



# Runtime Measurements in the Cloud

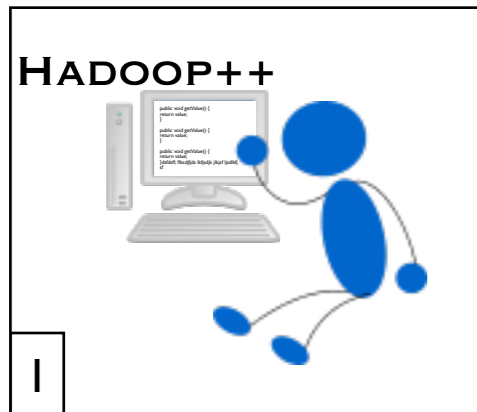
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Observing, Analyzing, and Reducing Variance

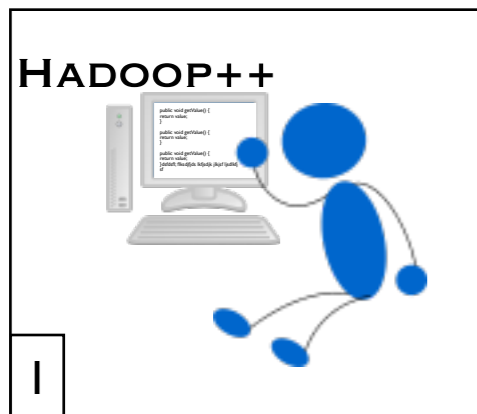
Jörg Schad, Jens Dittrich, and Jorge-Arnulfo Quiané-Ruiz

# Motivation

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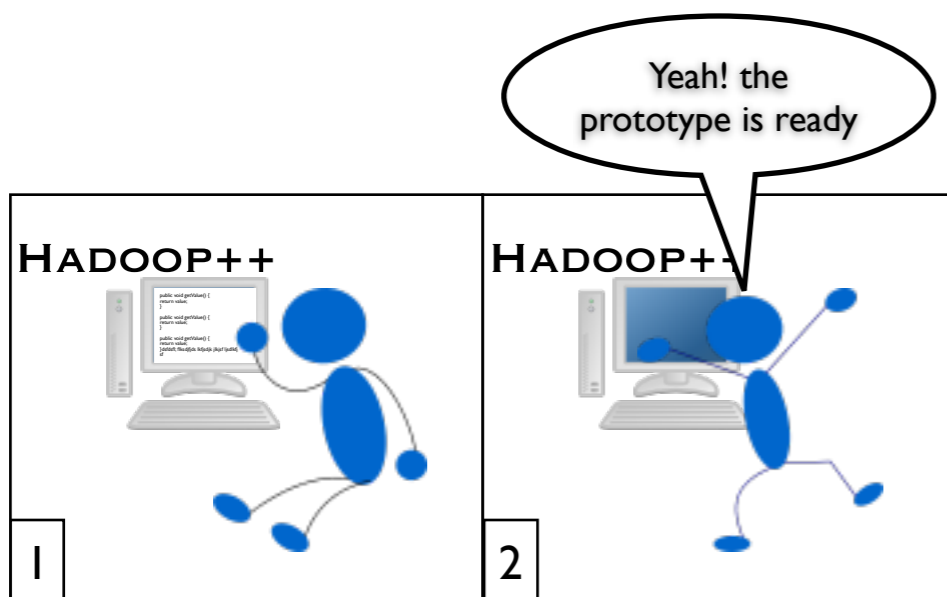
J. Dittrich et al., *Hadoop++: Making a Yellow Elephant Run Like a Cheetah (Without It Even Noticing)*

