Lineage Stash: Fault Tolerance Off the Critical Path

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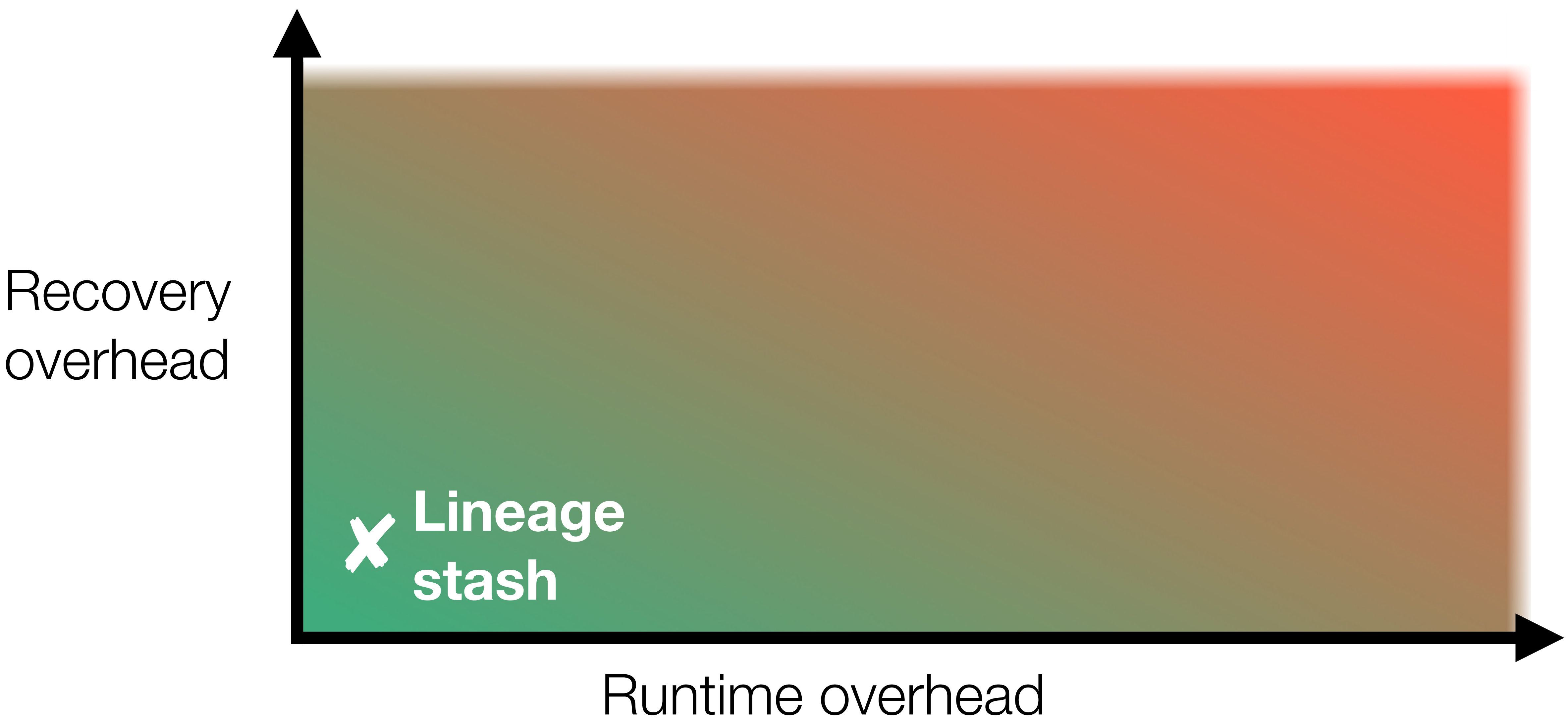
Low latency is increasingly important in data processing systems

Data processing is used today in **online** systems.

- Stream processing
- Graph processing
- Control systems

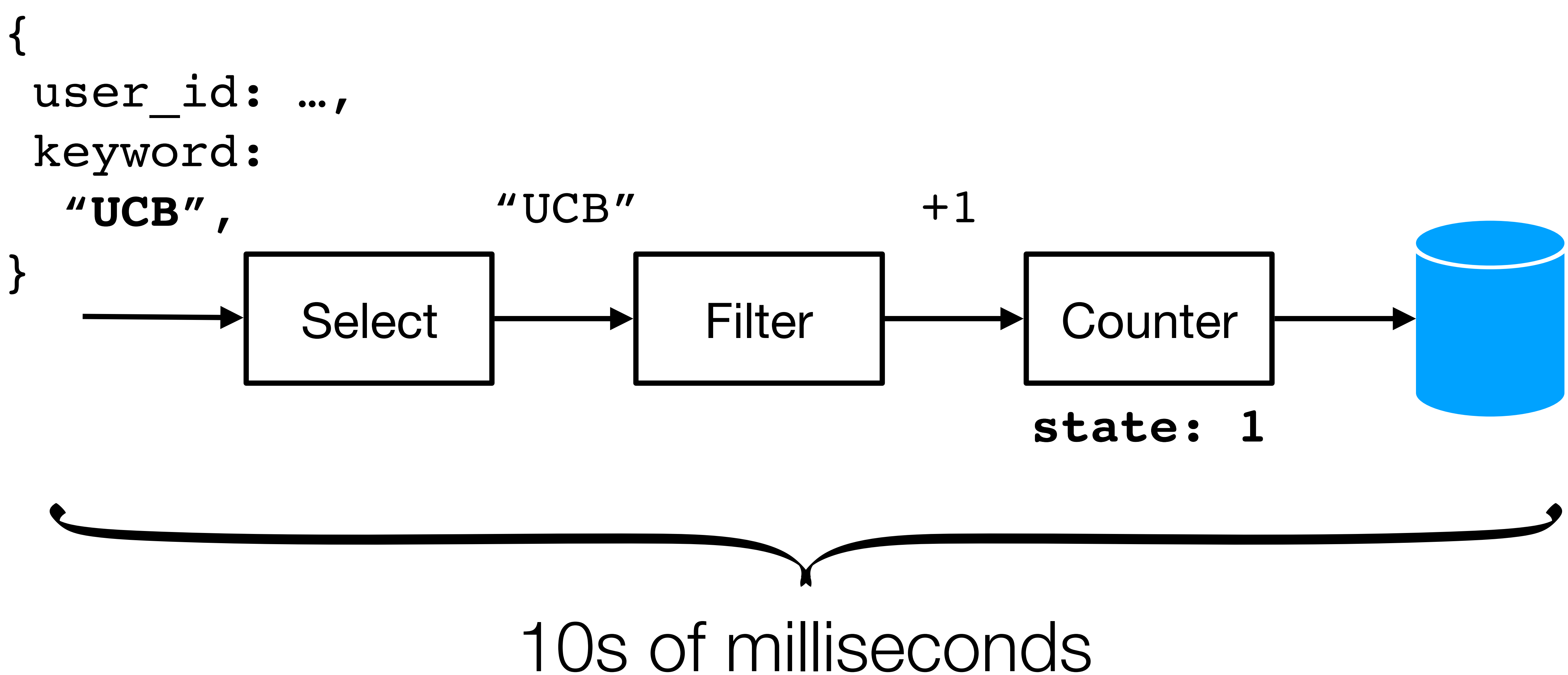
Data processing at **large scale** also requires the ability to **recover** results after a failure.

Tradeoff between low latency and recovery time



Stream processing example

Display the number of times “UCB” has been queried.



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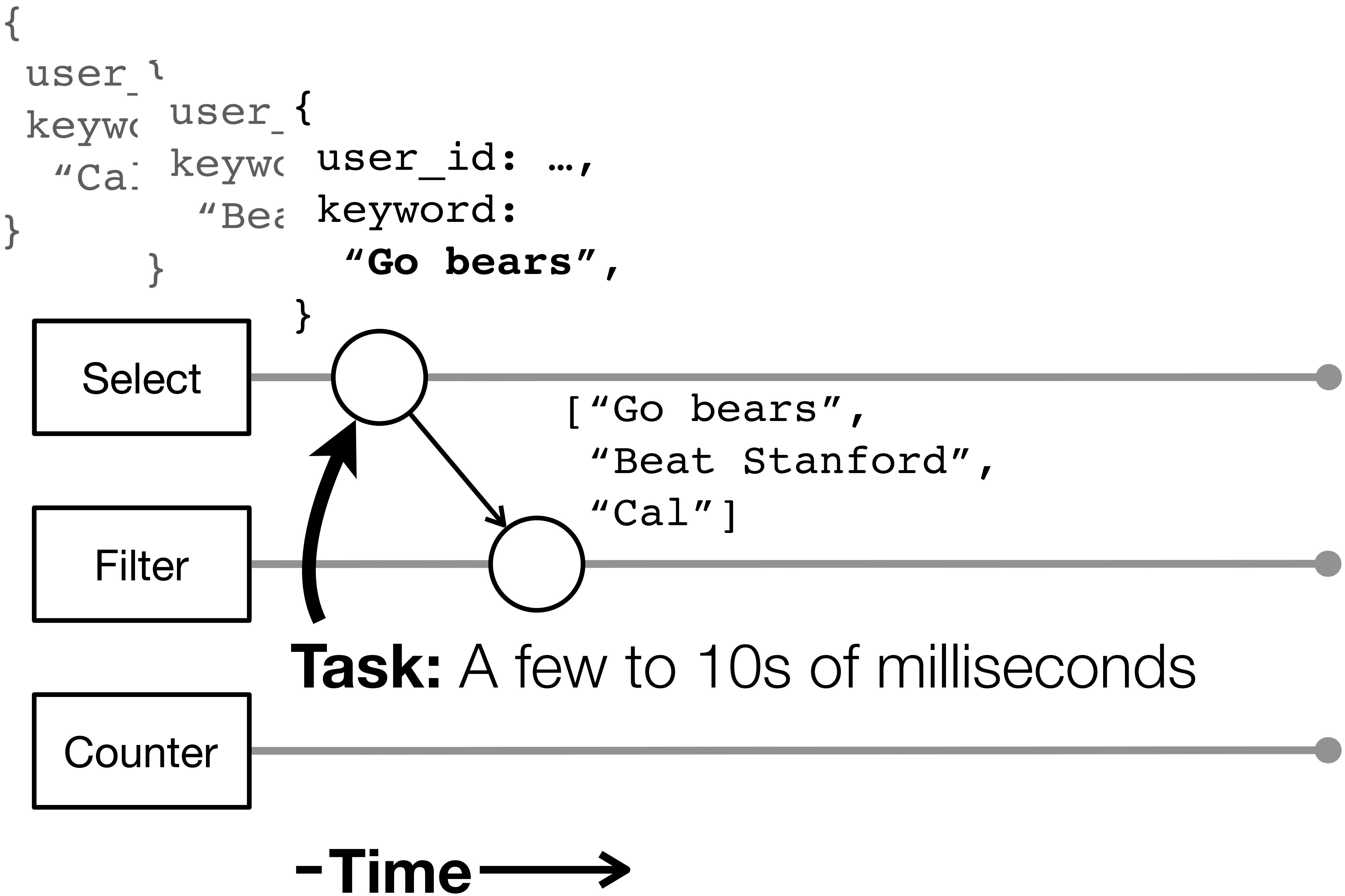

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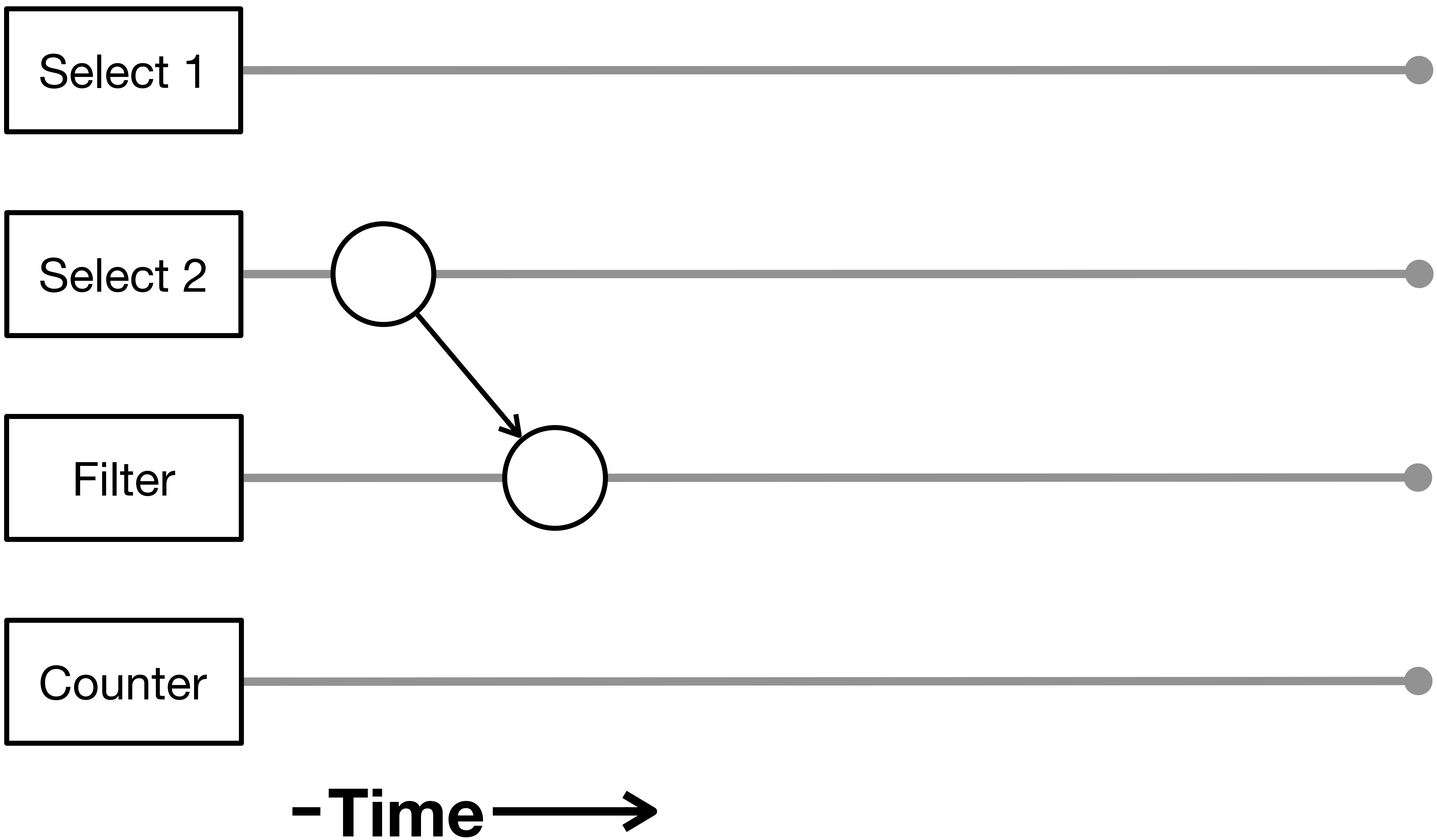

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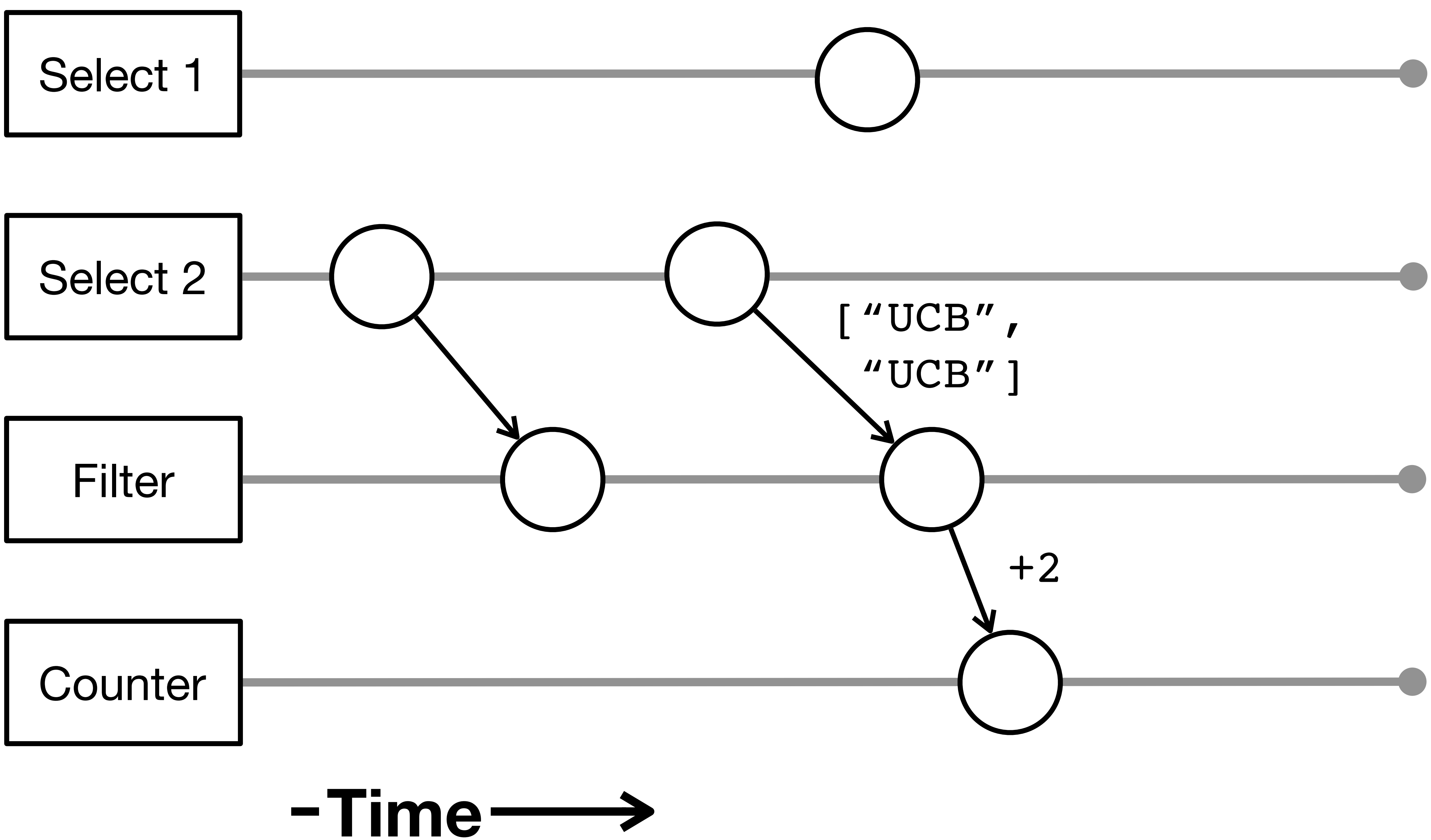
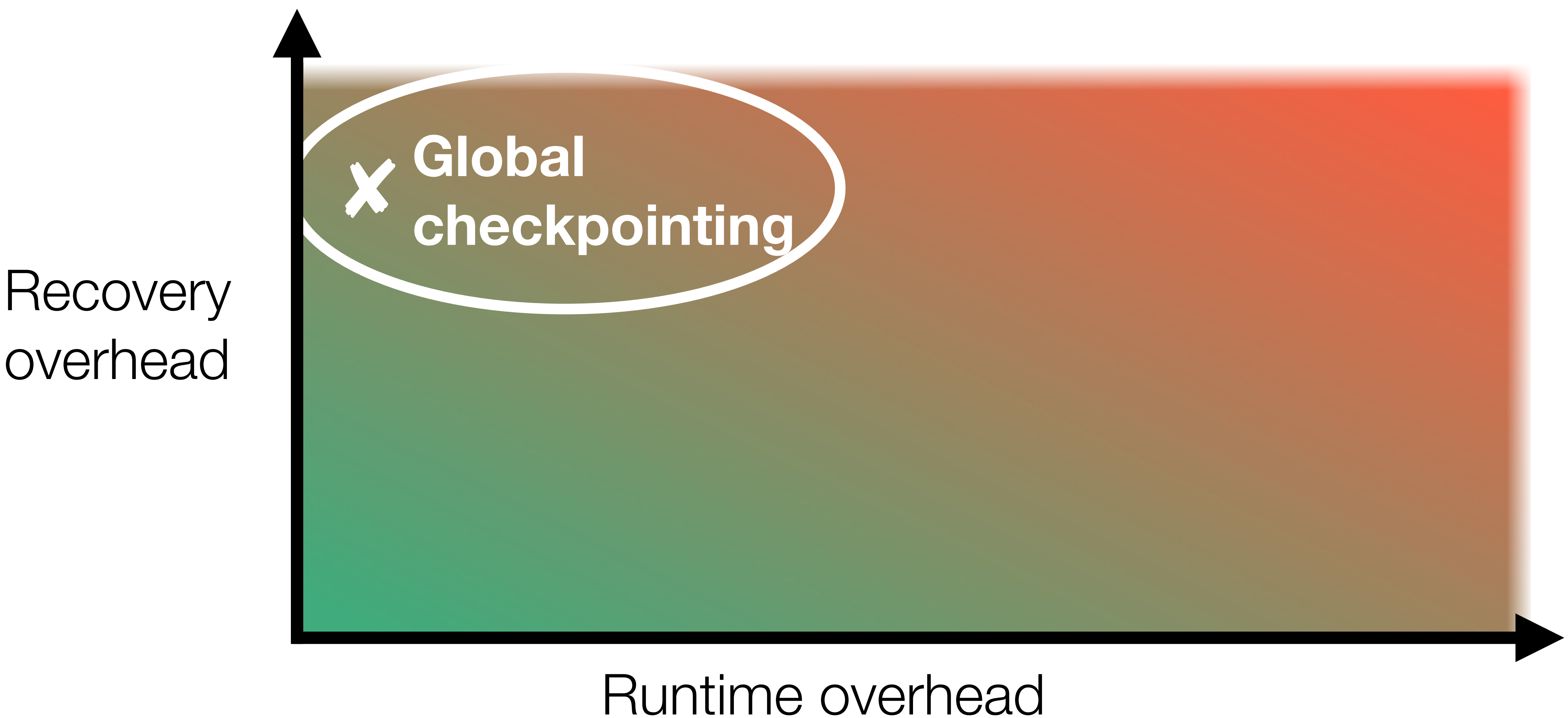
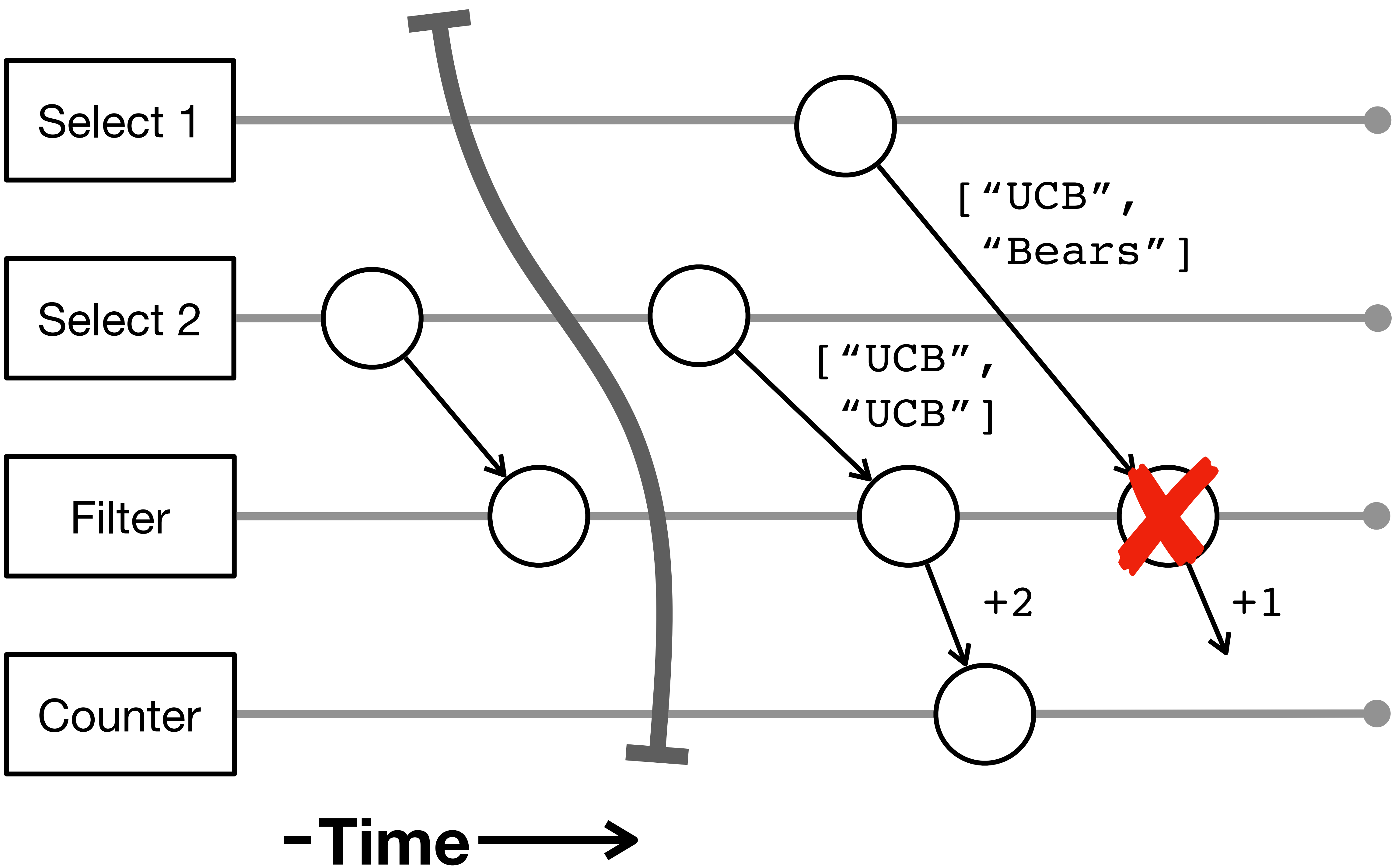


Tradeoff between low latency and recovery time



Global checkpointing



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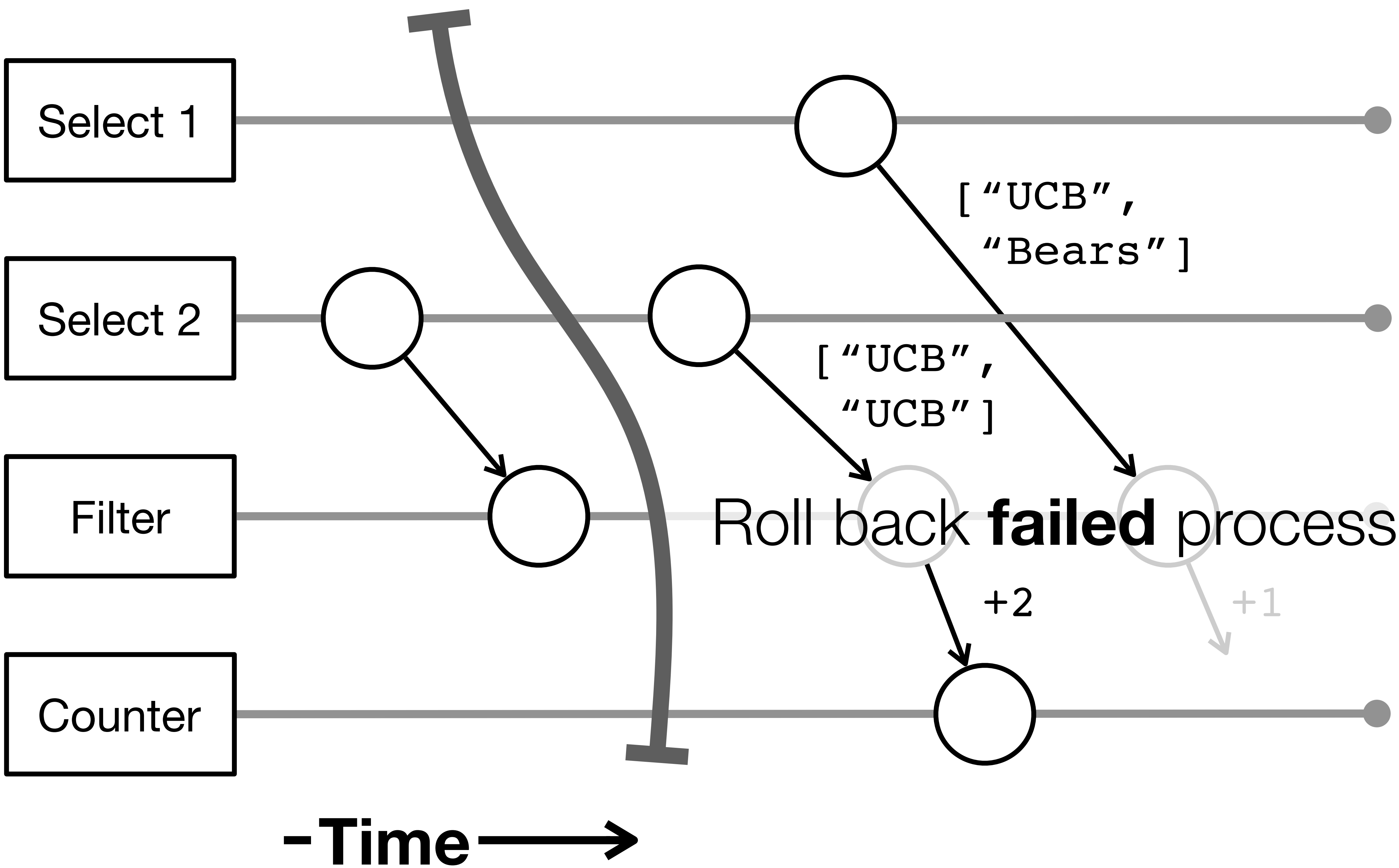

