# Flumina: Correct Distribution of Stateful Streaming Computations

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# Motivation

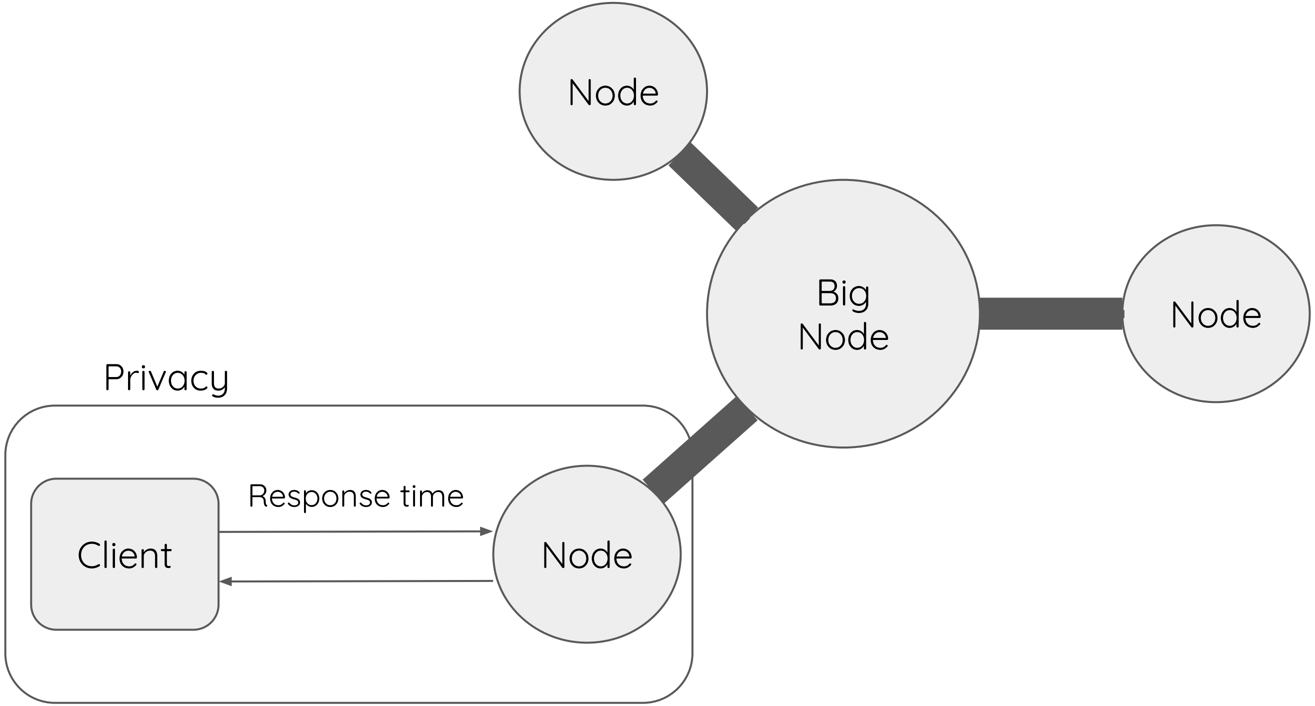
# Stream Processing

Compared to batch processing:

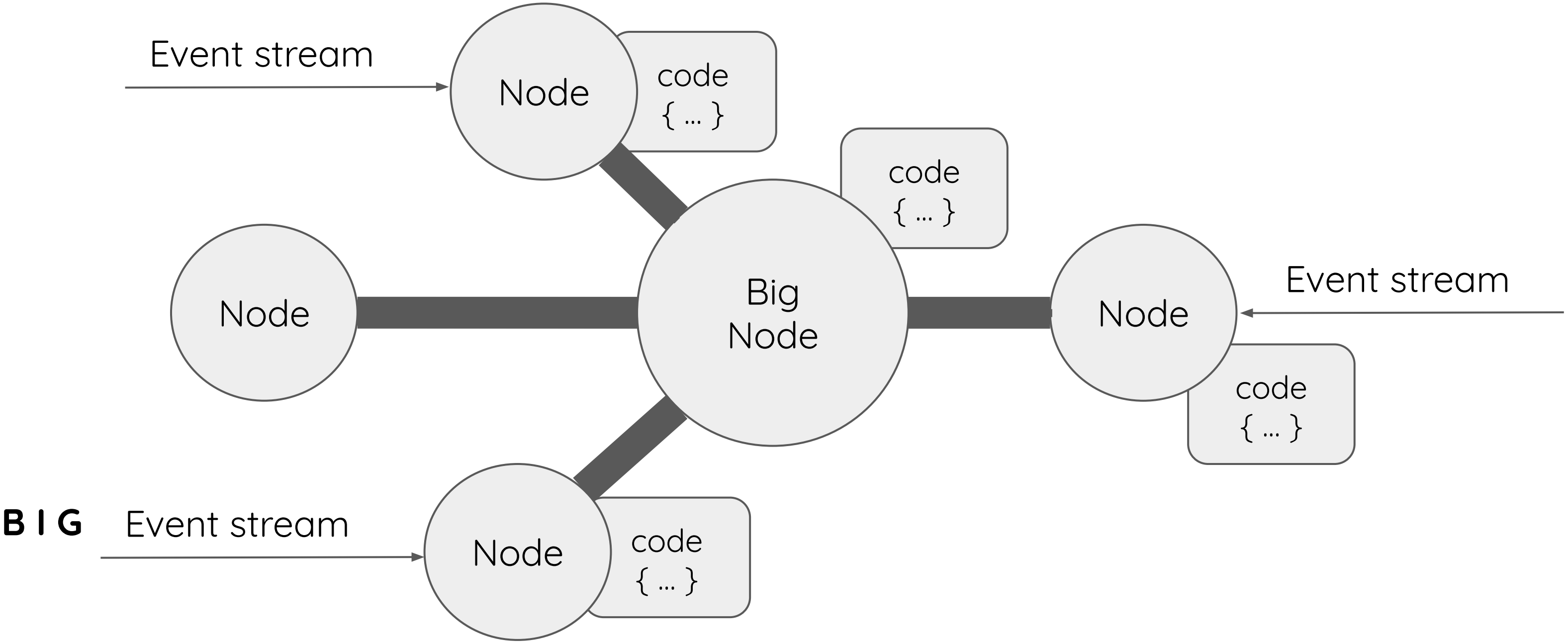
- Low response times
- Can support larger datasets
- More natural for some applications

