TECHNISCHE UNIVERSITÄT DRESDEN

Department of Computer Science Institute for Systems Architecture, Systems Engineering Group

Minimizing Latency in Fault-Tolerant Distributed Stream Processing Systems

Andrey Brito[1], Christof Fetzer[1], Pascal Felber[2]

[1] Technische Universität Dresden, Germany
[2] Université de Neuchâtel, Switzerland

ICDCS'09, June 23rd, 2009

Goal

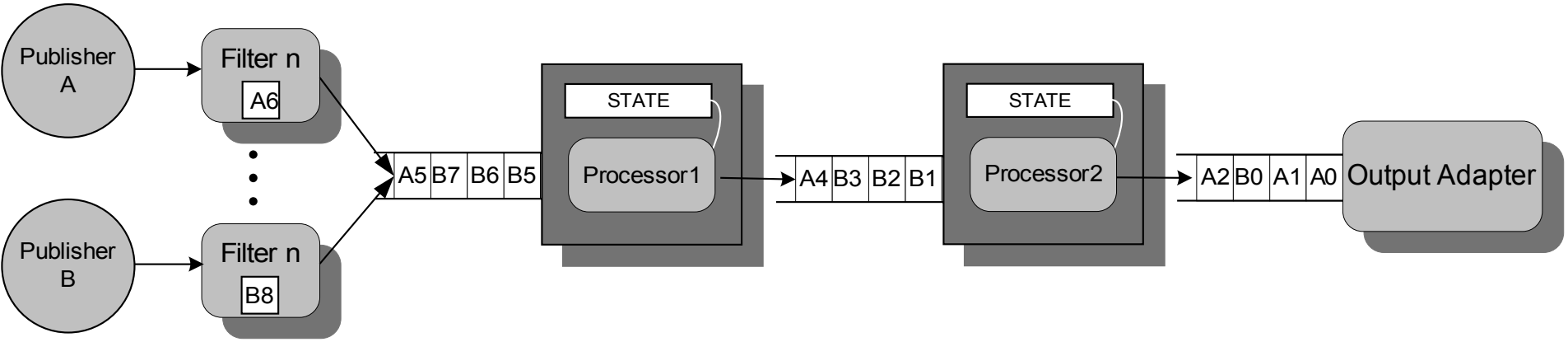
Minimize the cost of logging/checkpointing in event stream processing systems

Contribution: Usage of an speculation framework based on transactional memory to overlap logging and processing

Motivation (1)

- Event stream applications
  - Directed acyclic graph of operators
  - Some operators don't keep state
    - Trivially parallelizable
  - Some do keep state
    - Not trivially parallelizable
  - Sometimes they are order sensitive
    - Need to process events sequentially, maybe even waiting for the order to be restored

Application example



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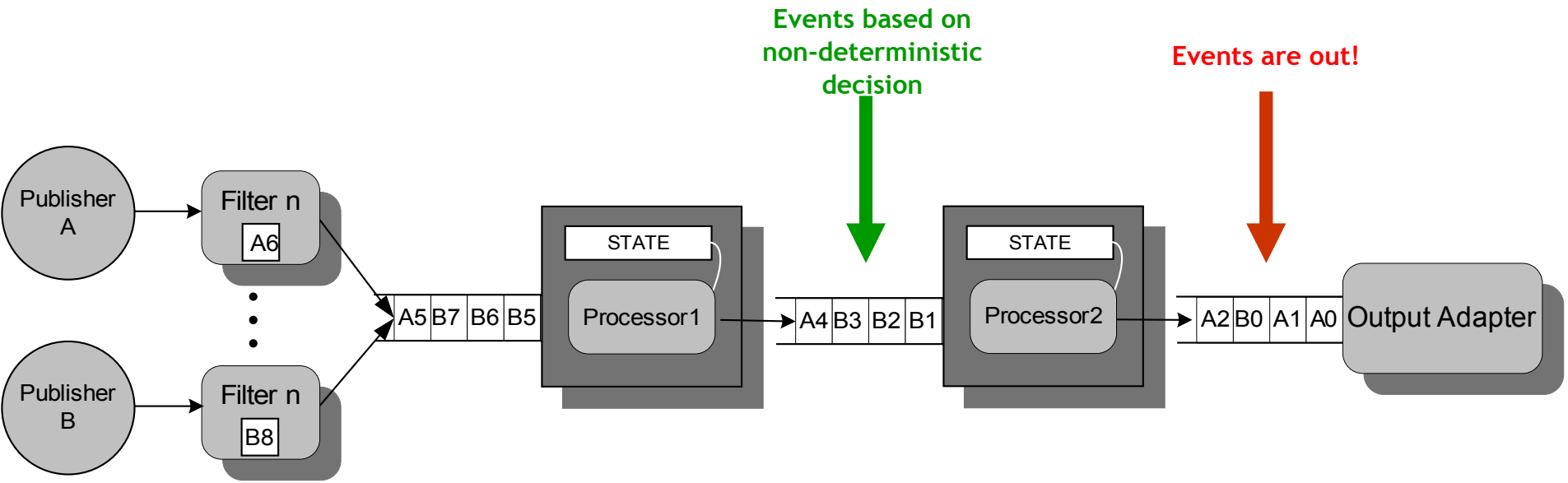

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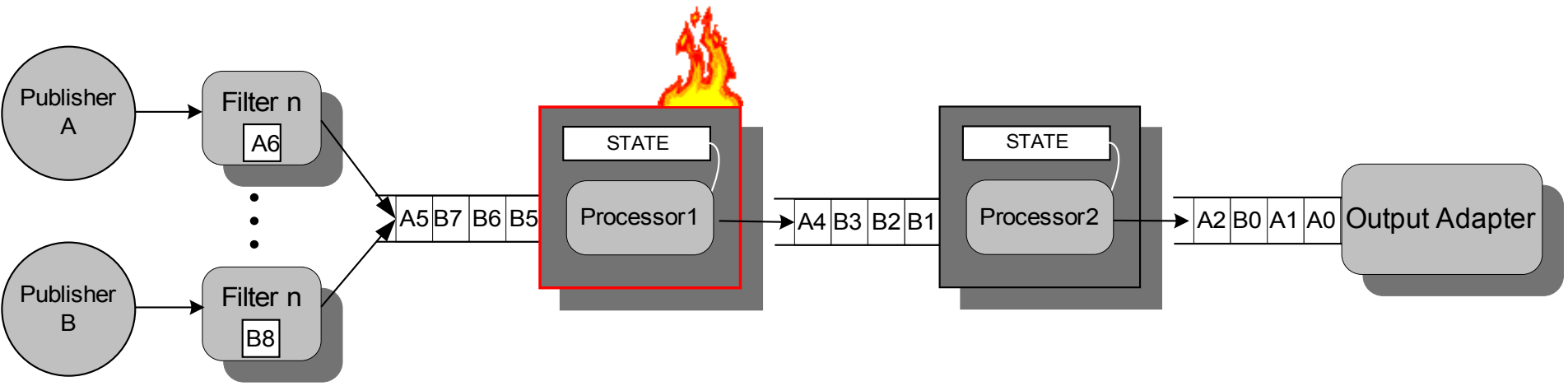

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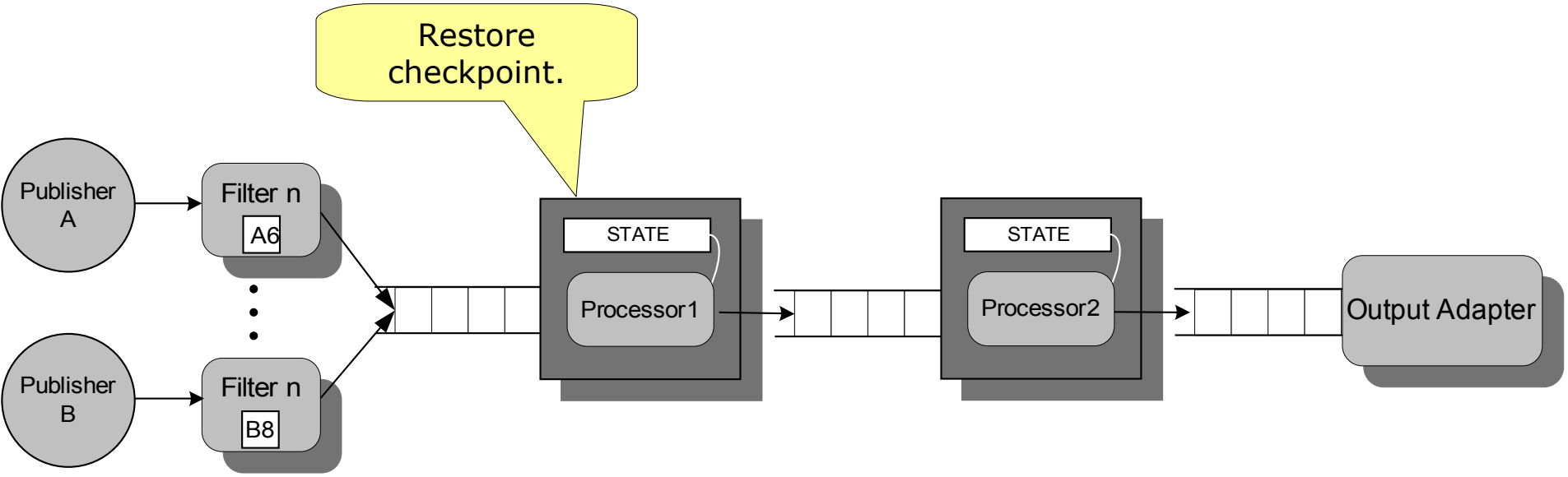

