Temporal graph analytics on Apache Flink Stateful Functions

Speculative Red Hat Collaboratory Project

CASP Systems

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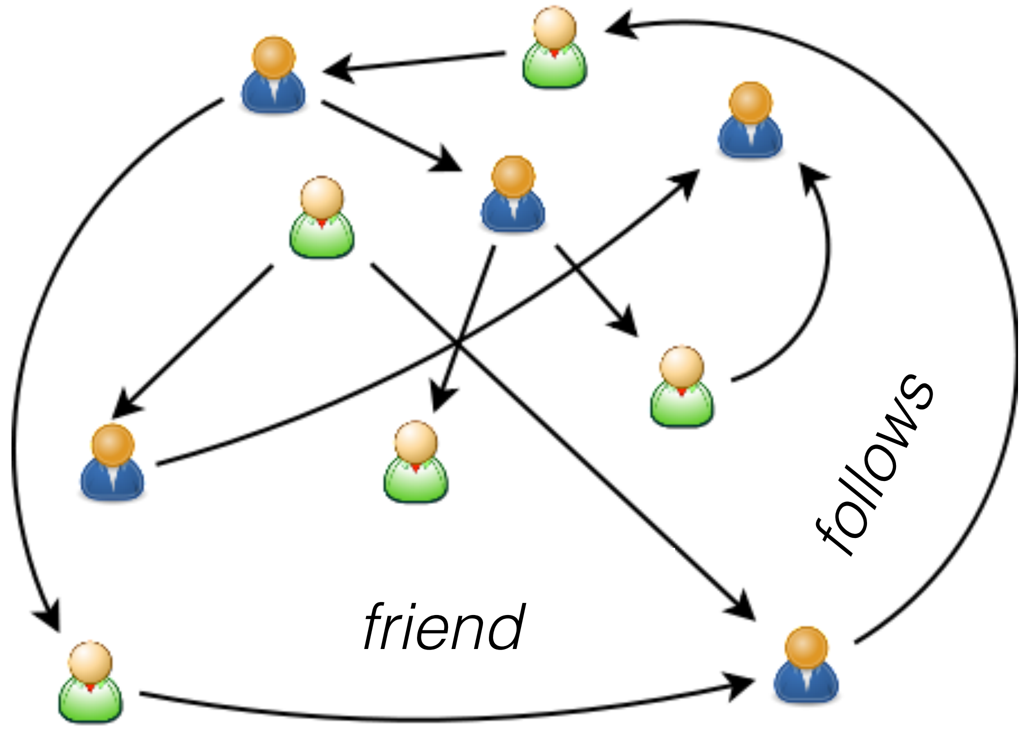
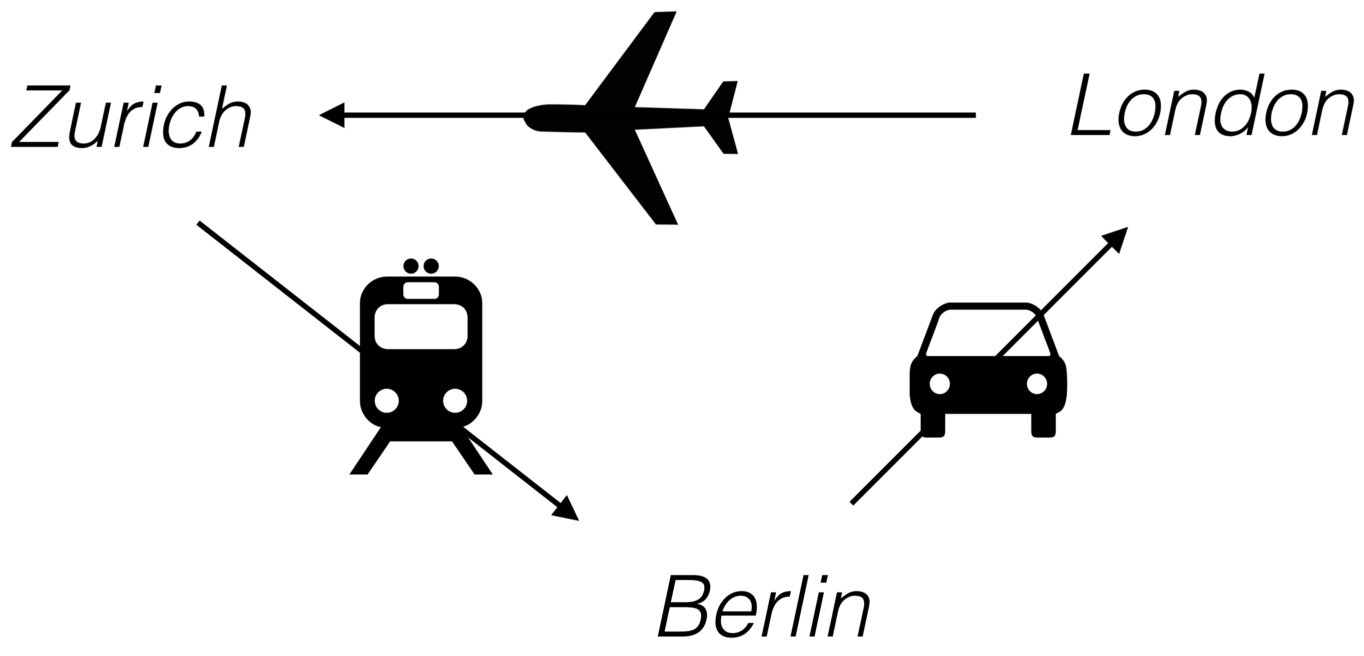
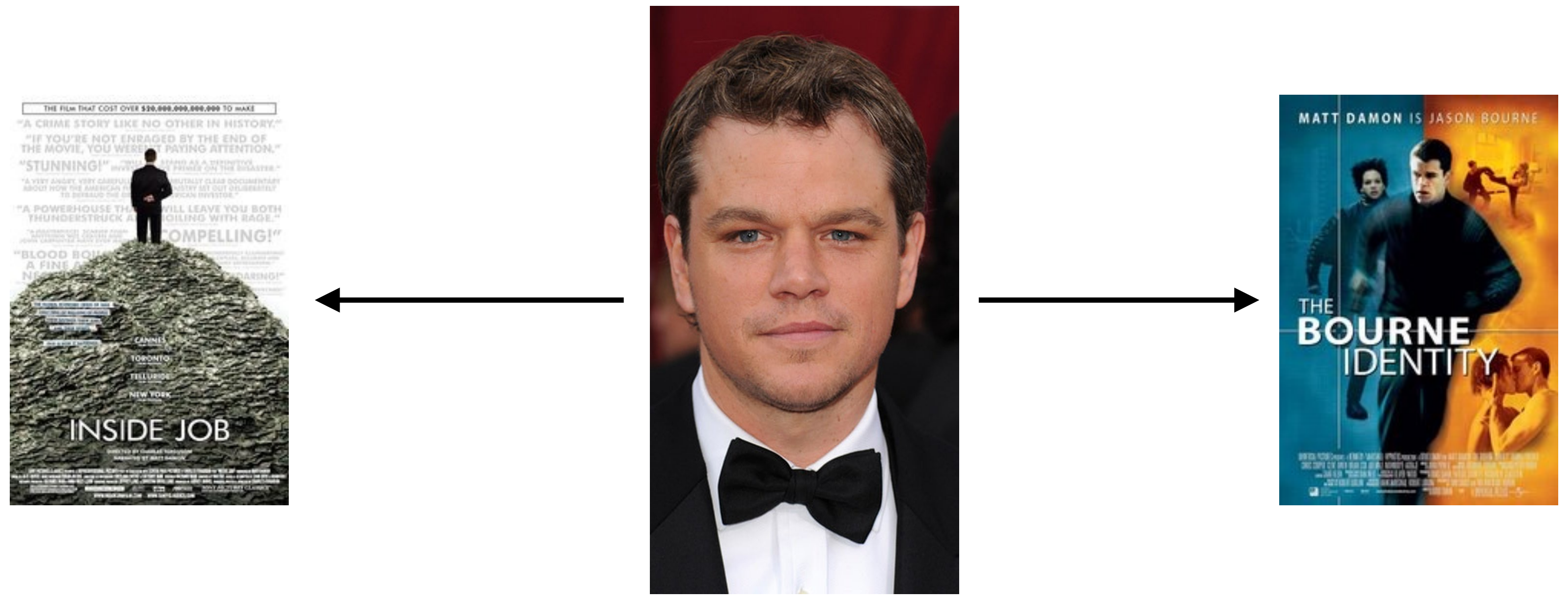
Modeling the world as a graph