# Let there be …

# Edge computing



# Writing distributed code is hard :'(



# Existing Stream Processing Solutions

Flink

APACHE STORM

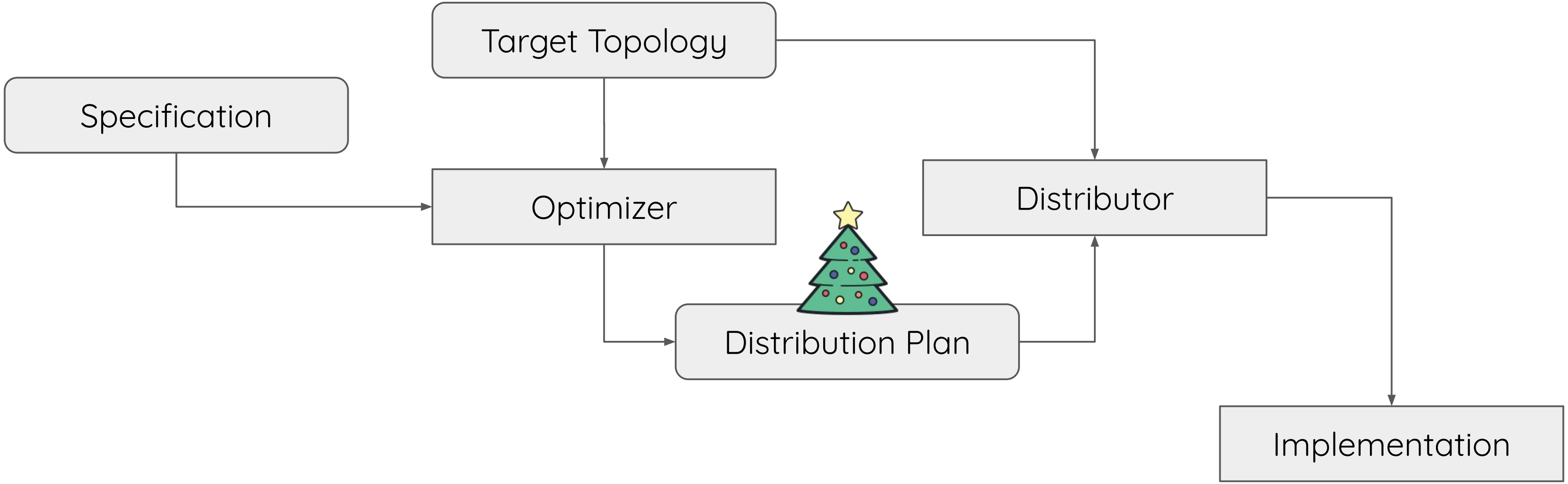
APACHE Spark™

HERON

# Problems of existing solutions

- Computation has to be tuned depending on
    - performance requirements
    - underlying computational resources
    - knowledge about data (input rates, locality)
- No formal definition of correctness

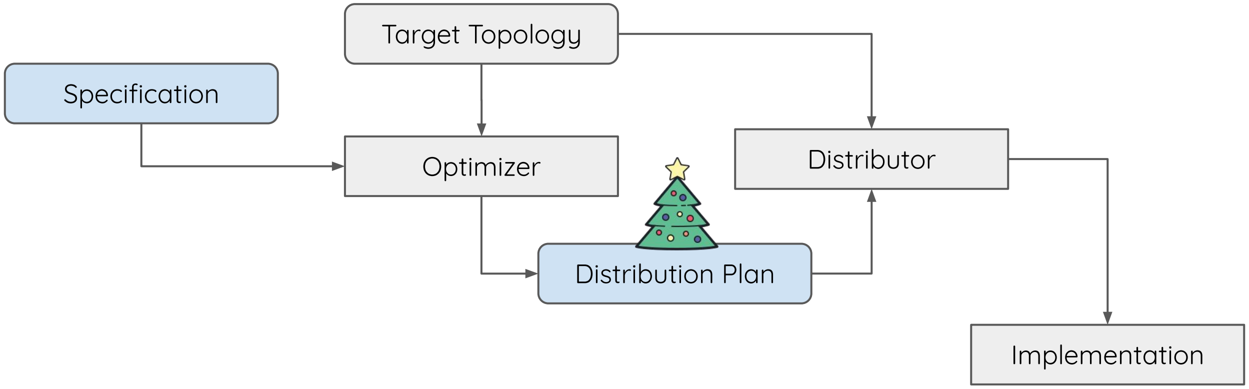
# Flumina



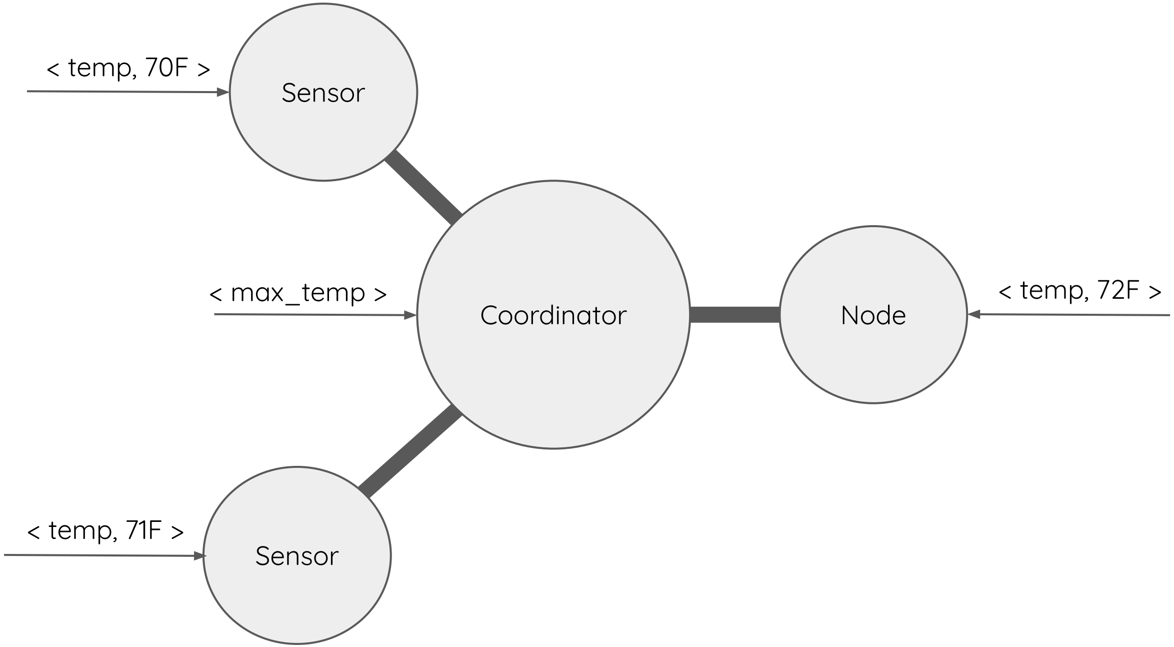
**Main idea:**

Independent events can be processed concurrently with minimal communication

# Conceptual model



# Example



```
state  := int // max temp so far
temp_e := <temp, int>

update_temp :: temp_e -> state -> state
update_temp <temp, Val> OldMax :=
    return max(OldMax, Val)
```

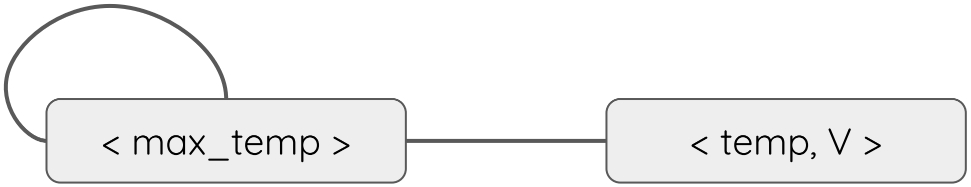
```
max_e := <max_temp>

update_max :: max_e -> state -> state
update_max <max_temp> OldMax :=
    output(<day_max_temp, OldMax);
    return 0
```