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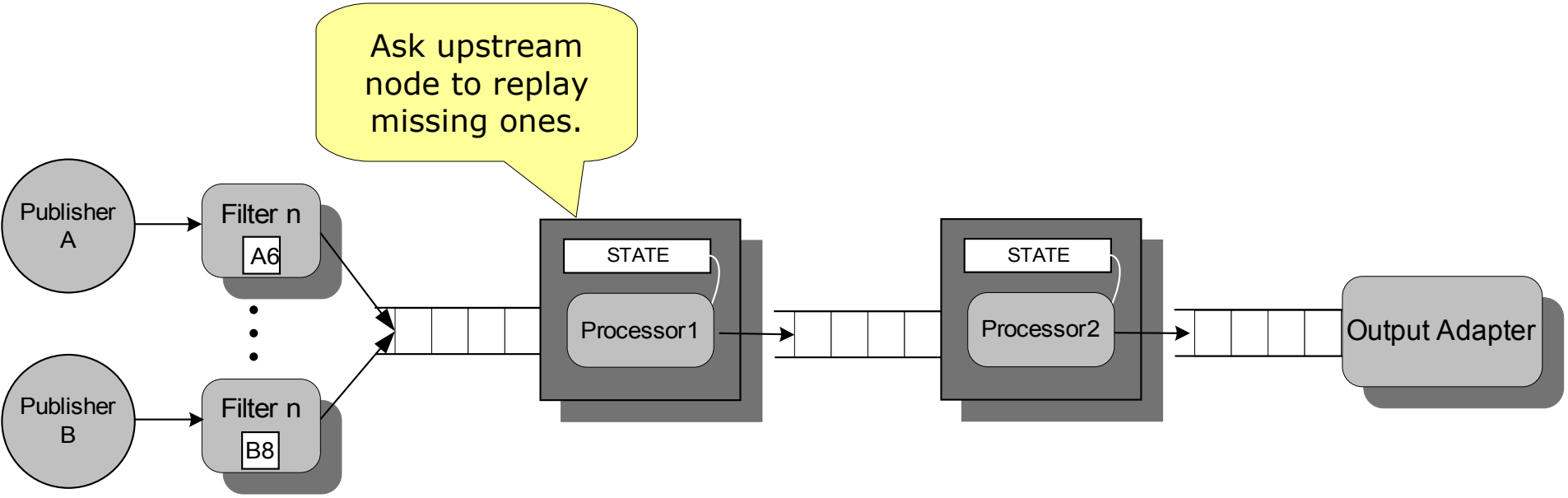

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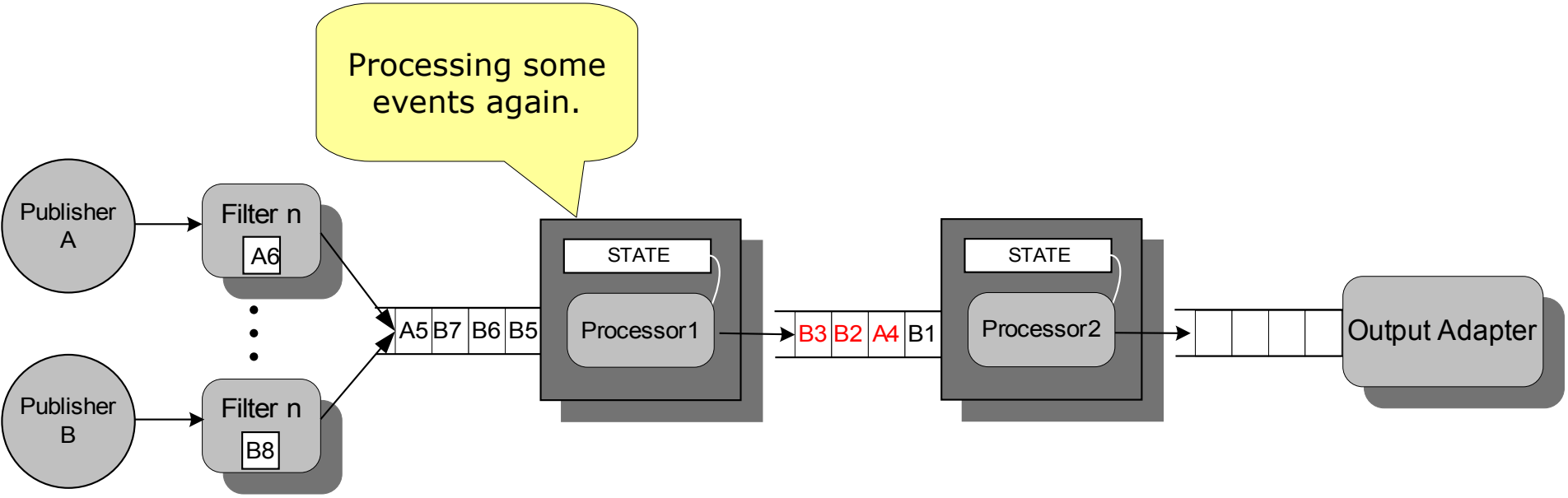

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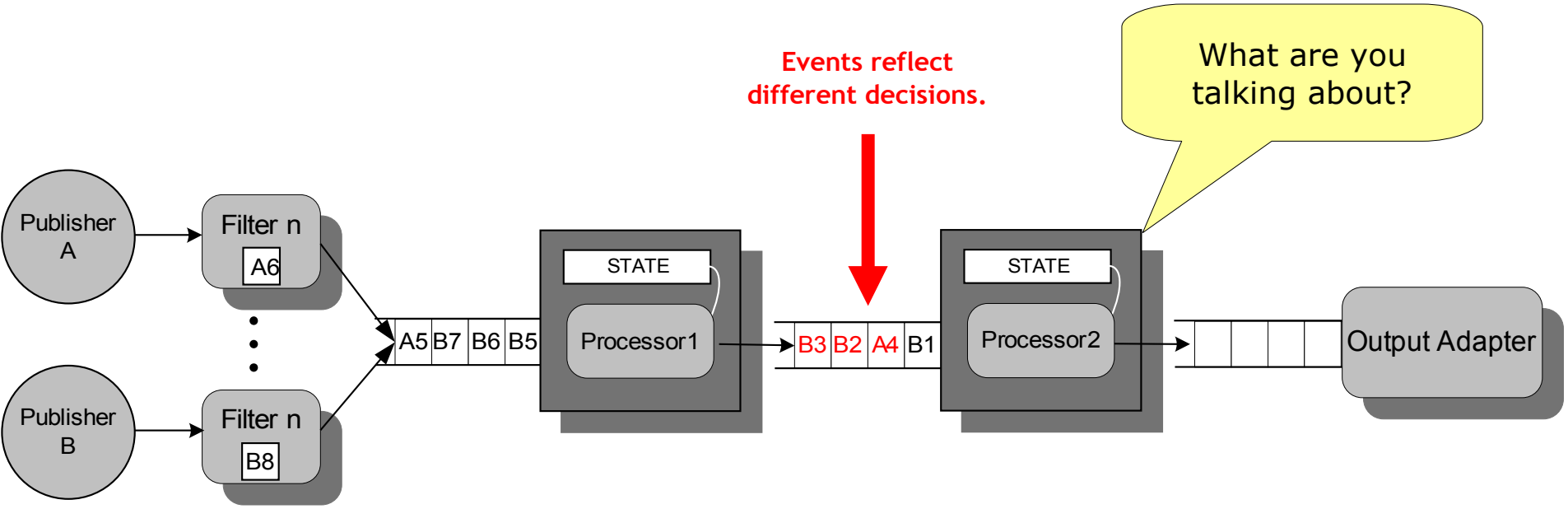
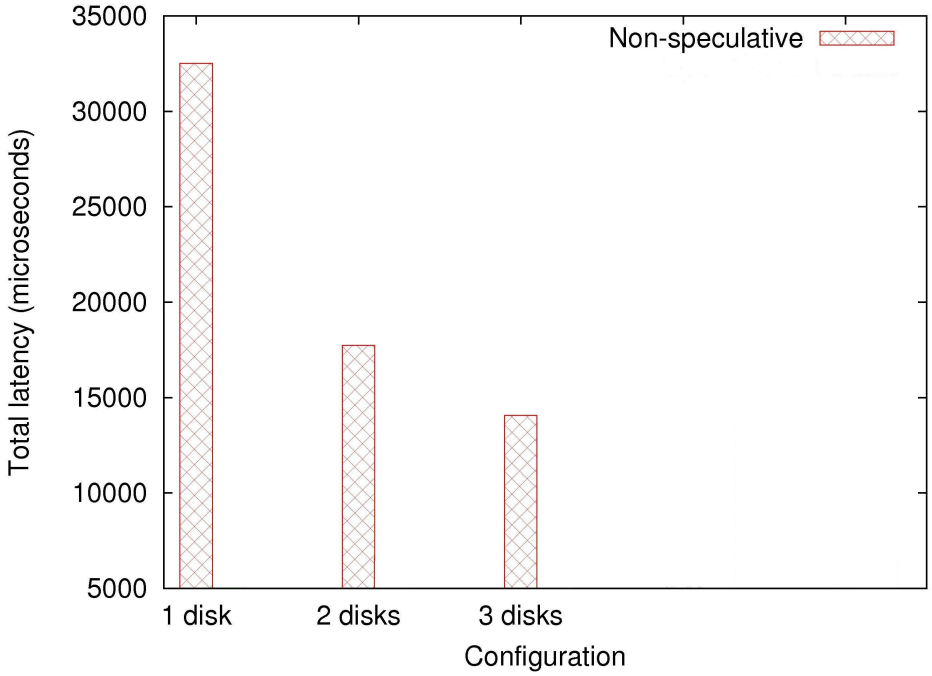


Incomplete log of non-deterministic decisions → no repeatability

Motivation (2)

- Fault-tolerant event stream applications
  - Precise recovery
  - Even if order does not matter, repeatability does
  - Non-determinism
    - Input order from different streams
    - Non-determinism in processing (multi-threading, time, random numbers)
  - Log or checkpoint before each output

Logging is expensive



My solution

- Speculate...
- … to parallelize stateful components
- … to not have to wait for events
- … to not have to wait for logging

