Systems@ETH zürich

OSDI | 18

Three steps is all you need

fast, accurate, automatic scaling decisions for distributed streaming dataflows

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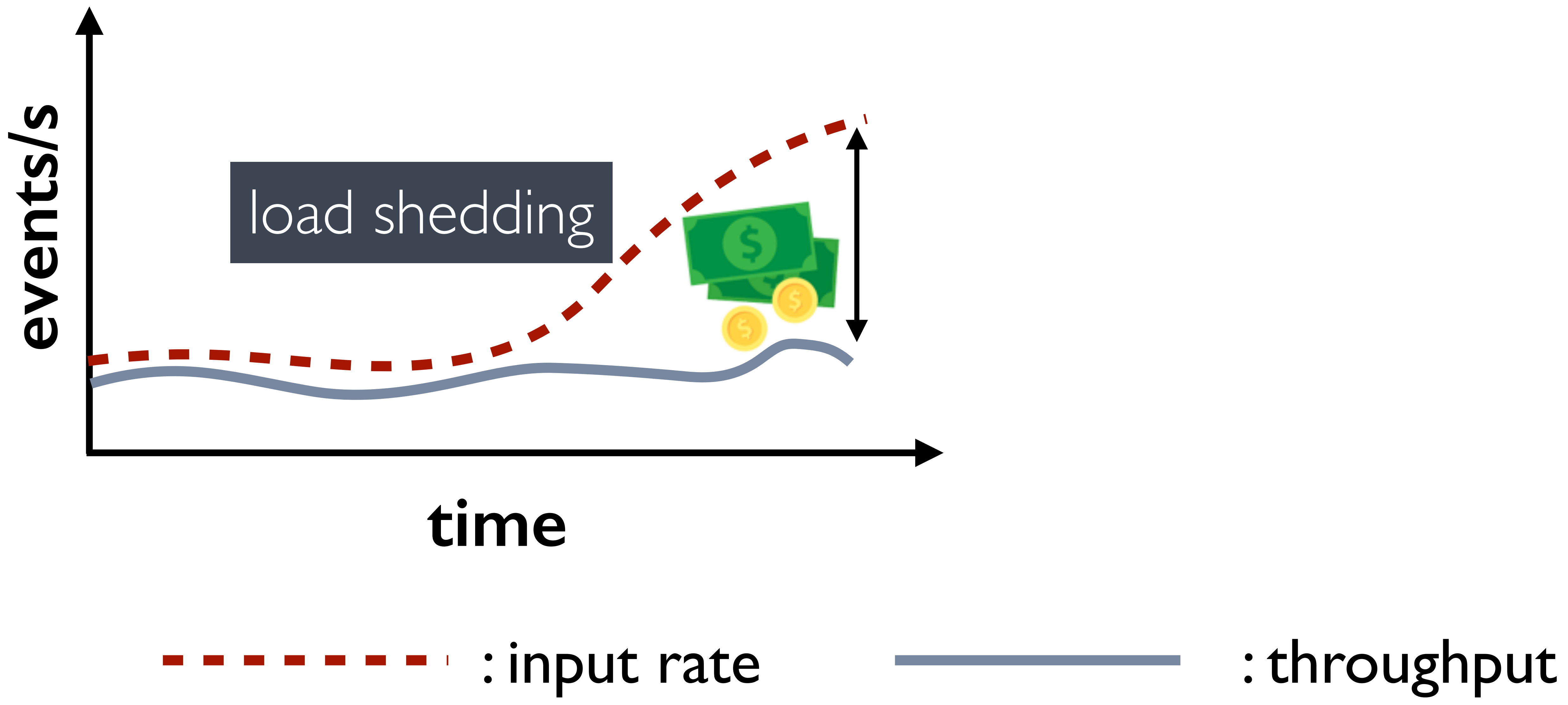

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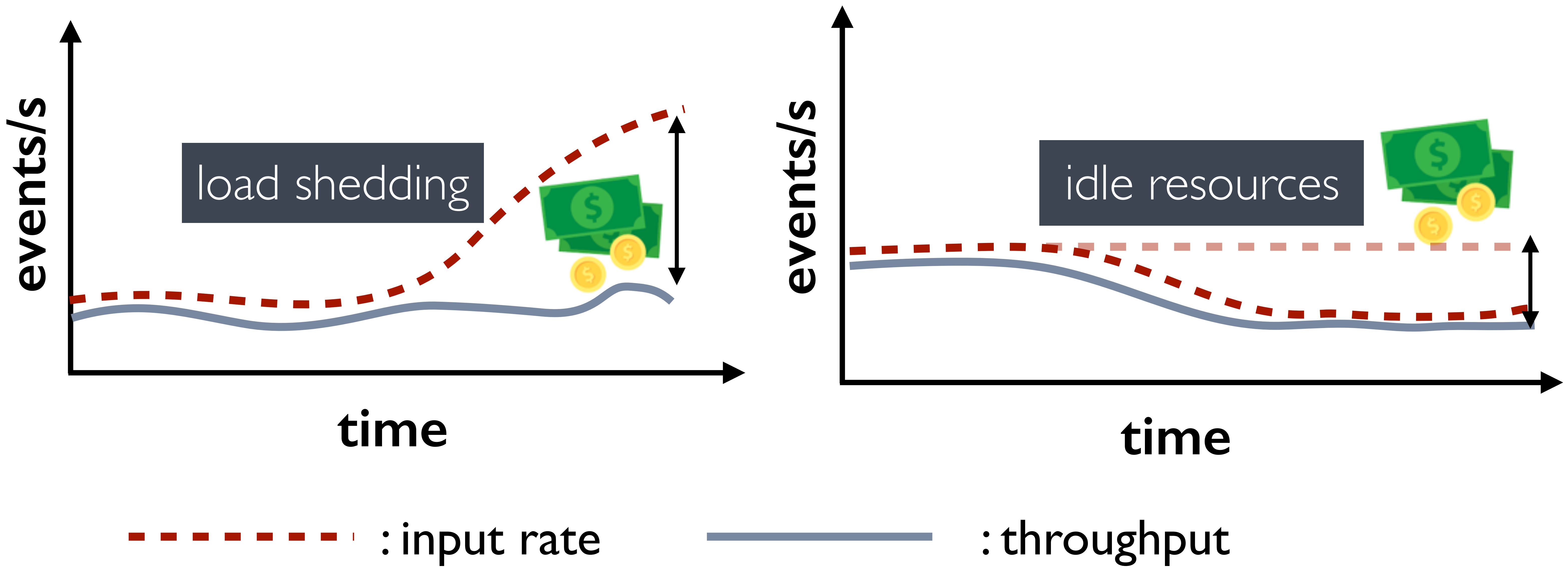

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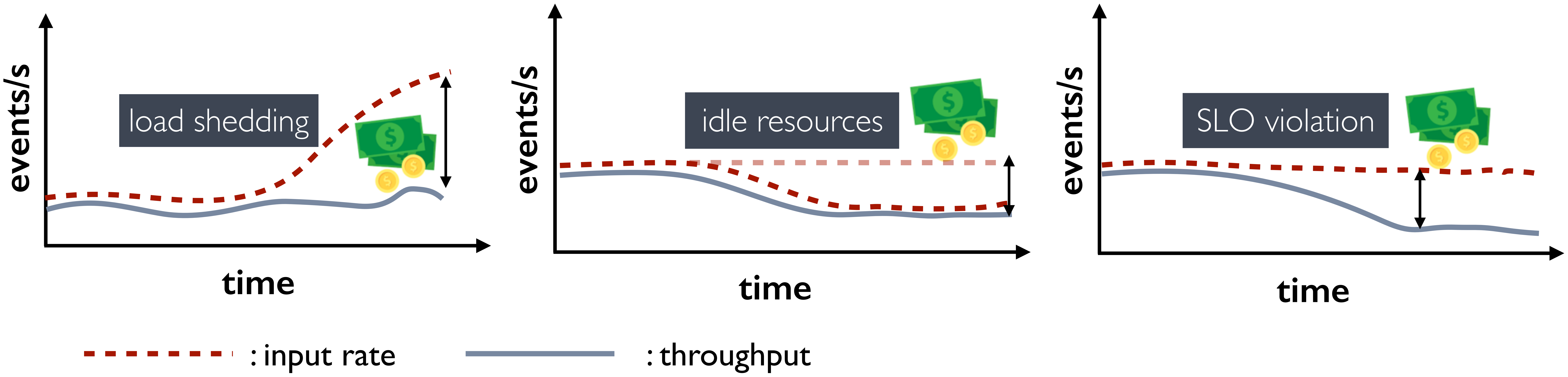
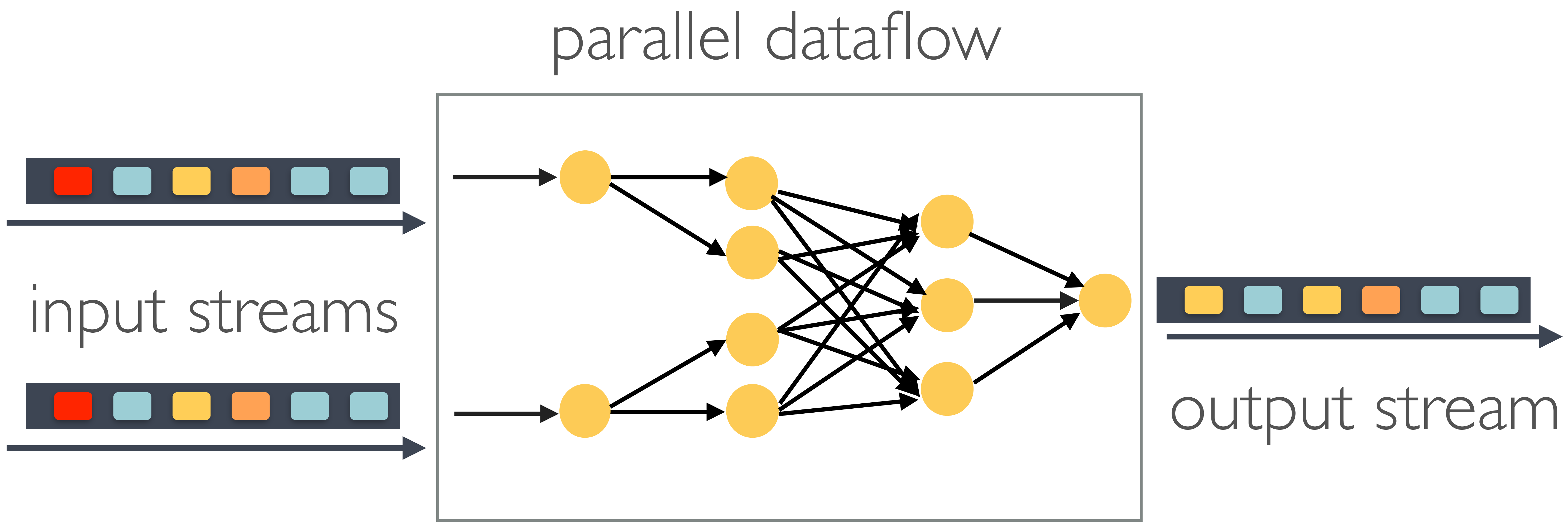
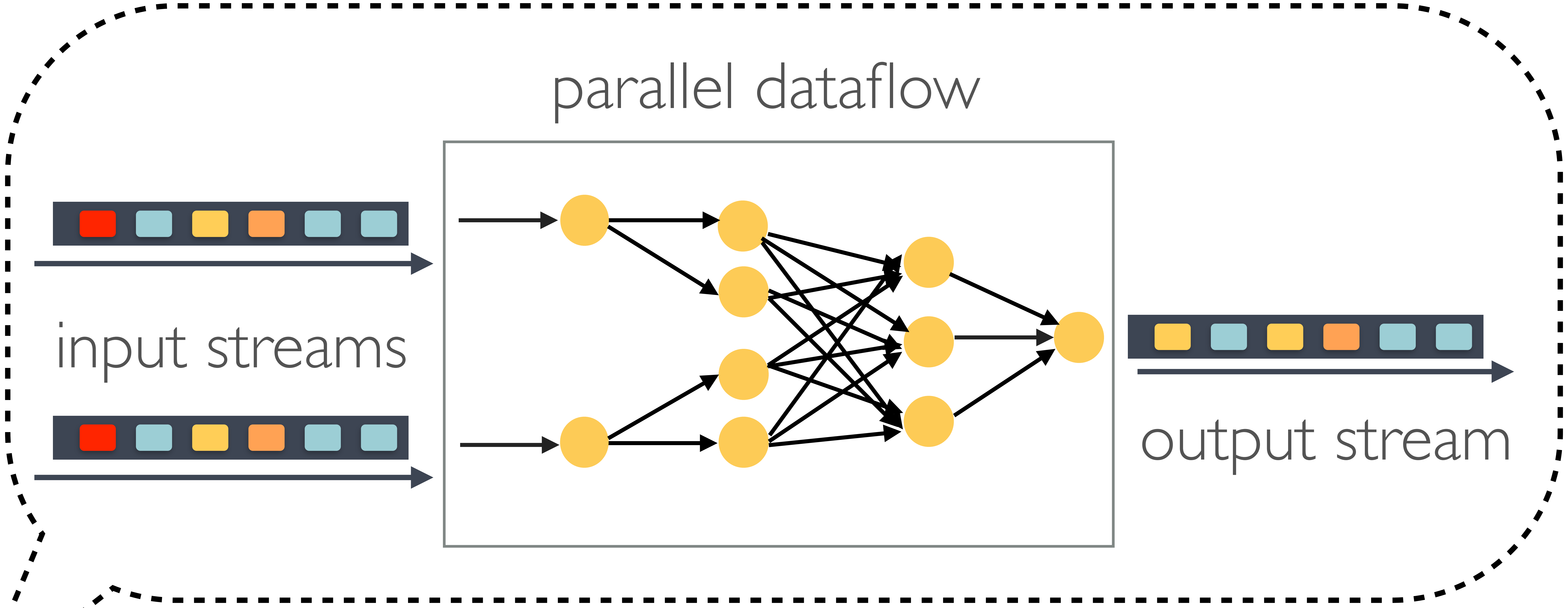


CONFIGURING PARALLELISM FOR A STREAMING JOB



CONFIGURING PARALLELISM FOR A STREAMING JOB

1. monitor event rates

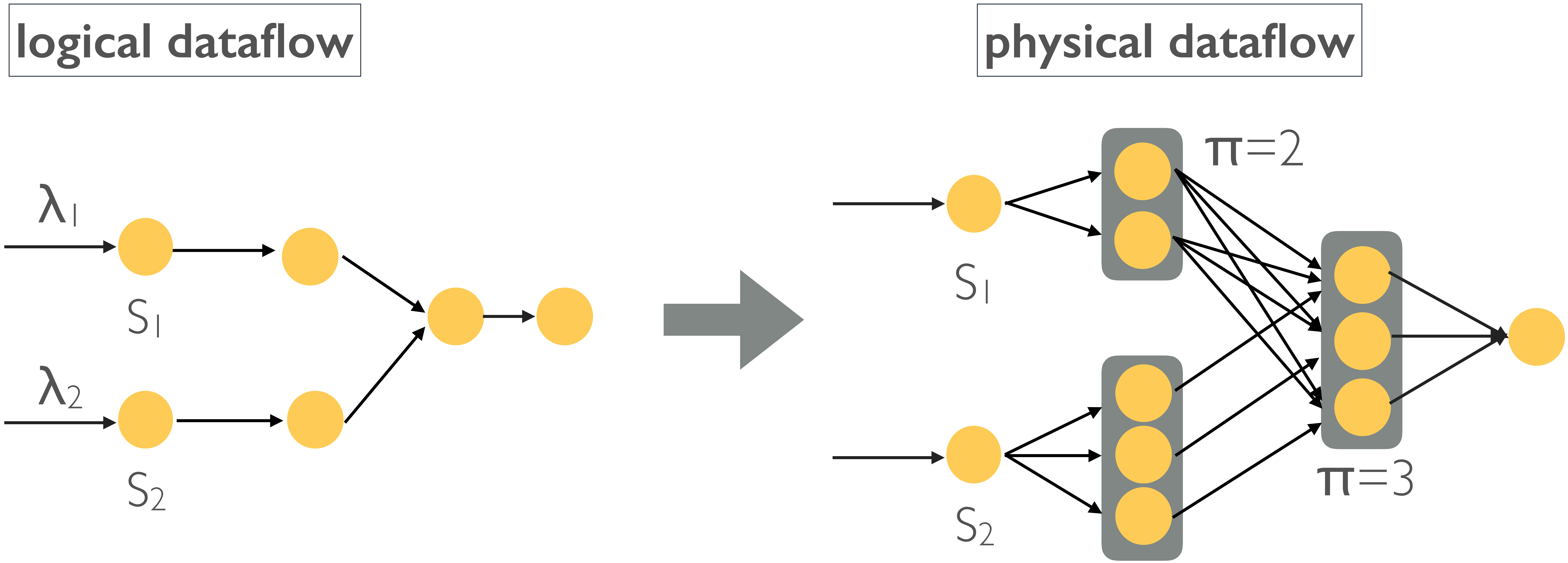


2. configure parallelism

3. deploy and test performance

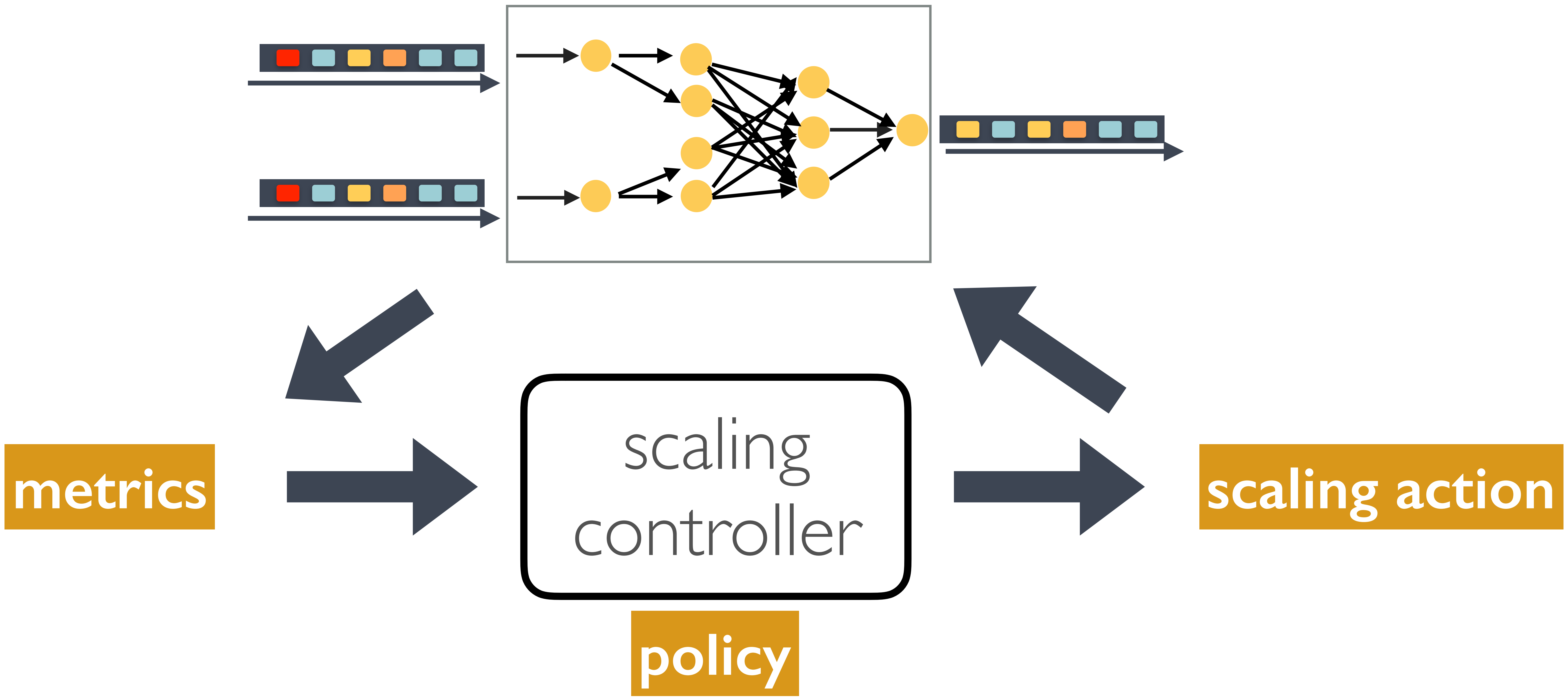
until the target throughput is met

THE SCALING PROBLEM



Given a logical dataflow with sources $S_1, S_2, \ldots S_n$ and rates $\lambda_1, \lambda_2, \ldots \lambda_n$ identify the minimum parallelism π_i per operator i, such that the physical dataflow can sustain all source rates.

