Proctor – Detecting and Investigating Performance Interference in Shared Datacenters

Ram Kannan, Animesh Jain, Michael Laurenzano, Lingjia Tang, Jason Mars

MICHIGAN ENGINEERING
UNIVERSITY of MICHIGAN

ClarityLab

Datacenters

Datacenters

- ✦ Datacenters
  - ✓ Huge power/performance requirements*

*Barroso et al, The Datacenter as a Computer

Datacenters

- Datacenters
  - ✓ Huge power/performance requirements*
  - ✓ Expensive (over $1 billion)

*Barroso et al, The Datacenter as a Computer

Datacenters

- ✦ Datacenters
  - ✓ Huge power/performance requirements*
  - ✓ Expensive (over $1 billion)

- ✦ Application Colocation

*Barroso et al, The Datacenter as a Computer

Datacenters

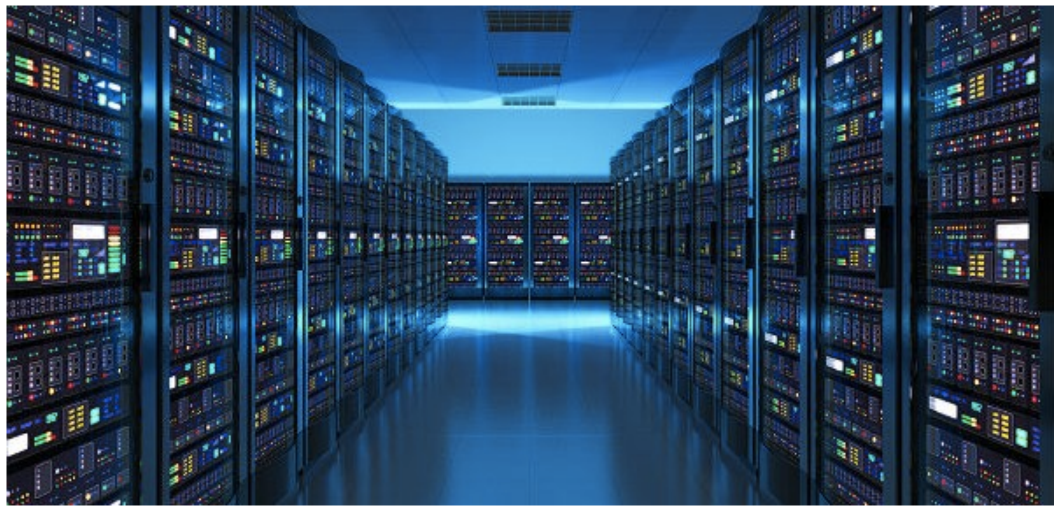
- ✦ Datacenters
  - ✓ Huge power/performance requirements*
  - ✓ Expensive (over $1 billion)

- ✦ Application Colocation
  - ✓ Improves resource utilization

*Barroso et al, The Datacenter as a Computer

Datacenters

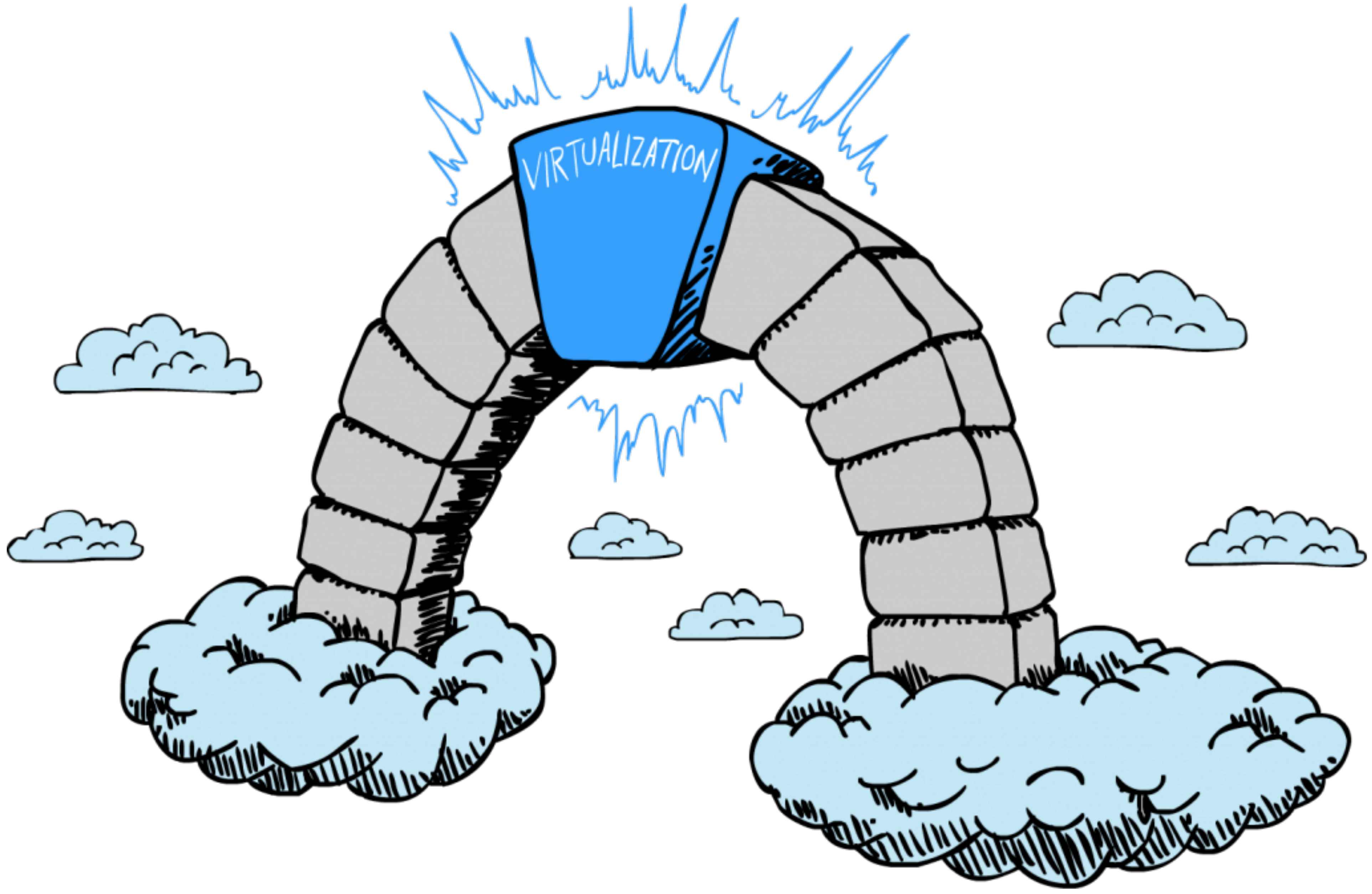
- ✦ Datacenters
  - ✓ Huge power/performance requirements*
  - ✓ Expensive (over $1 billion)



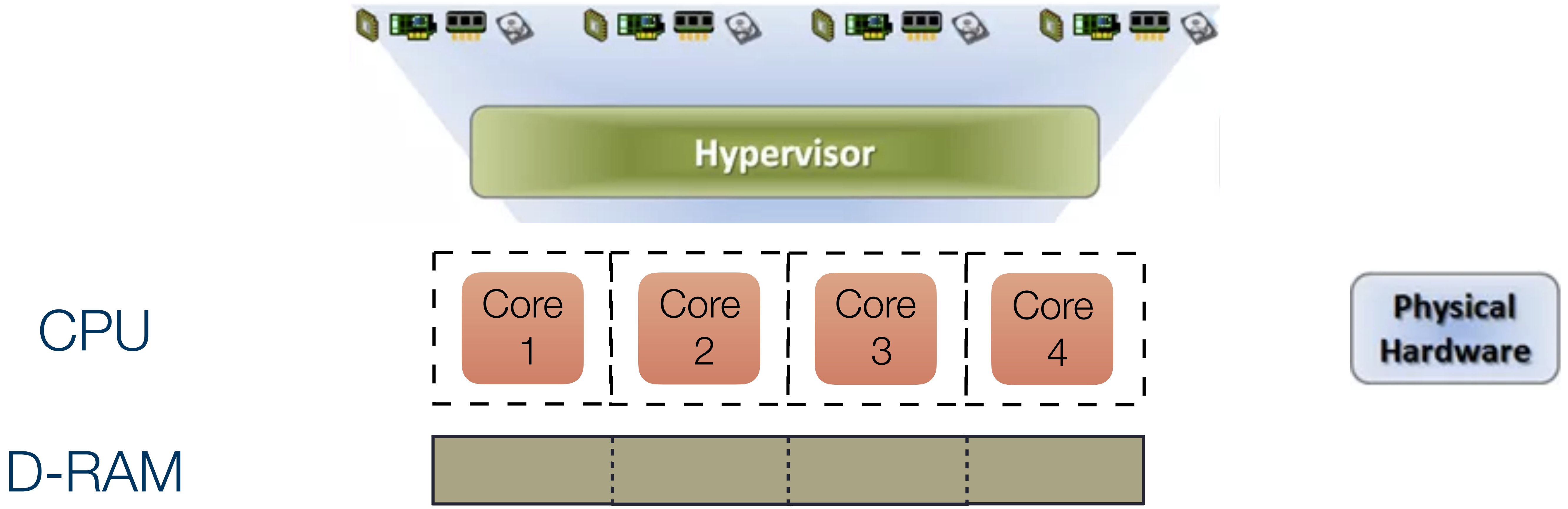
- ✦ Application Colocation
  - ✓ Improves resource utilization
  - ✓ Reduces cost