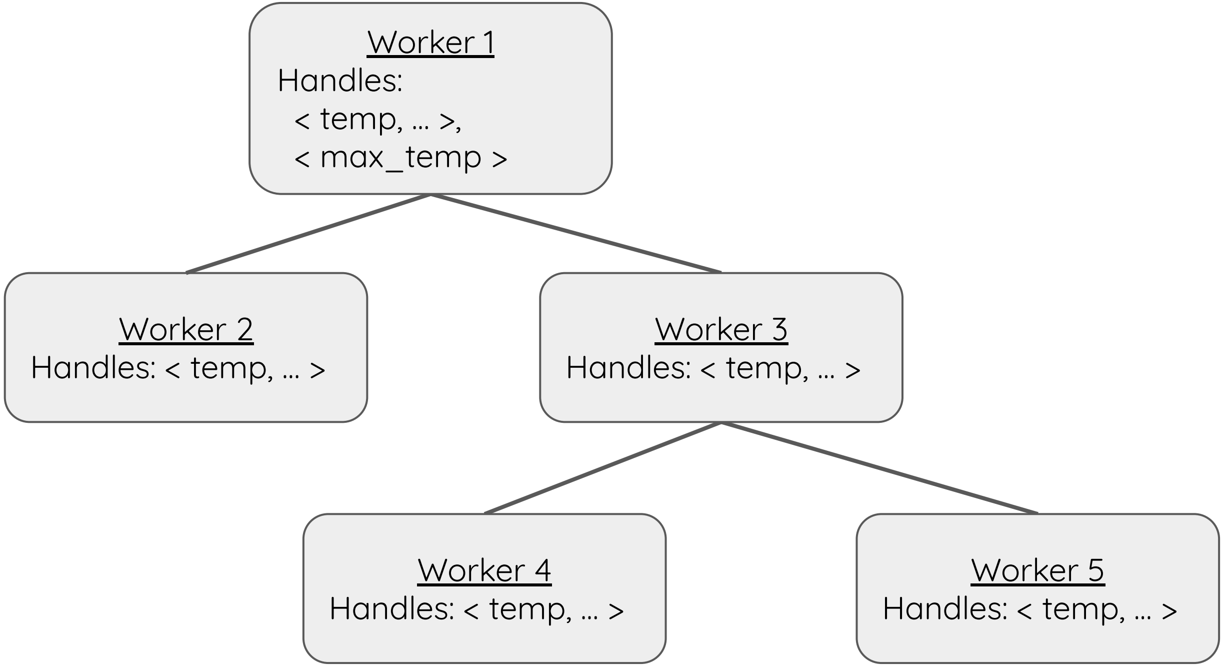
# Dependency relation

< max_temp > events depend on < temp, V > events

< max_temp > events depend on < max_temp > events



# Distribution 🎄 model



Worker 1
Handles:
< temp, … >,
< max_temp >

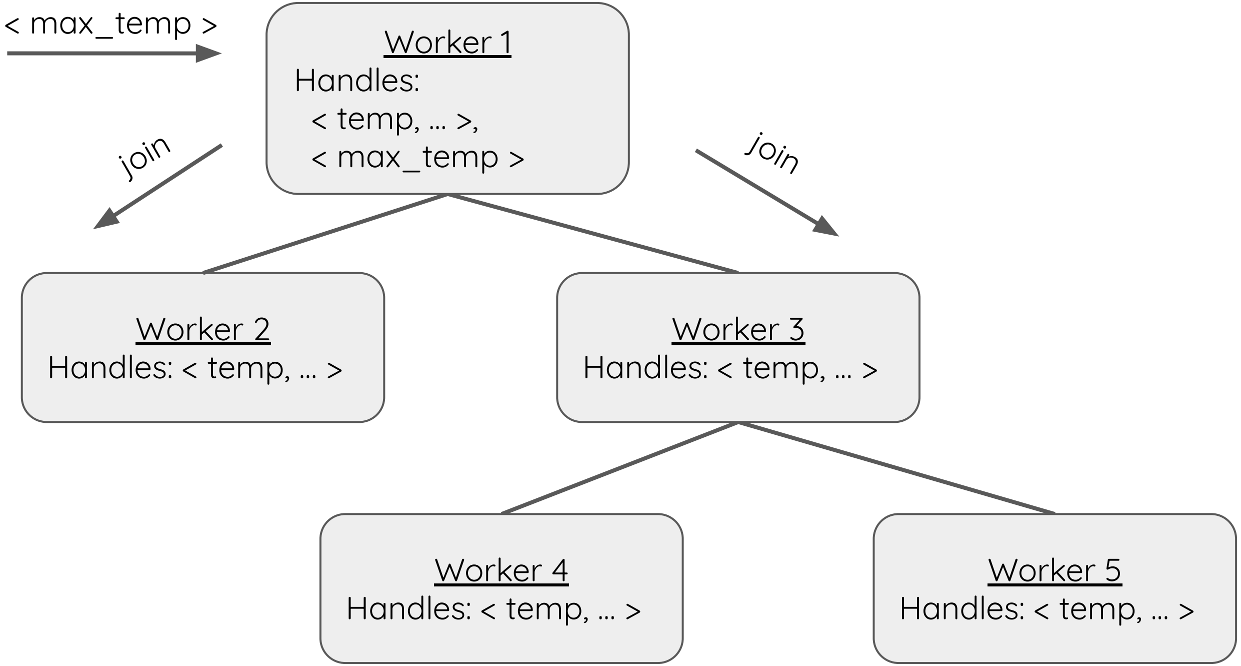
Worker 2
Handles: < temp, … >

Worker 3
Handles: < temp, … >

Worker 4
Handles: < temp, … >

Worker 5
Handles: < temp, … >

# Distribution 🎄 model



< max_temp >

join

join

Worker 1

Handles:

< temp, ... >,

< max_temp >

Worker 2

Handles: < temp, ... >

Worker 3

Handles: < temp, ... >

Worker 4

Handles: < temp, ... >

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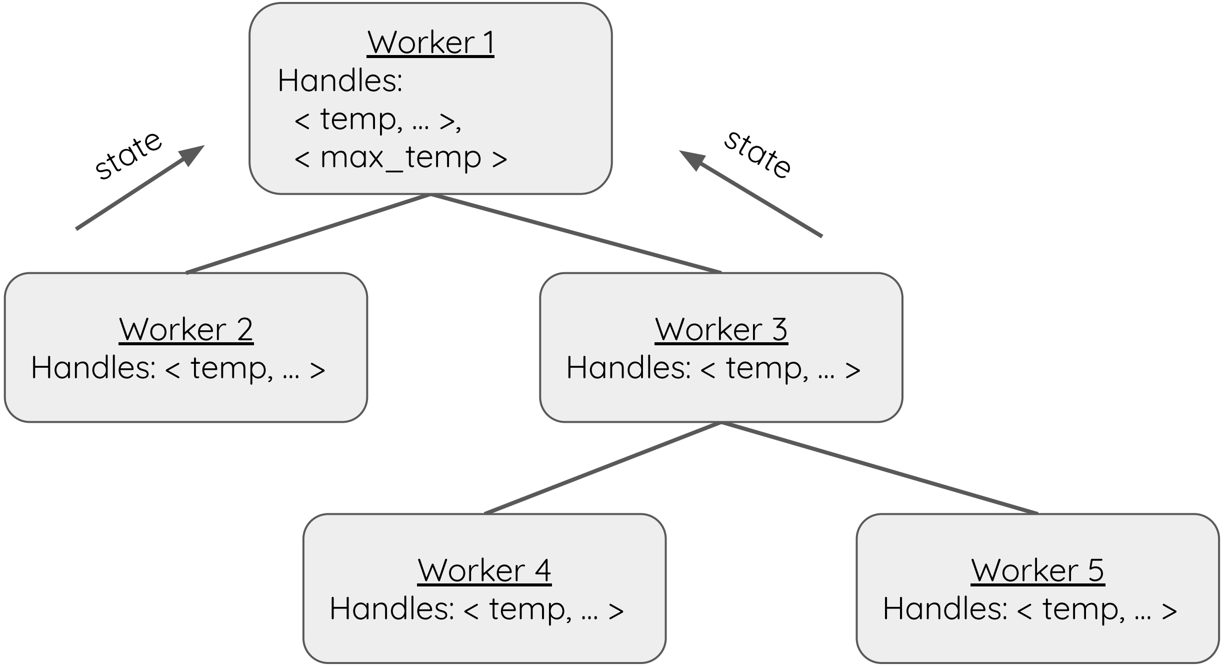
Handles: < temp, ... >