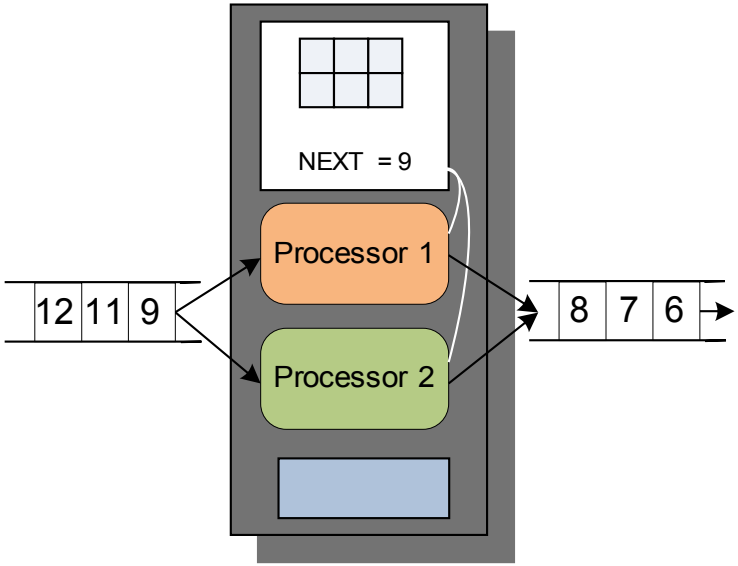
Outline

- How the speculation works
- Logging algorithm
- Experiments
- Final remarks

How the speculation works

- Base: TinySTM
  - Some extra features added
  - But same basic rule: “it appears to be atomic”
- Goal: track accesses to shared memory
  - Instrumentation
    - Reads and writes are intercepted
    - Hold back writes, validate reads until all dependencies satisfied

Speculative execution: parallelization



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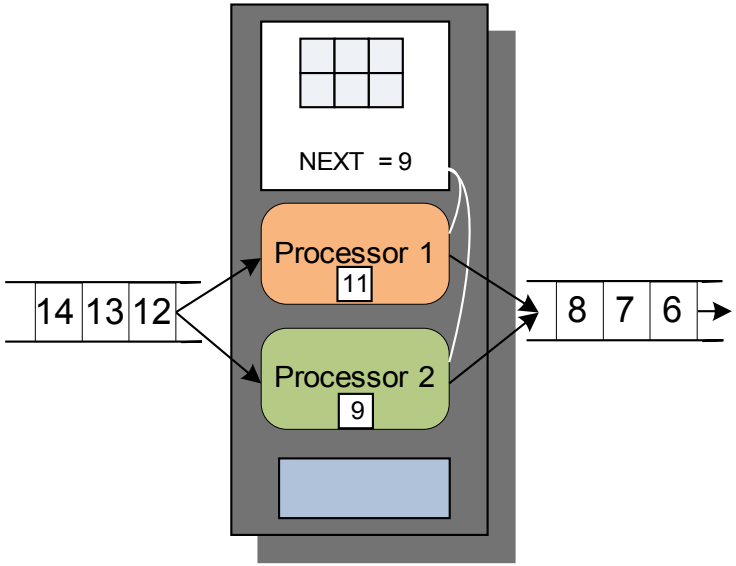

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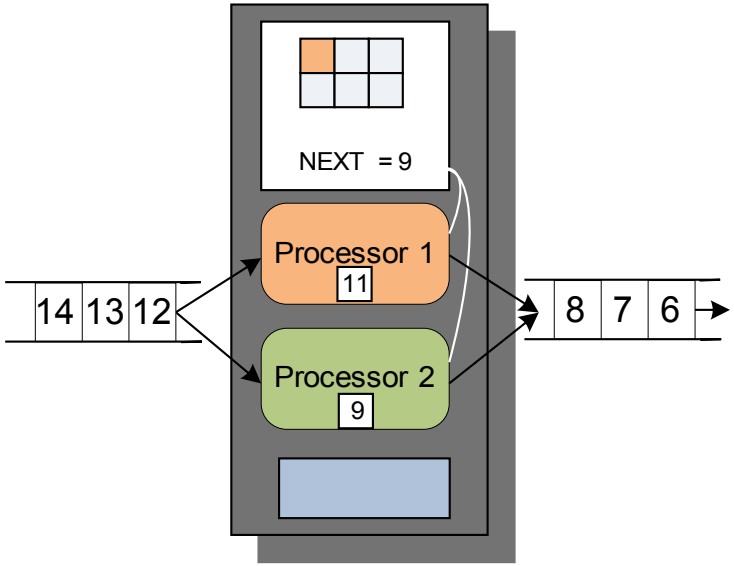

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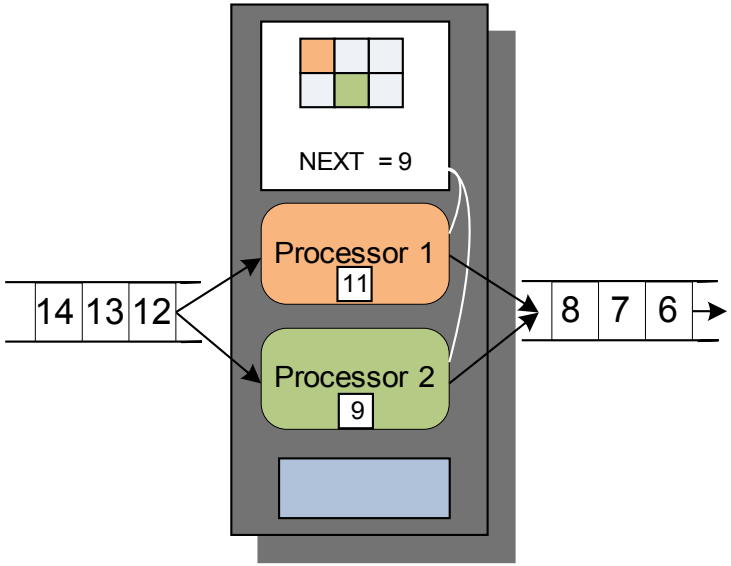

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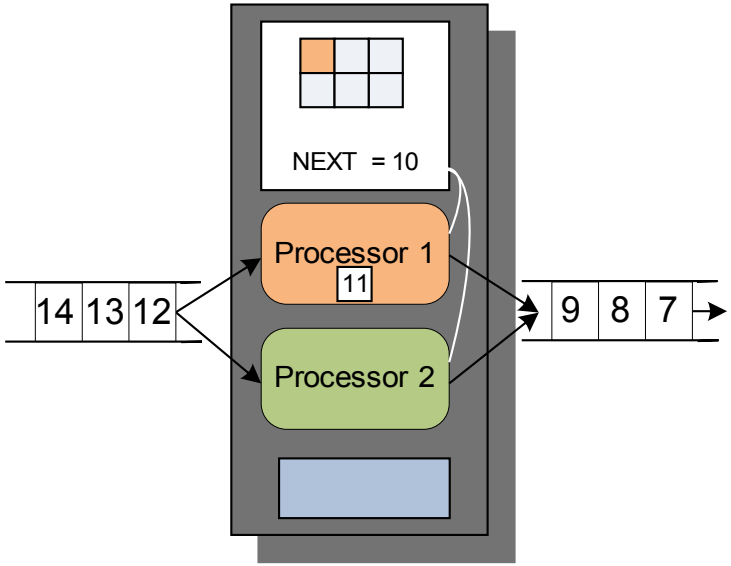
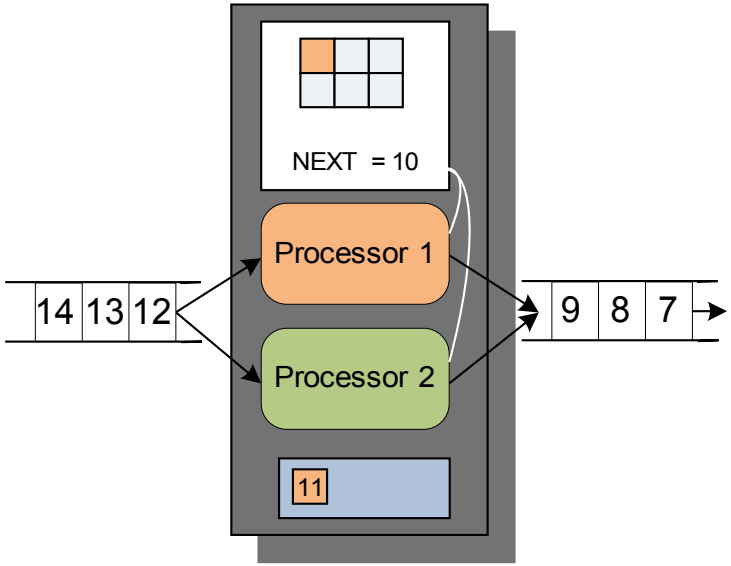


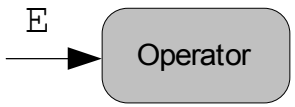
Speculative execution: parallelization

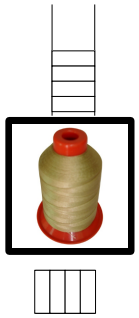


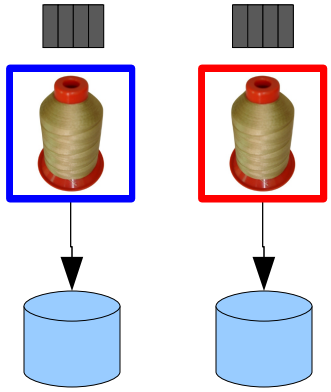
Logging algorithm

- Operator enqueues all events & decisions
- N+1 threads for N disks
  - One groups requests in a buffers
  - The others write their buffers to disk

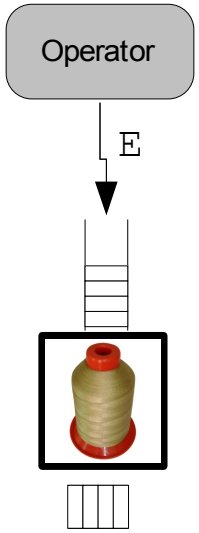
Logging algorithm

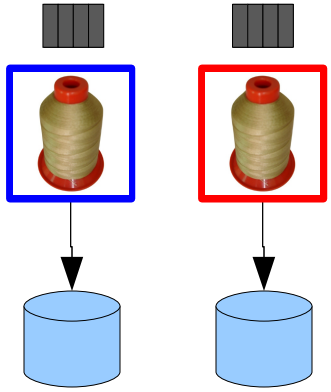






Logging algorithm





Logging algorithm

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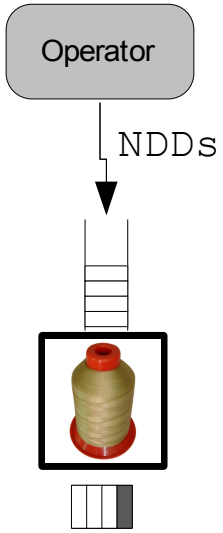