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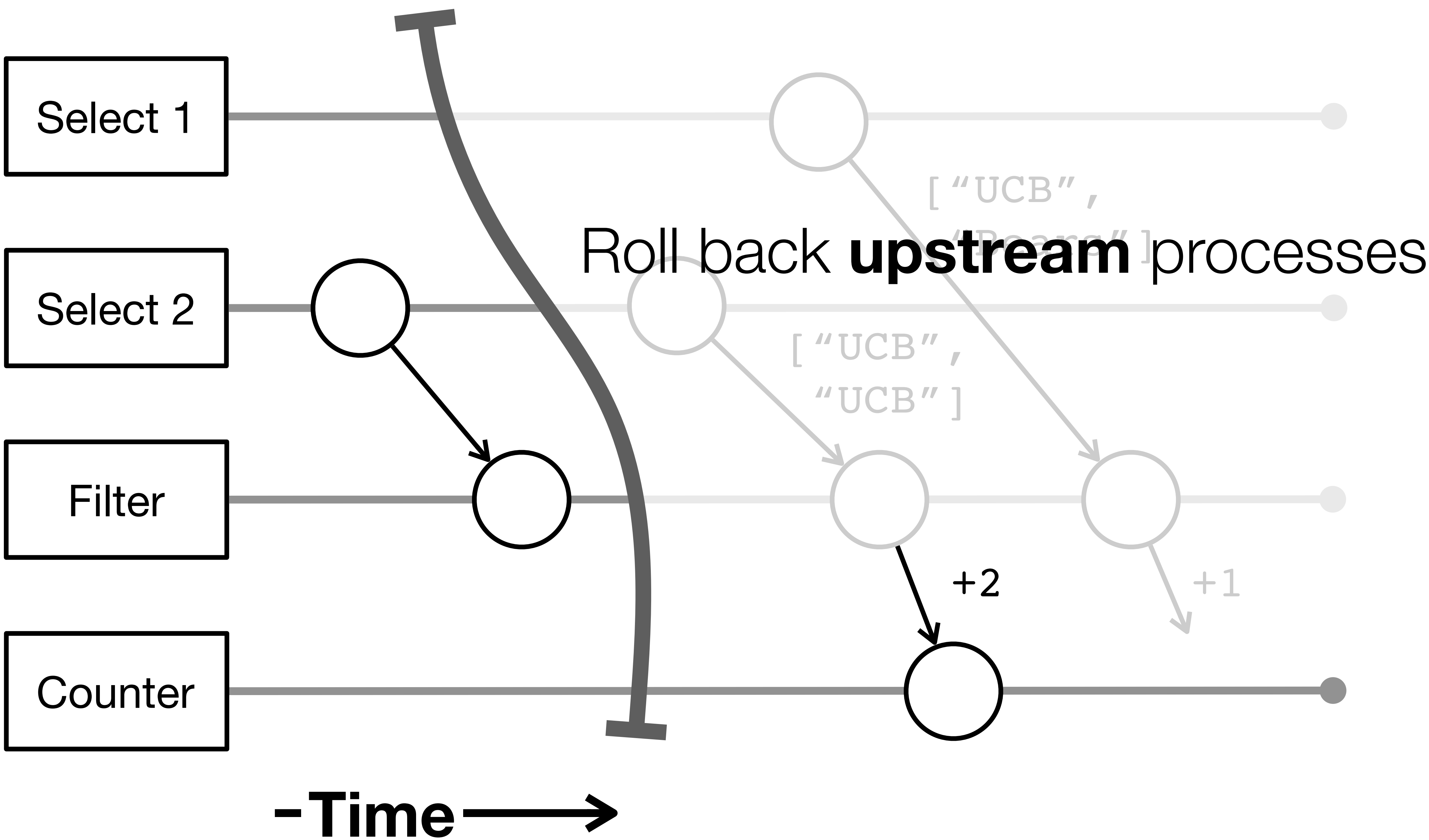

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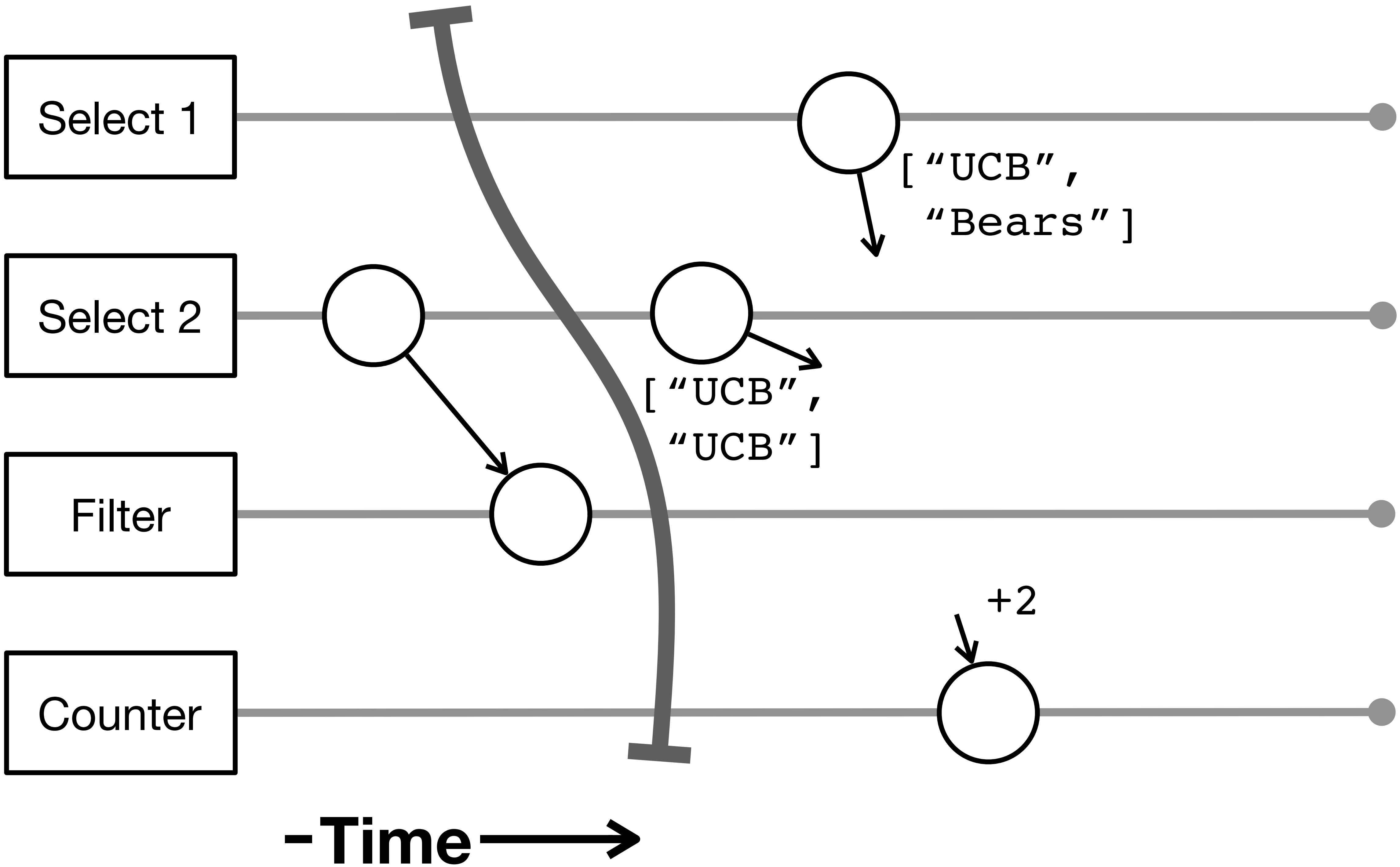

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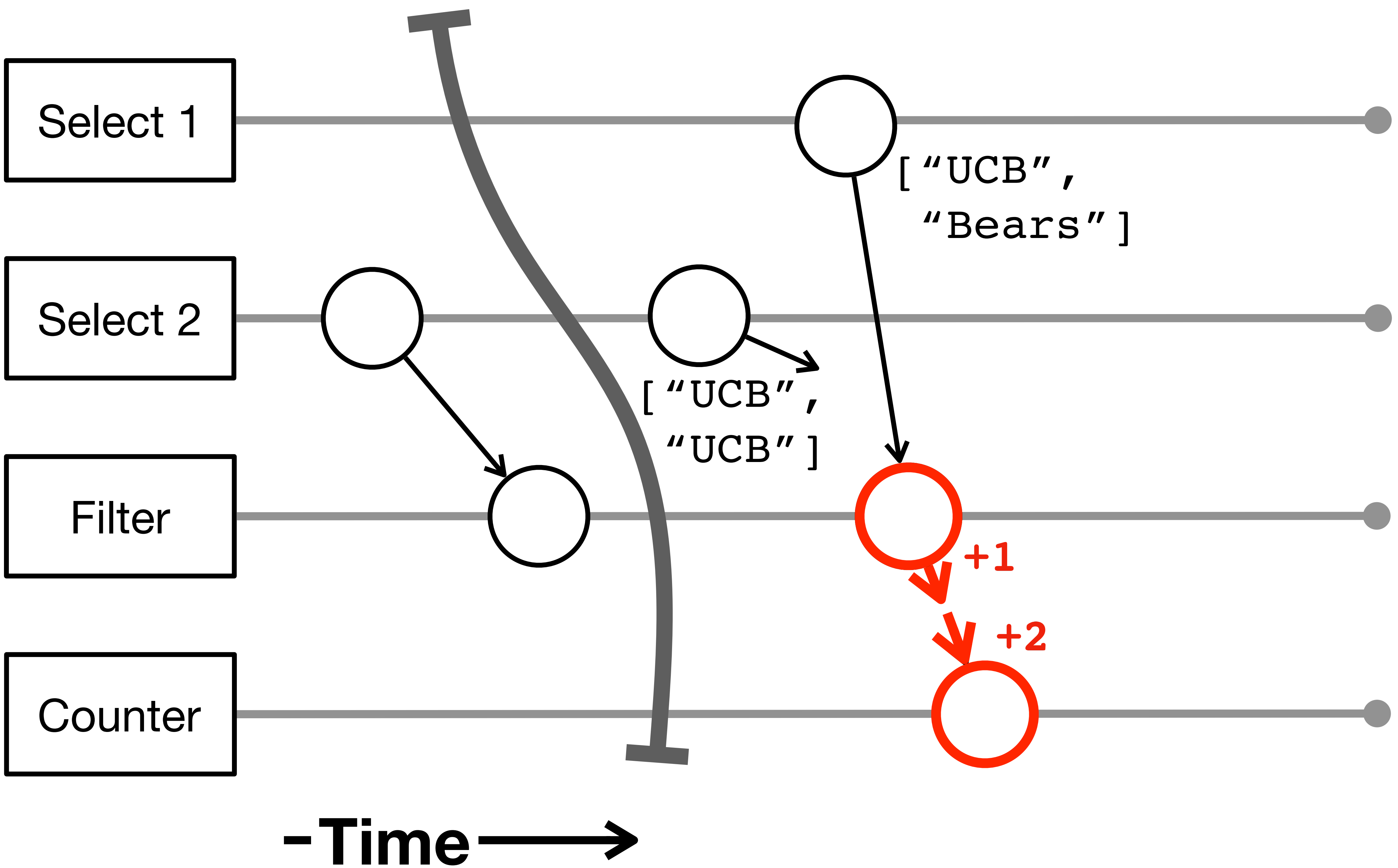

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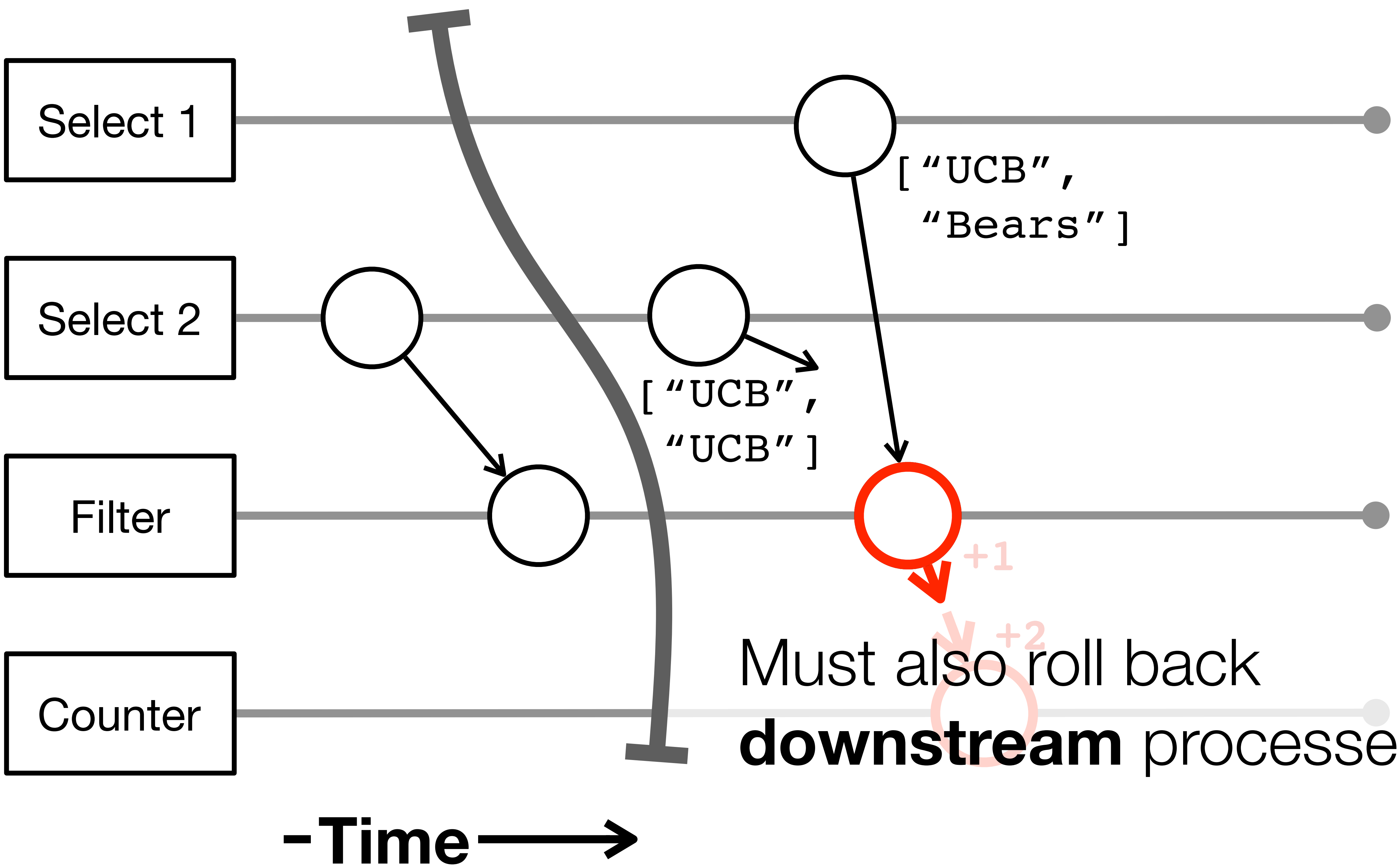
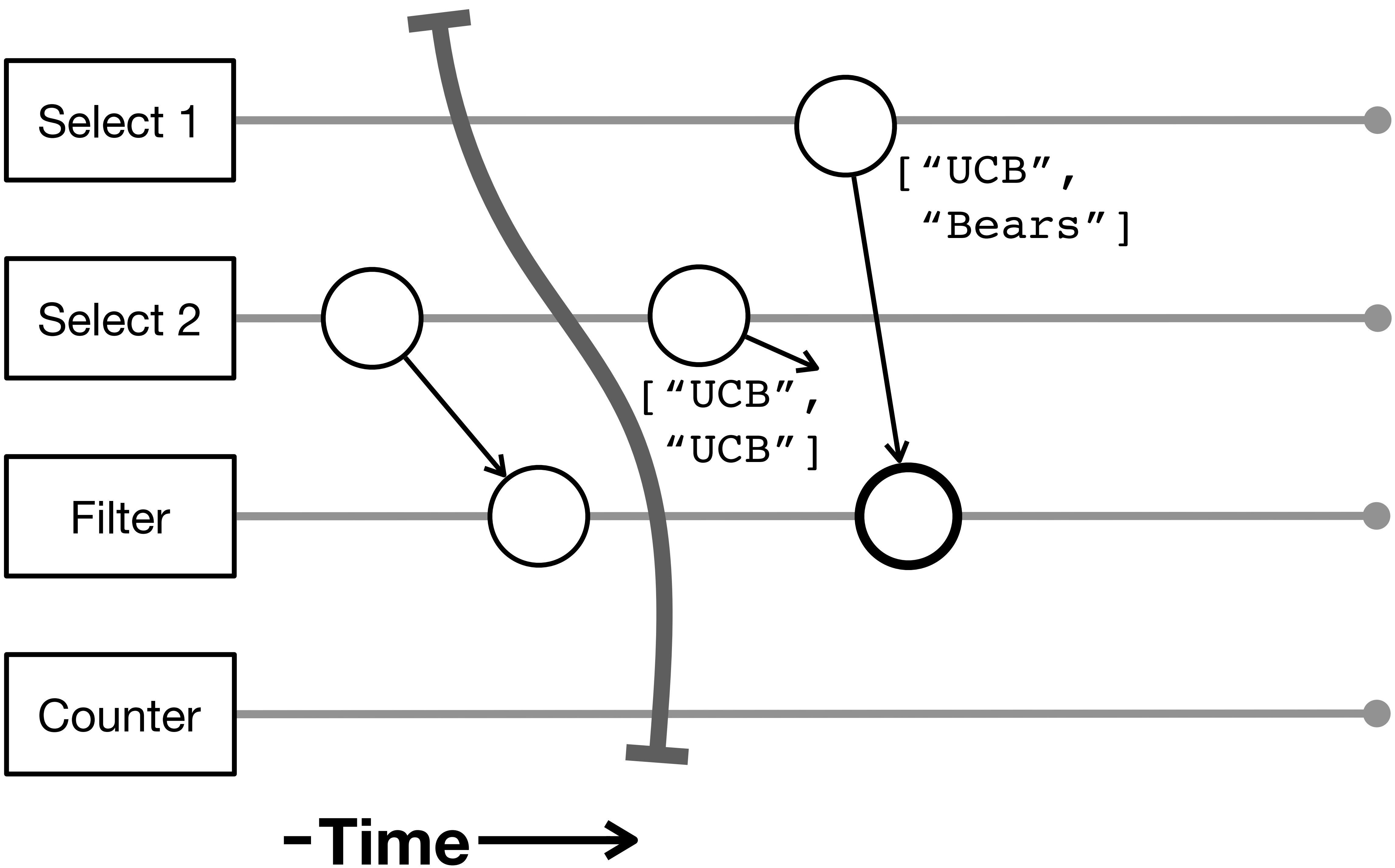


Must also roll back **downstream** processes

Global checkpointing



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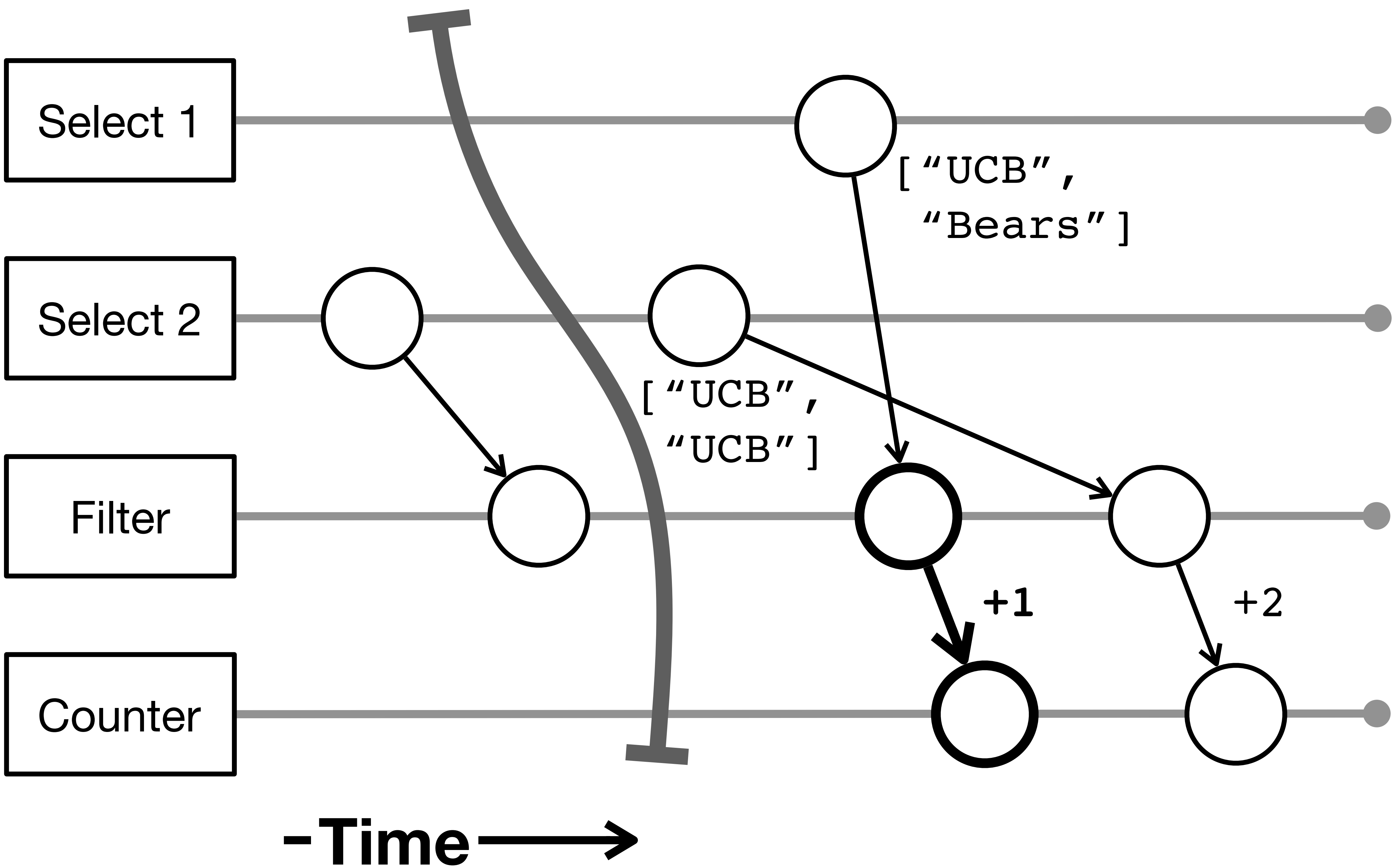

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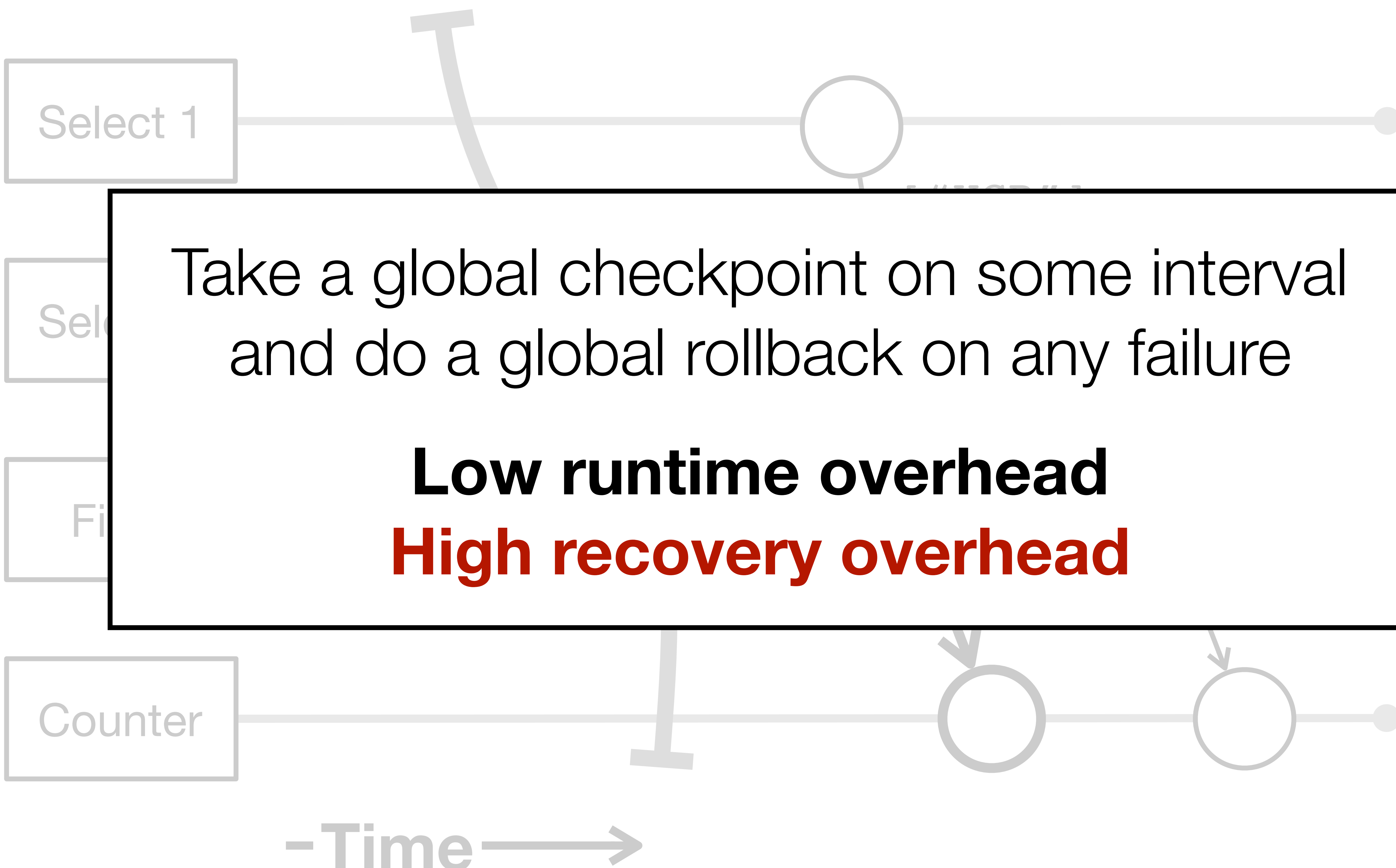
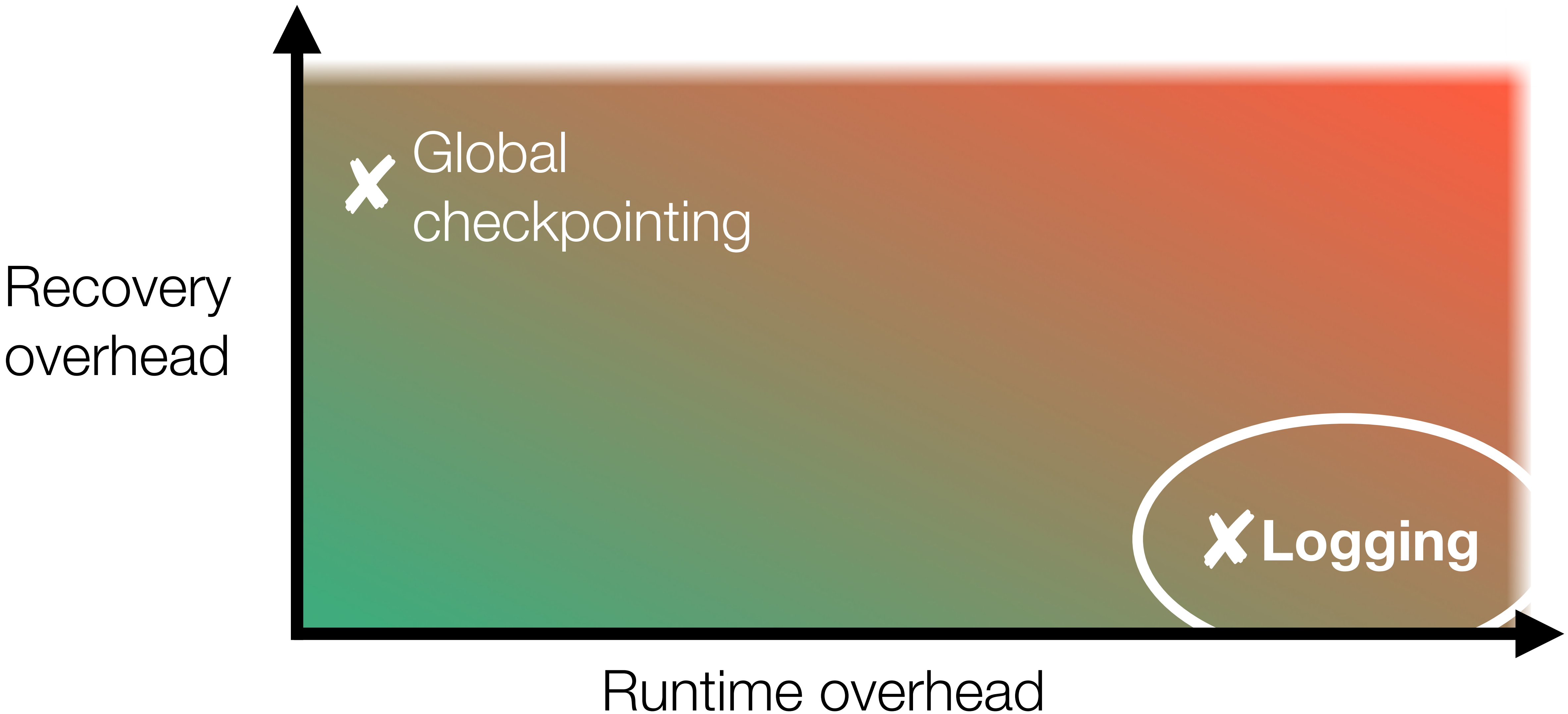


Take a global checkpoint on some interval and do a global rollback on any failure