AUTOMATIC SCALING OVERVIEW



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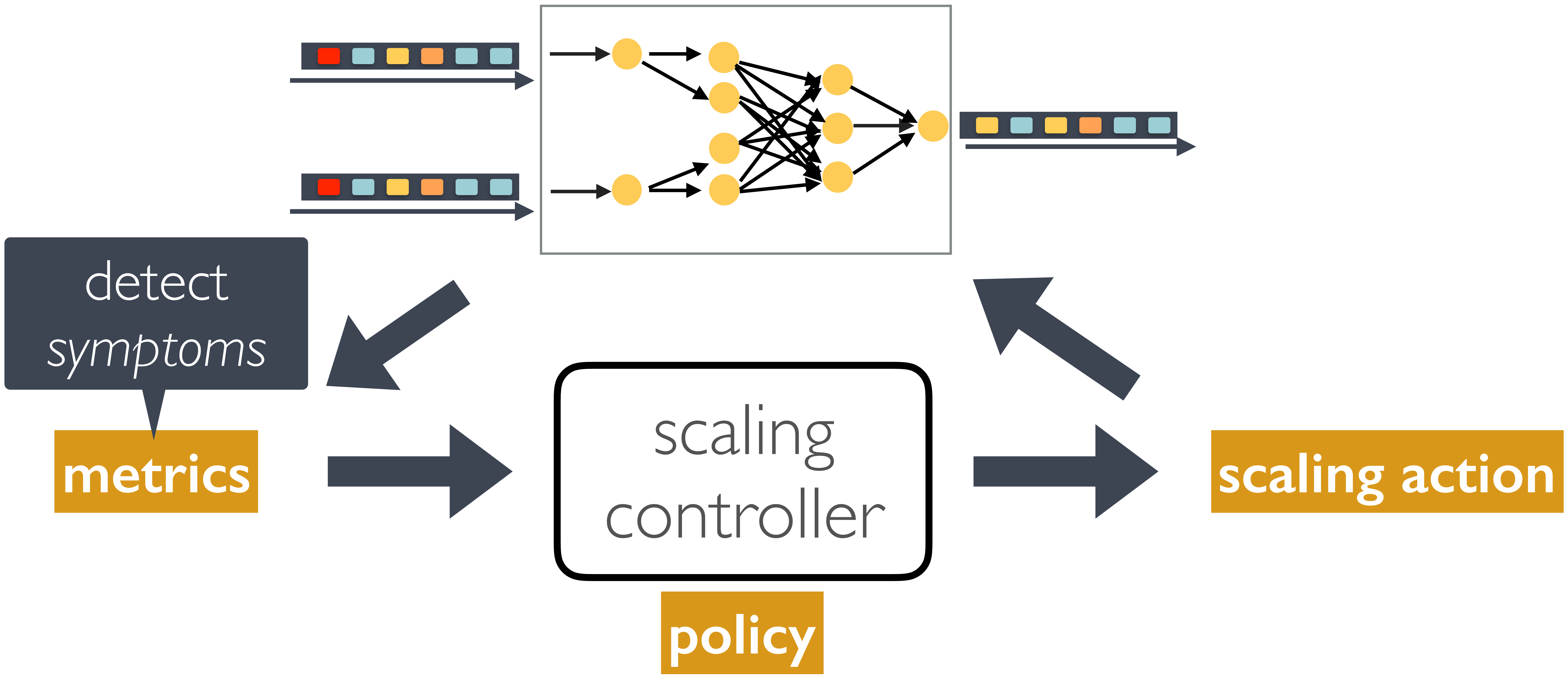

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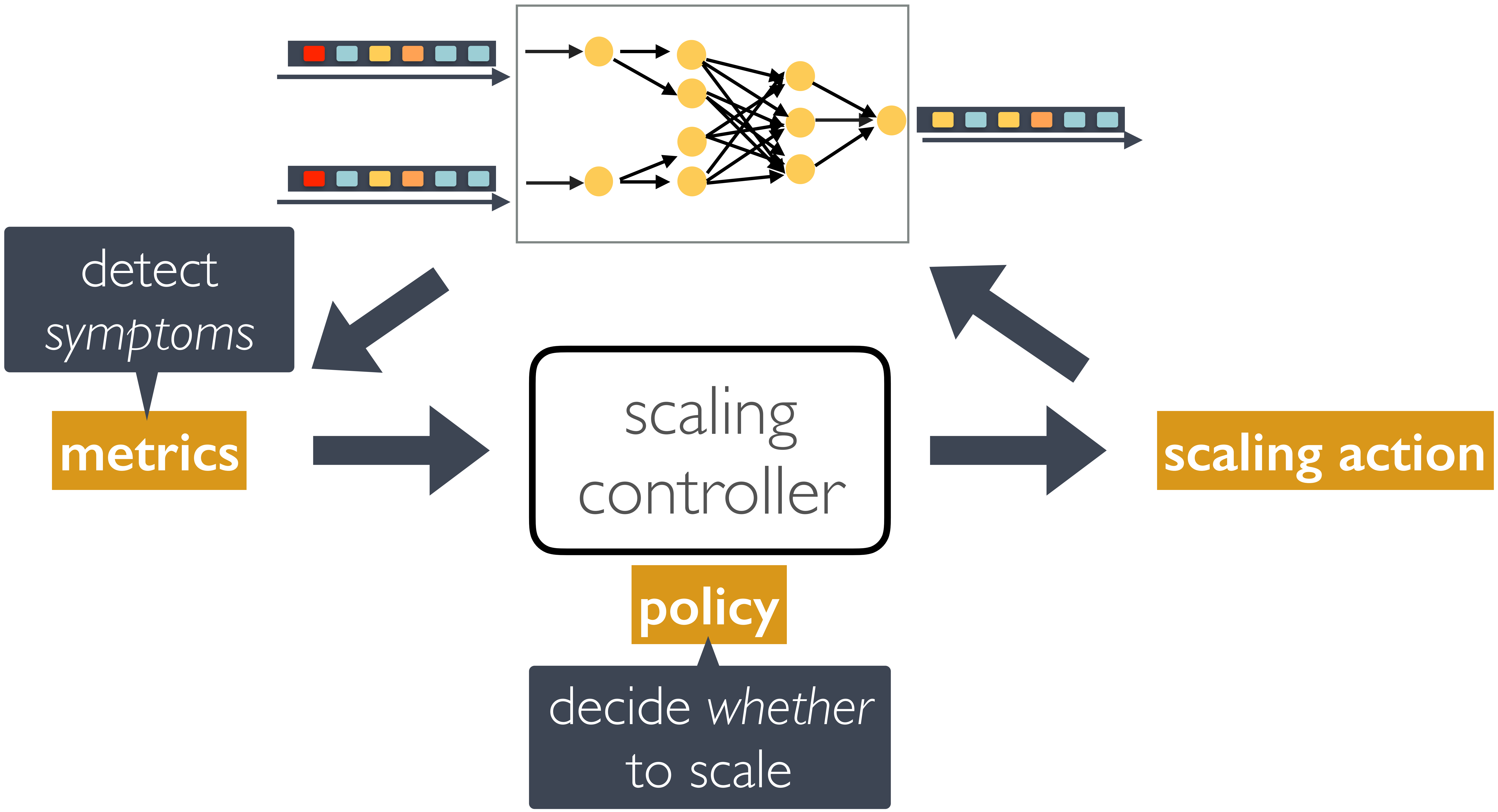

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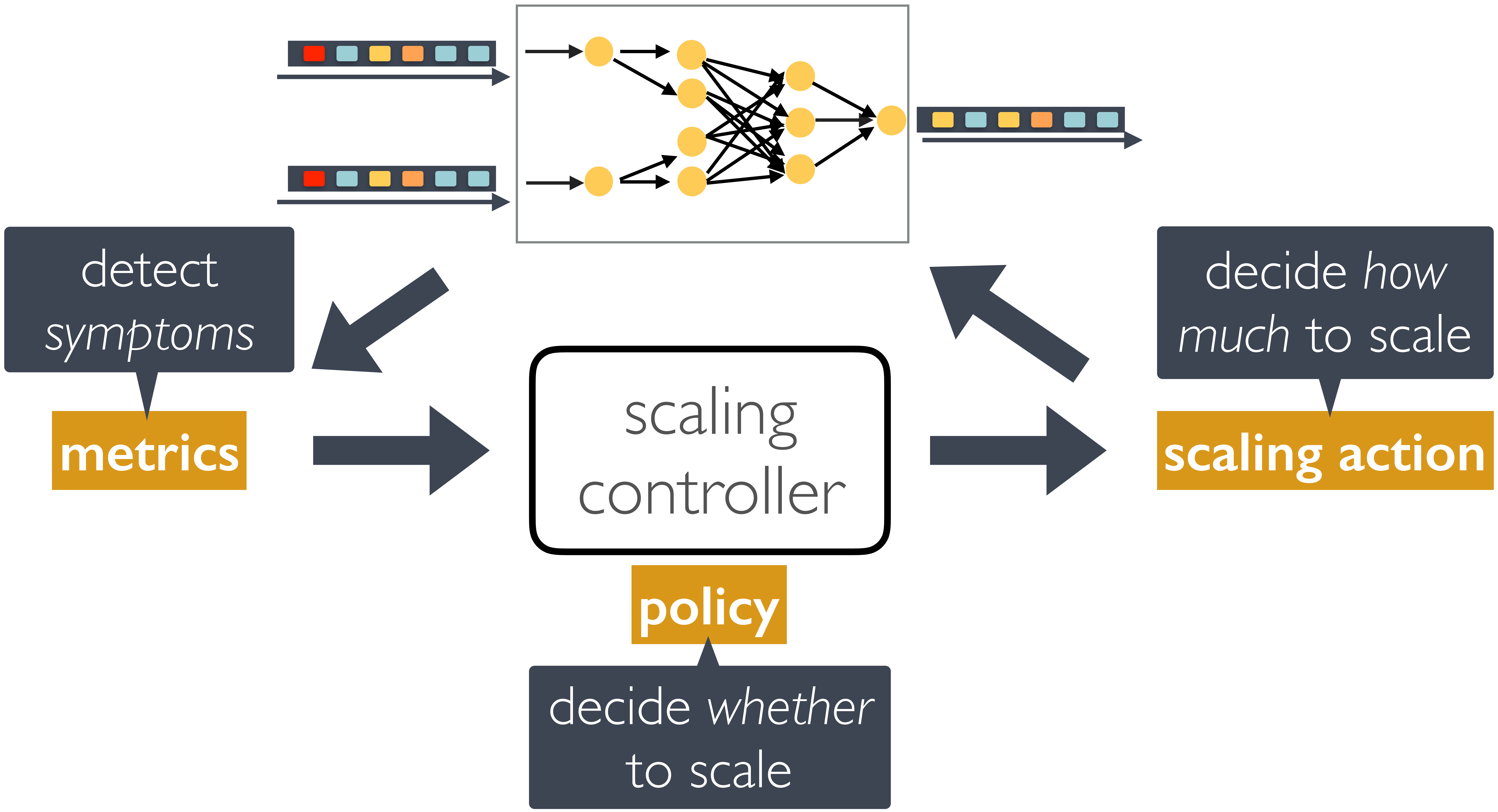

Existing approaches

- Borealis
- StreamCloud
- Seep
- IBM Streams
- Spark Streaming
- Google Dataflow
- Dhalion
- …

metrics | **policy** | **scaling action**

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CPU utilization
backlog, tuples/s
backpressure signal

policy

scaling action

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✗ **oscillations**

✗ **temporary over- and under-provisioning**

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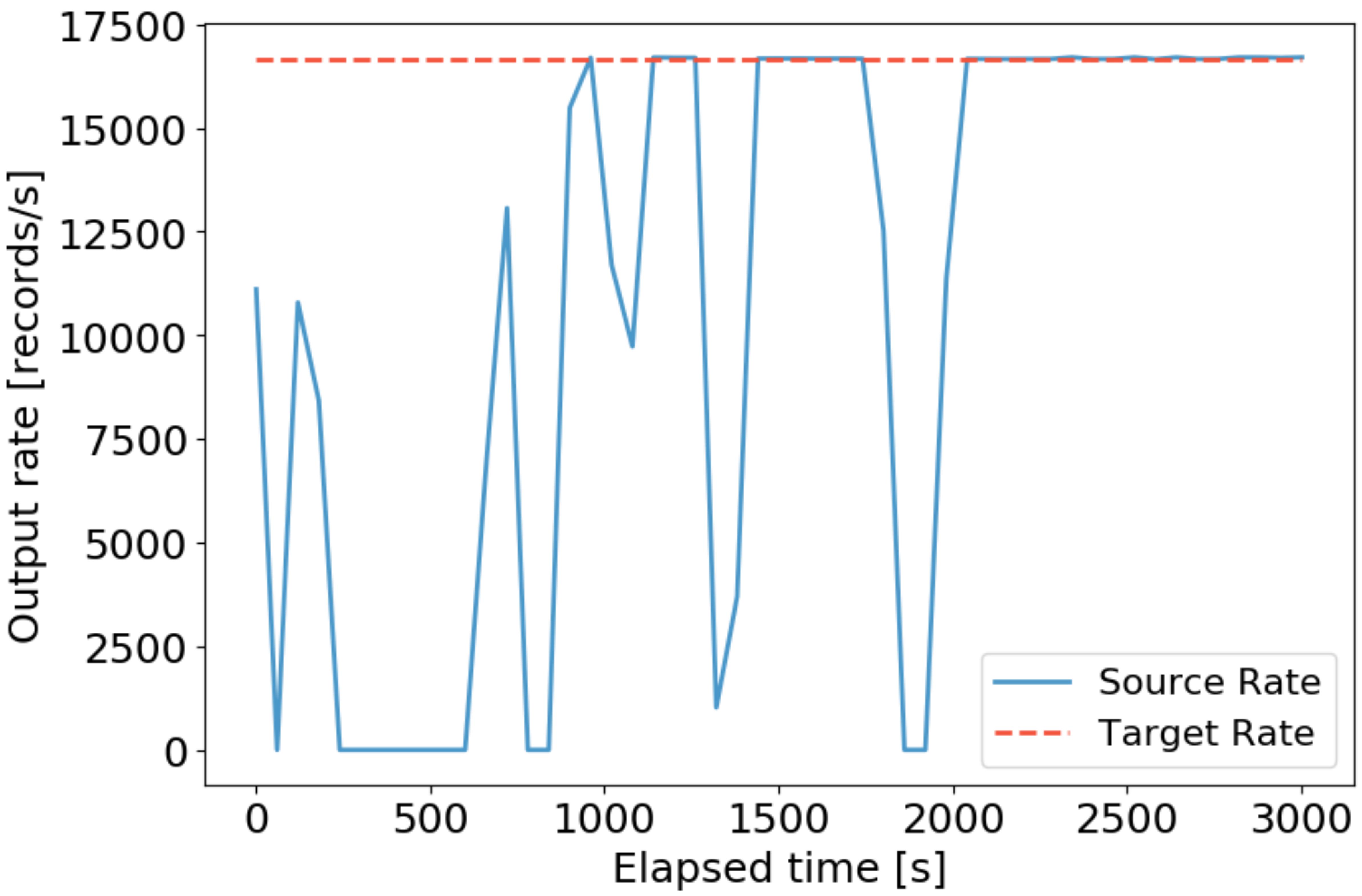
metrics	**policy**	**scaling action**
CPU utilization backlog, tuples/s backpressure signal	threshold and rule-based *if CPU > 80% => scale*	small changes, one operator at a time
problematic due to interference, multitenancy	sensitive to noise, manual, hard to tune	non-predictive, speculative steps
✗ **oscillations**	✗ **temporary over- and under-provisioning**	✗ **slow convergence**

effect of Dhalion's scaling actions in an initially under-provisioned wordcount dataflow