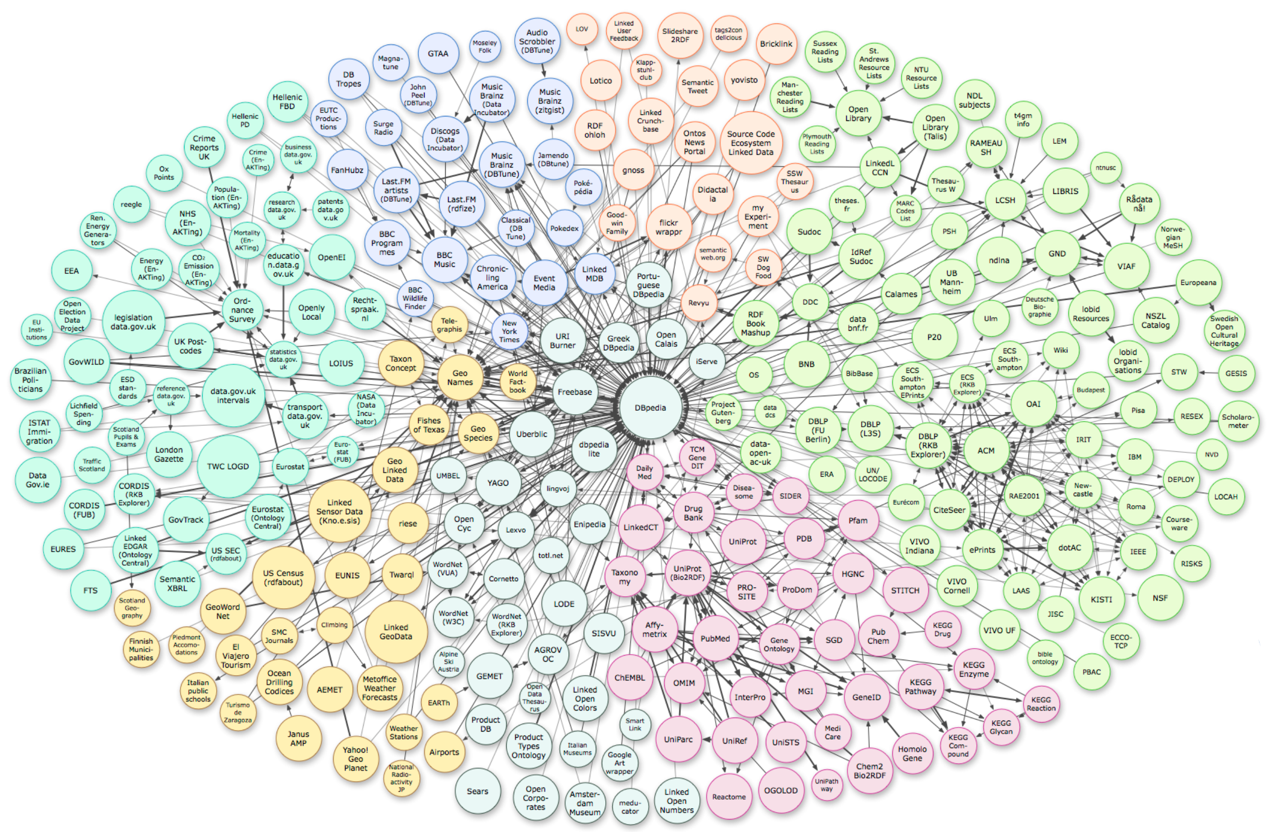
Social networks



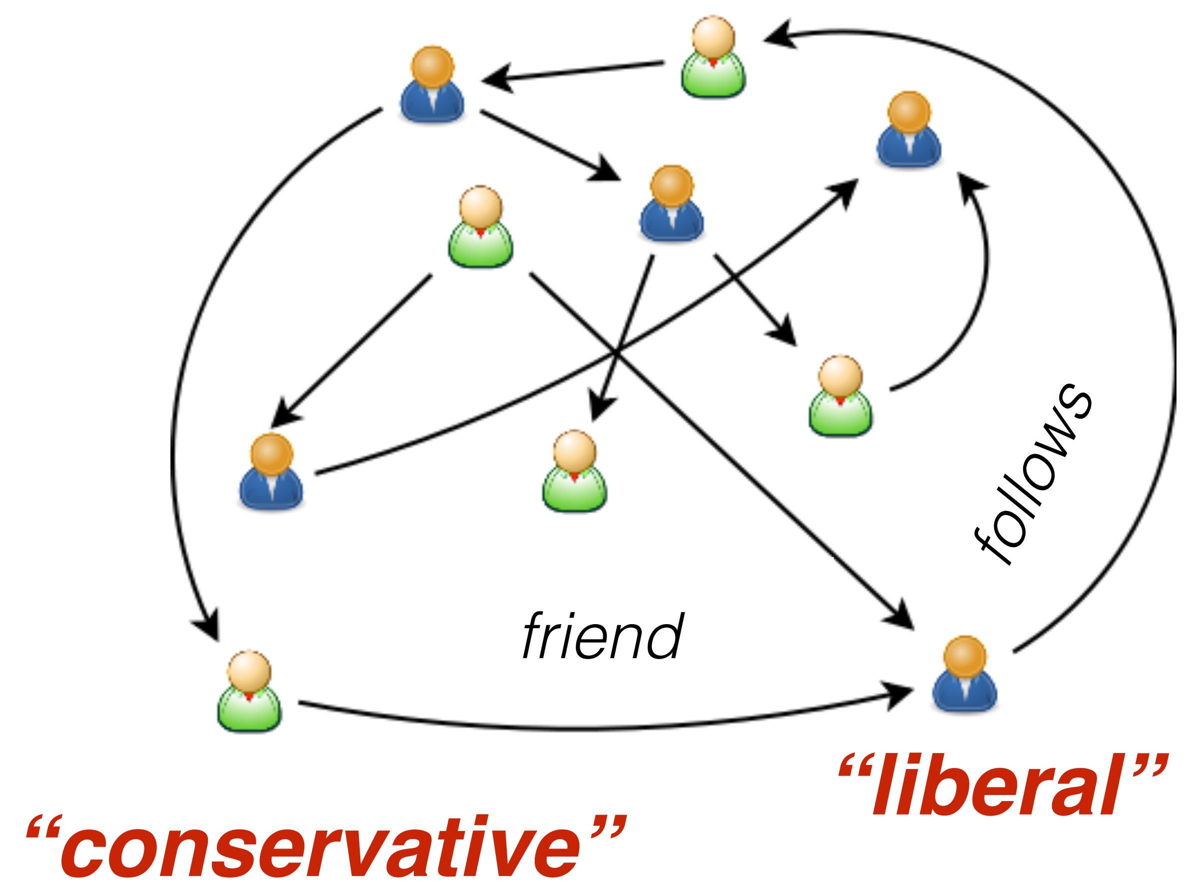
Transportation networks

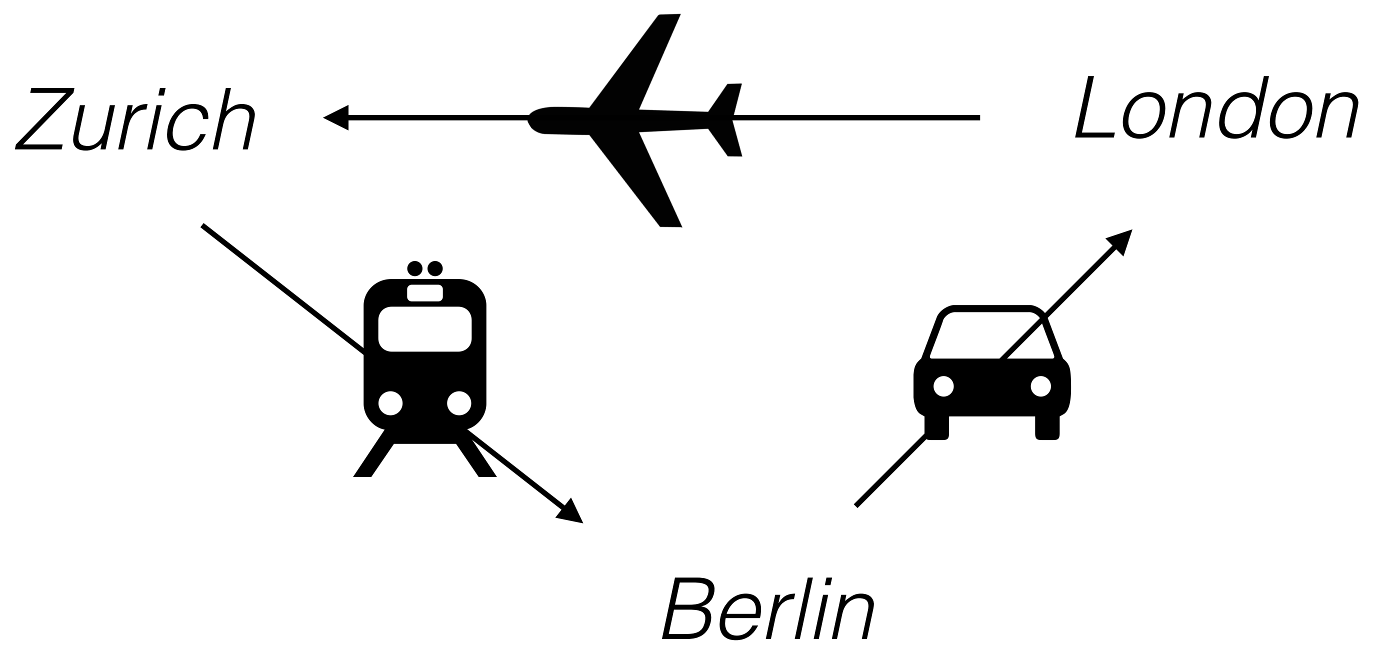


Actor-movie networks

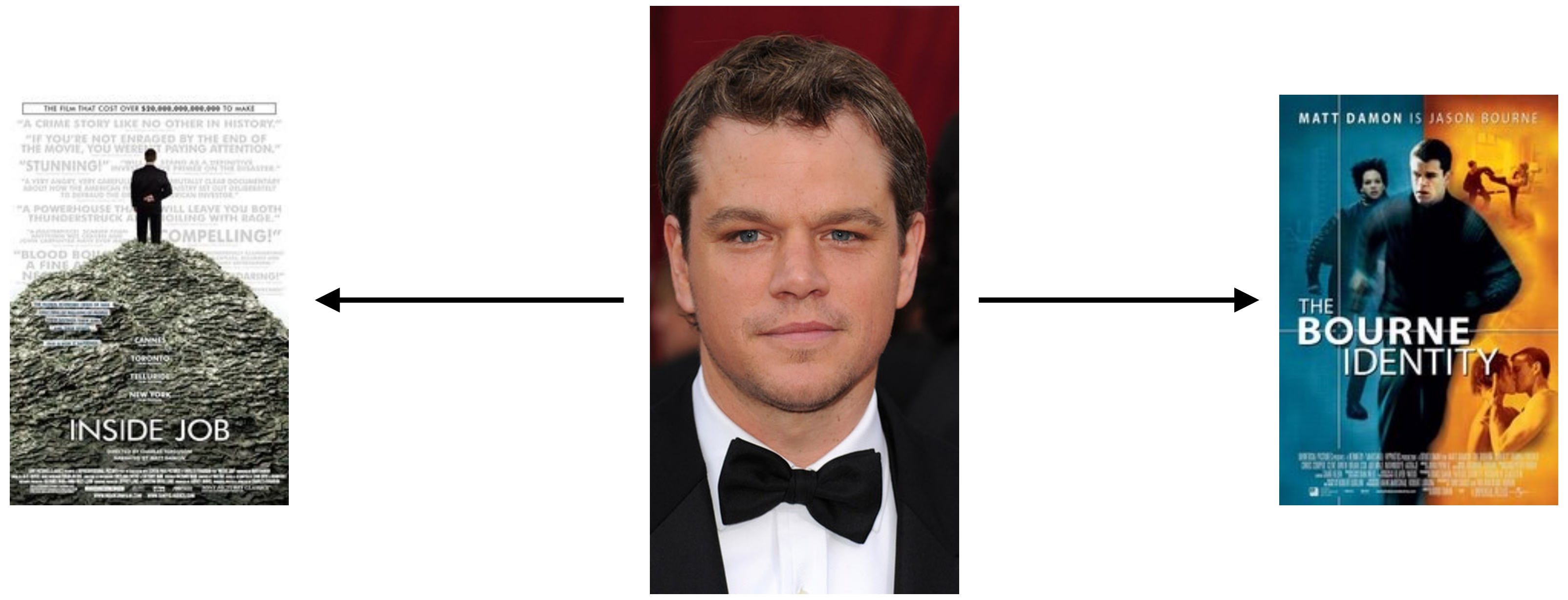


The web

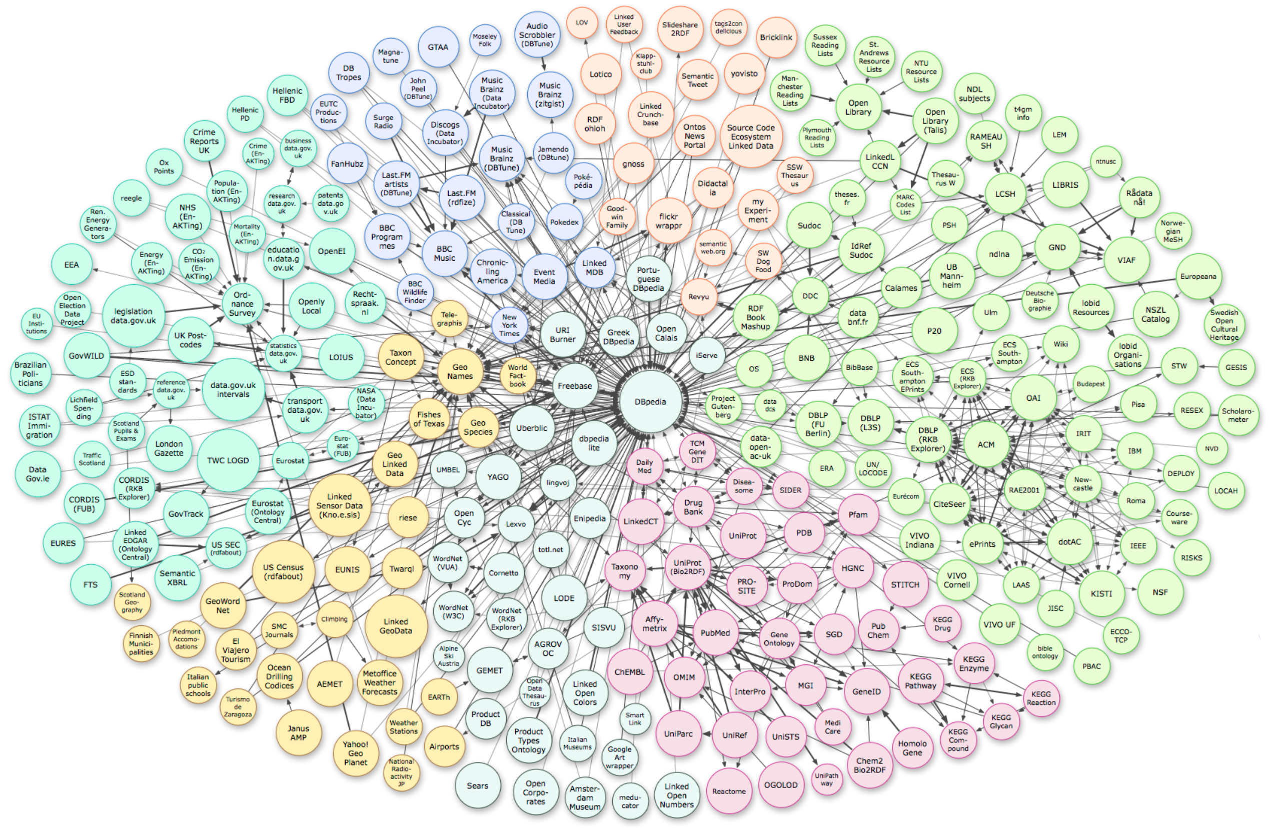




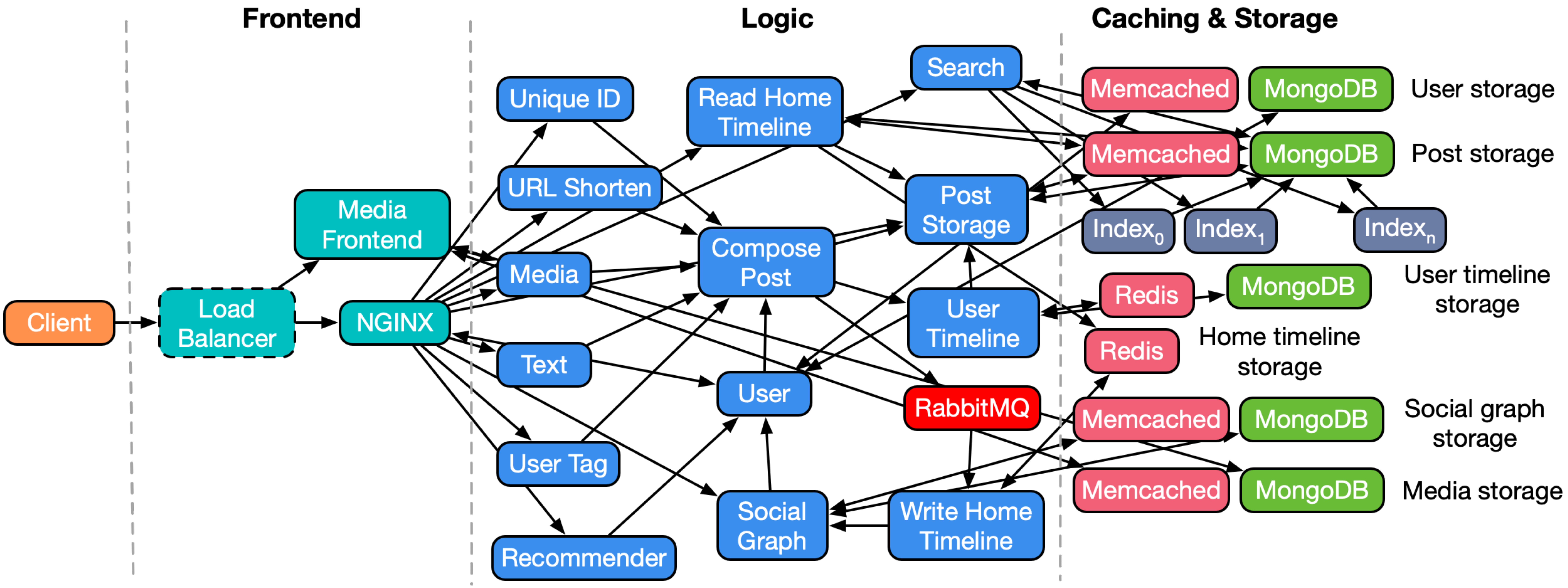
What’s the cheapest way
to reach Zurich from London through Berlin?



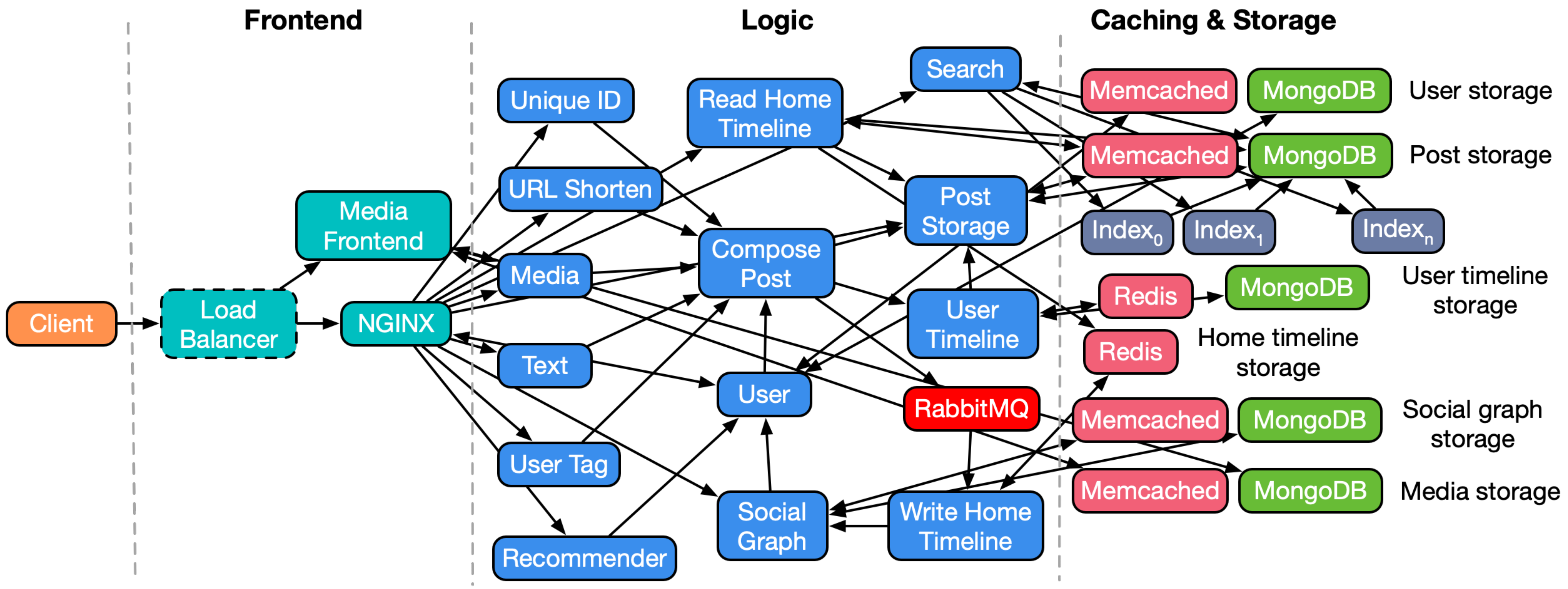
If you like “Inside job”
you might also like “The Bourne Identity”