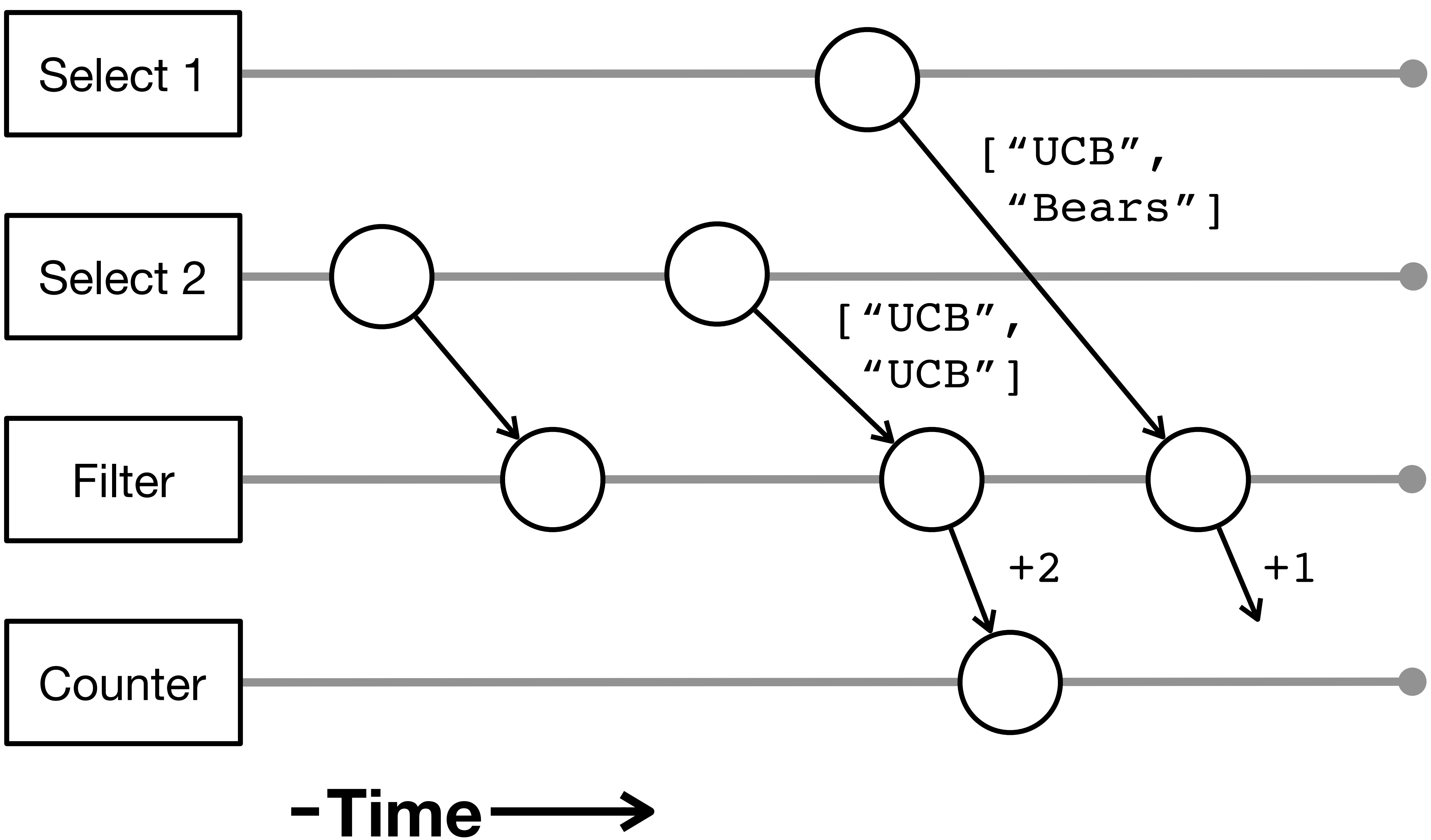
Low runtime overhead

High recovery overhead

Tradeoff between low latency and recovery time



Logging



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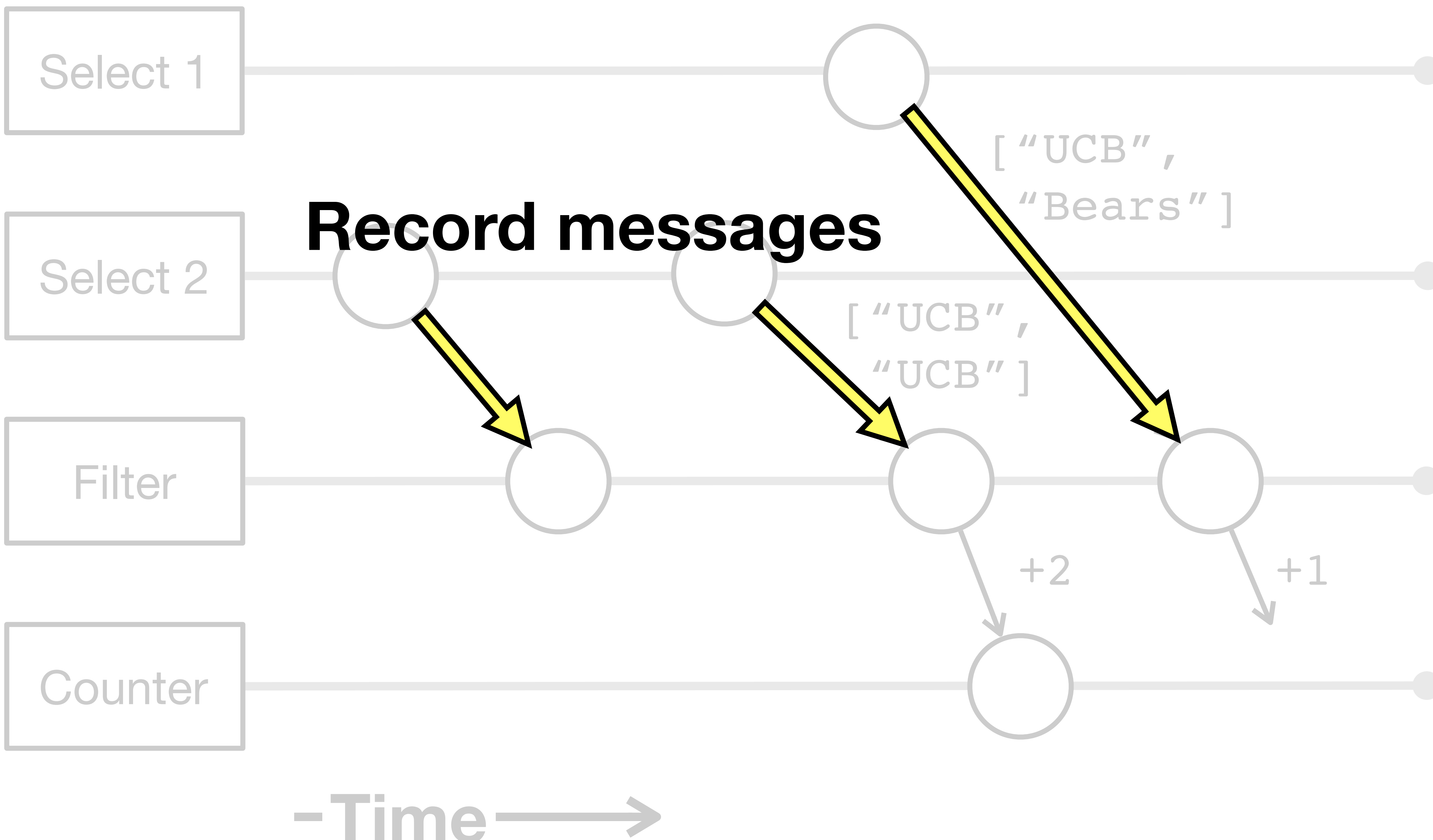
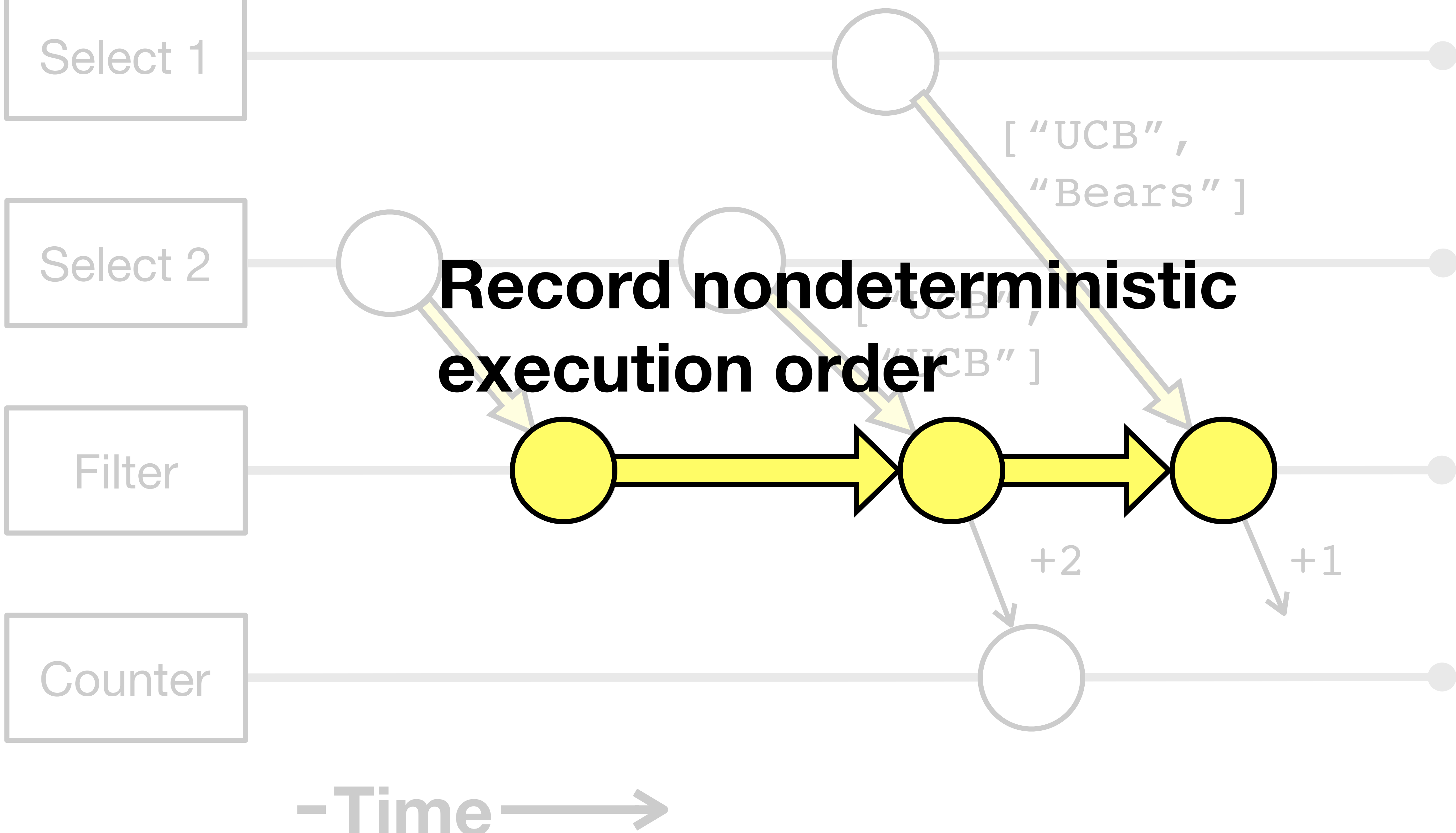
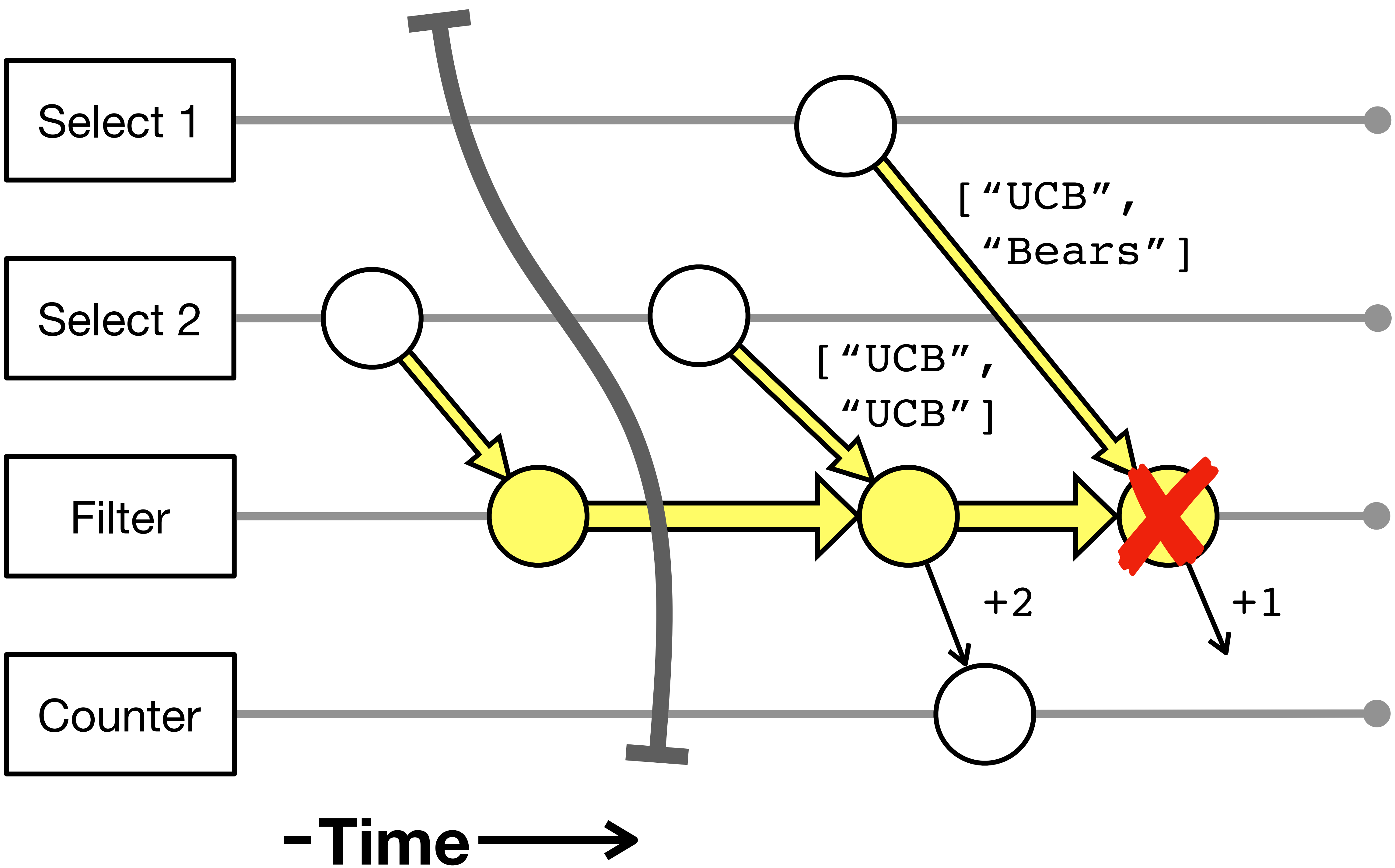

Select 1
Select 2
Filter
Counter
Record messages
["UCB",
"Bears"]
["UCB",
"UCB"]
+2
+1
Time

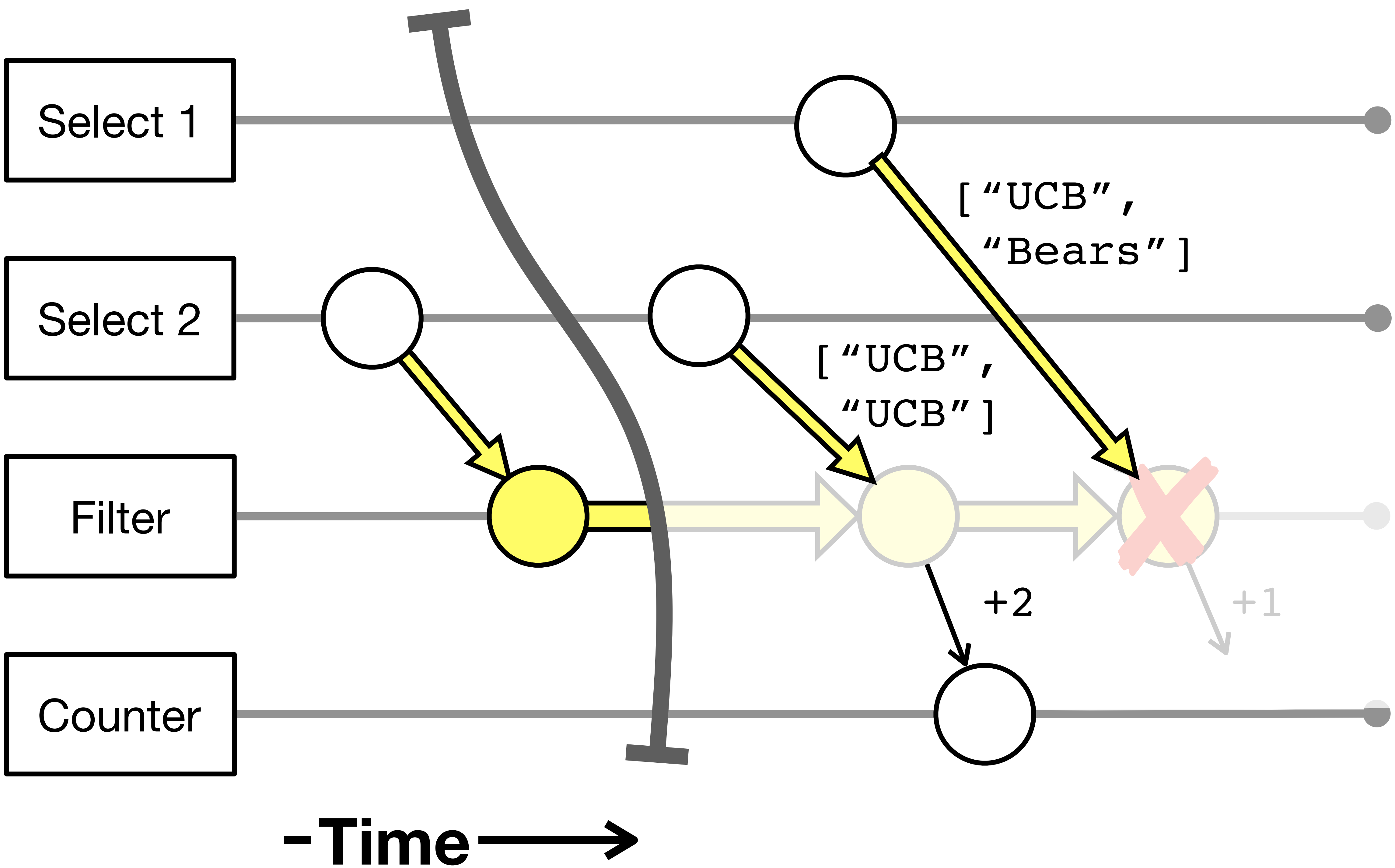
Logging


Select 1
Select 2
Filter
Counter
[“UCB”,
“Bears”]
Record nondeterministic
execution order
+2
+1
Time

Logging



Logging



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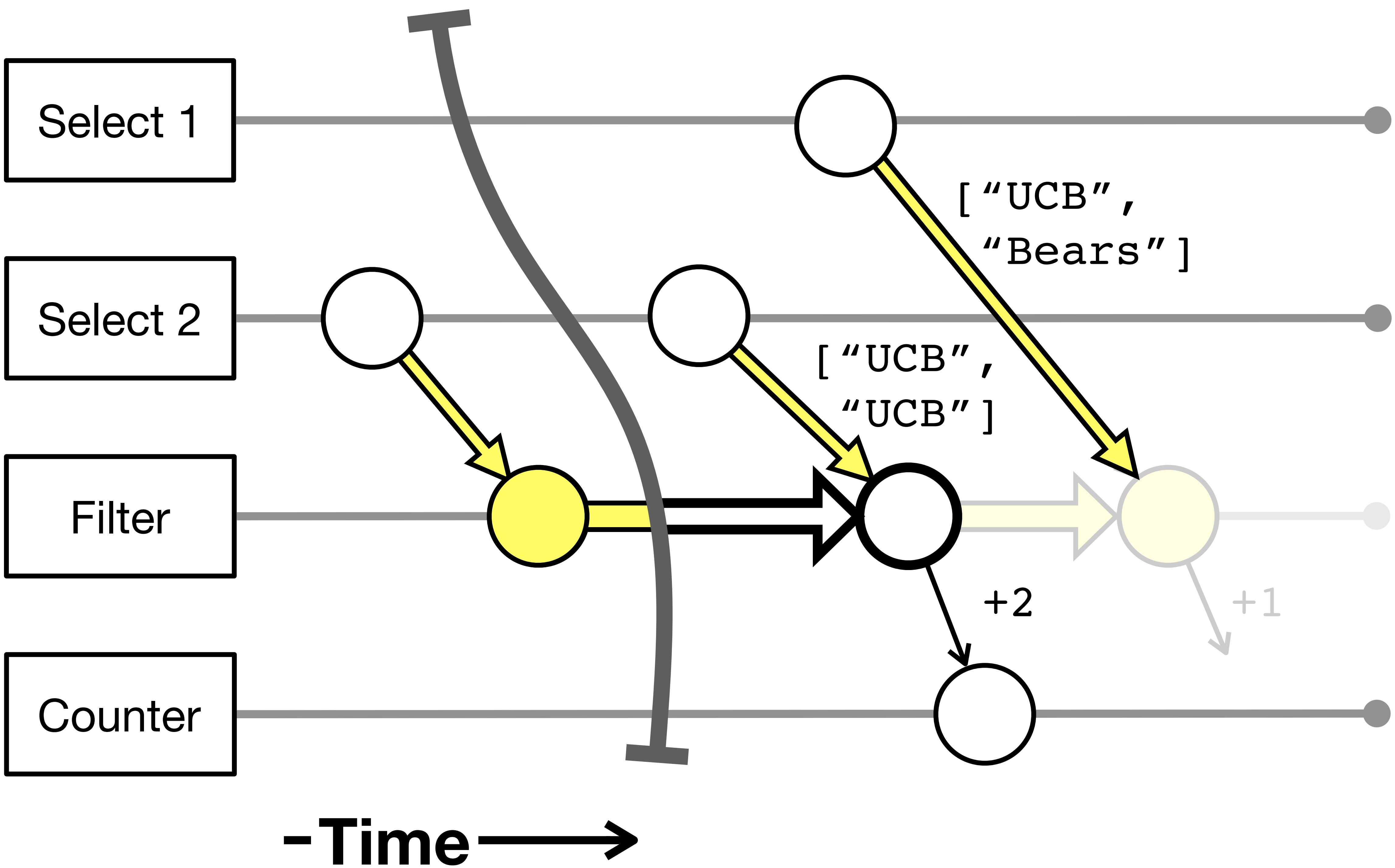
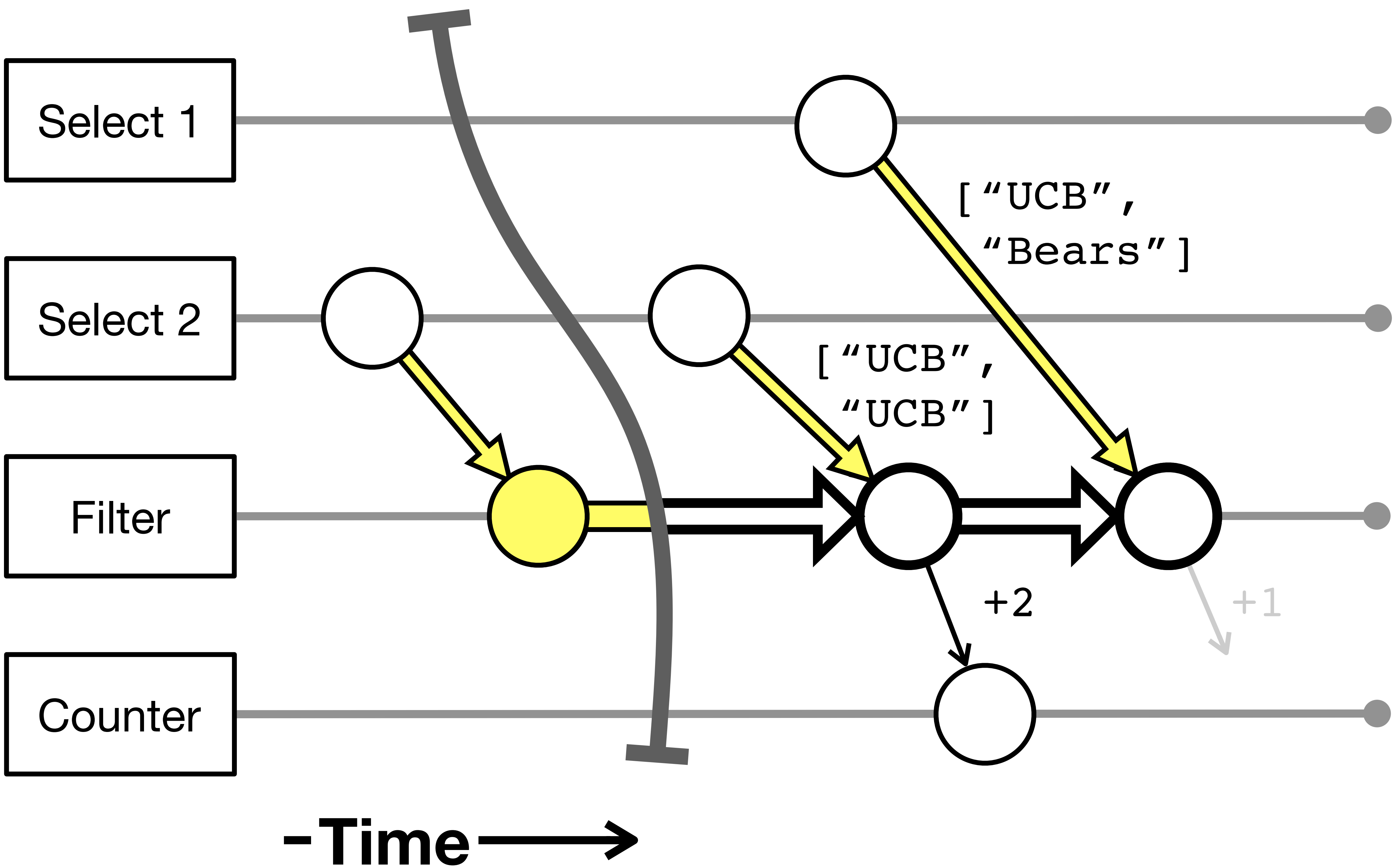


Logging



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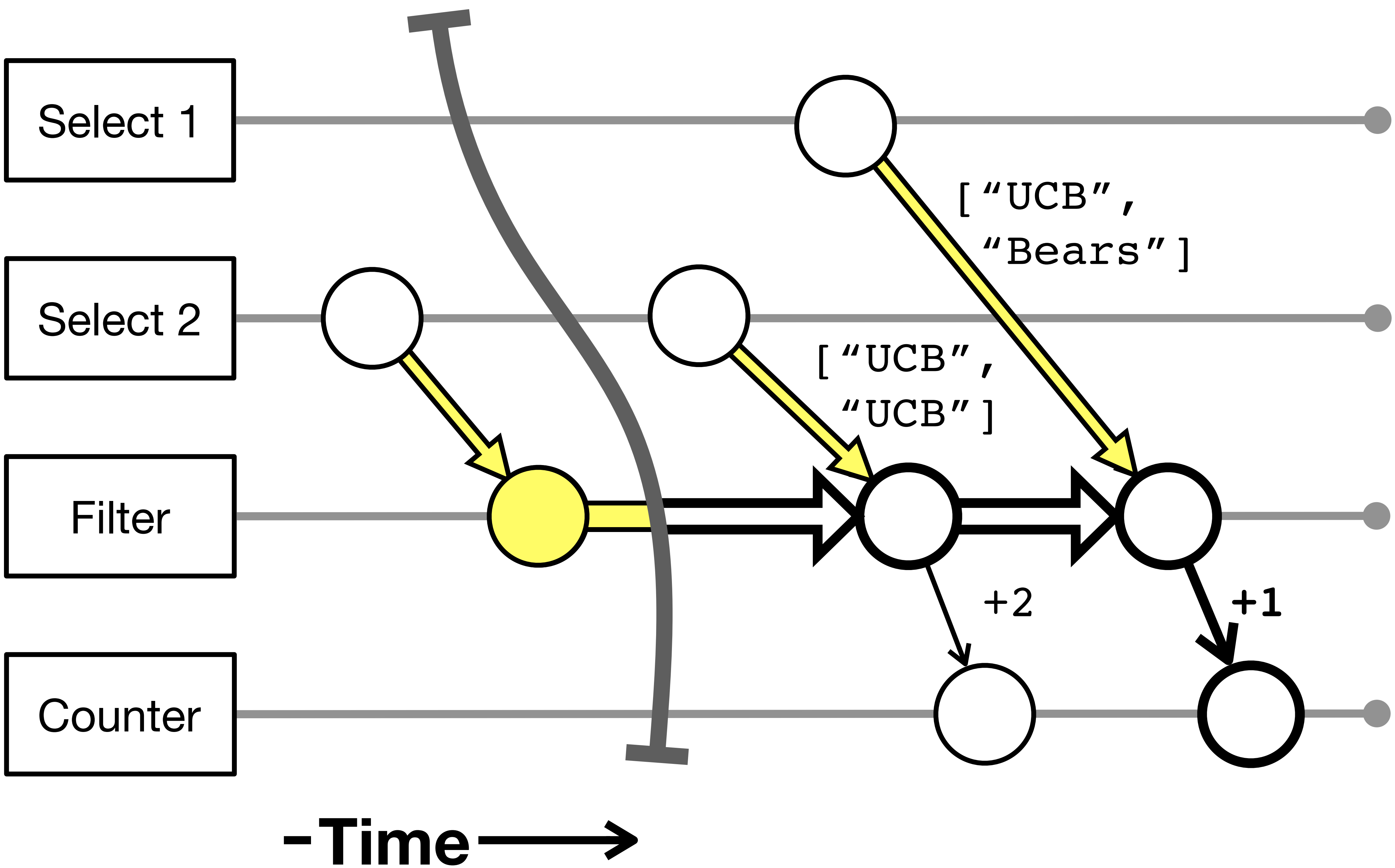

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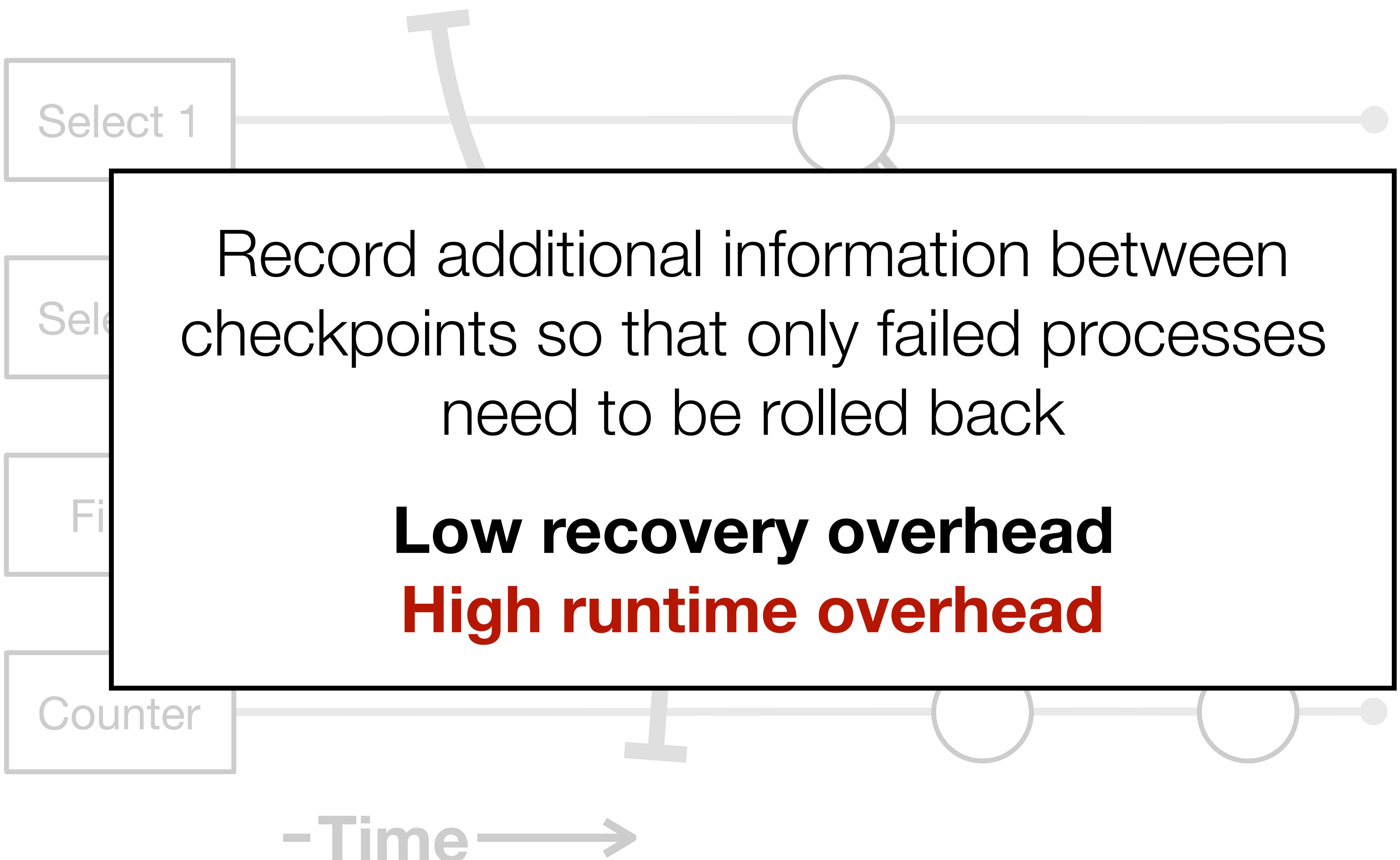
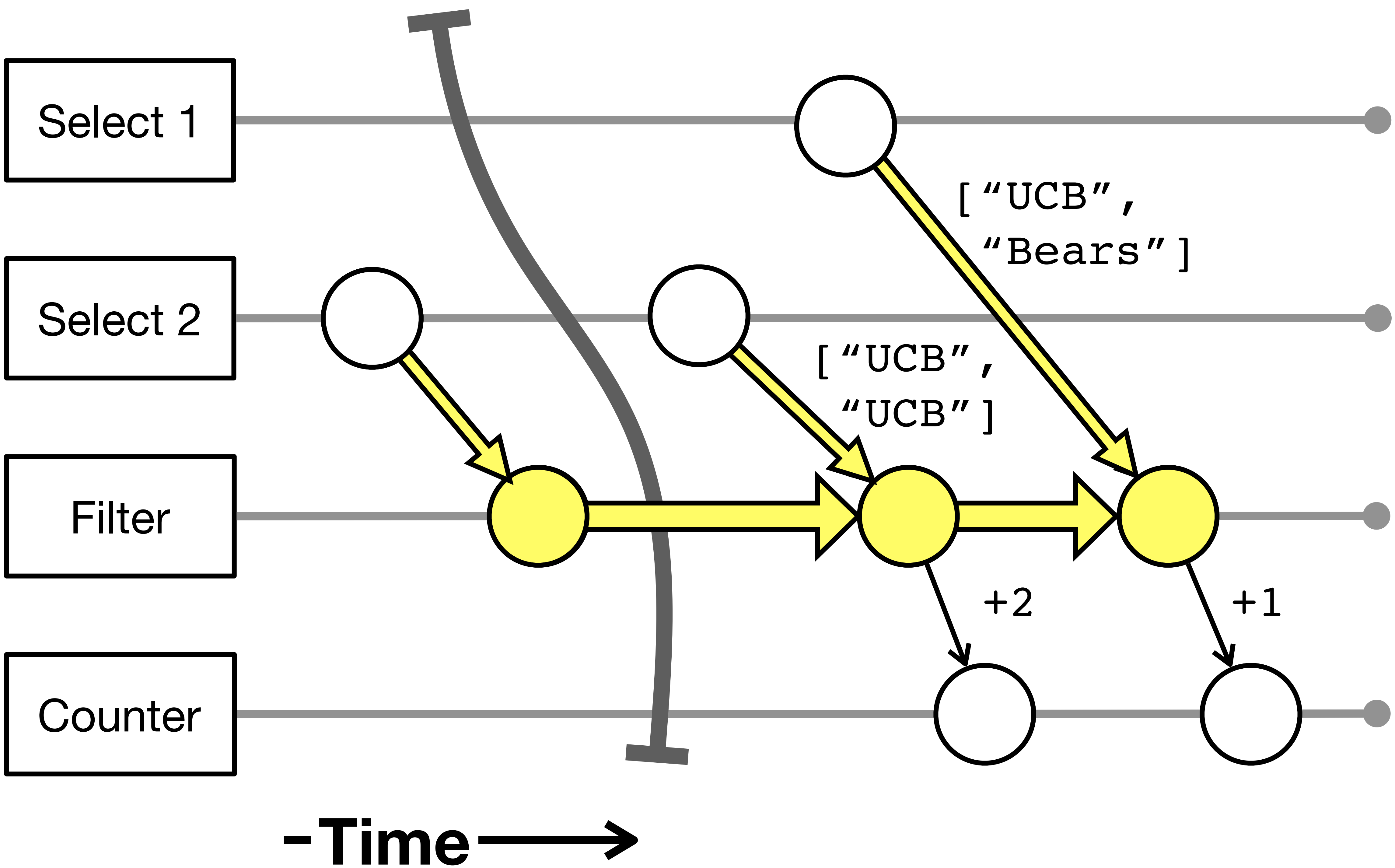