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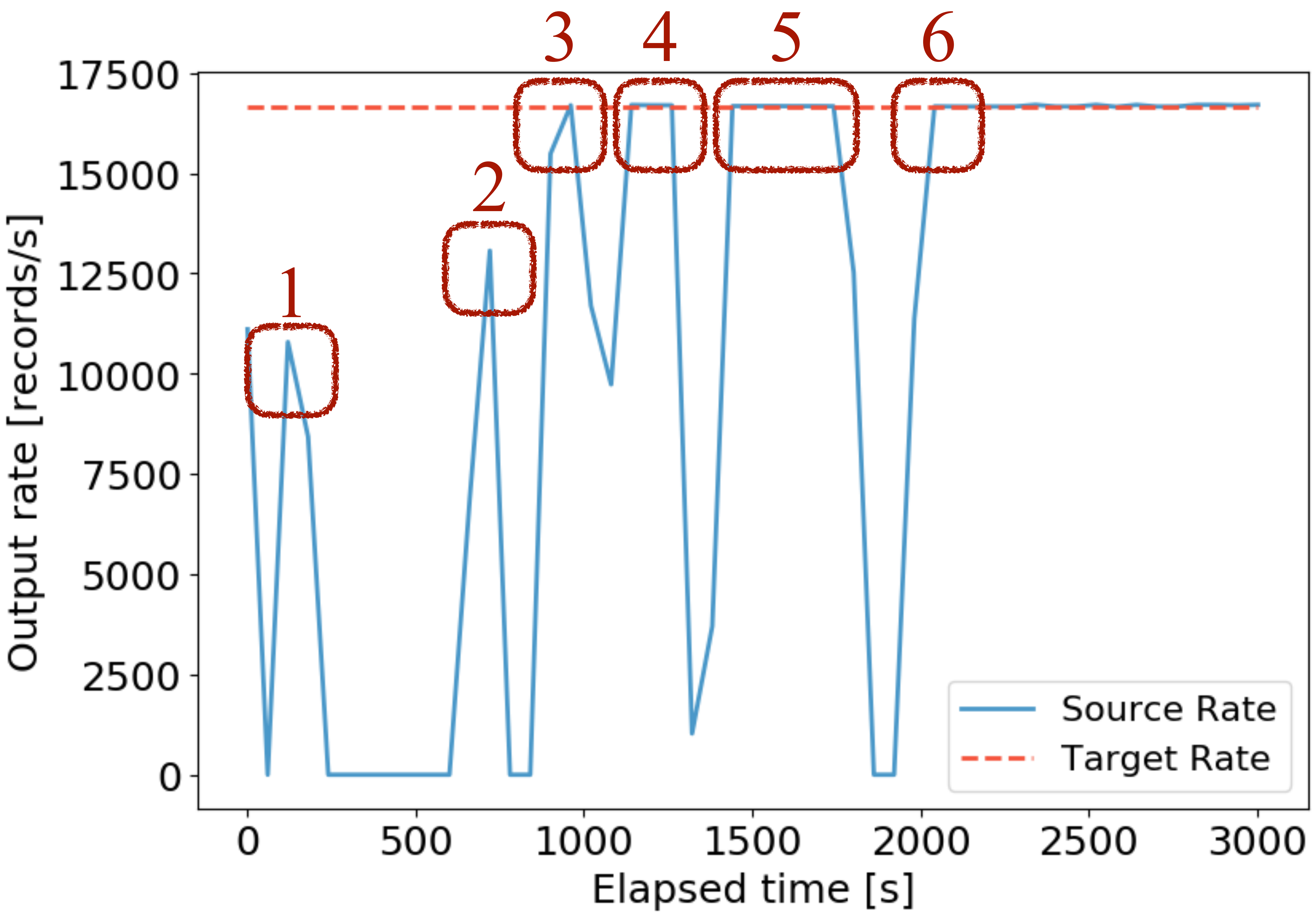

metrics

externally observed

policy

threshold-based

scaling action

non-predictive, single-operator

OUR APPROACH: DS2

metrics

~~externally observed~~

policy

~~threshold-based~~

scaling action

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true rates through instrumentation

dataflow dependency model

predictive, dataflow-wide actions

OUR APPROACH: DS2

metrics

~~externally observed~~

policy

~~threshold-based~~

scaling action

~~non-predictive, single-operator~~

true rates through instrumentation

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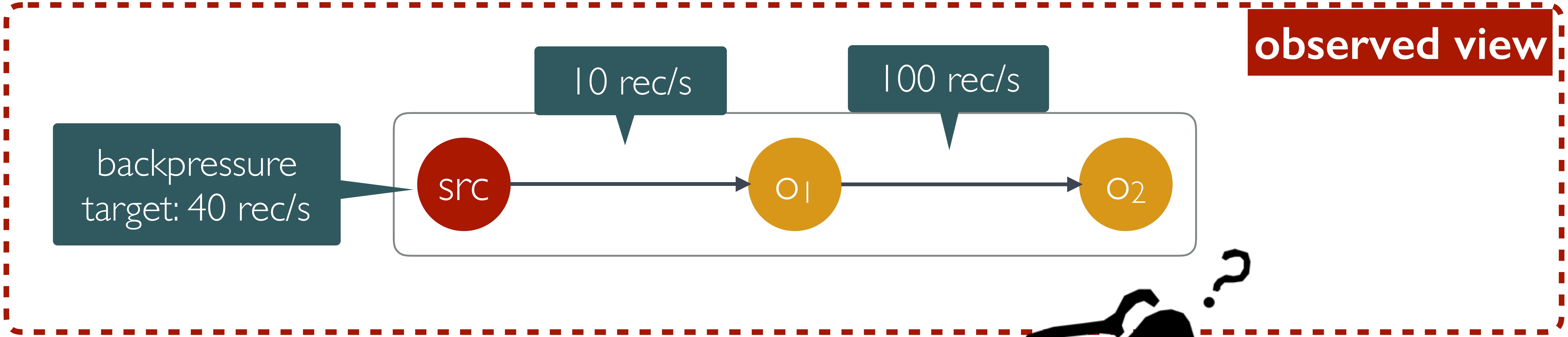
✓ **no oscillations**

✓ **true rates as bounds to avoid over/under-shoot**

✓ **fast convergence**

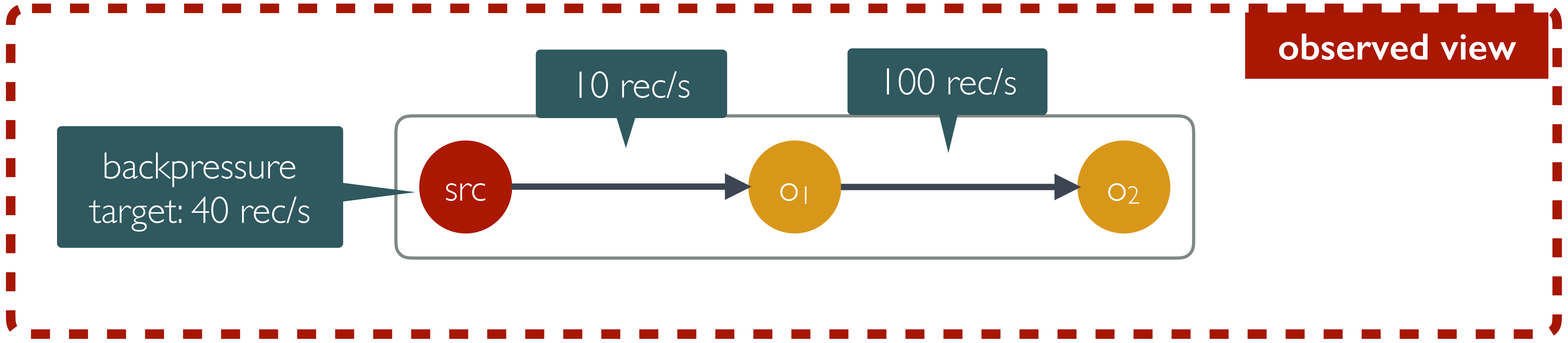

backpressure target: 40 rec/s
10 rec/s
100 rec/s
src
o1
o2

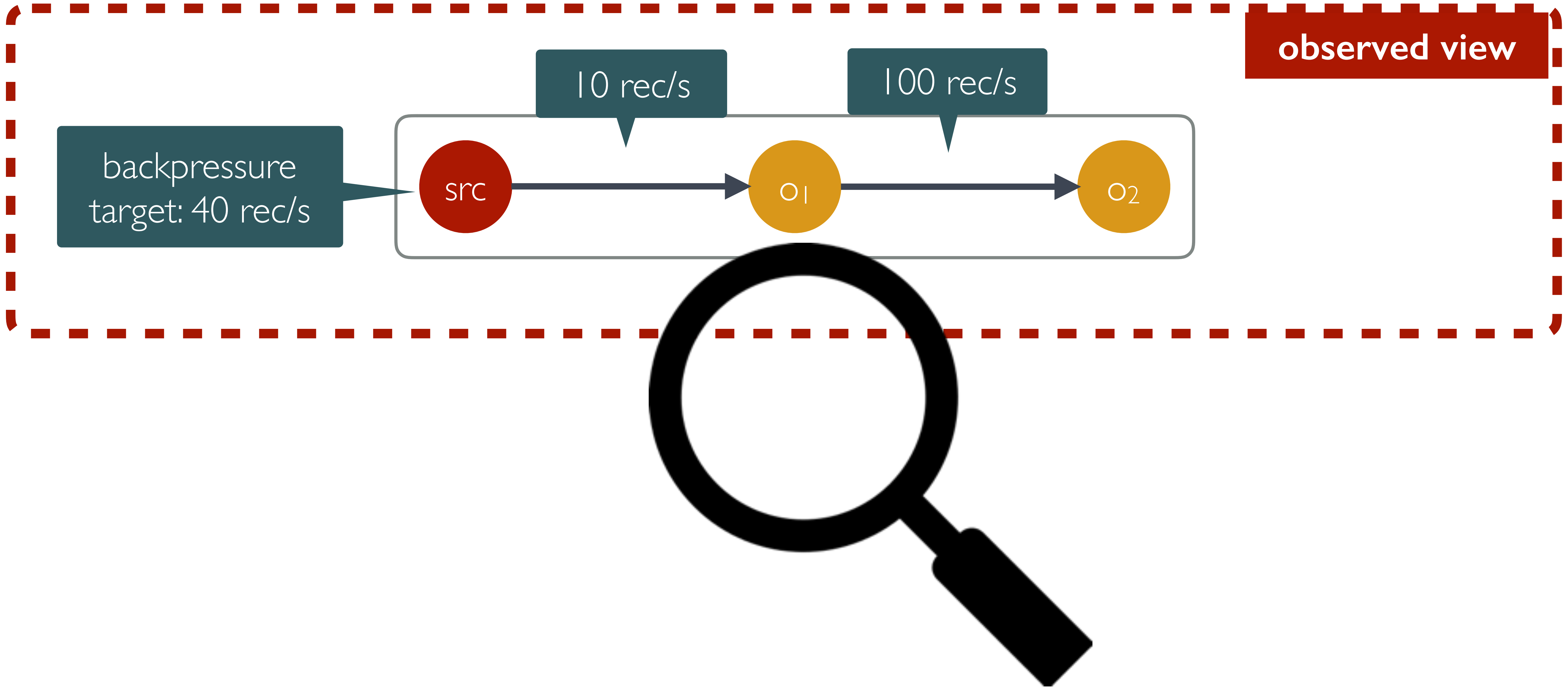


Which operator is the bottleneck?

What if we scale o_1 x 4?

How much to scale o_2?


observed view
10 rec/s
100 rec/s
backpressure
target: 40 rec/s
src
o1
o2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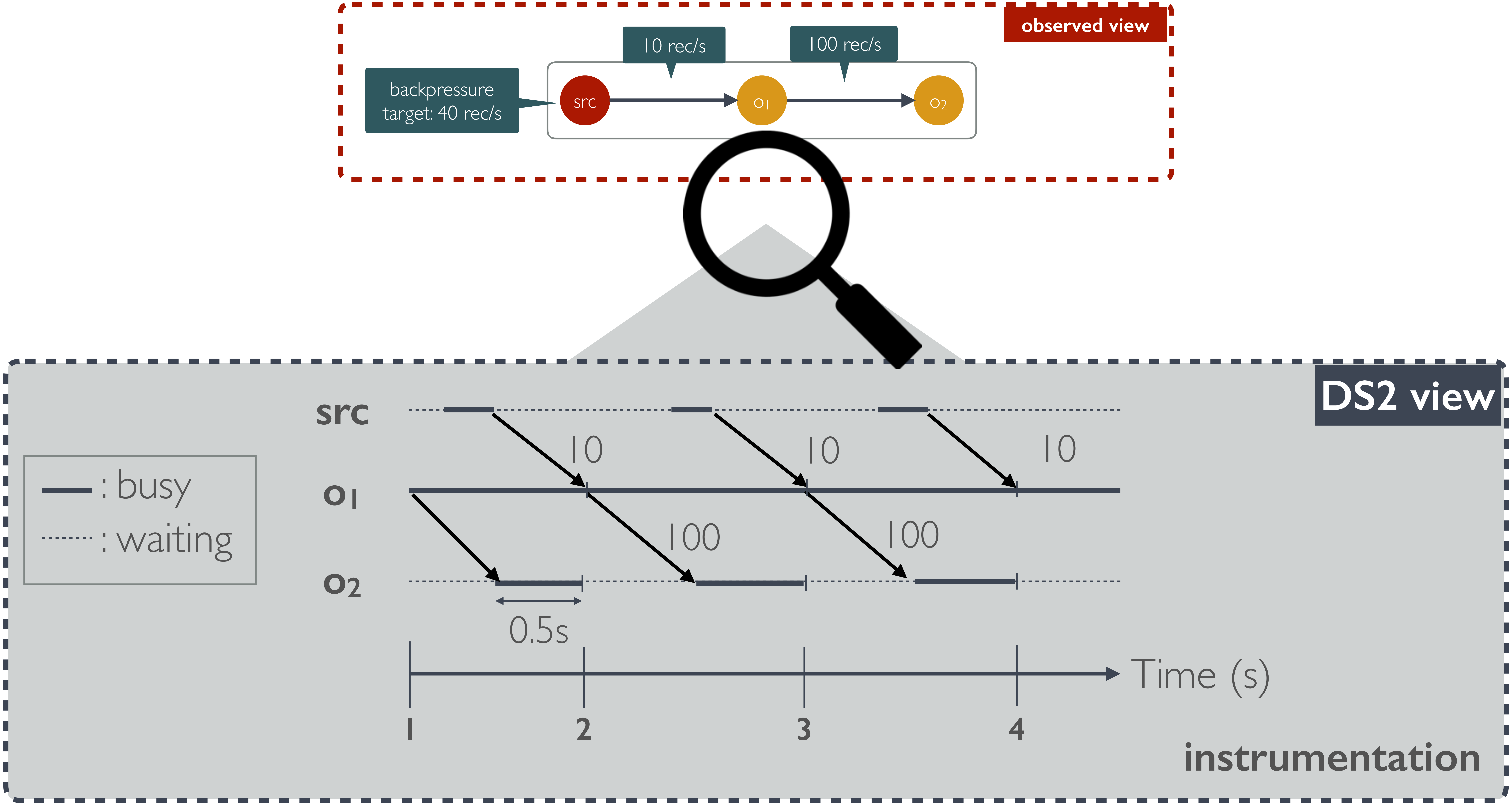
observed view
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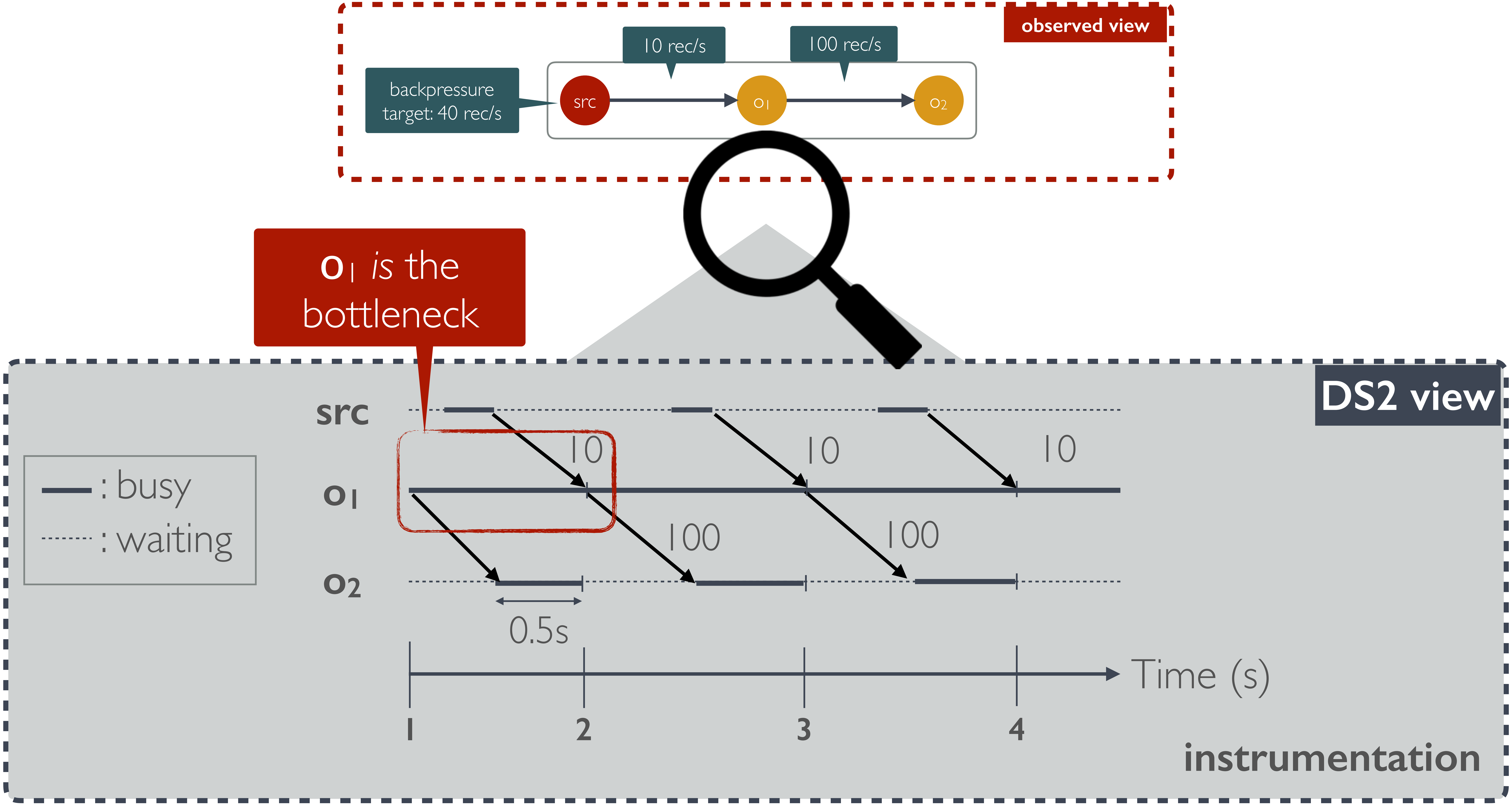
target: 40 rec/s
src
o1
o2
DS2 view
src
o1
o2
: busy
: waiting
10
10
10
100
100
0.5s
Time (s)
1
2
3
4
instrumentation