These are the top-10 relevant results
for the search term “graph”



https://github.com/delimitrou/DeathStarBench/tree/master/socialNetwork



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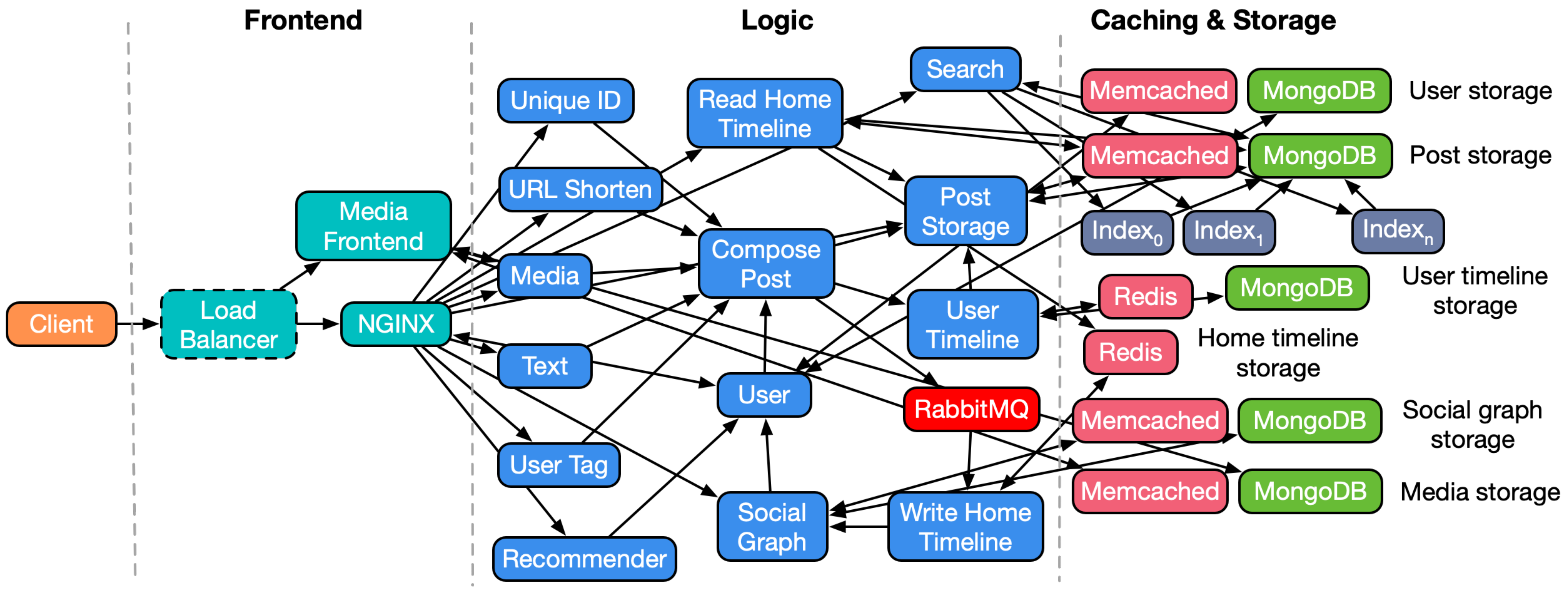

- Which services are reachable from service “User Timeline”?

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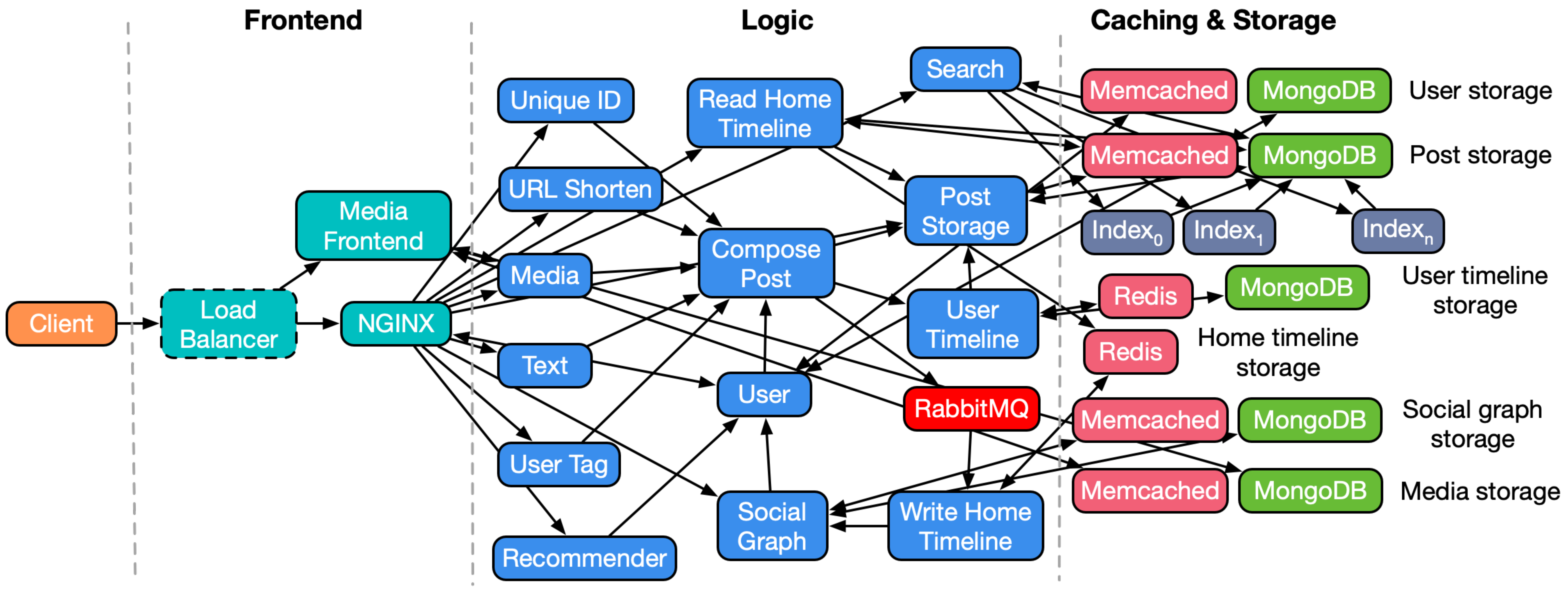

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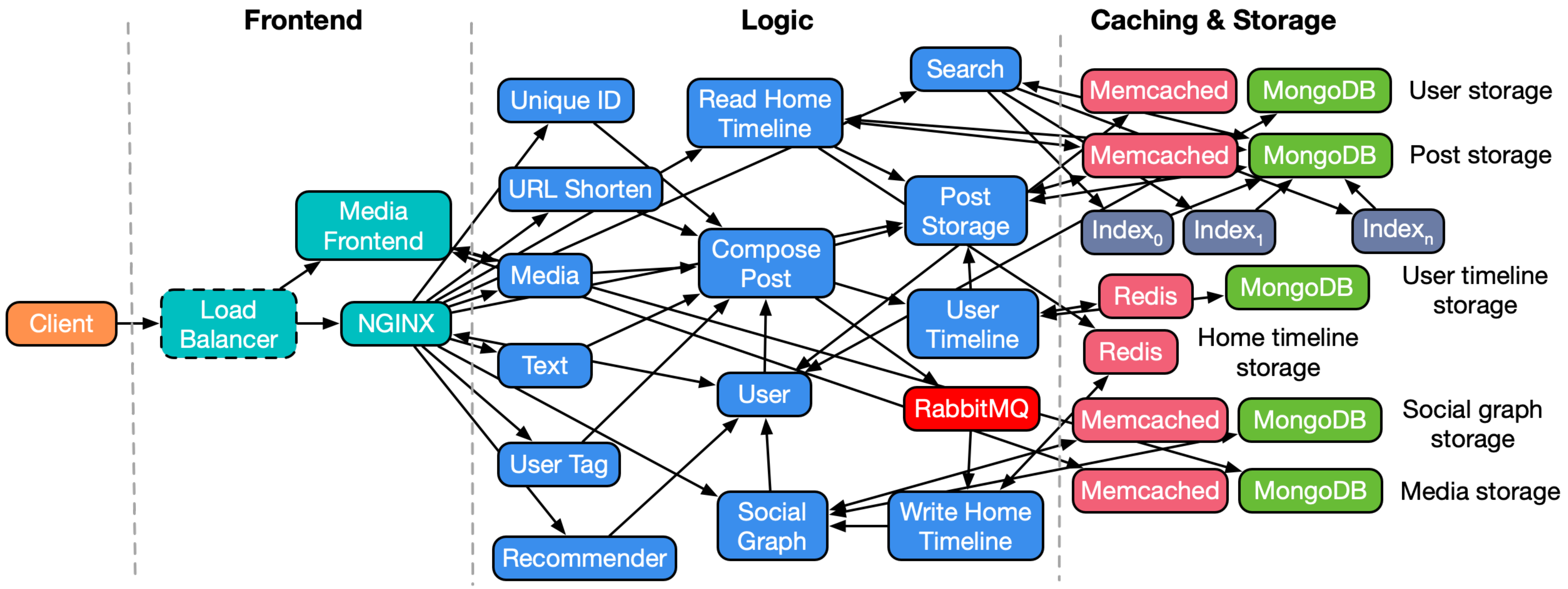

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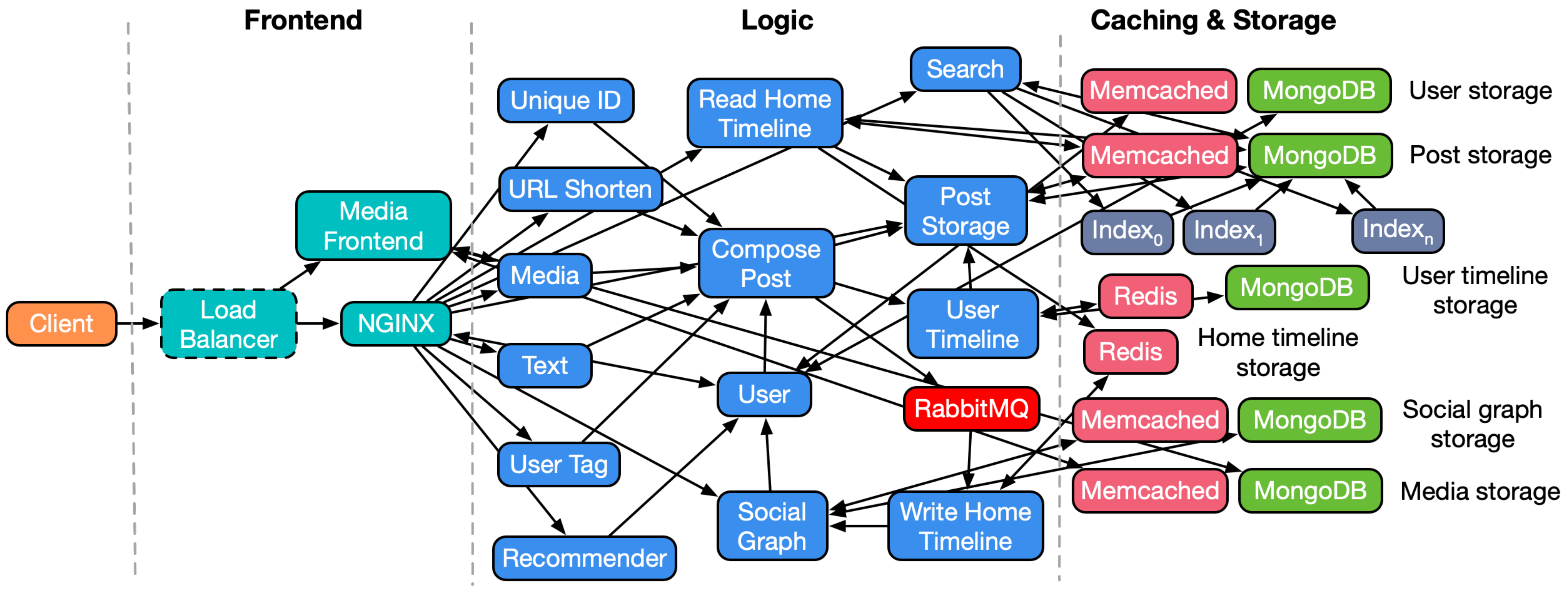

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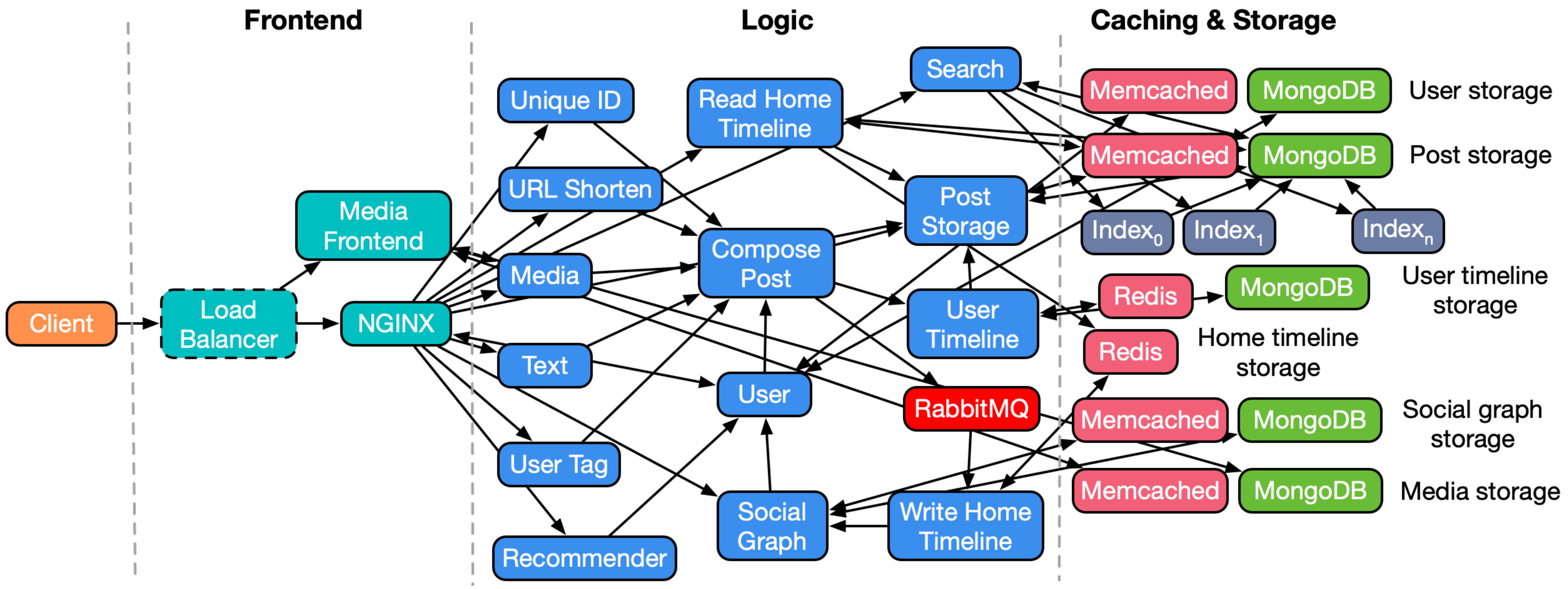