**VLDB 2010**

Presentation on Wednesday at 12:00

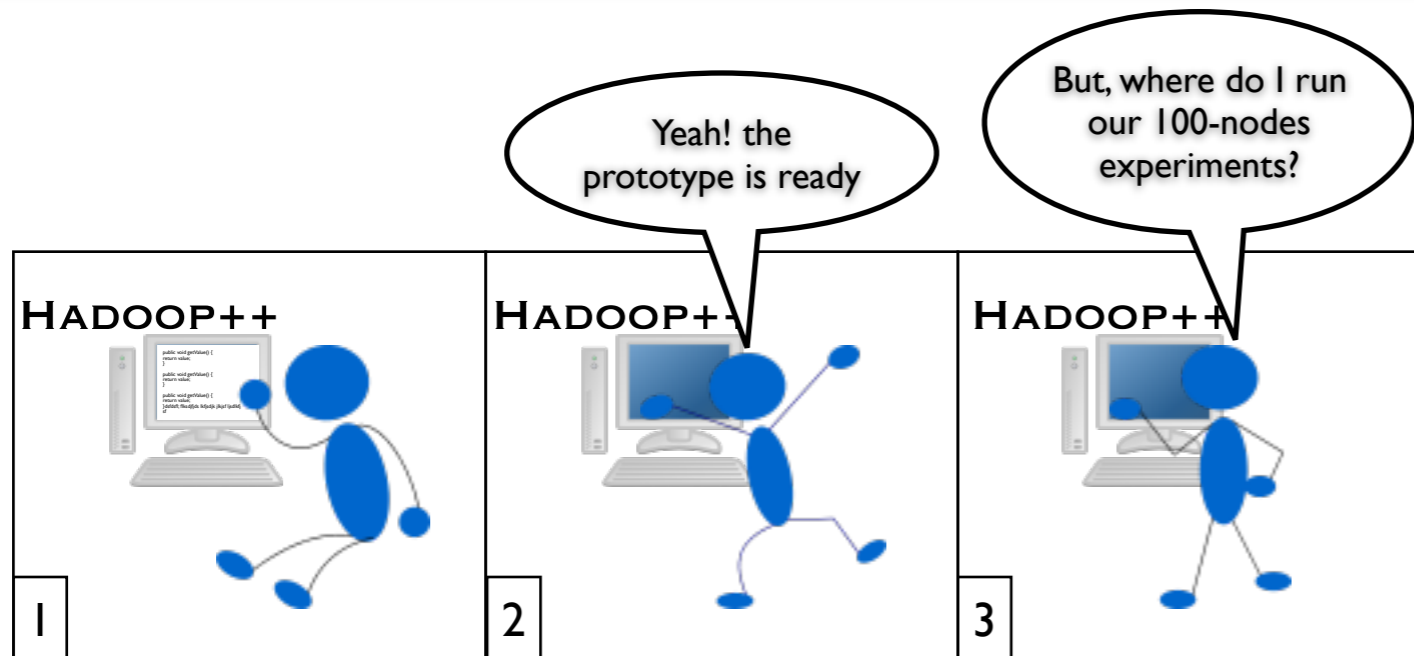
Research track: Cloud computing session

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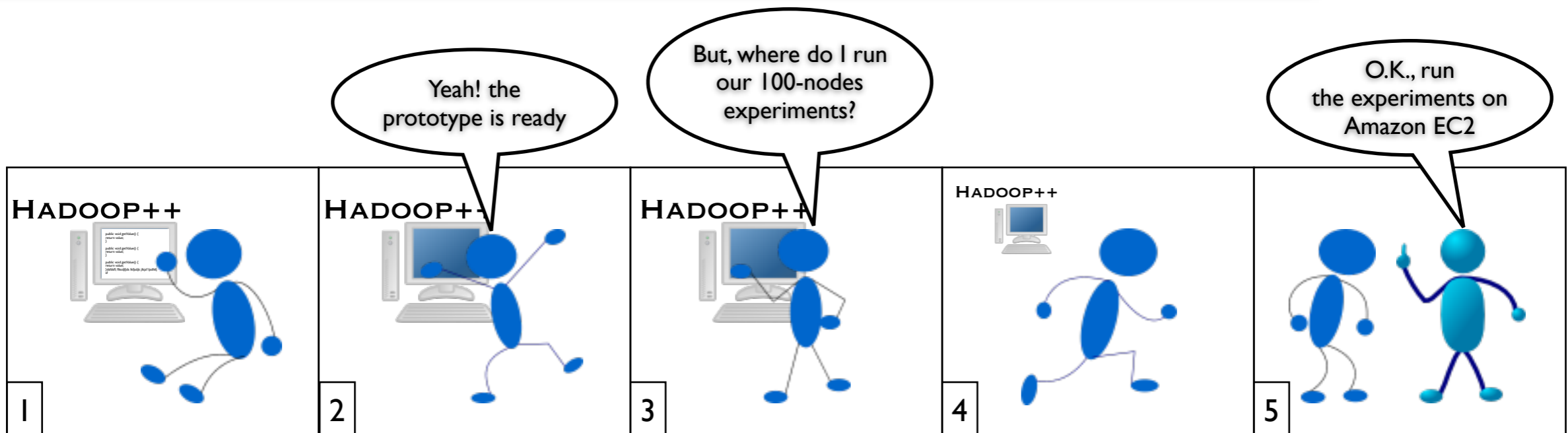