observed view
10 rec/s
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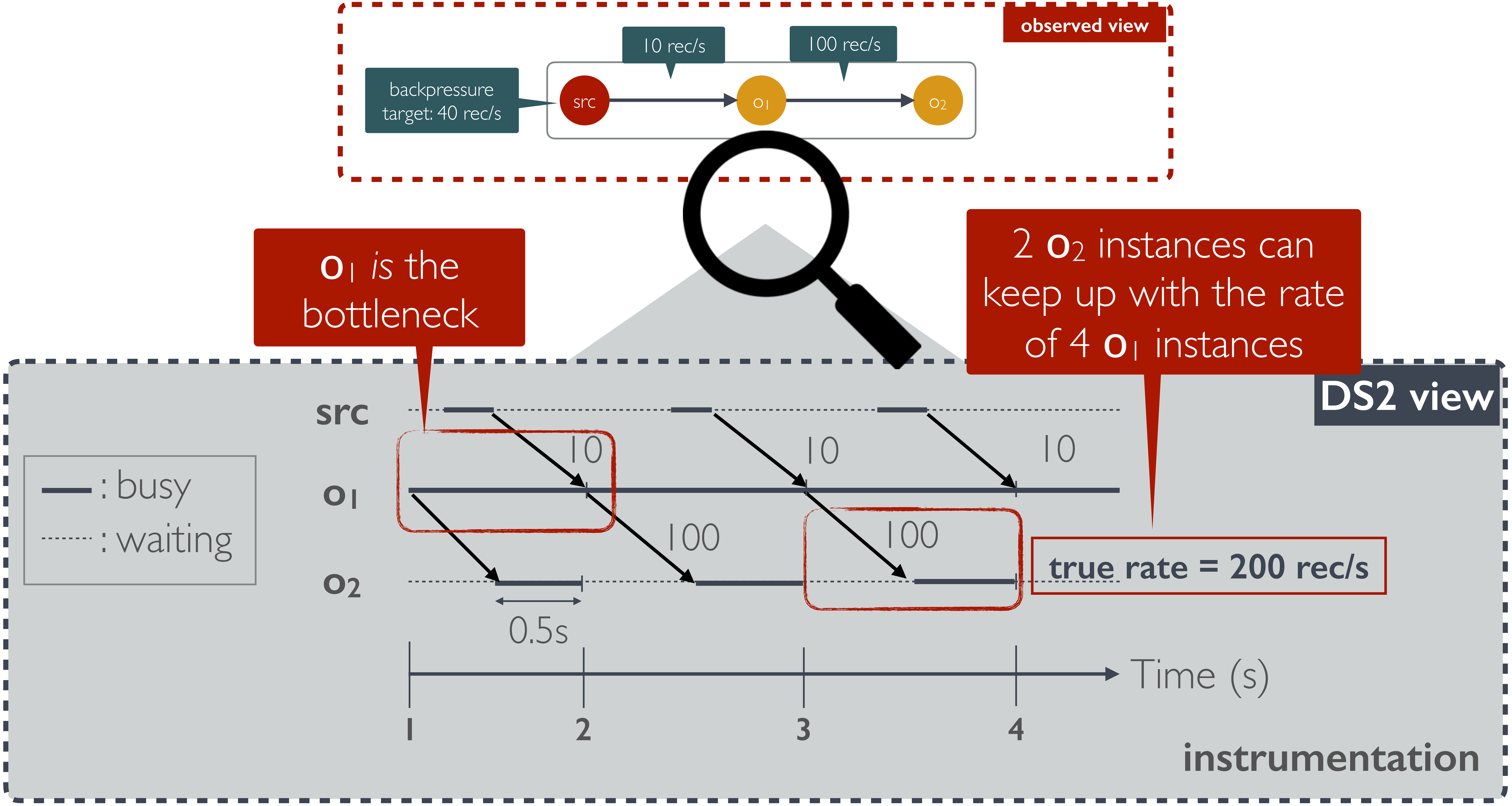
backpressure target: 40 rec/s
src
o1
o2
o1 is the bottleneck
DS2 view
src
o1
o2
: busy
: waiting
10
10
10
100
100
0.5s
Time (s)
1
2
3
4
instrumentation


observed view
10 rec/s
100 rec/s
backpressure target: 40 rec/s
src
o1
o2
o1 is the bottleneck
2 o2 instances can keep up with the rate of 4 o1 instances
DS2 view
src
o1
o2
: busy
: waiting
10
10
10
100
100
true rate = 200 rec/s
0.5s
Time (s)
1
2
3
4
instrumentation

THE DS2 MODEL

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Useful time: The time spent by an operator instance in **deserialization**, **processing**, and **serialization** activities.

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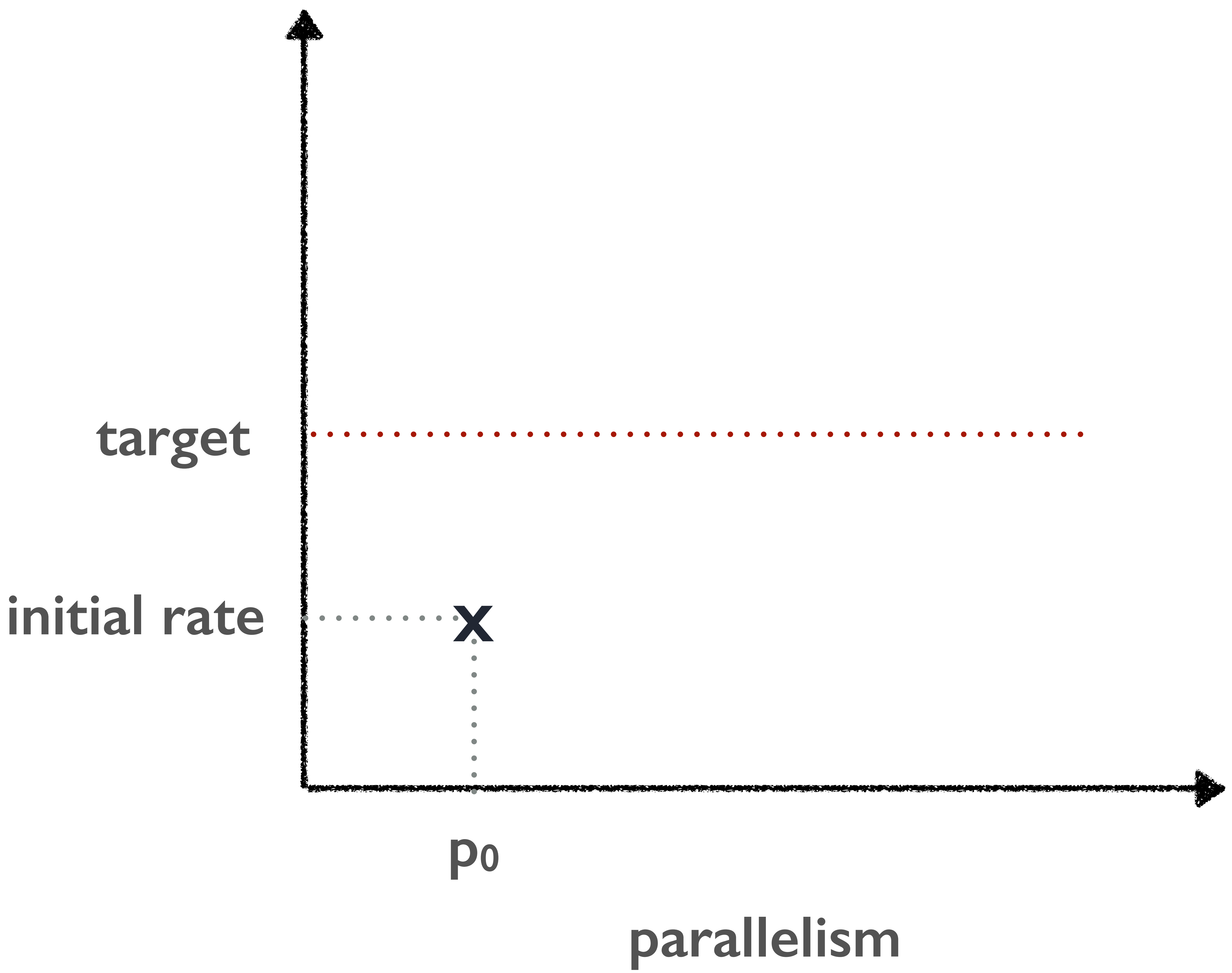
True processing (resp. output) rate: The number of **records** an operator instance can process (resp. output) **per unit of useful time**.

Optimal parallelism for o_i : $\dfrac{\text{aggregated true output rate of upstream ops}}{\text{average true processing rate of } o_i}$

CONVERGENCE STEPS

if the actual scaling is linear,
convergence takes **one** step

- **no overshoot** when scaling up: ideal rate is an *upper* bound
- **no undershoot** when scaling down: ideal rate is a *lower* bound



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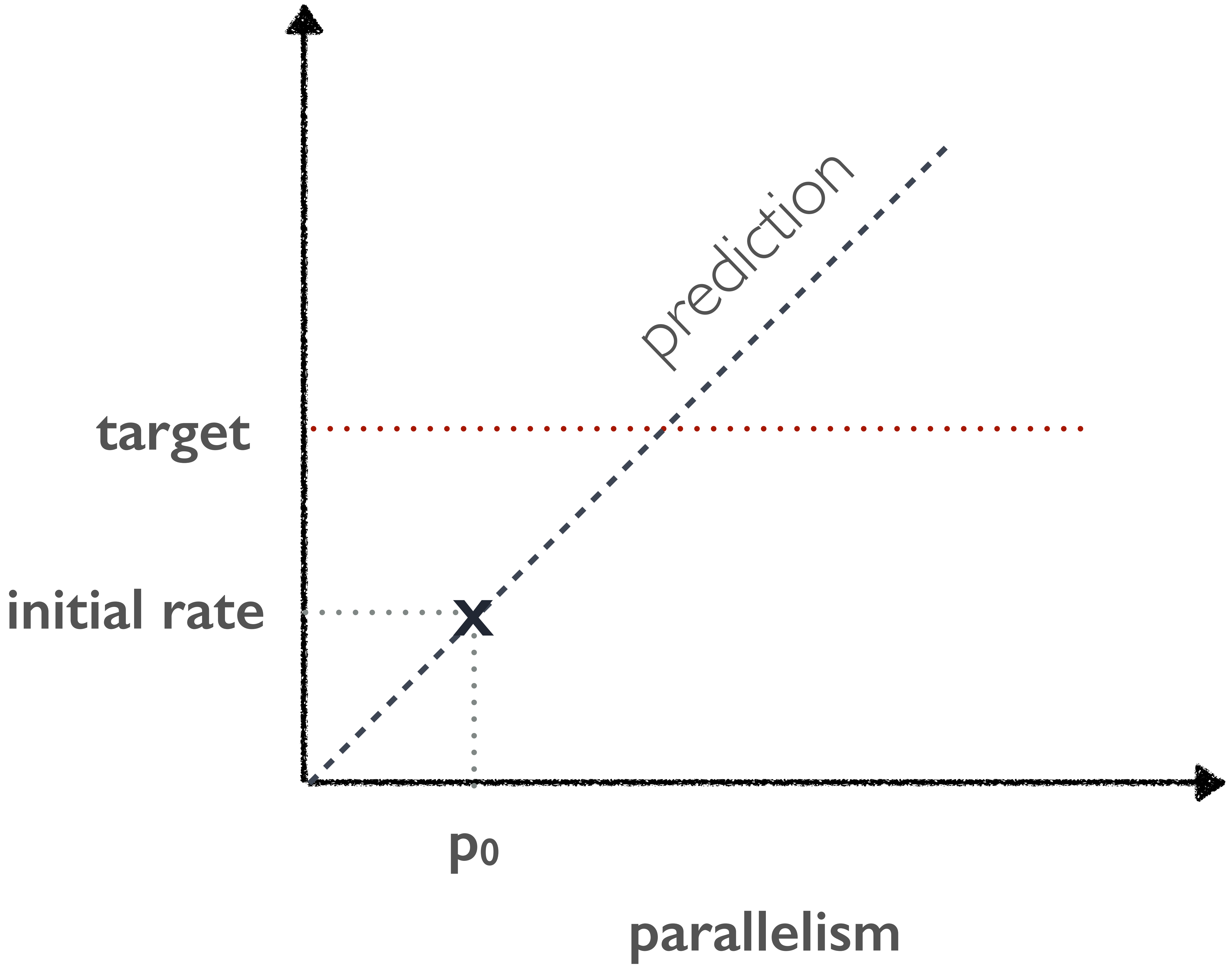

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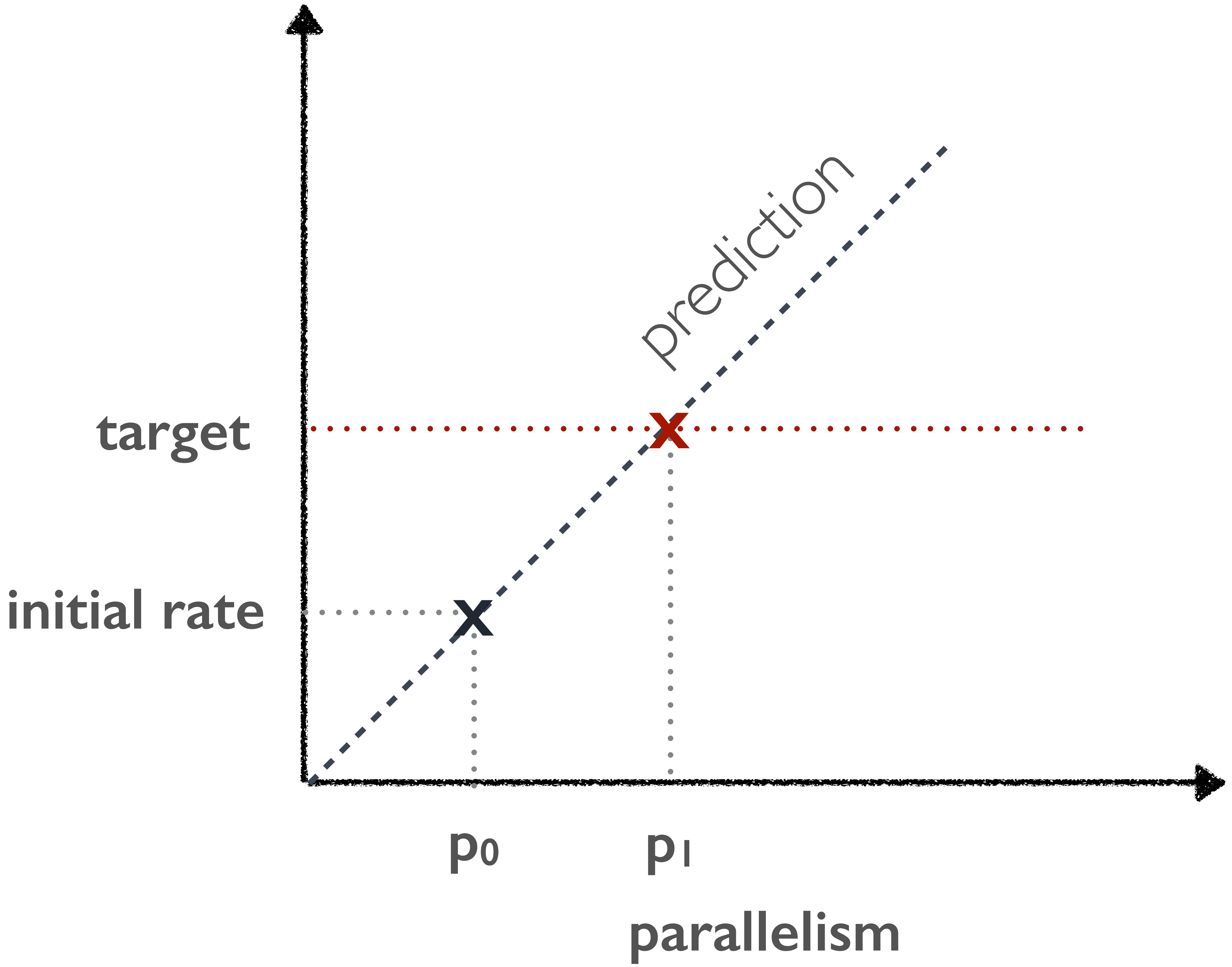