*Barroso et al, The Datacenter as a Computer

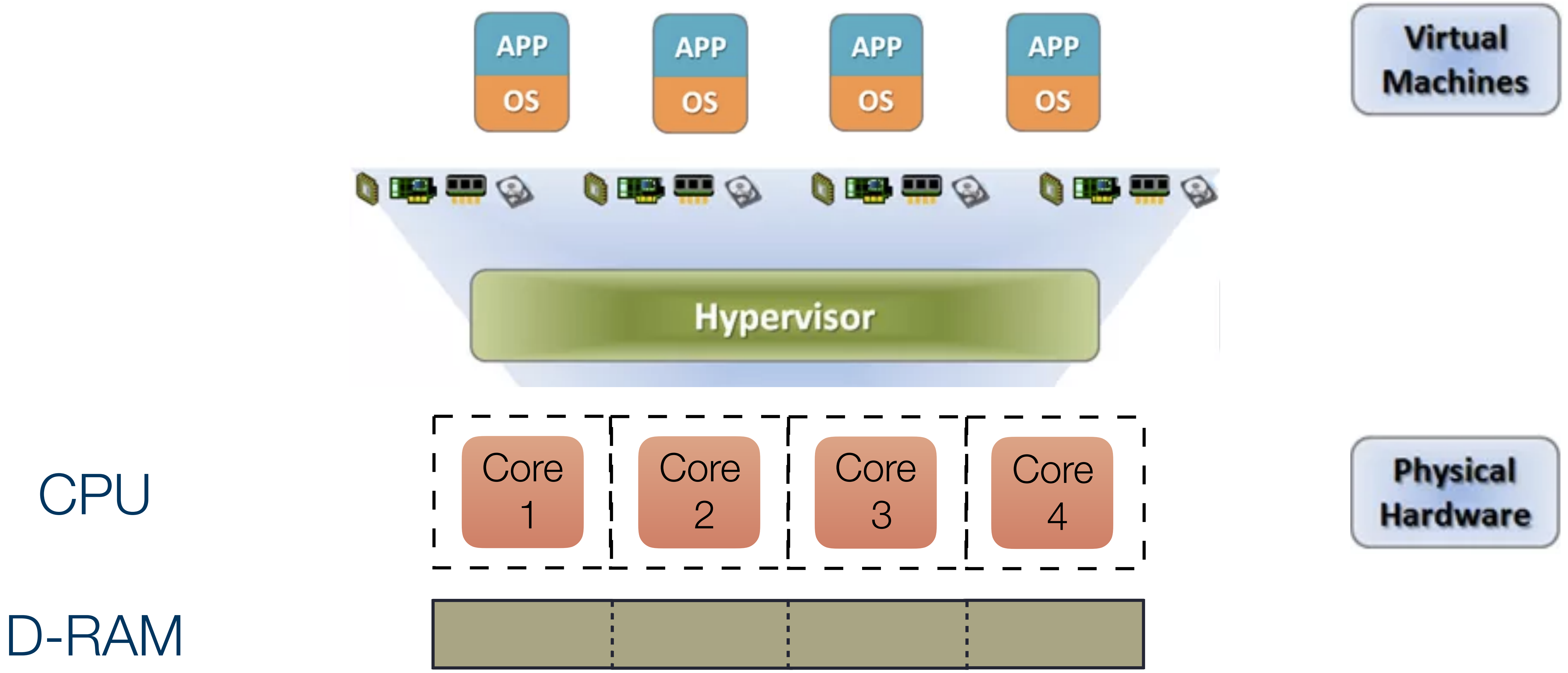
Virtualization



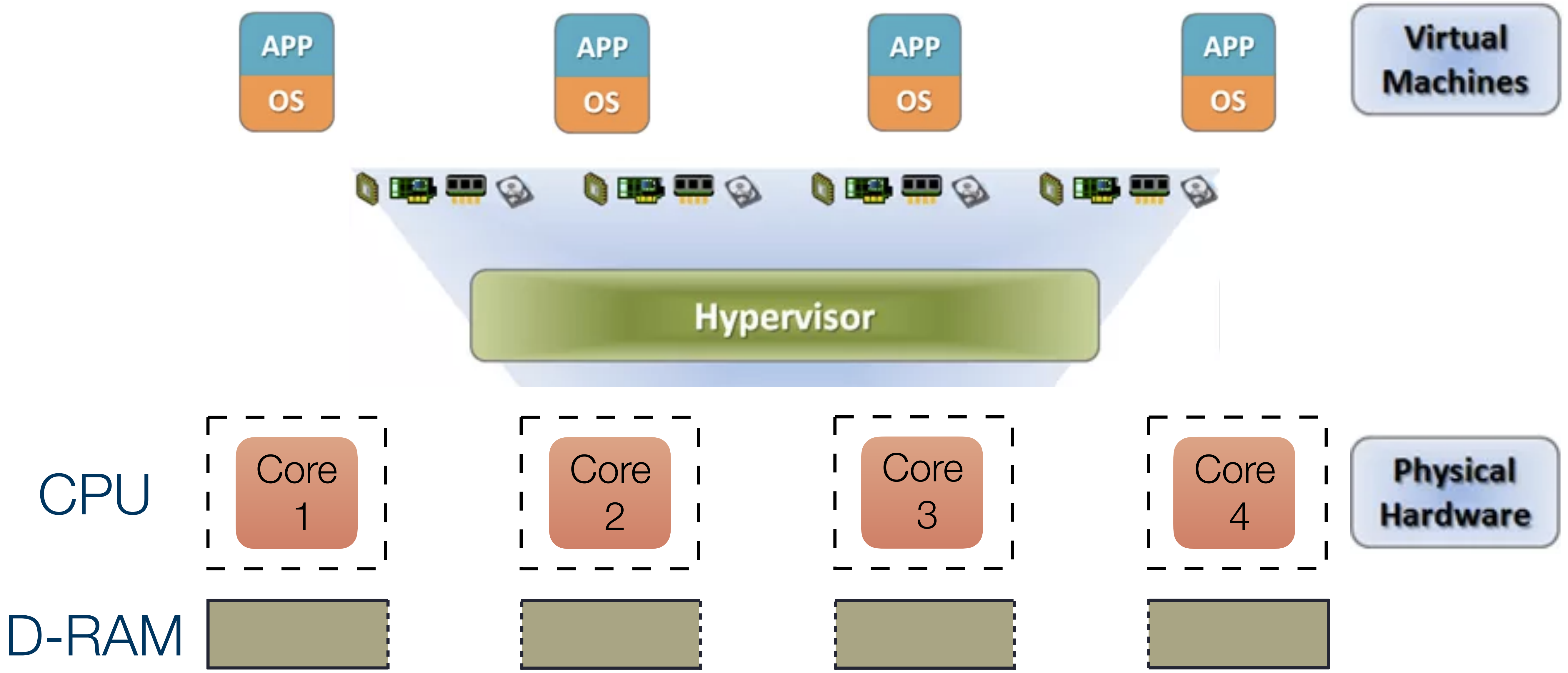
Application Execution



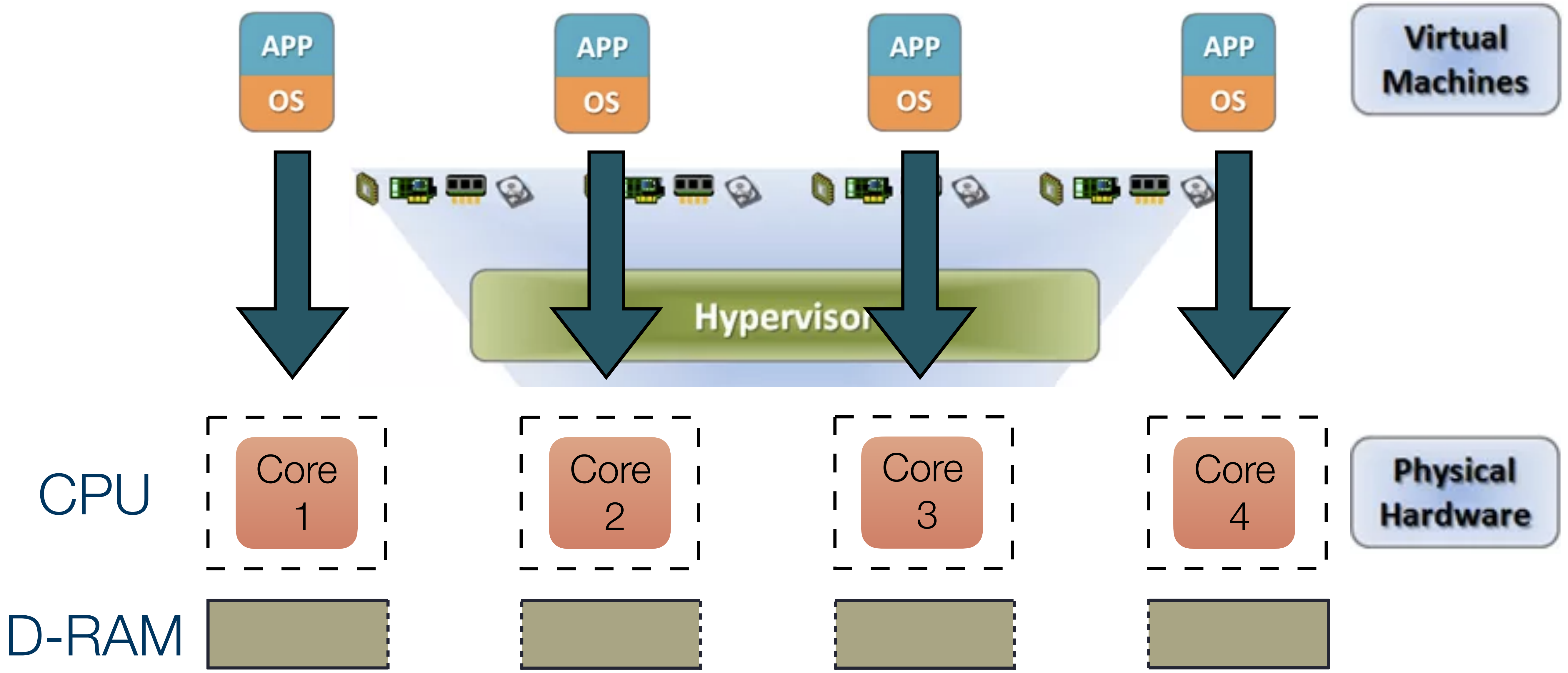
Application Execution



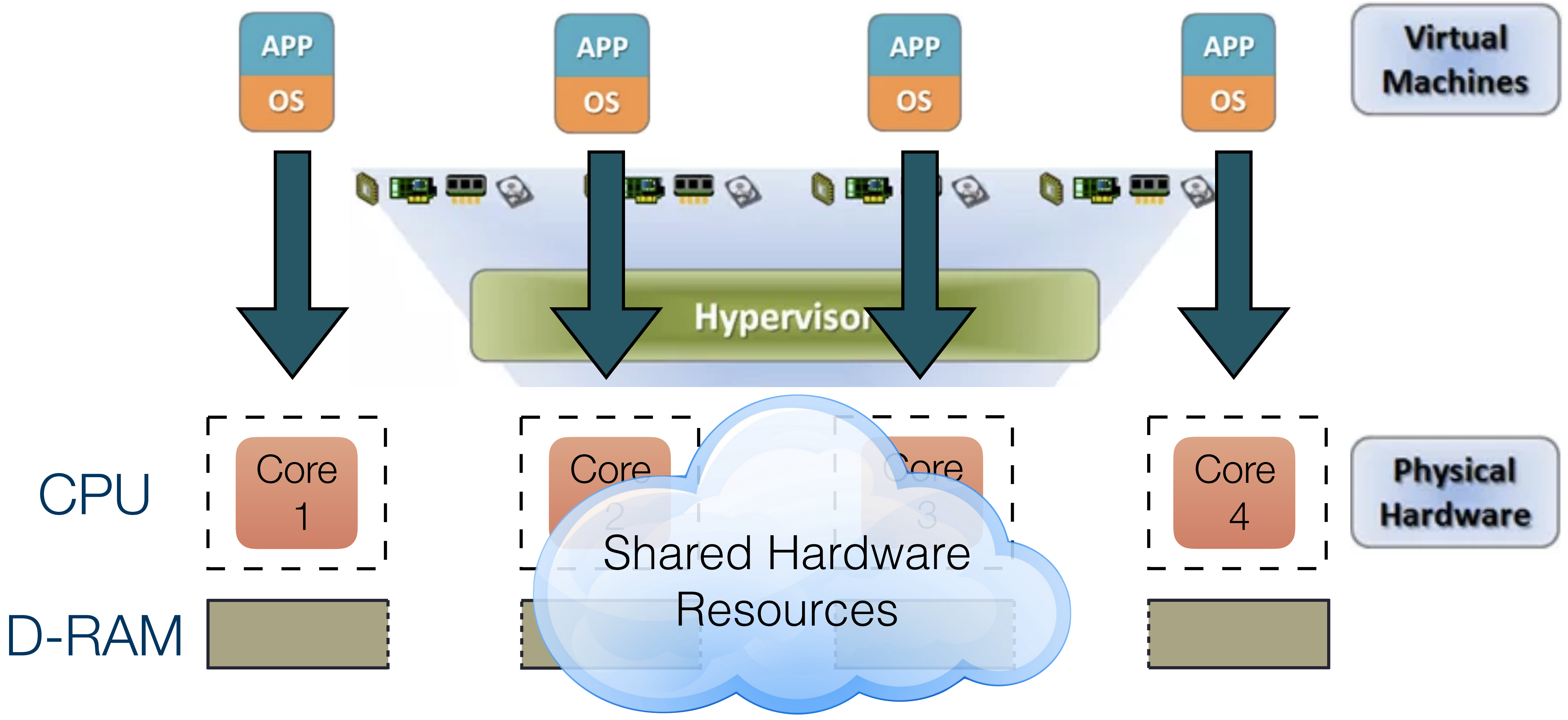
Application Execution



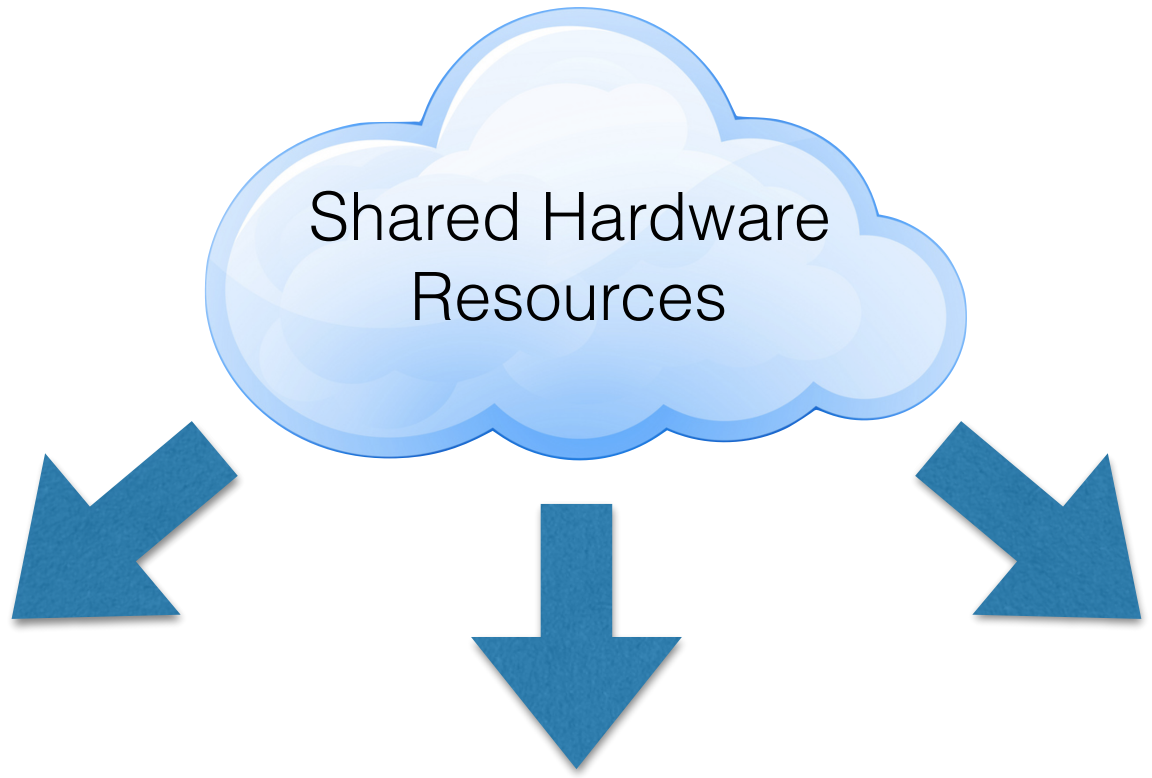
Application Execution



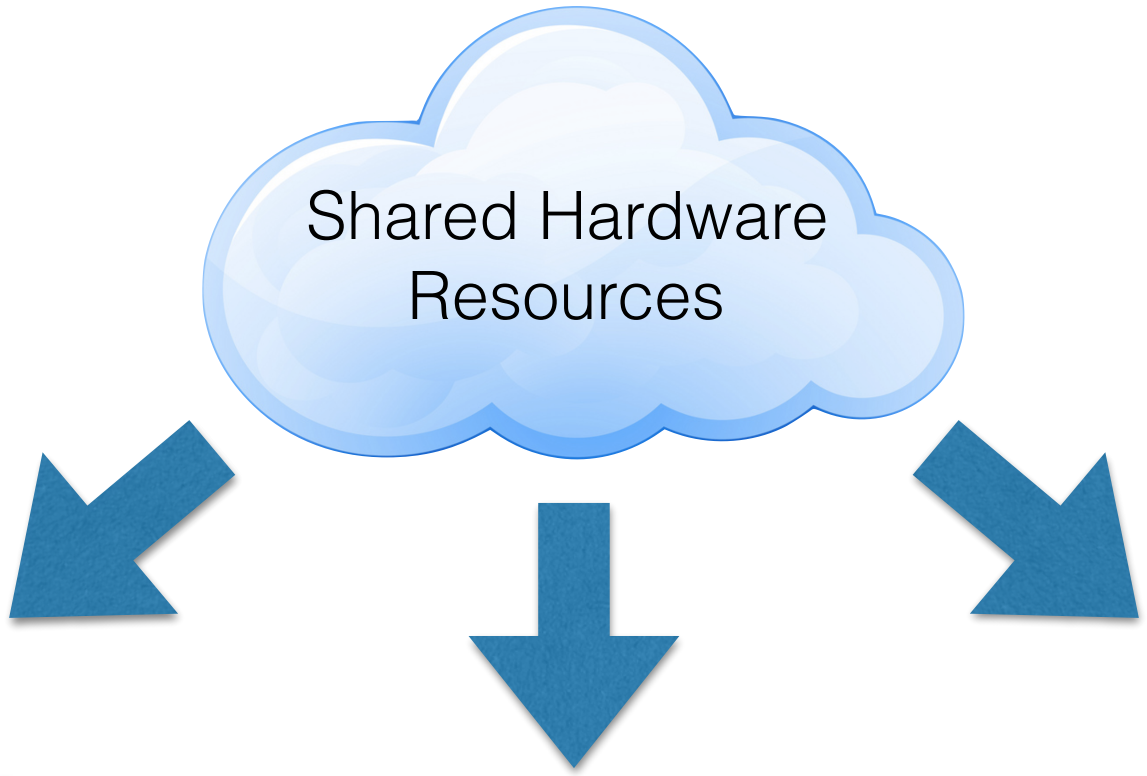
Application Execution



Sources of Contention

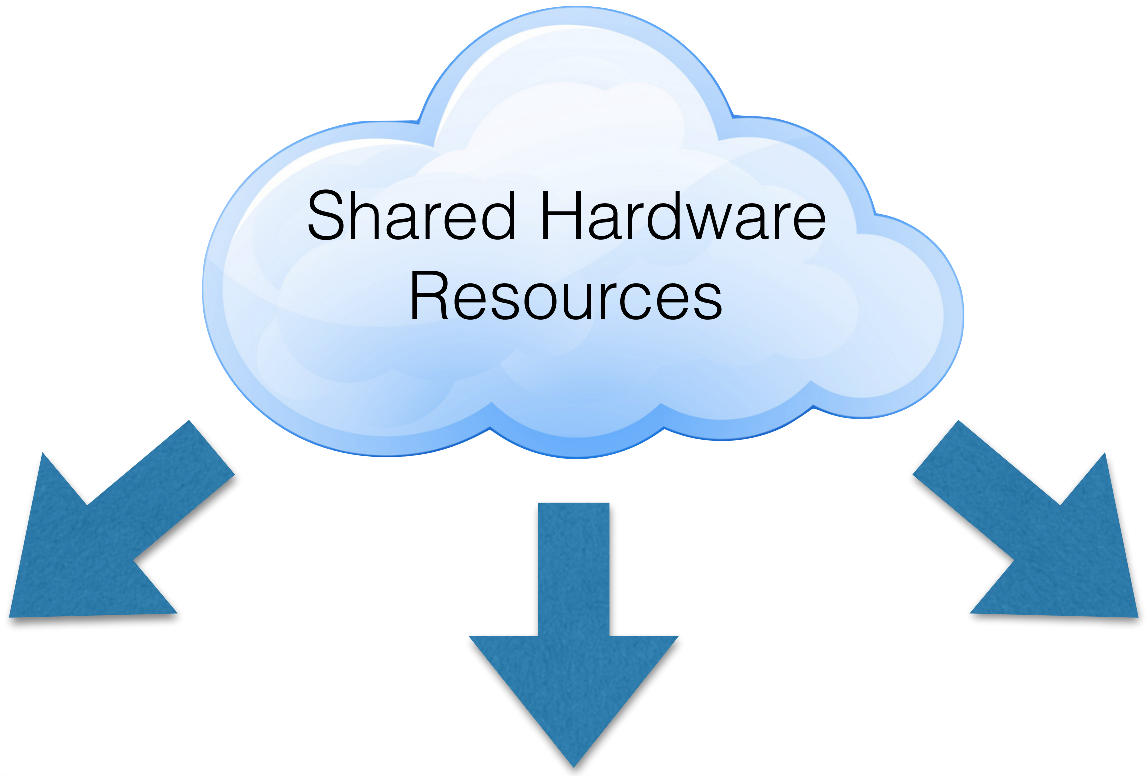


Sources of Contention



Disk

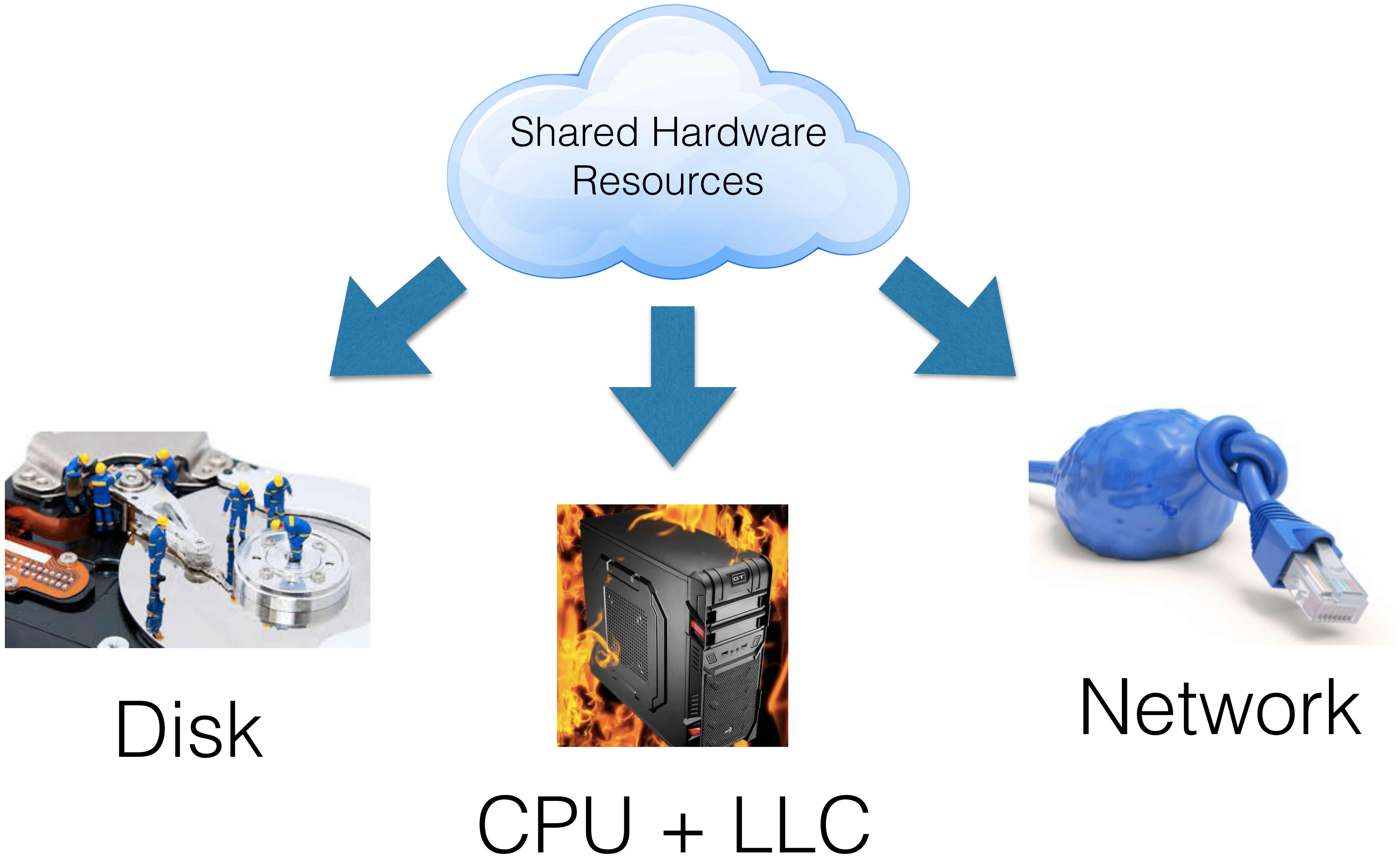
Sources of Contention



Disk

CPU + LLC

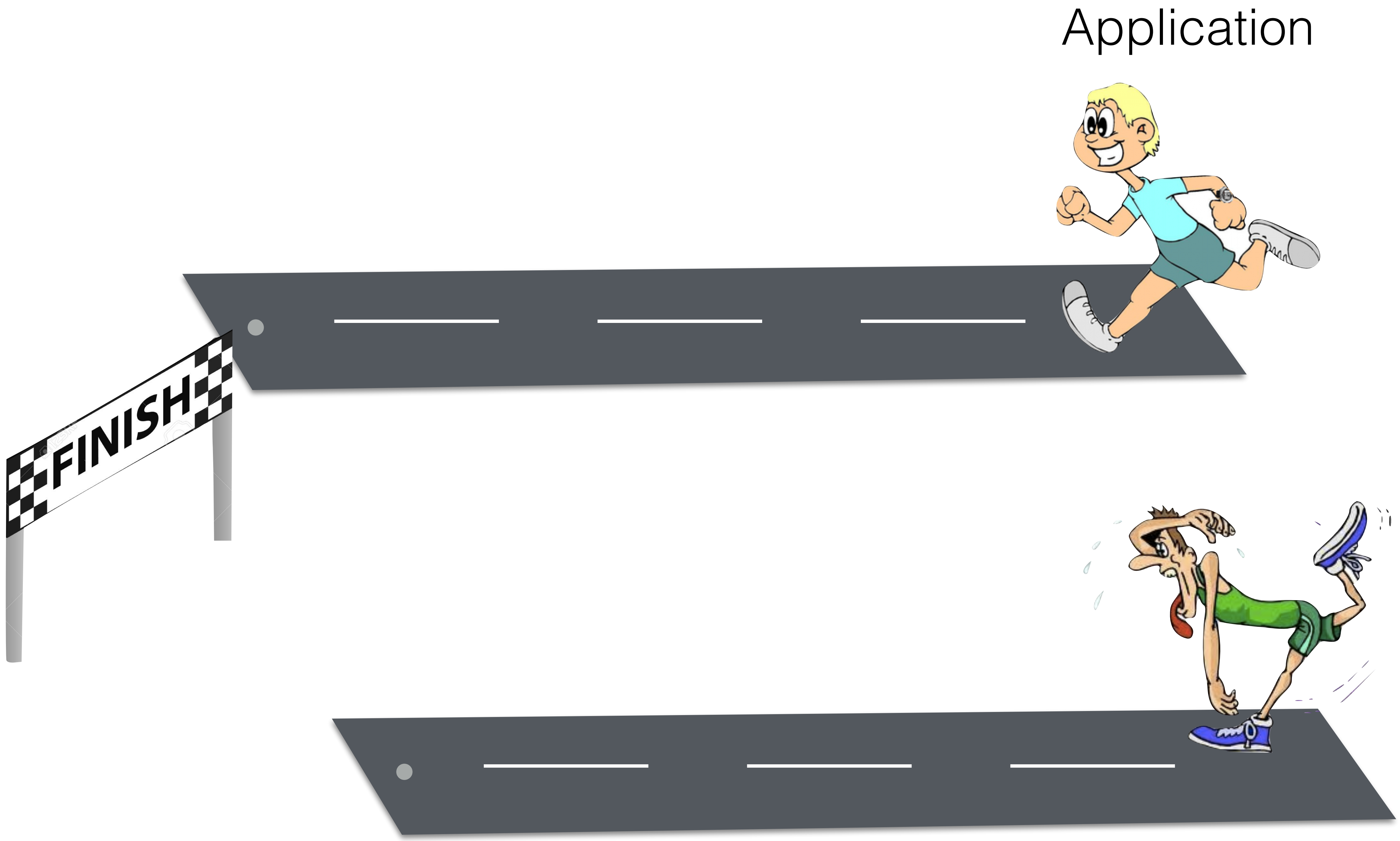
Sources of Contention



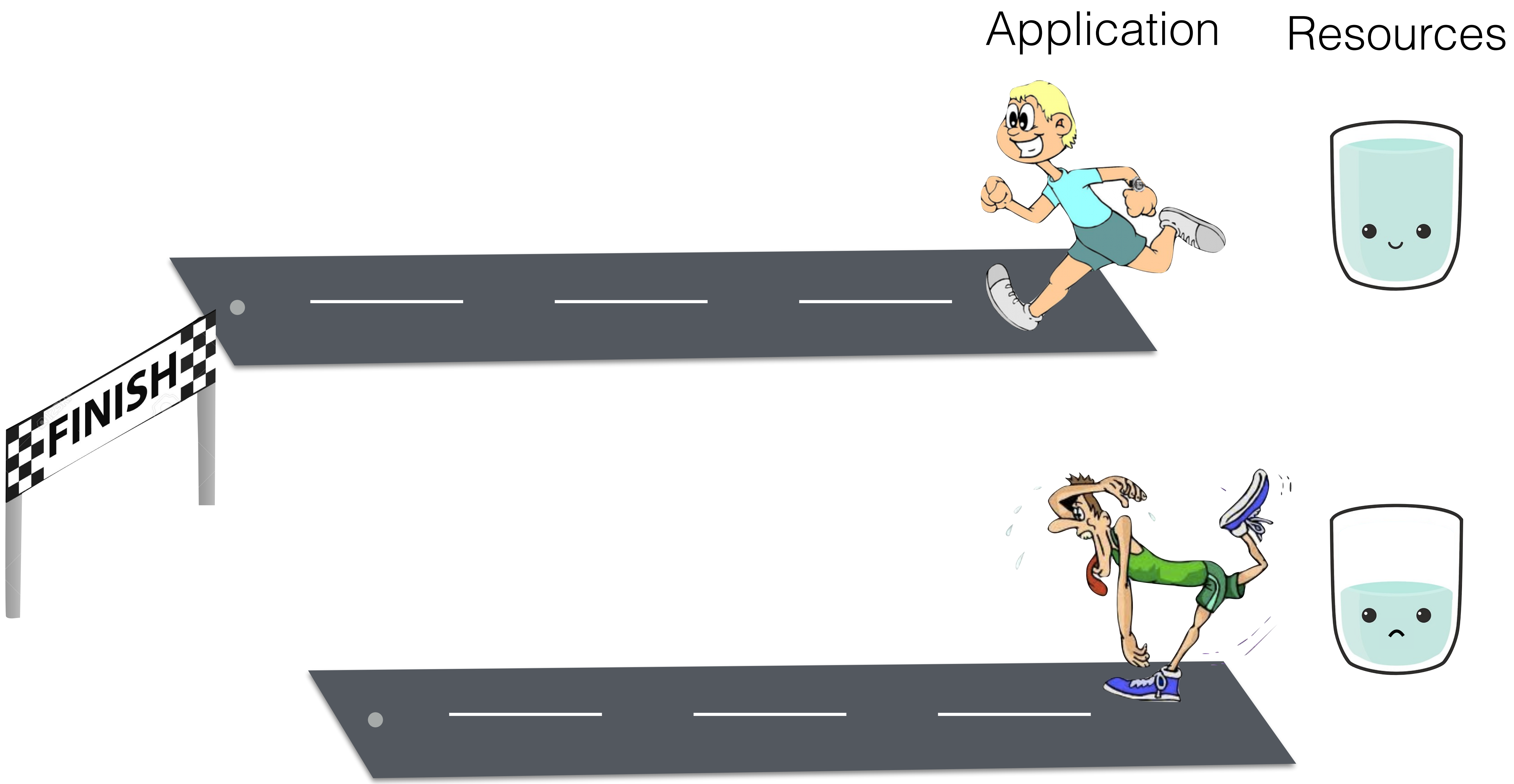
ClarityLab

Effects of contention — Poor Performance!!