# Distribution 🎄 model



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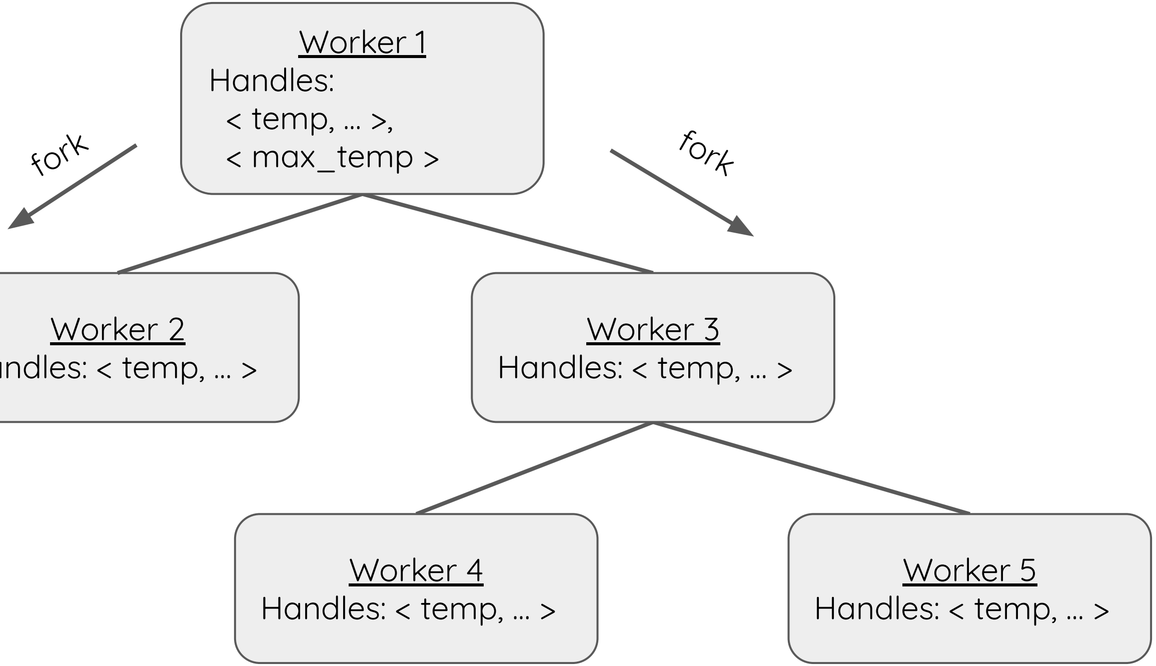
# Distribution 🎄 model



Worker 1
Handles:
< temp, ... >,
< max_temp >

fork

fork

Worker 2
Handles: < temp, ... >

Worker 3
Handles: < temp, ... >

Worker 4
Handles: < temp, ... >

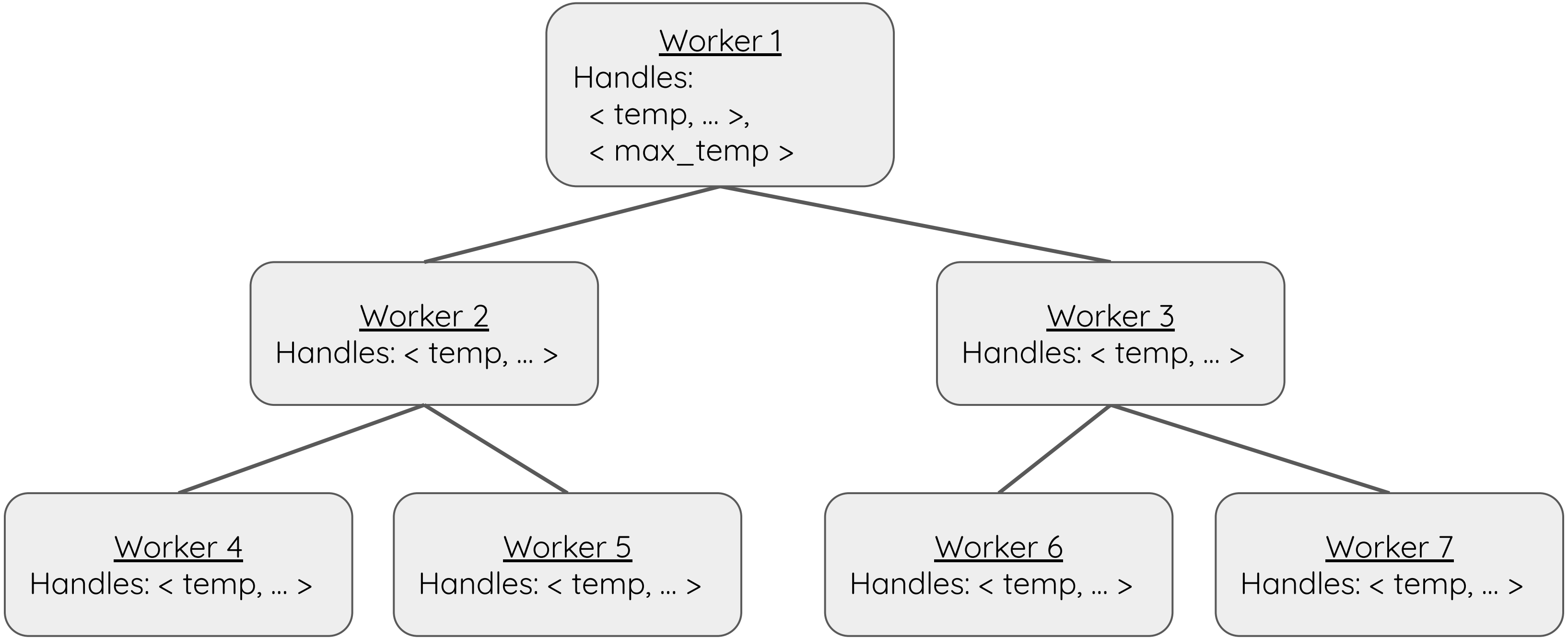
Worker 5
Handles: < temp, ... >

# Fork - Join

```
// State
state  := int // max temp so far

// Events
temp_e := <temp, int>
max_e := <max_temp>

update_temp :: temp_e -> state -> state
update_temp <temp, Val> OldMax :=
    return max(OldMax, Val)

update_max :: max_e -> state -> state
update_max <max_temp> OldMax :=
    output(<day_max_temp, OldMax);
    return 0
```

```
fork :: state -> (state * state)
fork Max :=
    return (Max, Max)

join :: state -> state -> state
join Max1 Max2 :=
    return max(Max1, Max2)
```

# Fork - Join



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Worker 2
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Worker 3
Handles: < temp, … >