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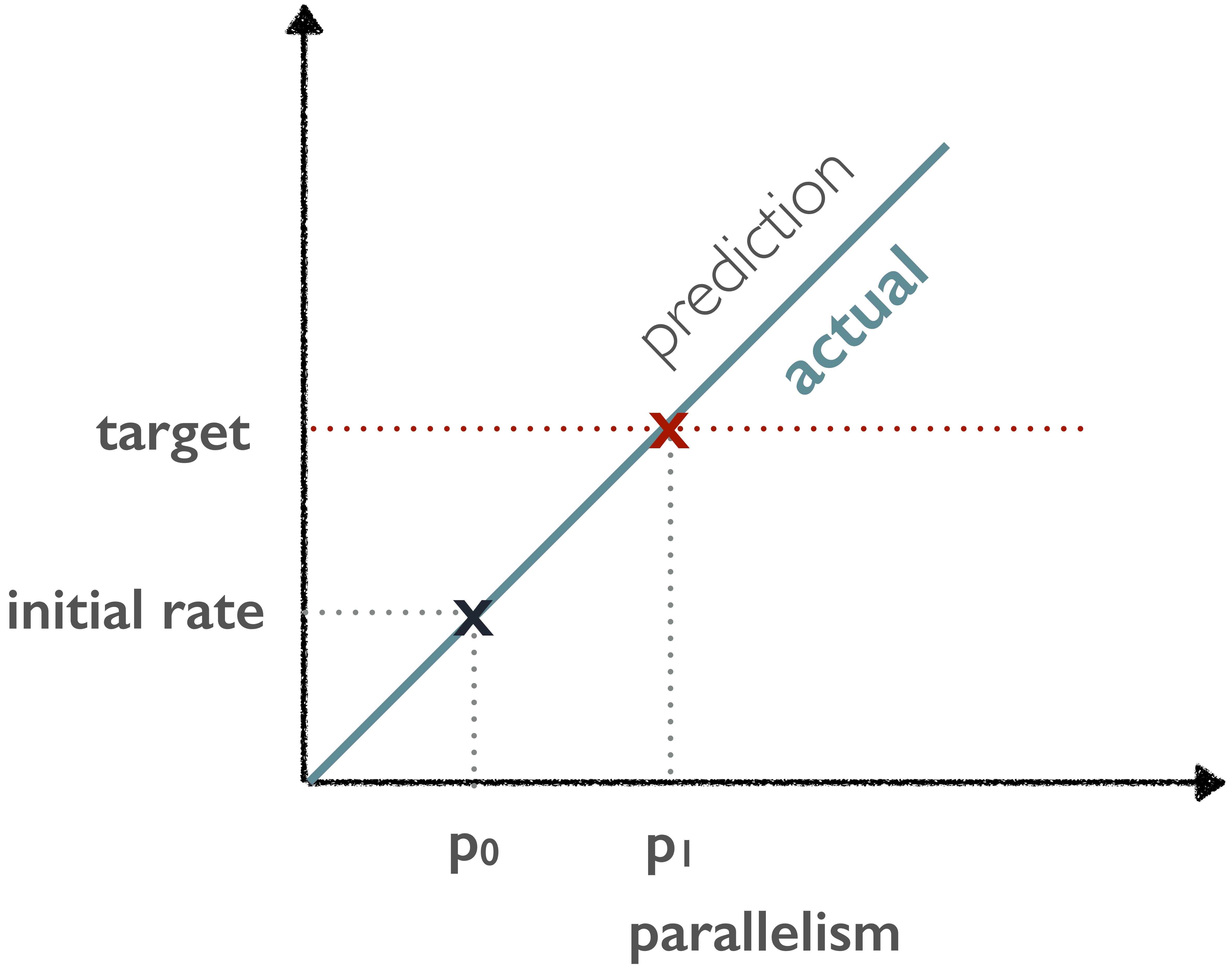
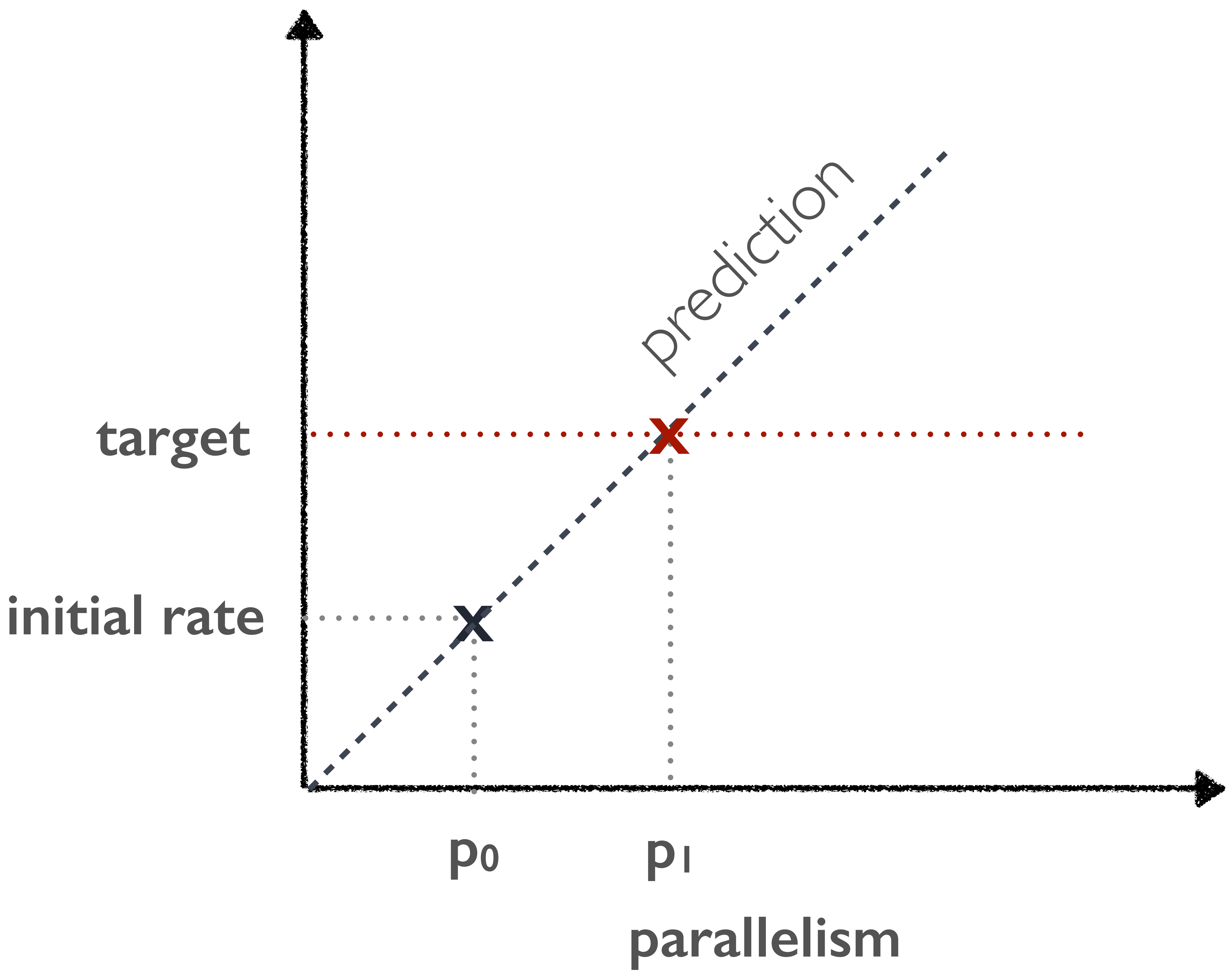


CONVERGENCE STEPS

In practice, rates are commonly **sub-linear** due to other overheads (e.g. worker coordination).



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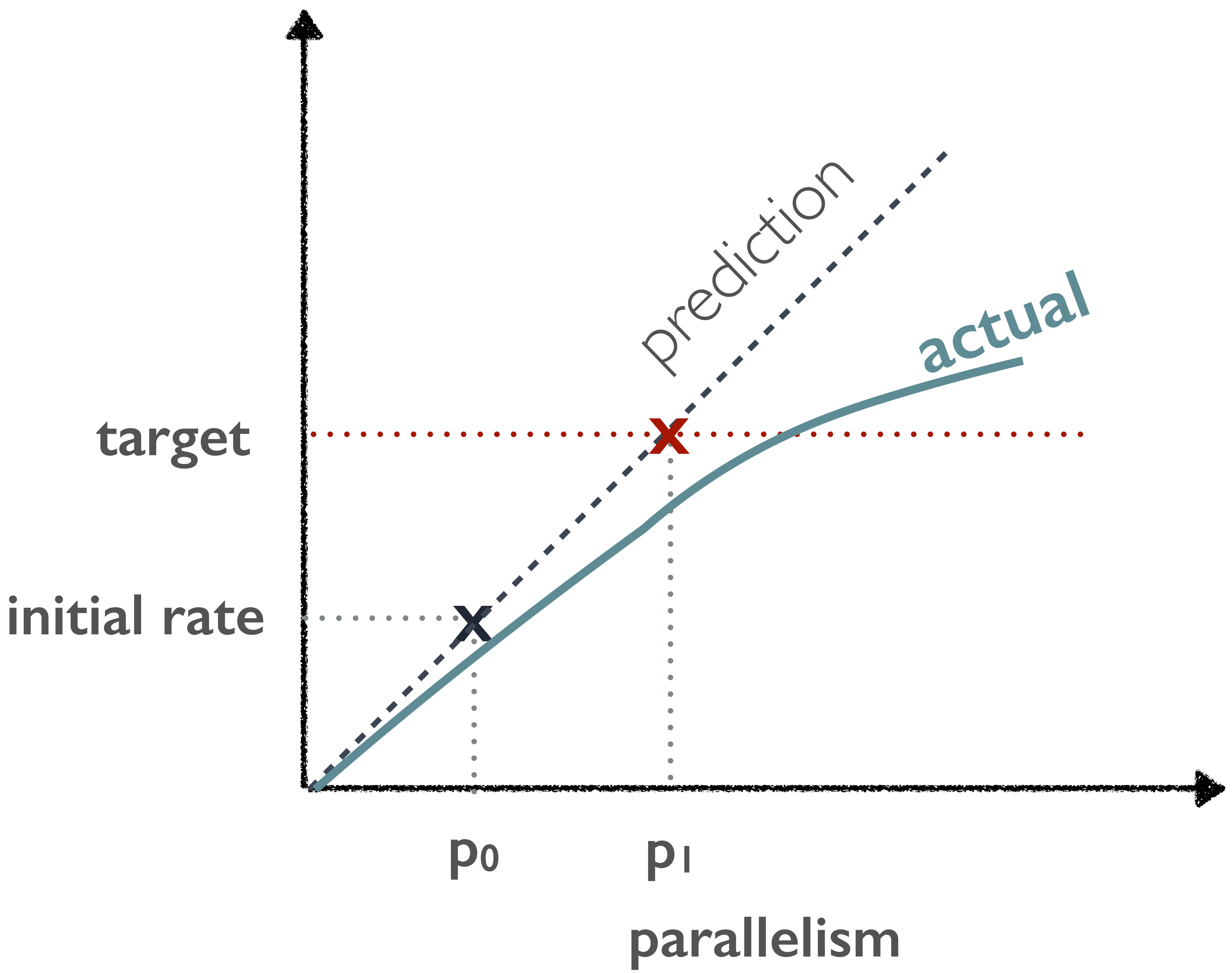

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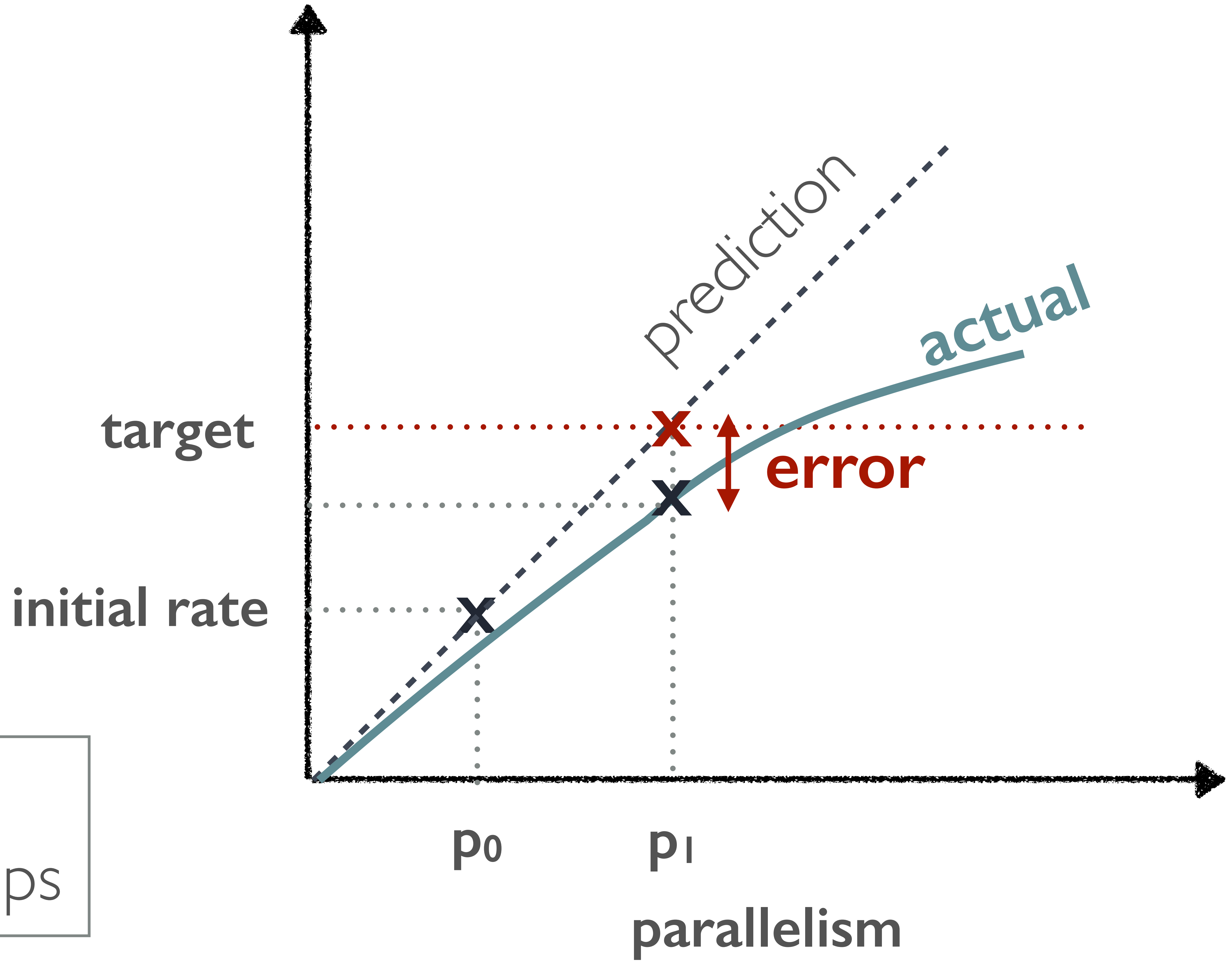
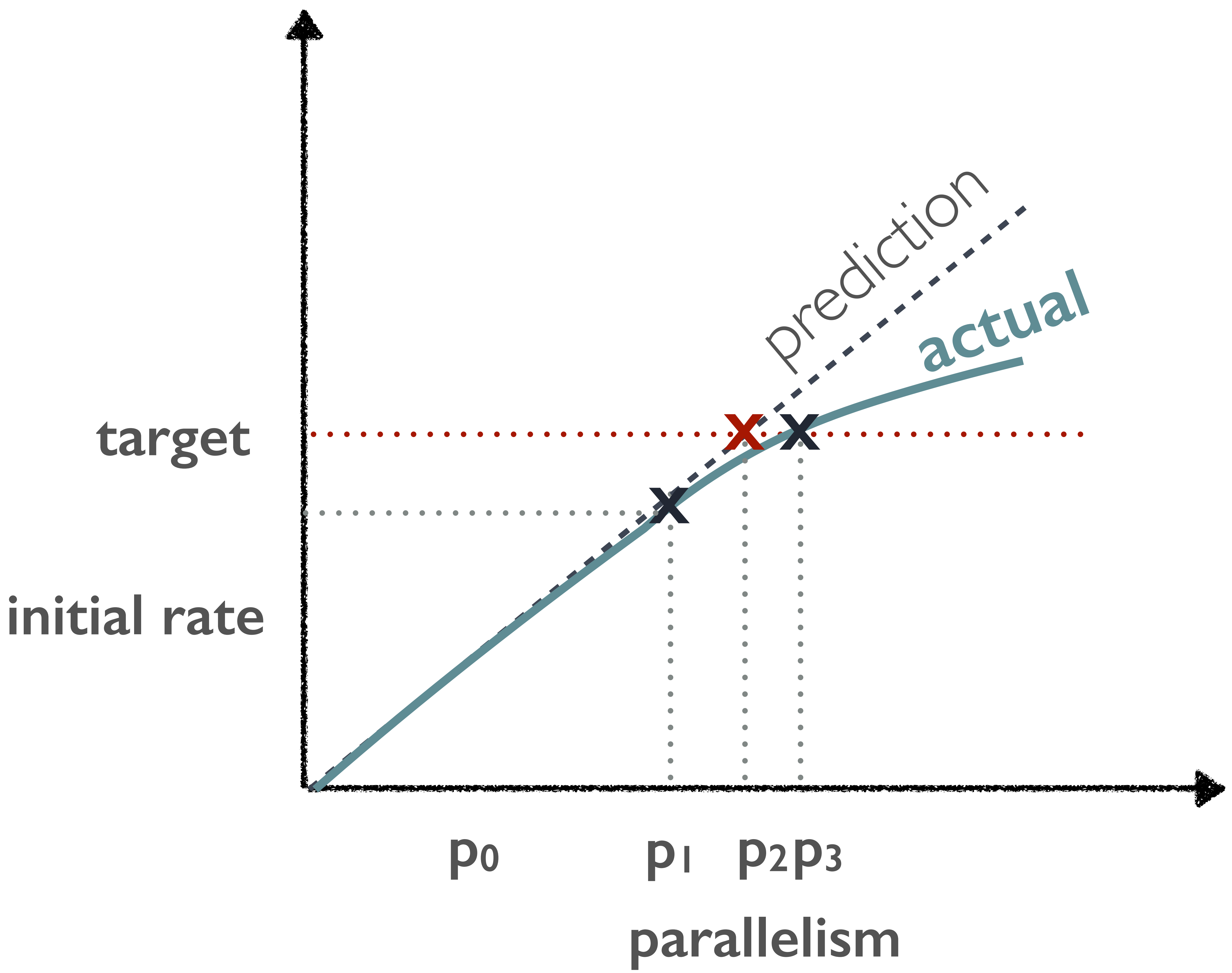


