Score* is a Scala **trait** with methods for adding two scores and returning a “global” score to compare it with others
- Examples : *SimpleScore(val: Int)*, *UserScore(a,b,c: Int)*

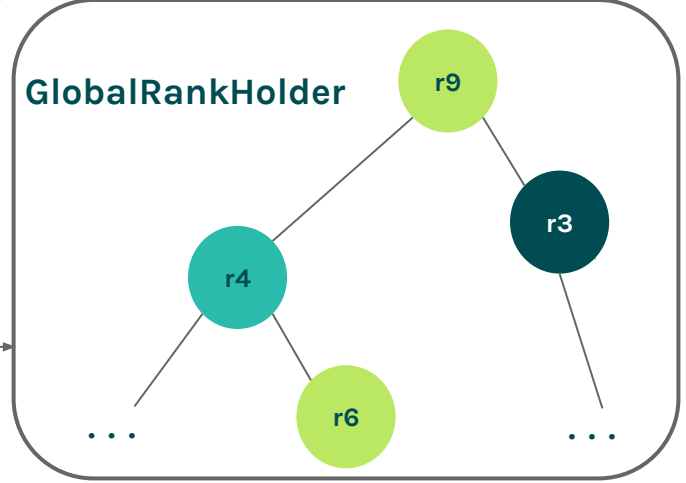
Partial Rankings

- Each **Top-K** returned from the *Board* must be assigned a event timestamp from which the computation begun, becoming a *RankingResult*
- Since **Top-K**s can be partial rankings, a merge method is defined
- Given two partial rankings (r_1 and r_2), the merged ranking r_3 (useful for global ranking) is defined by:
  - $timestamp(r_3) = min(\ timestamp(r_1), timestamp(r_2)\ )$
  - $K(r_3) = min(\ K(r_1), K(r_2)\ )$
  - $rank(r_3) = (\ rank(r_1) + rank(r_2)\ ).topK(\ K(r_3)\ )$

Global Ranking Holder

- Data structure used for holding and updating global rankings
- Ranks are kept in a *TreeMap* ordered by event timestamp
- Offers methods for:
  - Clearing rankings older than delta ms from current event timestamp (save memory)
  - Computing **global ranking** with given partial ranking by checking the *TreeMap* for older matching rankings and merging it with them while also updating the map

Ranking Overview



Partial Ranker Operator

Global Ranker Operator

Board

Top-K

RankElement(id1, s1)

RankElement(id2, s2)

RankElement(id6, s6)

RankElement(id10, s10)

RankElement(id21, s21)

RankElement(id42, s42)

RankElement(id1, s1)

RankElement(id42, s42)

RankElement(id6, s6)

RankElement(id10, s10)

event

timestamp

r1=(t1,rank1,k1)

Merge

r3=(t3,rank3,k3)