Record additional information between checkpoints so that only failed processes need to be rolled back

Low recovery overhead

High runtime overhead

Log the **lineage** to reduce the **amount** logged



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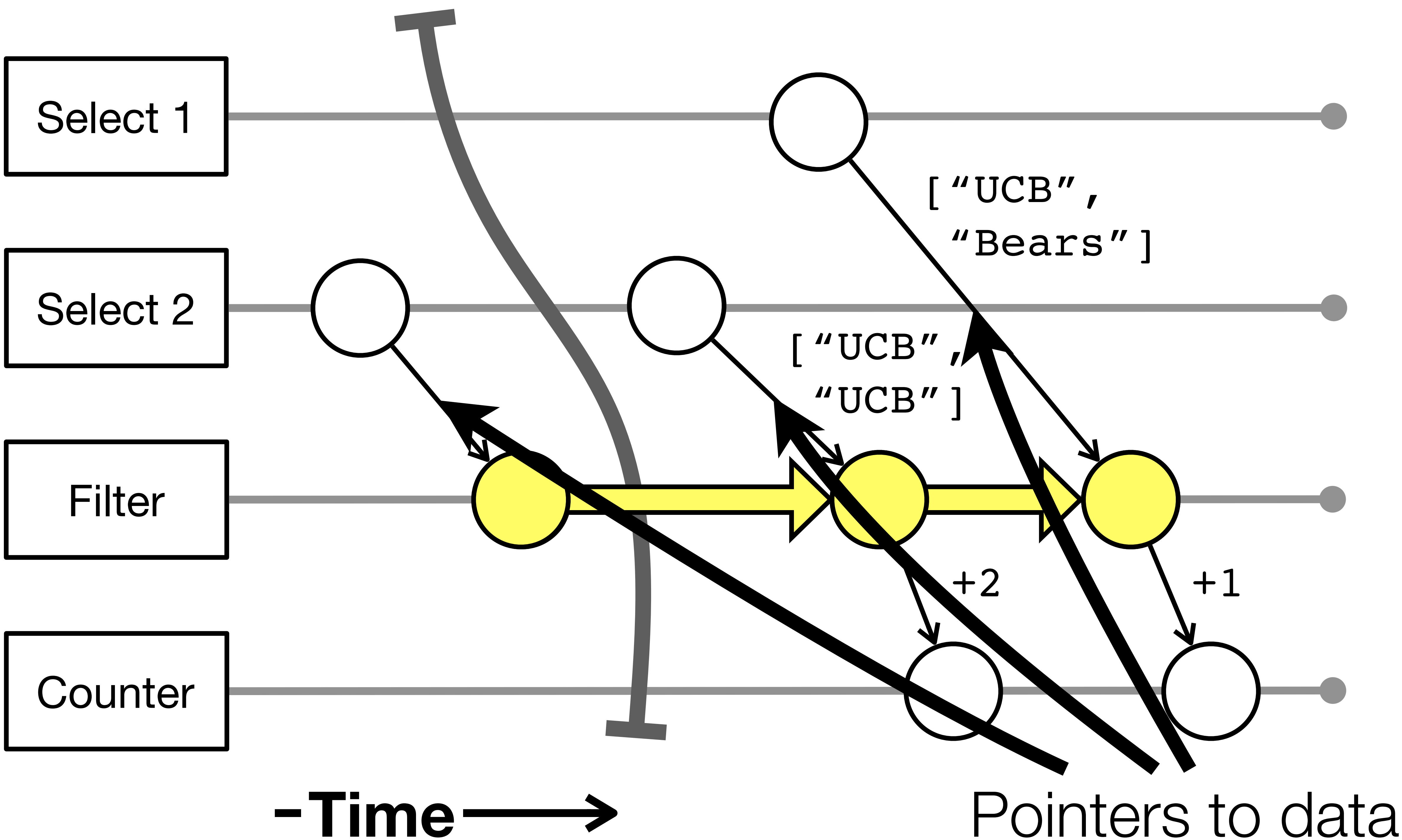

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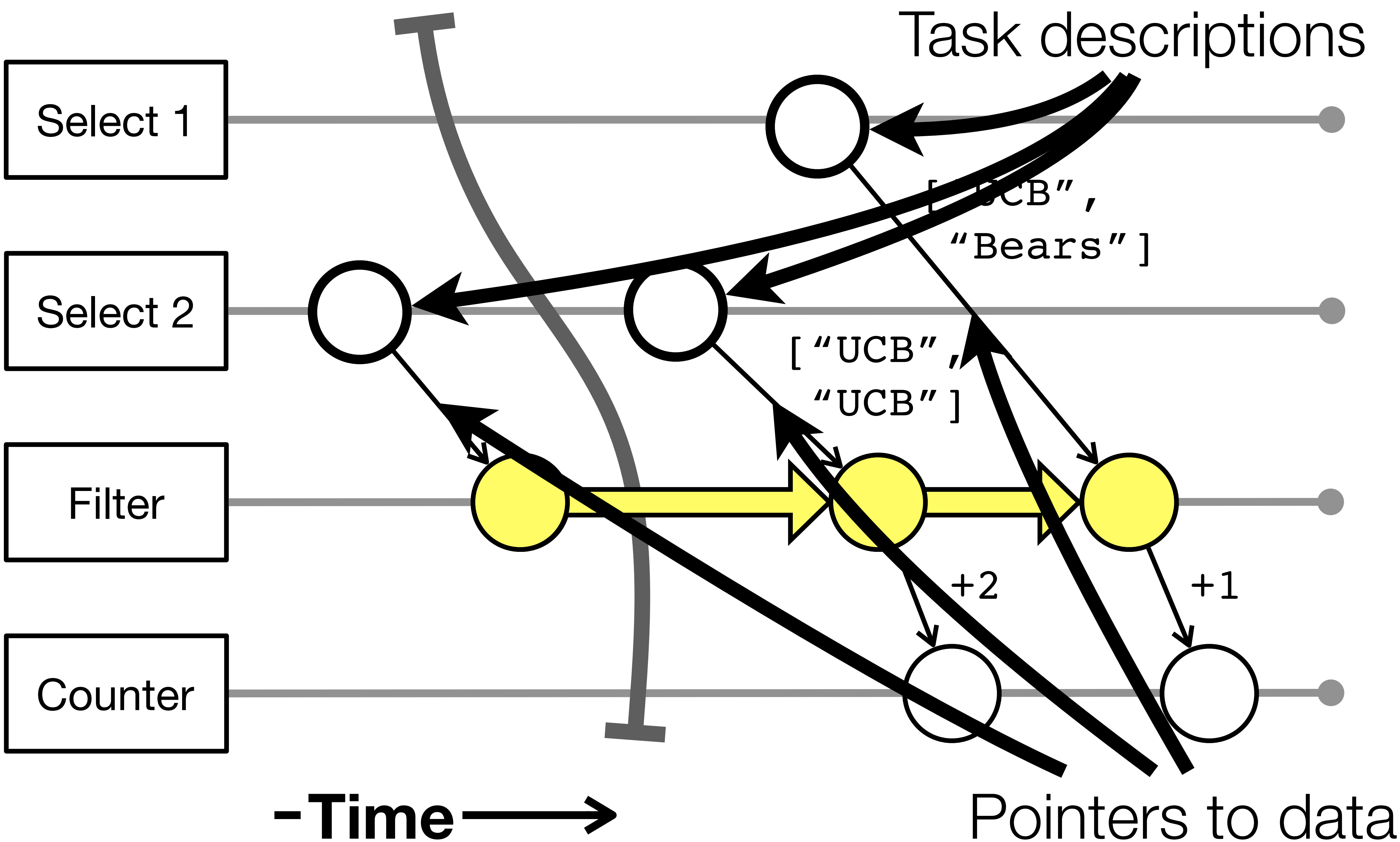
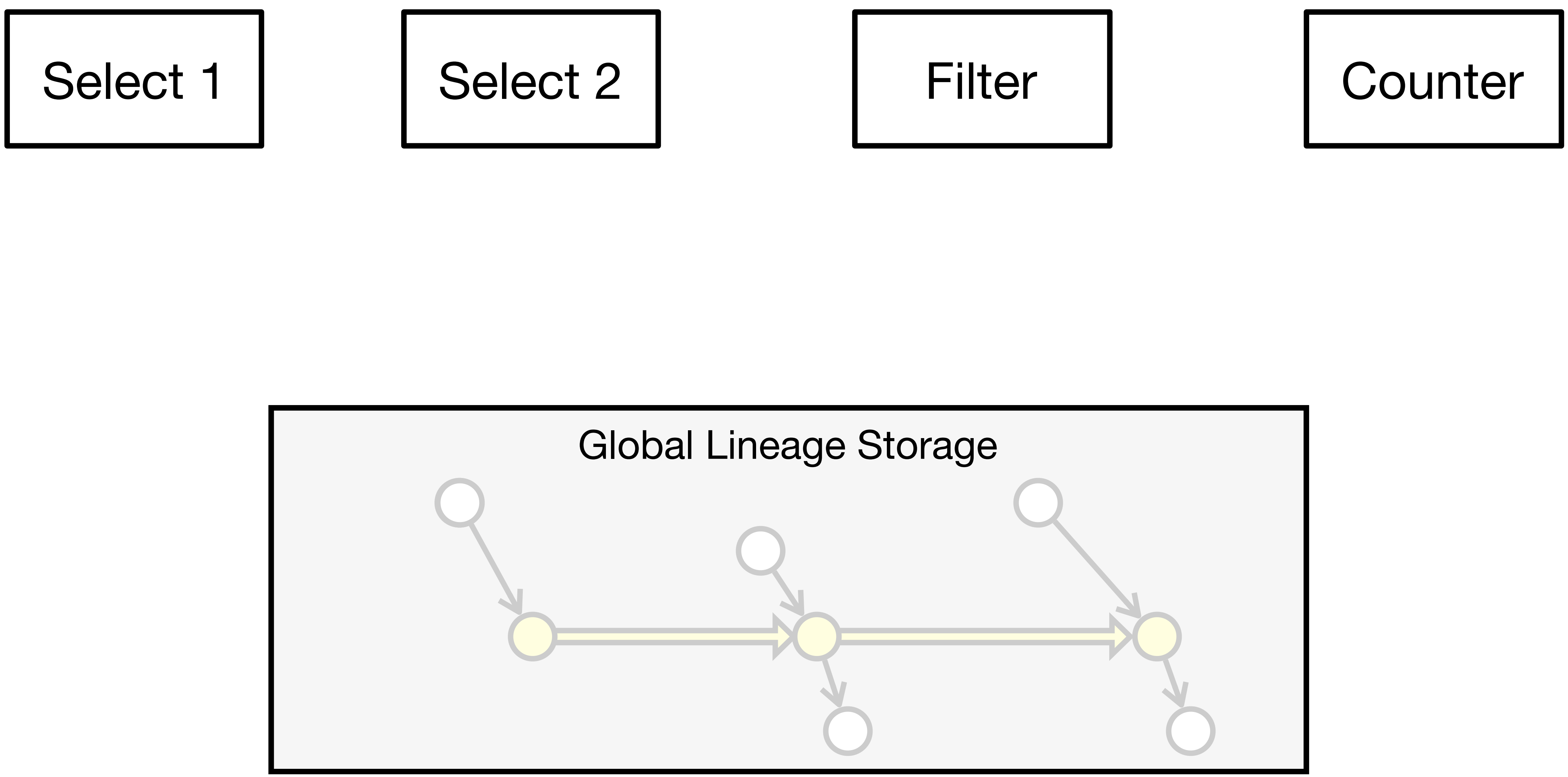


But logging still requires a **synchronous** round-trip to remote storage



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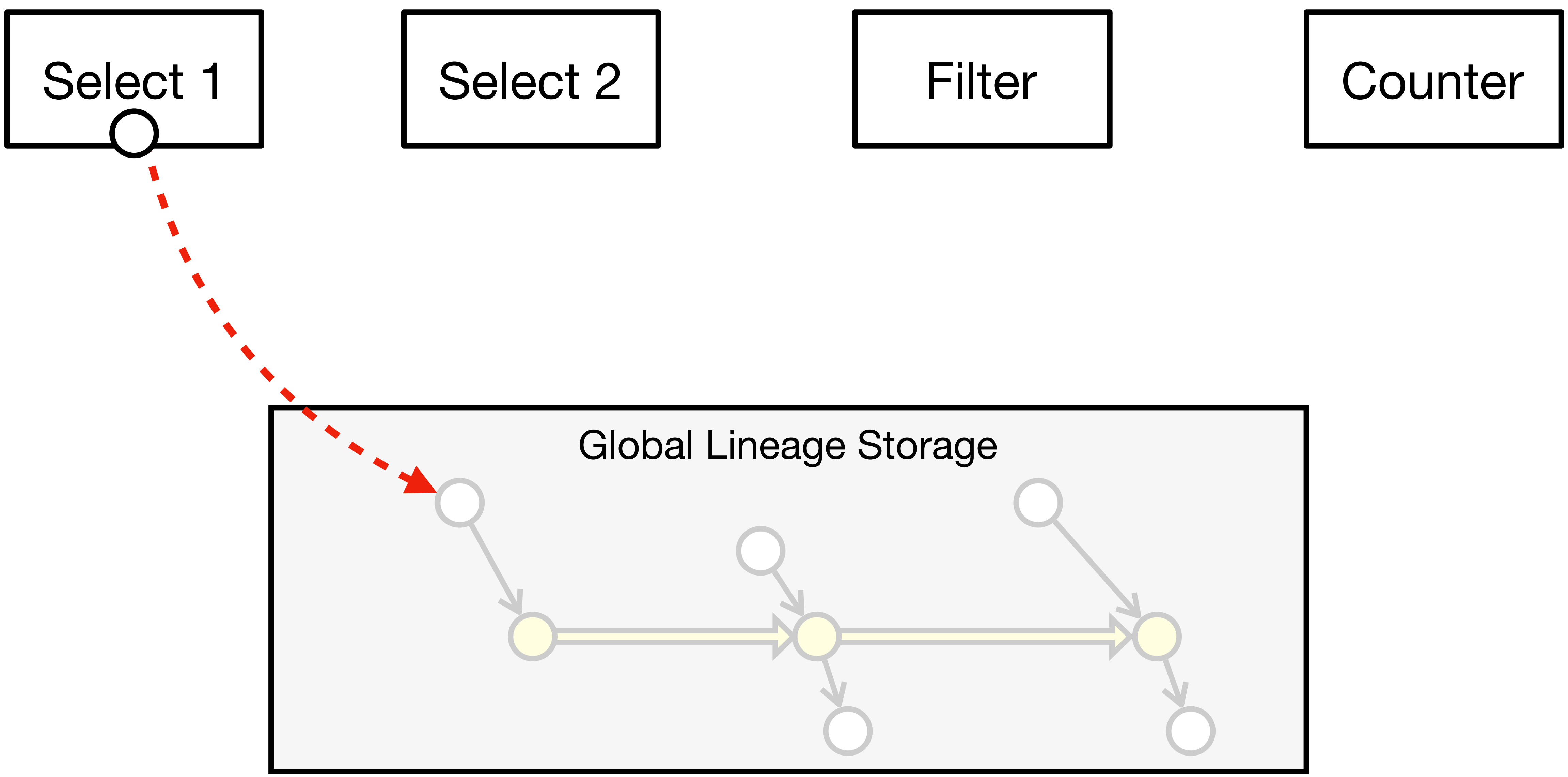

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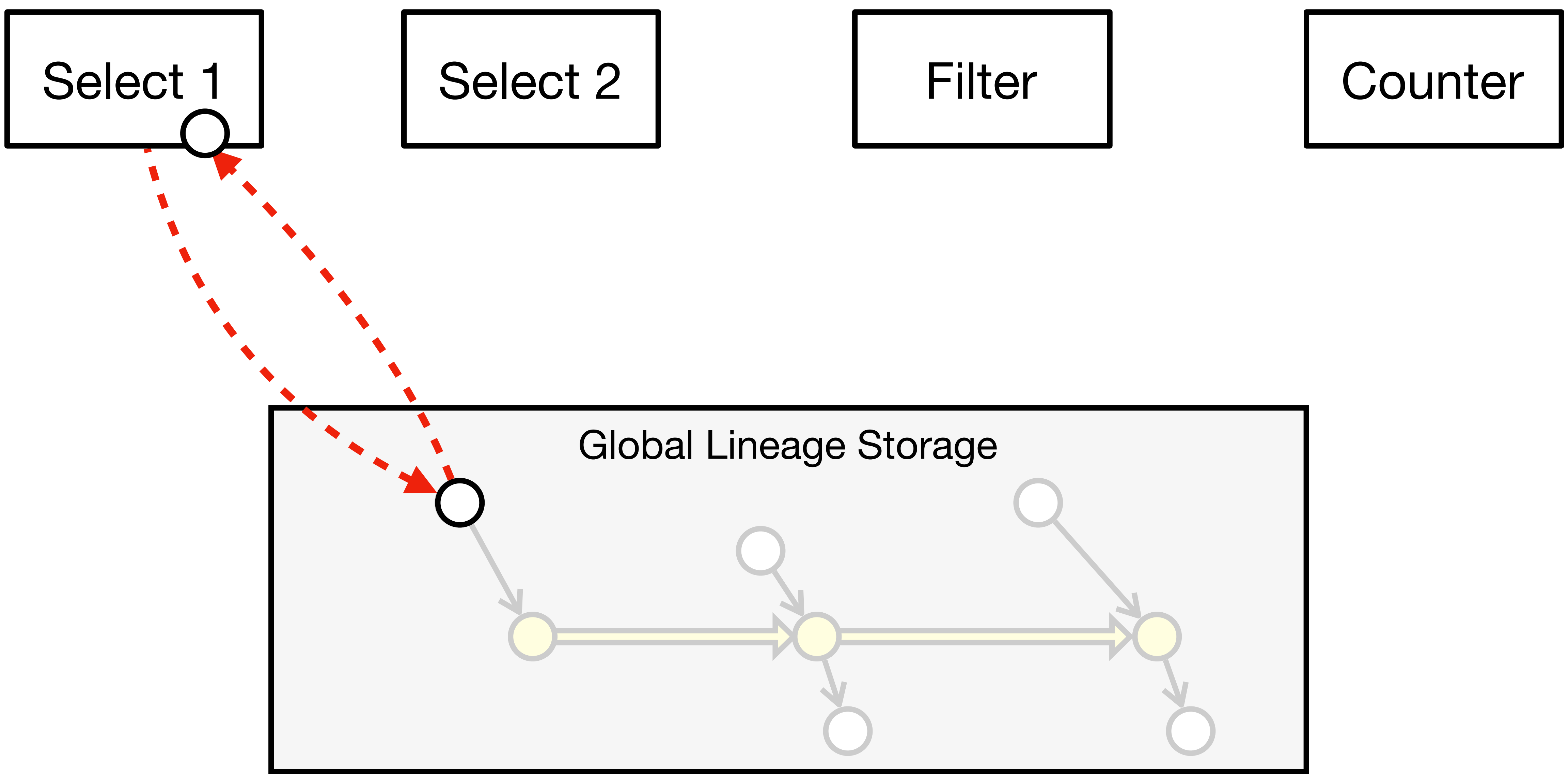

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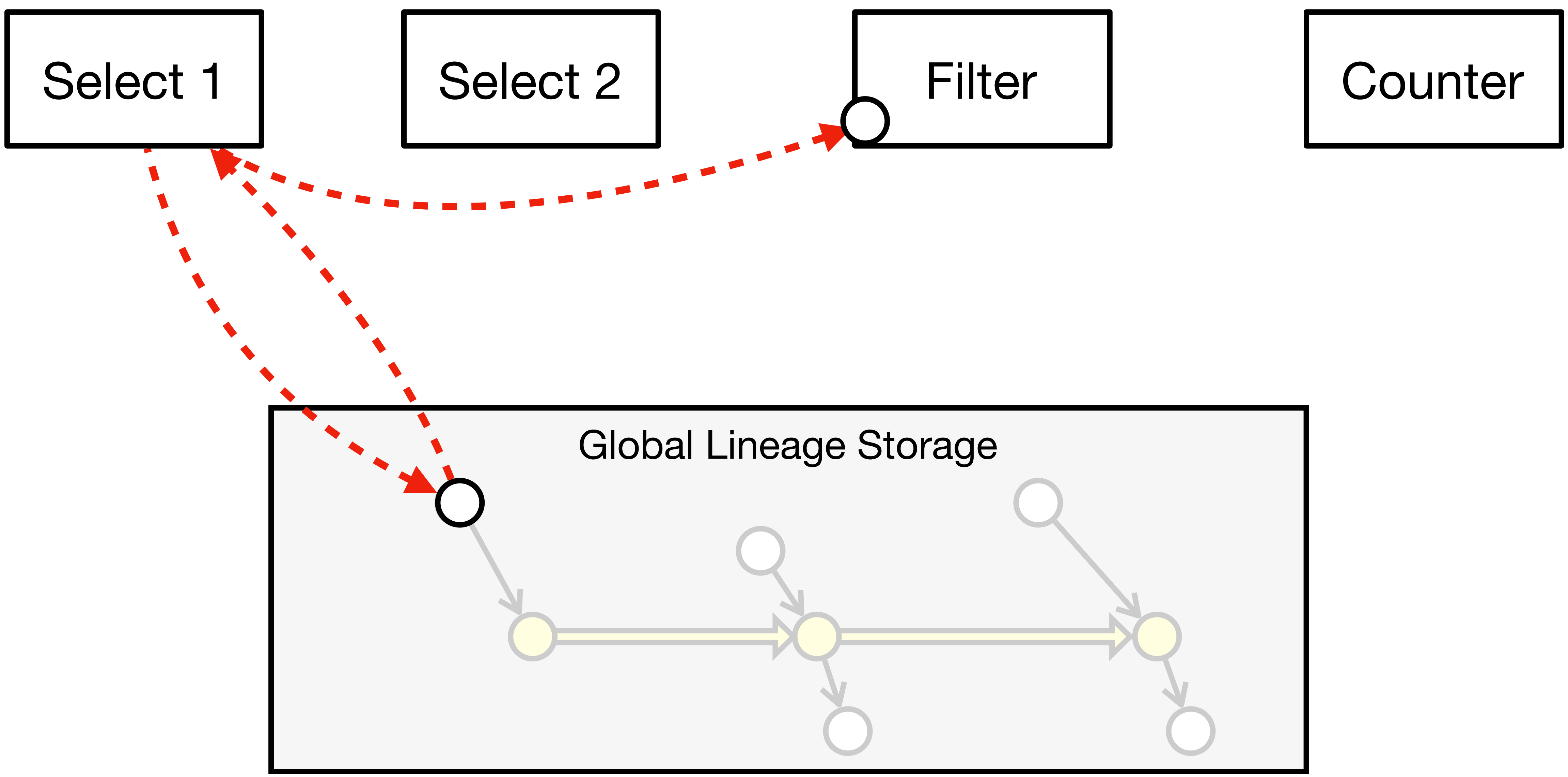

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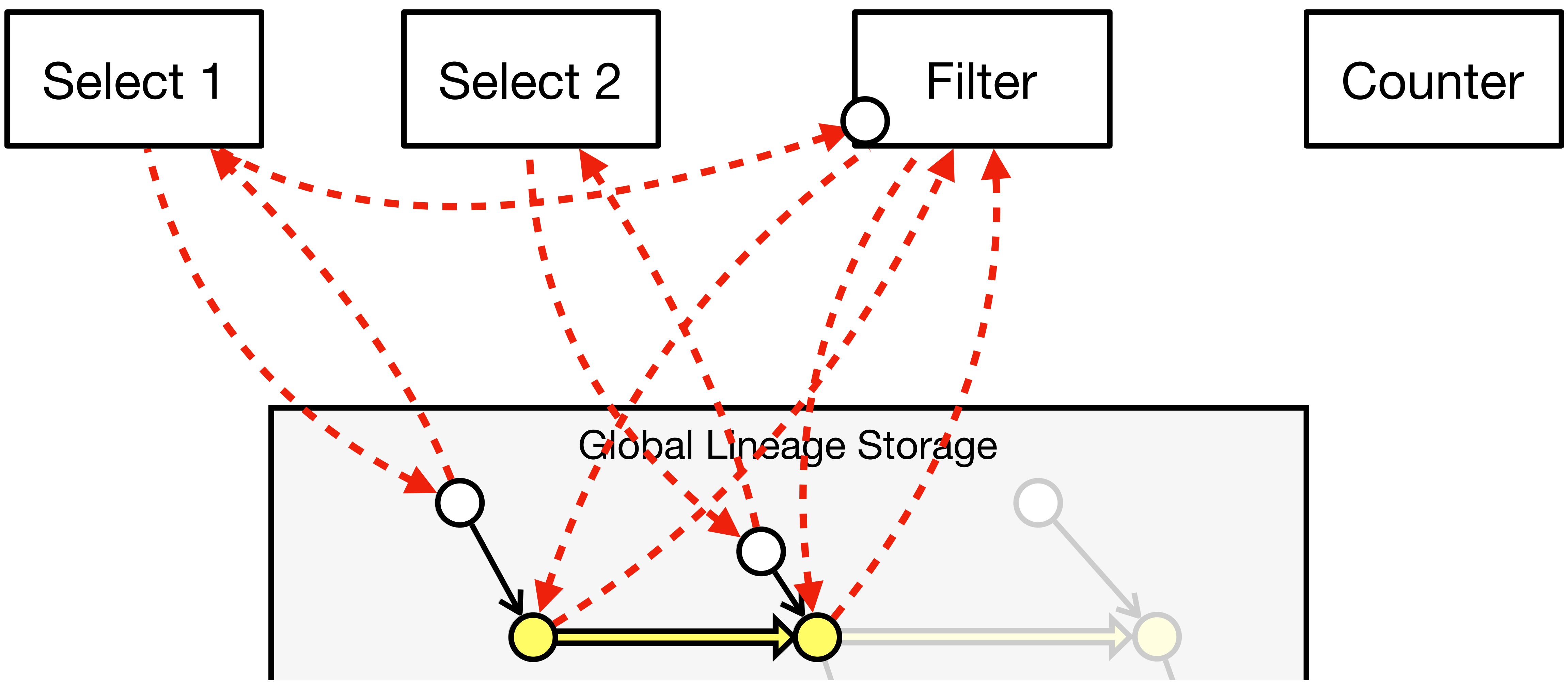


Scheduling delay / task >= **1RTT** + 1RPC

Task latency depends on global storage latency

Lineage stash contribution

How do we achieve both **low runtime *and* low recovery overhead** for **fine-grained** data processing applications?

Solution: Asynchronously log the lineage off the critical path of execution.