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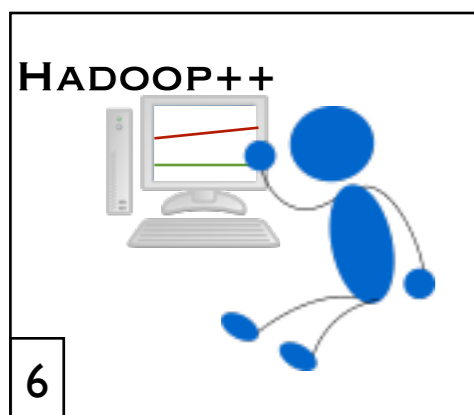
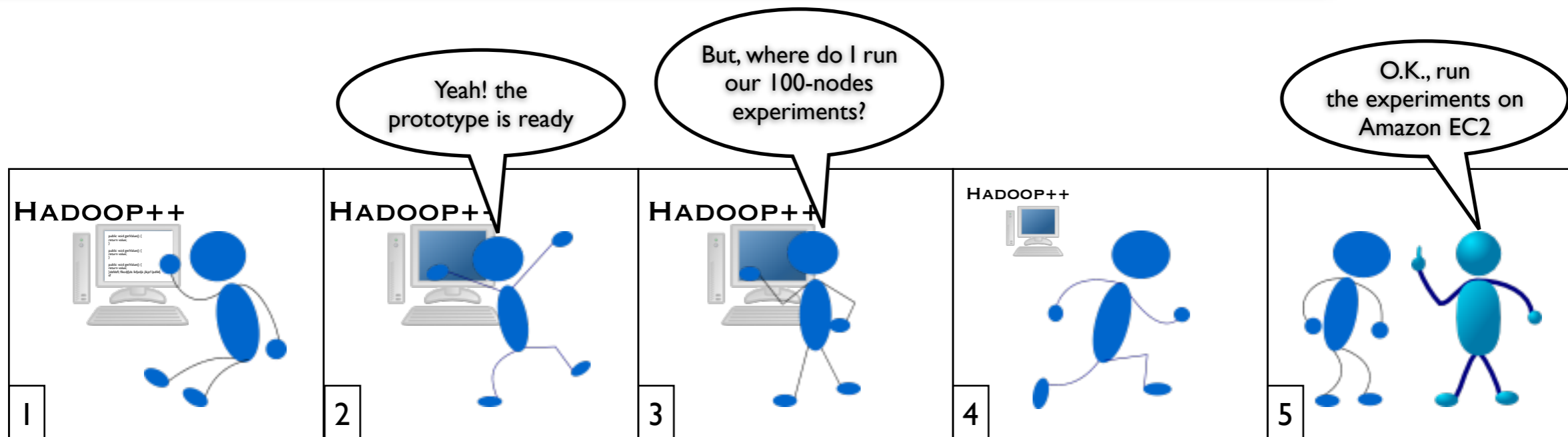