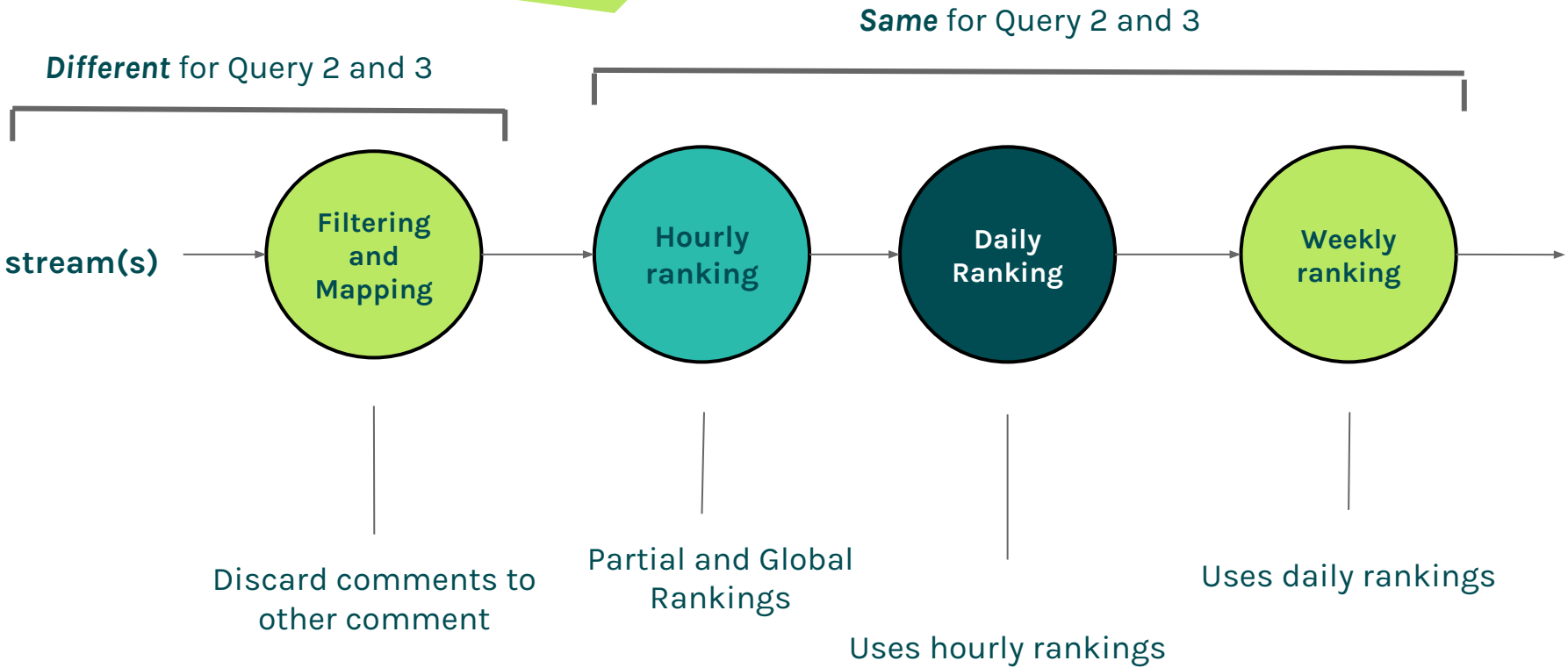
Global rank

event

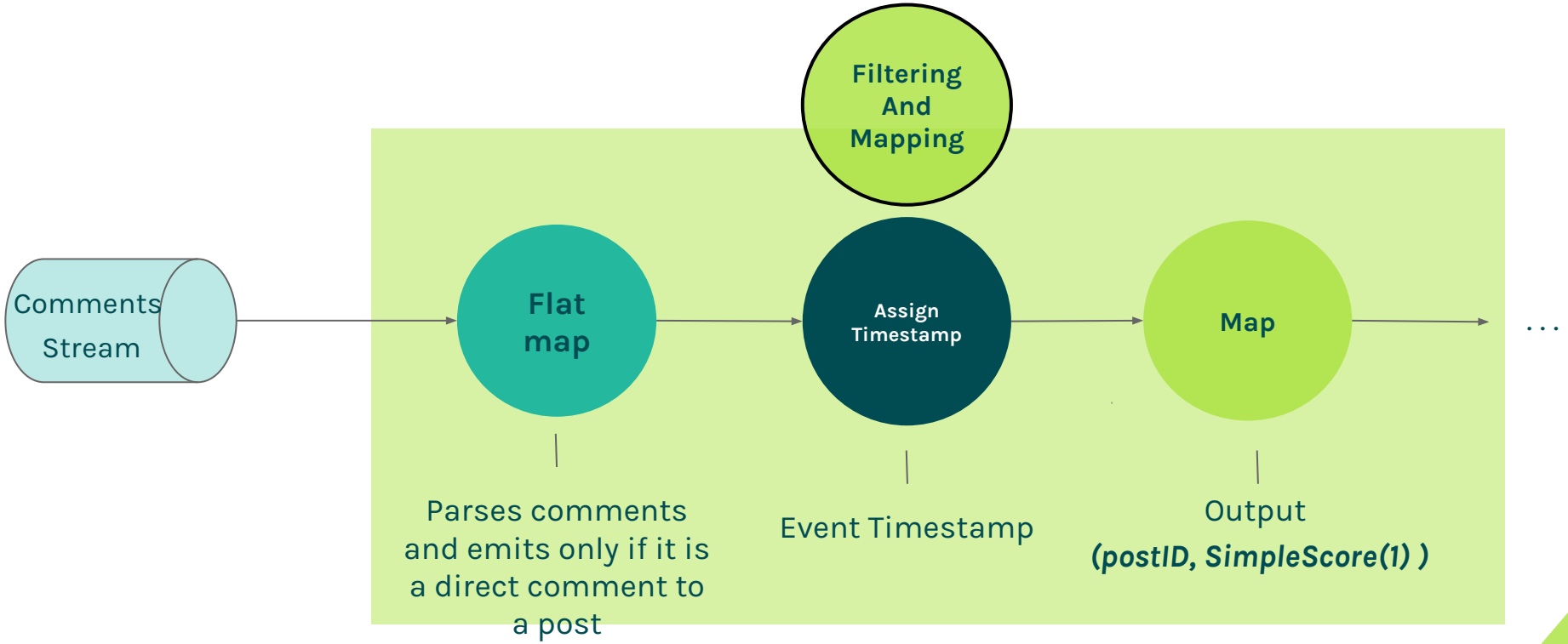
timestamp

r2=(t2,rank2,k2)