Lineage reconstruction to reduce amount logged

Causal logging to log nondeterminism

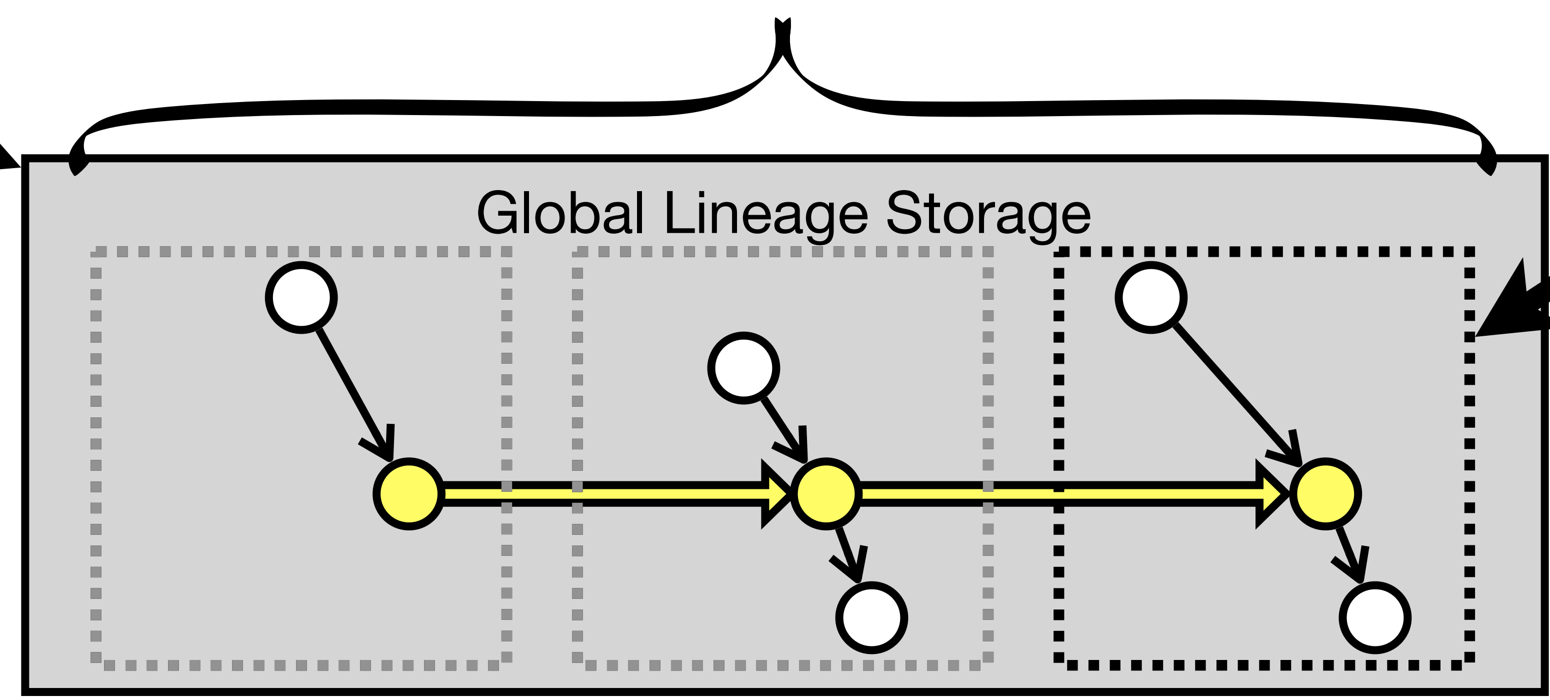
Lineage stash architecture

Replicated for **durability**.

Select 1 Select 2 Filter Counter

Persistent key-value store.

Sharded for horizontal **scalability**



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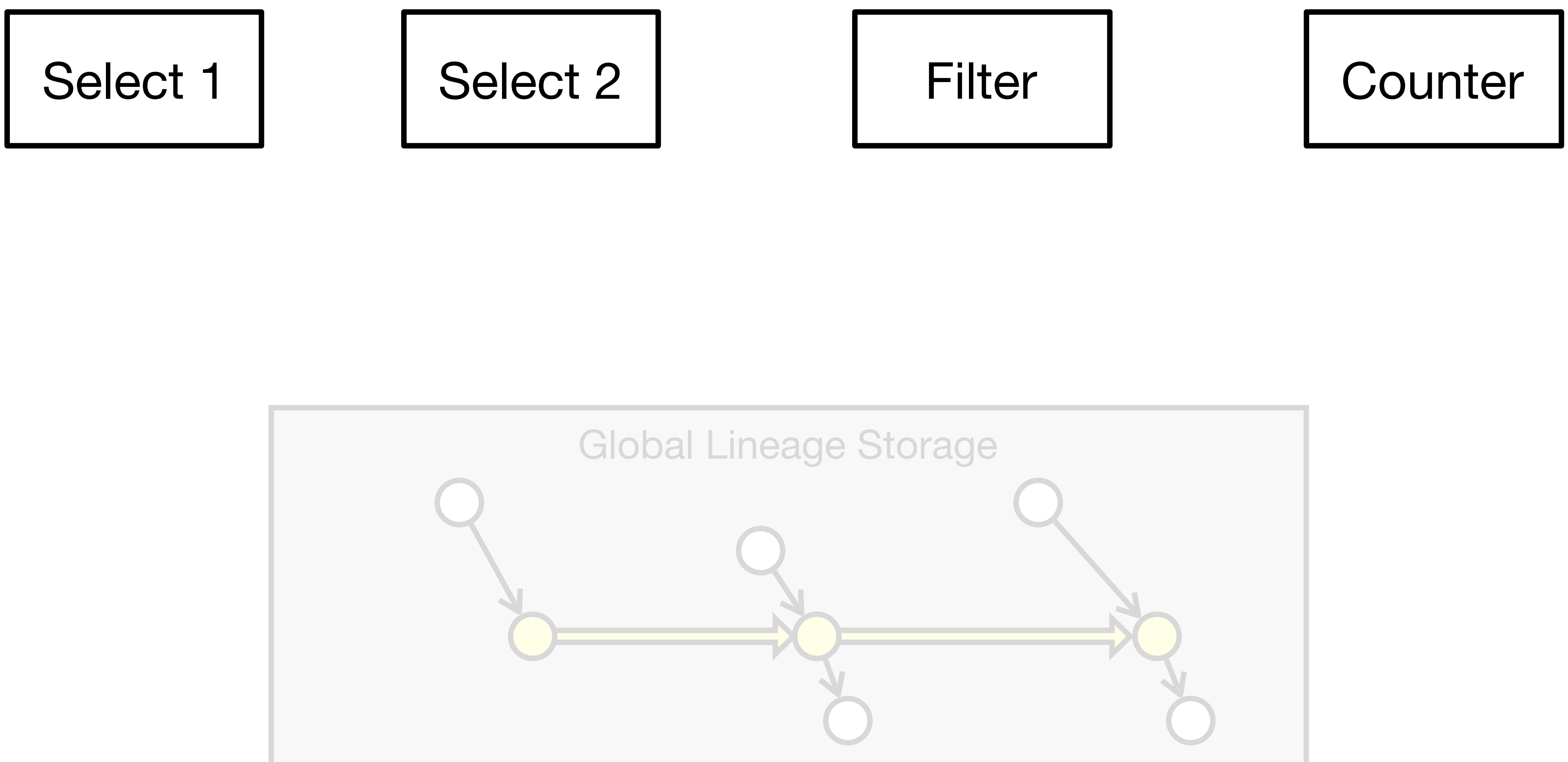

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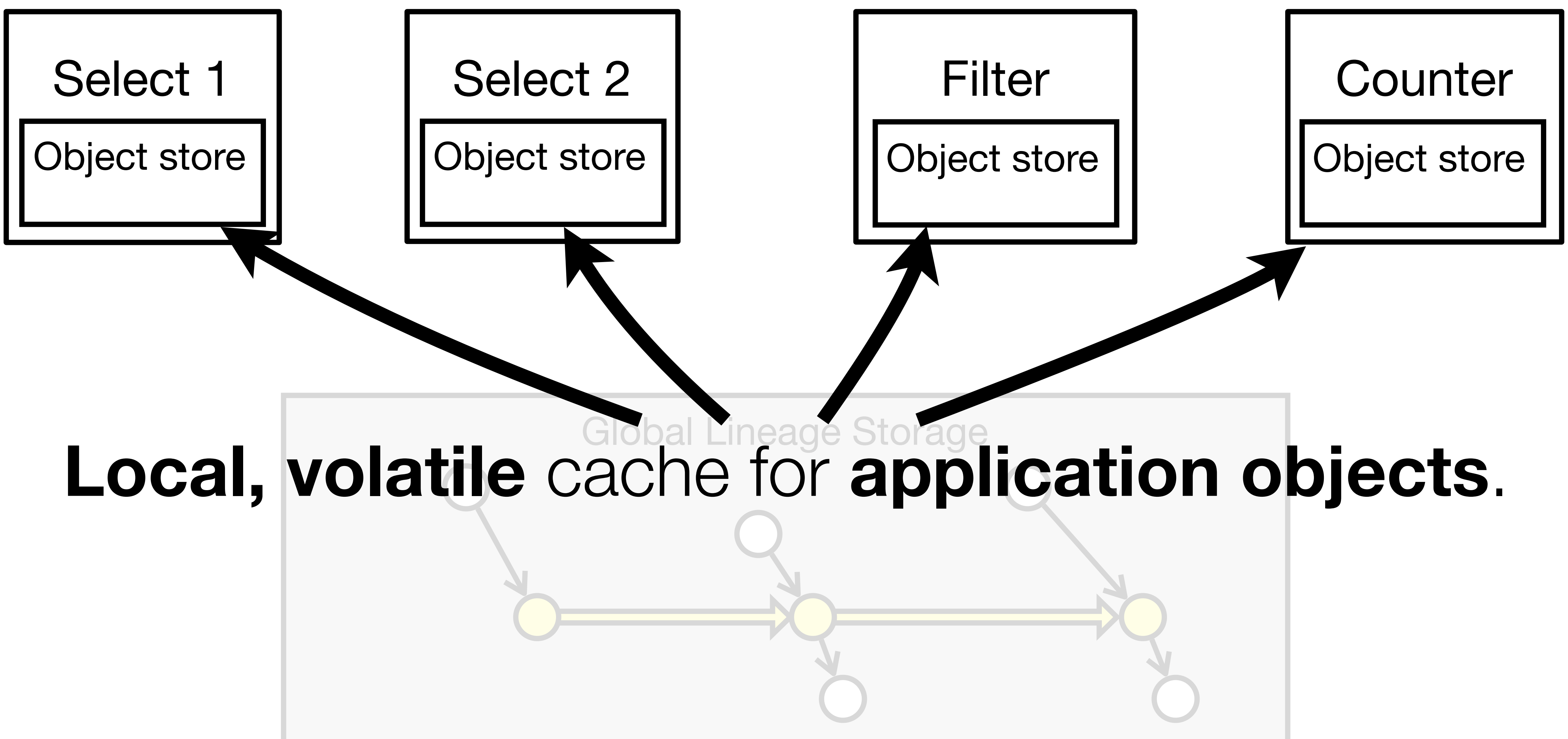
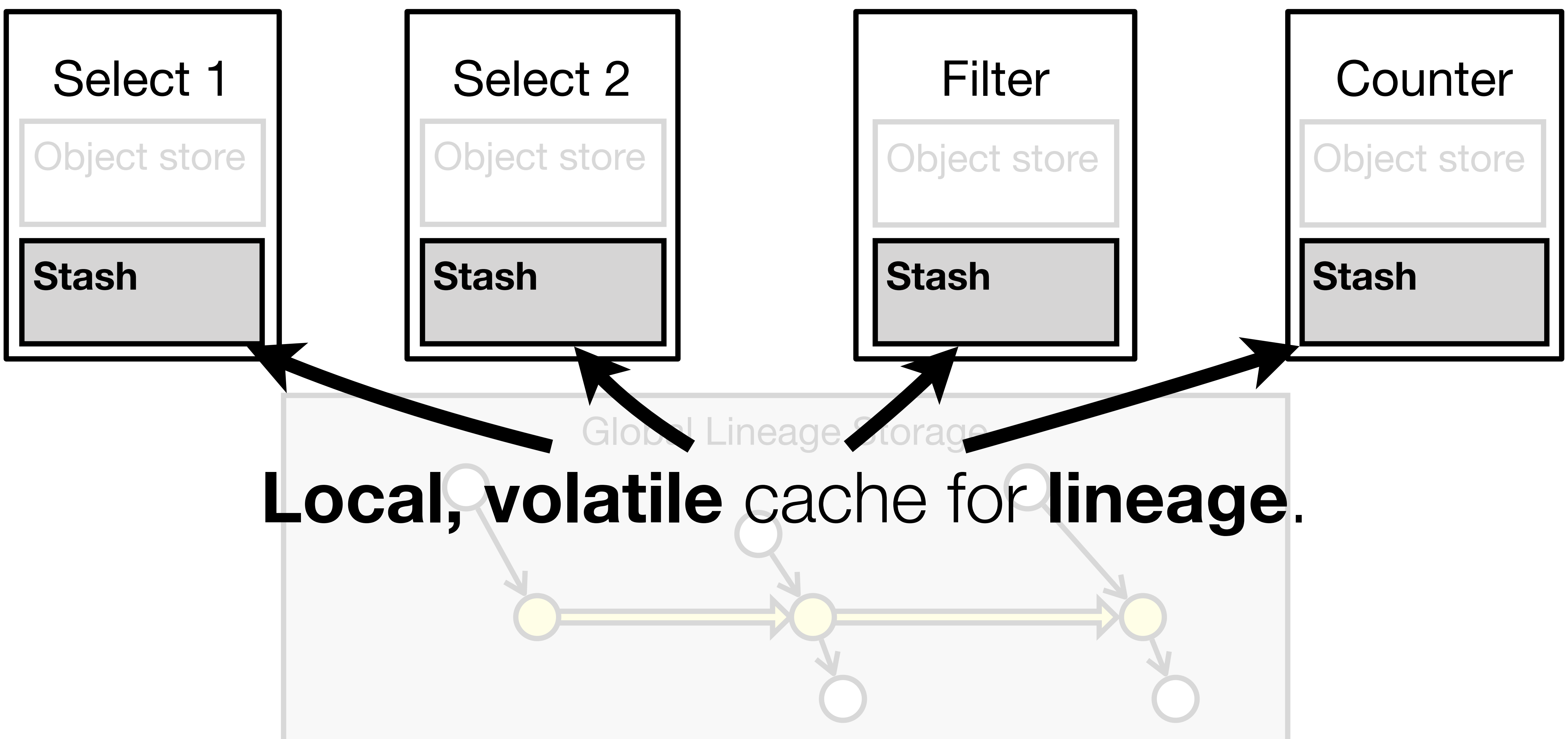


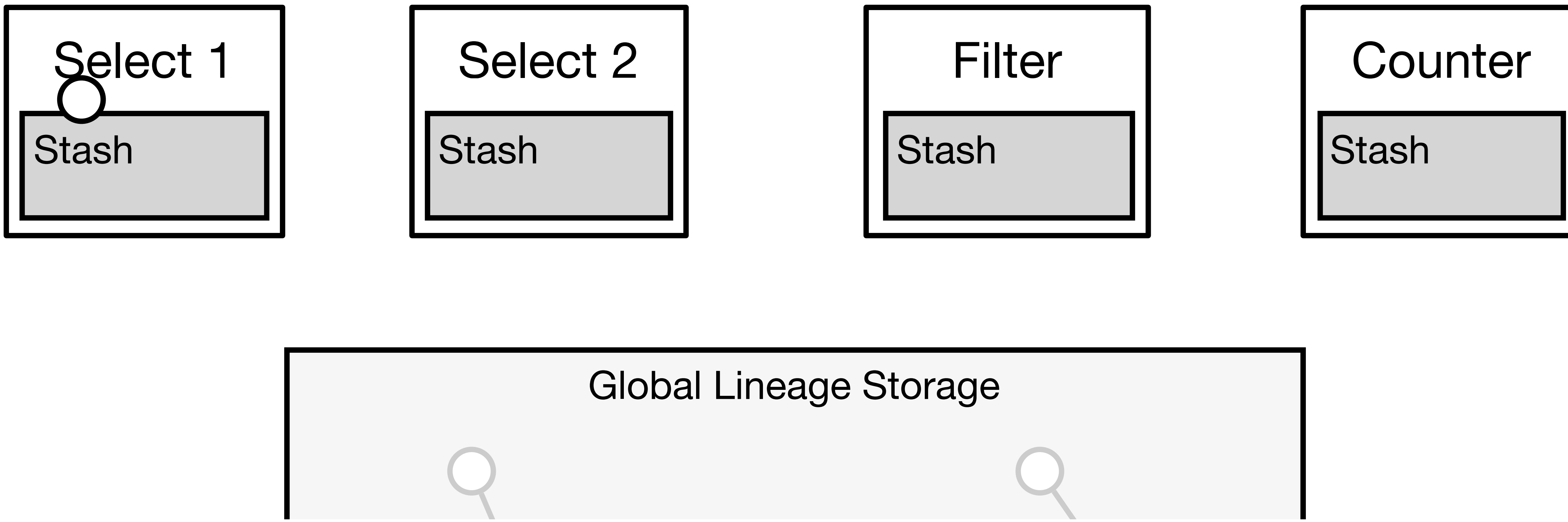
Local, volatile cache for **application objects**.

Lineage stash architecture



Local, volatile cache for **lineage**.

Lineage stash: Logging the **lineage, asynchronously**



(1) Write lineage to **local, volatile** lineage stash.

(2) **Asynchronously** flush to **remote** storage.

Scheduling delay / task = ~~1RTT~~ + **1RPC**

Task latency **independent of** global storage latency

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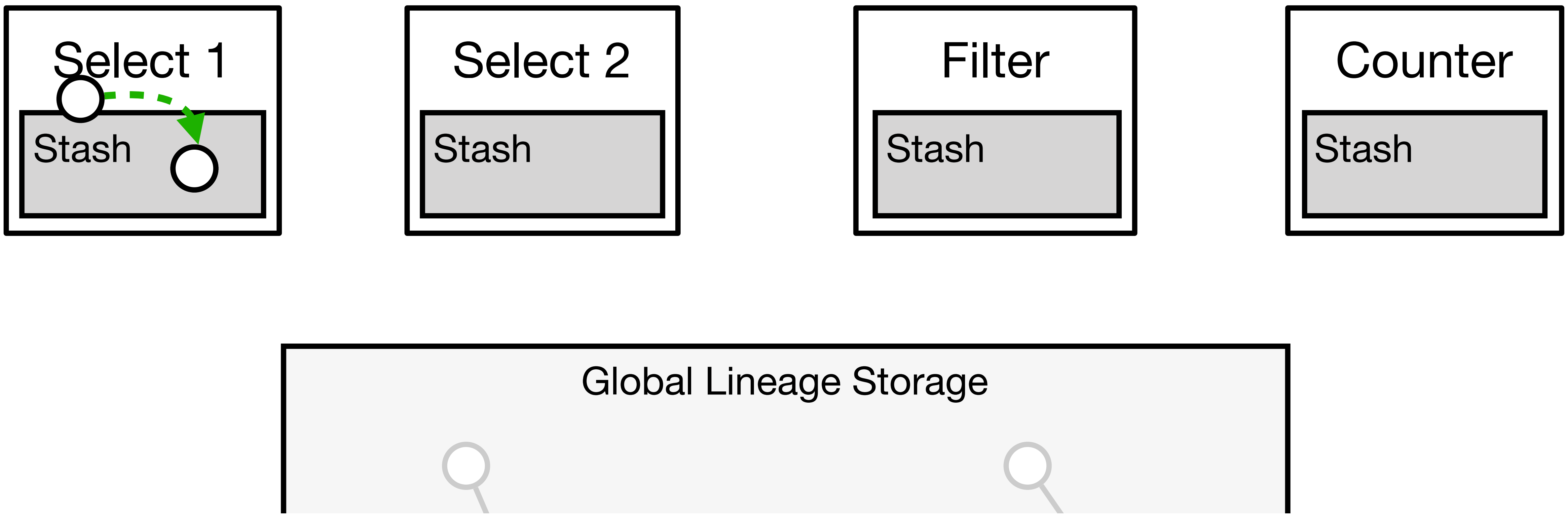

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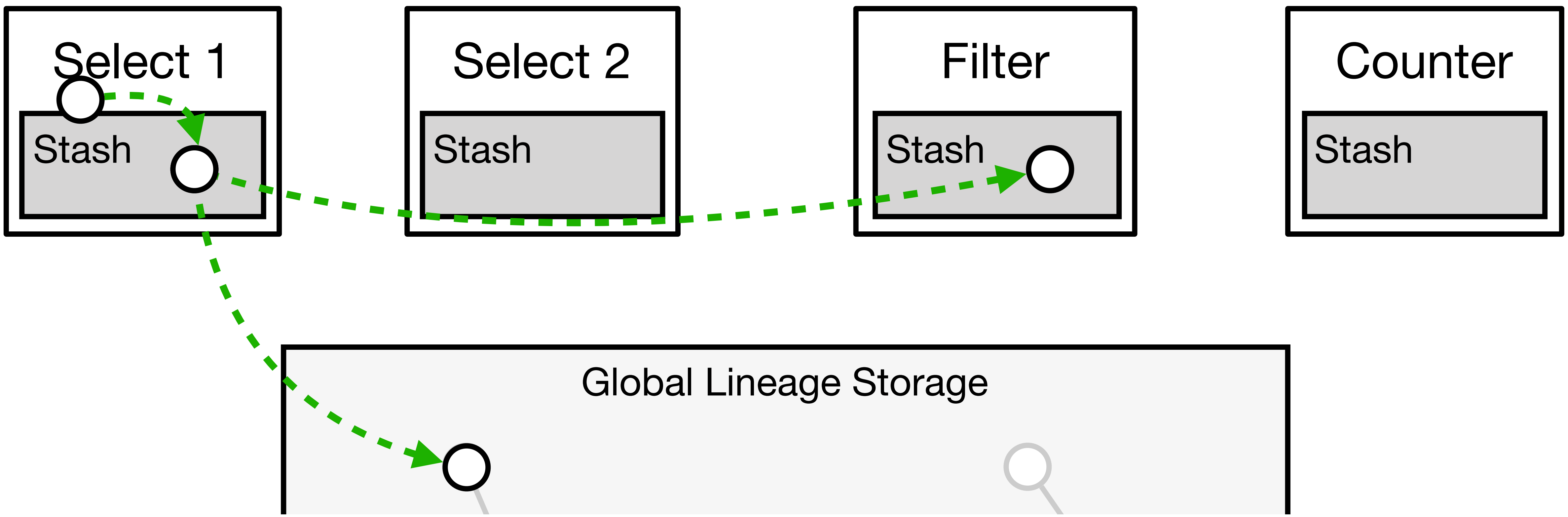

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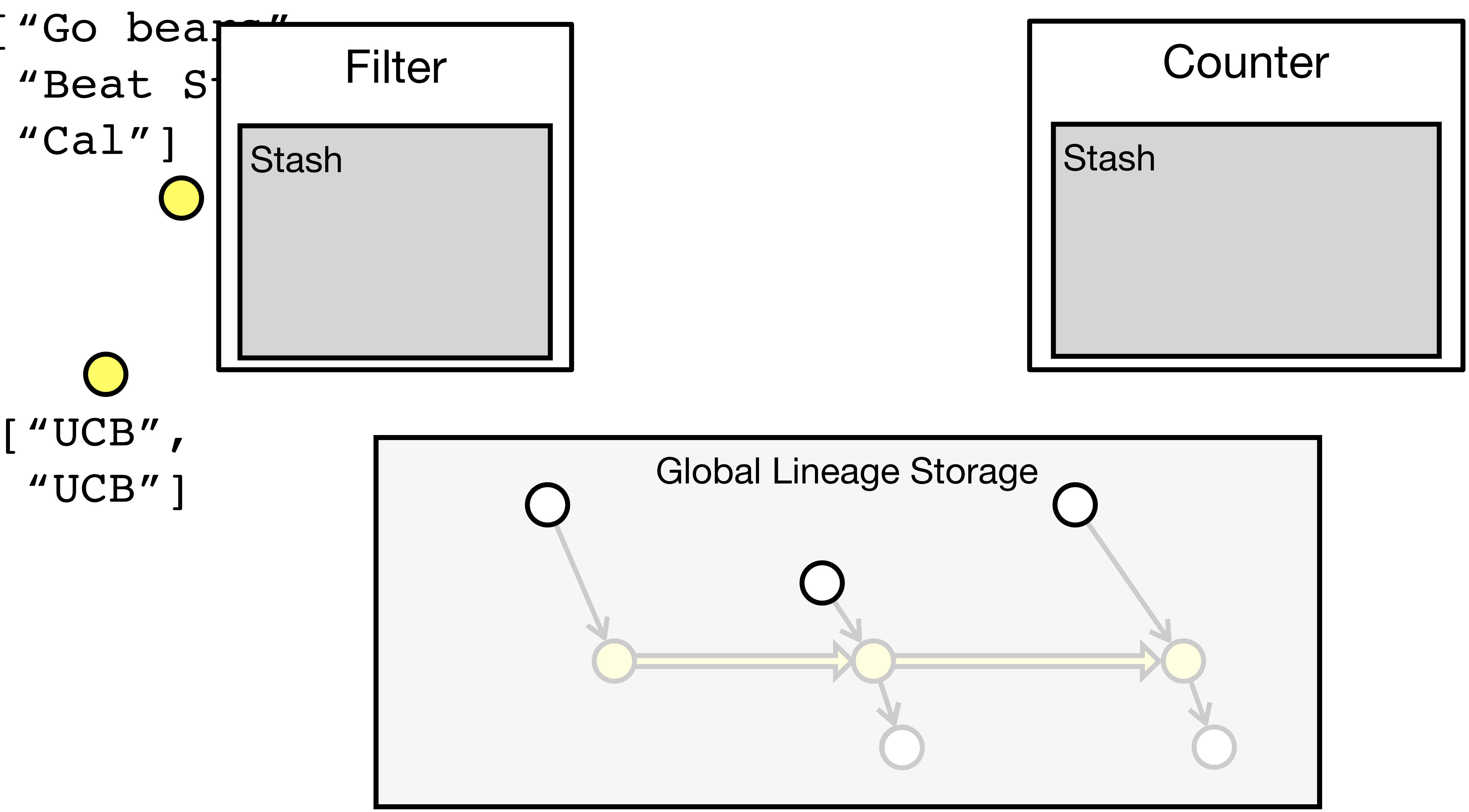
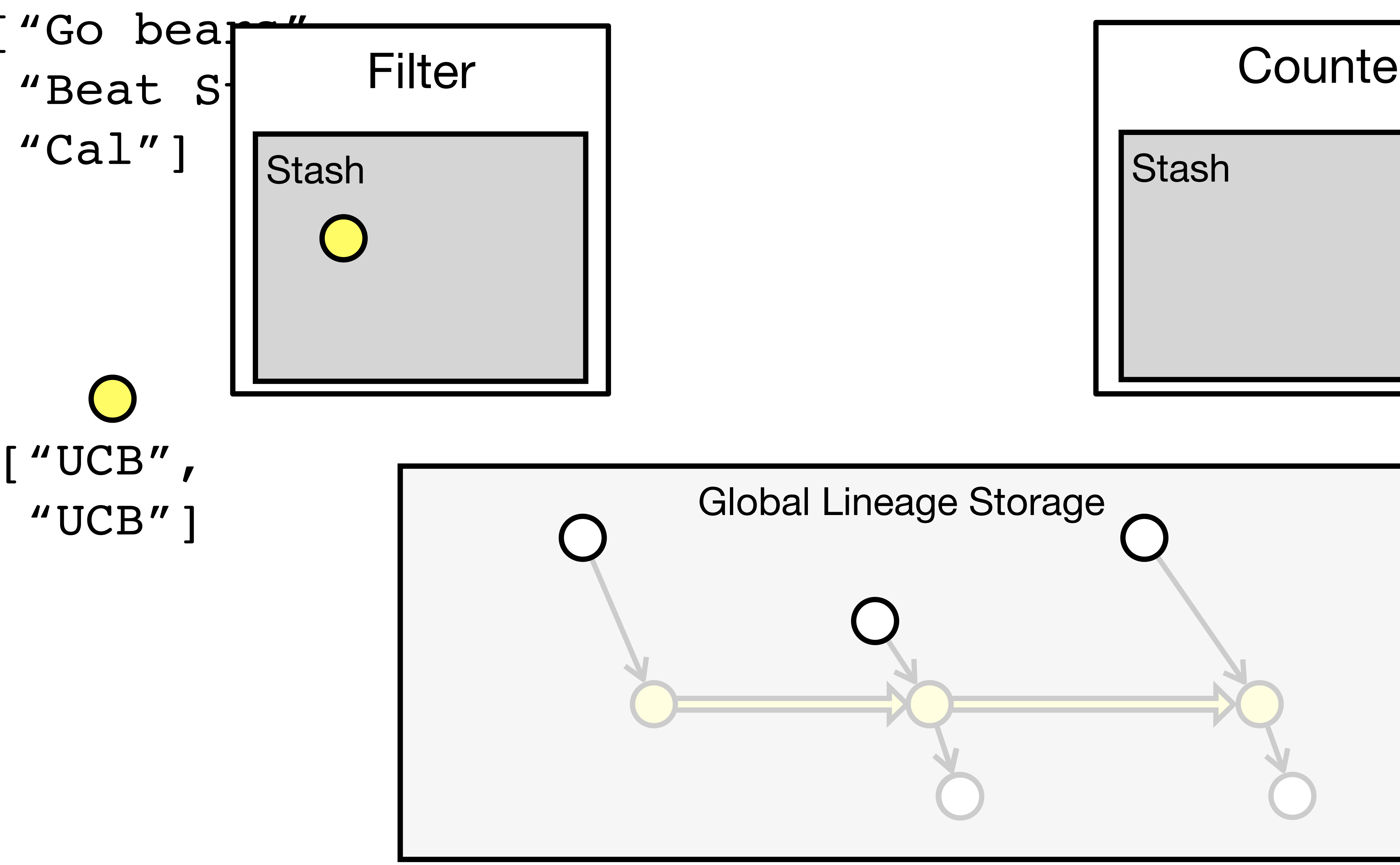


Lineage stash: Logging the **lineage, asynchronously**



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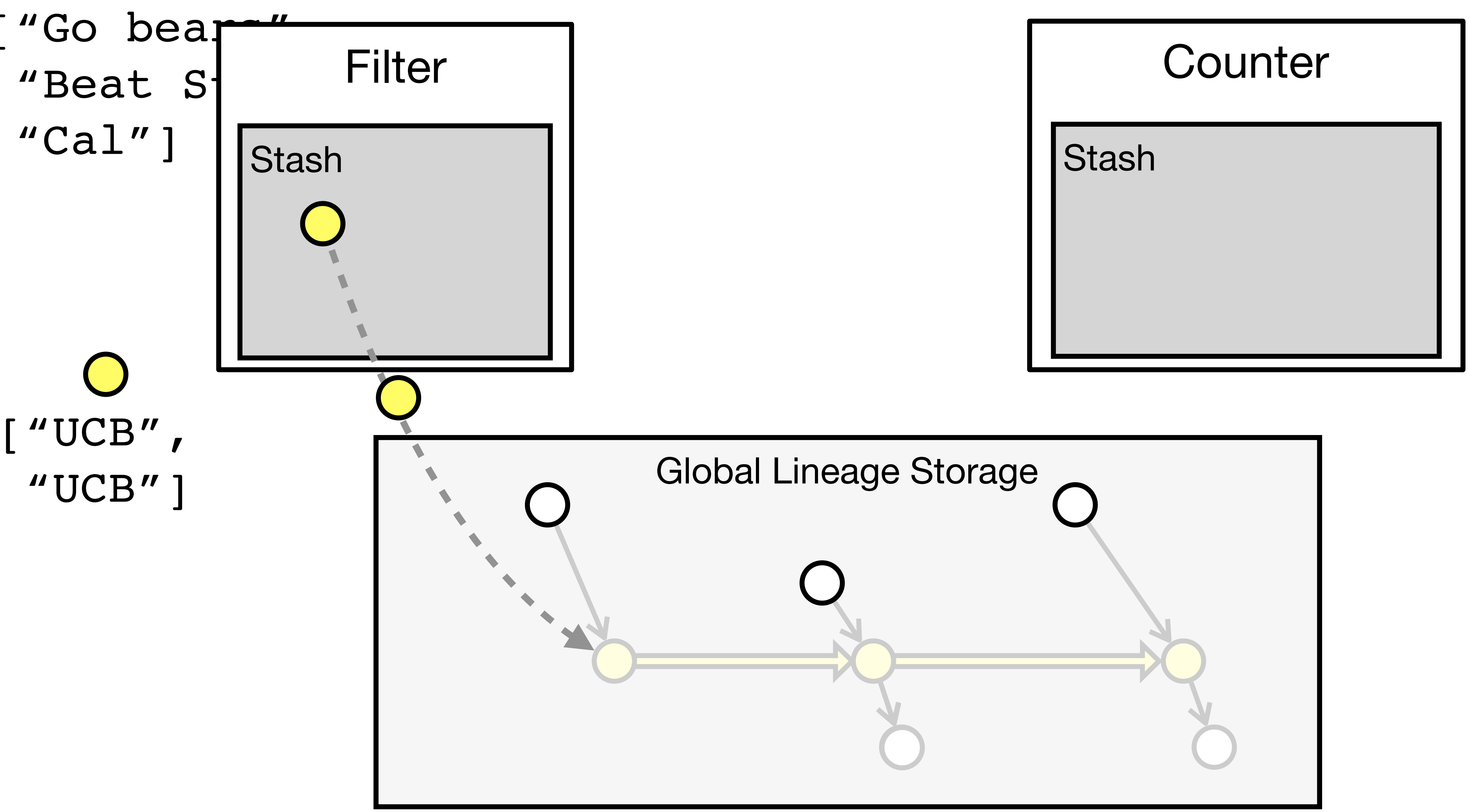