Worker 4
Handles: < temp, … >

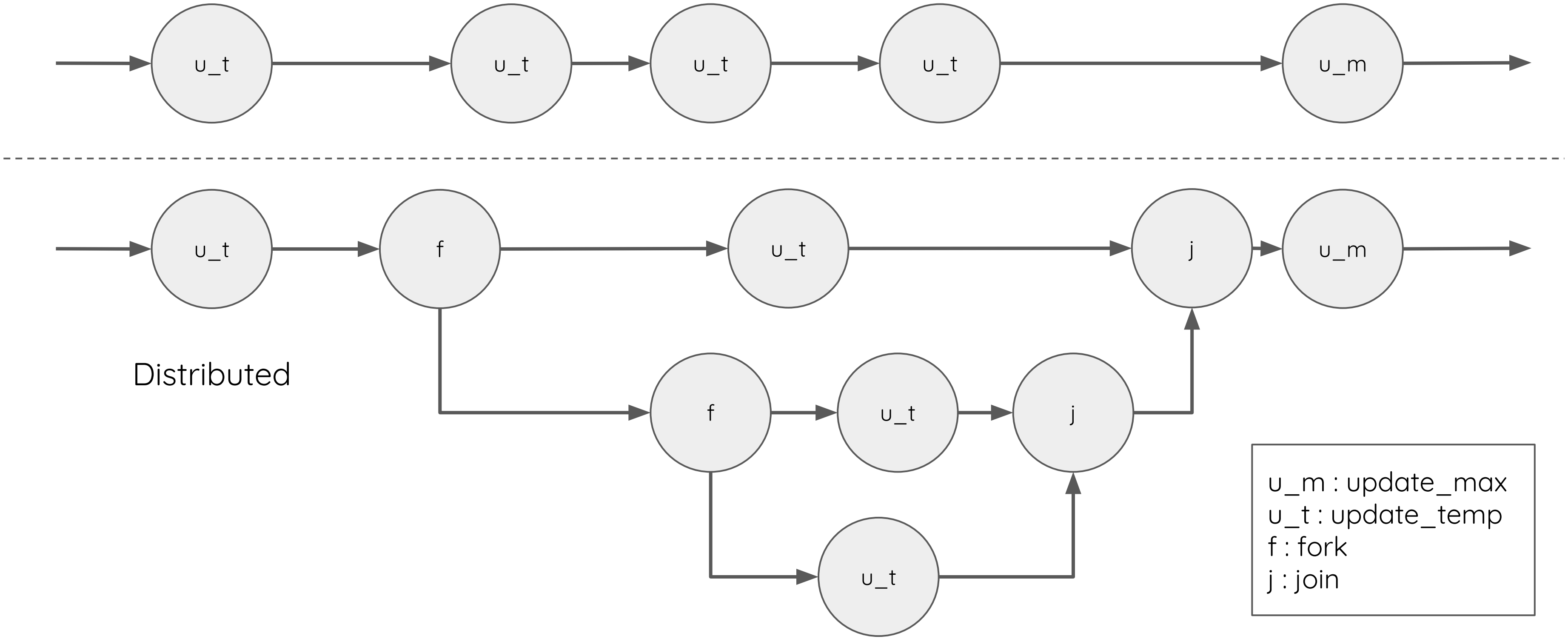
Worker 5
Handles: < temp, … >

Worker 6
Handles: < temp, … >

Worker 7
Handles: < temp, … >

# Fork-join

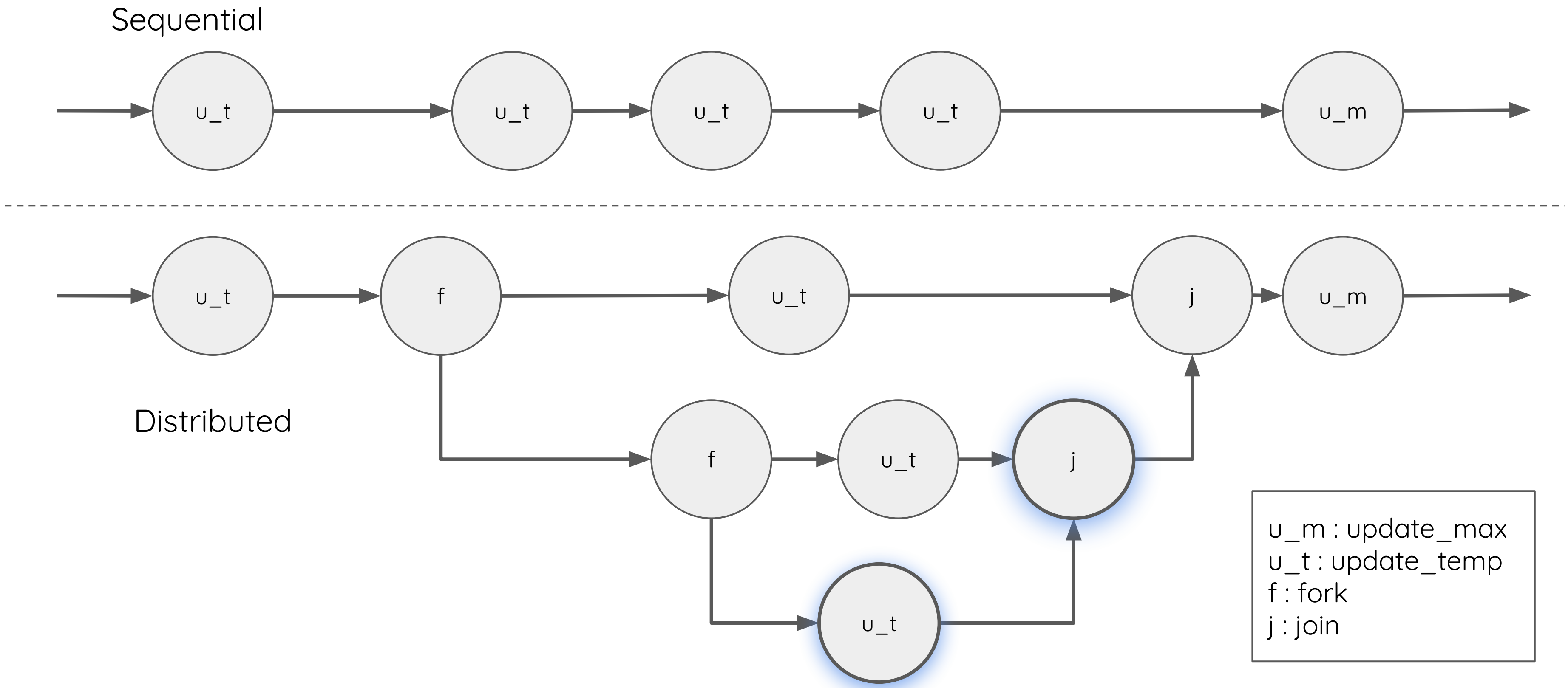
Sequential



Distributed