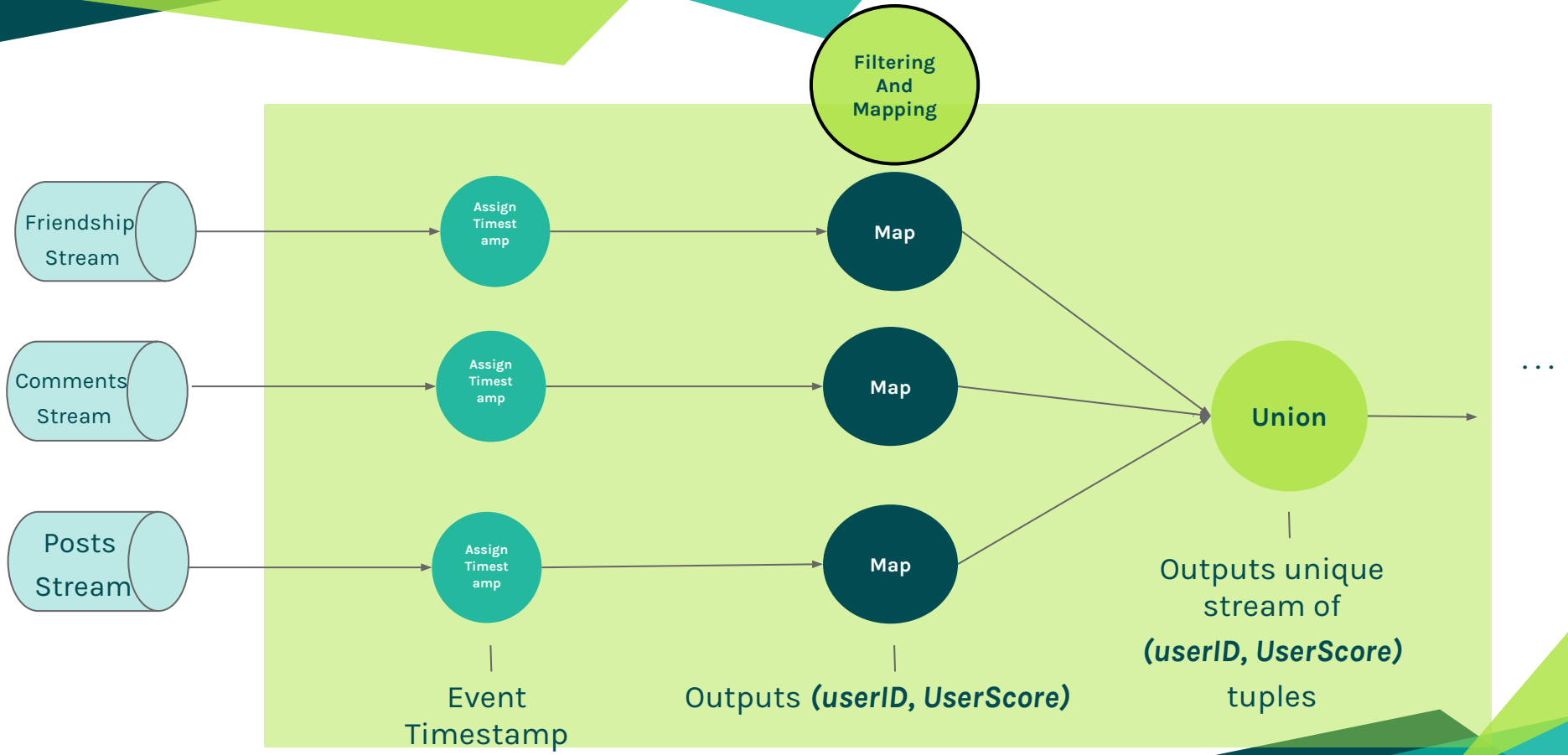
Flink Ranking Queries Overview



Query 2 - Flink



Query 3 - Flink

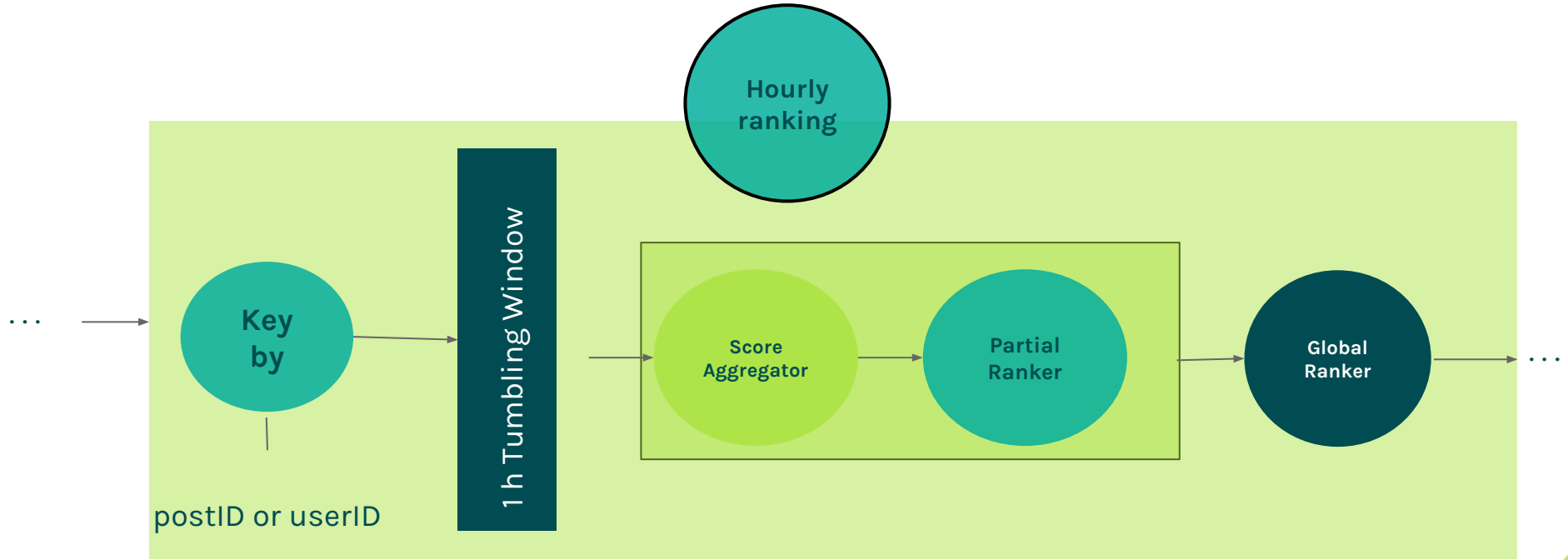


Ranking Operator in Flink

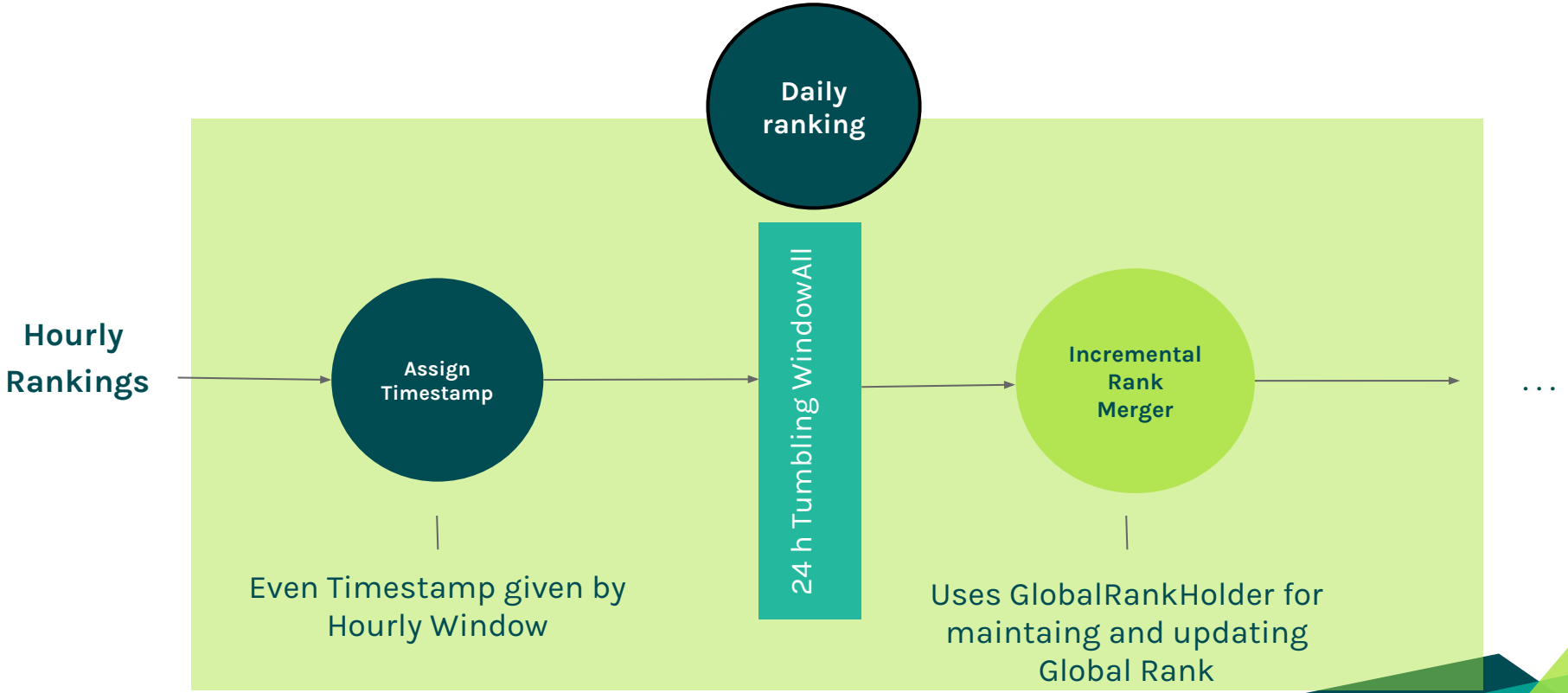
Same general approach for computing ranking for different window types and sizes:

```
<keyed-stream>
  .window(<Tumbling or Sliding Event Time Window>)
  .aggregate(<Score Aggregator>, PartialRanker)
  .setParallelism(< gte 1 >)
  .process(GlobalRanker)
  .setParallelism(1)
```