Temporal graph queries

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Modeling temporal graphs with **edge events**

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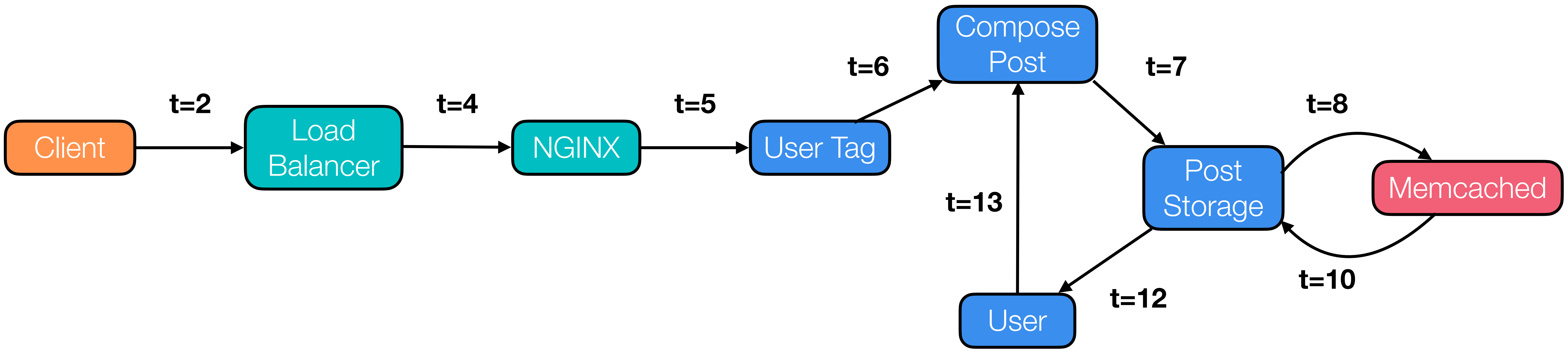

Challenging requirements for existing systems

Queries

- Point-in-time
- Continuous

Access patterns

- Full-graph
- Neighborhood-local

Workloads

- Iterative analytics
- Path traversals
- Frequent updates

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Graph DBs (e.g. Neo4j)

Batch graph processing systems (e.g. Apache Giraph)

Data stream processing systems (e.g. Apache Flink)

Bridging the gap: Temporal graph analytics on **Flink Stateful Functions**

Actor-like programming model

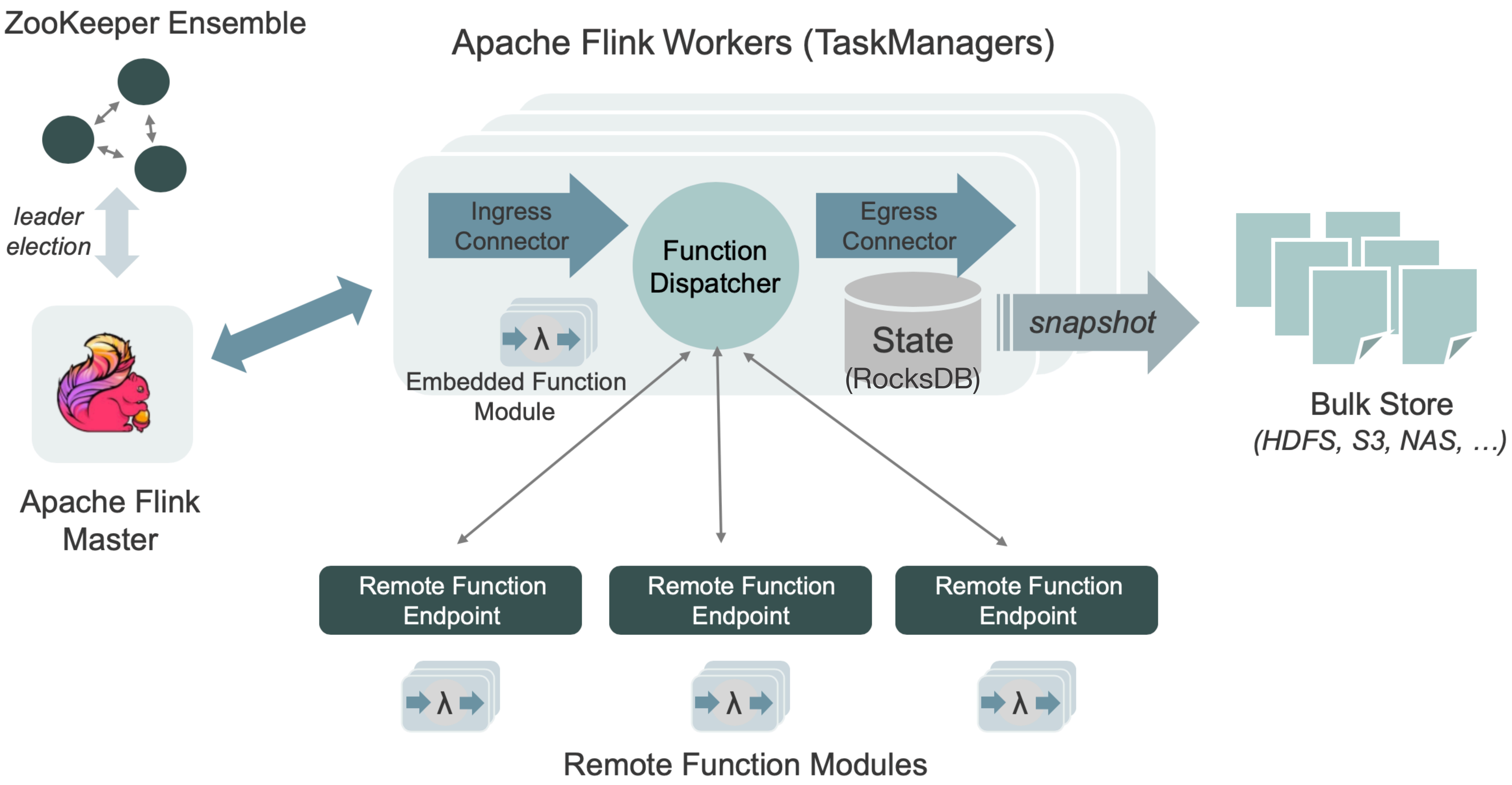
- Built-in support for streams
- Flexibility in expressing iterative, path, and search queries

Decoupling of computation and state

- Support for concurrent graph updates and queries
- Ingestion and analytics can scale independently