u_m : update_max
u_t : update_temp
f : fork
j : join

# Fork-join



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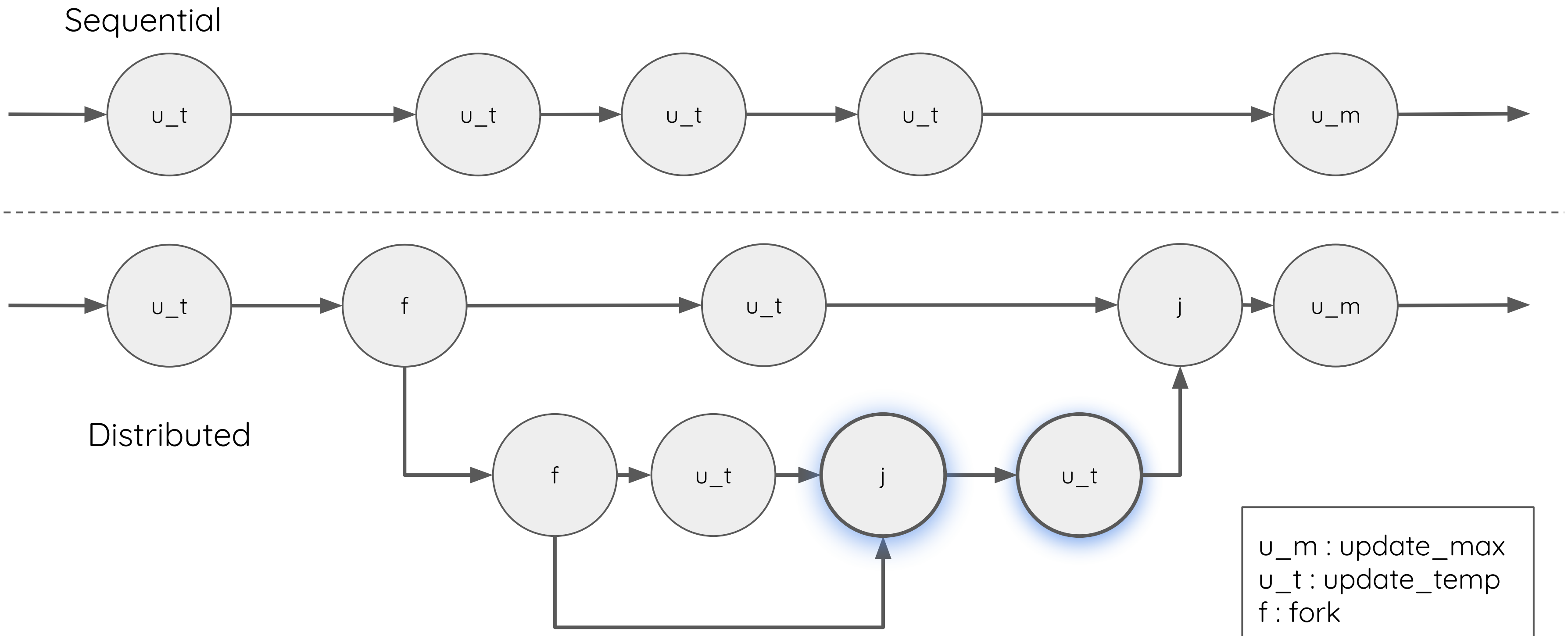

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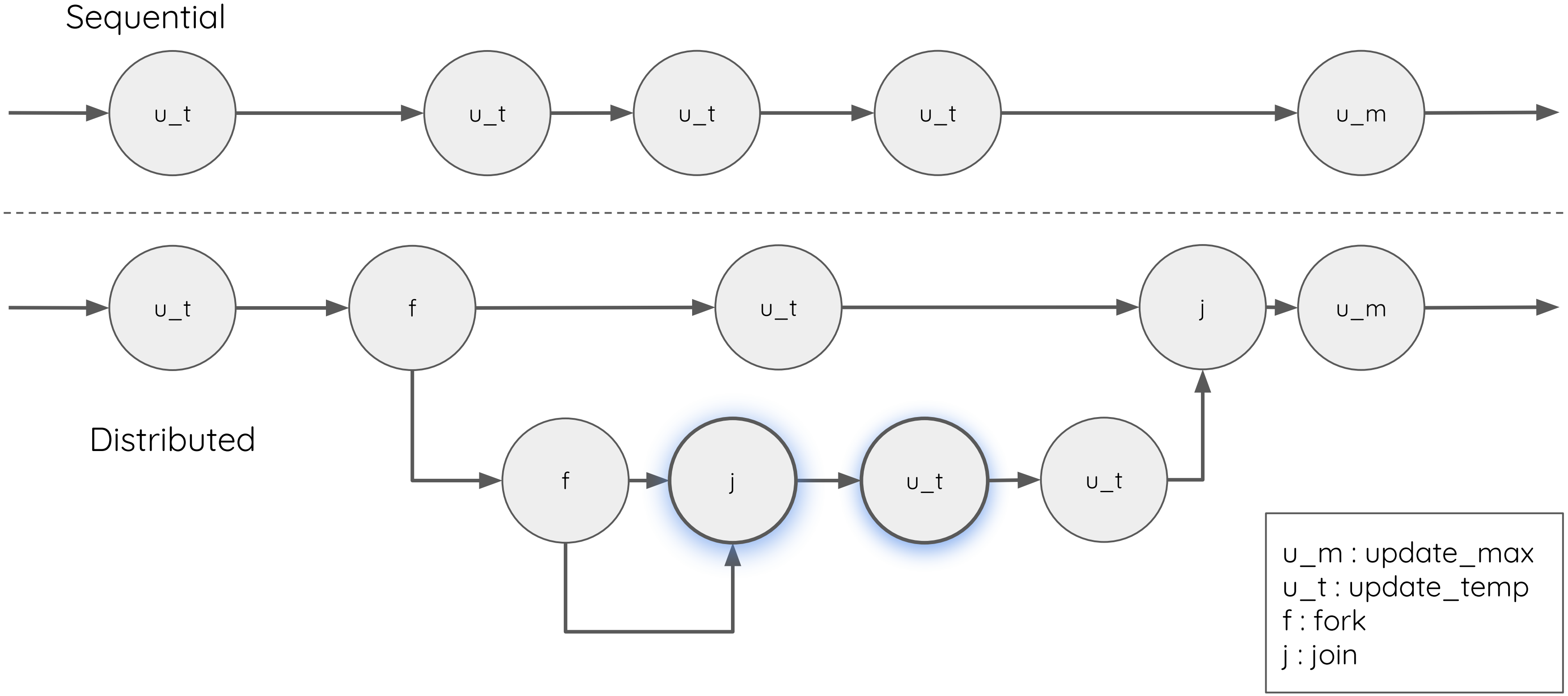