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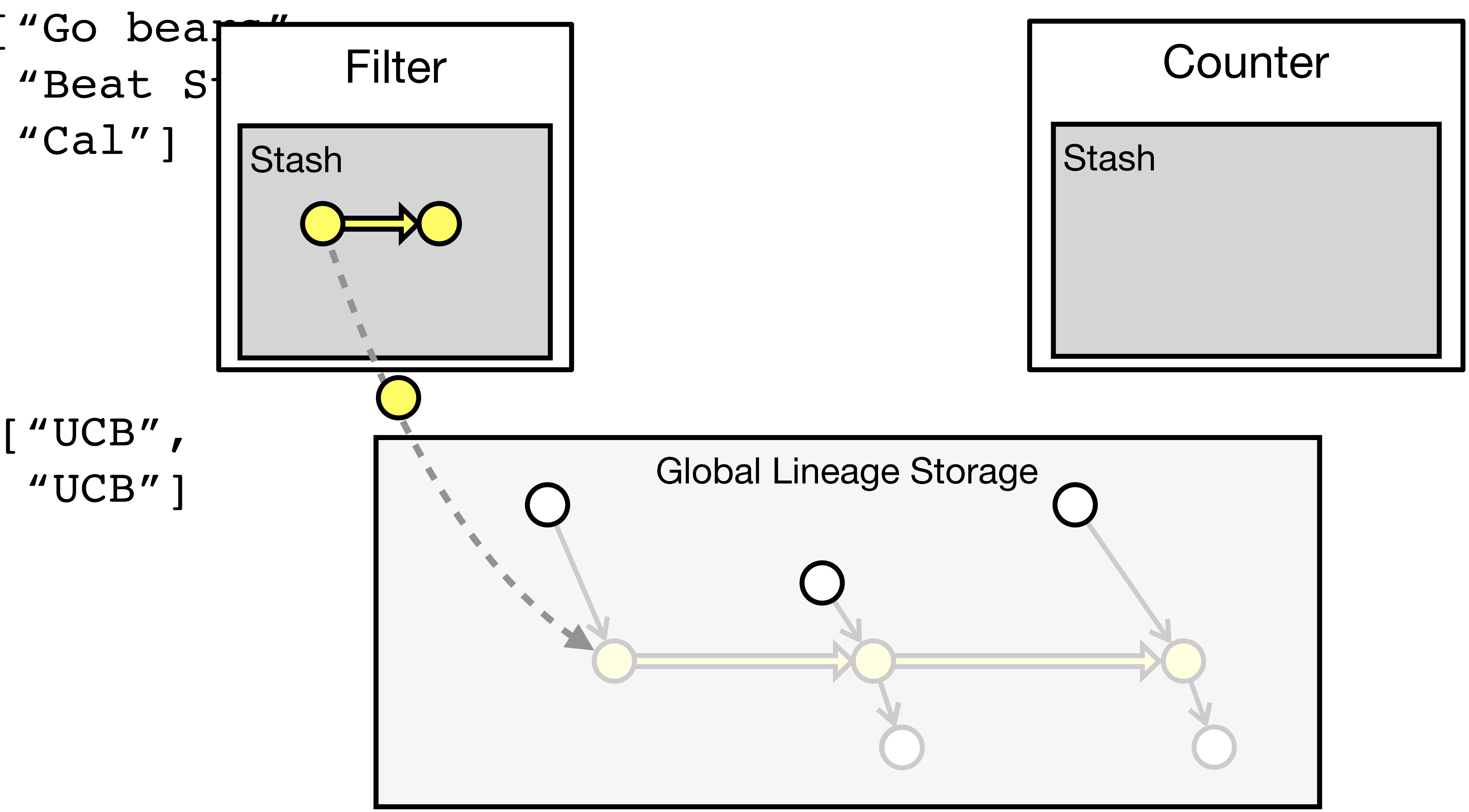

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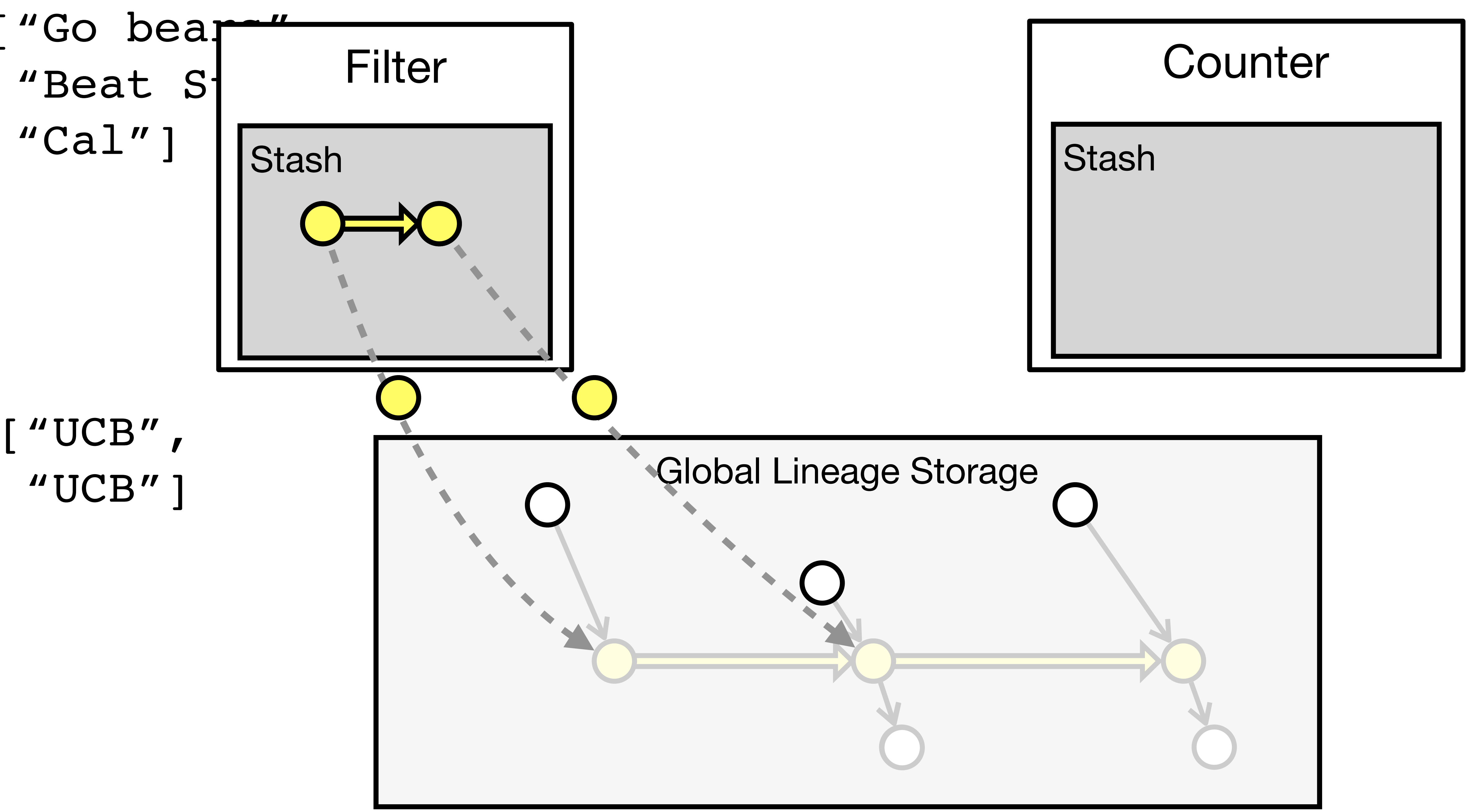

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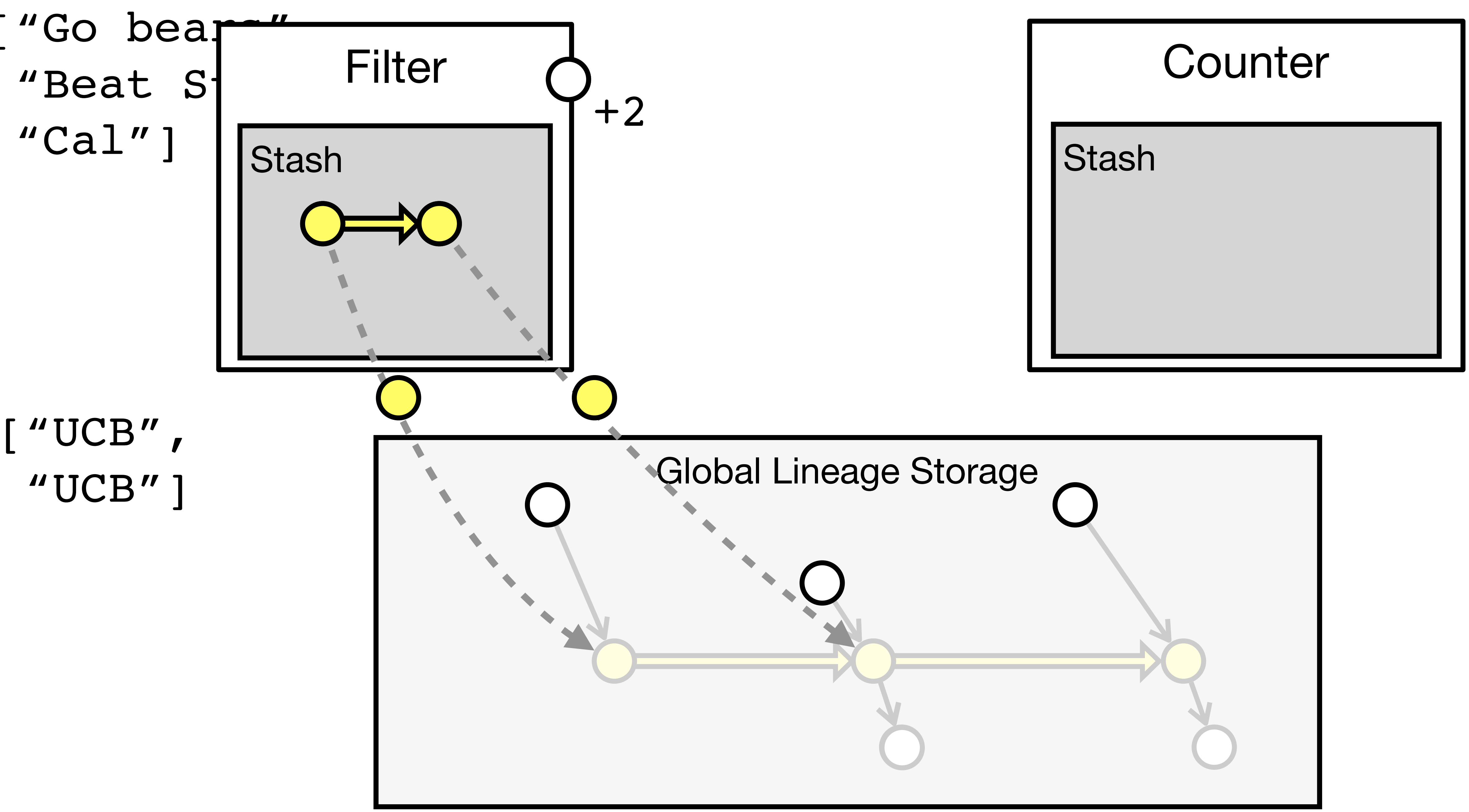

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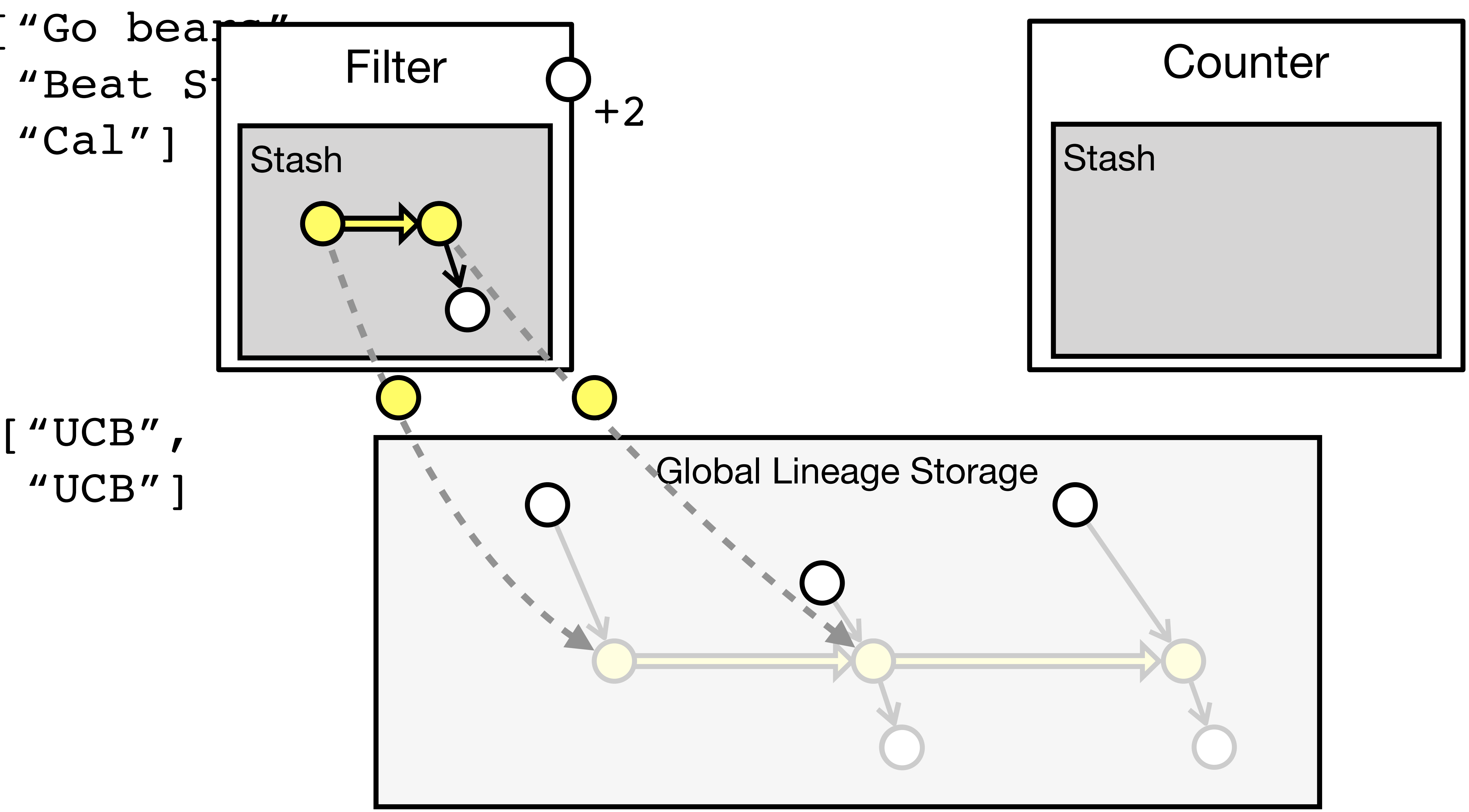

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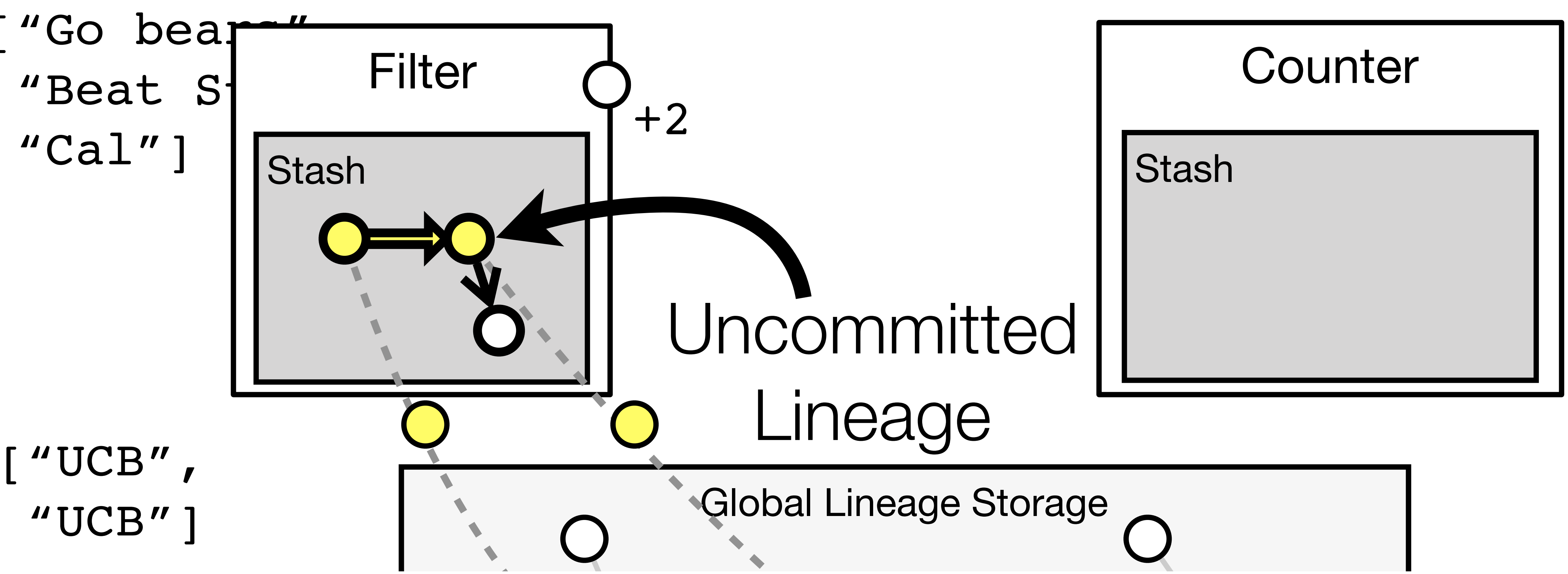
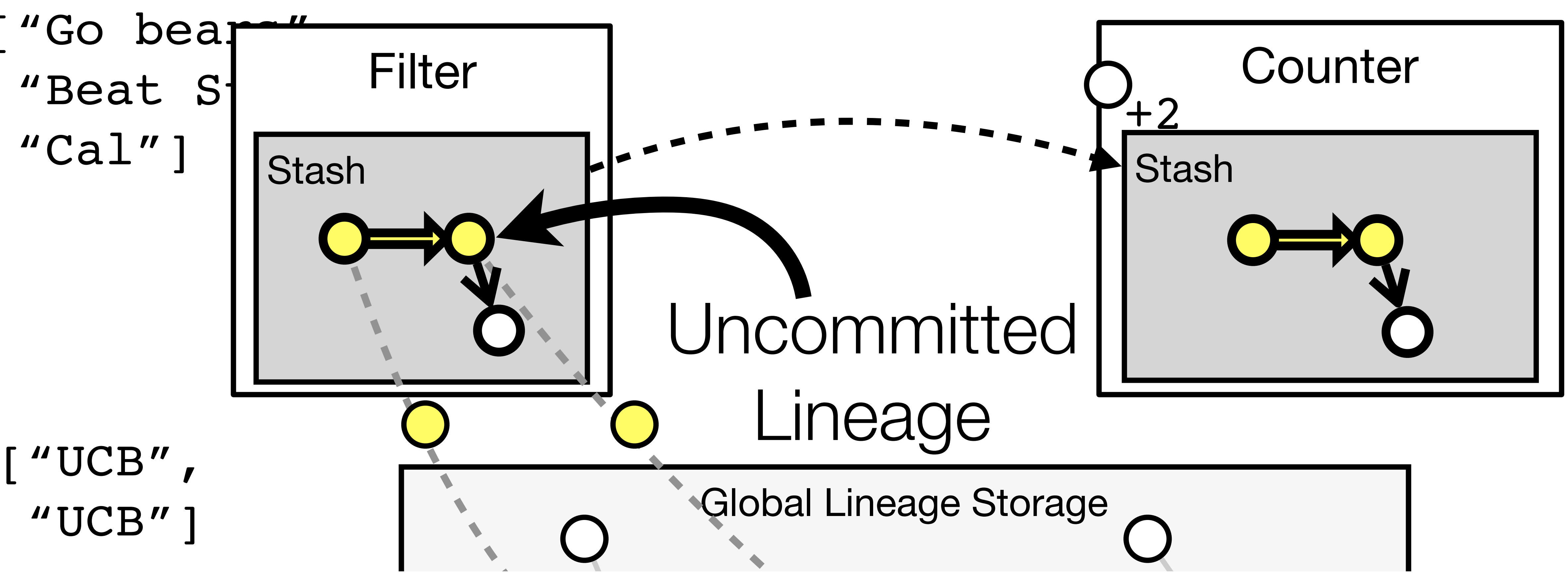


(3) Forward uncommitted lineage.

Lineage stash: Logging the **lineage, asynchronously**



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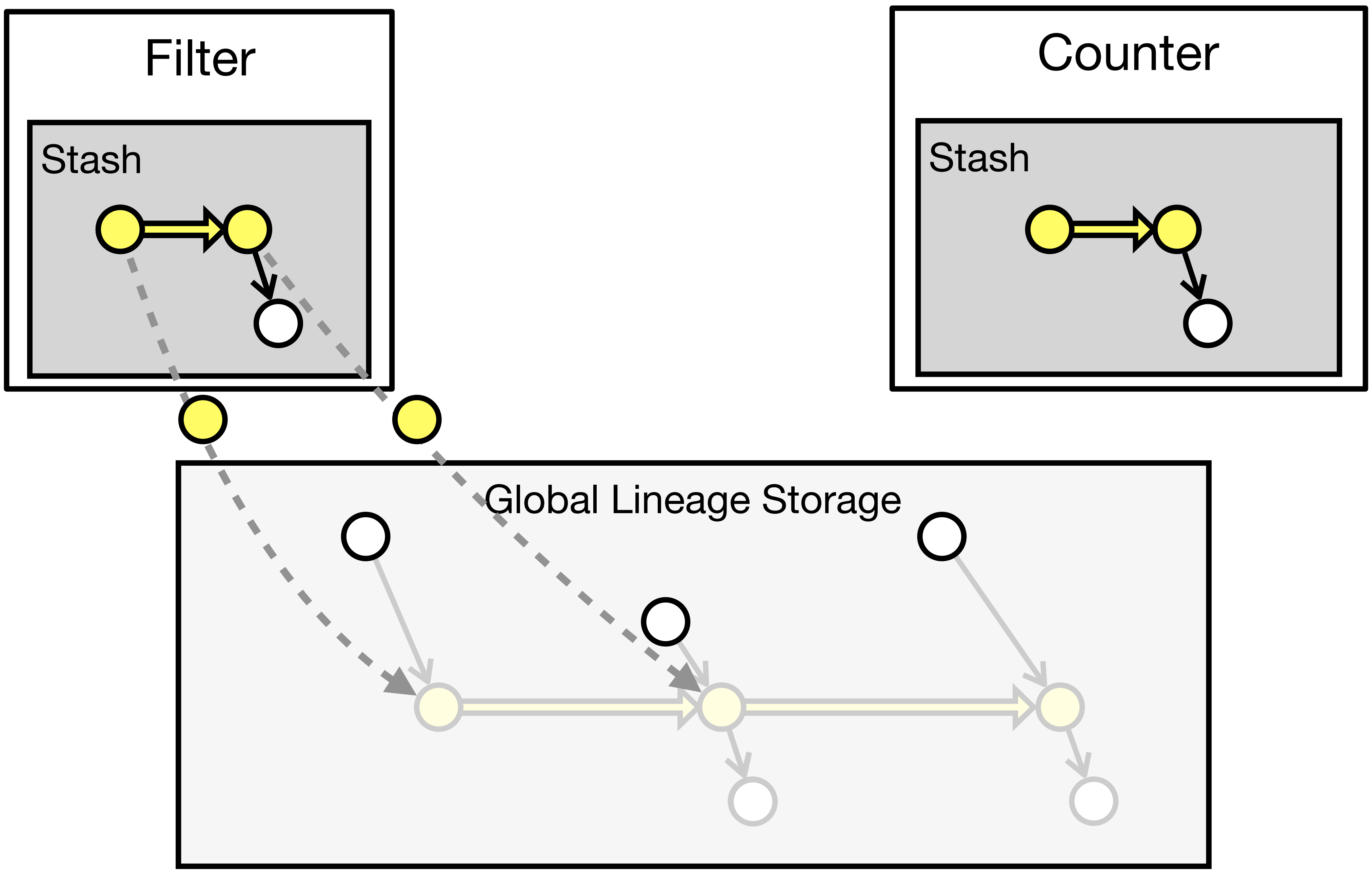
Lineage stash recovery



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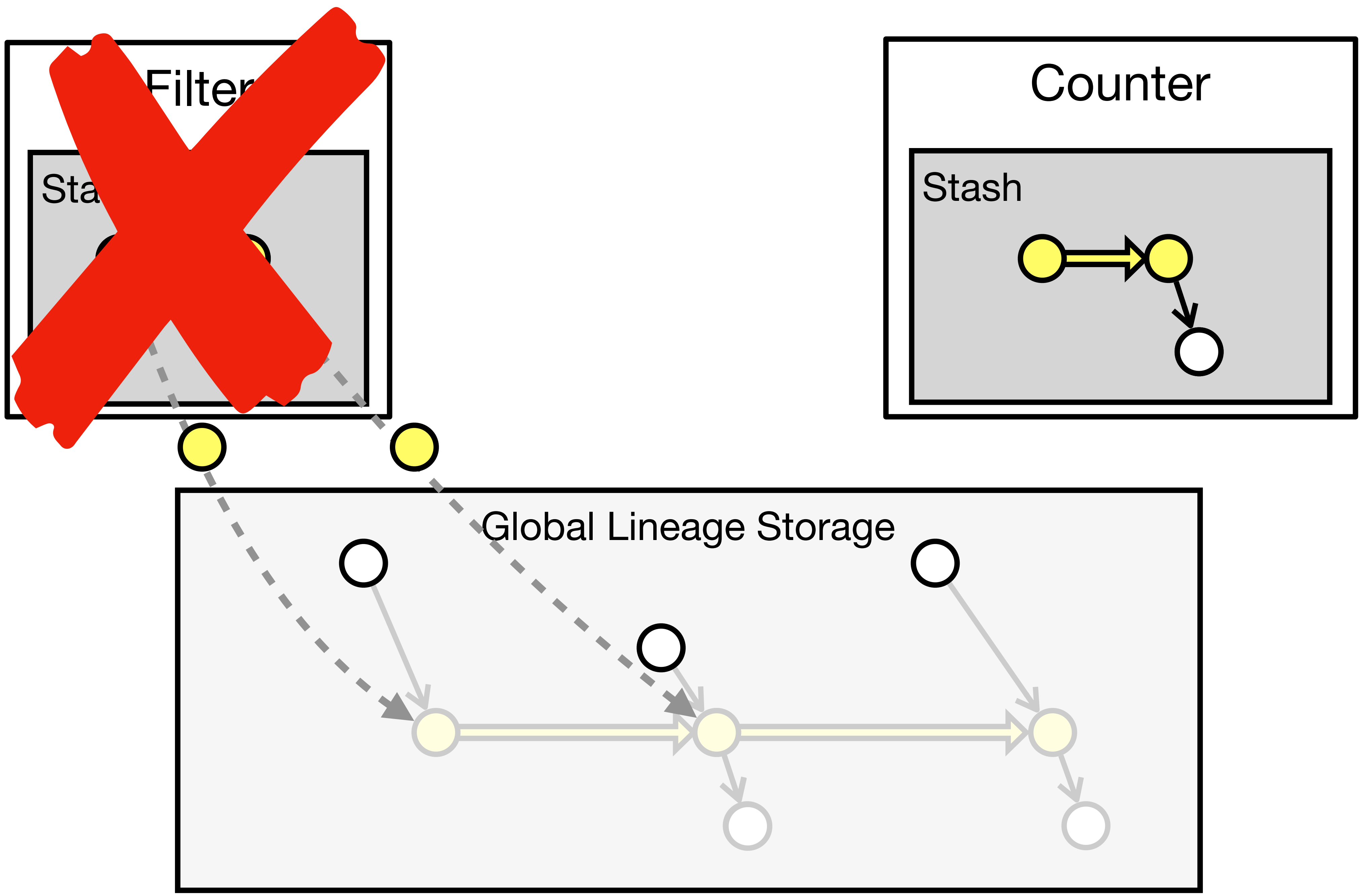