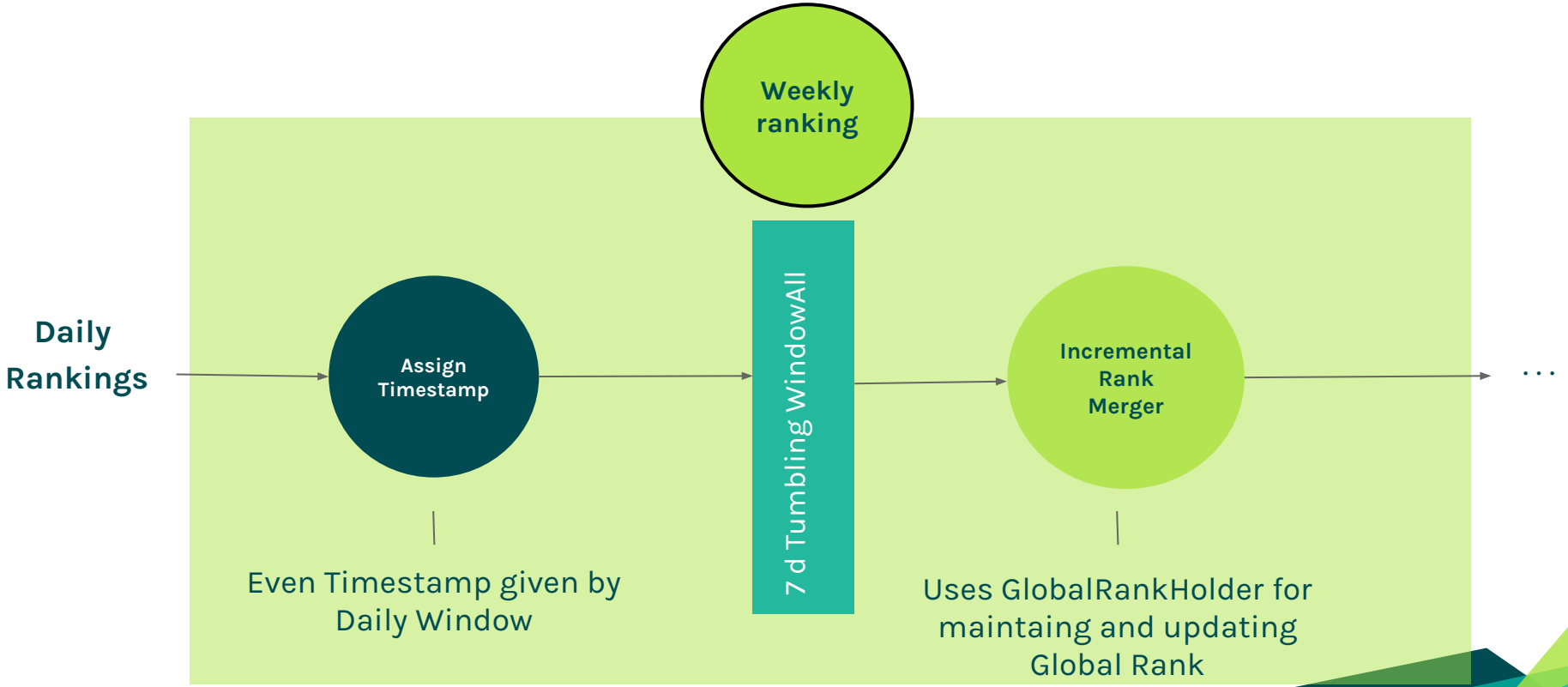
Query 2 & 3 - Flink



Query 2 & 3 - Flink



Query 2 & 3 - Flink



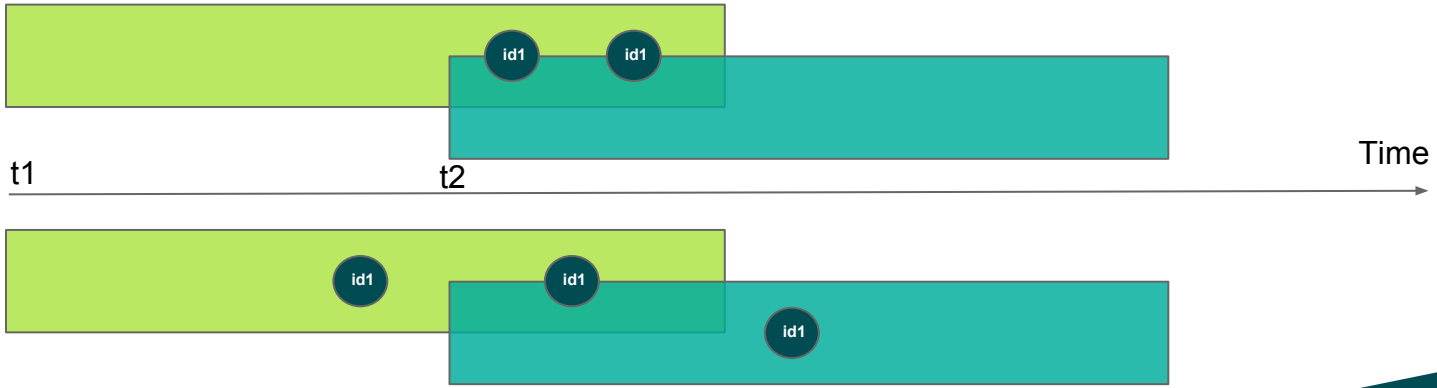
Sliding Windows Ranking Problems in Flink

Given rankins:

- R1 = {t1, { id1, score = 2} }
- R2 = {t2, {id1, score = 2}}

With t1 and t2 timestamp of two overlapping windows.