Sequential

Distributed

u_m : update_max
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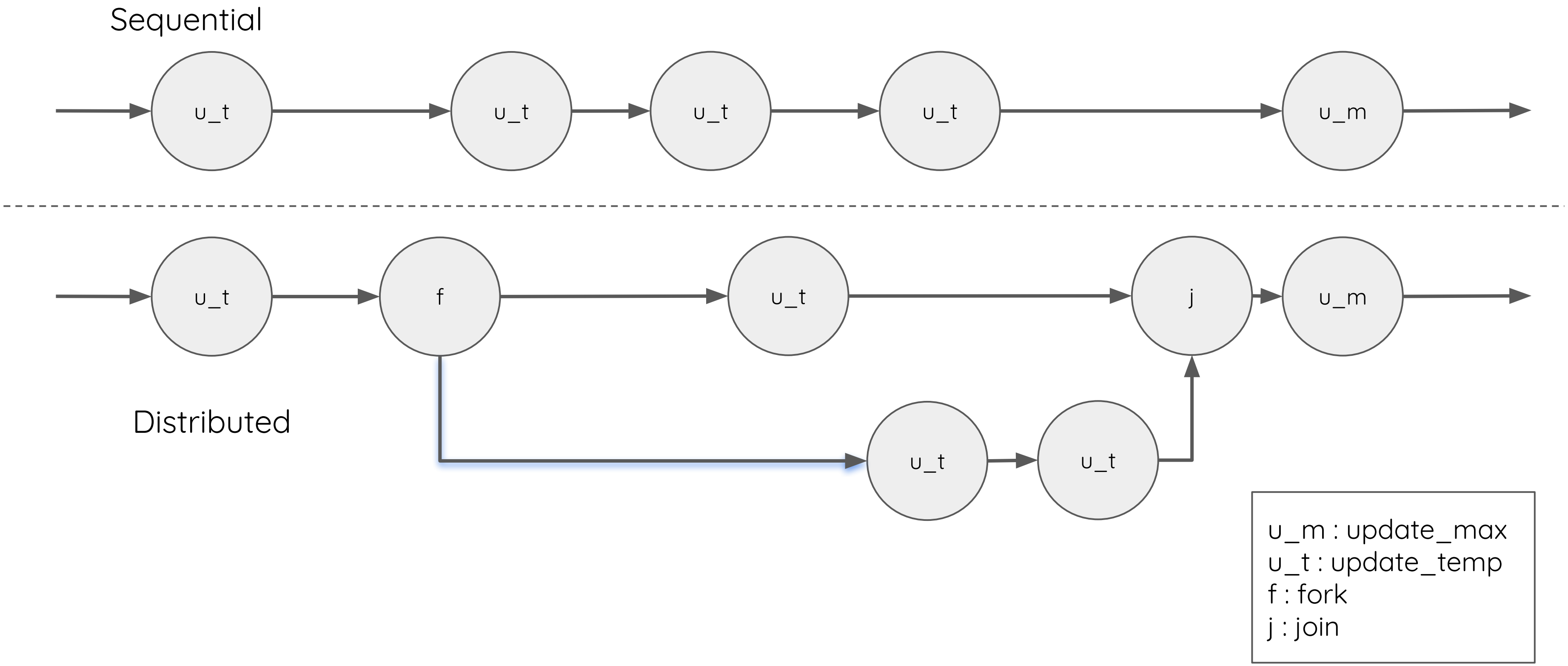
# Fork-join



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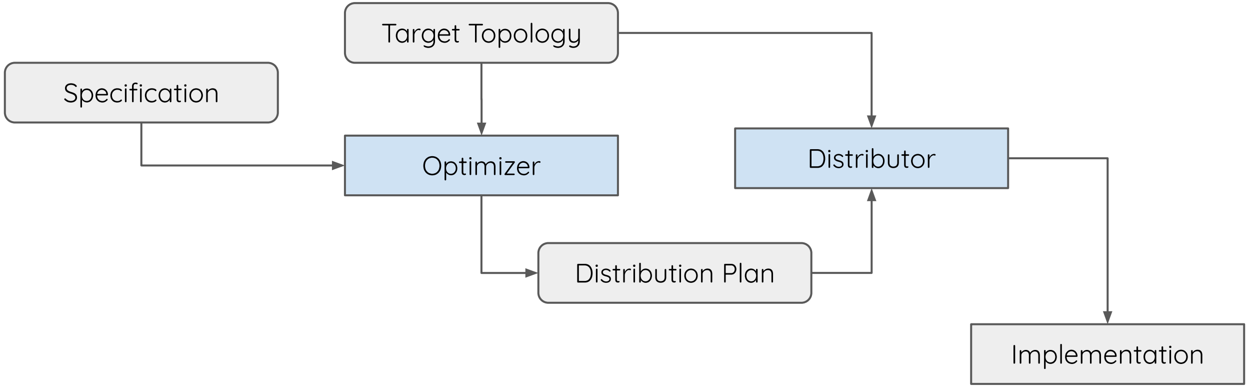
# Automated Distribution