when the actual scaling is sub-linear, convergence takes **more than one** steps

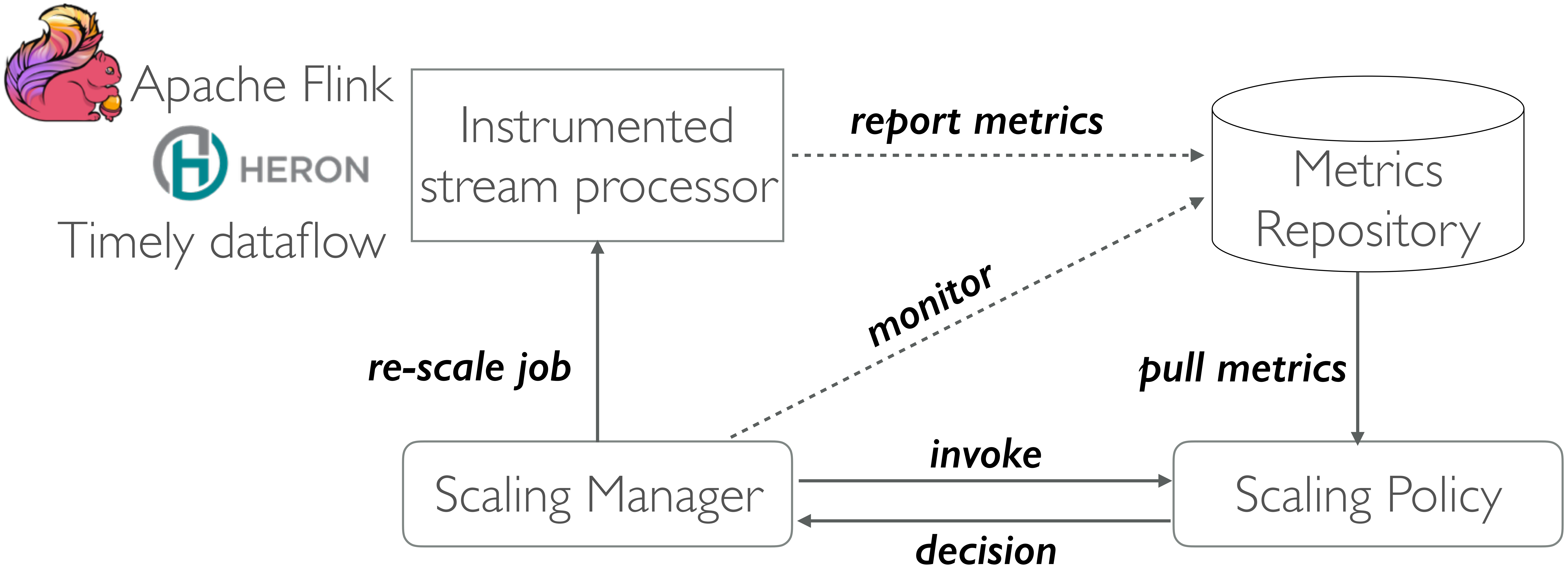
CONVERGENCE STEPS

In practice, rates are commonly **sub-linear** due to other overheads (e.g. worker coordination).

In our experiments, DS2 took **up to three steps** to converge for complex queries.

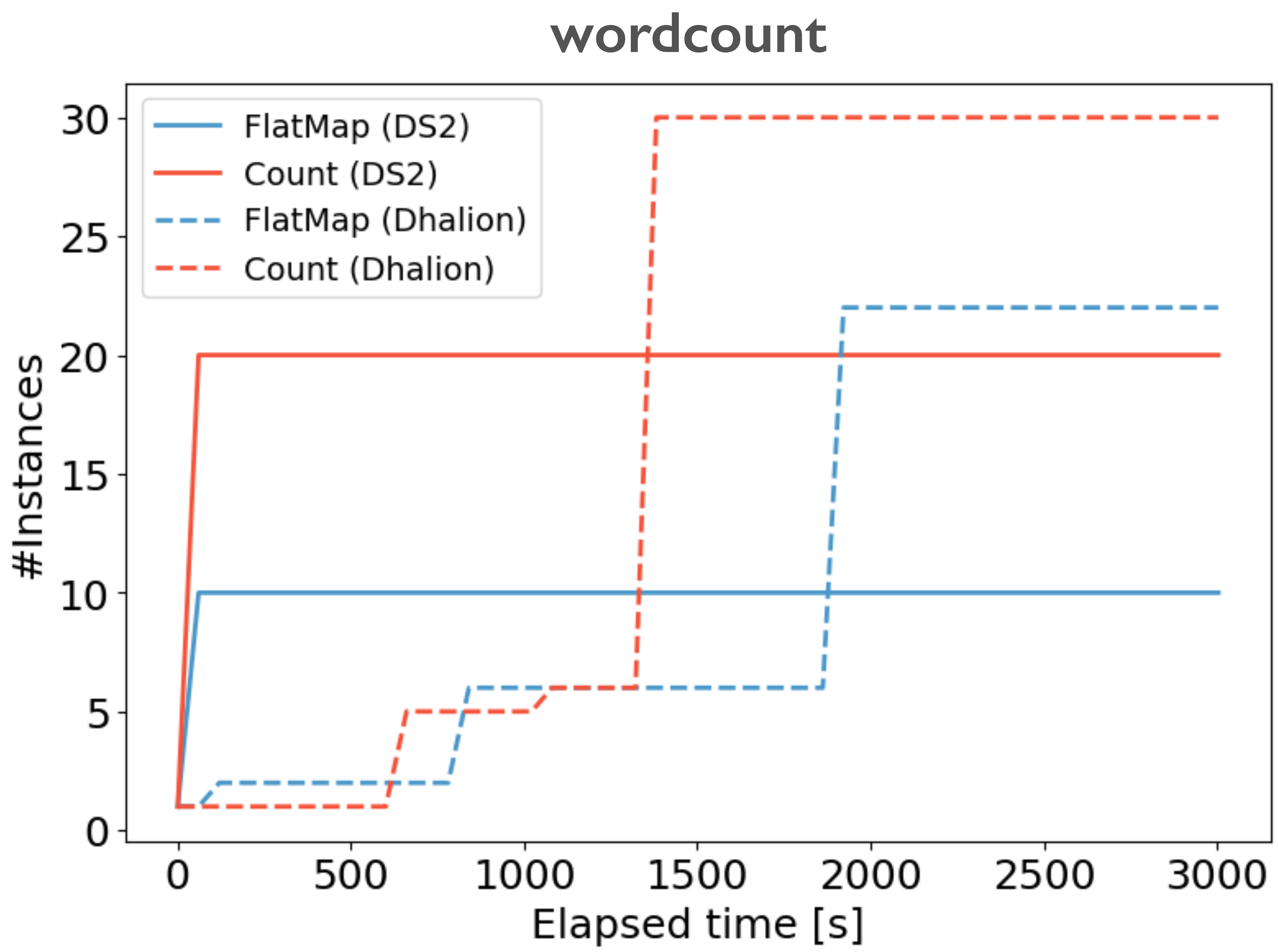


DS2 operates *online* in a *reactive* setting



EVALUATION

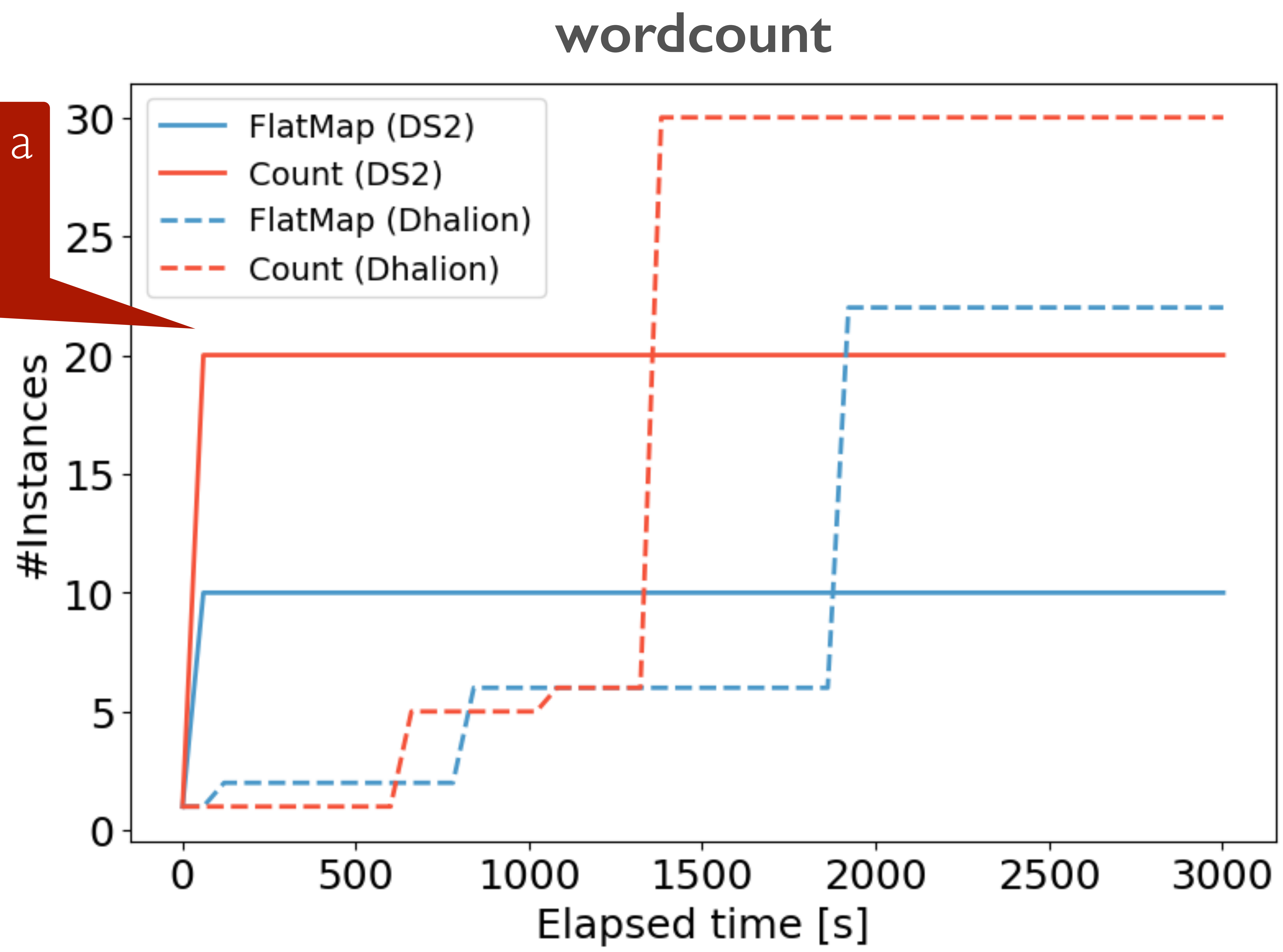
DS2 VS. DHALION ON HERON



Target rate: 16.700 rec/s

DS2 VS. DHALION ON HERON

DS2 converges in a **single step** for both operators



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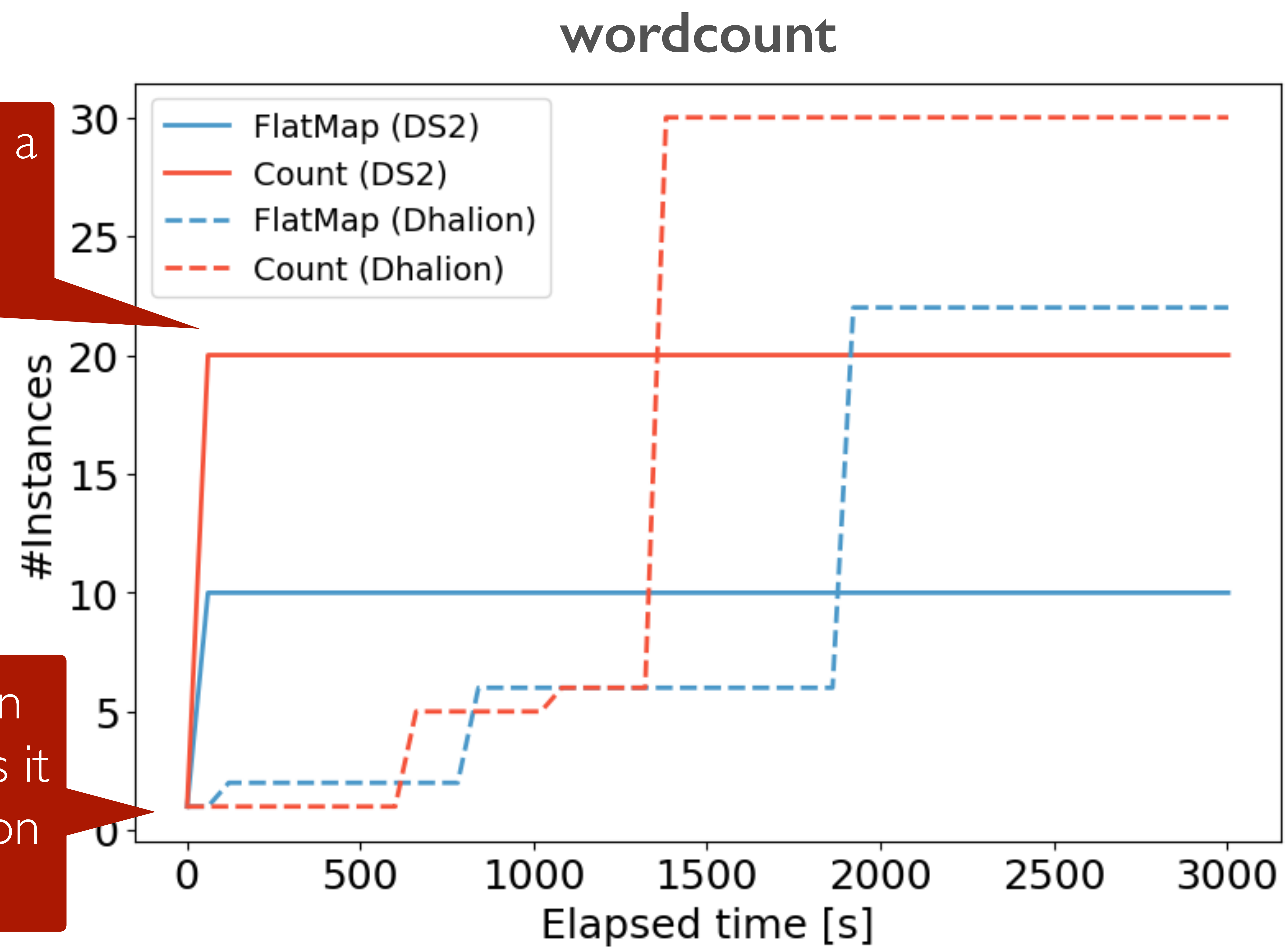

DS2 converges in **60s**, i.e. as soon as it receives the Heron metrics

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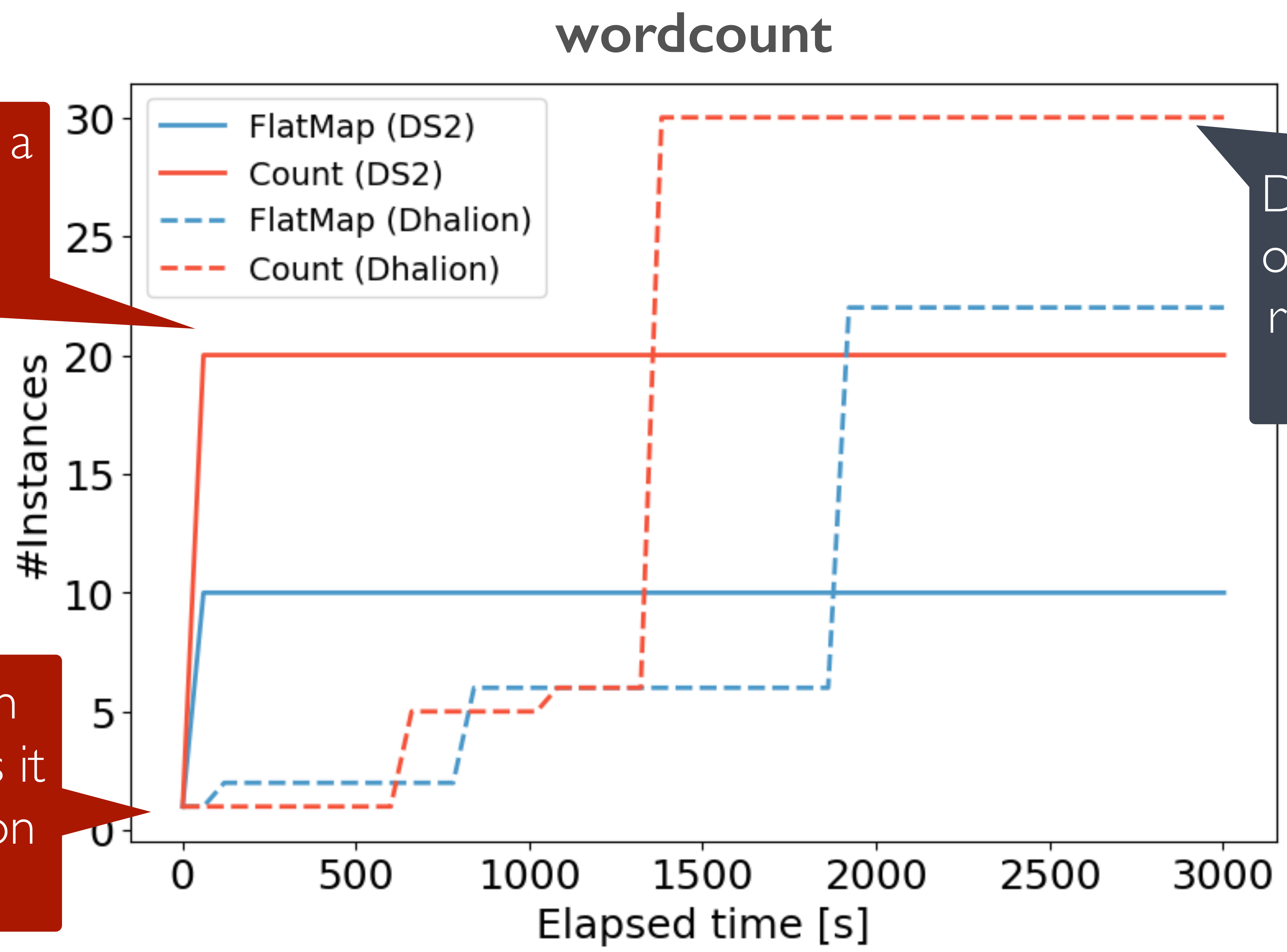