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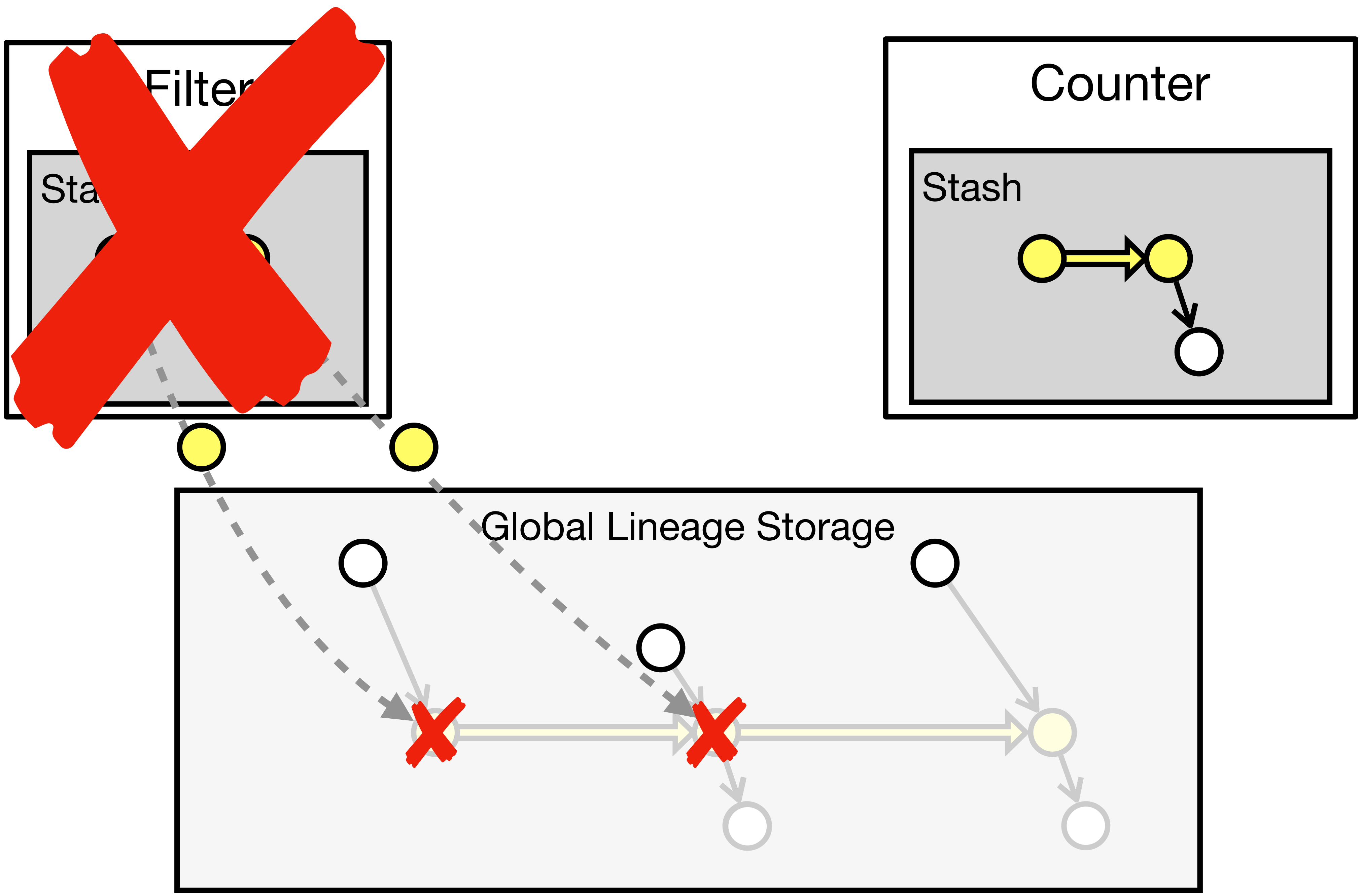

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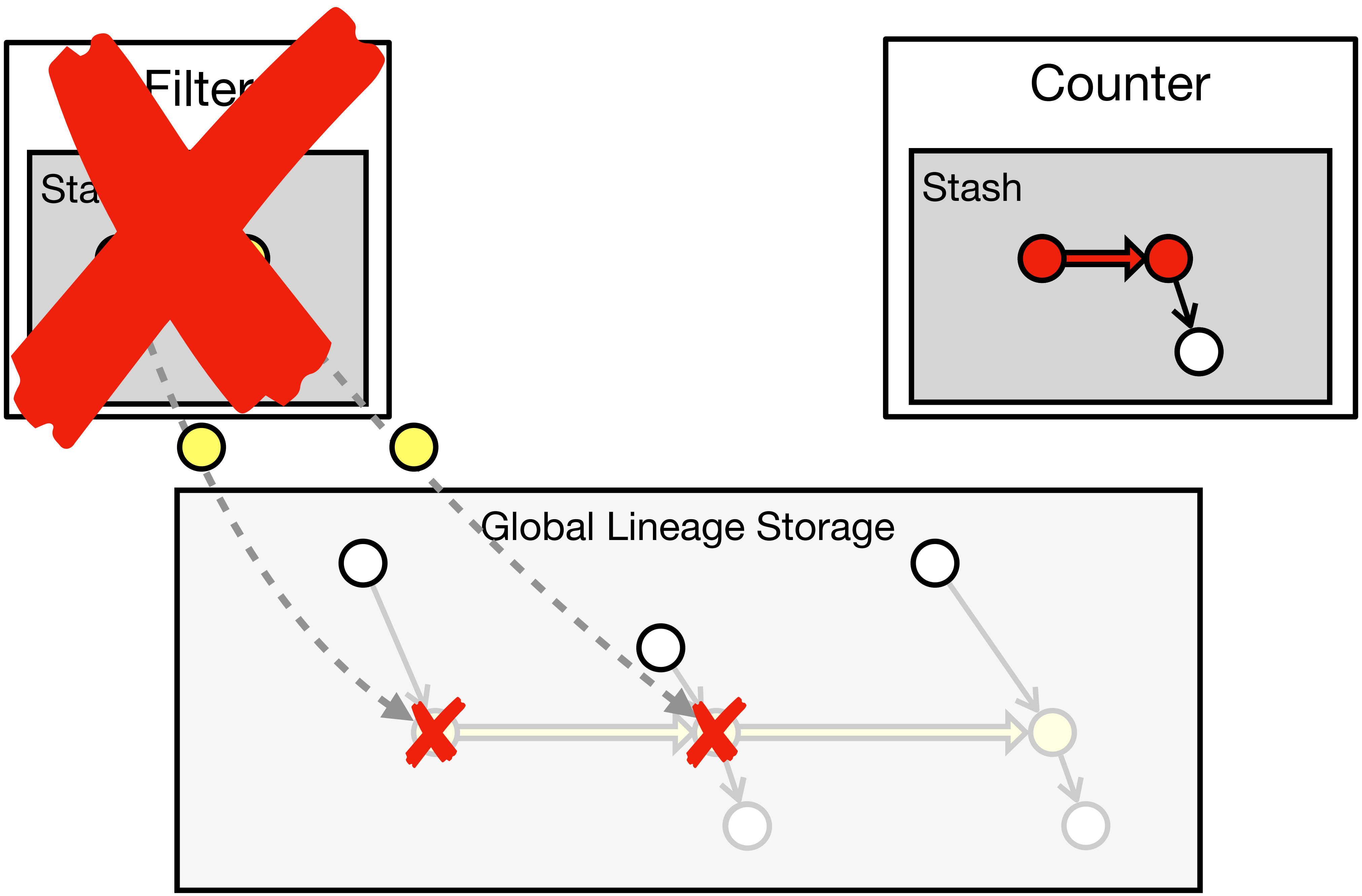
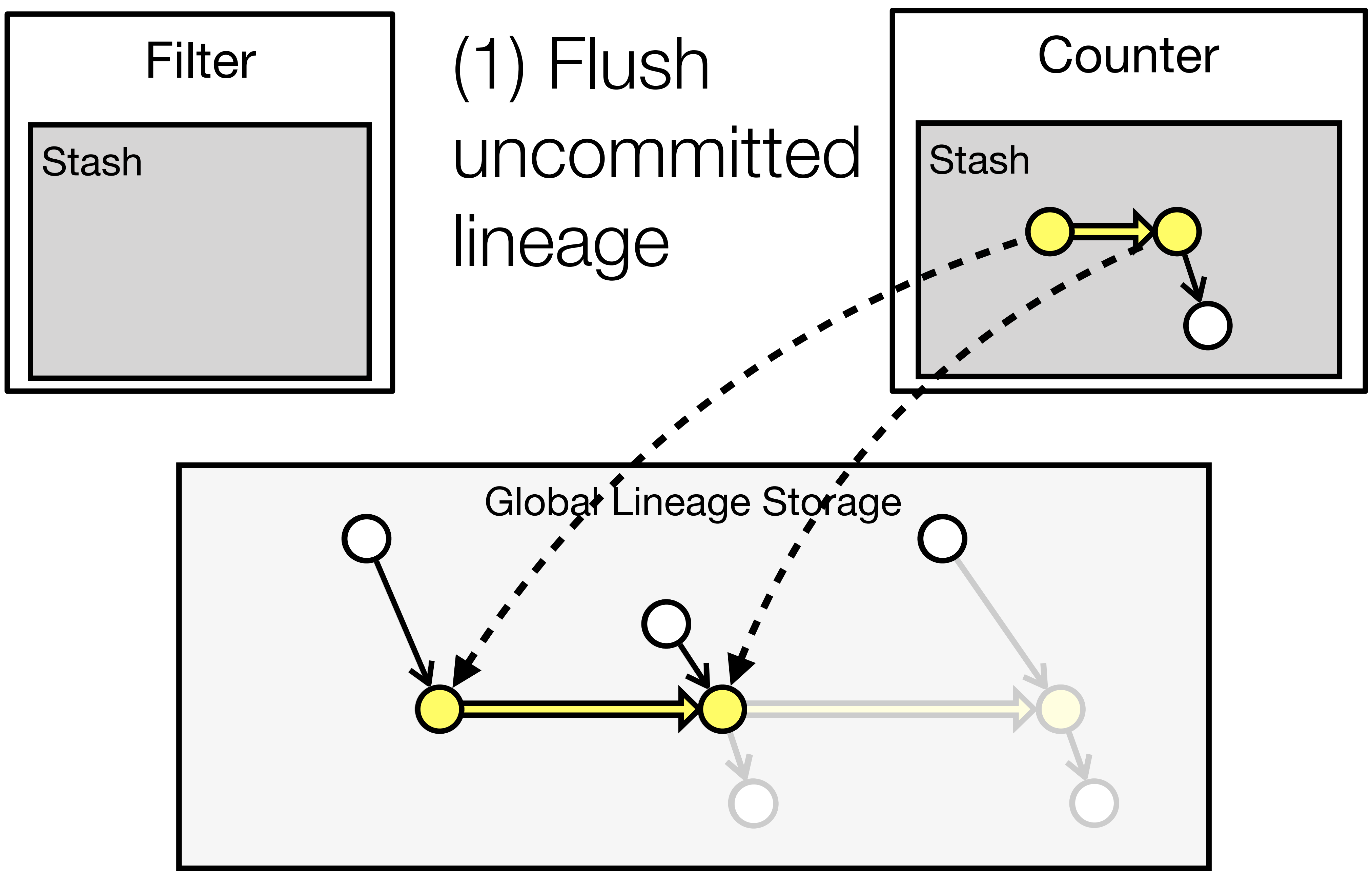


Lineage stash recovery

(1) Flush uncommitted lineage



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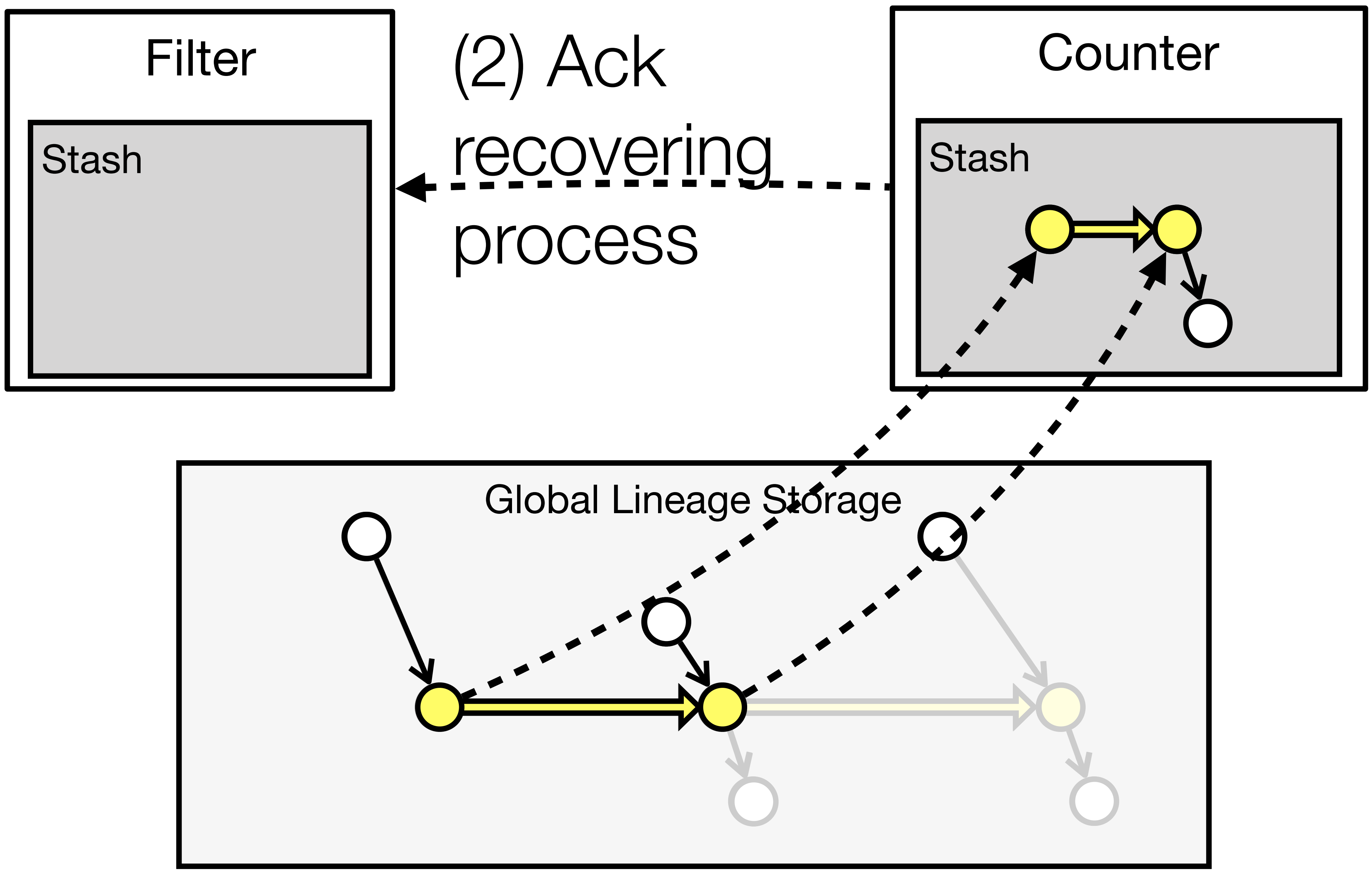

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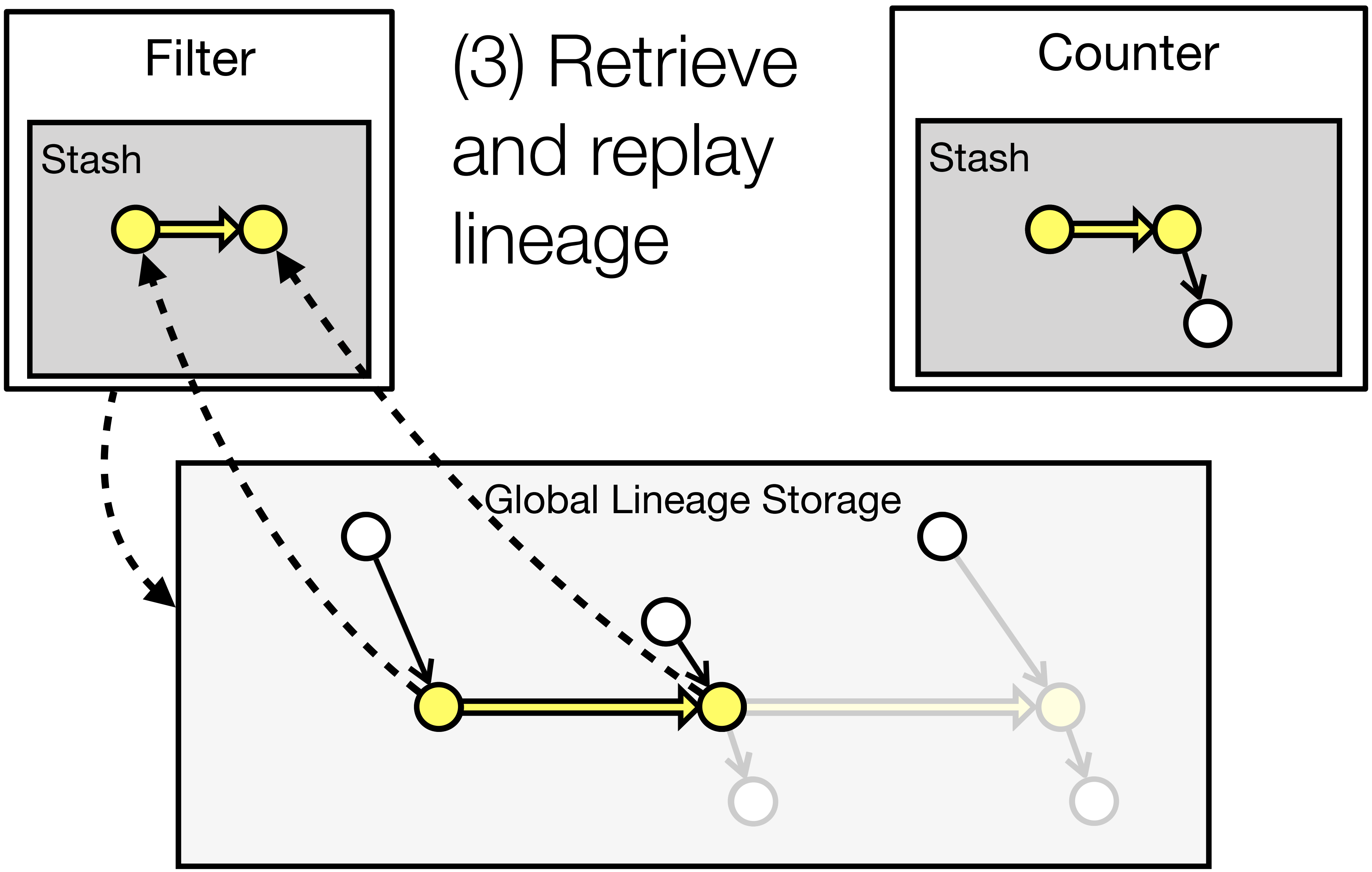

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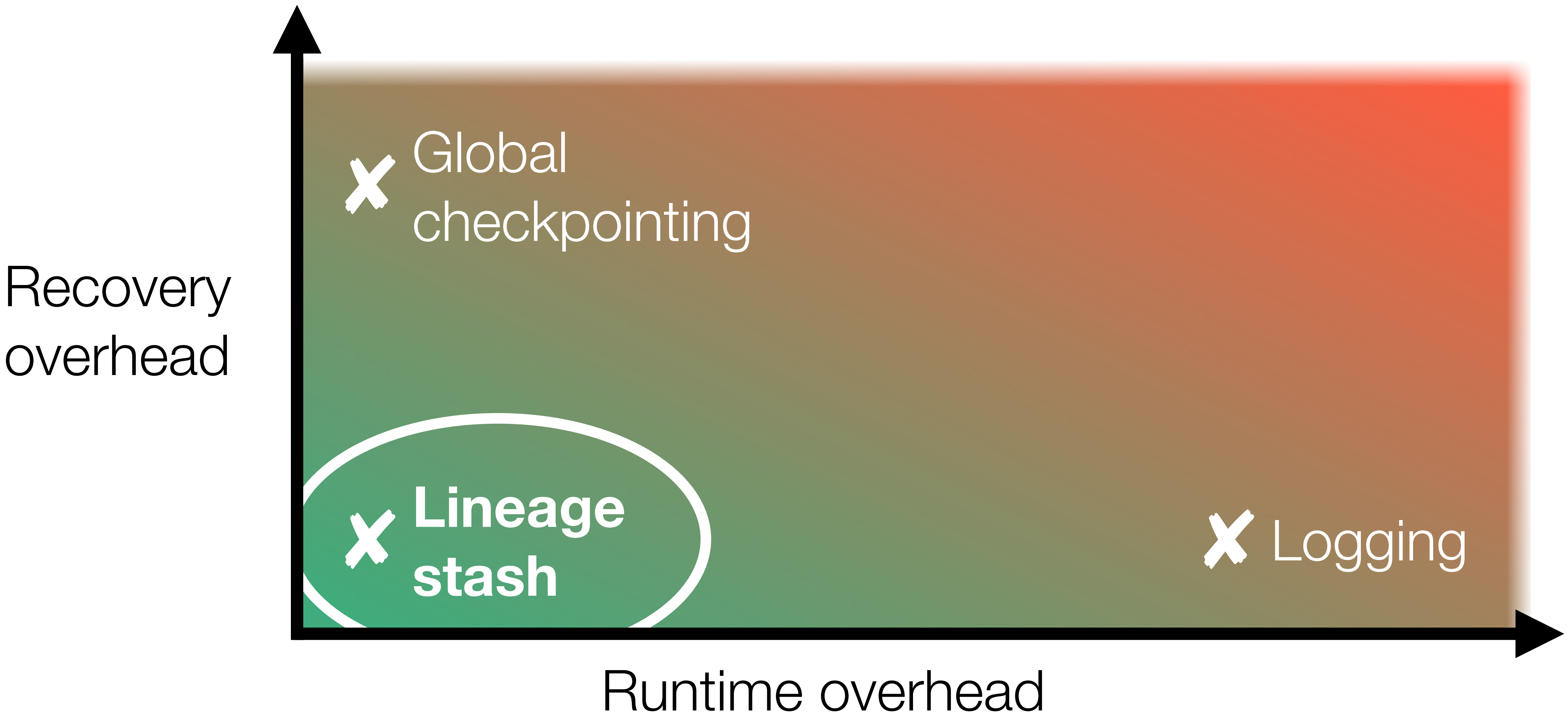
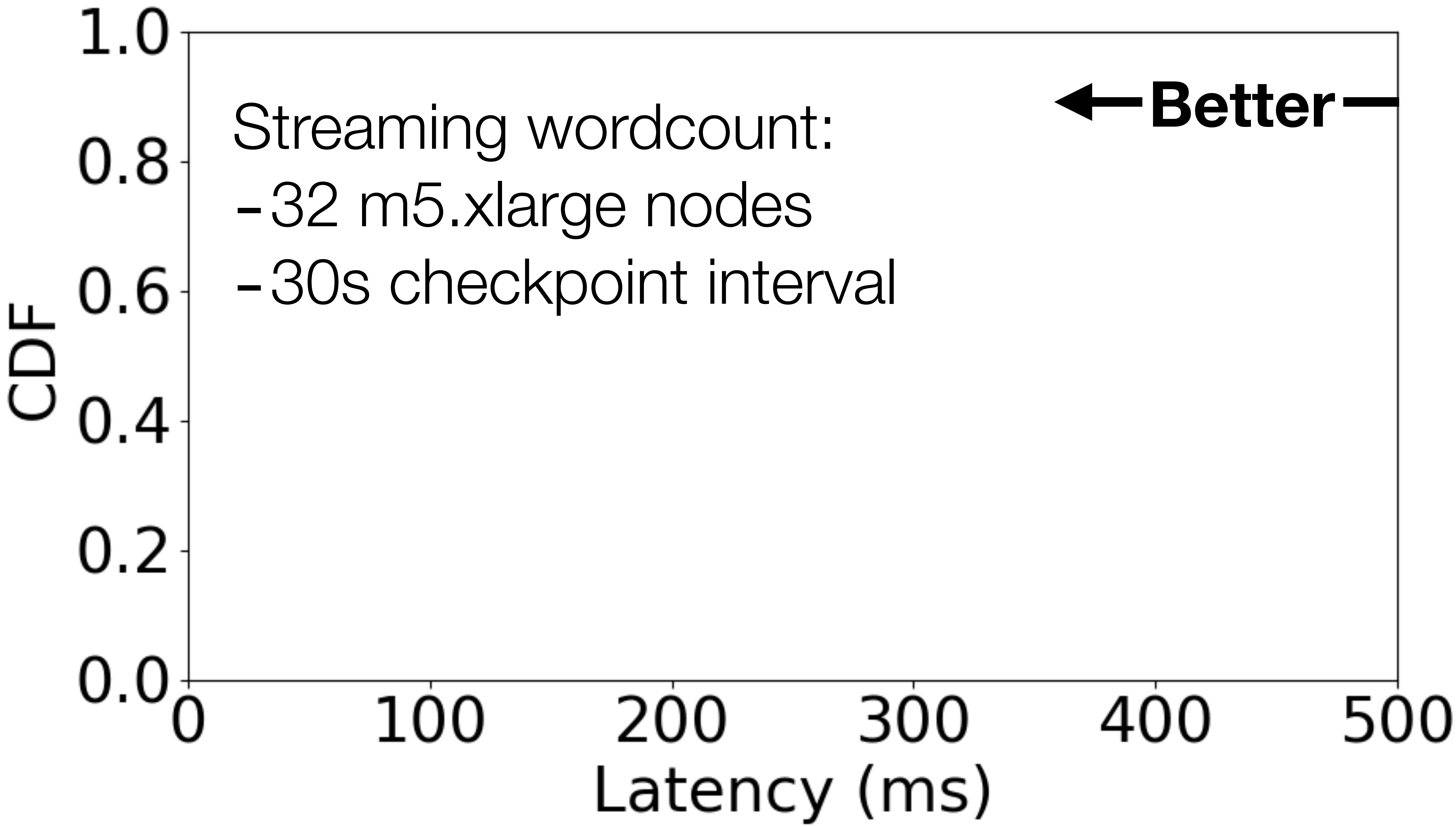


Latency without failures



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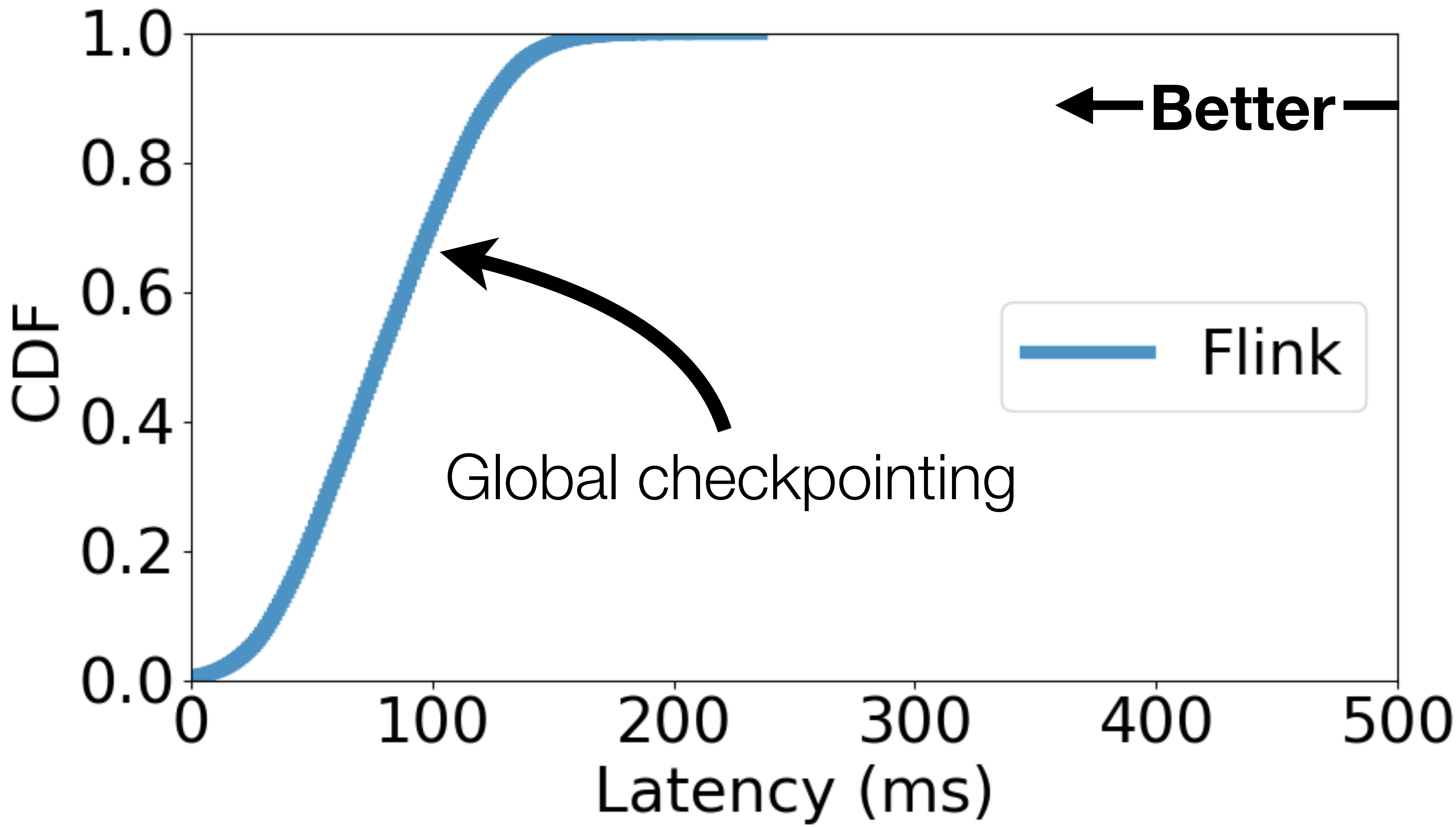

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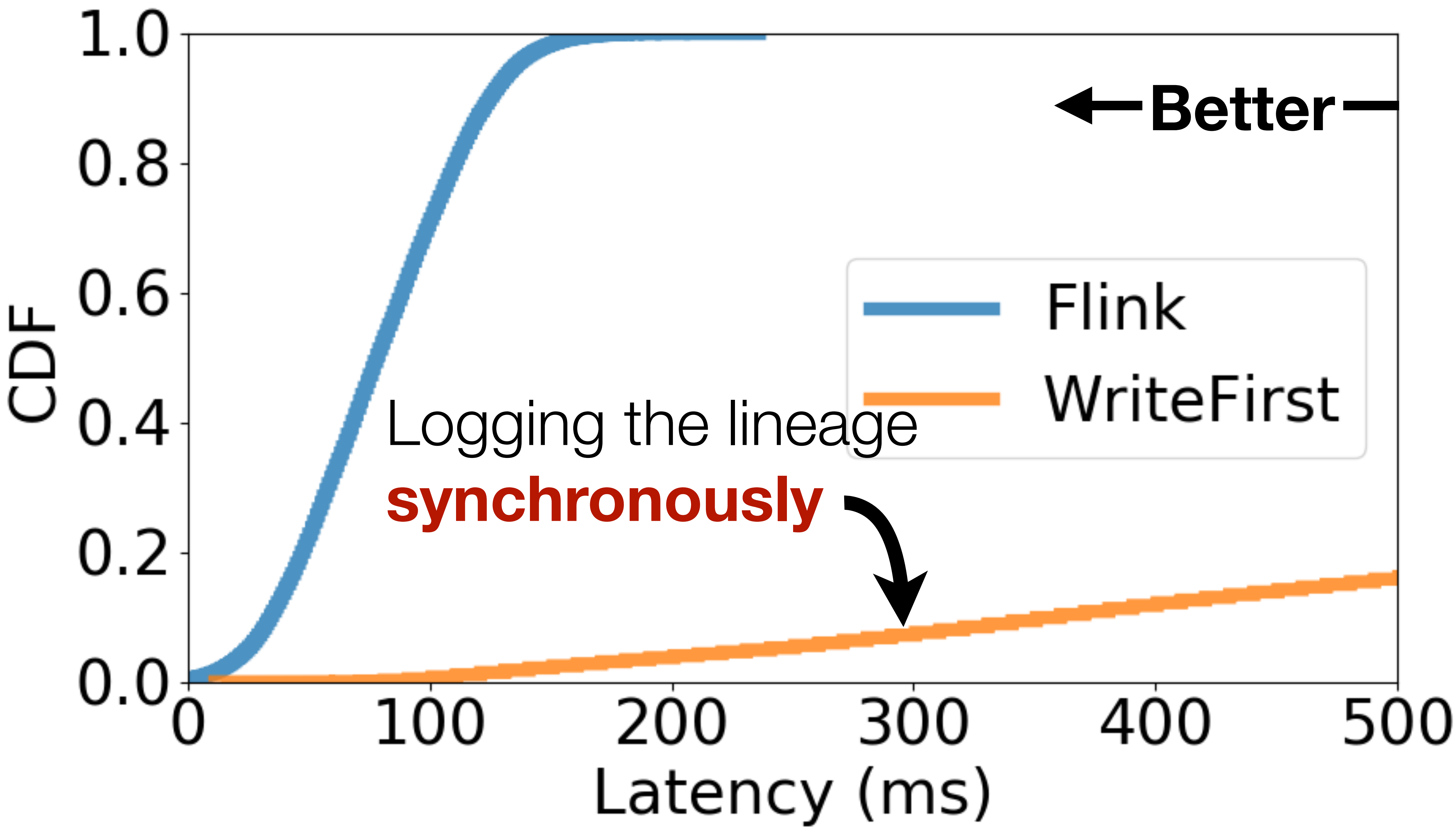