Target Topology

Specification

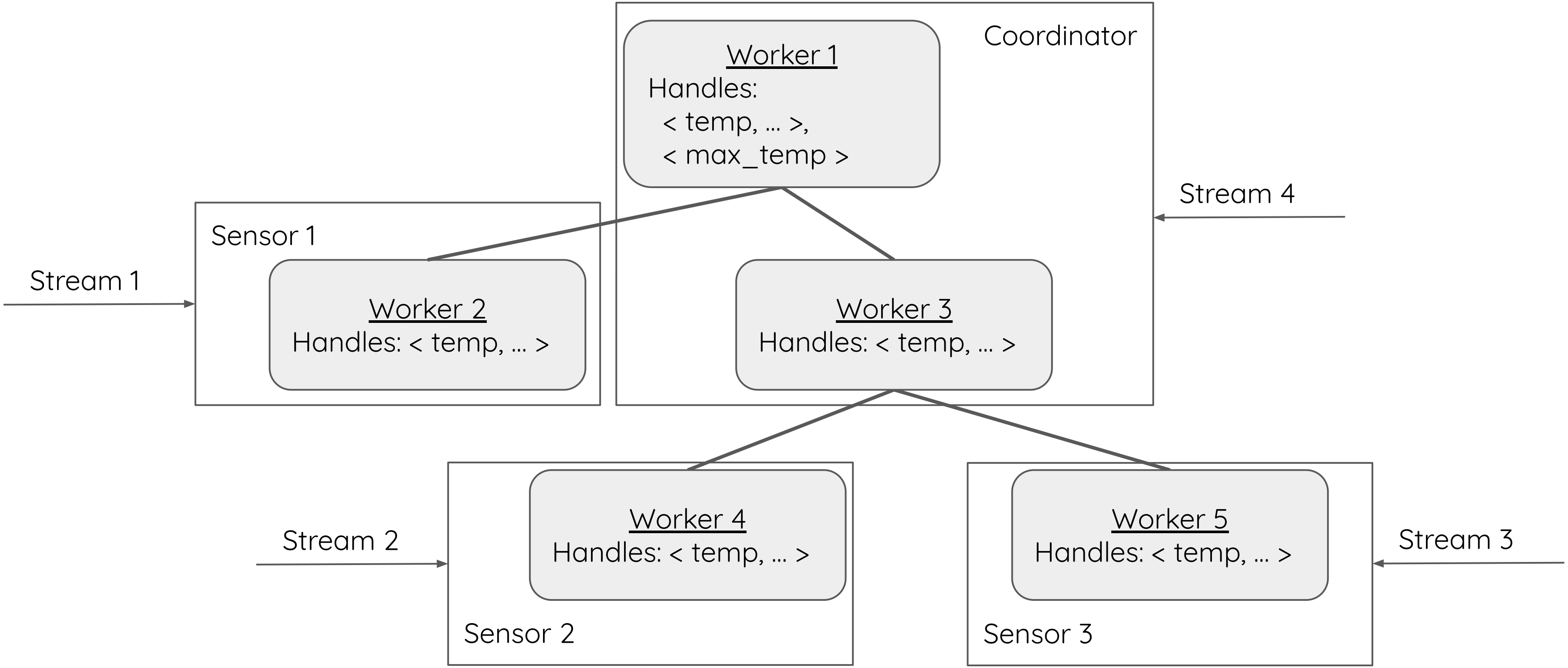
Optimizer

Distributor

Distribution Plan

Implementation

# Automated Distribution

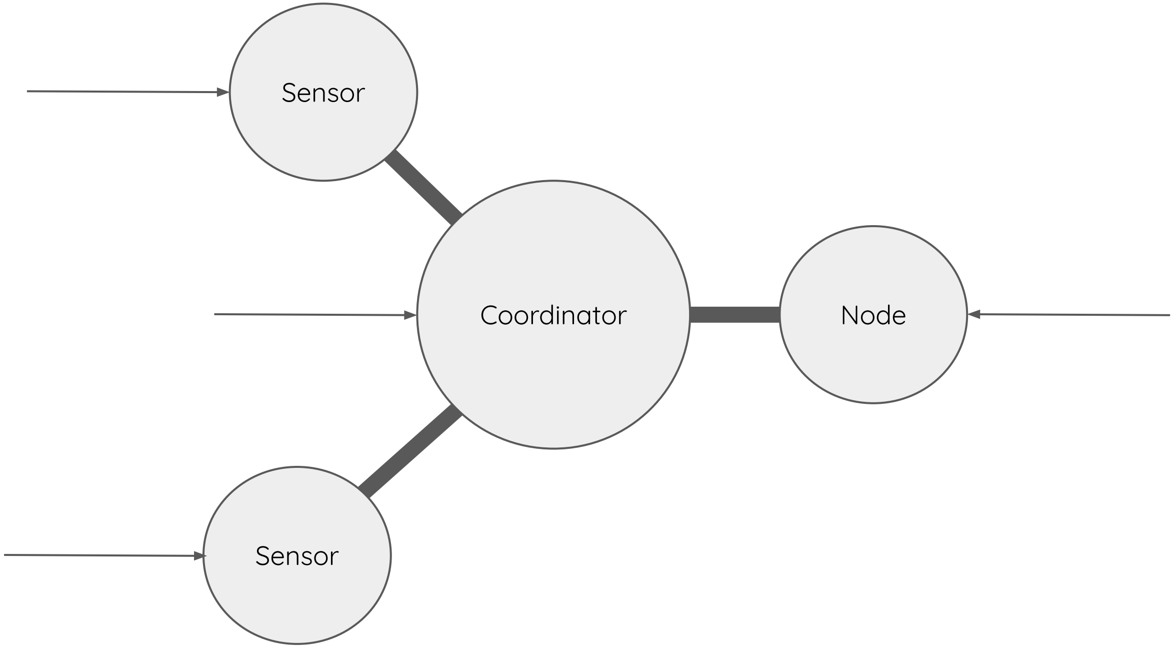


# Evaluation

# Setup

Single node with 18 cores

# Microbenchmarks



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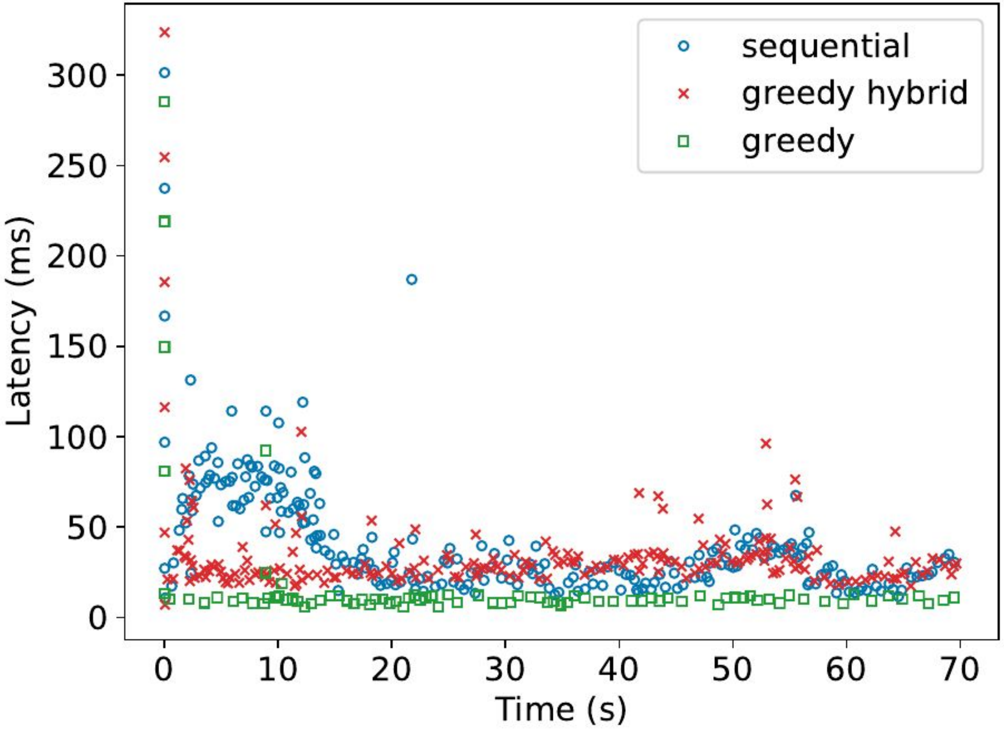
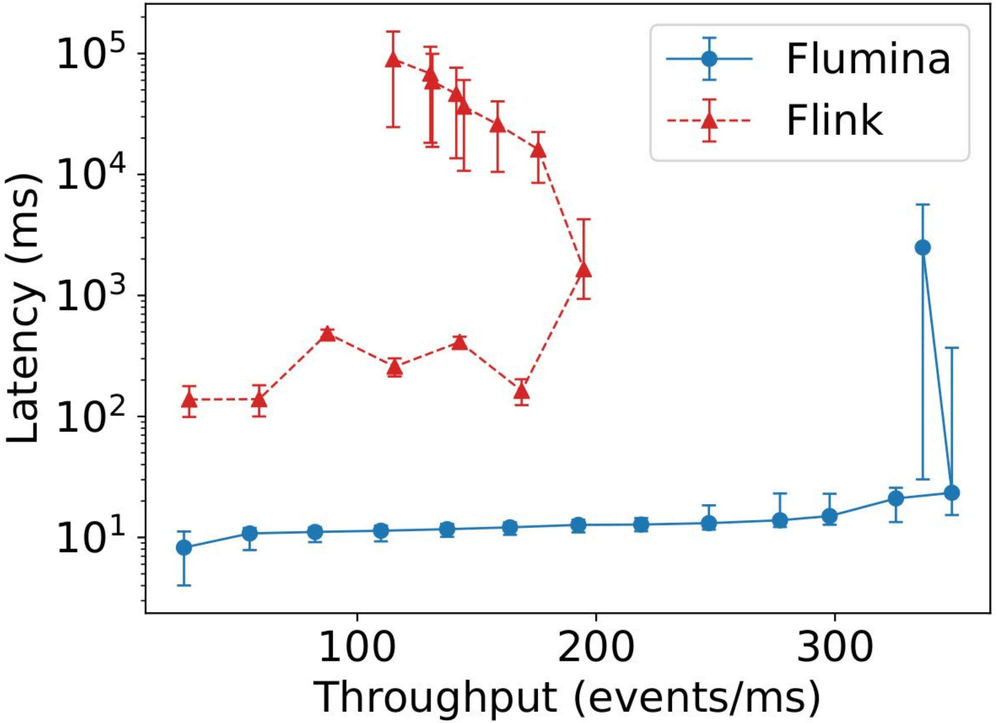
# Microbenchmarks



# Flumina vs Flink -- Scaling



# Case studies

- Distributed Outlier Detection
    - Sequential: 700 LoC
    - Distributed: + 50 LoC
- Energy Management
    - Sequential: 200 LoC
    - Distributed: + 60 LoC

# Conclusion

# Future Work

- Verification of Flumina code
- Synthesis of fork-join pairs
- Online re-distribution
- High level query language
- Privacy