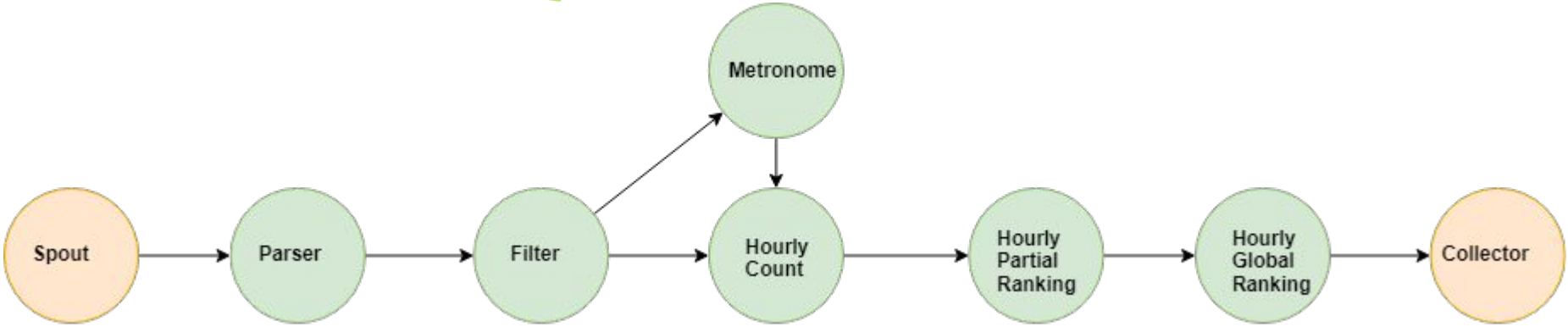
Multiple possible outcomes and can't know when to increment score and by how much.



Ranking Query With Sliding Windows in Flink

- Sliding windows for computing daily and weekly rankings given hourly rankings give inaccurate results
- Can’t know what happened exactly in two overlapping windows
- If we take non-overlapping windows, can lose what happened in the transition from one to another
- **Solution:** replicate input stream and apply general approach with different sliding window sizes
- *Cons*:
  - Same data replicated for many sliding windows
  - Throughput decreases and latency increases

Query 2 Storm



Parse Avro record

Discard comments to comment

1h Tumbling window

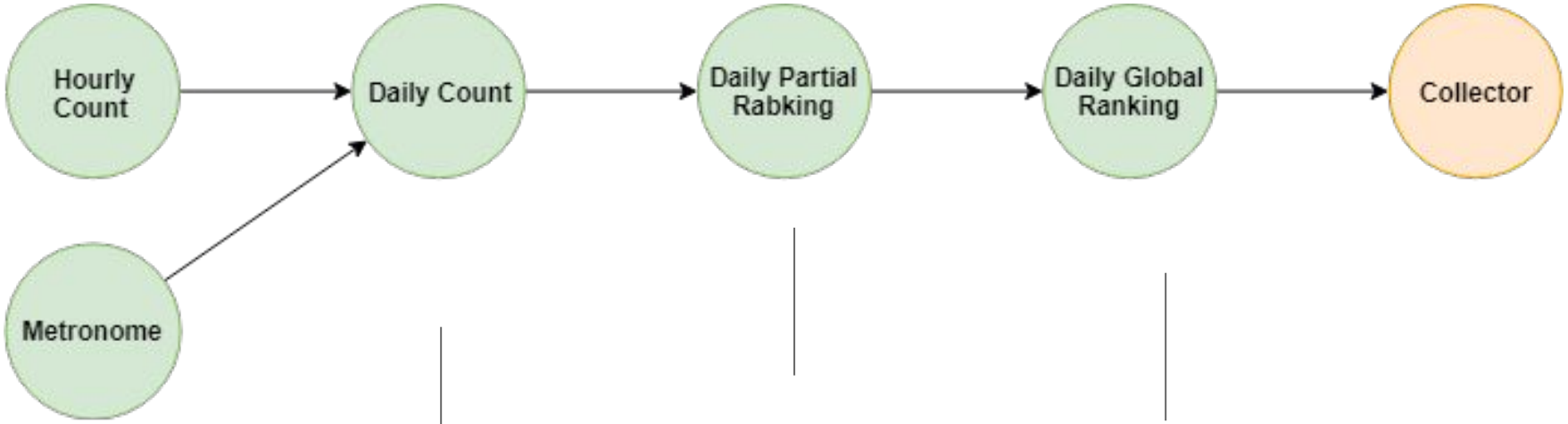
Compute partial Ranking

Merge partial ranking

Query 2 Storm

- **Spout**: Read record from Kafka topic
- **Filter**: Discard comments to comment
- **Metronome** emits a special tuple to beat time based on the record timestamp (event time). It affects the emission rate of the windows (the slide interval)
- **WindowCount**: Keep one windowed count for each post
- **PartialRanking**: Compute ranking on a group of post
- **GlobalRanking**: Merge partial ranking to get final top-K
- **Collector**: Write results in a Kafka topic

Query 2 Storm



Aggregate daily count in a 24h tumbling window

Compute partial ranking for group of post

Merge partial ranking

Query 2 Storm

- Tuples by the Filter are distributed by the *post_id* field to the WindowCount
  - **Fields grouping**
- The **WindowCount** and **PartialRanking** bolts executes as many tasks.
- The **Metronome** tuples must be forwarded to all the windowed bolts
  - **All grouping**: The stream is replicated across all the bolt's task

4.