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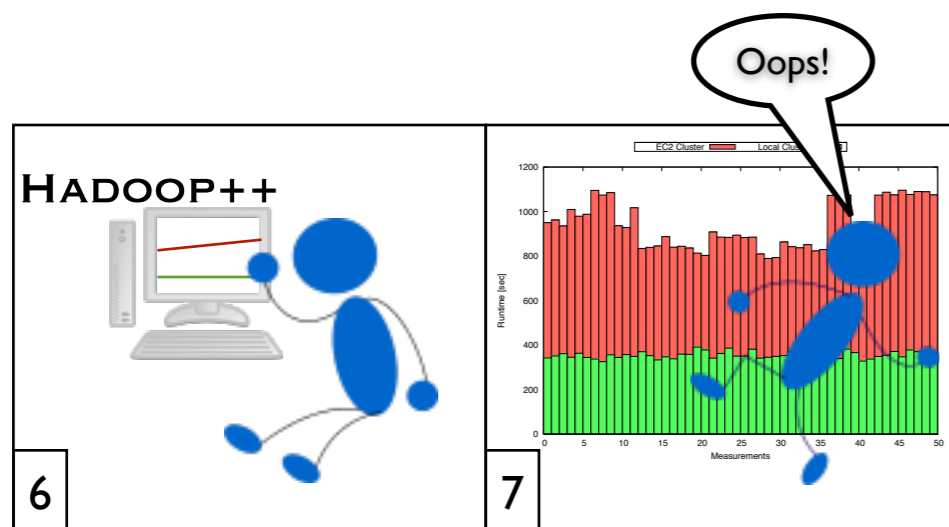
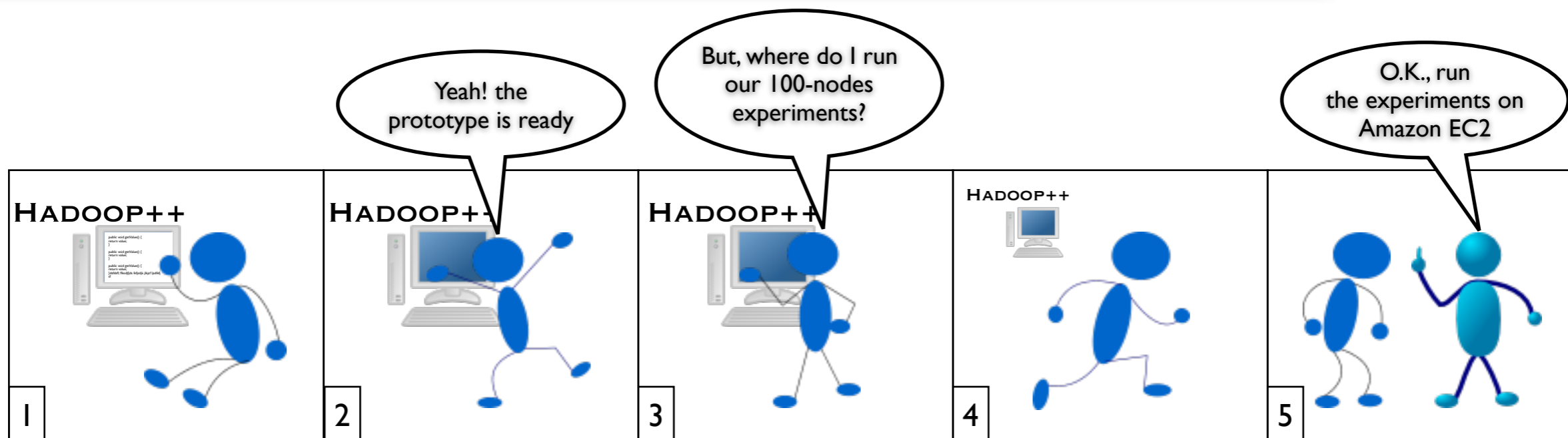