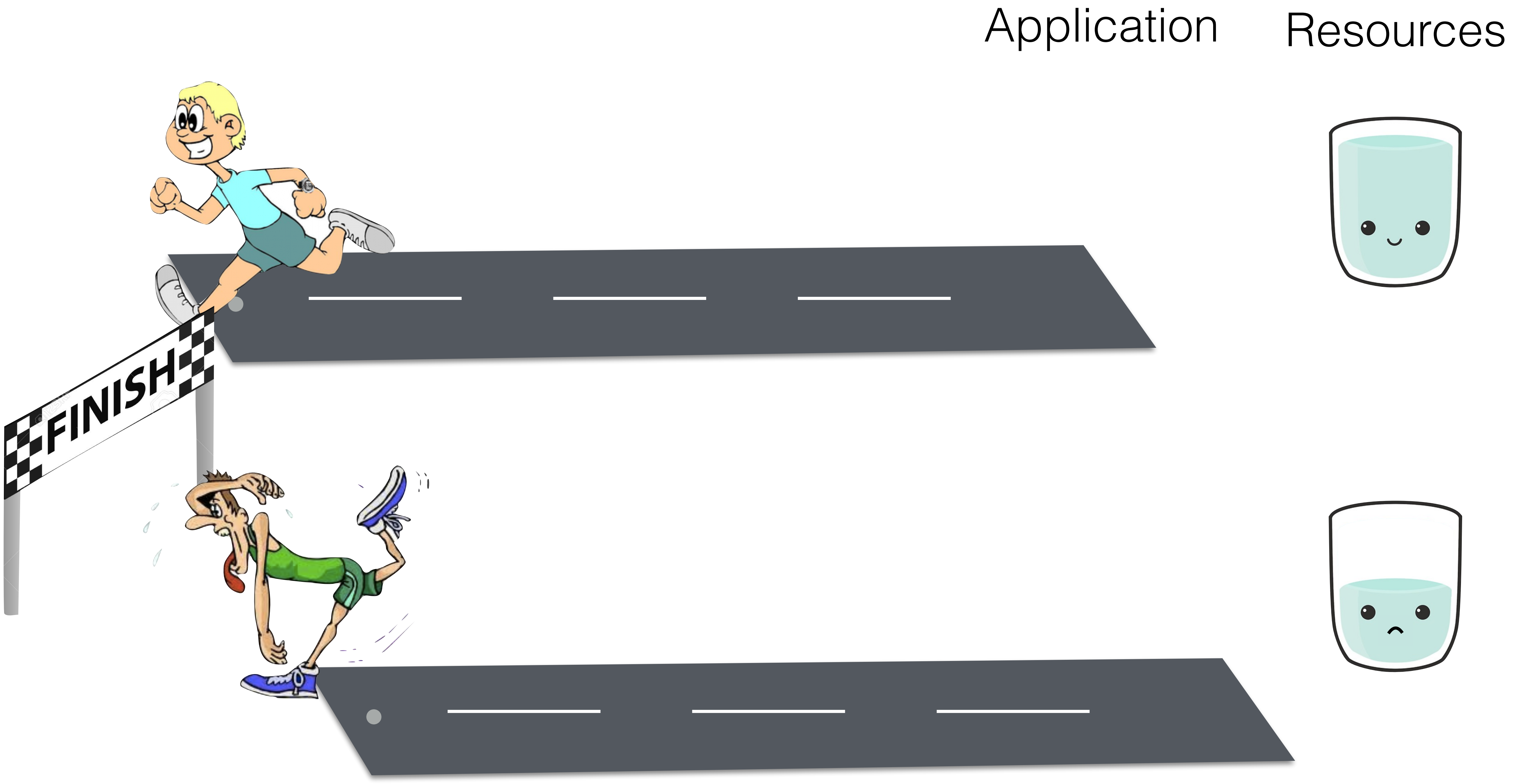
Effects of contention — Poor Performance!!



Effects of contention — Poor Performance!!



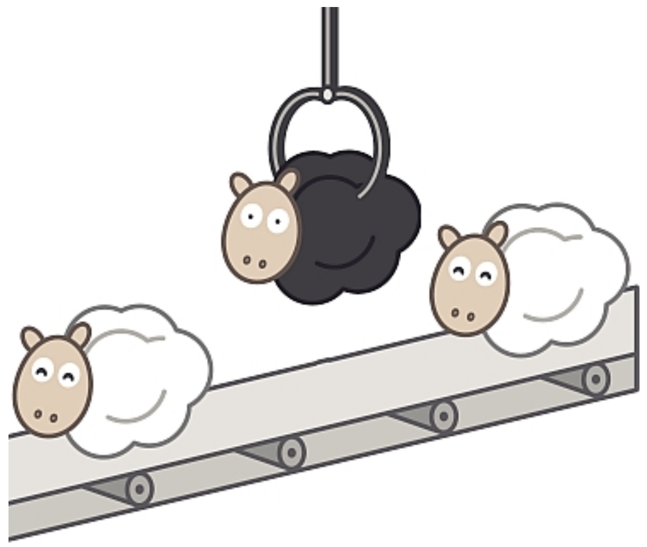
Effects of contention — Poor Performance!!



How do we handle contention?

How do we handle contention?

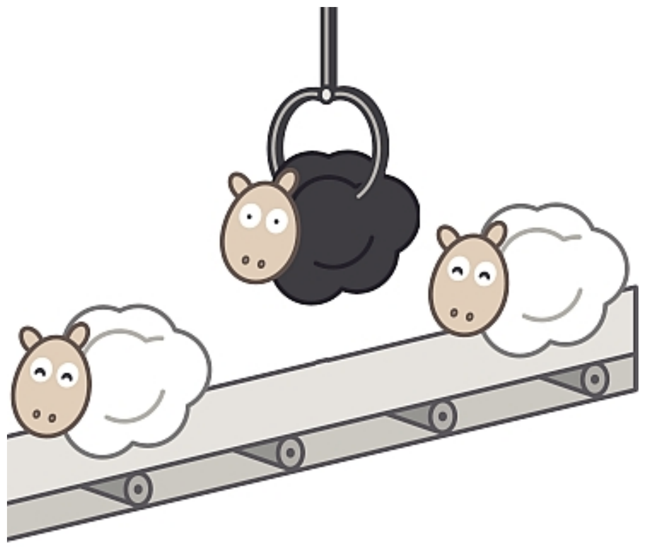
Detection



How do we handle contention?

Detection

Investigation

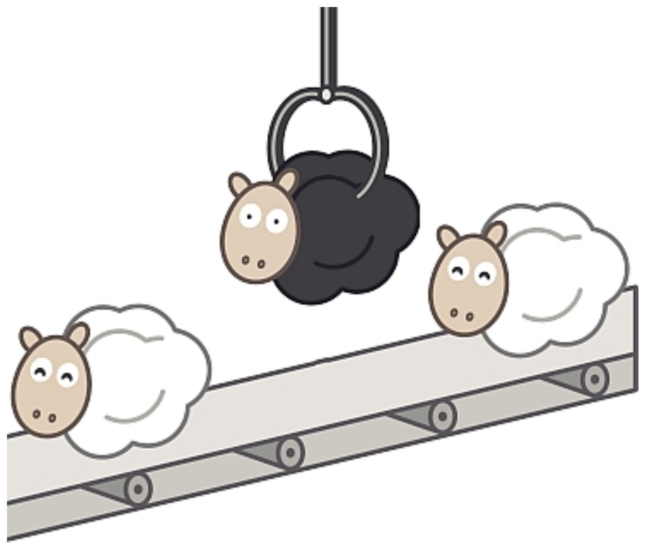


How do we handle contention?

Detection

Investigation

Mitigation

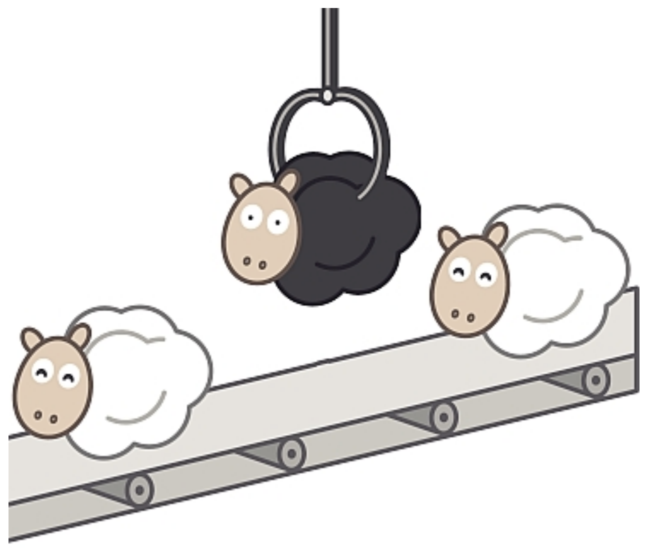


How do we handle contention?

Detection

Investigation

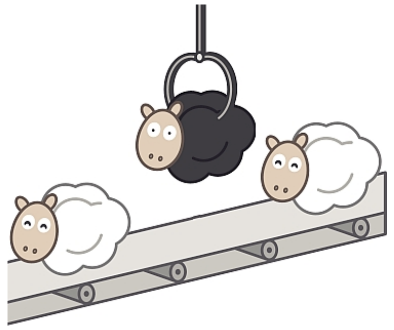
Mitigation



Challenges

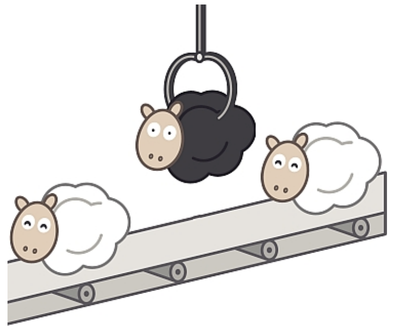
Challenges

- Absence of a priori information



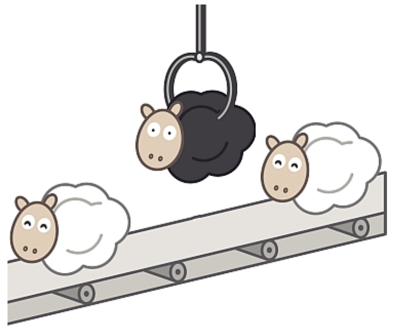
Challenges

- Absence of a priori information



Challenges

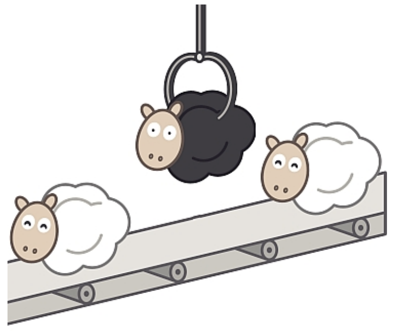
- Absence of a priori information



- Multiple sources of contention

Challenges

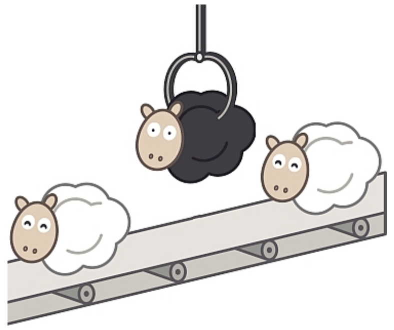
- Absence of a priori information



- Multiple sources of contention

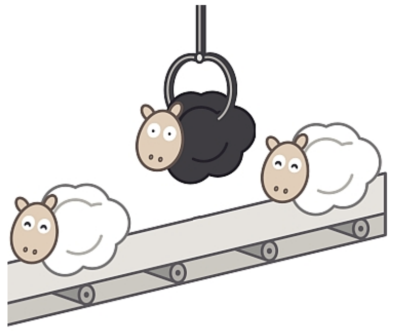
Challenges

- Absence of a priori information



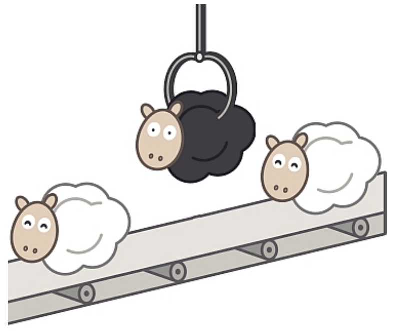
- Multiple sources of contention

- High overheads



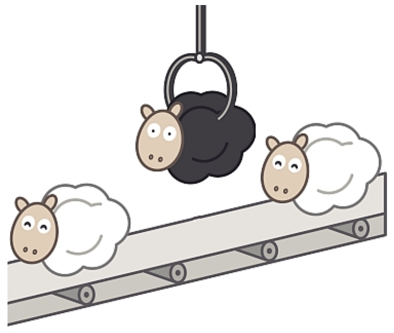
Challenges

- Absence of a priori information



- Multiple sources of contention

- High overheads



Bubble Up	ASM	Bubble Flux	Deep Dive	CPI^2	Parda
[Mars Micro' 11]	[Mars Micro' 15]	[Yang Micro' 13]	[Novakovic ATC' 13]	[Zhang Eurosys' 13]	[Gulati FAST' 09]

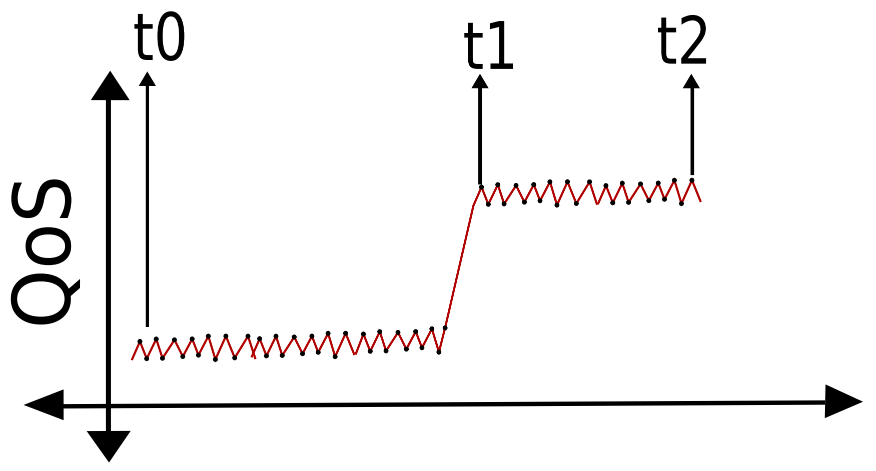
Outline

- Motivation
- Proctor – Overview and Design
- Evaluation
- Conclusion

Proctor Overview

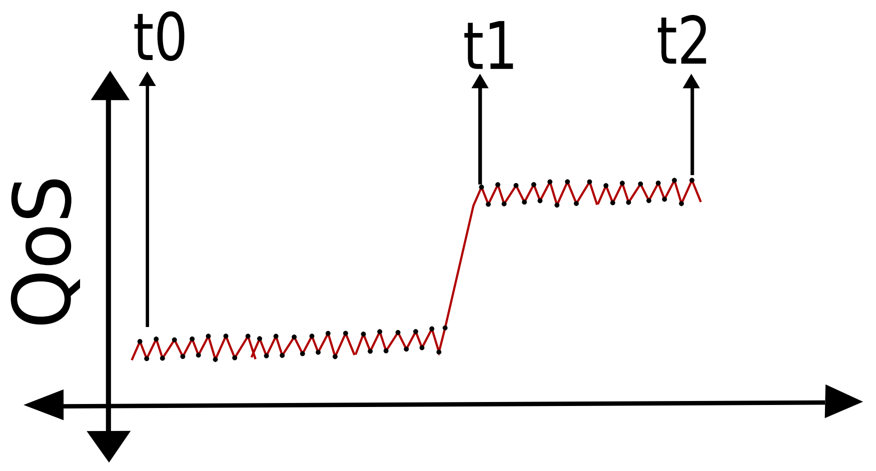
Proctor Overview

Detection (PDD)

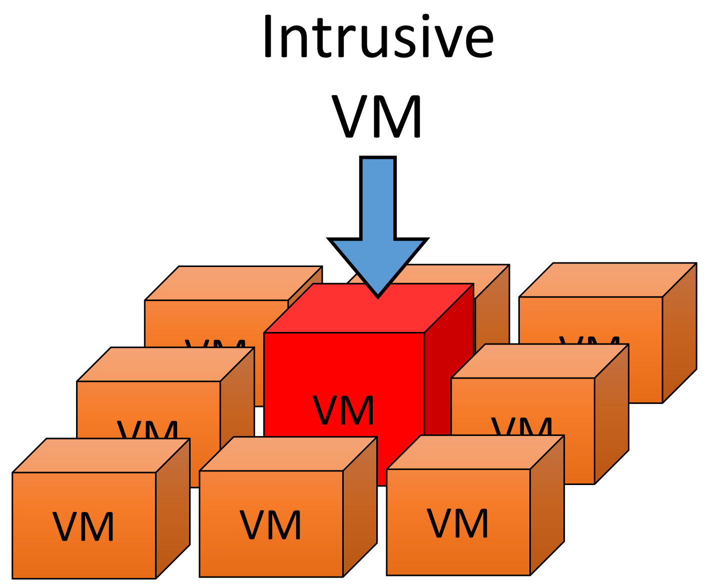


Proctor Overview

Detection (PDD)



Investigation (PDI)