Deployment

Local and Cloud deployment

Local Deploy

- Every system component is built as a Docker Image
- Made from existing images
- Allows running pseudo-distributed cluster (Flink, Storm and Zookeeper)
- All components run on same network

Cloud Deploy

Google Cloud Platform

Google Cloud Platform was used as the deploy environment.

In particular services offered by the Kubernetes Engine.

Kubernetes

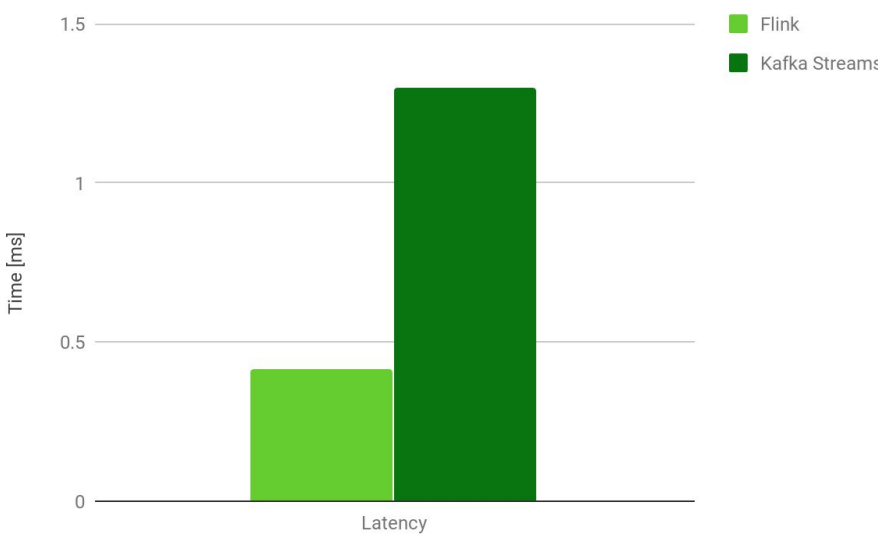
- Used to deploy System components
  using Docker container on a
  3-node cluster with each 2 vCPU and 7.5 GB of memory
- Flink, Kafka and Zookeeper as StatefulSets managed with
  parallel policy and exposed by Headless (intra-cluster)
  and “Normal” (inter-cluster) Services
- Storm workers managed by a ReplicationController while other components (Nimbus, UI) deployed as simple Pods
- Kubernetes Deployment with OpenJDK for simulating Kafka producers

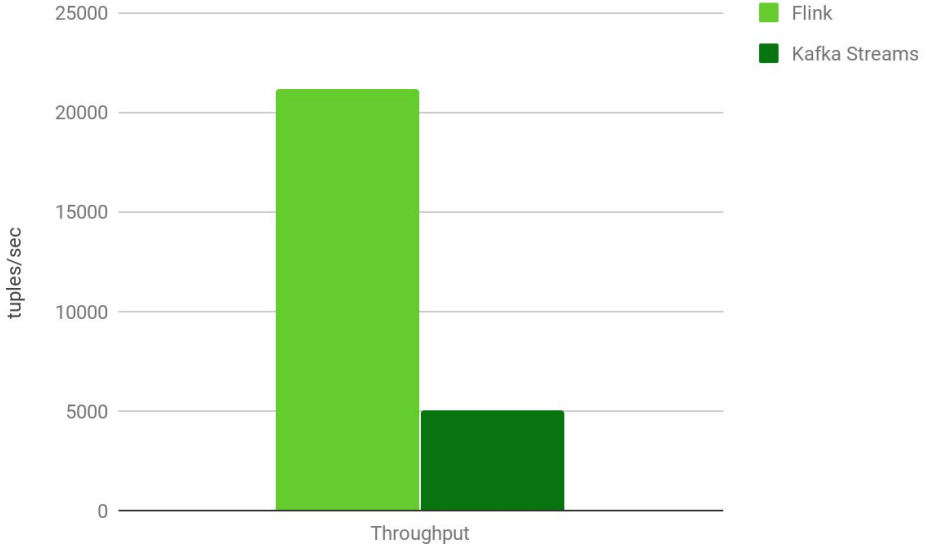
5.