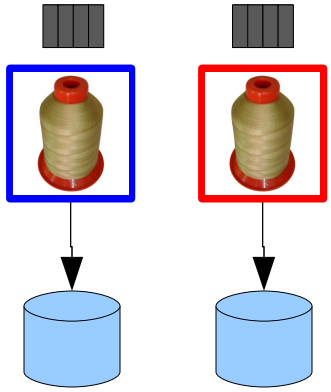

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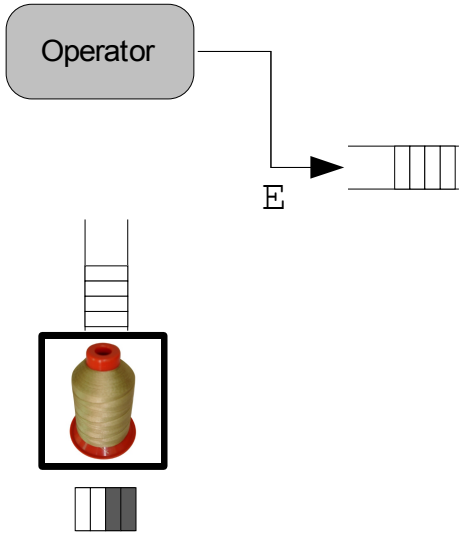

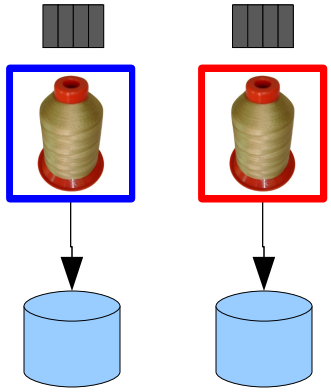

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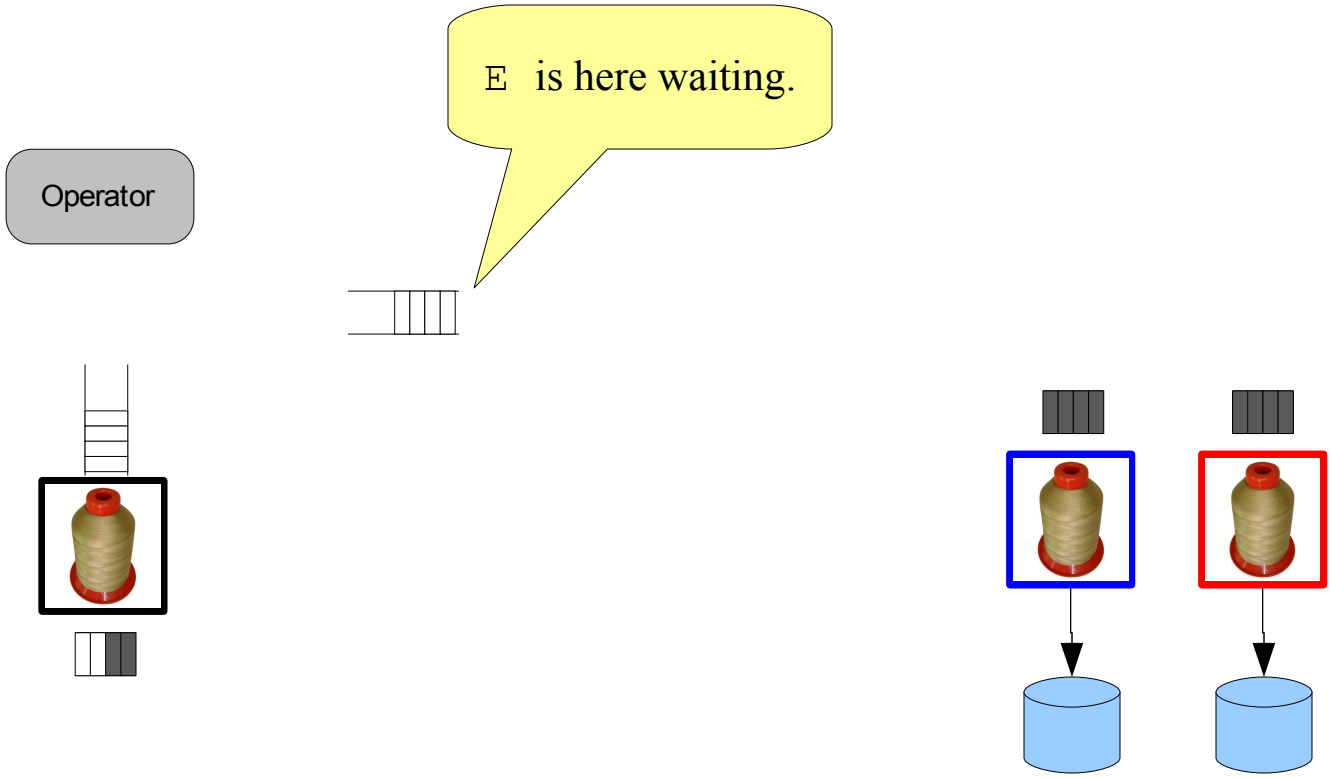

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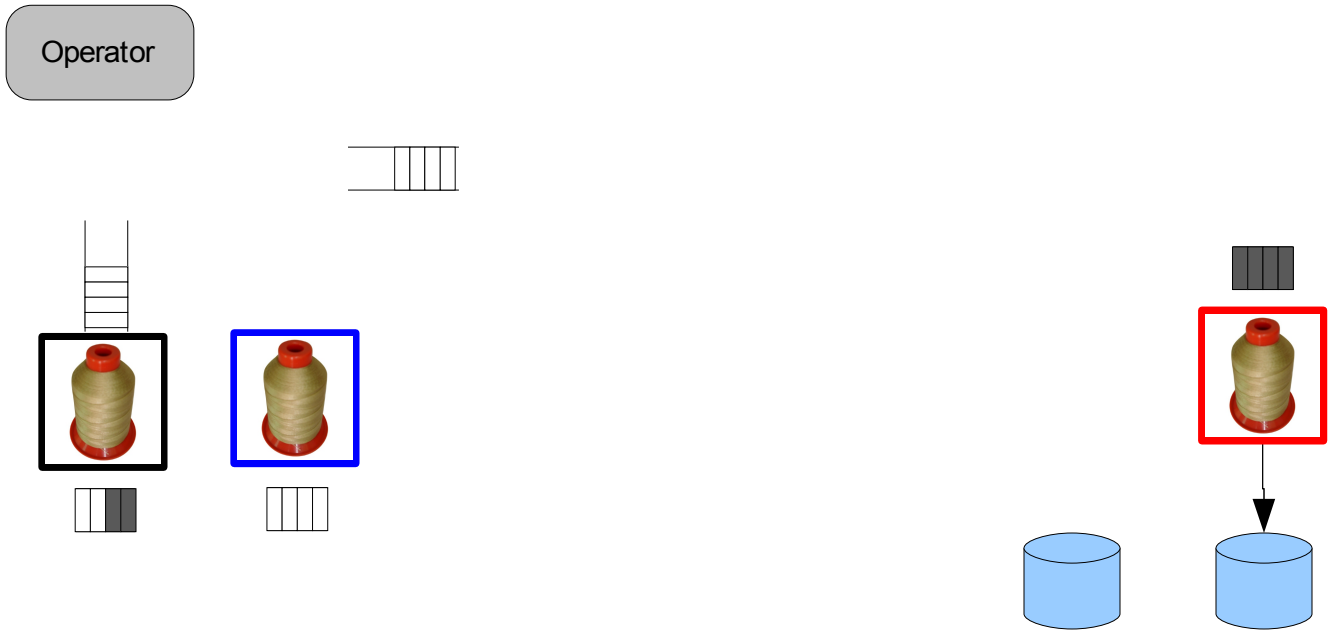

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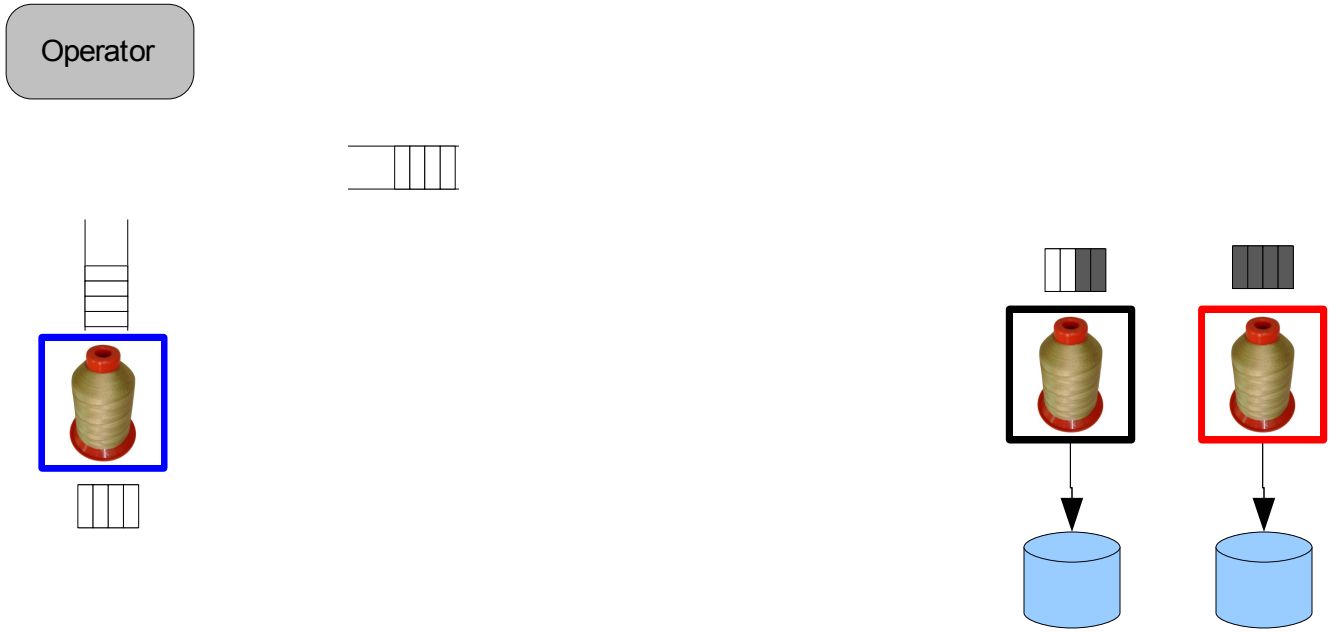