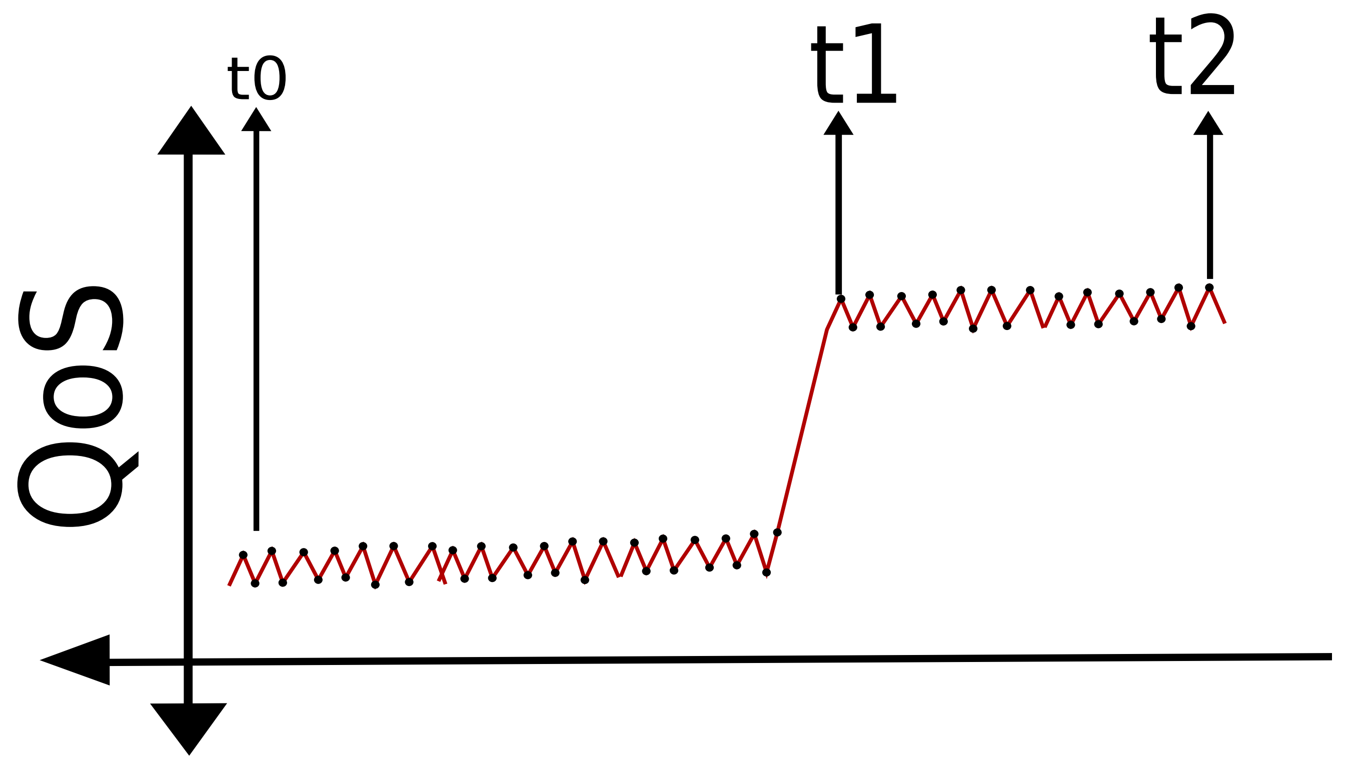
Step Detection

Step Detection

- ✦ Step Detection — Sliding window based approach

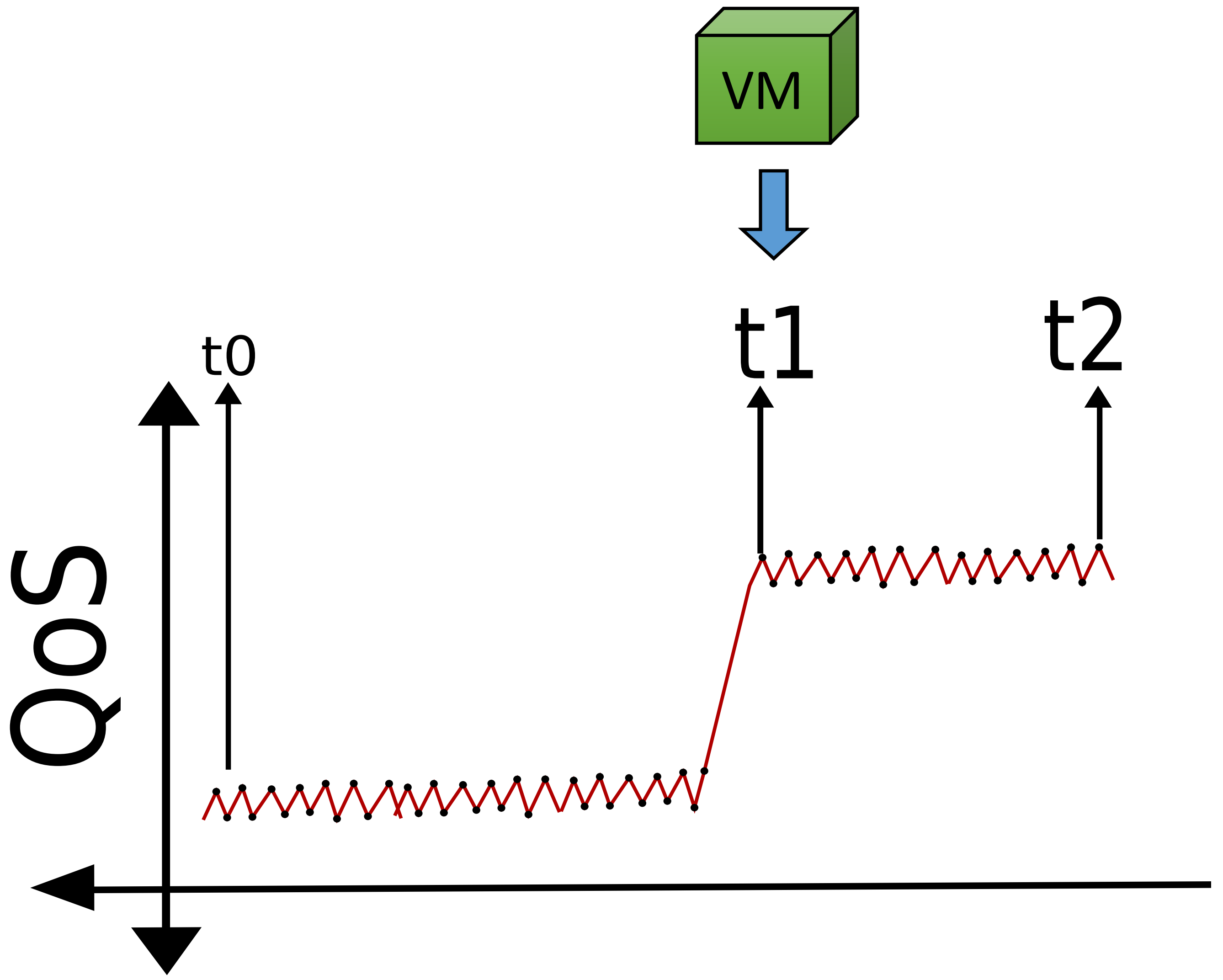
Step Detection

- Step Detection — Sliding window based approach



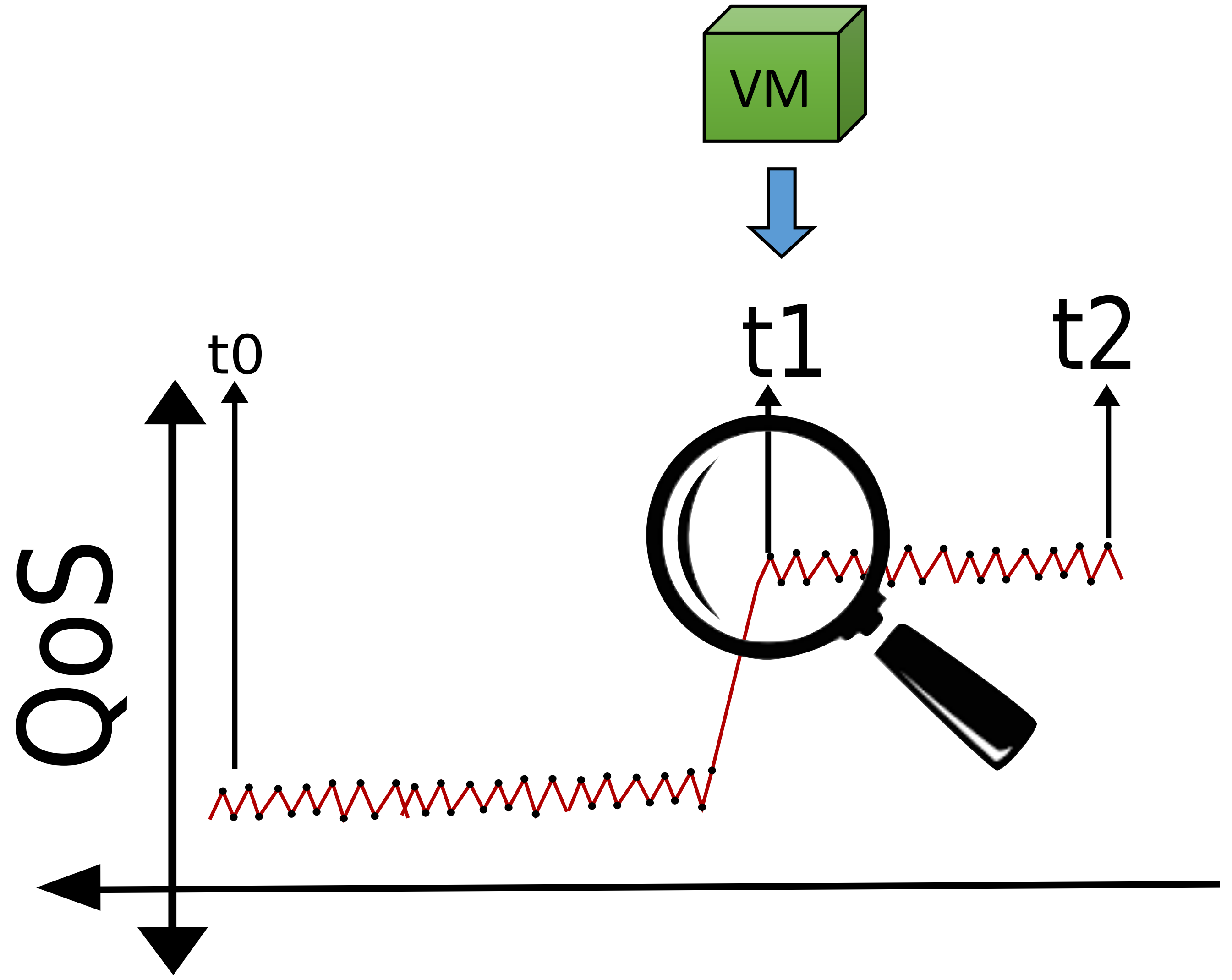
Step Detection

- Step Detection — Sliding window based approach



Step Detection

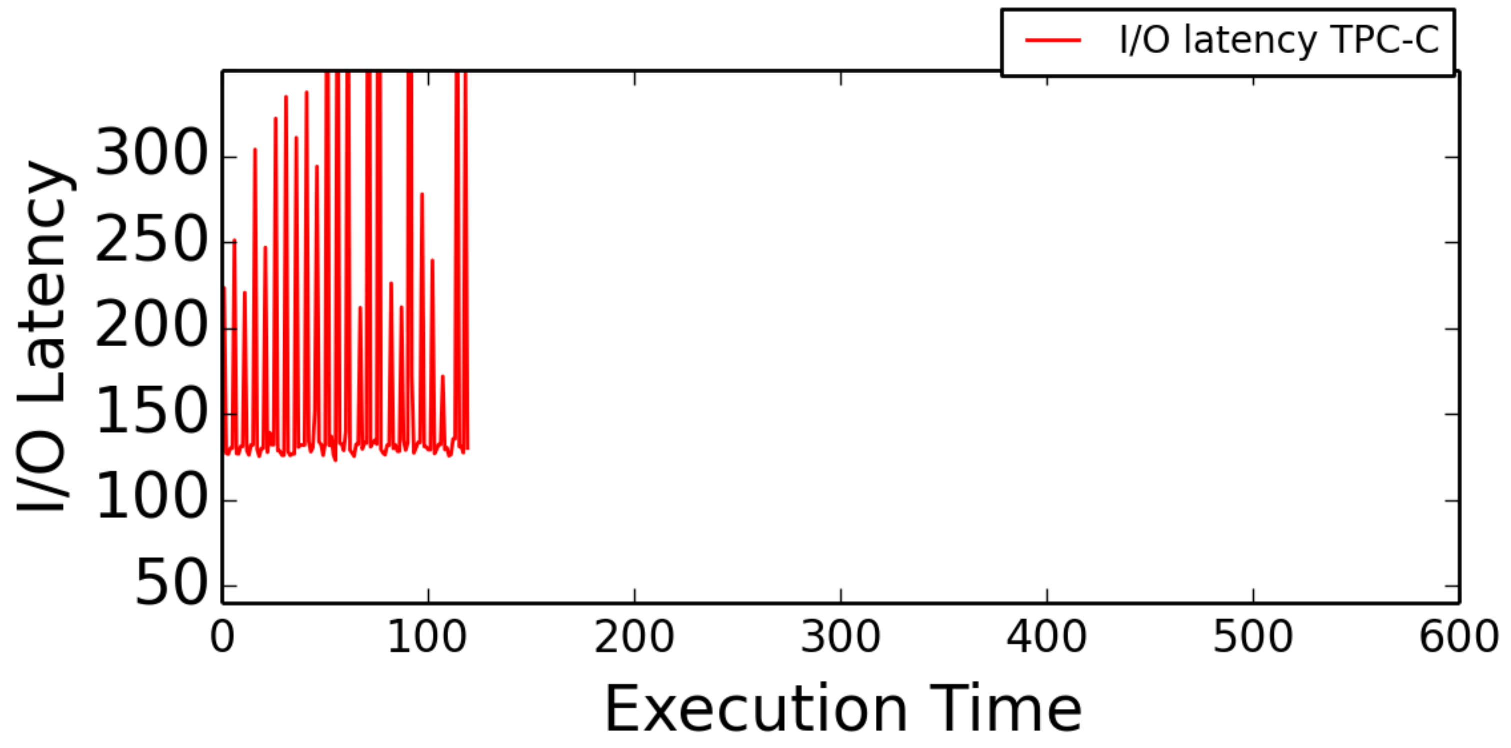
✦ Step Detection — Sliding window based approach



Step Detection — Challenges

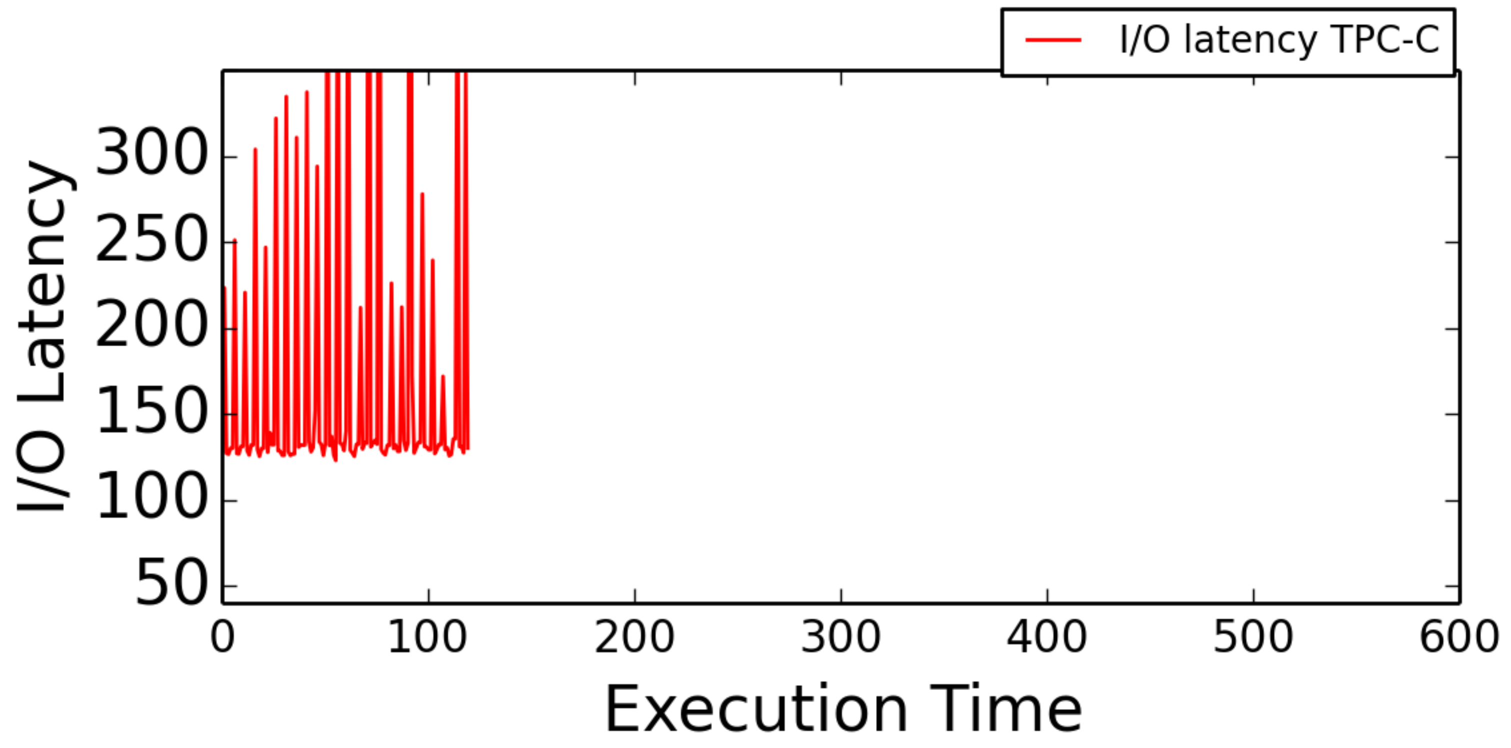
Step Detection — Challenges

✦ Noise — Telemetry from system software tools is noisy.



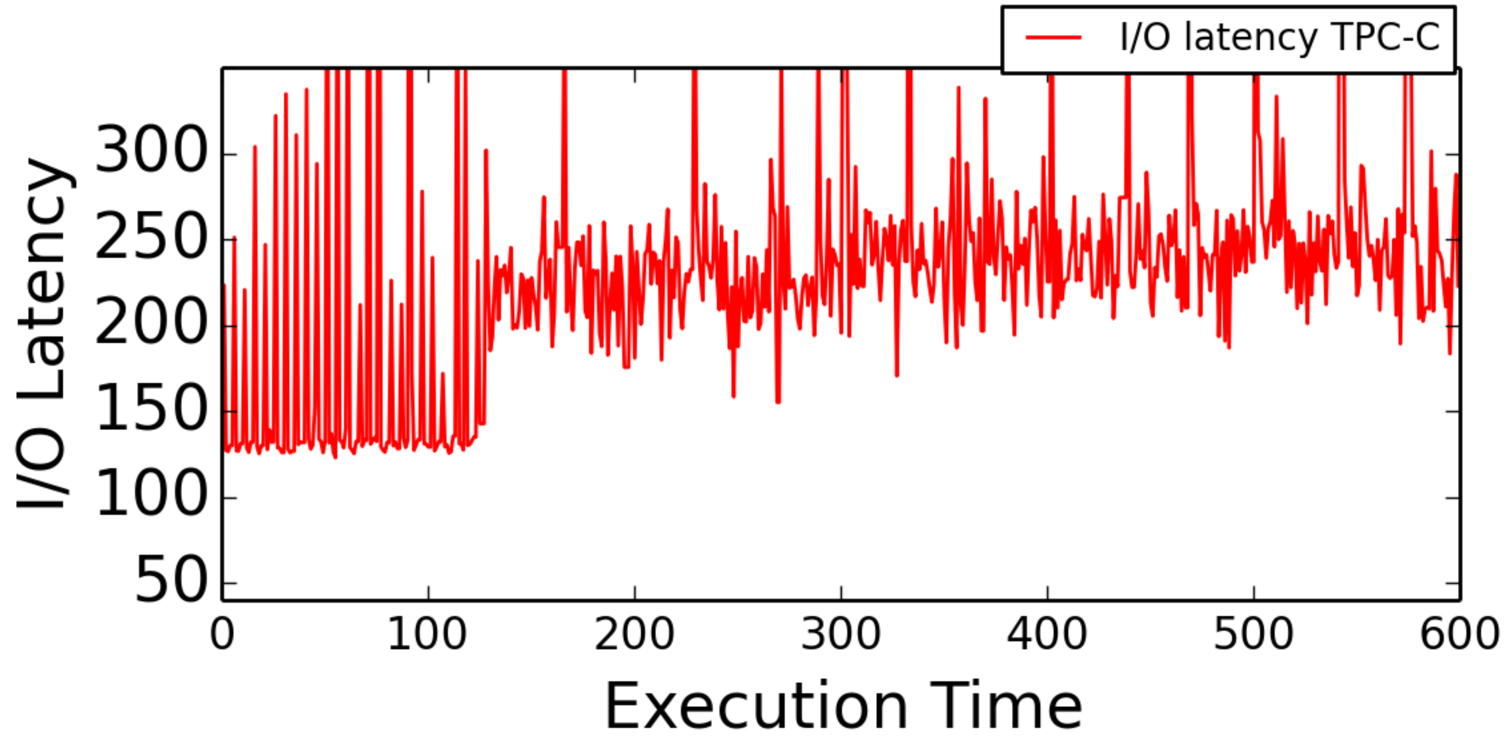
Step Detection — Challenges

- Noise — Telemetry from system software tools is noisy.