Performance Comparison

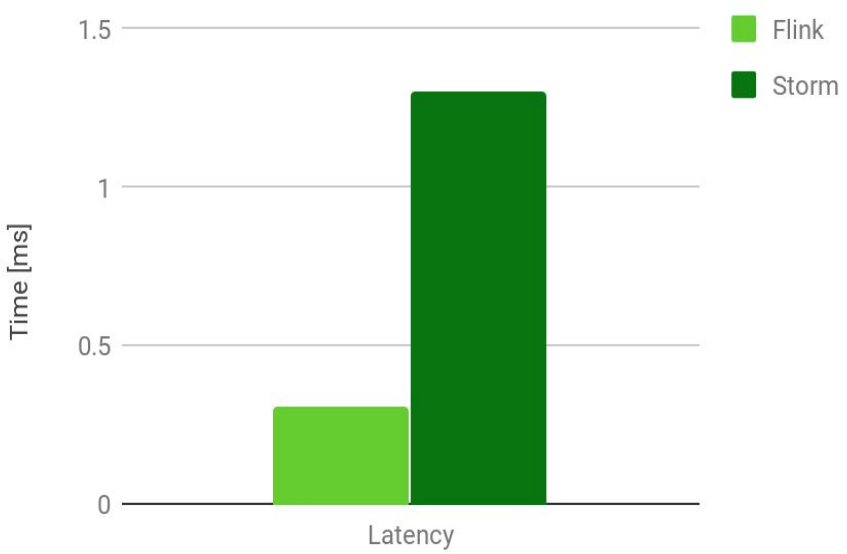
Different Framework Comparison

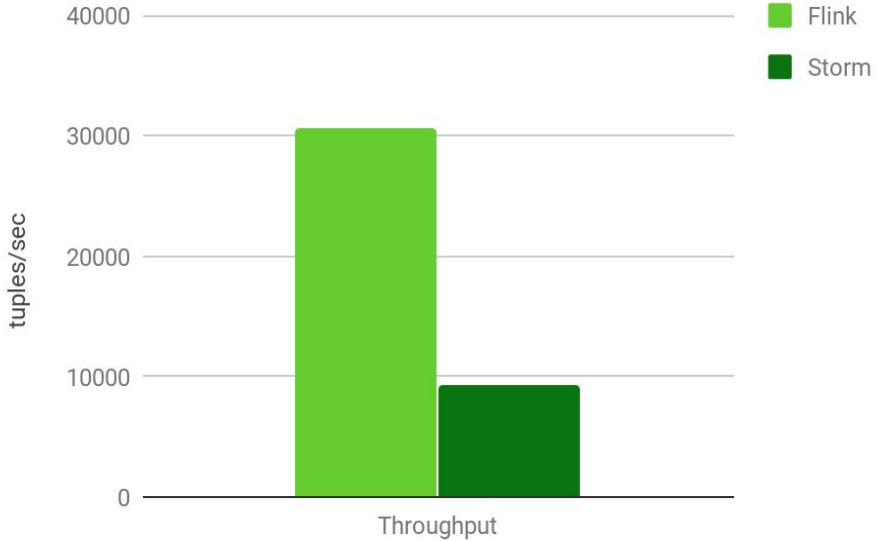
Query 1 performances



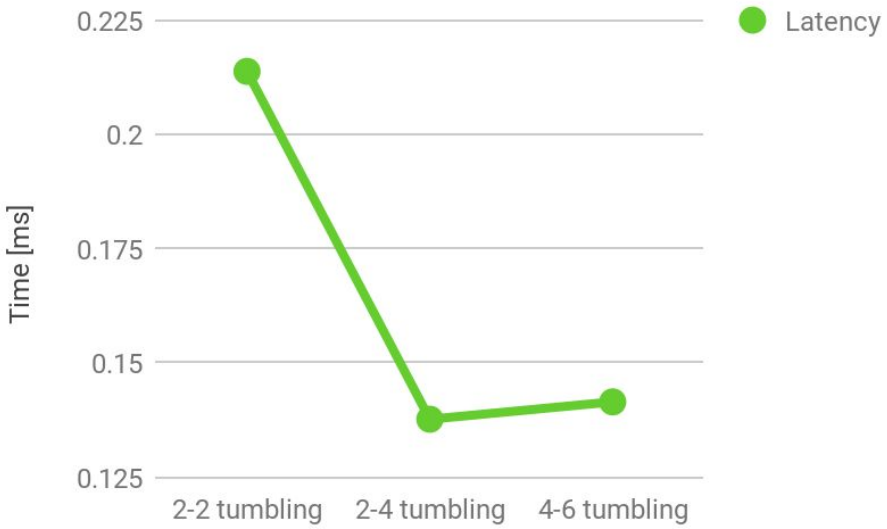


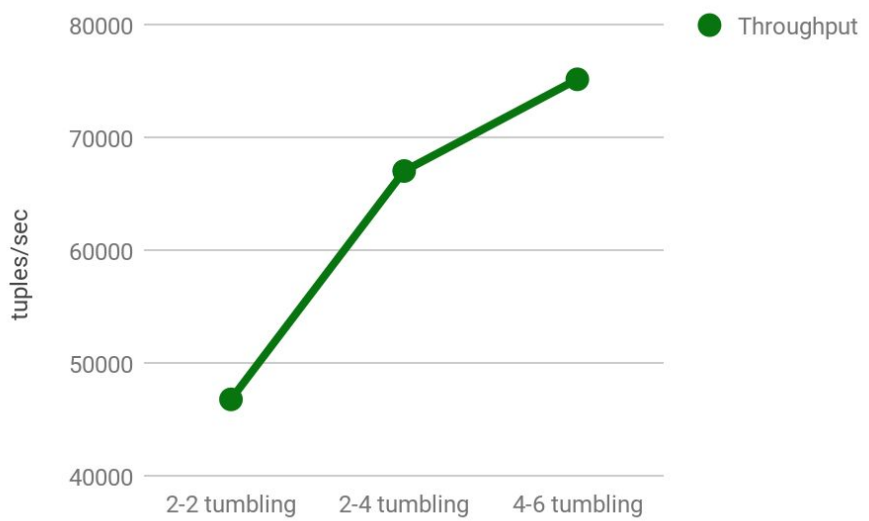
Query 2 performances





Query 3 Flink performance





Thank you for listening!