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Dhalion scales one operator at a time, resulting to a total of **six steps**

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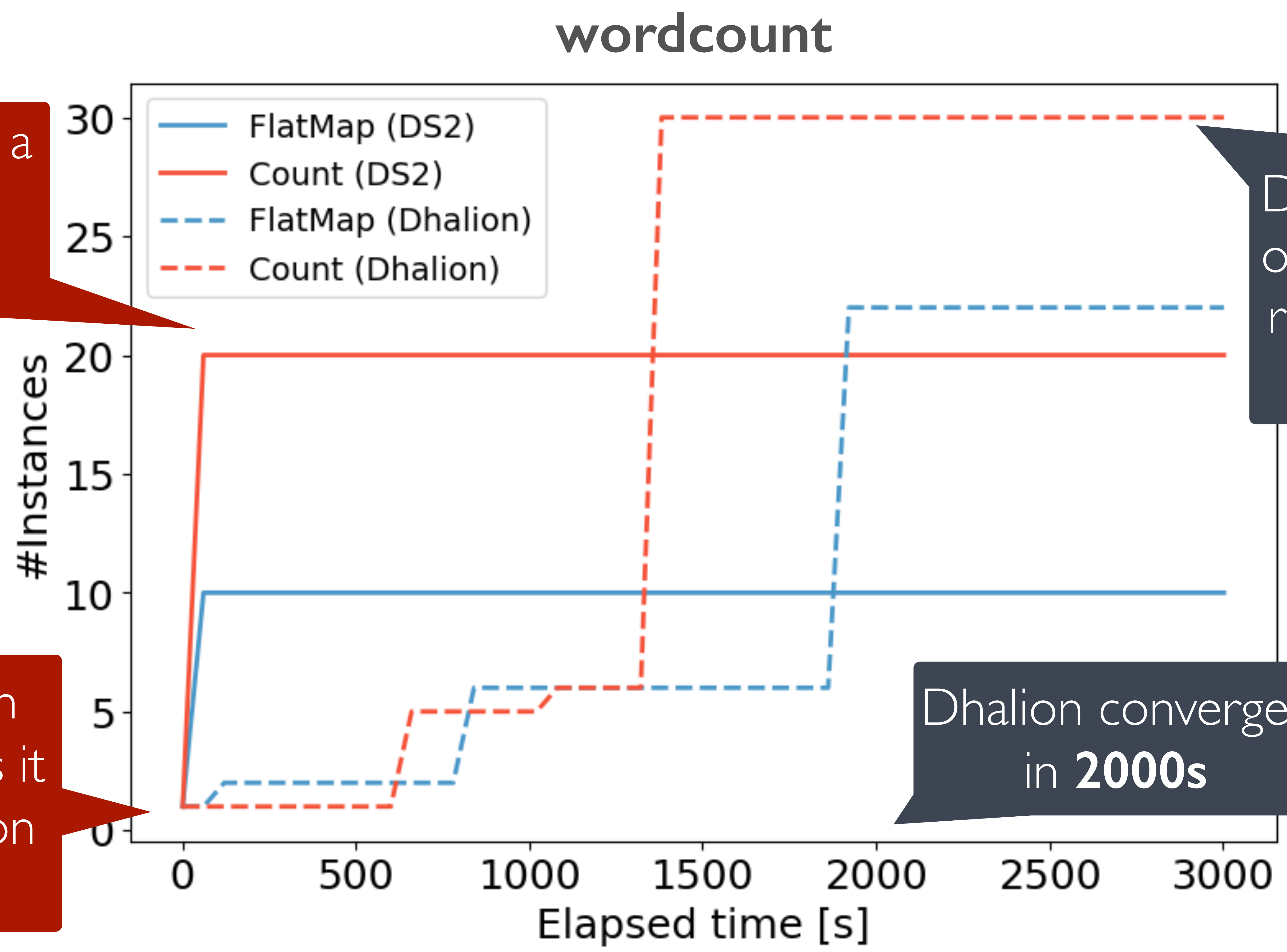

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Dhalion converges in **2000s**

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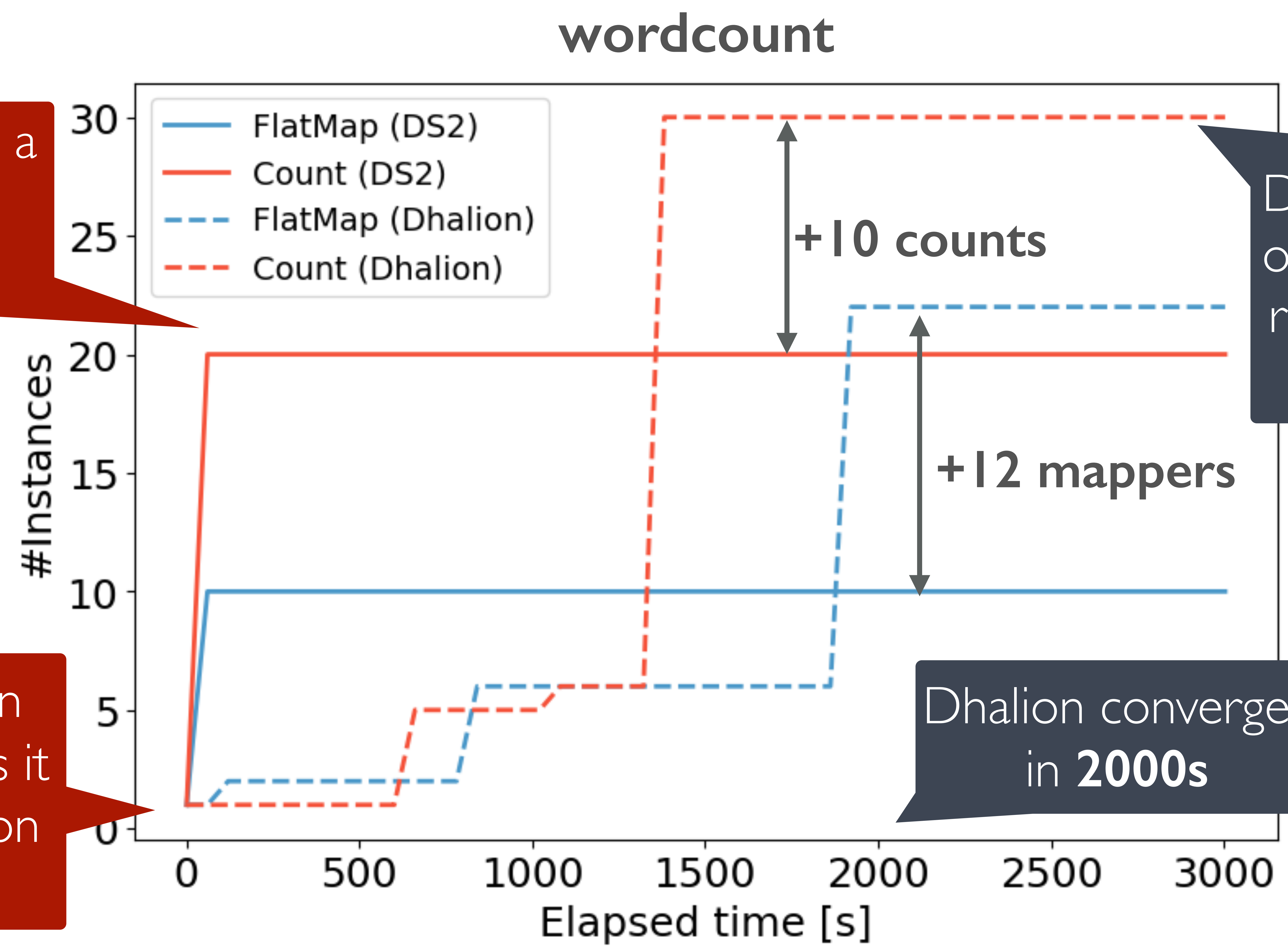

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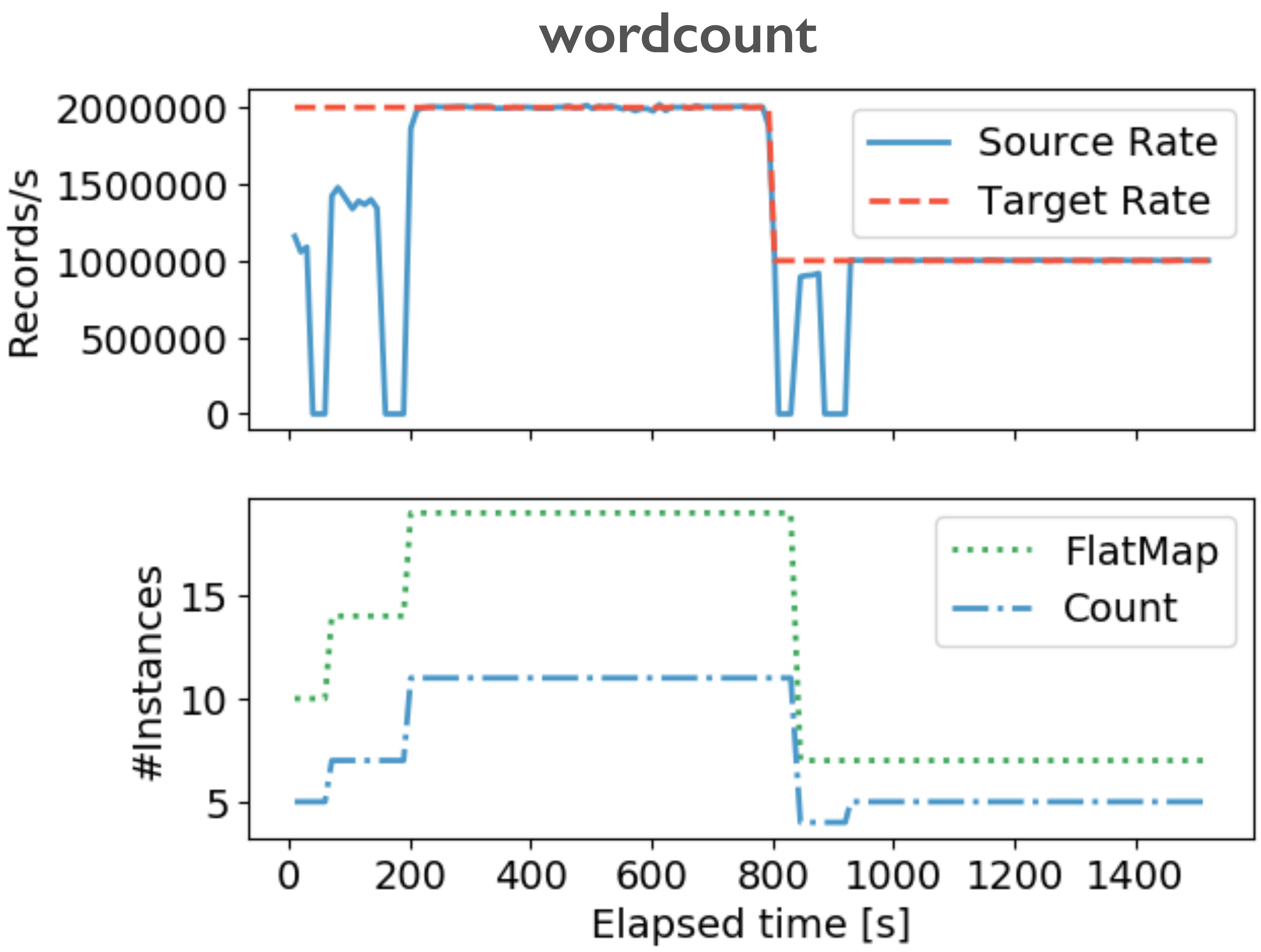
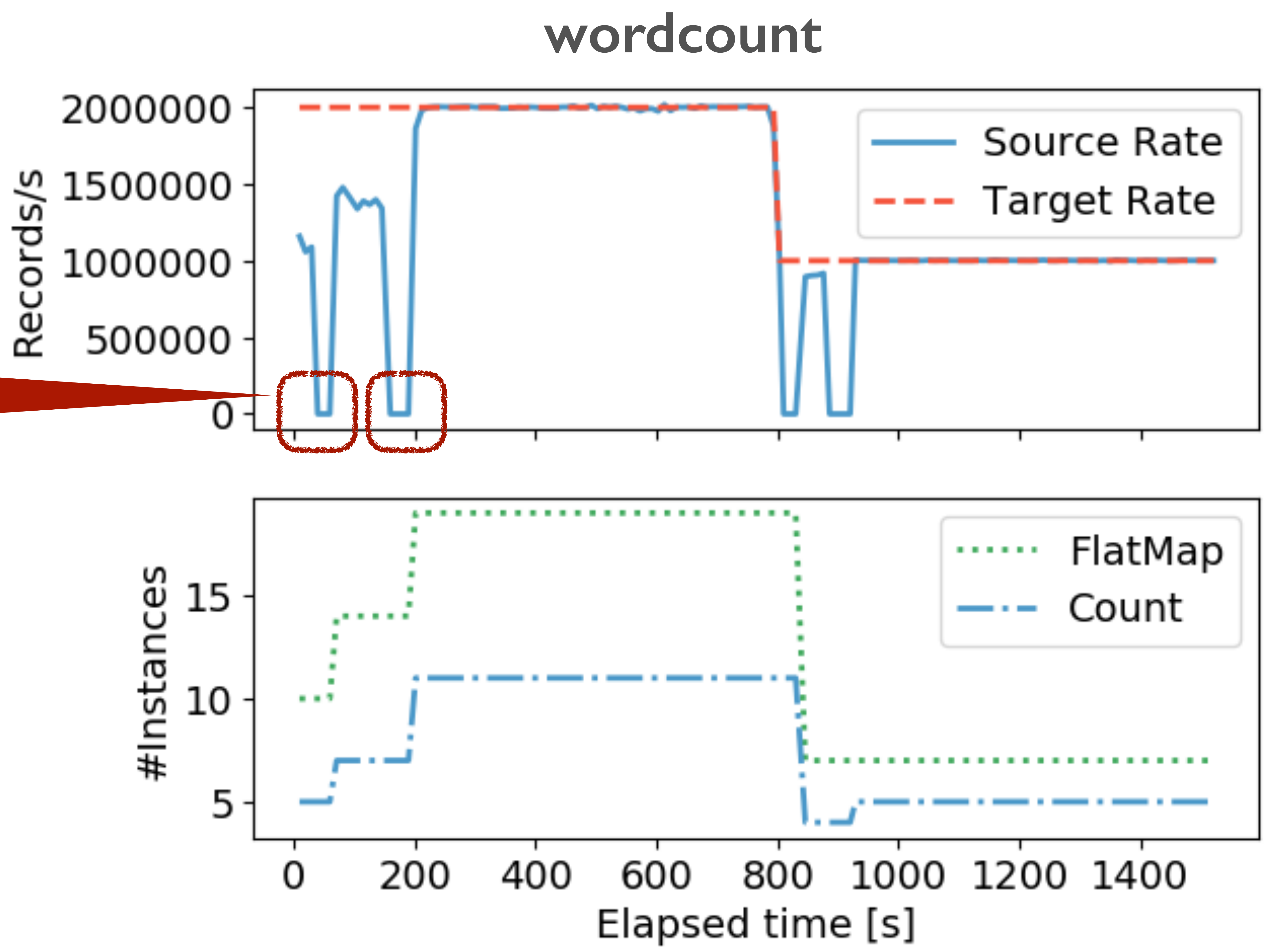
DS2 ON APACHE FLINK



Target rate: 2.000.000 rec/s

DS2 ON APACHE FLINK



Apache Flink savepoint and reconfiguration takes ~**30s**

Target rate: 2.000.000 rec/s

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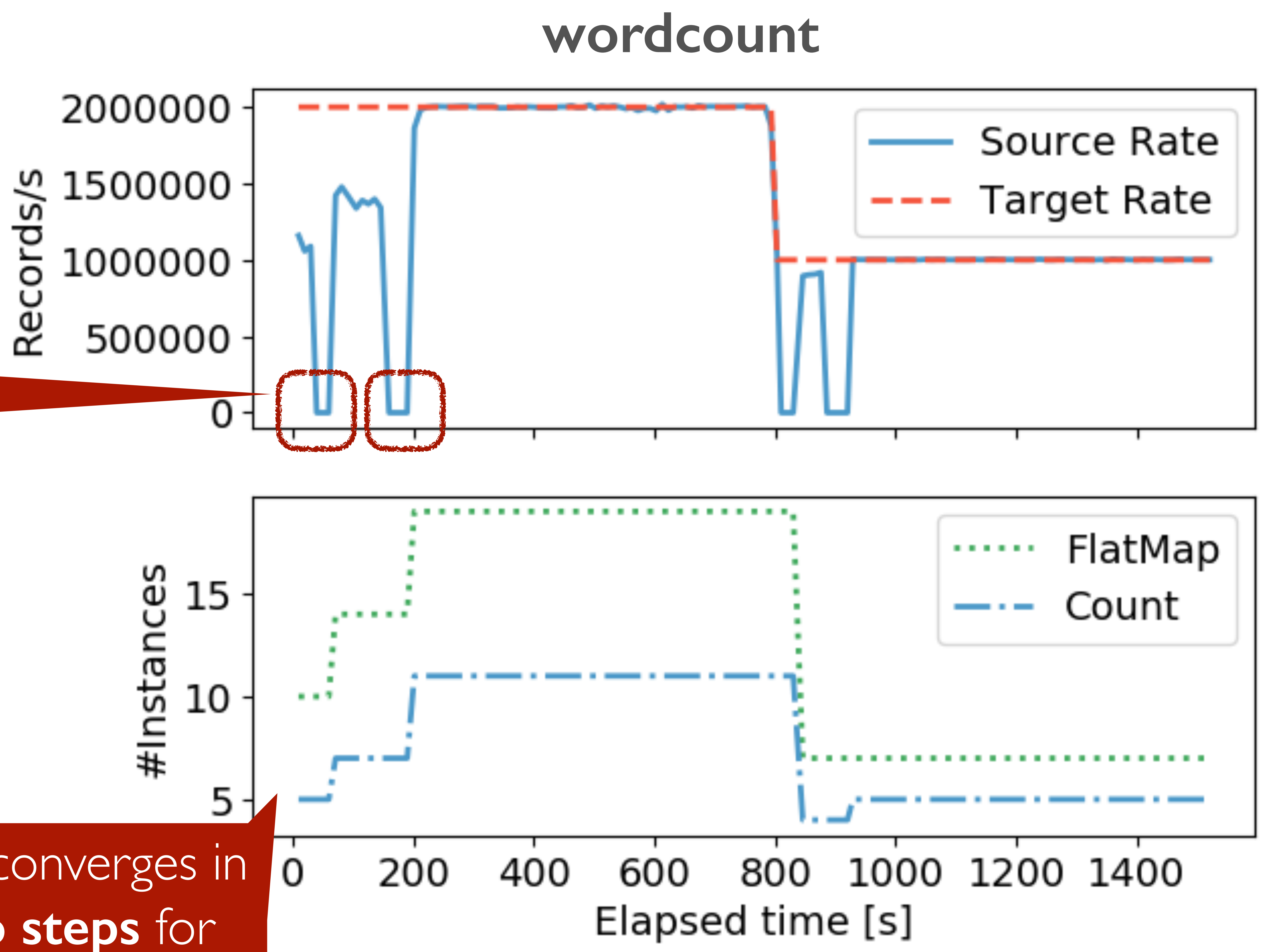