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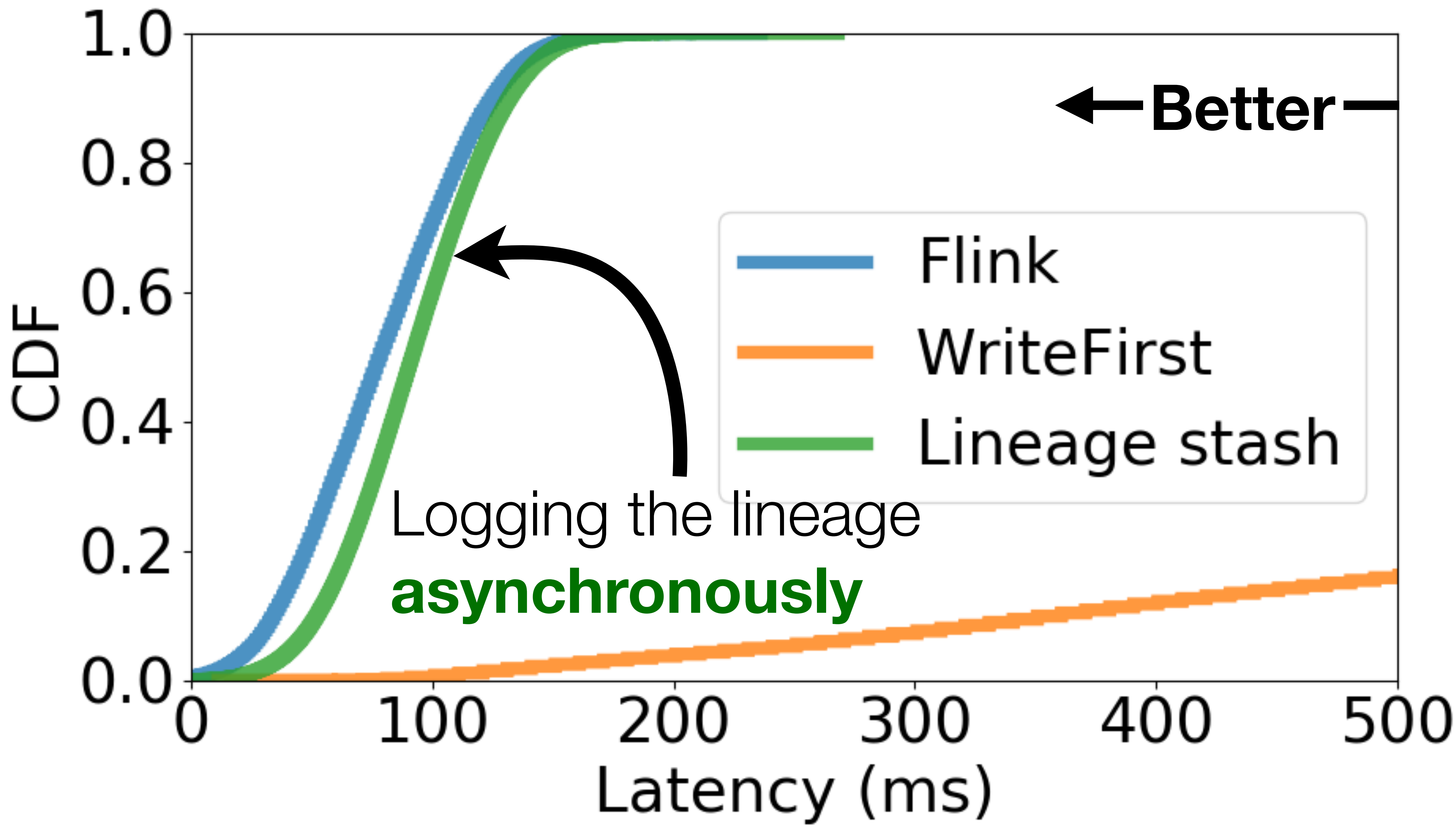
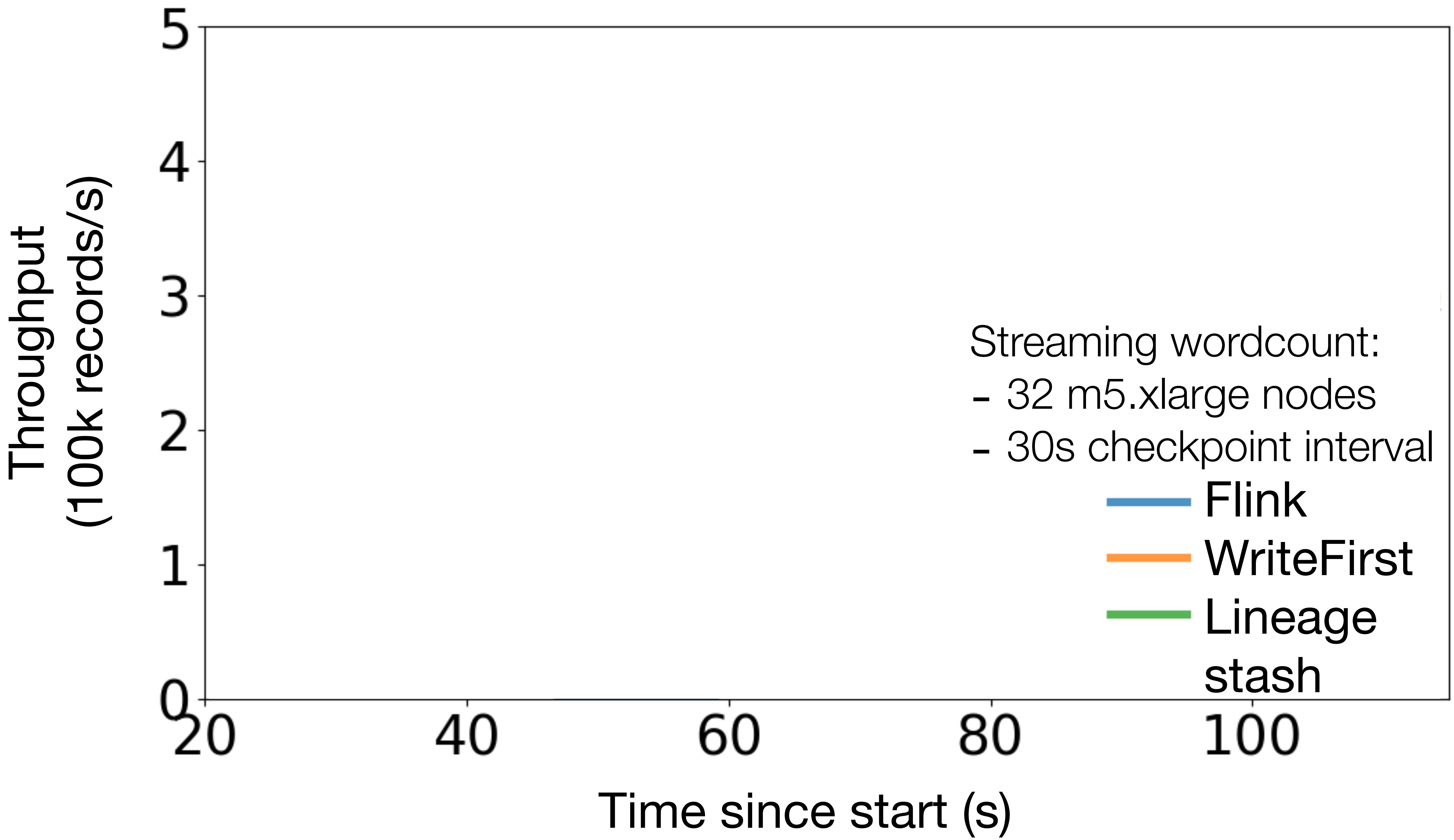


Throughput during recovery



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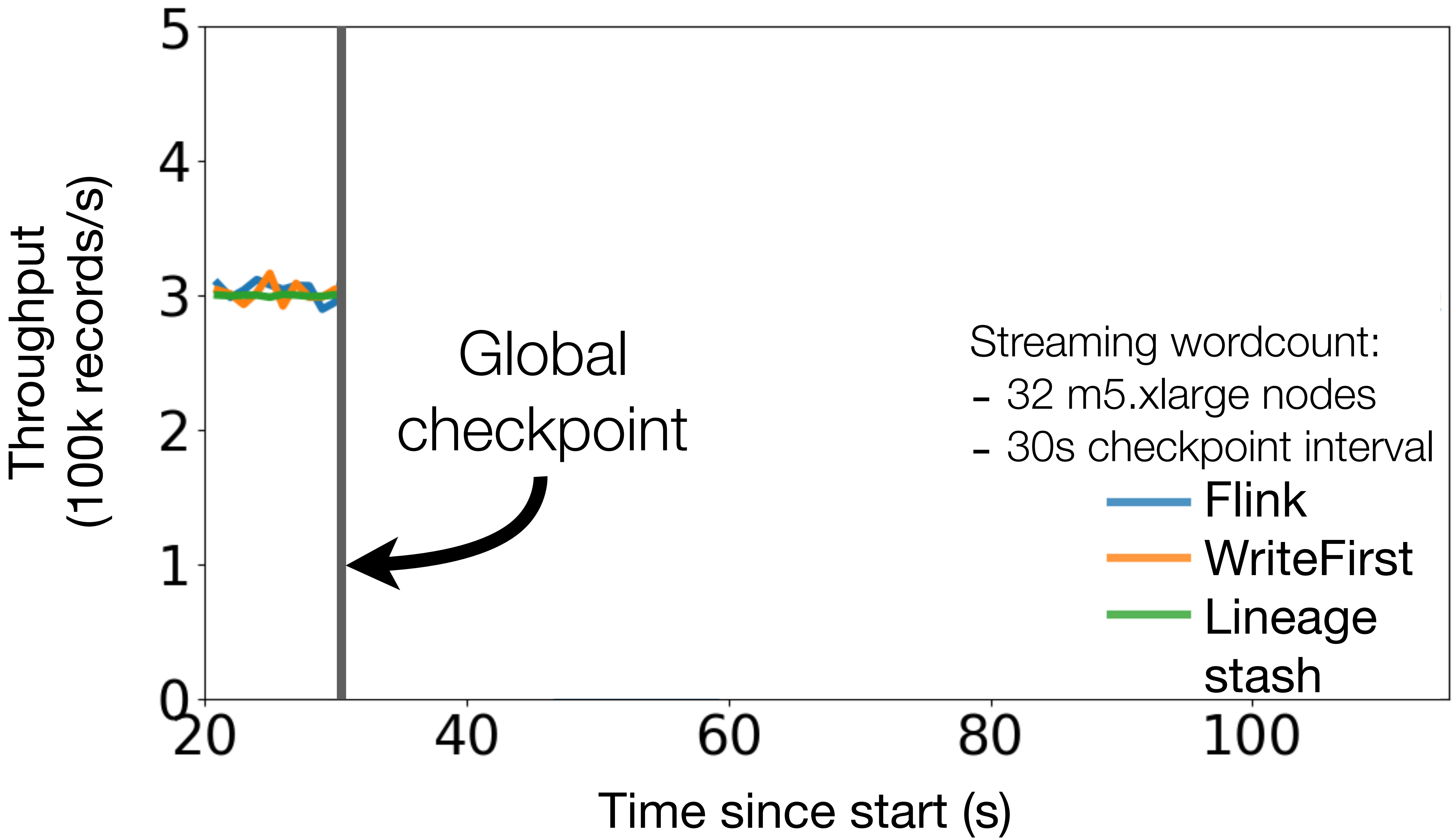

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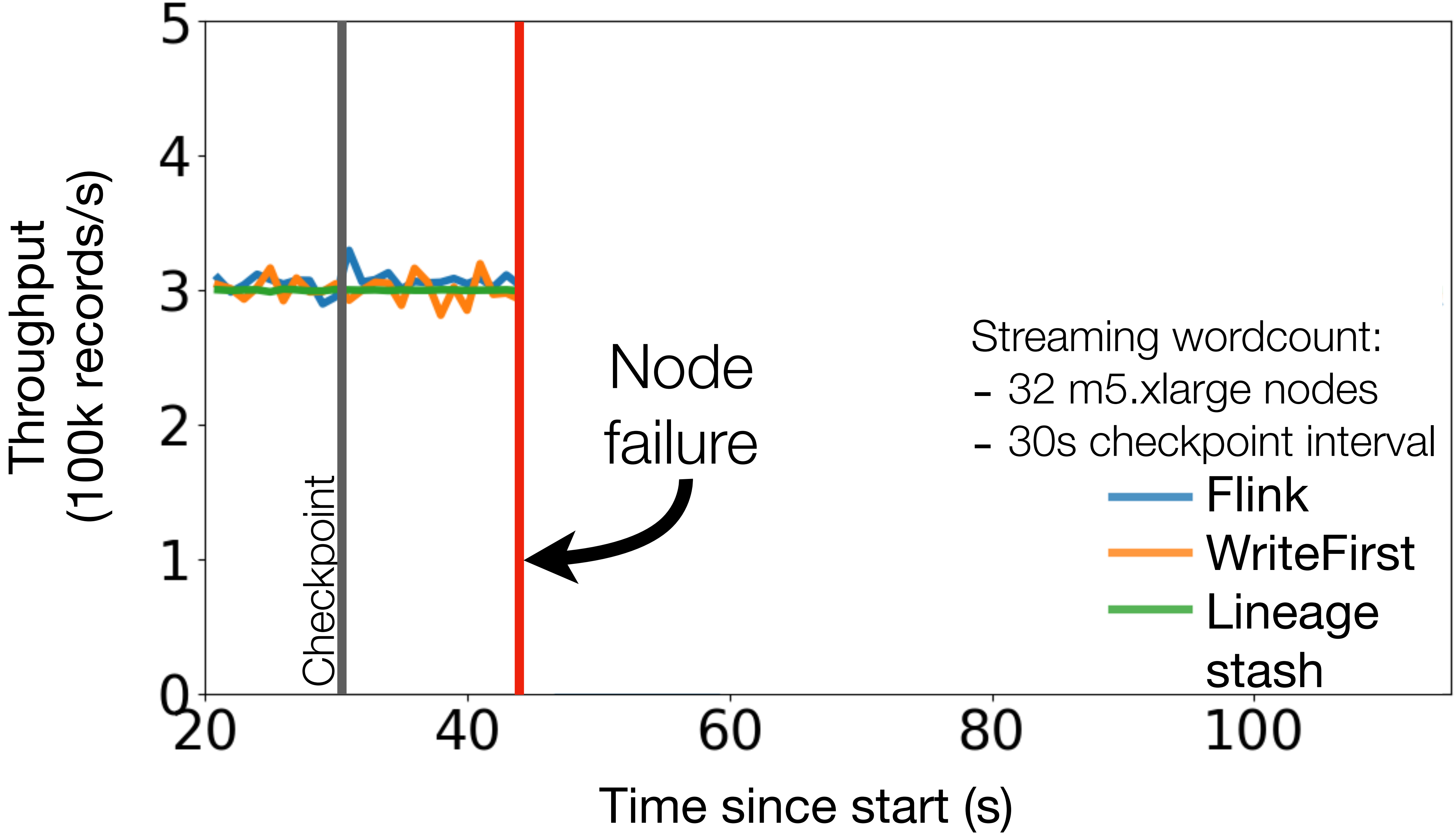

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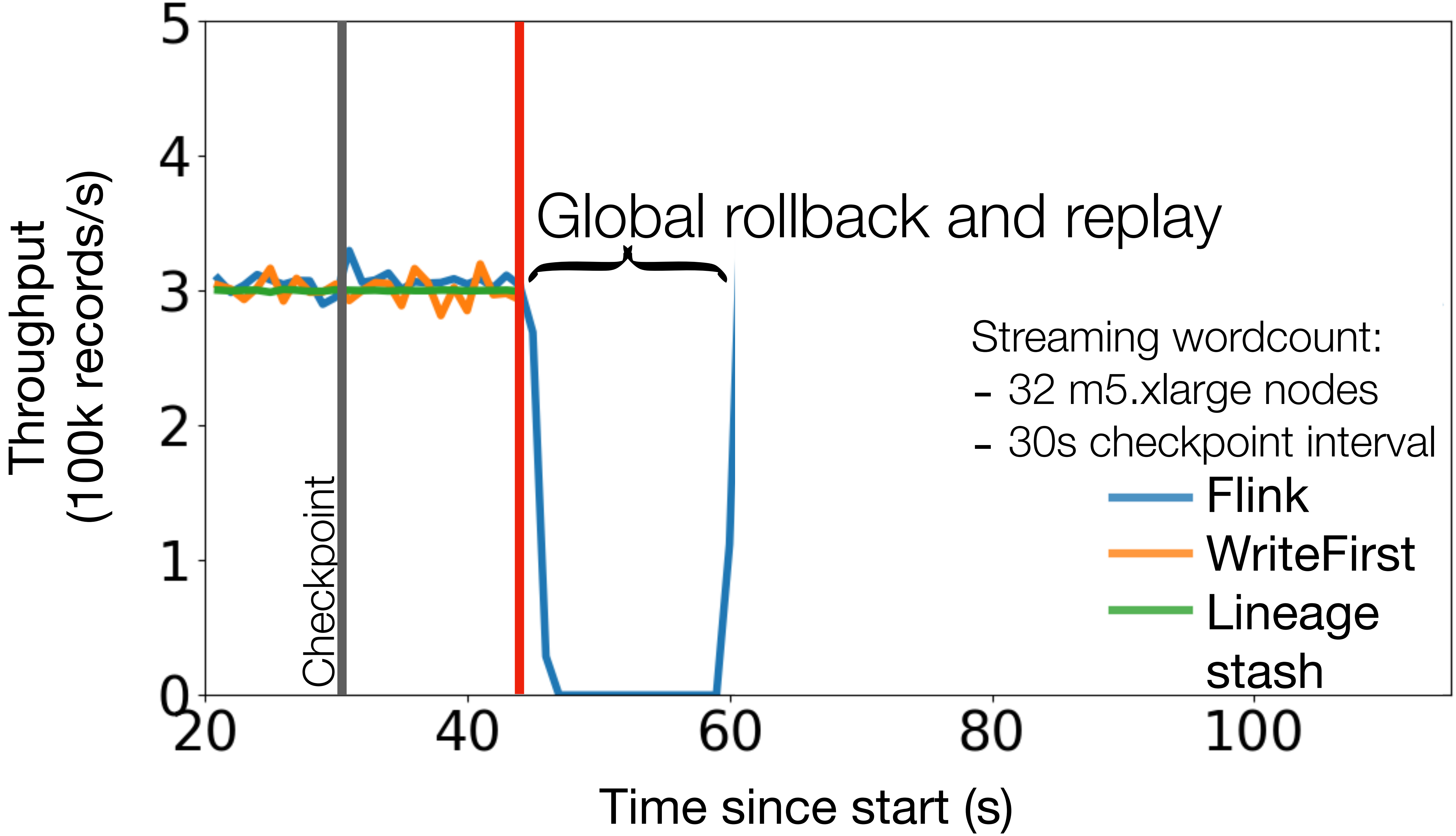

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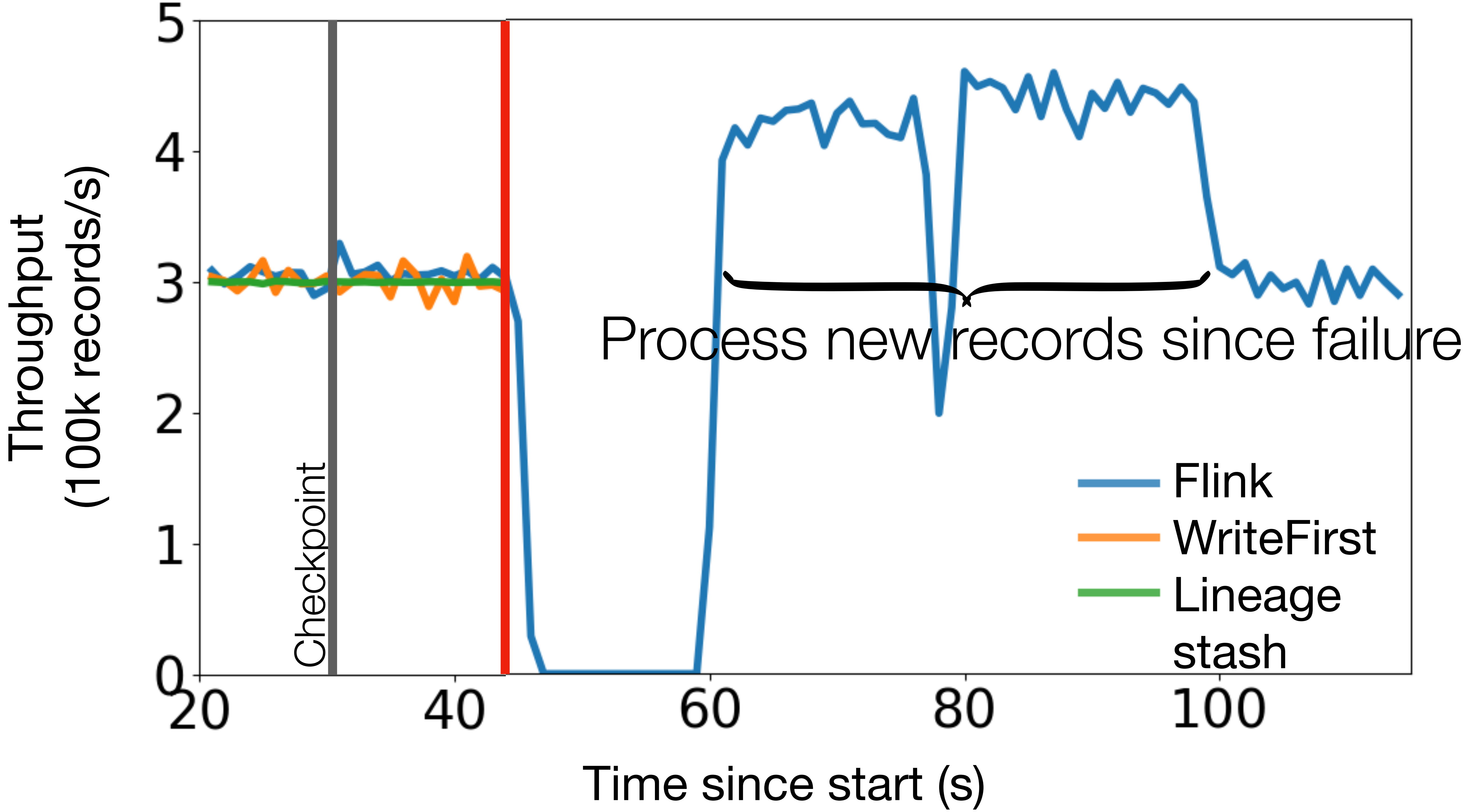
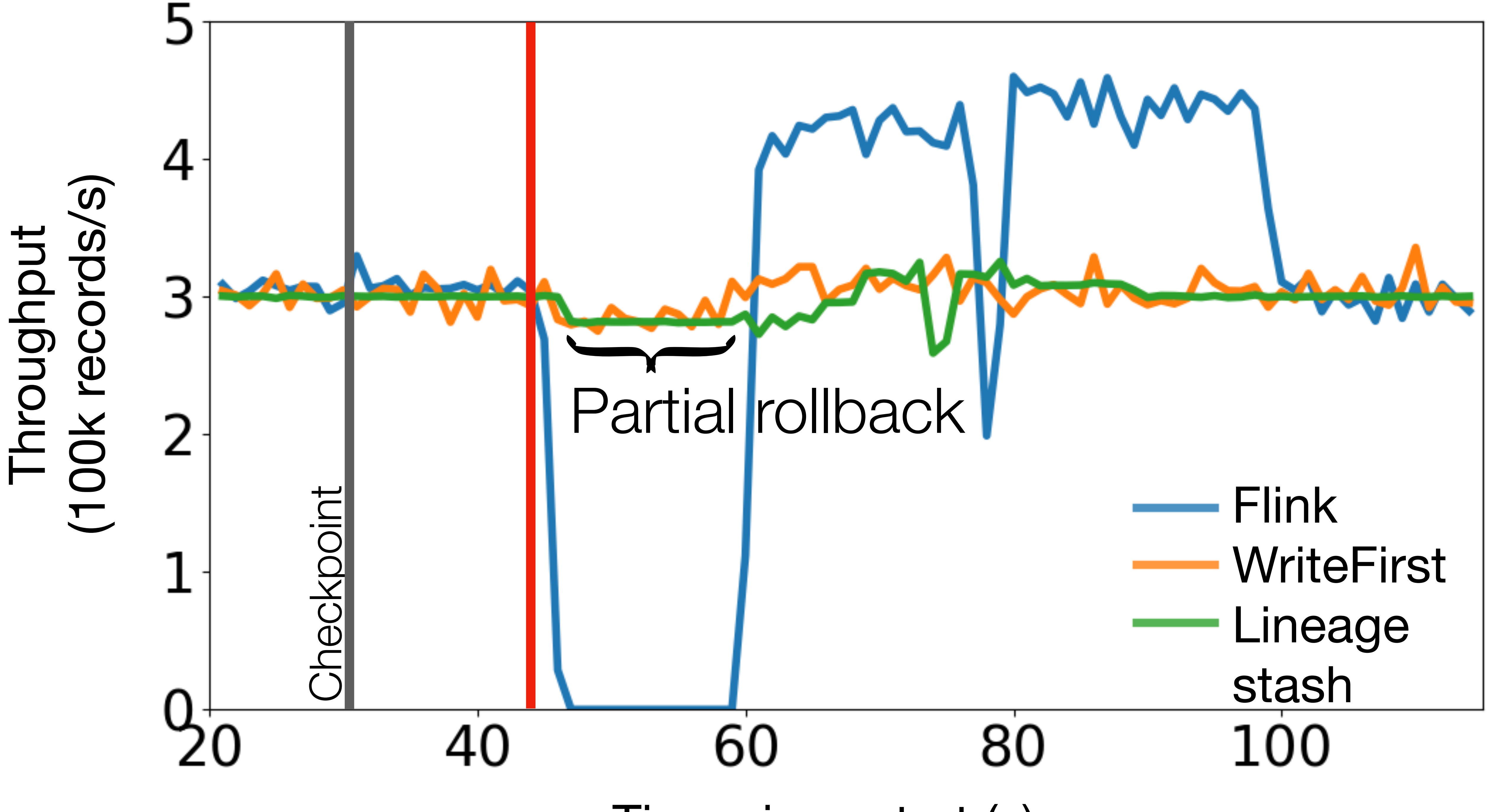
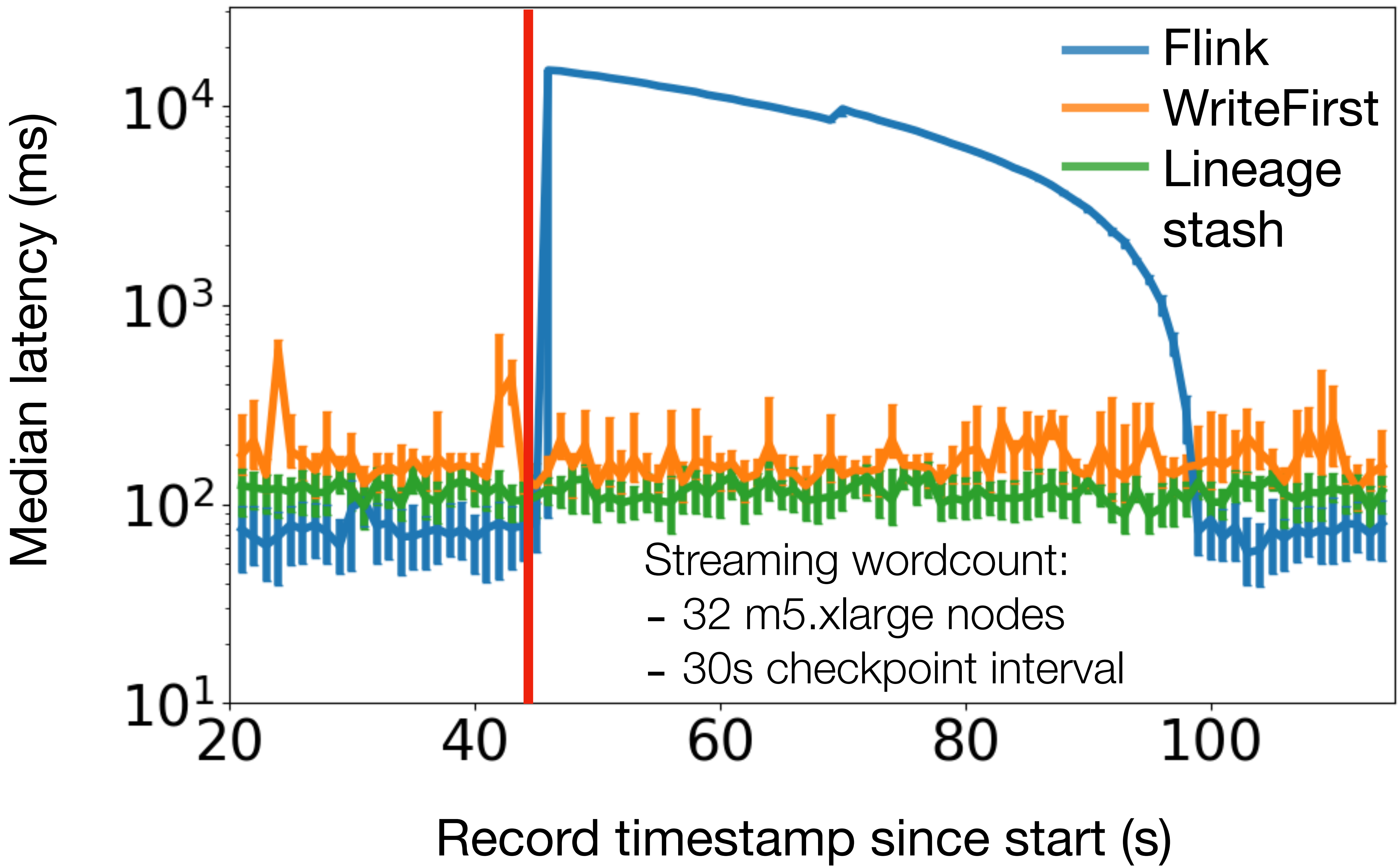


Throughput during recovery



Latency during recovery



Lineage Stash

See the paper (or email me: swang@berkeley.edu) for:

- Discussion and evaluation of other applications
- Nondeterminism in data processing applications
- Protocols for flushing and recovering the stash

Key idea: **Asynchronously** log the **lineage** and forward **uncommitted** lineage to guarantee recovery correctness.

Low latency during execution and low downtime after a failure for large-scale decentralized data processing applications.