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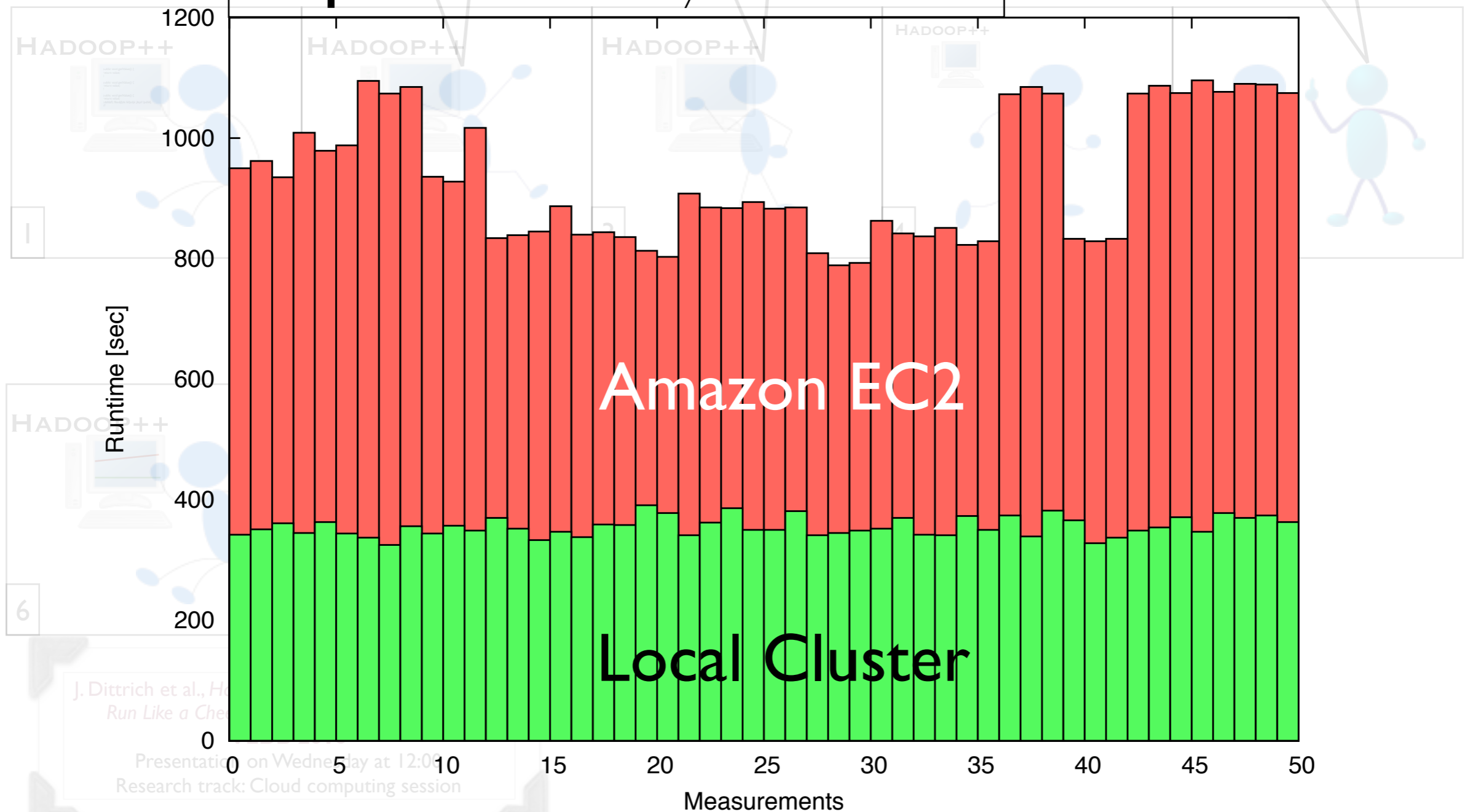