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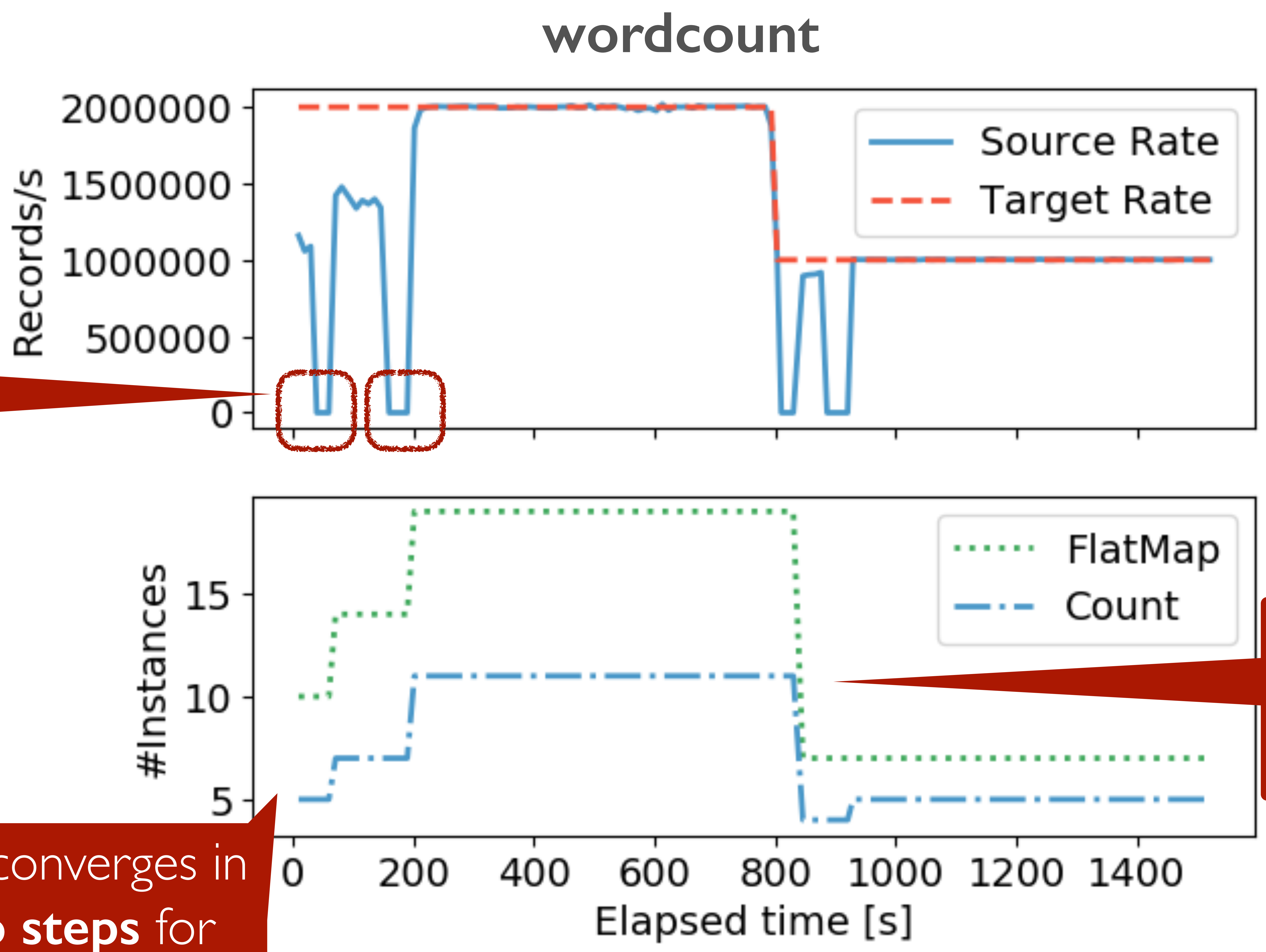
DS2 converges in **two steps** for both operators

Target rate: 2.000.000 rec/s

DS2 ON APACHE FLINK



Apache Flink savepoint and reconfiguration takes ~**30s**

DS2 reacts **3s** after the target rate has changed

DS2 converges in **two steps** for both operators

Target rate: 2.000.000 rec/s

CONVERGENCE - NEXMARK

initial parallelism	Q1: flatmap	Q2: filter	Q3: incremental join	Q5: tumbling window join	Q8: sliding window	Q11: session window
8 =>	12 => **16**	11 => 13 => **14**	16 => **20**	14 => 15 => **16**	**10**	12 => 22 => **28**
12 =>	**16**	**14**	18 => **20**	**16**	**10**	22 => **28**
16 =>	**16**	12 => **14**	**20**	**16**	8 => **10**	26 => **28**
20 =>	**16**	13 => **14**	**20**	14 => **16**	8 => **10**	**28**
24 =>	**16**	**14**	**20**	14 => **16**	8 => **10**	**28**
28 =>	**16**	**14**	**20**	13 => **16**	8 => **10**	**28**

=> : scaling action

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scale-up

=> : scaling action

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20 =>	**16**	13 => **14**	**20**	14 => **16**	8 => **10**	**28**
24 =>	**16**	**14**	**20**	14 => **16**	8 => **10**	**28**
28 =>	**16**	**14**	**20**	13 => **16**	8 => **10**	**28**

scale-up

scale-down

=> : scaling action

CONVERGENCE - NEXMARK

initial parallelism	Q1: flatmap	Q2: filter	Q3: incremental join	Q5: tumbling window join	Q8: sliding window	Q11: session window
8 =>	12 => **16**	11 => 13 => **14**	16 => **20**	14 => 15 => **16**	**10**	12 => 22 => **28**
12 =>	**16**	**14**	18 => **20**	**16**	**10**	22 => **28**
16 =>	**16**	12 => **14**	**20**	**16**	8 => **10**	26 => **28**
20 =>	**16**	13 => **14**	**20**	14 => **16**	8 => **10**	**28**
24 =>	**16**	**14**	**20**	14 => **16**	8 => **10**	**28**
28 =>	**16**	**14**	**20**	13 => **16**	8 => **10**	**28**

scale-up

scale-down

a single step for many queries and initial configurations

=> : scaling action

CONVERGENCE - NEXMARK

at most **3 steps**

initial parallelism	Q1: flatmap	Q2: filter	Q3: incremental join	Q5: tumbling window join	Q8: sliding window	Q11: session window
8 =>	12 => **16**	11 => 13 => **14**	16 => **20**	14 => 15 => **16**	**10**	12 => 22 => **28**
12 =>	**16**	**14**	18 => **20**	**16**	**10**	22 => **28**
16 =>	**16**	12 => **14**	**20**	**16**	8 => **10**	26 => **28**
20 =>	**16**	13 => **14**	**20**	14 => **16**	8 => **10**	**28**
24 =>	**16**	**14**	**20**	14 => **16**	8 => **10**	**28**
28 =>	**16**	**14**	**20**	13 => **16**	8 => **10**	**28**

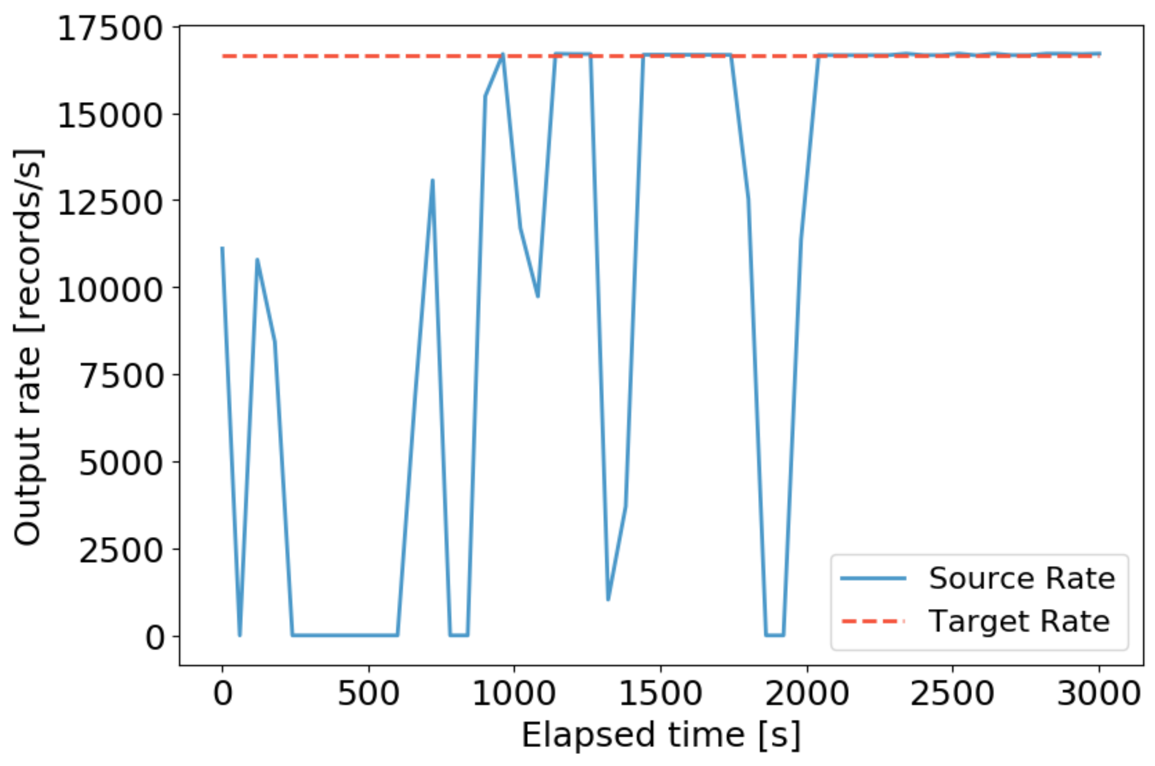
scale-up

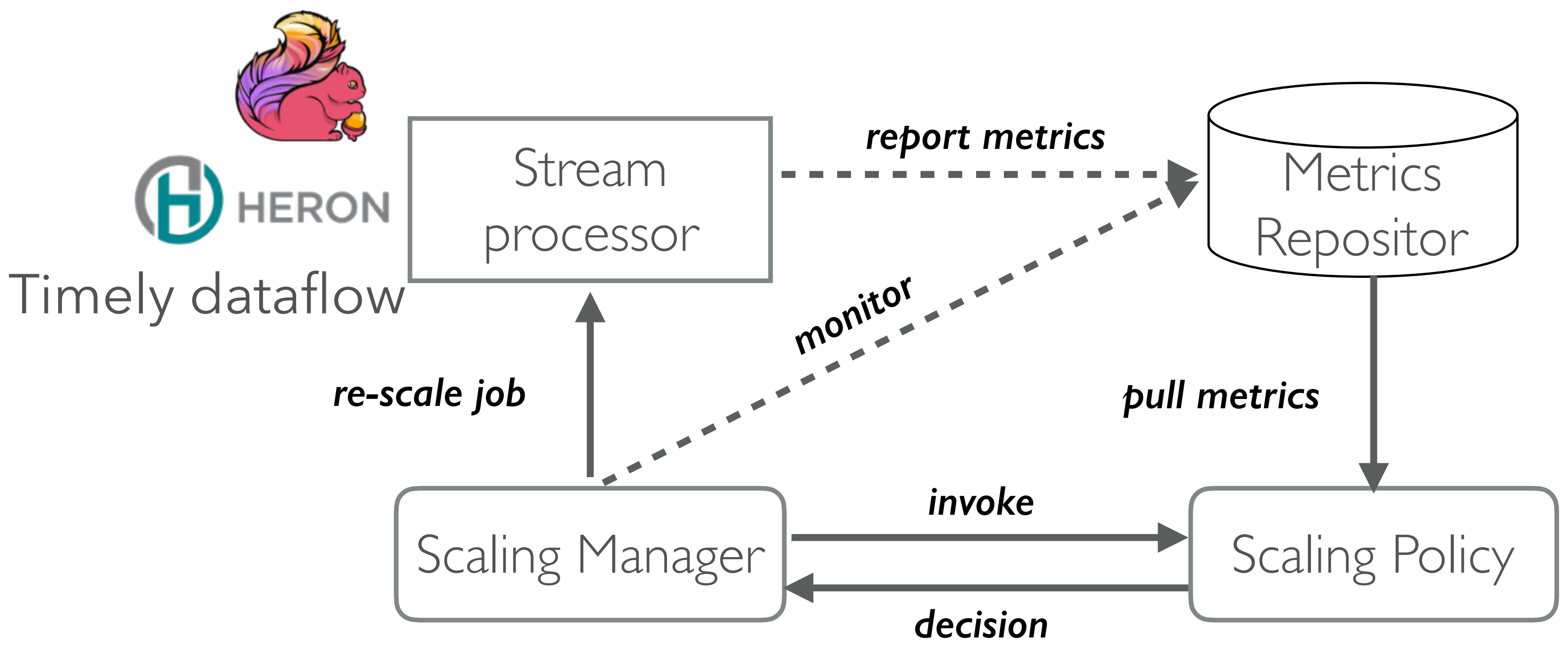
scale-down

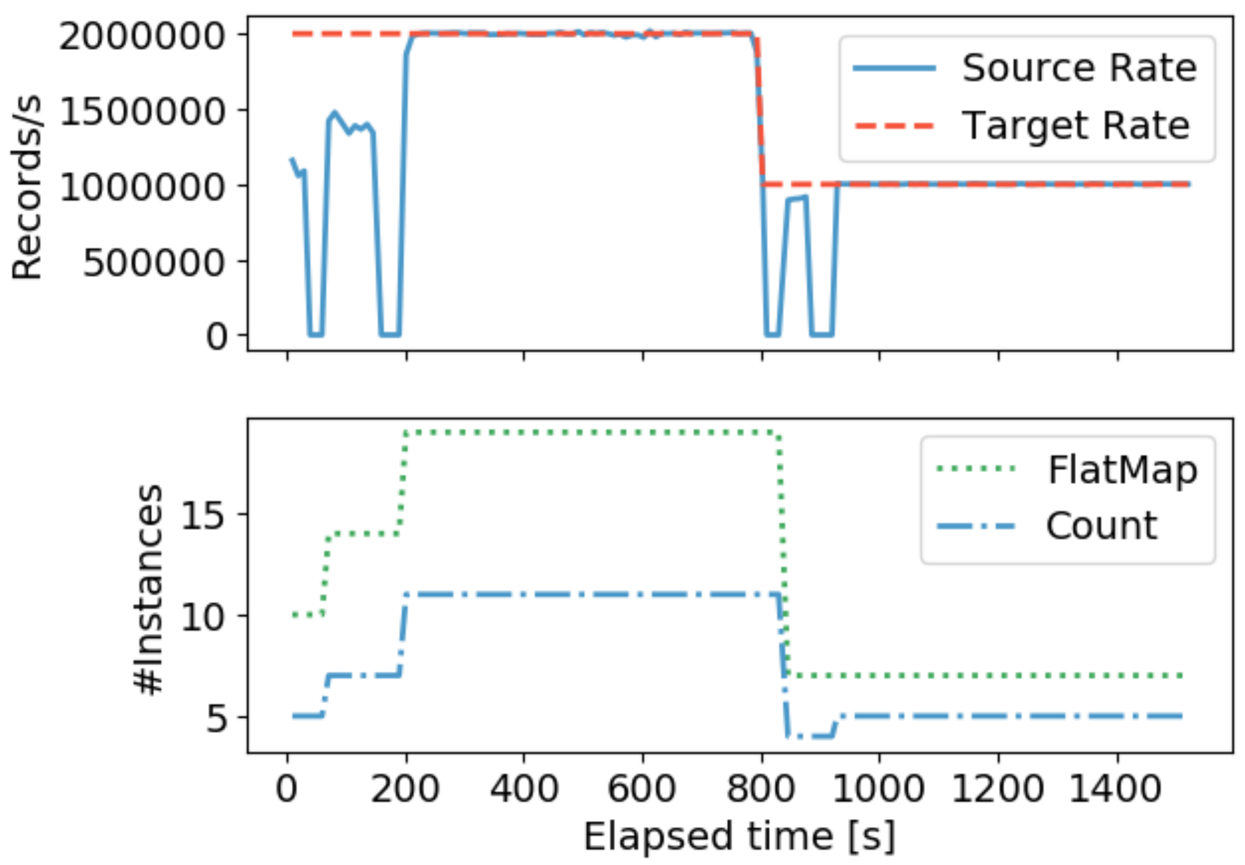
a single step for many queries and initial configurations

=> : scaling action

RECAP







Observed metrics **threshold-based policies** can lead to **oscillations**, **misconfiguration** and **slow convergence**.

DS2 uses **instrumentation** to measure **true processing** and **output rates** and estimate parallelism for all operators at once.

DS2 makes **fast** and **accurate** scaling decisions and converges in up to **three steps** even for non-linear, **complex dataflows**.

https://github.com/strymon-system/ds2

Three steps is all you need

fast, accurate, automatic scaling decisions
for distributed streaming dataflows

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