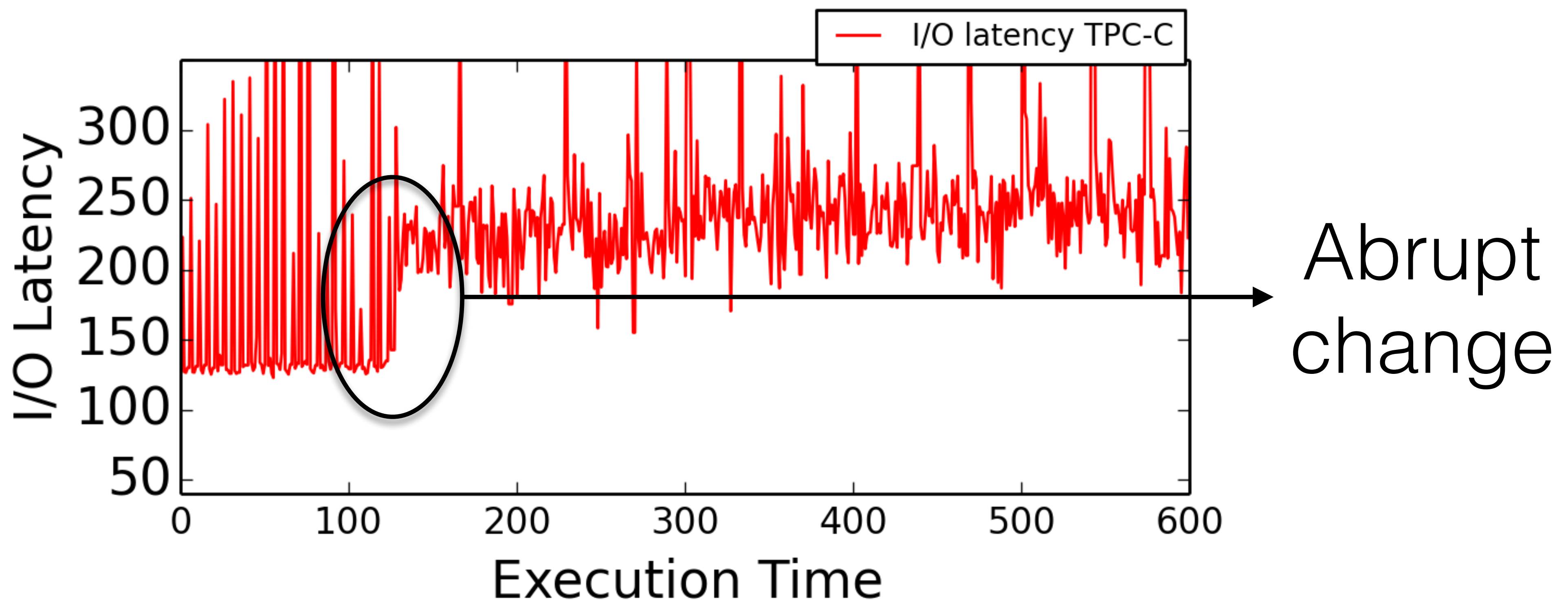
Step Detection — Challenges

- Noise — Telemetry from system software tools is noisy.
- Overshadows the abrupt change

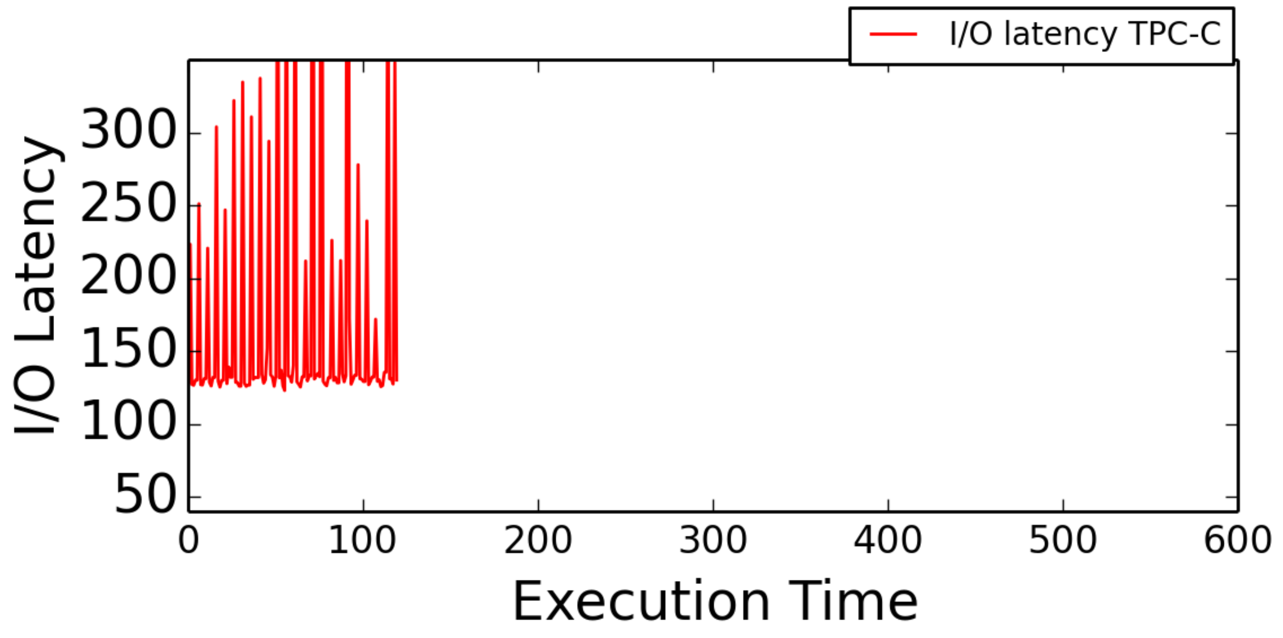


Step Detection — Challenges

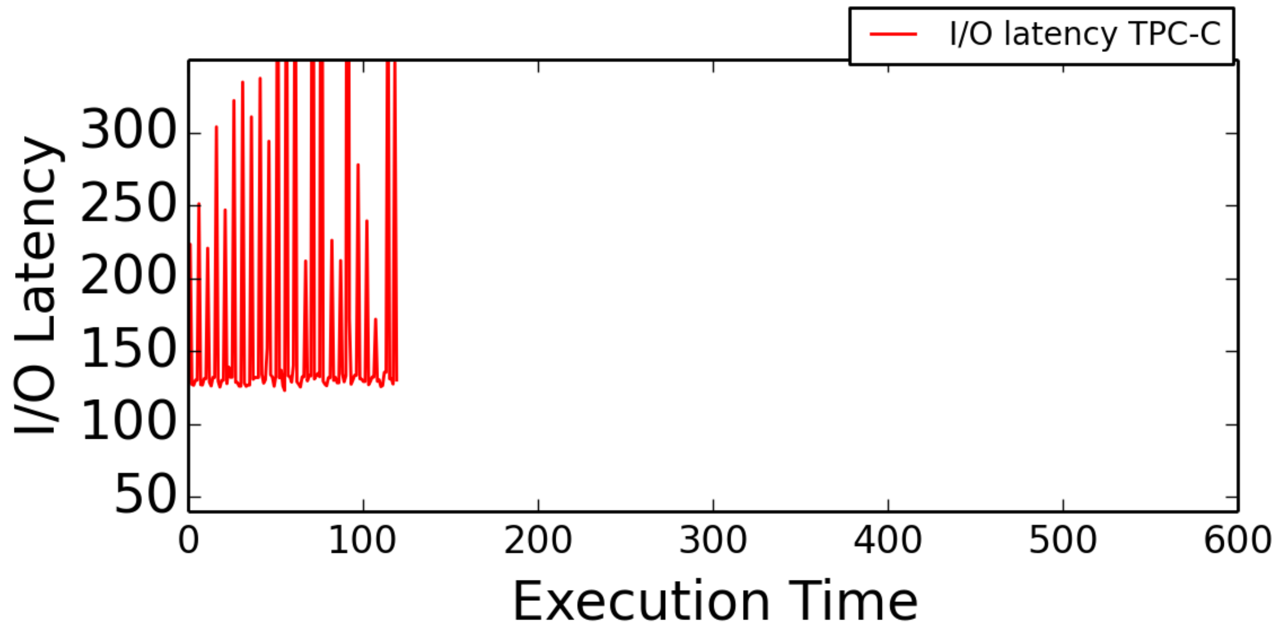
- ✦ Noise — Telemetry from system software tools is noisy.
- ✦ Overshadows the abrupt change