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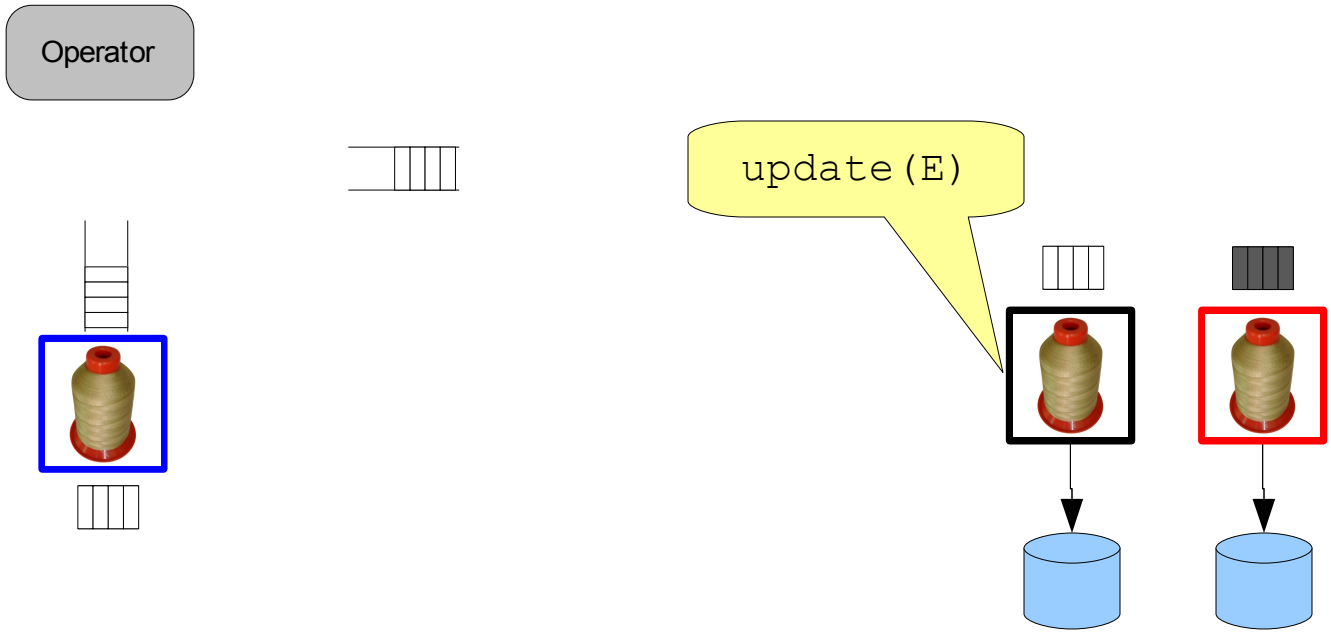

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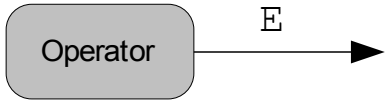

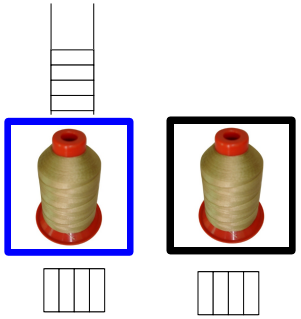

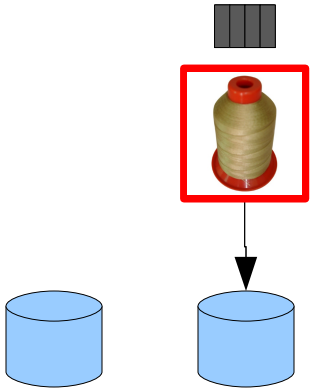

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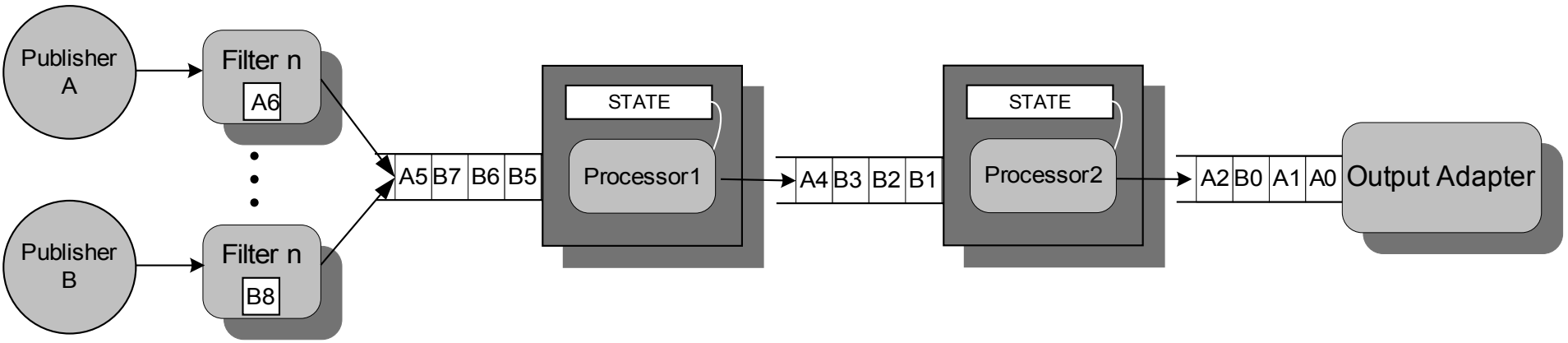

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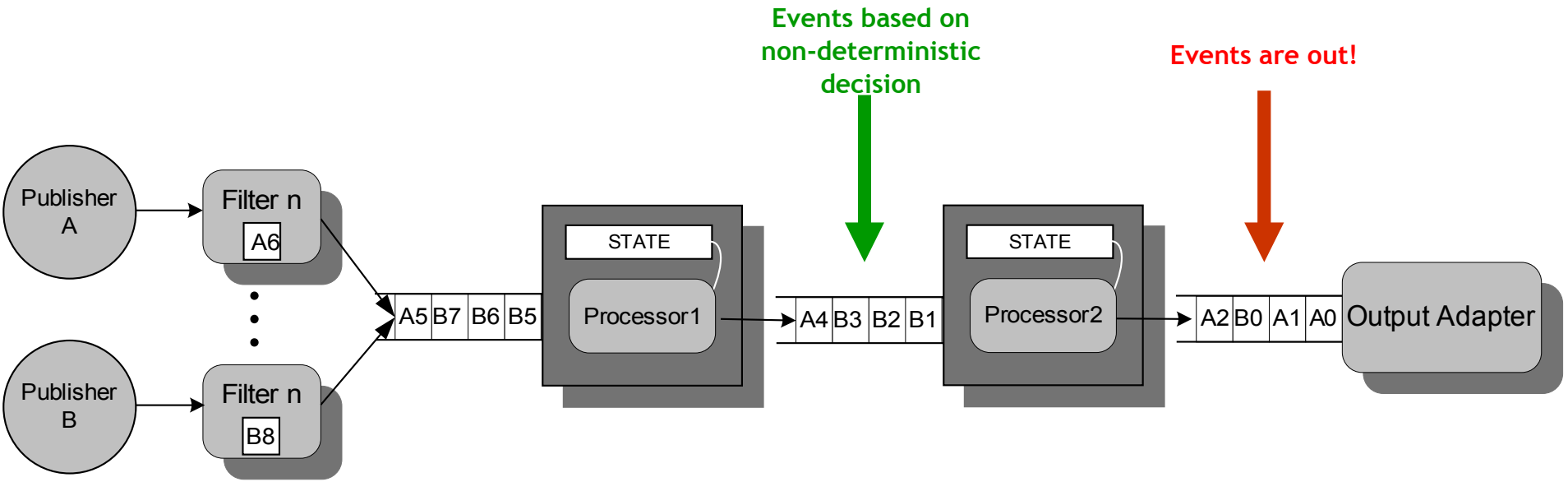

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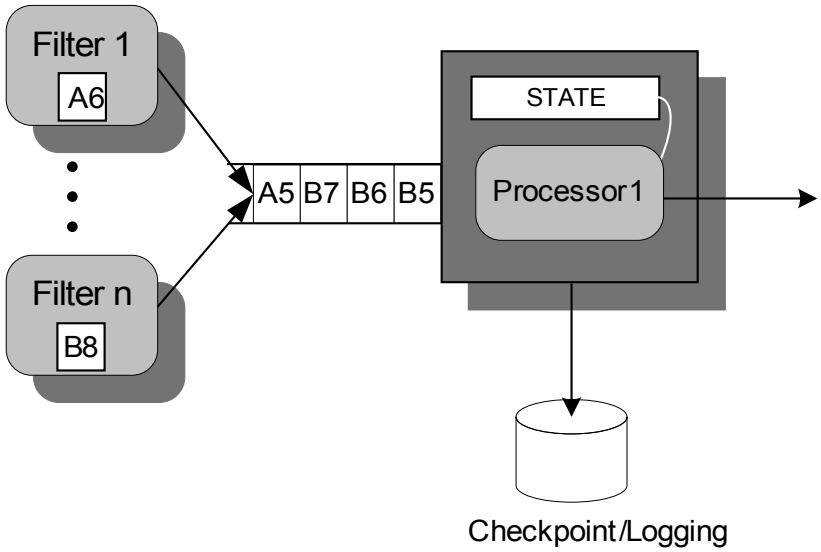

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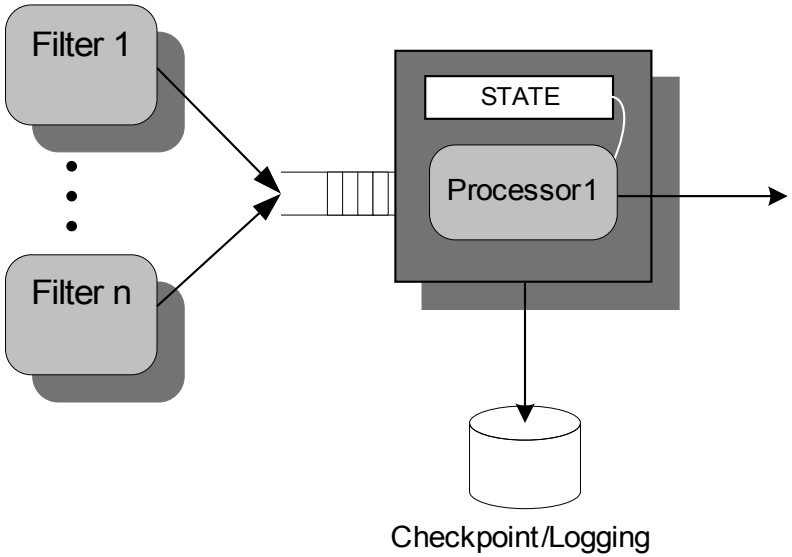