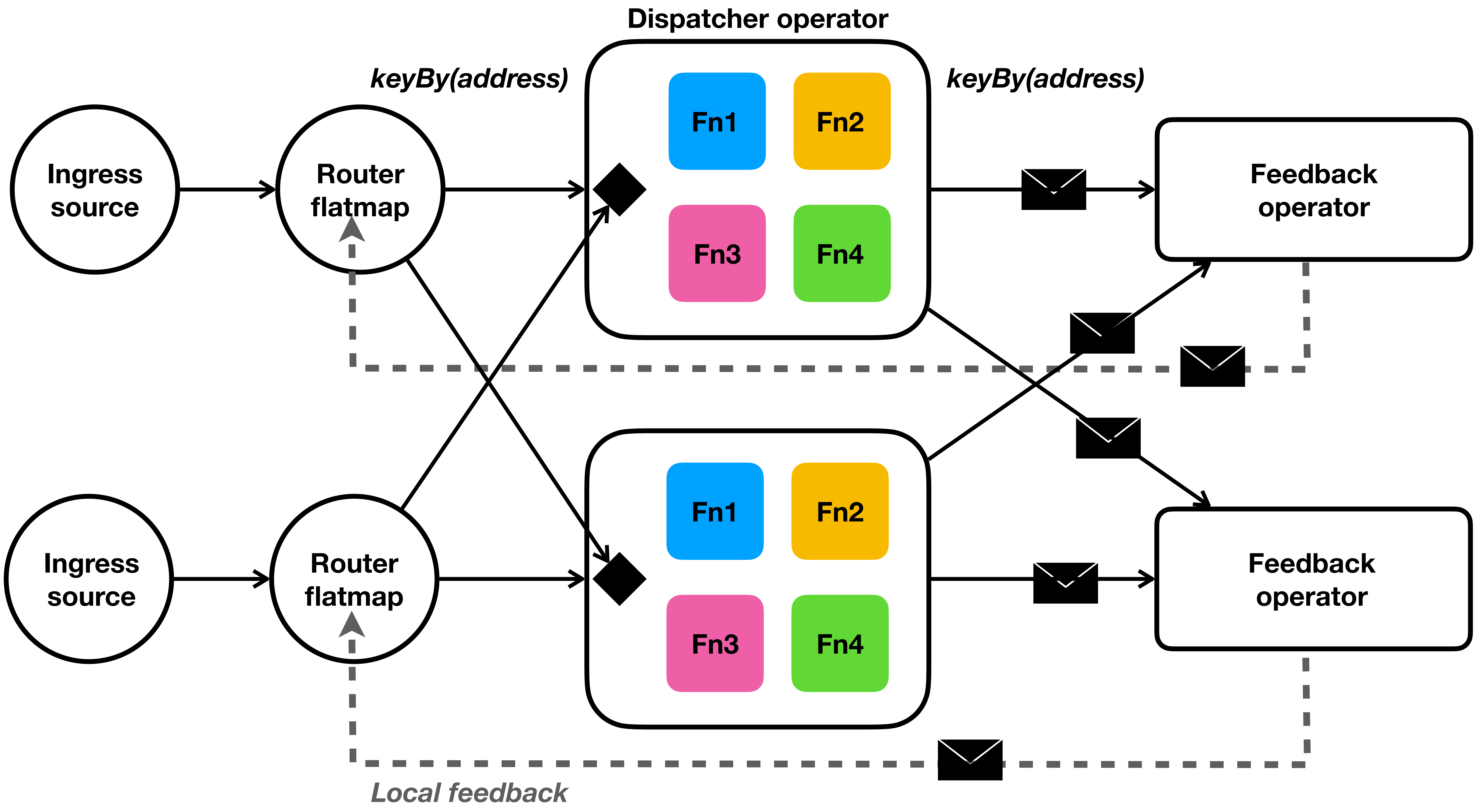
Flexible deployment

- Embedded compute for low latency
- Serverless remote compute for scalability

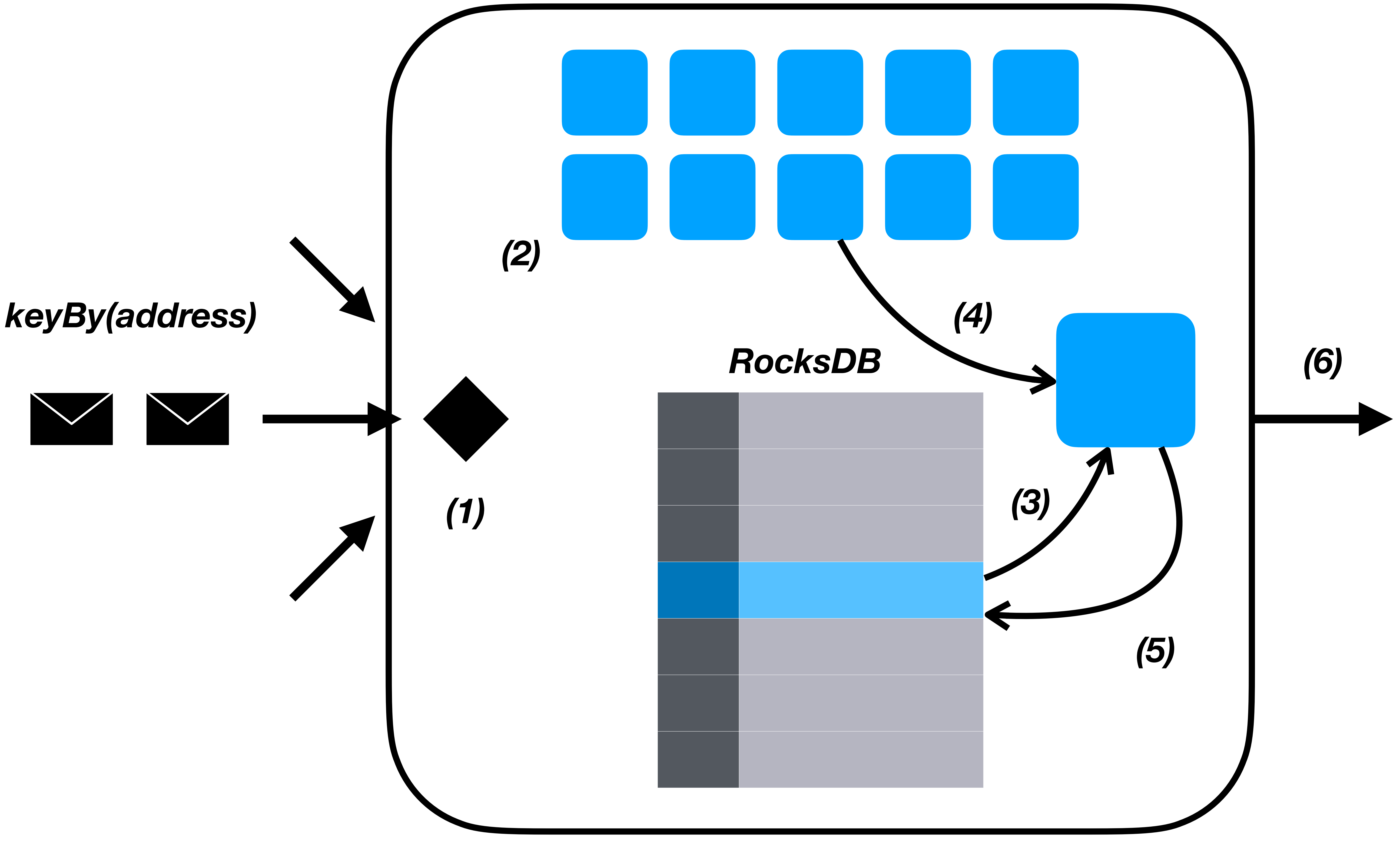


https://flink.apache.org/stateful-functions.html

Statefun as a dataflow

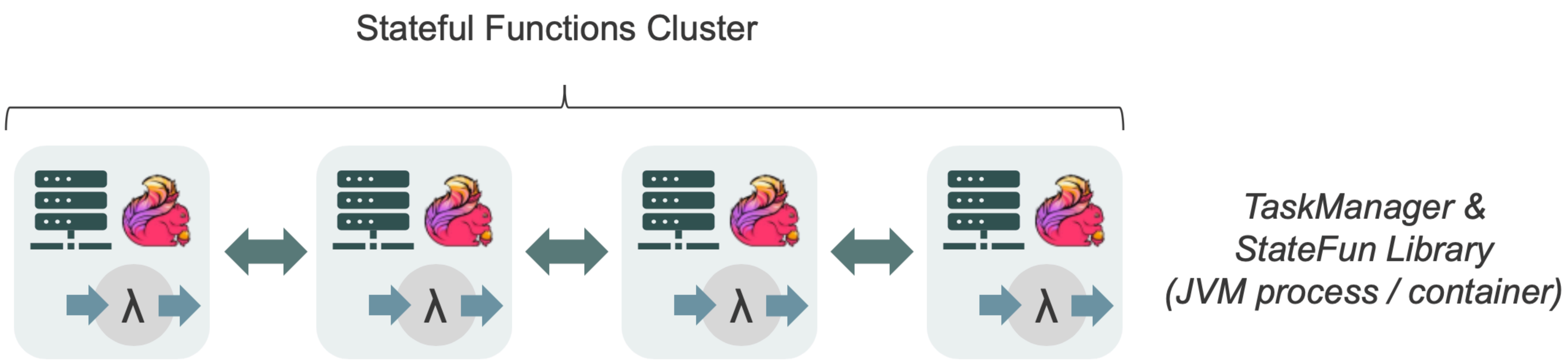


The function dispatcher operator



1. Extract function type
2. Load function
3. Load state
4. Invoke function
5. Update state
6. Output message

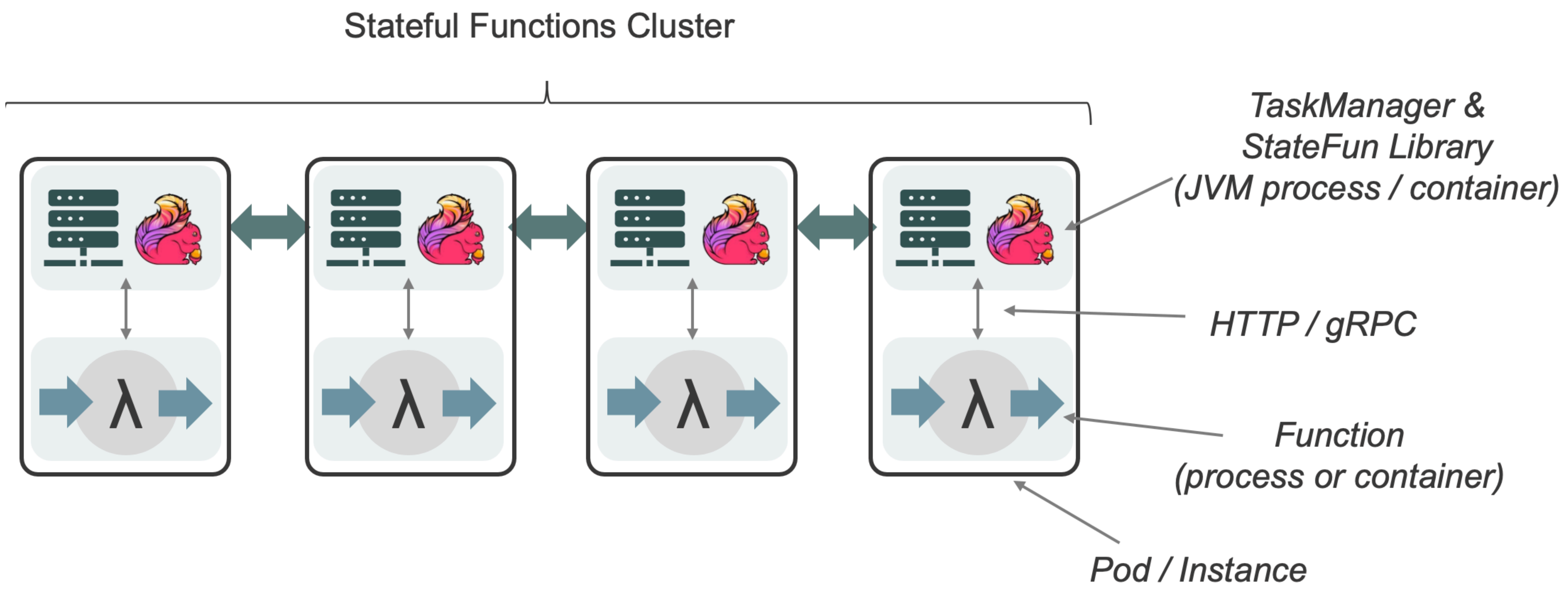
Deployment options: Embedded



- Functions are run in the JVM and are directly invoked with the messages and state access.

- Very performant but updates to functions require updating the Flink cluster.

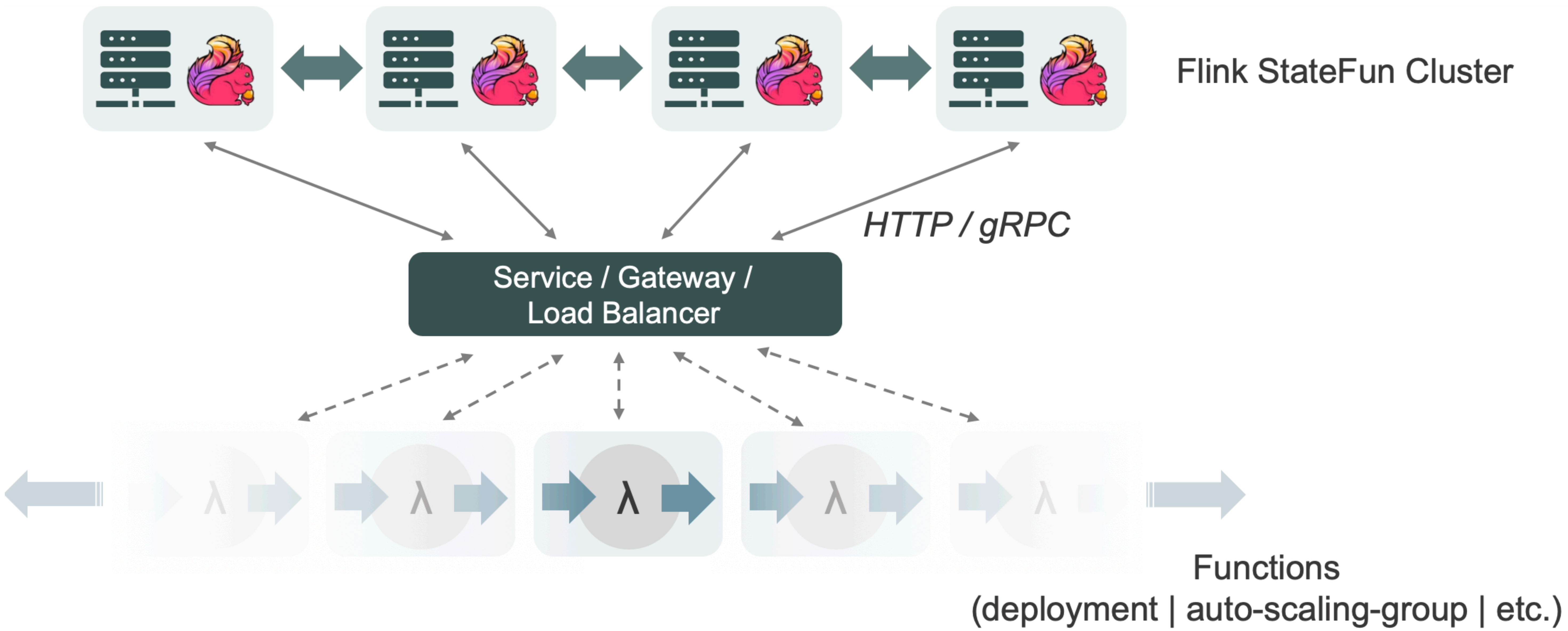
Deployment options: Co-located



- A Flink TaskManager interacts with one Function process sitting *“next to it”*.
    - Deploy pods consisting of a Flink container and the function side-car container; the two communicate via the pod-local network.

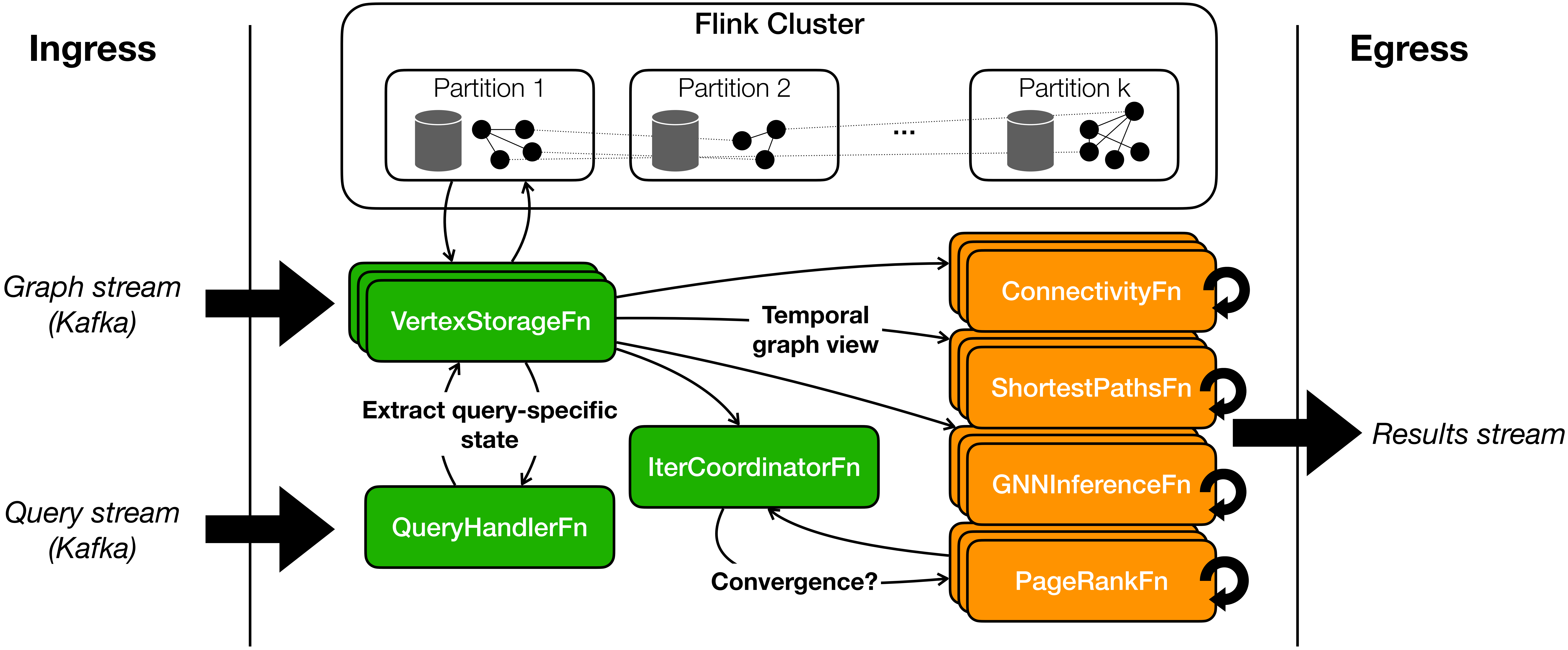
- Supports different languages but it cannot scale the state and compute parts independently.

Deployment options: Remote



- Physical *separation* - logical *co-location*.
- The state/messaging tier (i.e., the Flink processes), and the function tier are deployed, managed, and scaled independently.

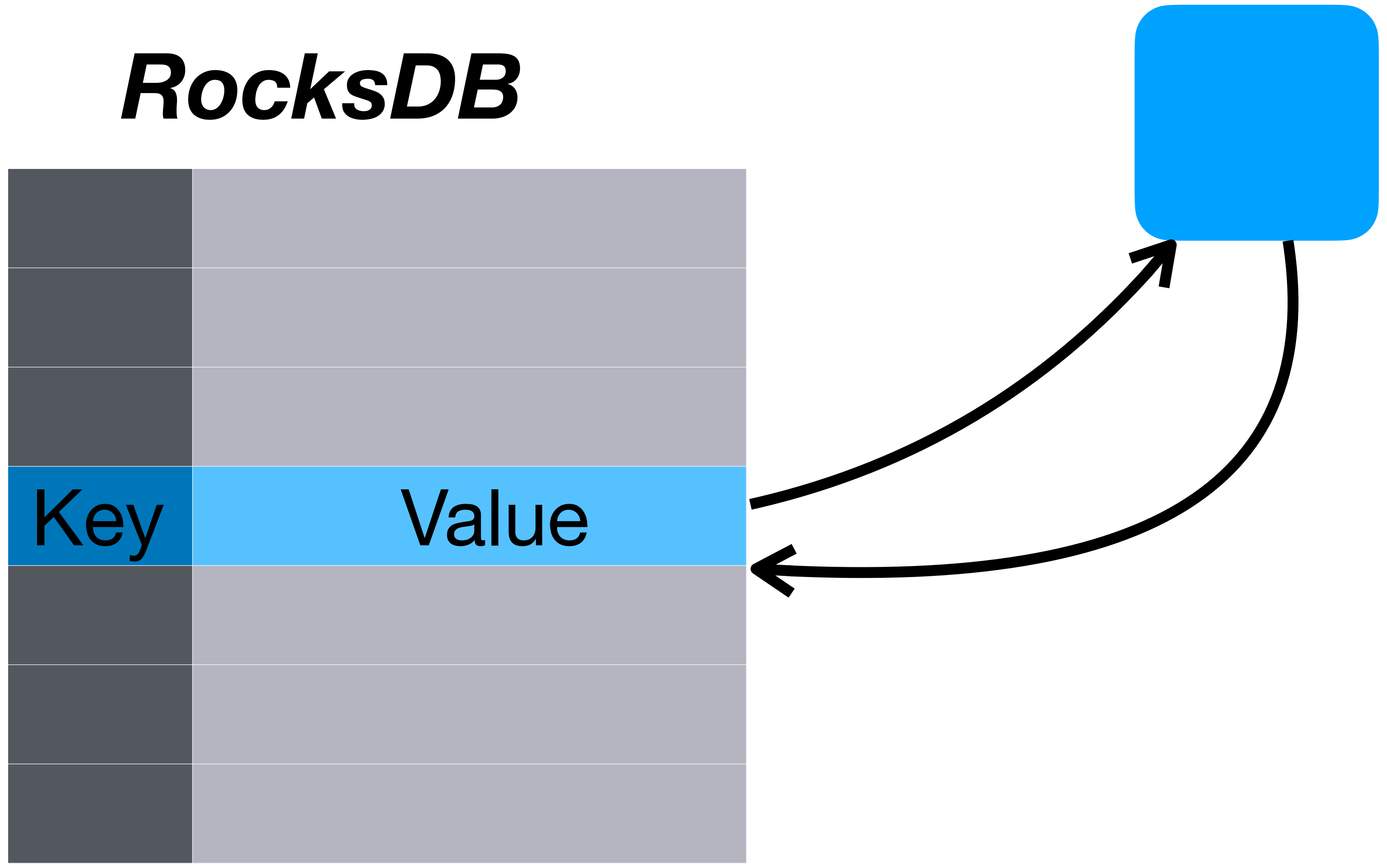
Prototype system architecture



Design considerations & challenges

- How to express queries as interacting functions?
- How to represent graph state on RocksDB?
  - Implications on concurrency and latency
- How to represent temporal neighborhoods?
  - Query vs. update time
- When to compute embedded vs. remotely?