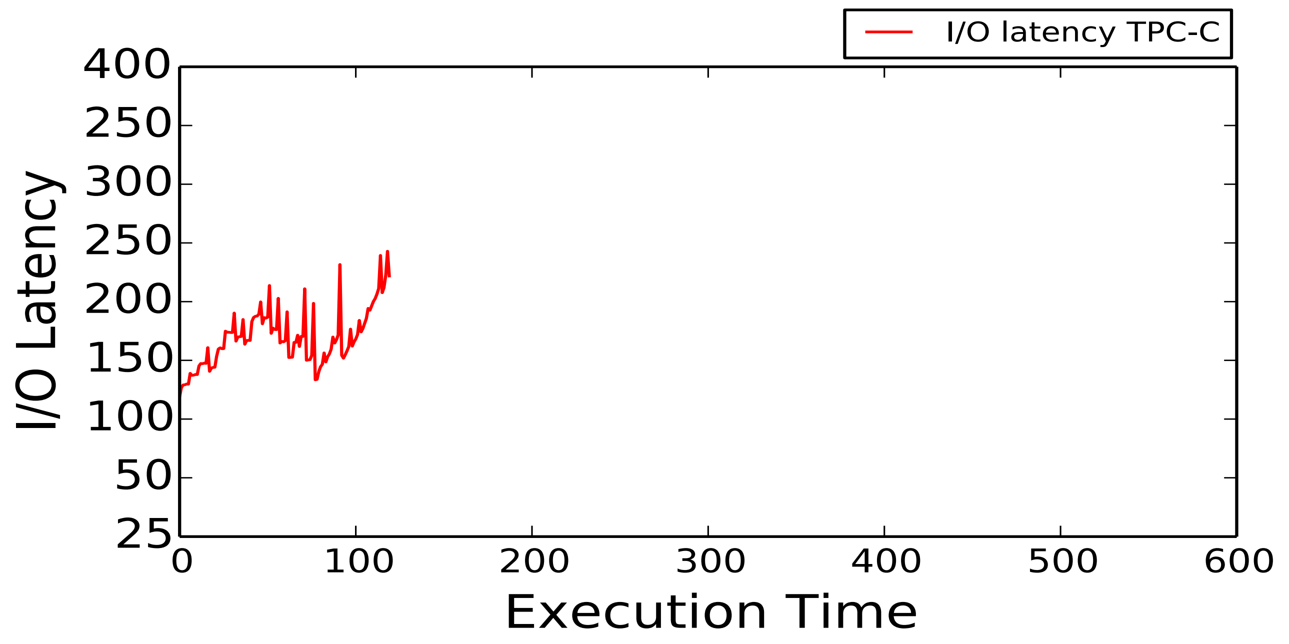


Current Approach — Moving Average



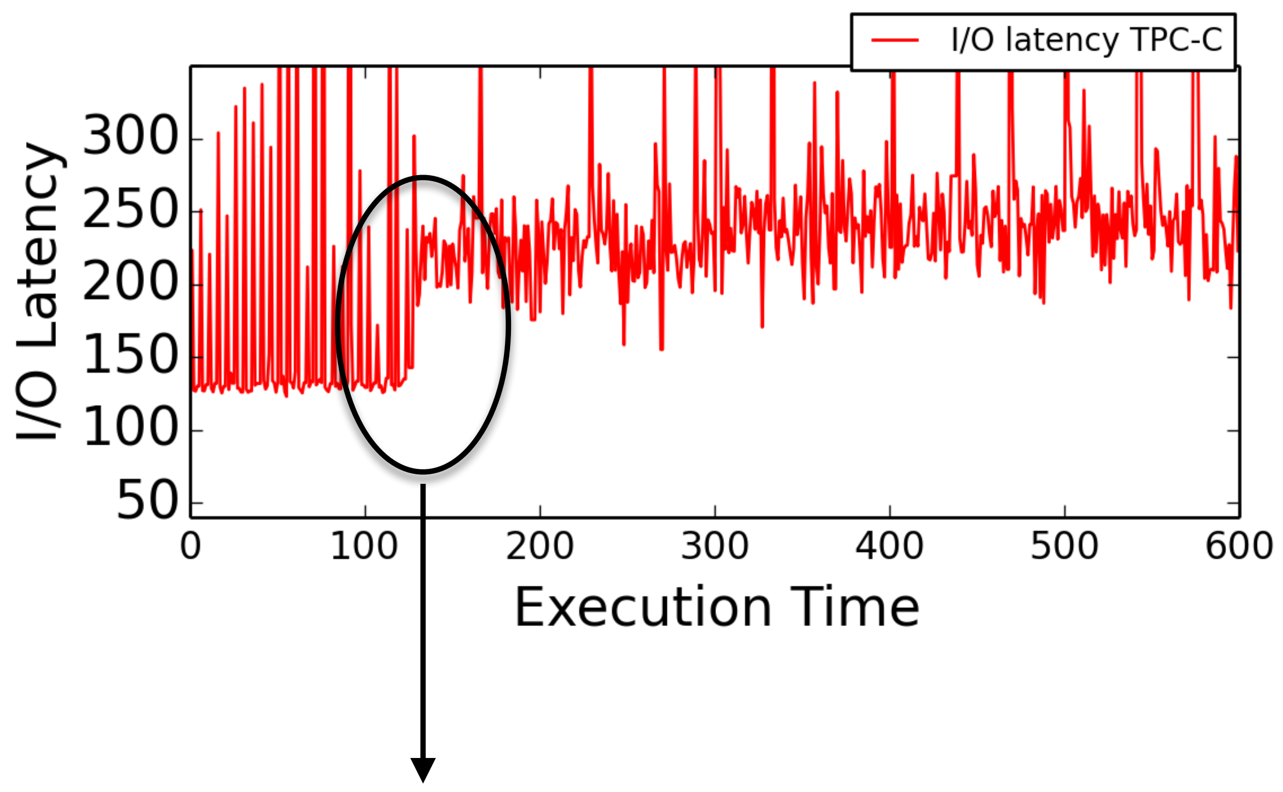
Current Approach — Moving Average



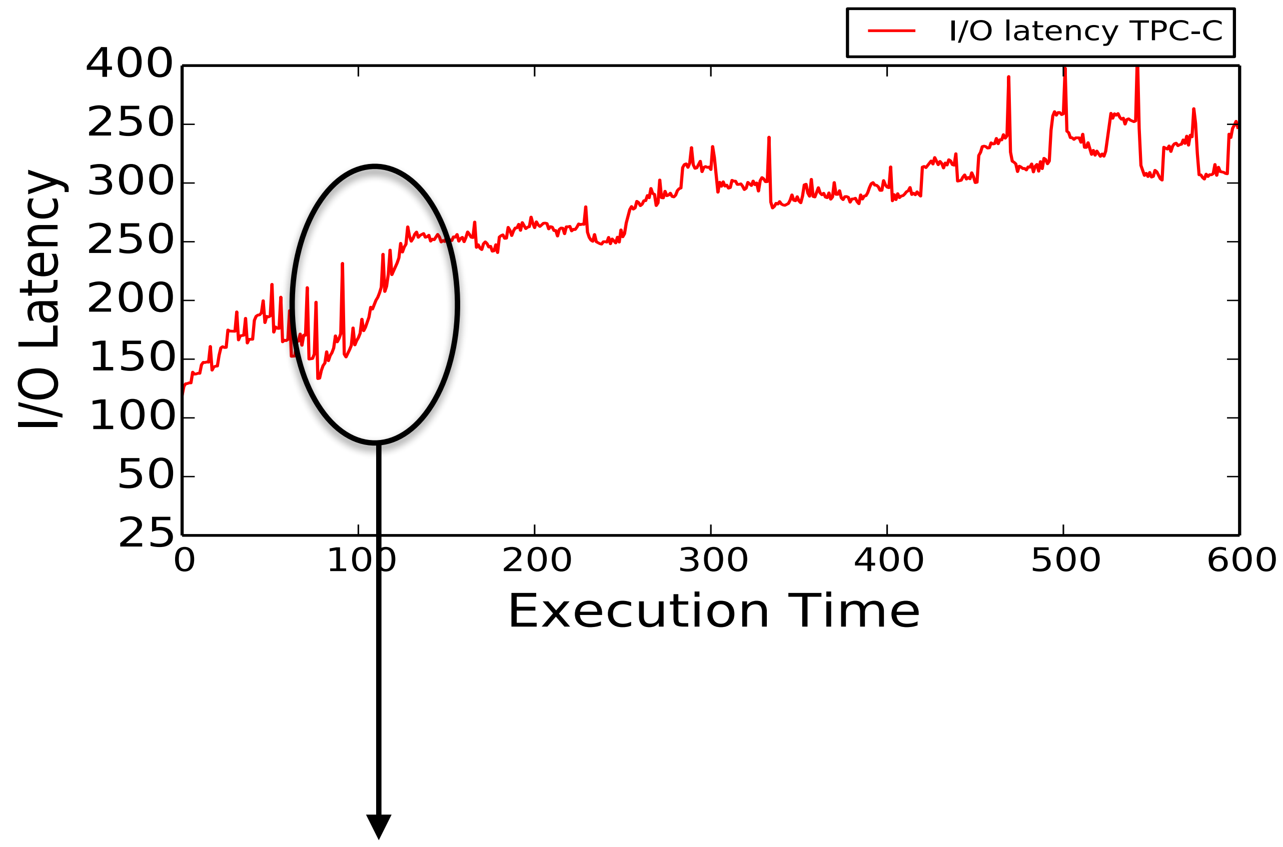


Current Approach — Moving Average

Current Approach — Moving Average



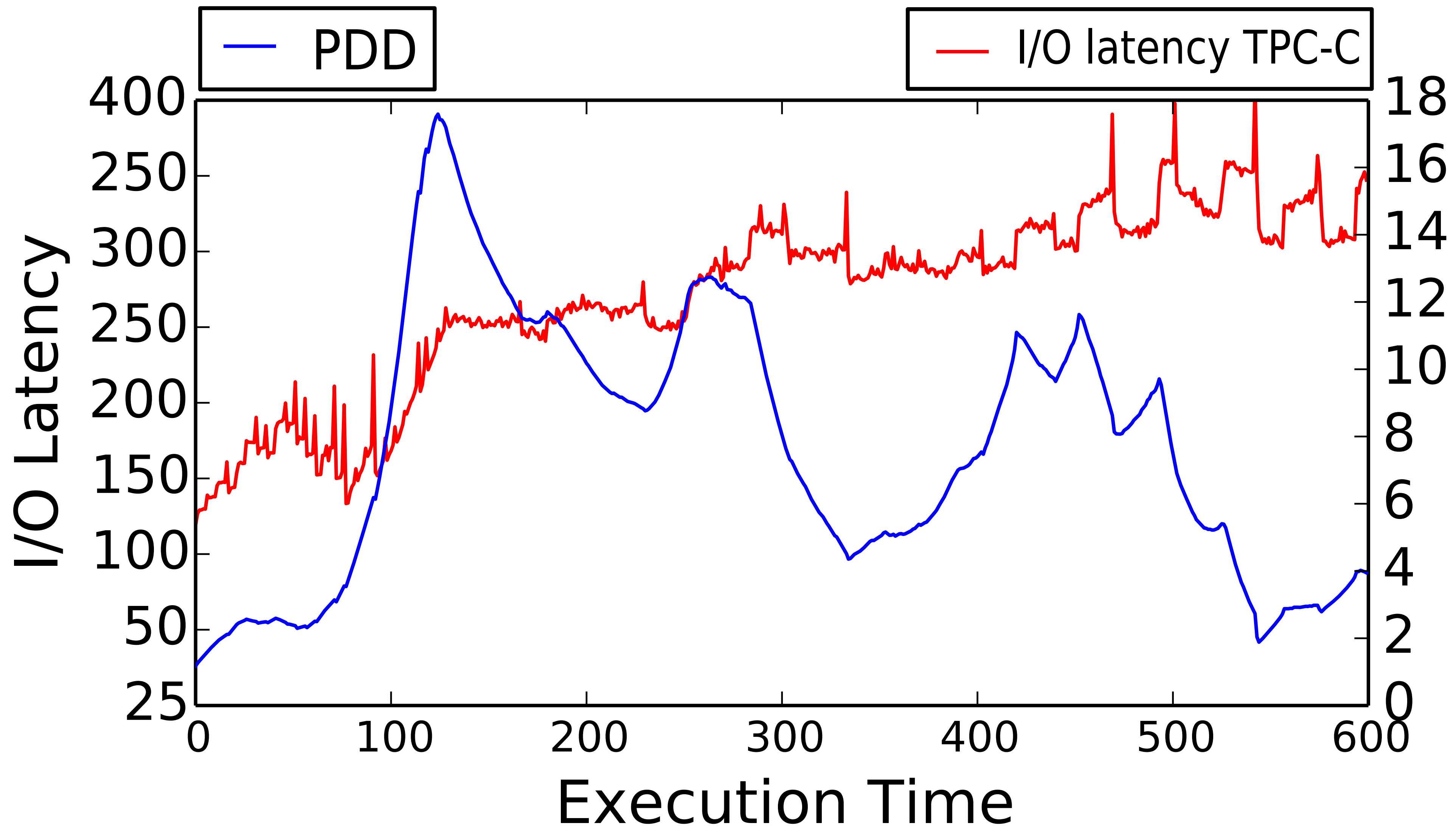
Abrupt change



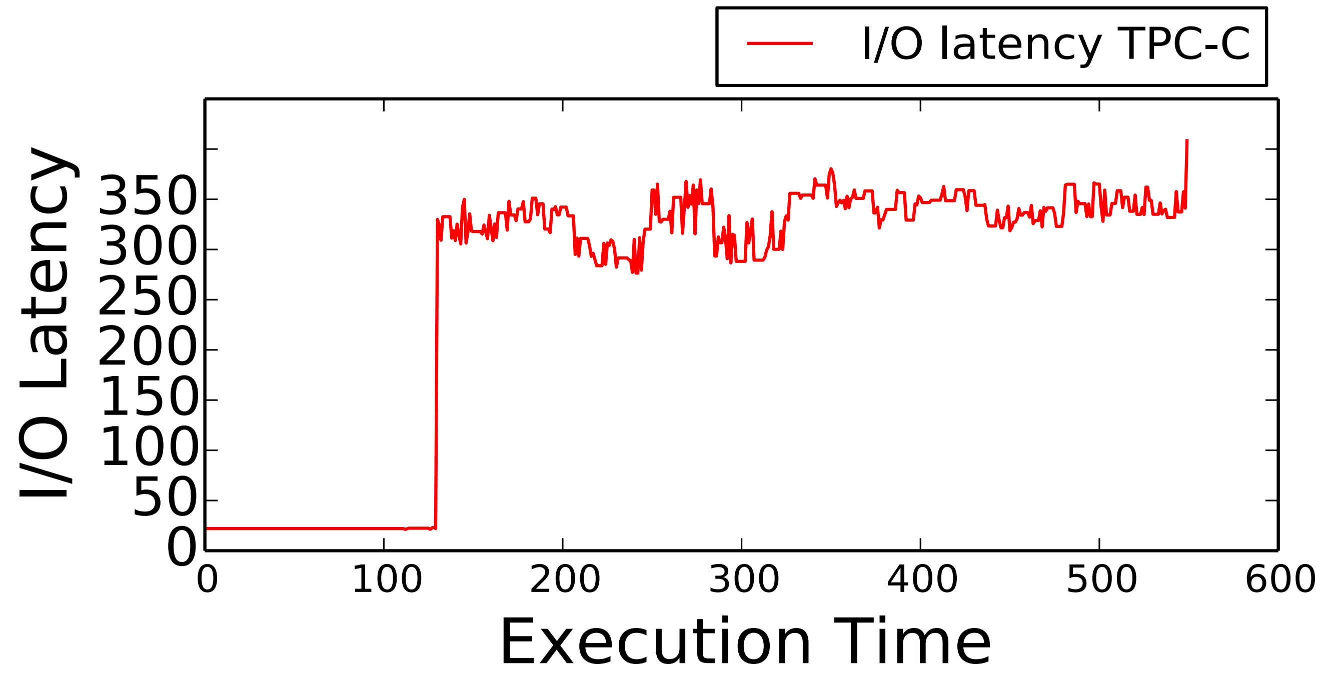
Gradual change

Current Approach — Moving Average

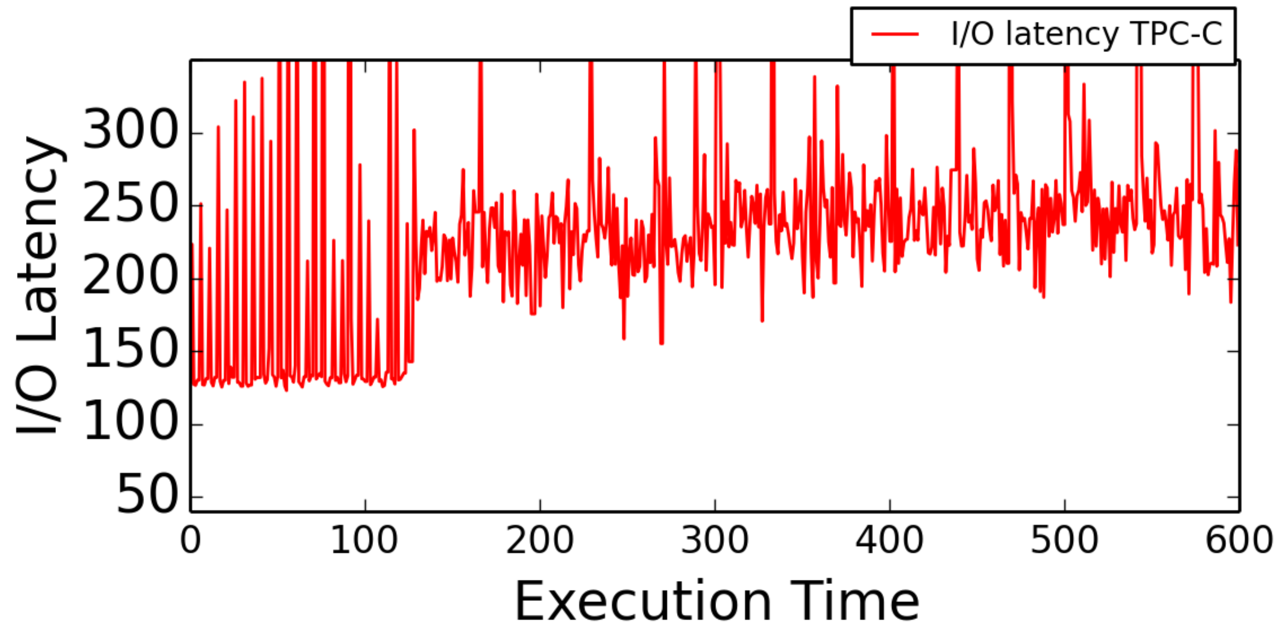
Current Approach — Moving Average

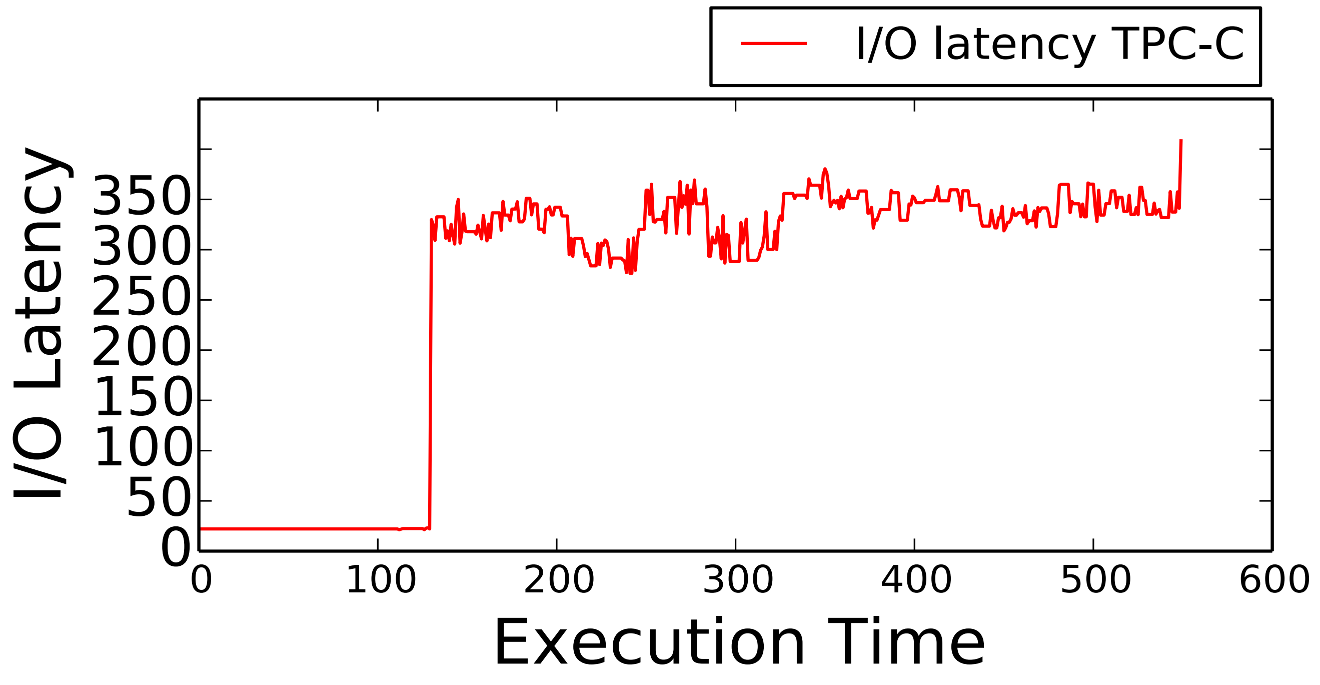


Proctor — Median Filter

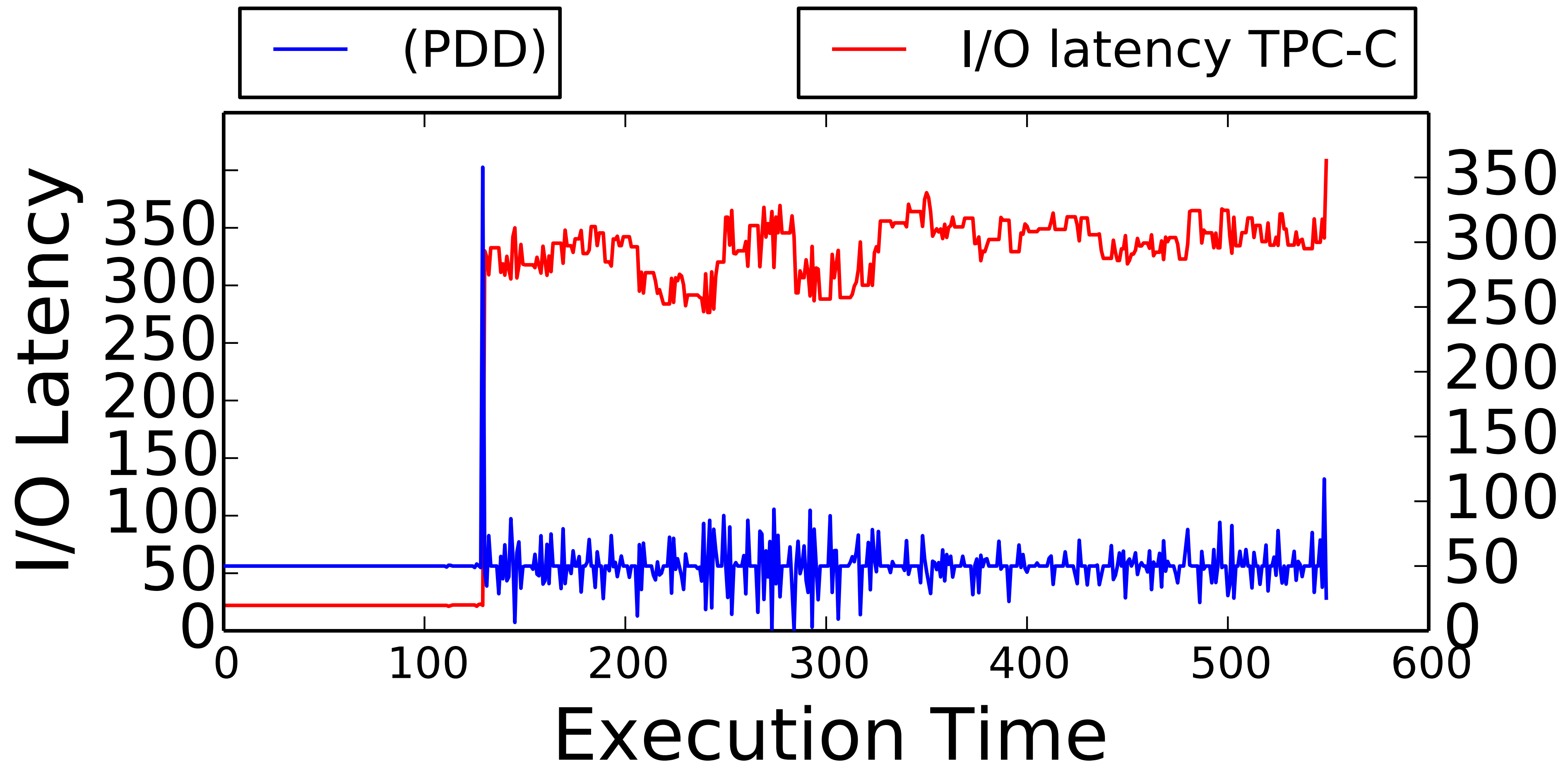


Proctor — Median Filter

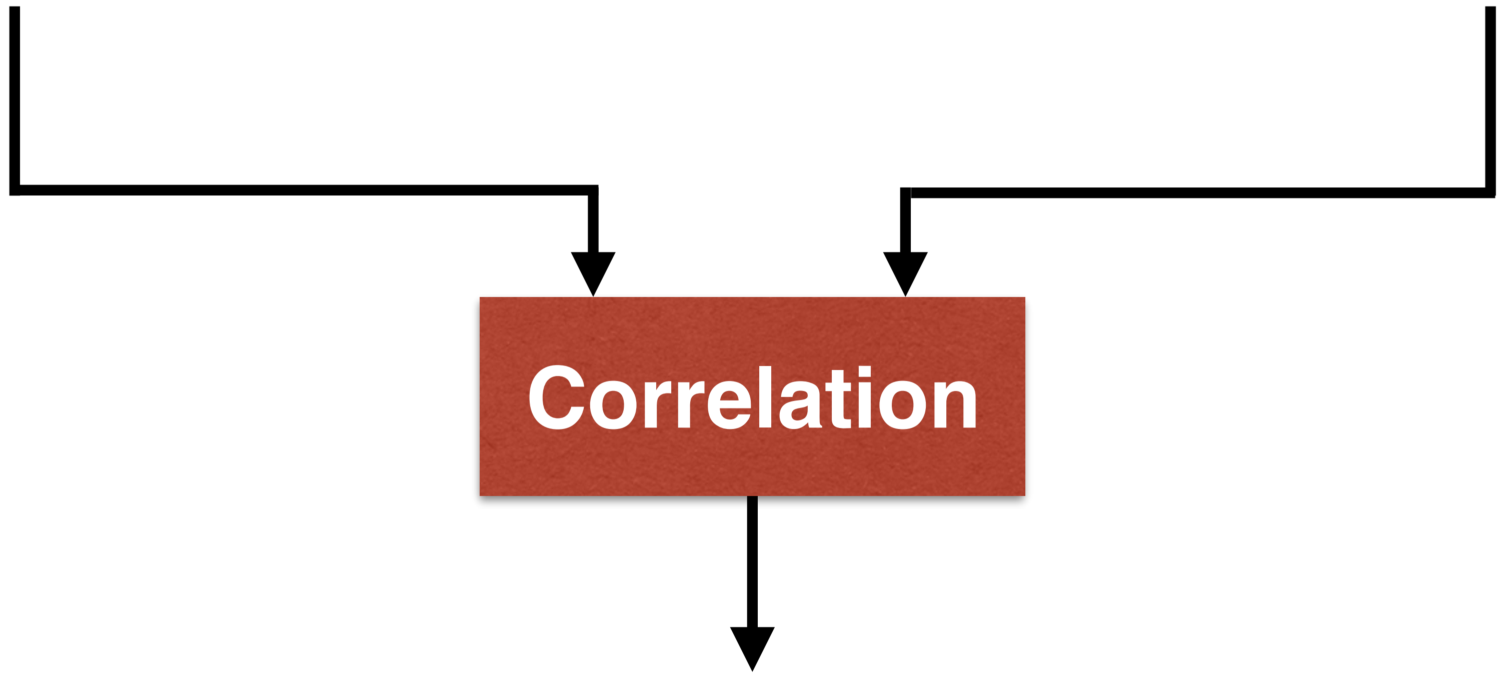




Proctor — Median Filter



Performance Degradation Investigation (PDI)



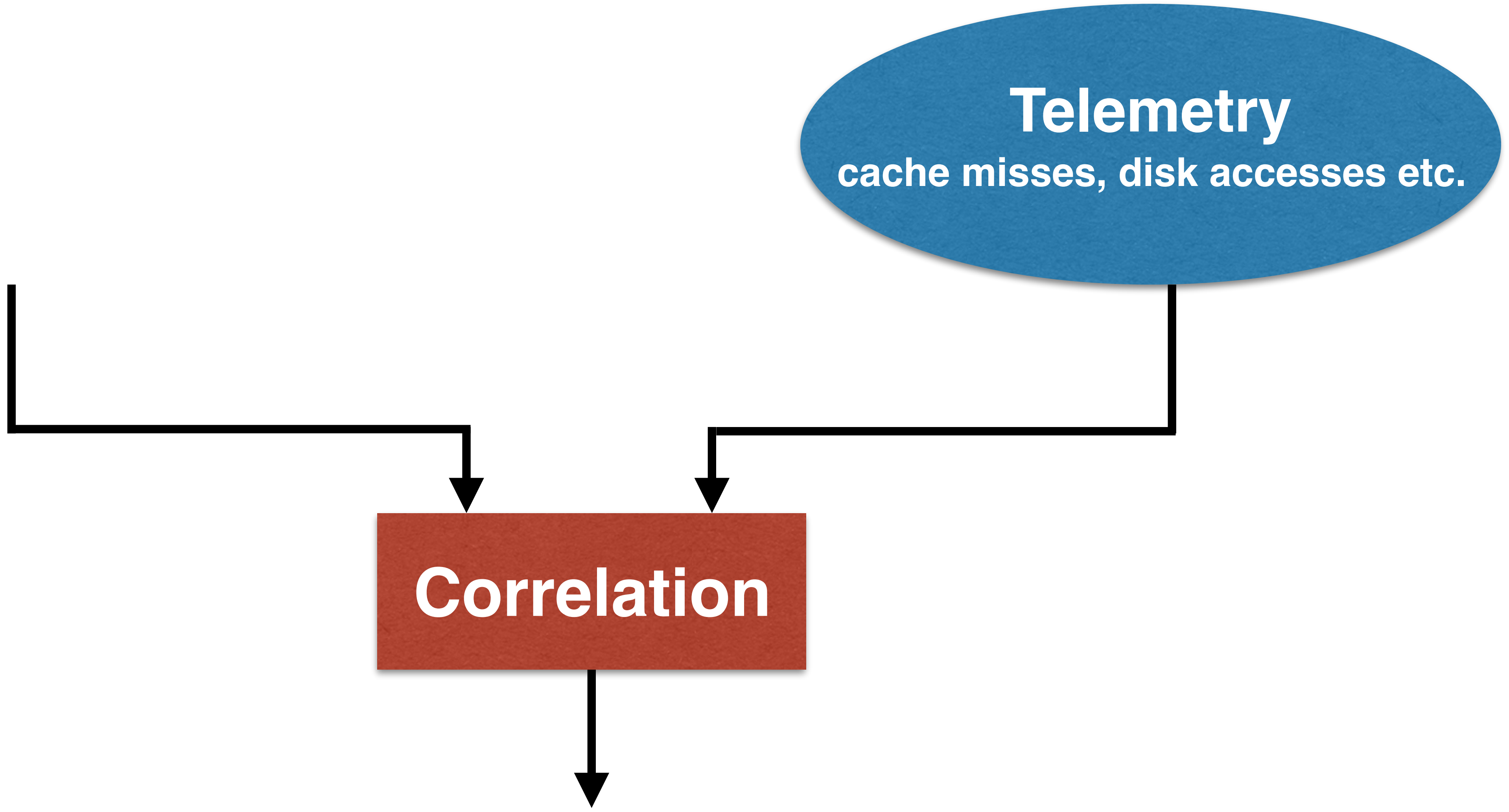
context switches
↓
cpu core contention

disk accesses
↓
I/O contention

cache misses
↓
cache contention

network throughput
↓
network contention

Performance Degradation Investigation (PDI)



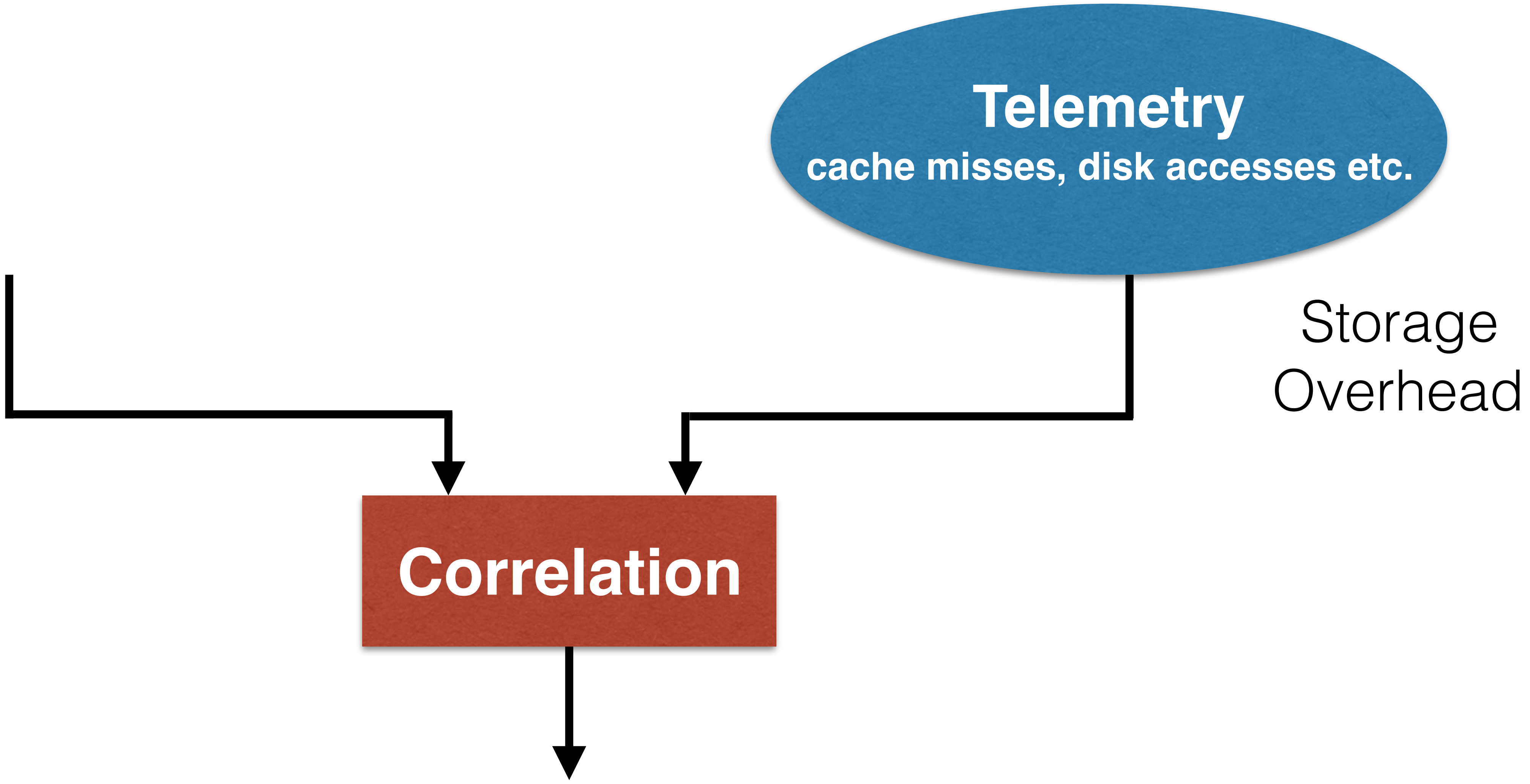
context switches
↓
cpu core contention

disk accesses
↓
I/O contention

cache misses
↓
cache contention

network throughput
↓
network contention

Performance Degradation Investigation (PDI)