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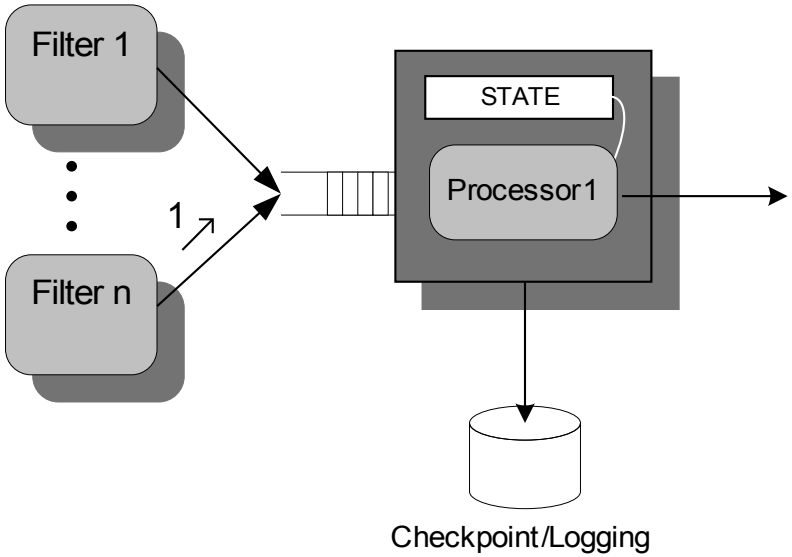

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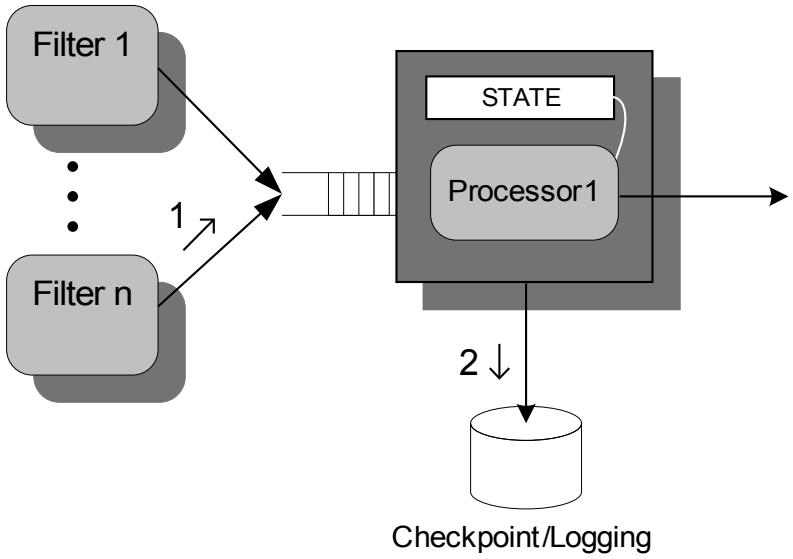

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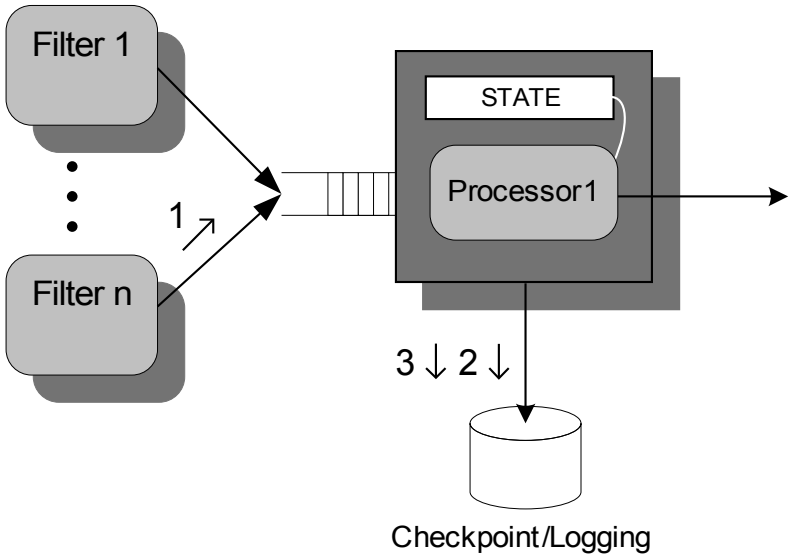

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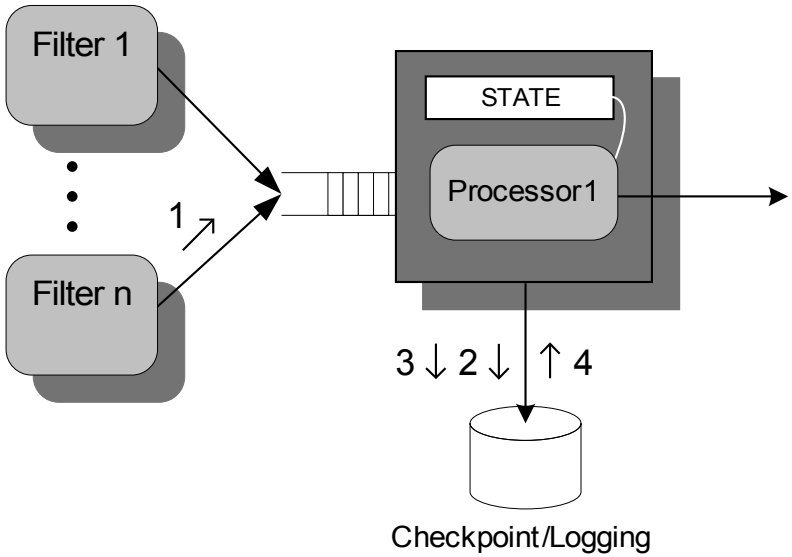

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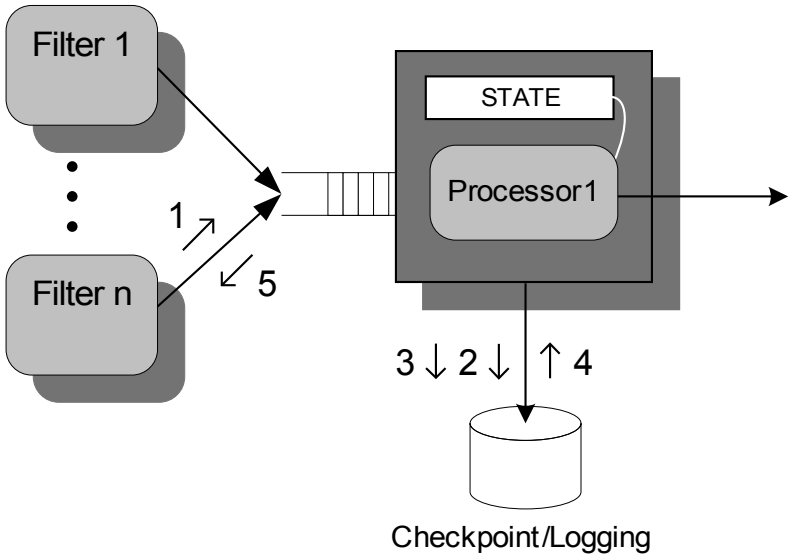

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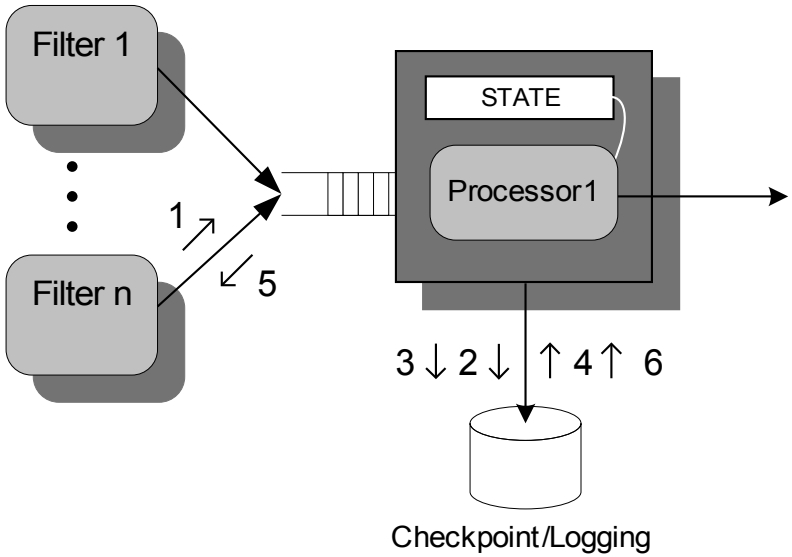