Representing temporal graphs in a KV store



- AFSF *co-partitions* messages and function state
- To ensure consistency, only **one function invocation per key** can be active at any point in time

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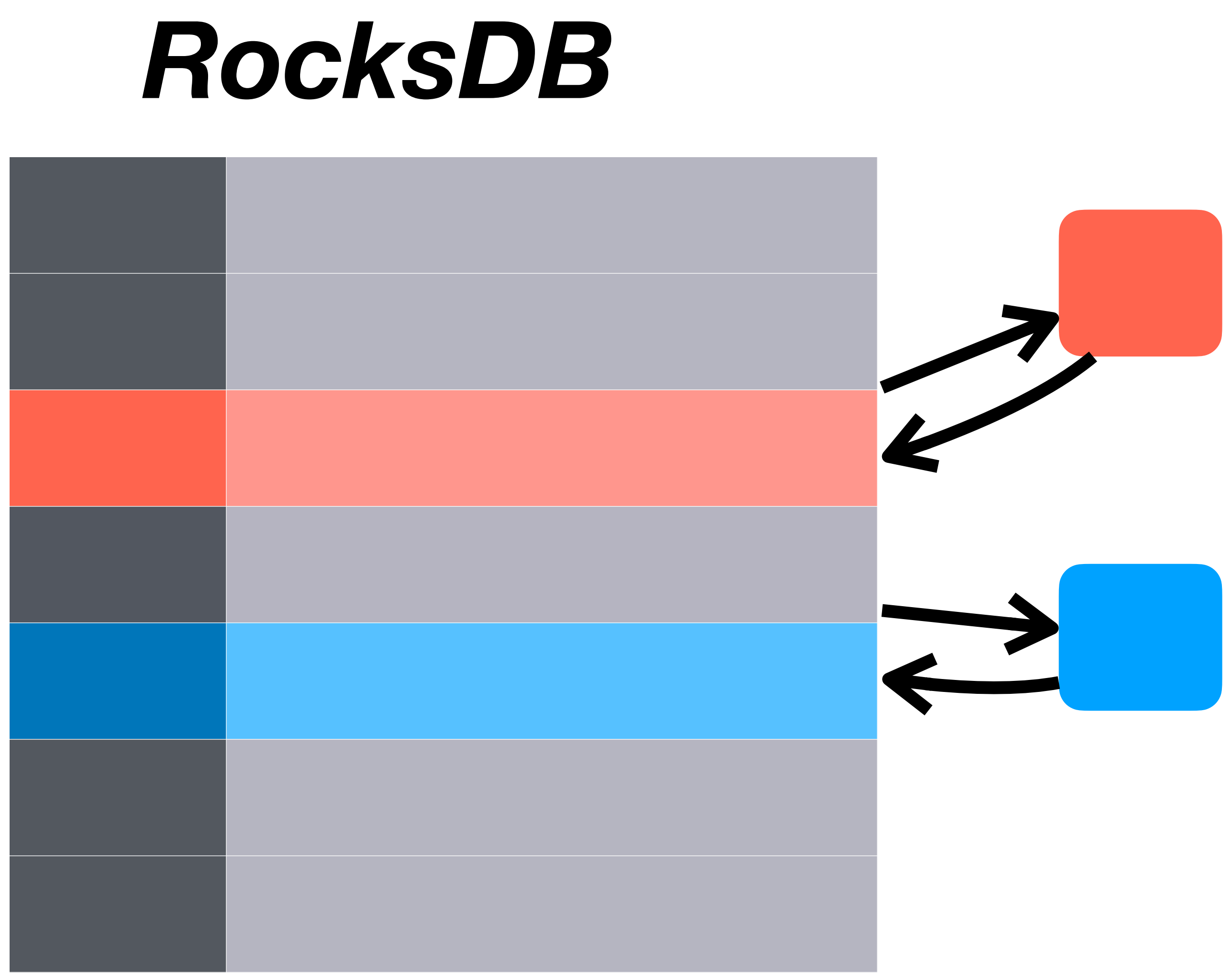
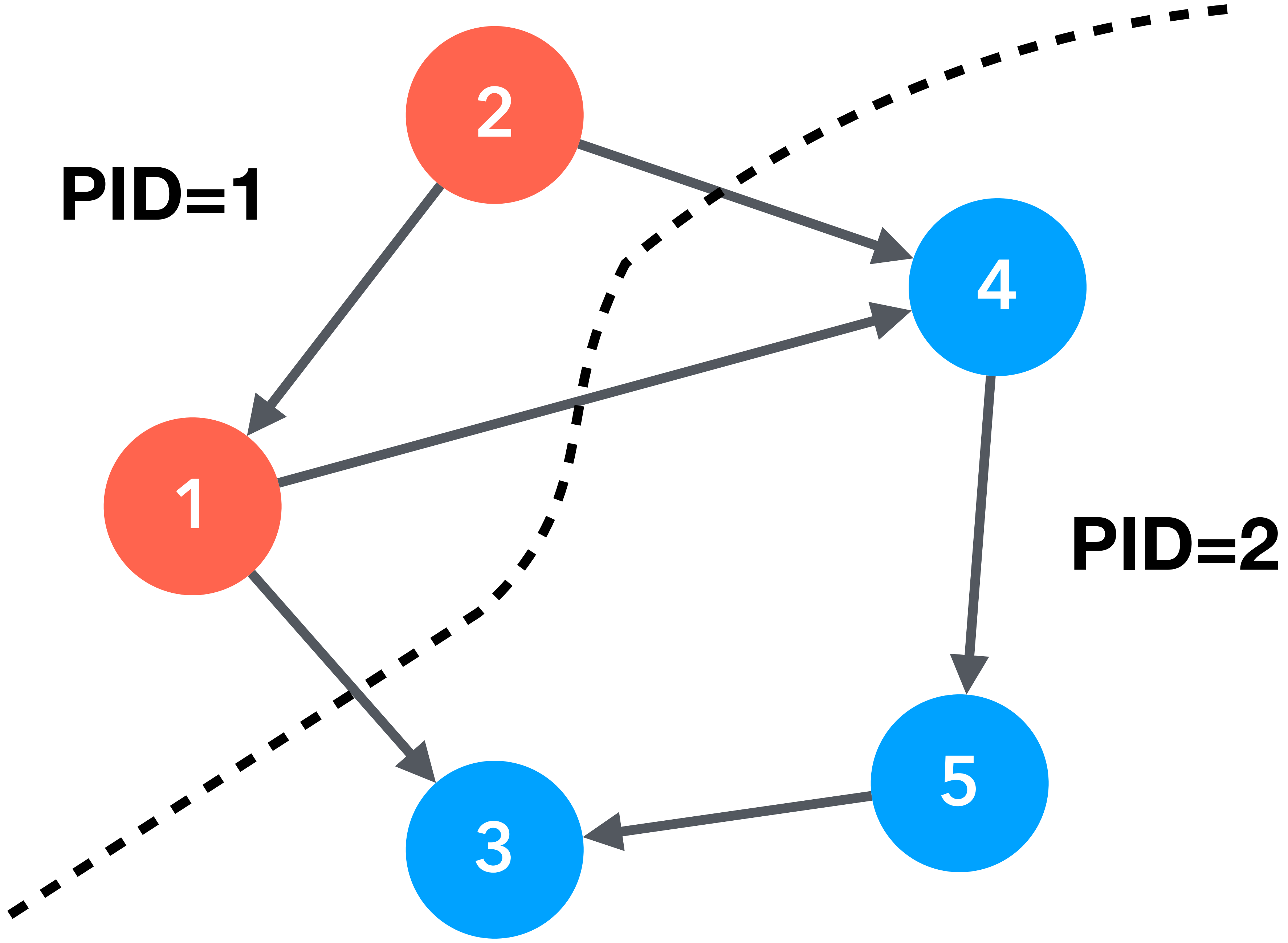
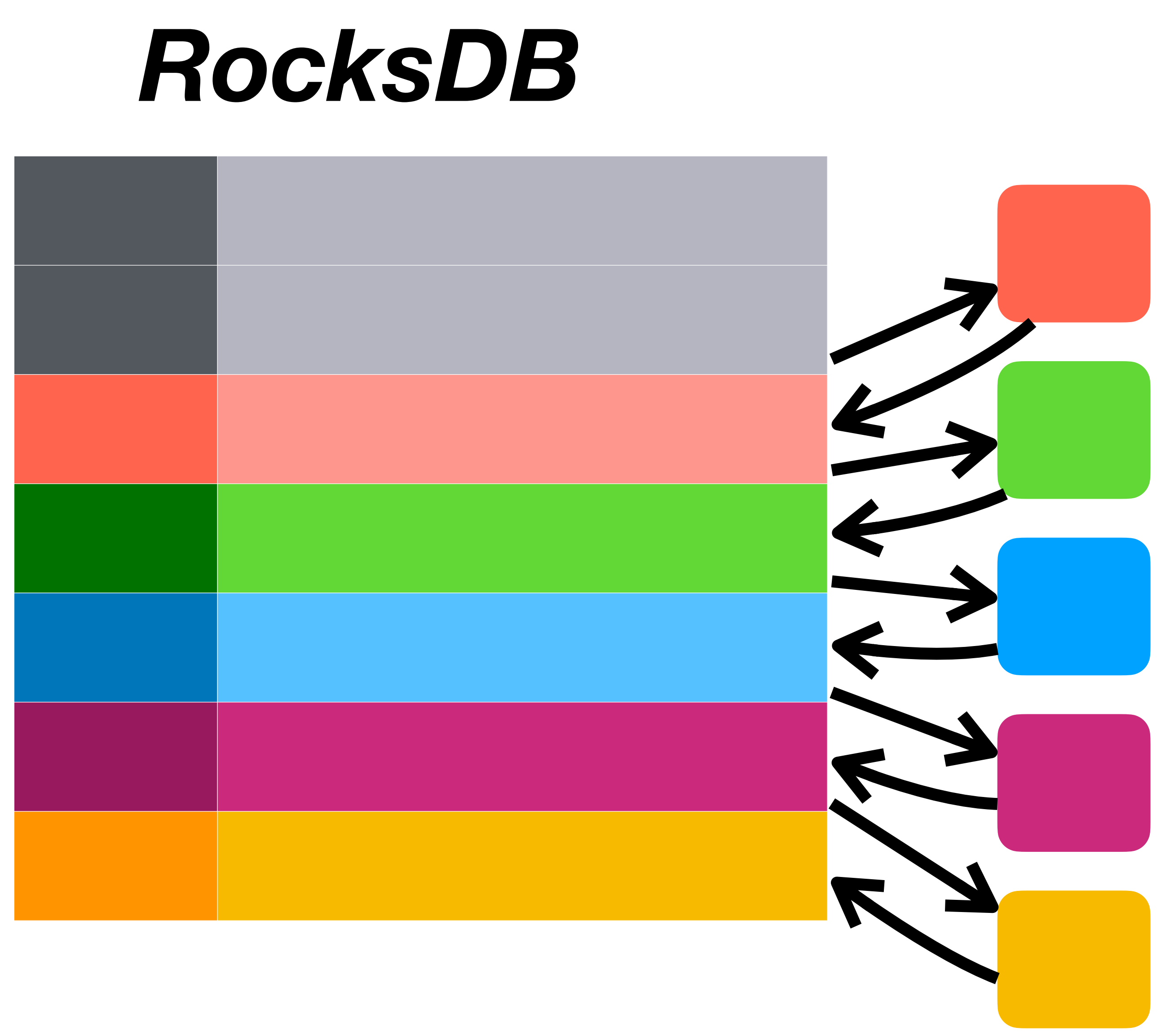
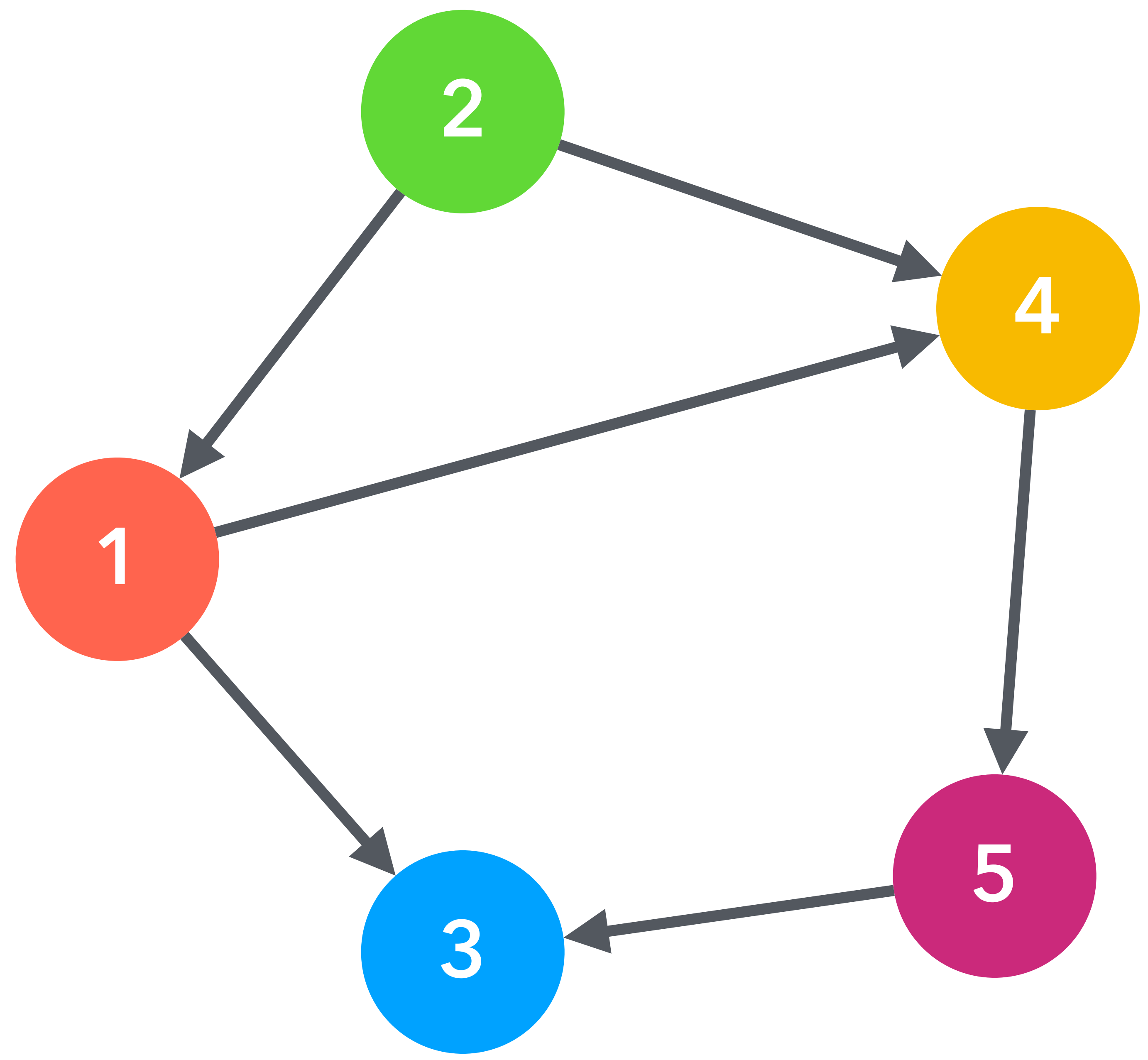