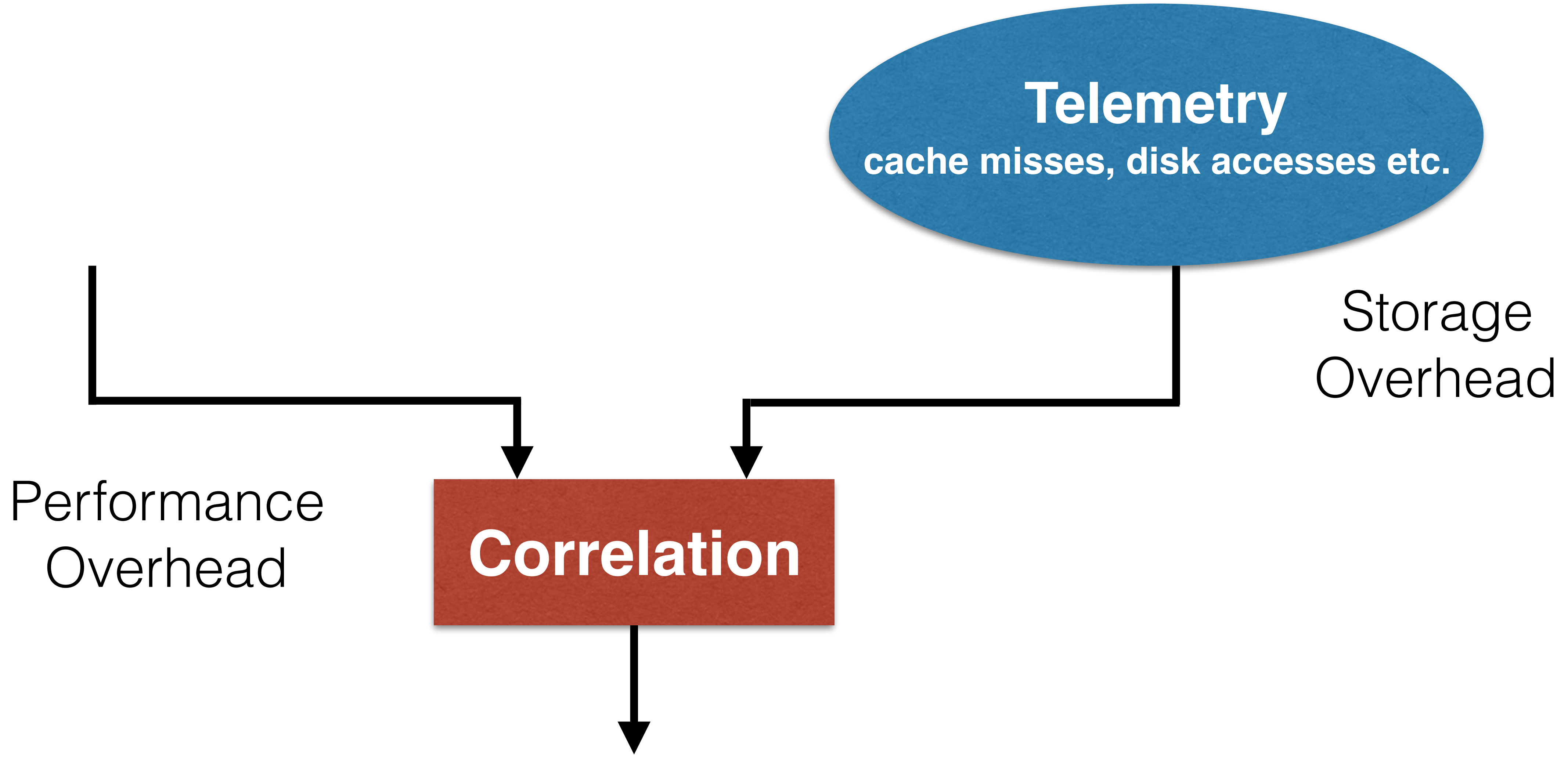
context switches ↓ cpu core contention

disk accesses ↓ I/O contention

cache misses ↓ cache contention

network throughput ↓ network contention

Performance Degradation Investigation (PDI)



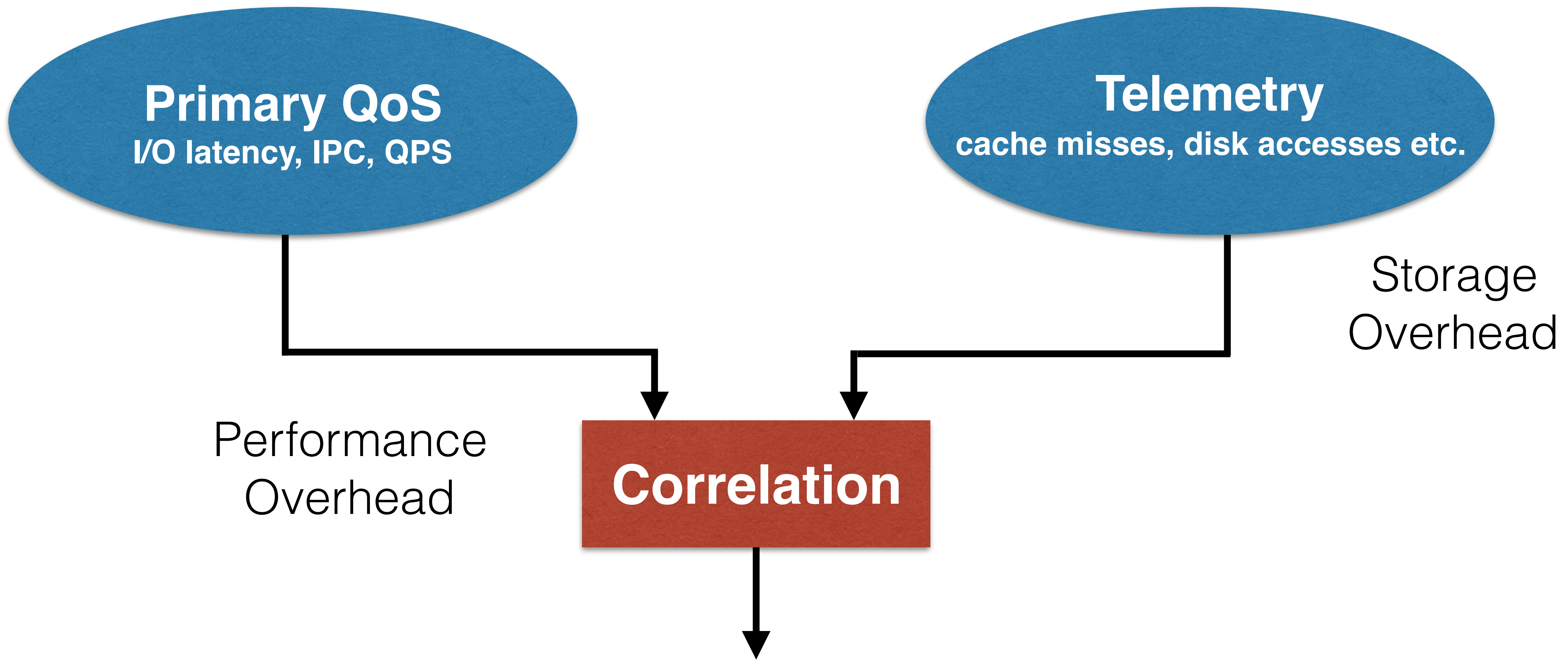
context switches ↓ cpu core contention

disk accesses ↓ I/O contention

cache misses ↓ cache contention

network throughput ↓ network contention

Performance Degradation Investigation (PDI)



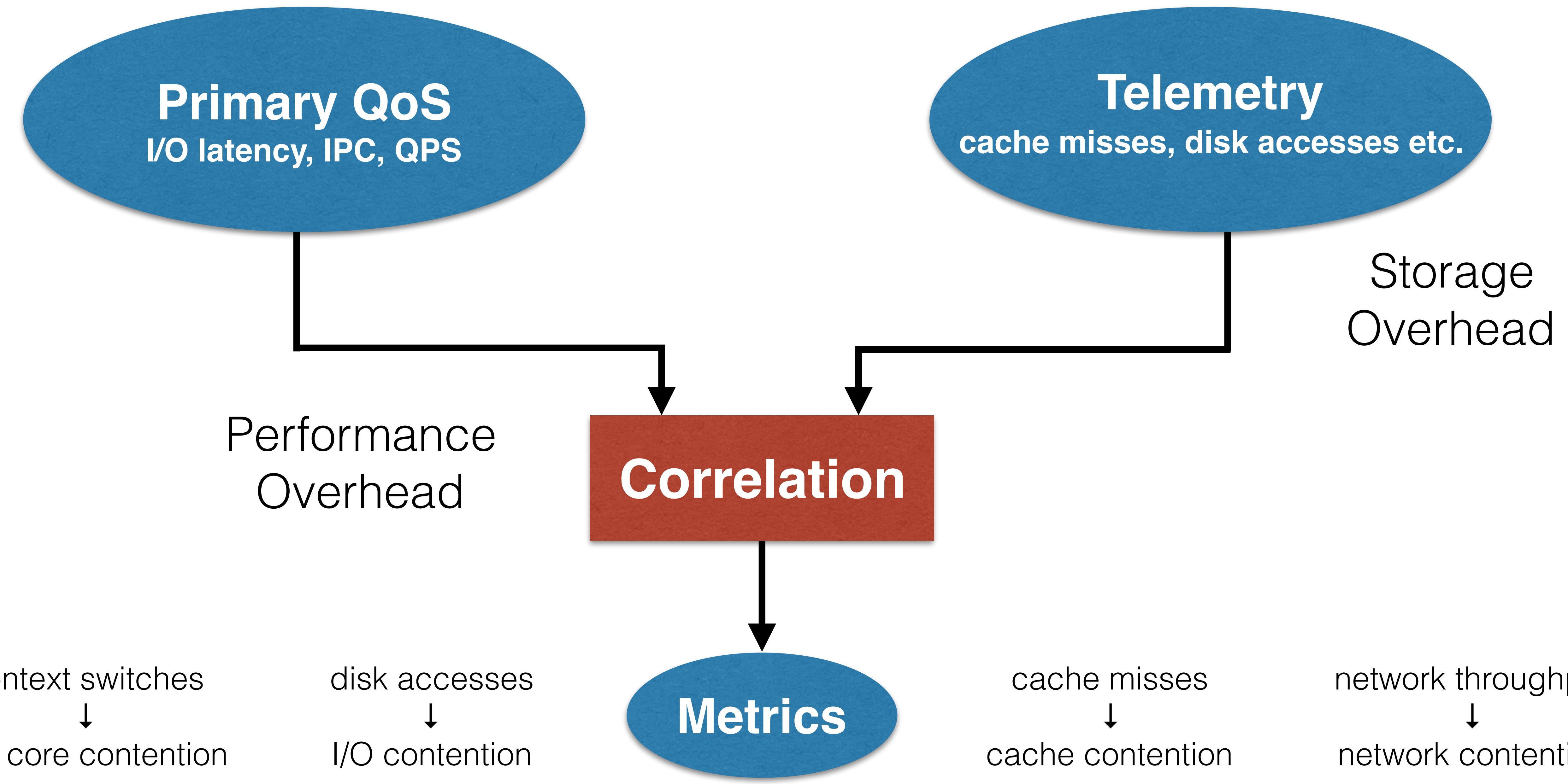
context switches ↓ cpu core contention

disk accesses ↓ I/O contention

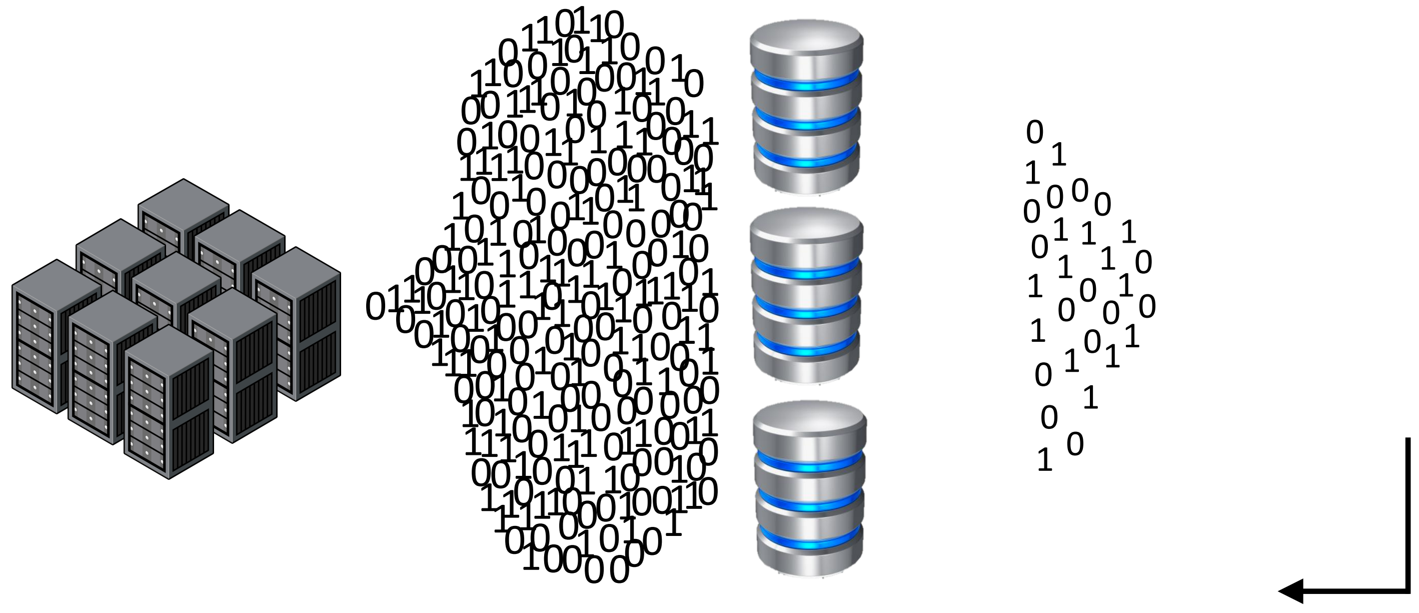
cache misses ↓ cache contention

network throughput ↓ network contention

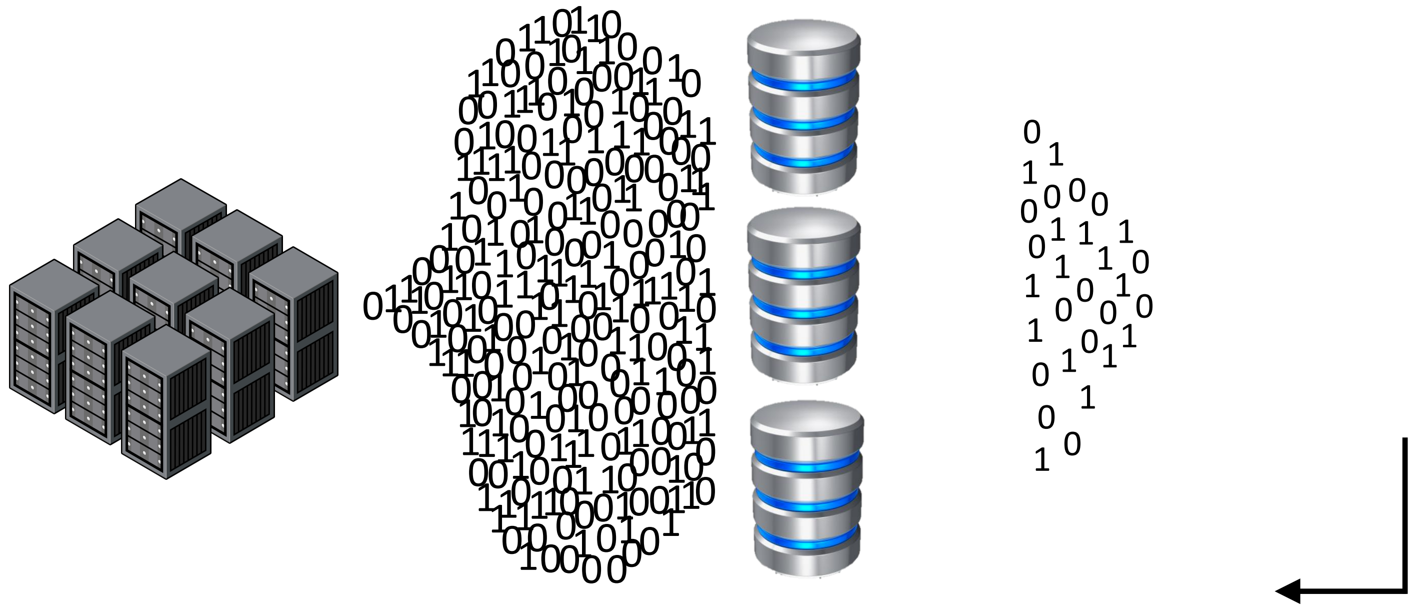
Performance Degradation Investigation (PDI)


Primary QoS
I/O latency, IPC, QPS
Telemetry
cache misses, disk accesses etc.
Storage Overhead
Performance Overhead
Correlation
Metrics
context switches ↓ cpu core contention
disk accesses ↓ I/O contention
cache misses ↓ cache contention
network throughput ↓ network contention