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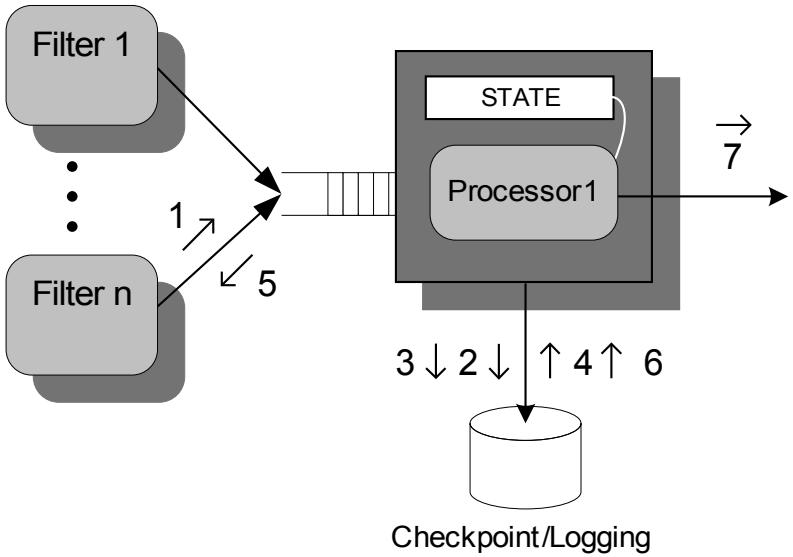
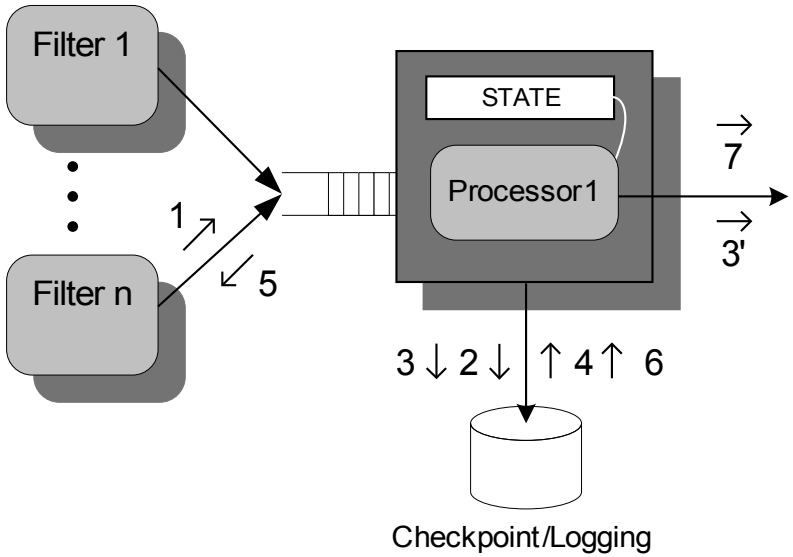


Speculative processing + Logging

- From the original node's viewpoint
  - Emit outputs as speculative
  - When logging requests are acknowledged, emit final
- The next downstream node
  - If speculative event modifies some state, keep track
    - Outputs that consider that part of the state are speculative
    - Speculative status is contagious

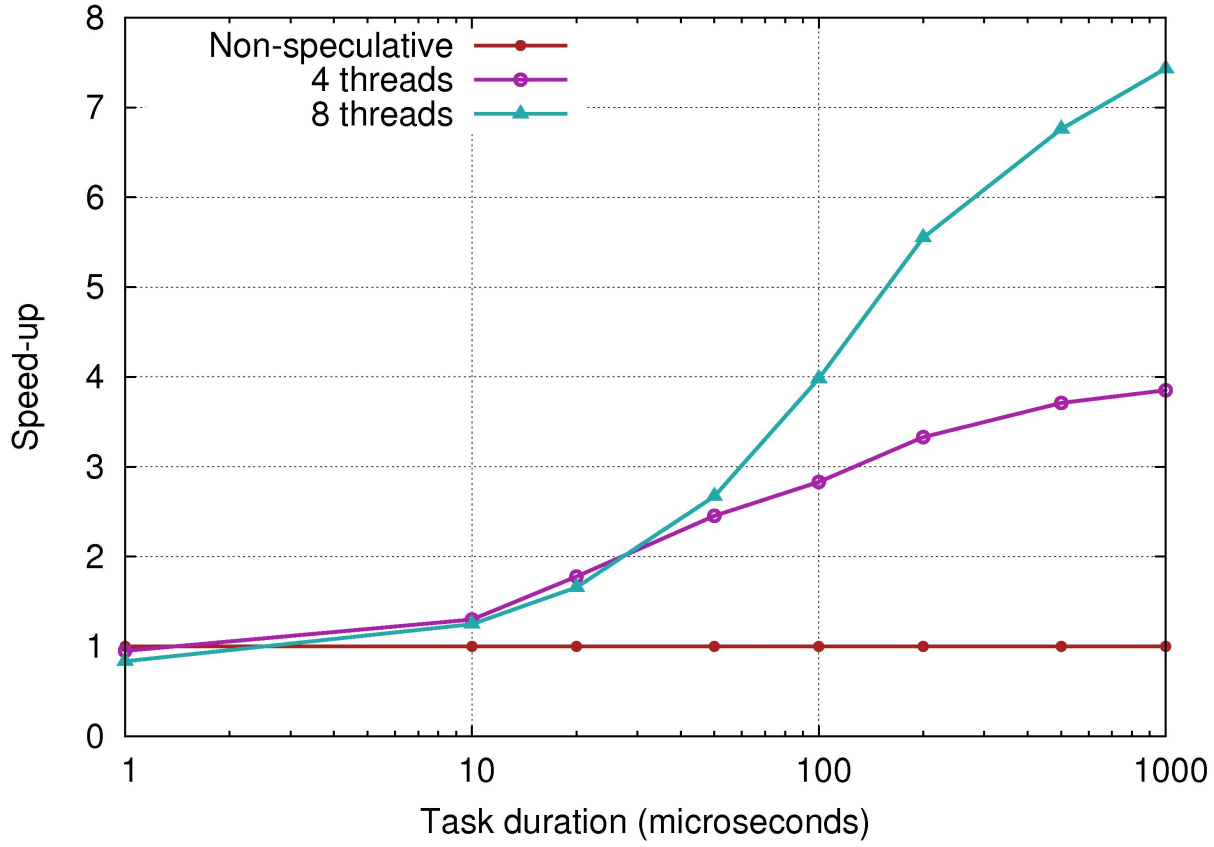
Speculation + Logging



Experiments

- Parallelization: benefits & STM's overheads
- Optimism control
- Overlapping processing and logging

Speculation costs & speed-ups



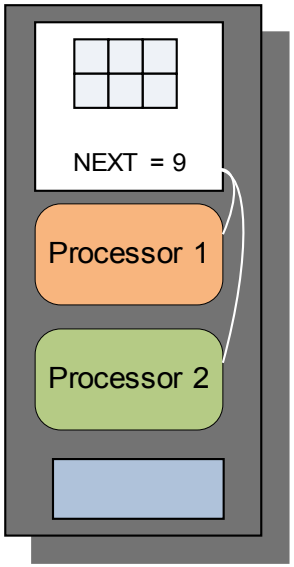
Hardware: Sun T1000

Speculation creation-commit-disposal overheads.

Few shared-memory accesses.

Amdahl's law influence.

Controlling optimism



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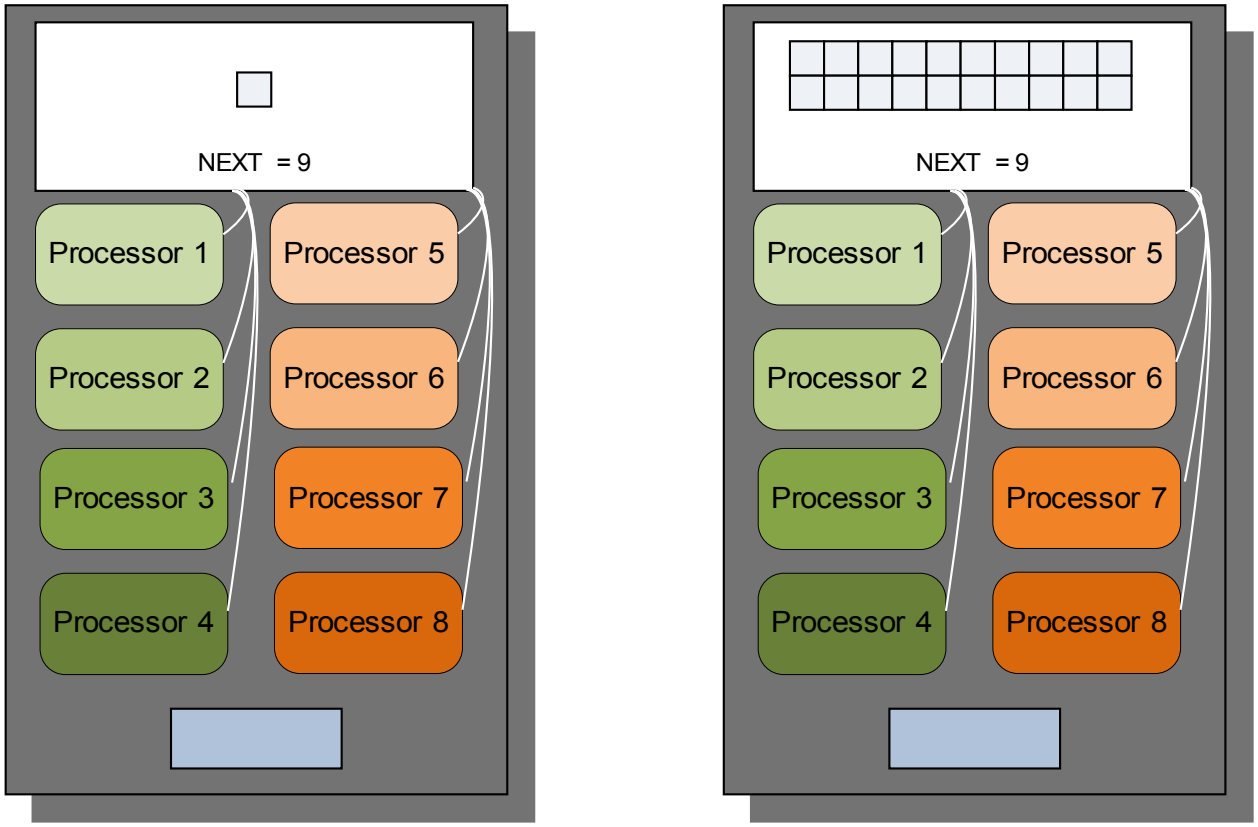
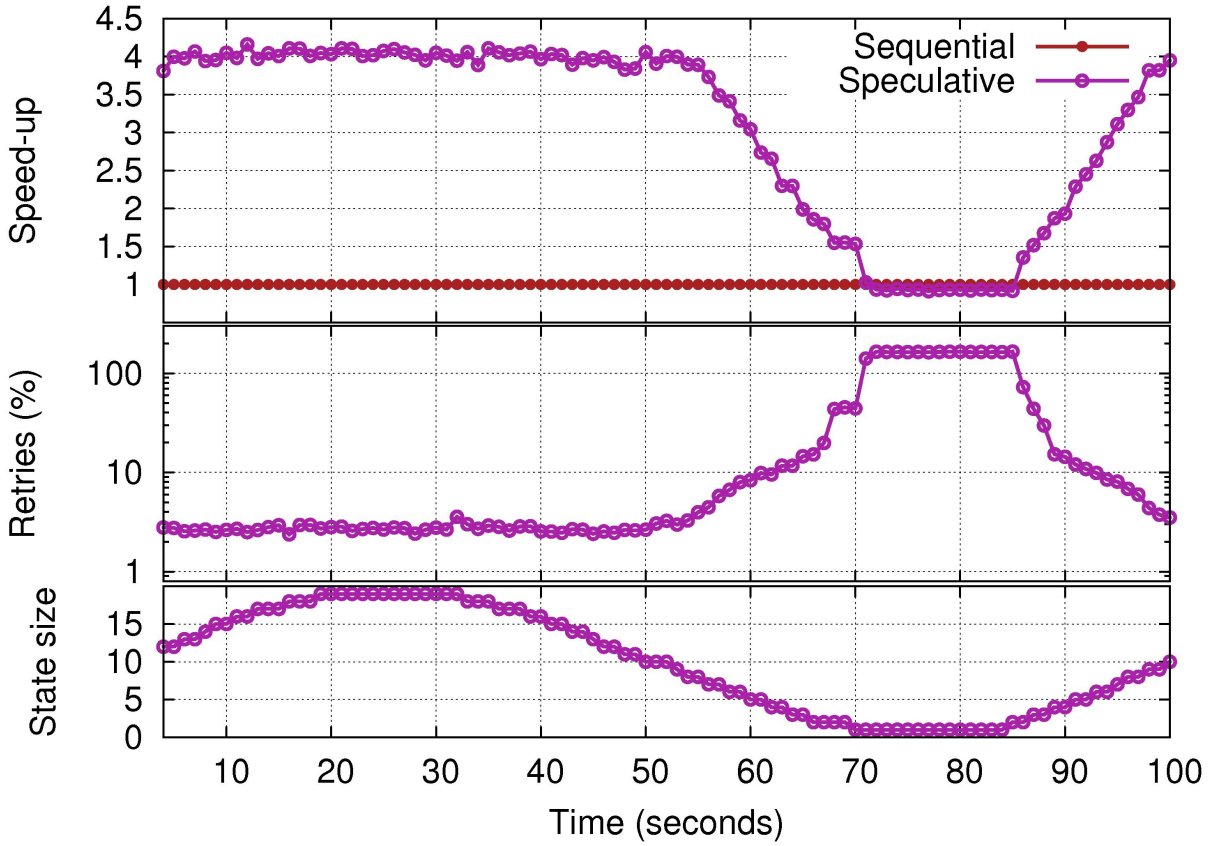