- (+) single-lookup access to neighboring subgraph
- (-) concurrency limited by #partitions

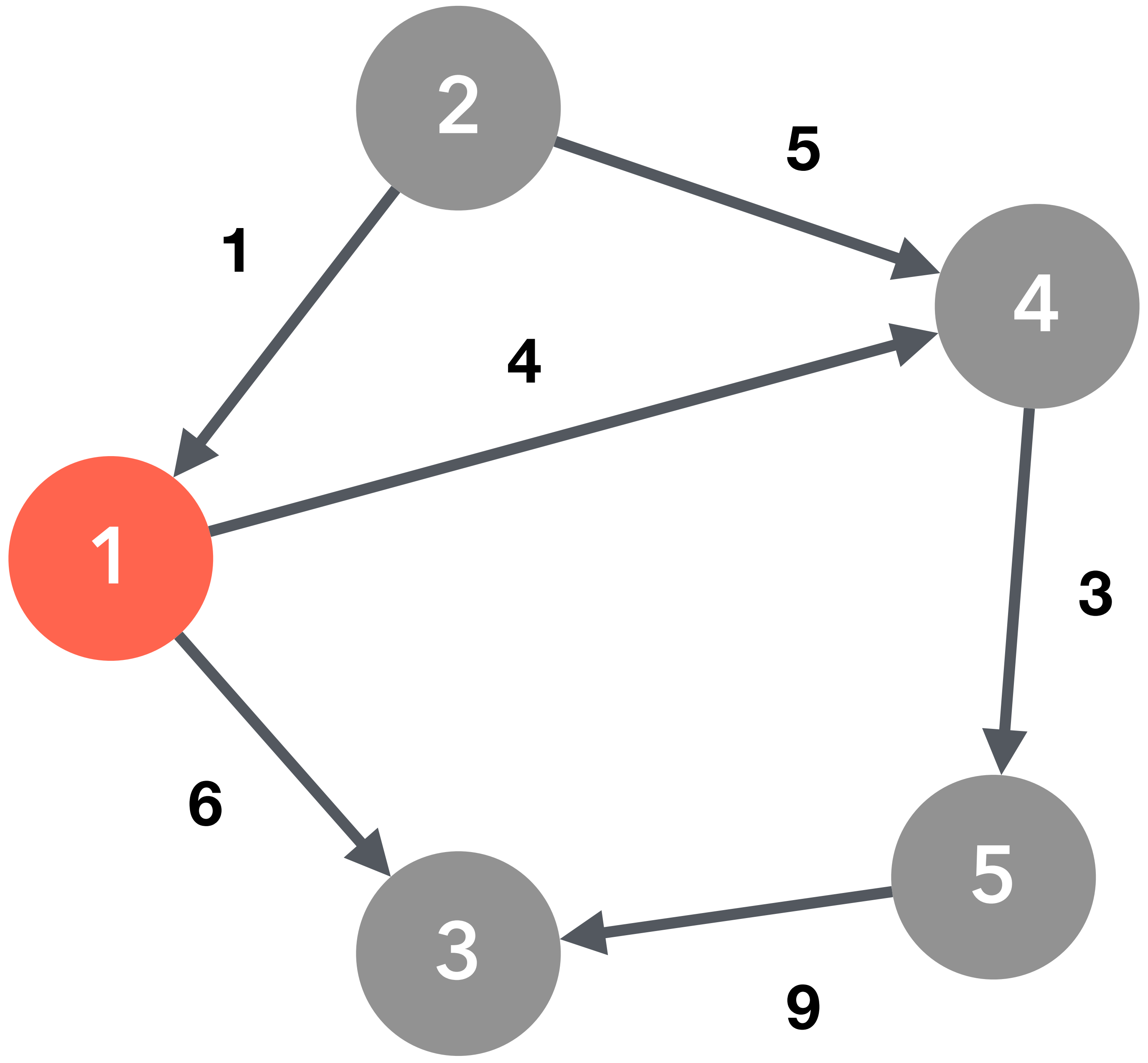
Representing temporal graphs in a KV store





- (+) maximum concurrency
- (-) multi-lookup access to neighboring subgraph

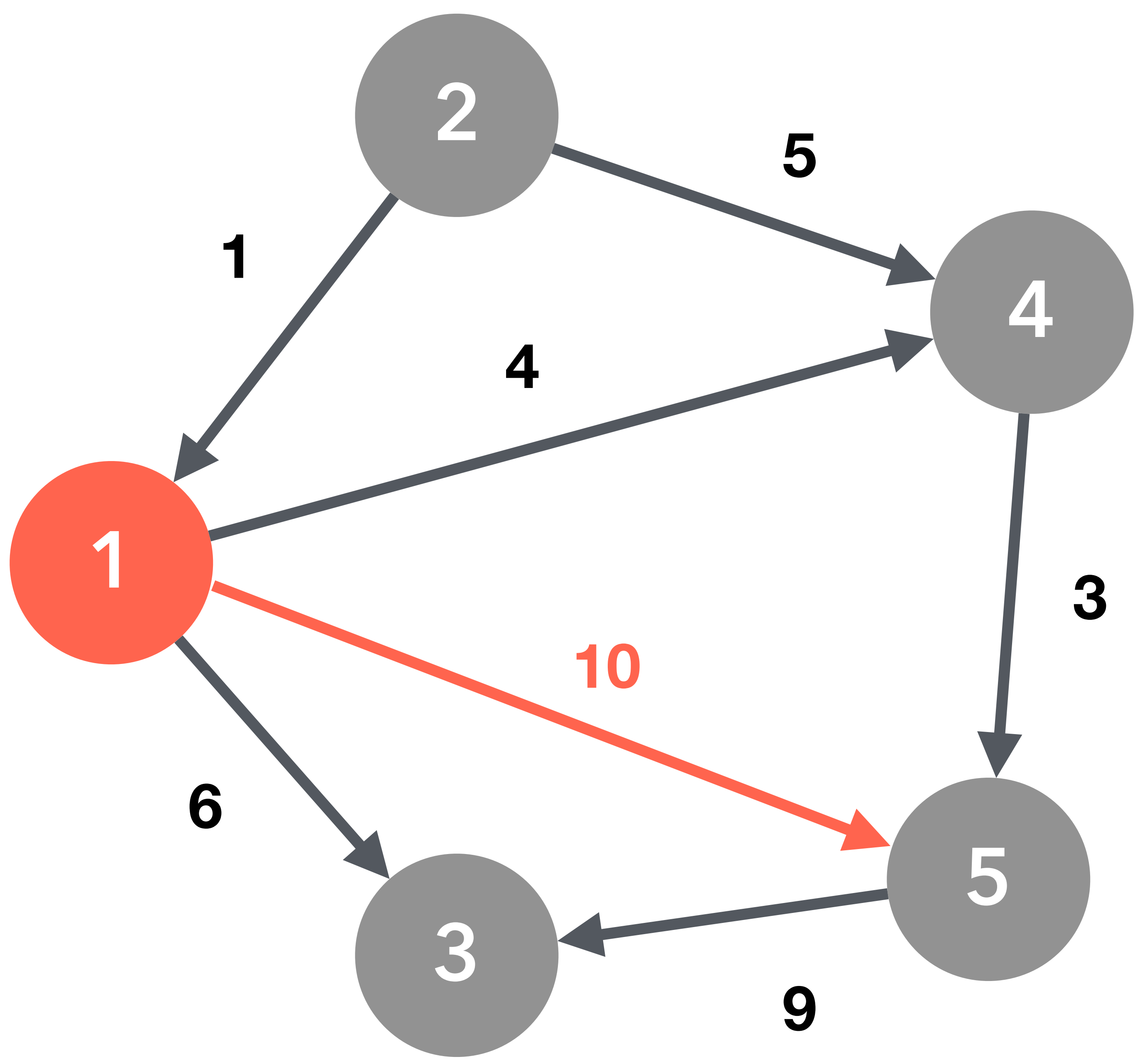
Storing a temporal neighborhoods in RocksDB