Sub-Sampling

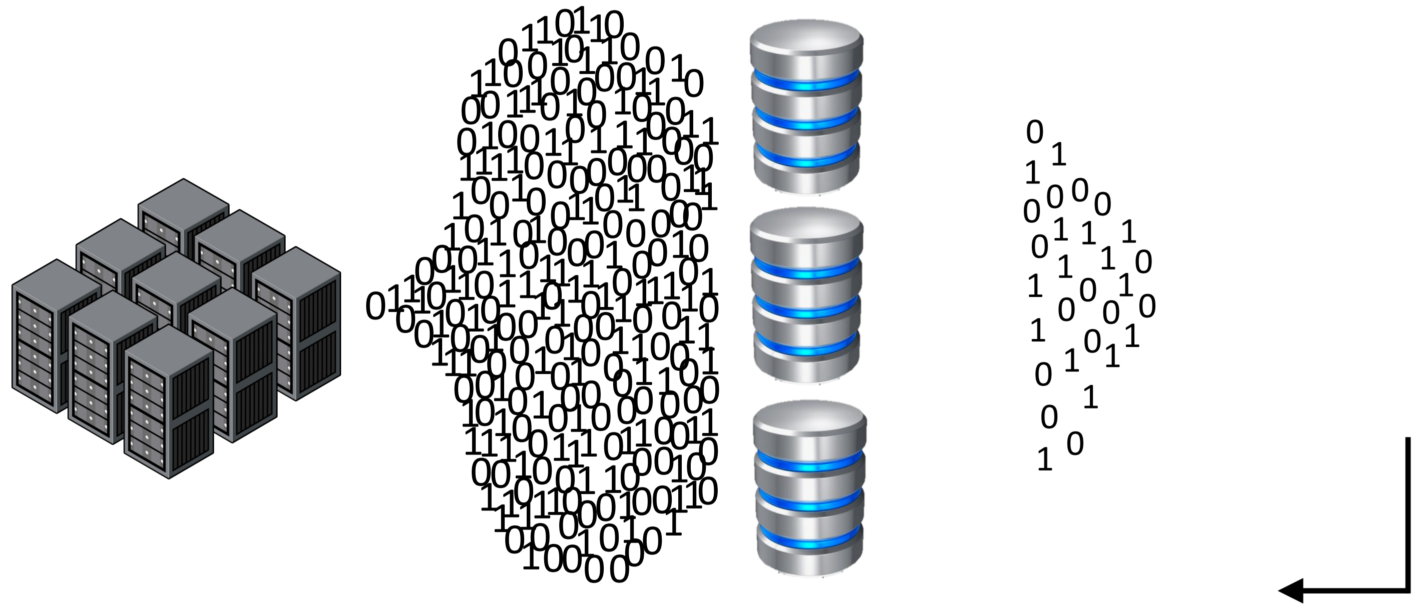


Sub-Sampling



Sub-Sampling

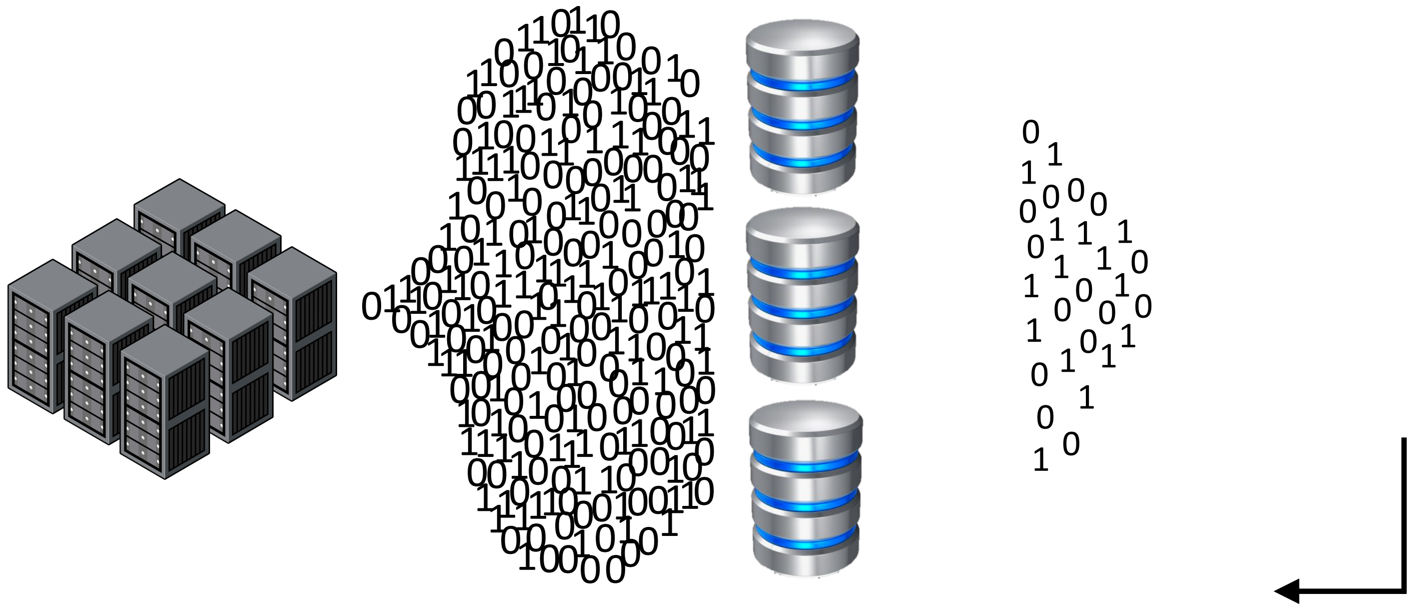
- Real Time Sub-sampling



Sub-Sampling

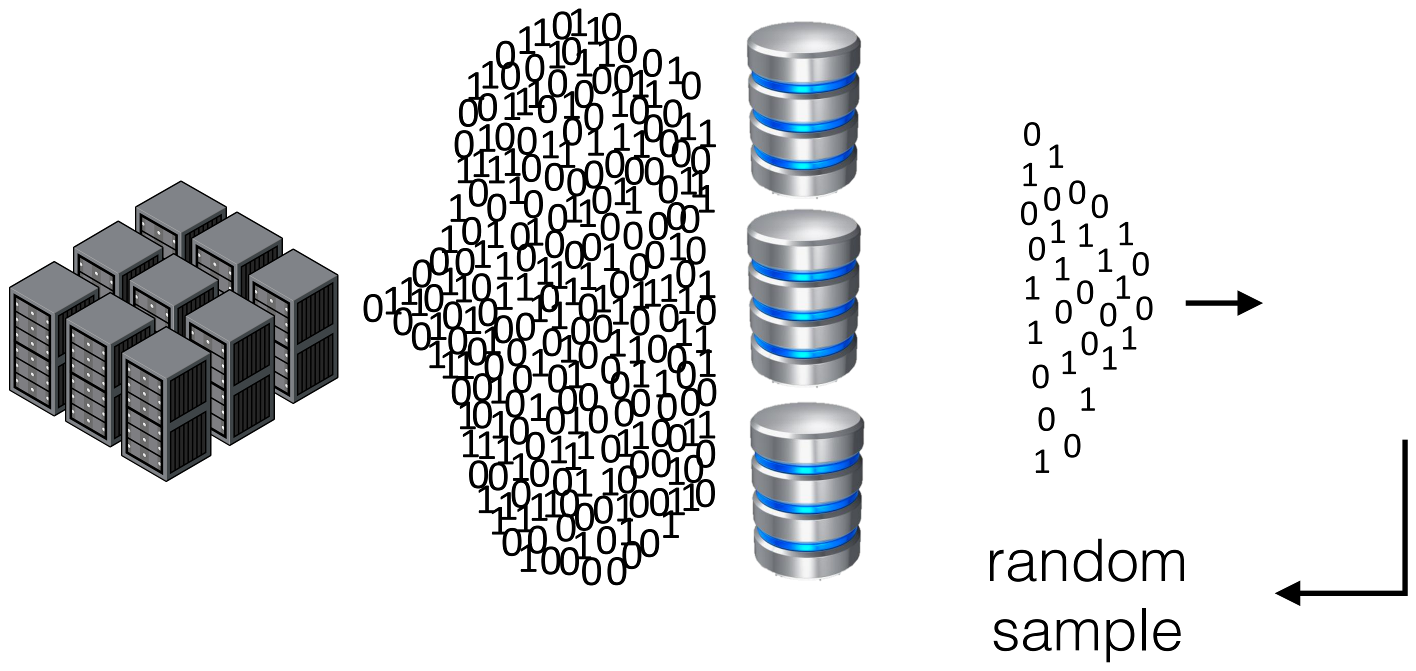
✦ Real Time Sub-sampling

  ✓ Retains statistical characteristics of original data



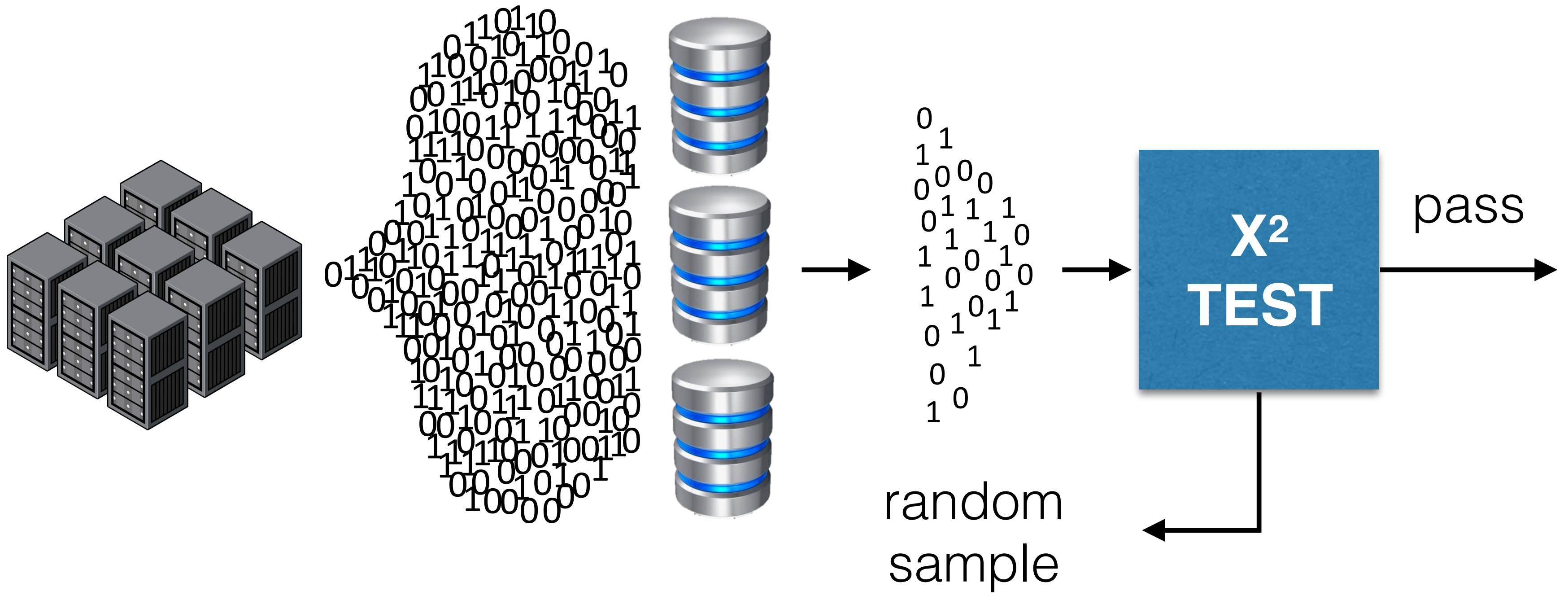
Sub-Sampling

- ✦ Real Time Sub-sampling
  - ✓ Retains statistical characteristics of original data
  - ✓ Generate random sample



Sub-Sampling

- ✦ Real Time Sub-sampling
  - ✓ Retains statistical characteristics of original data
  - ✓ Generate random sample
  - ✓ Passes hypothesis test (Pearson's Chi-square X^2 testing)



Outline

- Motivation
- Proctor – Overview and Design
- Evaluation
- Conclusion

Experimental Setup

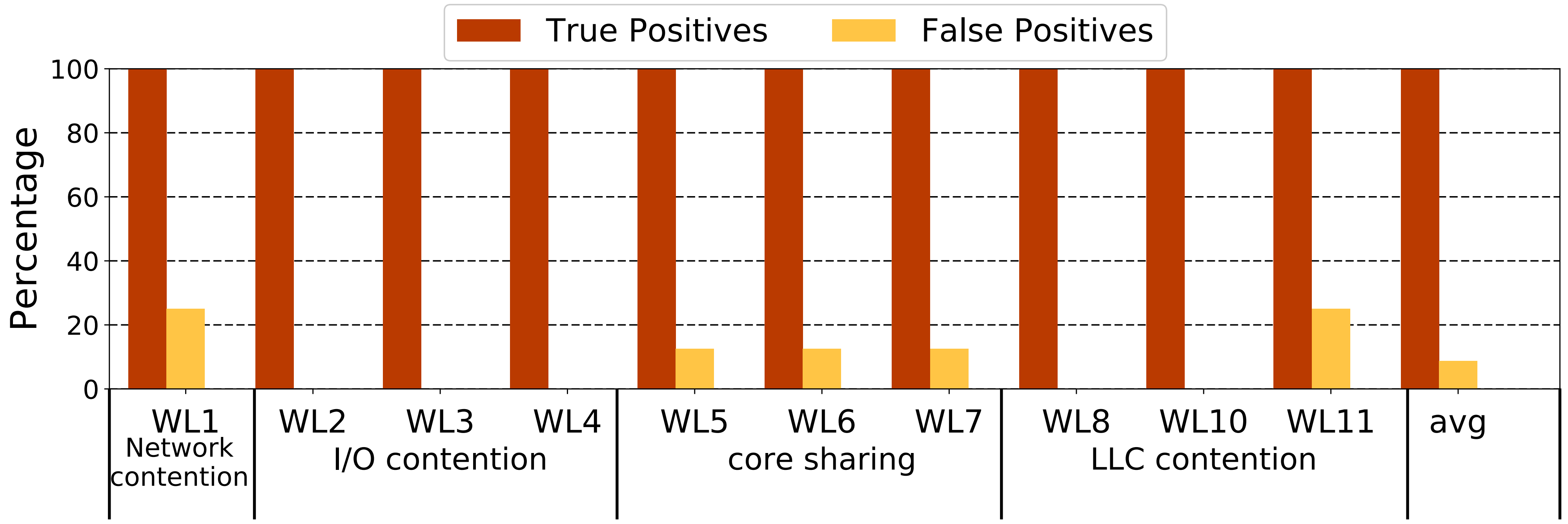
- ✦ Infrastructure
  - Intel Xeon E5-2630 @2.4 GHz, E3-1420 @3.7 GHz
- ✦ Tools
  - Linux kvm perf, iostat, netstats, kvm top
- ✦ Benchmarks
  - SPEC CPU2006, Big Data bench, OLTP bench, Redis, netperf, I/O blazer

	Work Load ID	**App 1 - Main app**	**App 2 - Colo app**	**App 3 - Colo app**	**App 4 - Colo app**	**App 5 - problematic app**
Network	WL1	Redis	Search	lbm	Sort	netperf
Disk I/O	WL2	Twitter	lbm	Redis	Sort	YCSB
	WL3	TPC - C	libquantum	Redis	Grep	Random I/O
	WL4	YCSB	sphinx3	Redis	Word Count	TPC - H
	WL5	TPC - H	lbm	Redis	K-Means	YCSB
CPU	WL6	Naive Bayes	libquantum	Redis	lbm	Page Rank
	WL7	Grep	TPC-C	Redis	sphinx3	Sort
	WL8	lbm	TPC-H	Redis	Sort	libquantum
LLC	WL9	omnetpp	TPC-H	Redis	Word Count	lbm
	WL10	libquantum	Random I/O	Redis	Grep	povray
	WL11	Redis	povray	Redis	povray	libquantum

PDD Accuracy

PDD achieves high accuracy

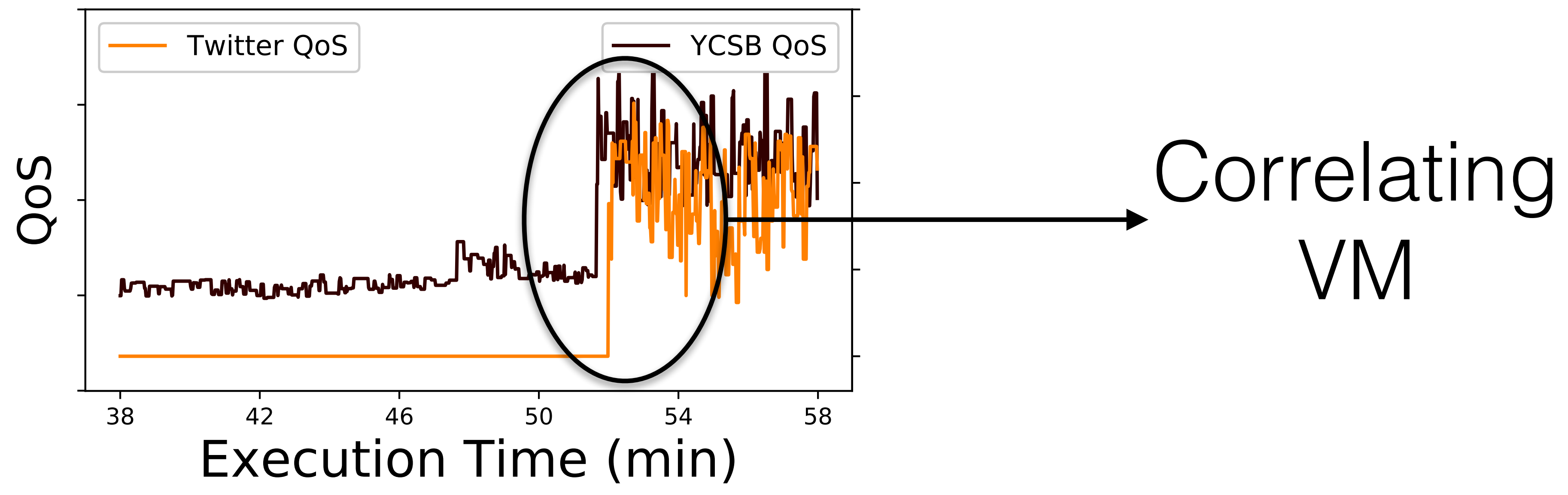
PDD Accuracy



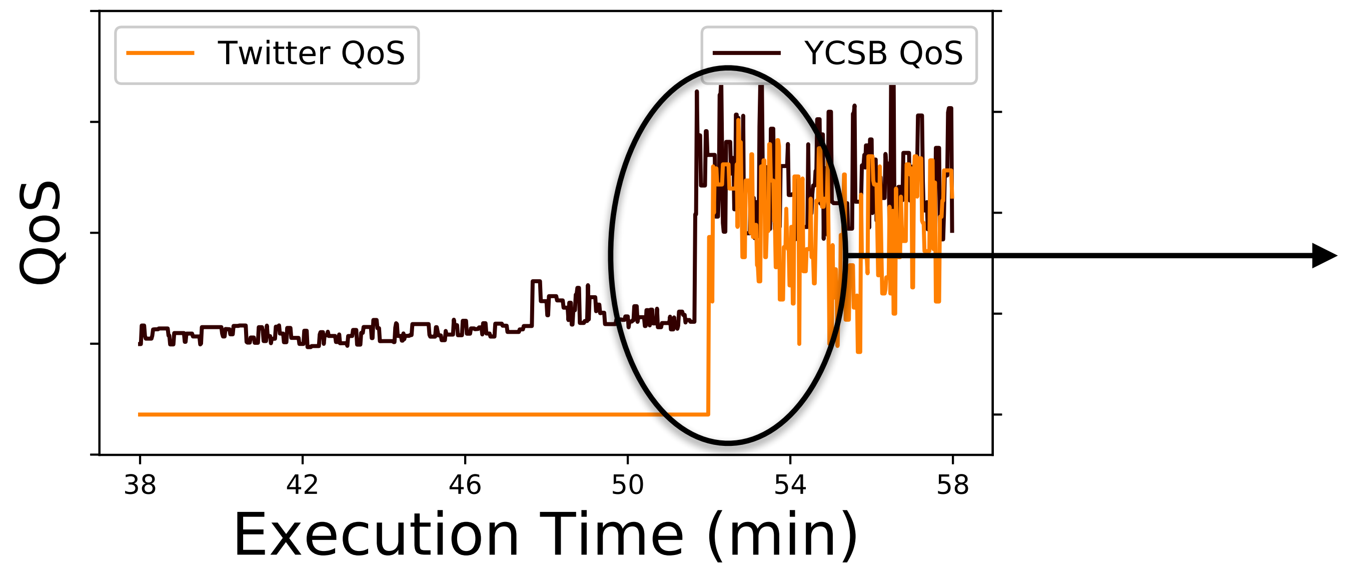
PDD achieves high accuracy

PDI Effectiveness

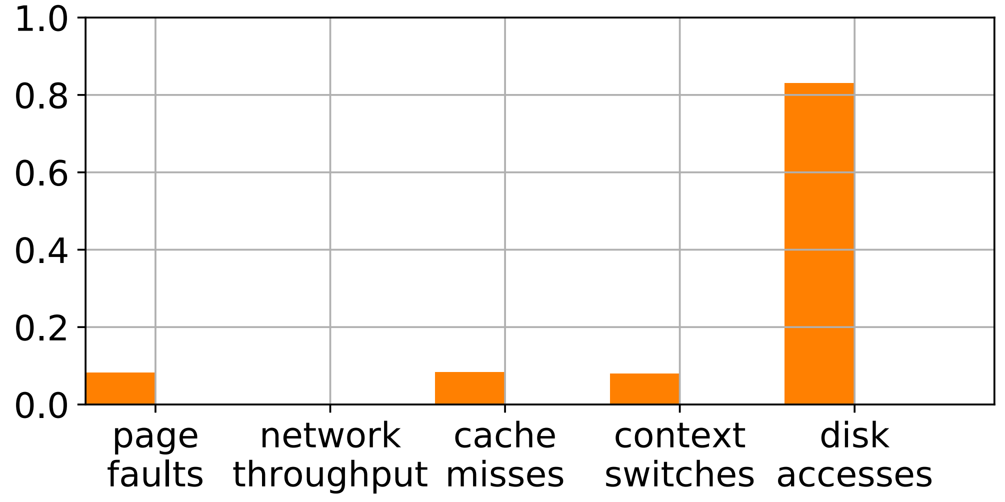
PDI Effectiveness



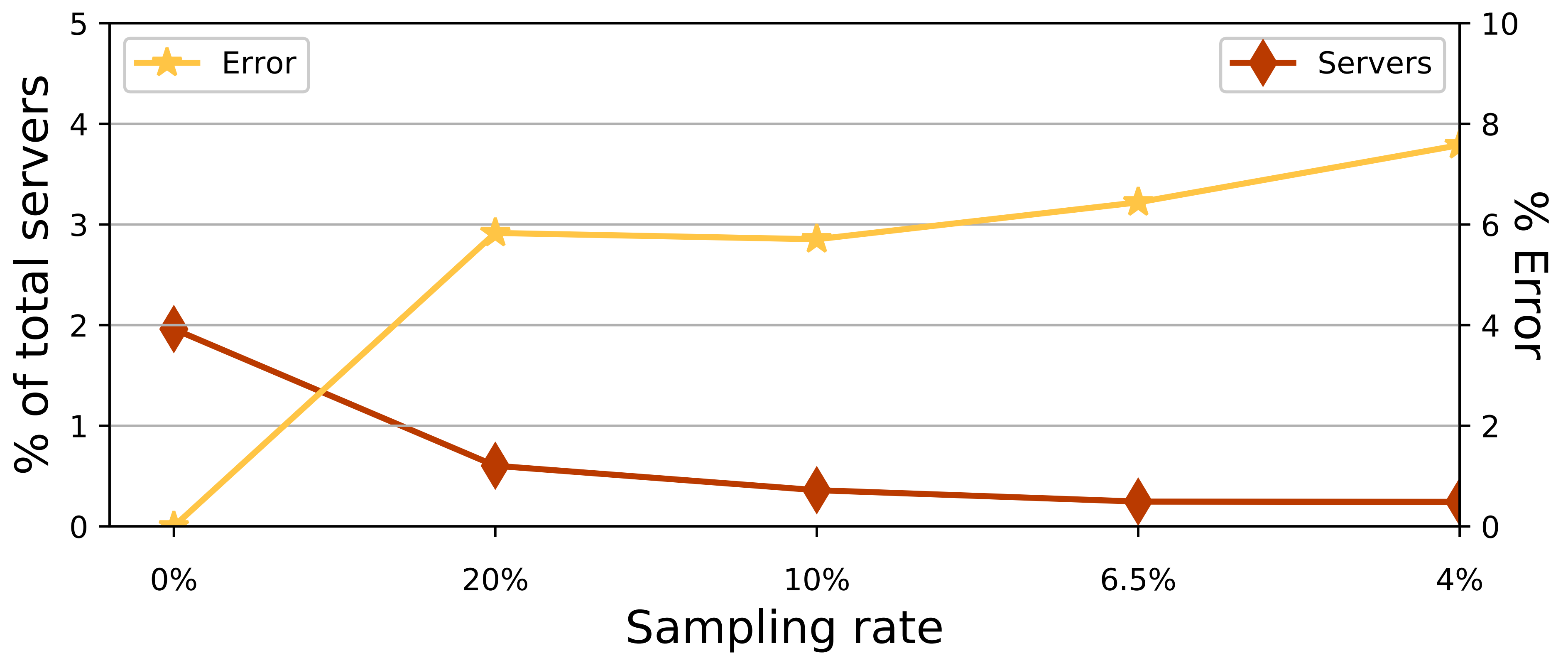
PDI Effectiveness



Correlating VM



Scalability



Conclusion