Controlling optimism



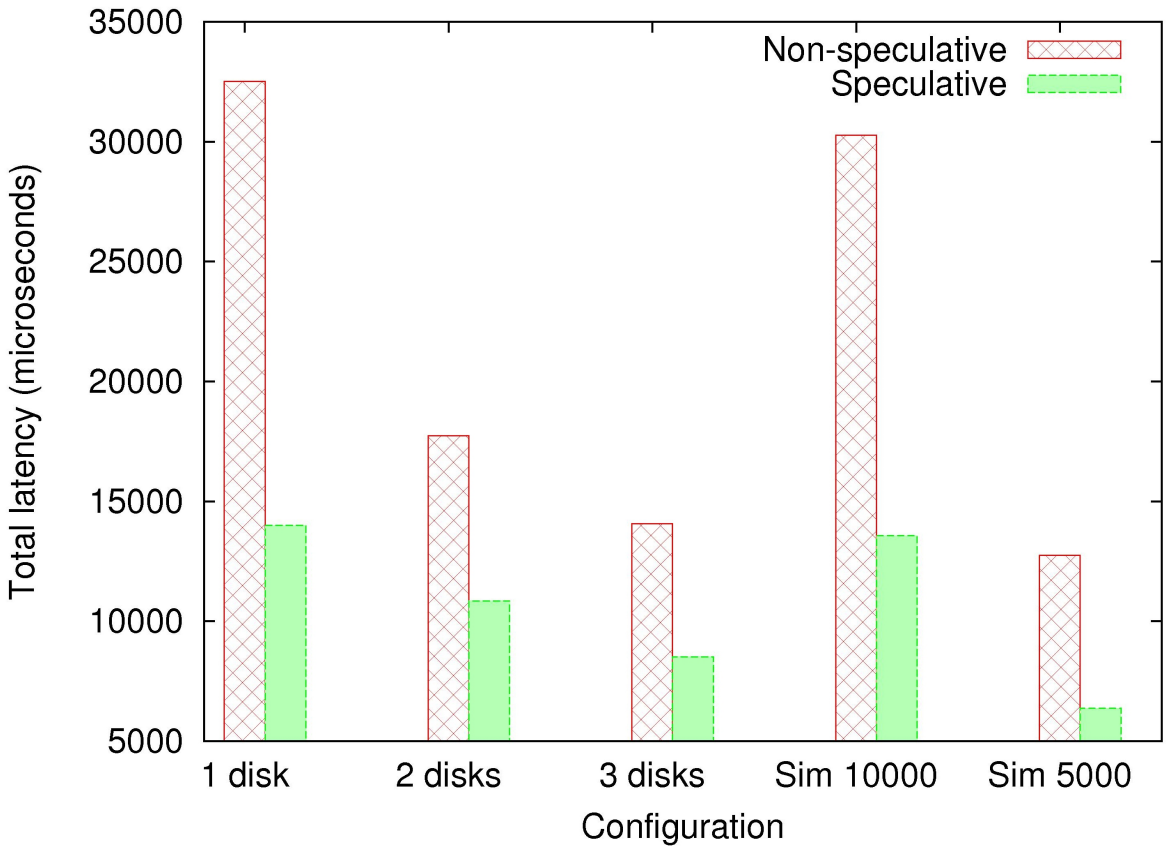
Hardware: SUN T1000

State size varies between 1 and 20.

Size=1: concurrent executions will conflict.

Size=20: considerable parallelism.

Motivation for distributed speculation: logging costs

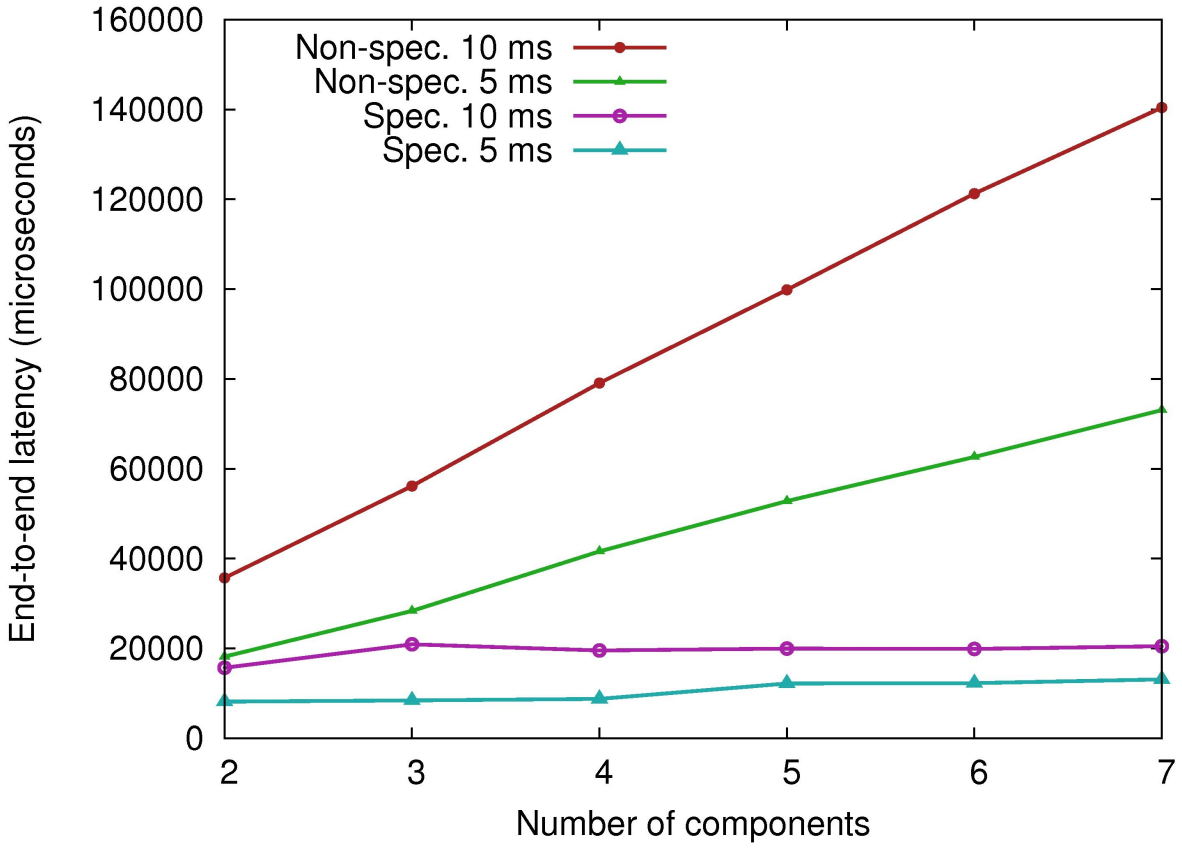


2 components do logging.

Non-speculative: only stable events are sent.

Speculative: send events before logging is finished.

Accumulated gains



X axis: number of components logging.

Even in a SAN/WAN, the shapes would look similar.

For deterministic components: add "fixed" latency.

Final remarks - Parallelization

- Parallelization through speculation
  - Easier, less bugs
    - Programmer does not need to fight with locks
    - Keeps sequential semantics
  - Waste of resources reduced with optimism control
- Overhead can be much lower with hardware support for TM (e.g., ASF)

Final remarks - Logging

- Overlap logging with processing
  - Independent of available parallelism
  - Distributed speculation possible due to less aborts
  - But do not let speculative results get out of the system
- In combination with speculative parallelization may even reduce logging

Thank you!

http://streammine.inf.tu-dresden.de
http://wwwse.inf.tu-dresden.de