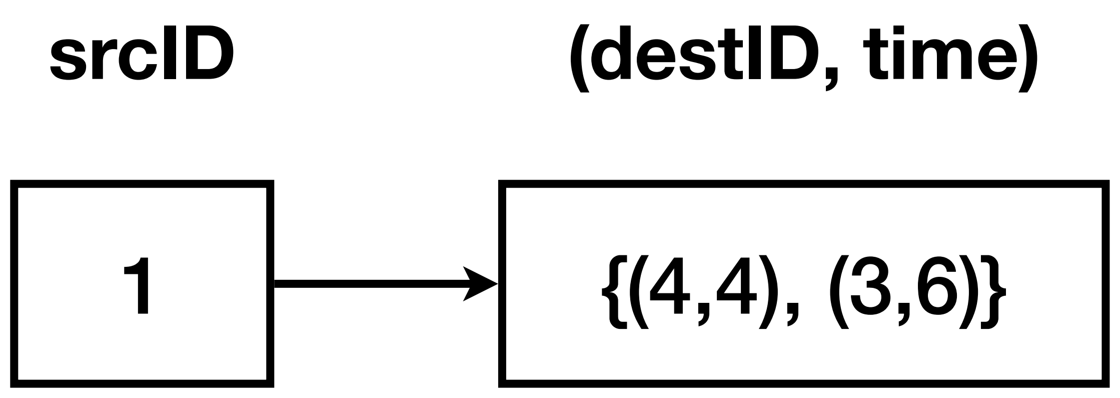


srcID **(destID, time)**

1 → {(4,4), (3,6)}

Storing a temporal neighborhoods in RocksDB





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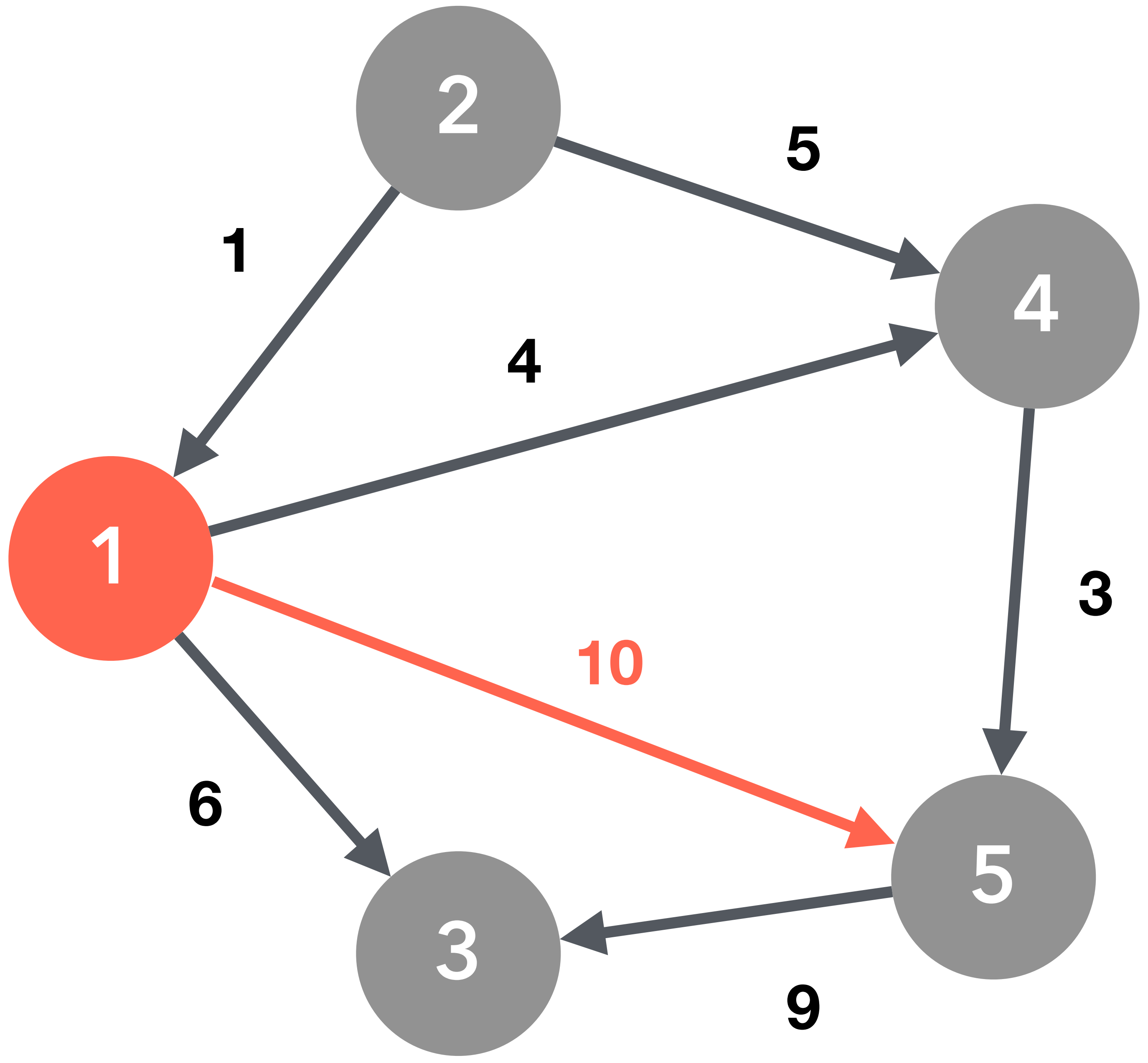
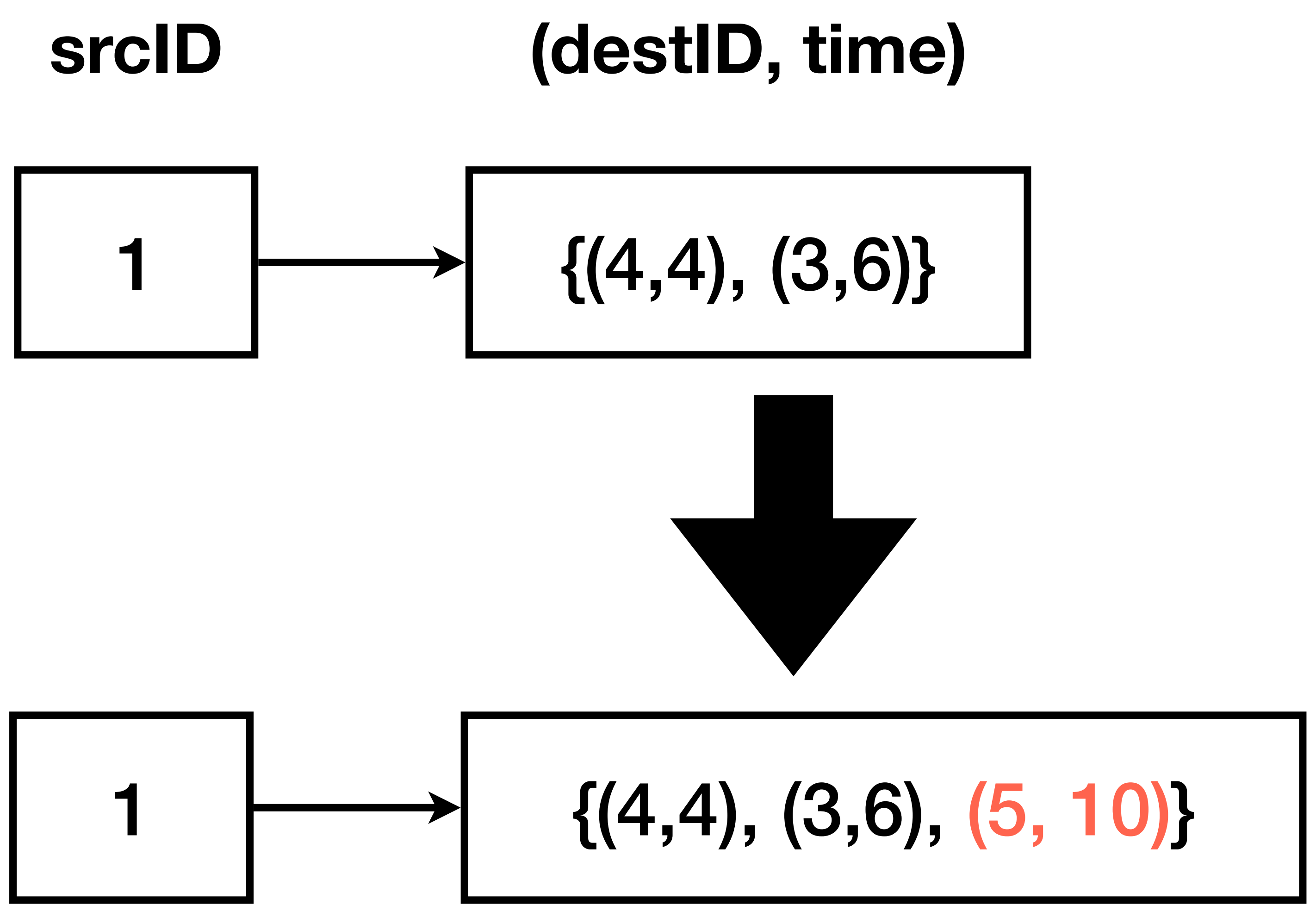
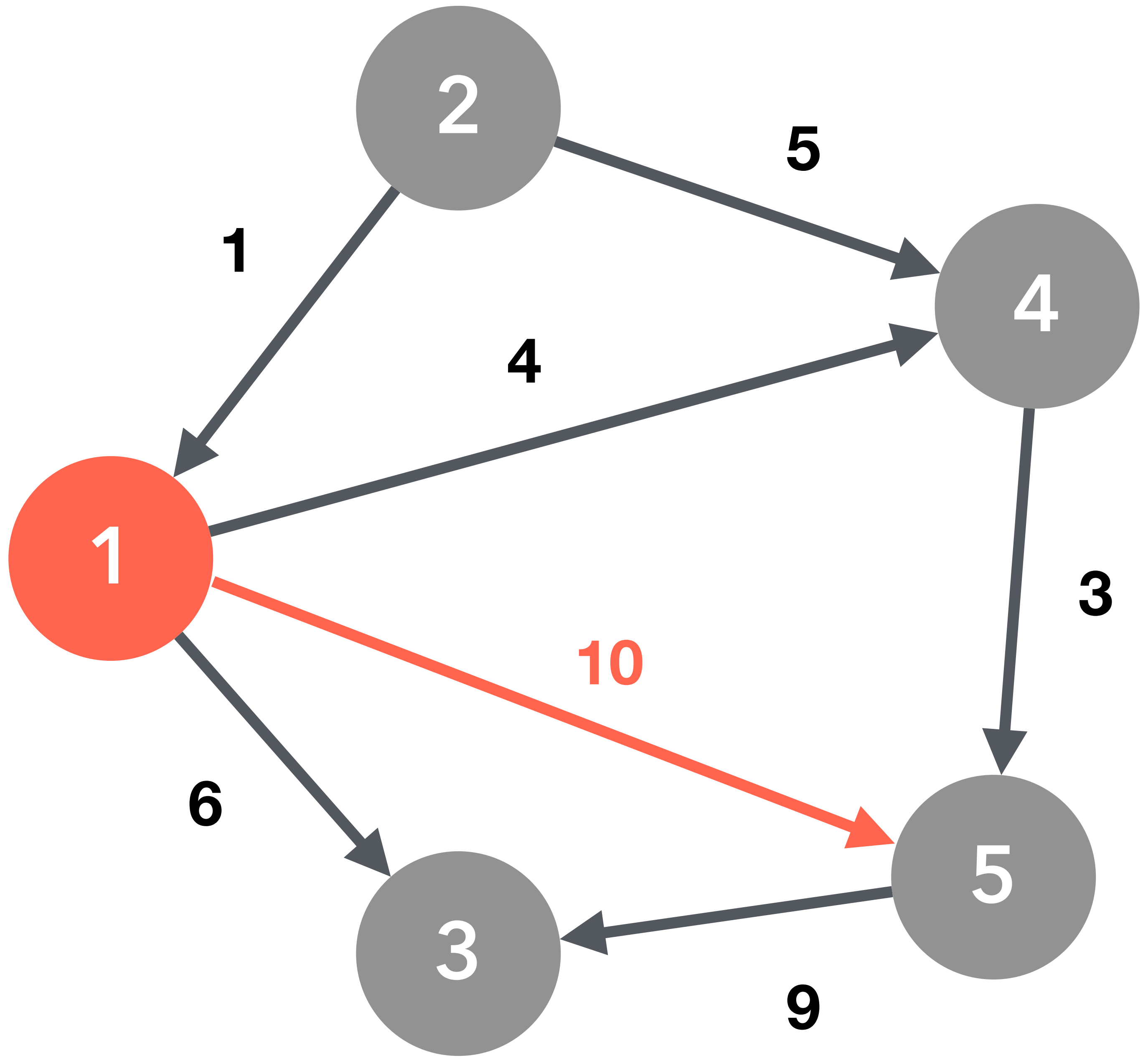




Deserialize neighborhood on lookup

Serialize neighborhood on update

Storing a temporal neighborhoods in RocksDB



In-memory

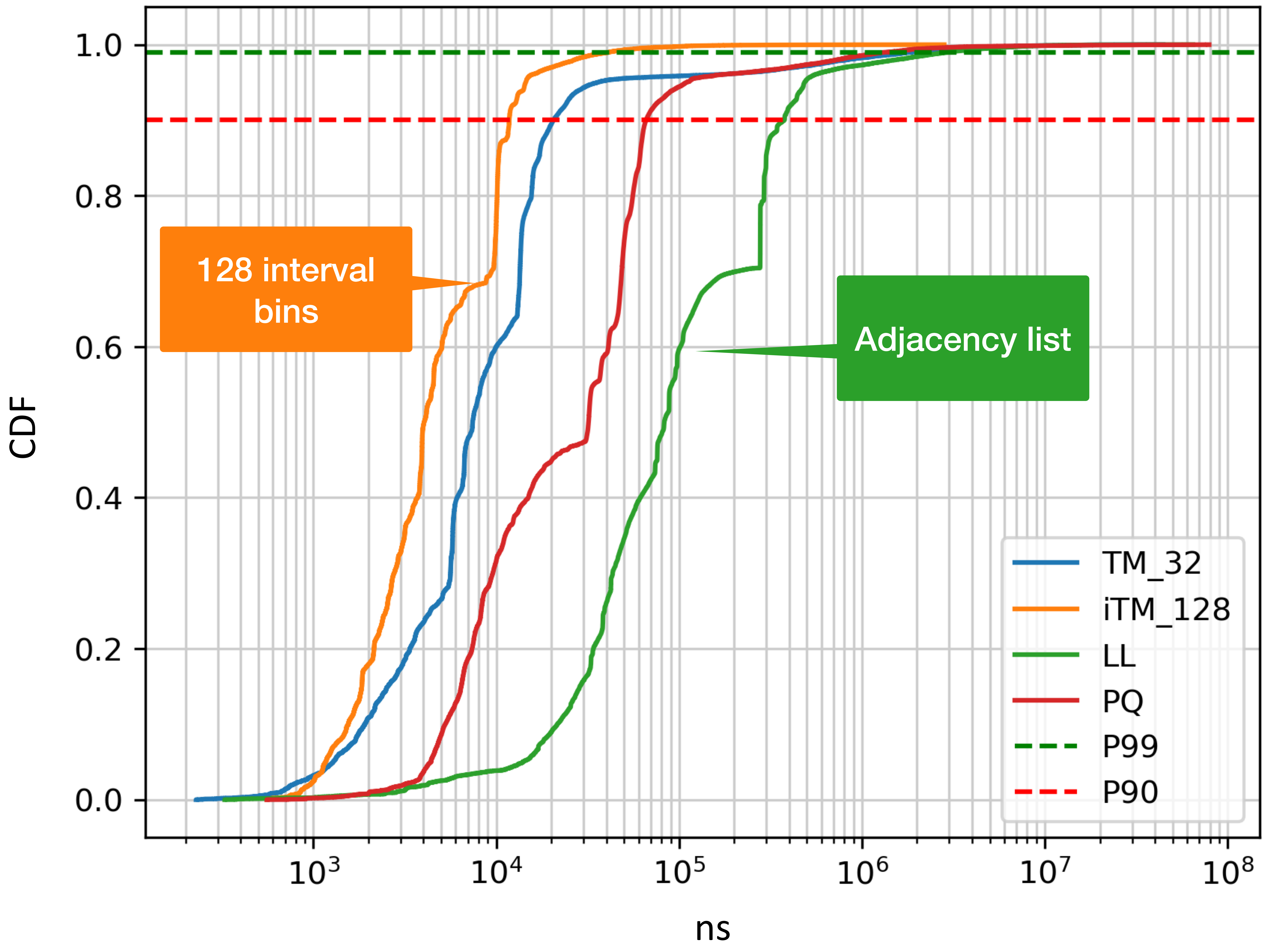
Time interval	binID
[0, 3]	1
[4, 6]	2
[7, 10]	3

RocksDB

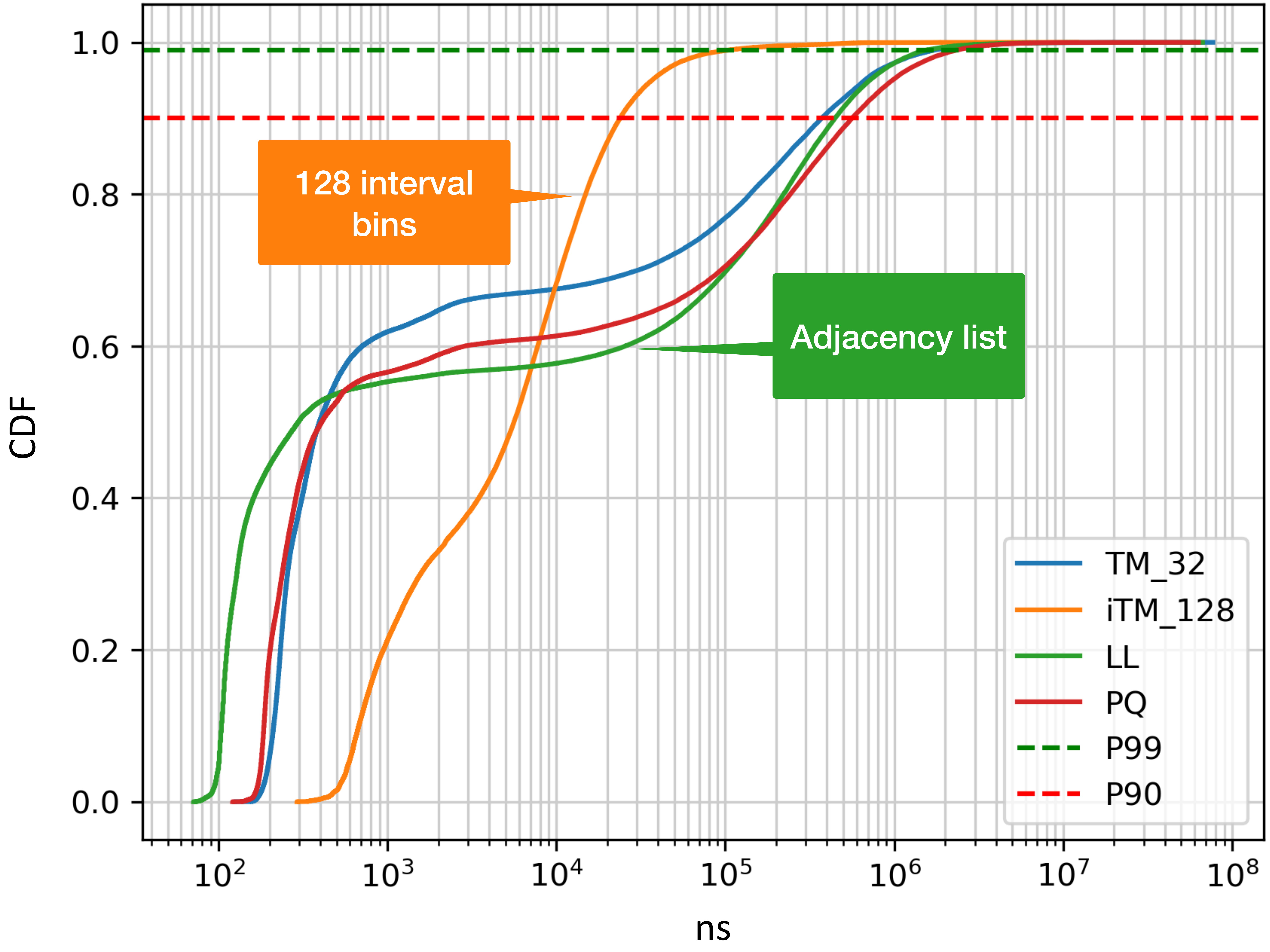
binID	(destID, time)
1	{}
2	{(4, 4), (3, 6)}
3	{5, 10}

Query and update only the relevant bin(s)

Read latency (100 connectivity queries)



Update latency (100 connectivity queries)



Ongoing and next steps

- Extending the library with more algorithms
- Evaluating embedded vs. remote function invocation
- Large-scale experiments on realistic scenarios
  - Micro-service traces collected from Jaeger
- Preparing a first open-source release

Project Team

PhD students

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Master students

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Faculty

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