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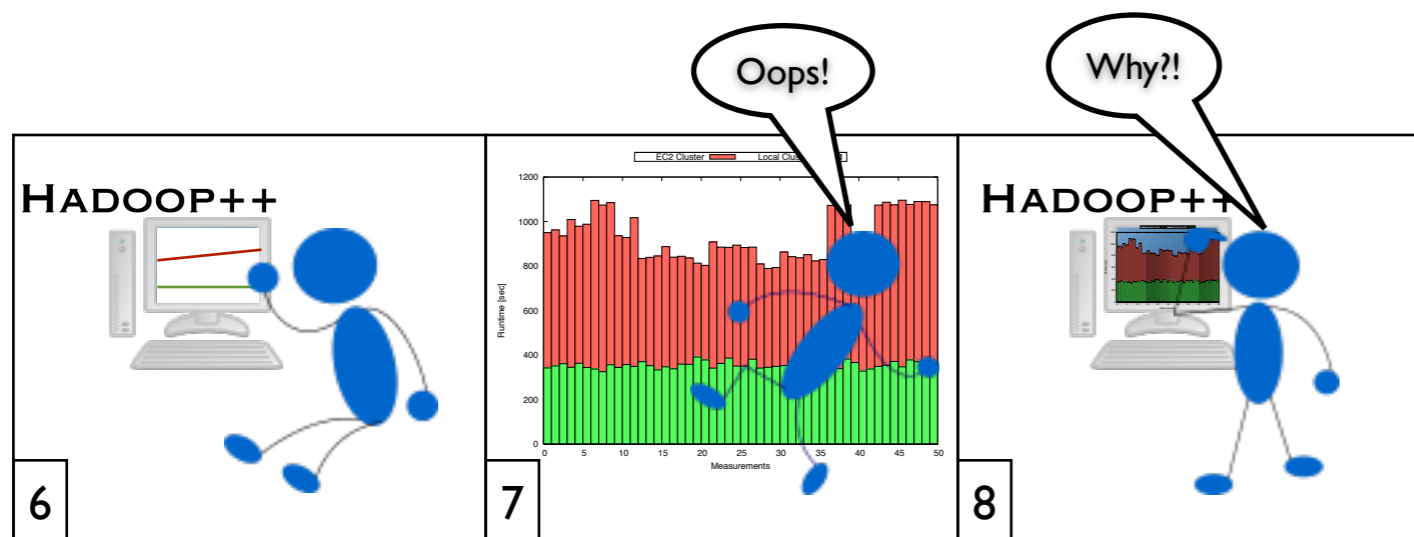
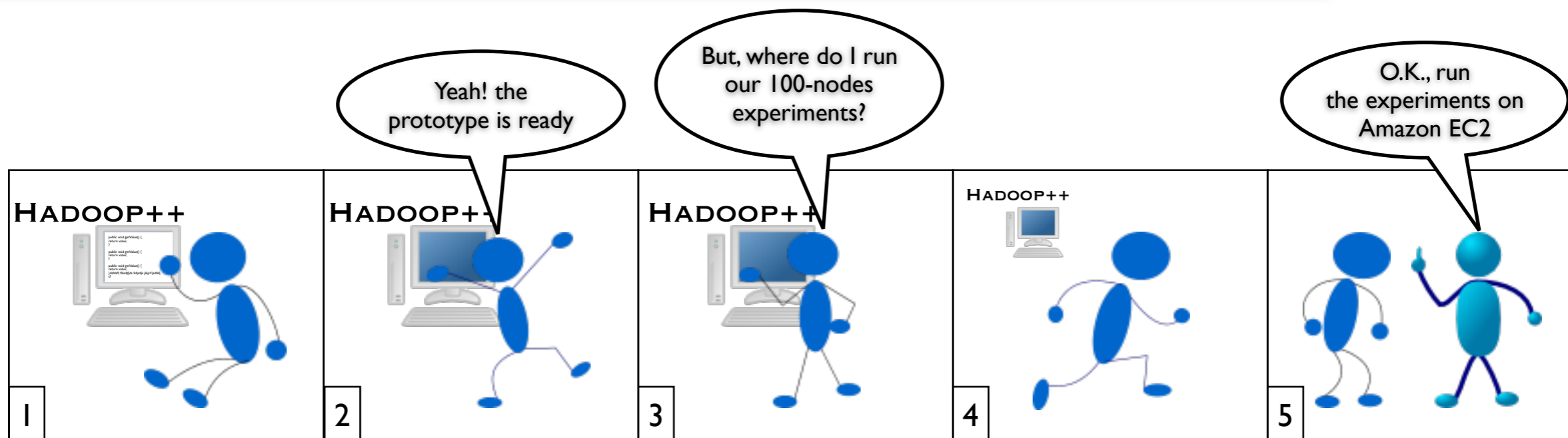
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- **Application:** a MapReduce aggregation job
- **Number of virtual nodes:** 50
- **Repetitions:** once every hour



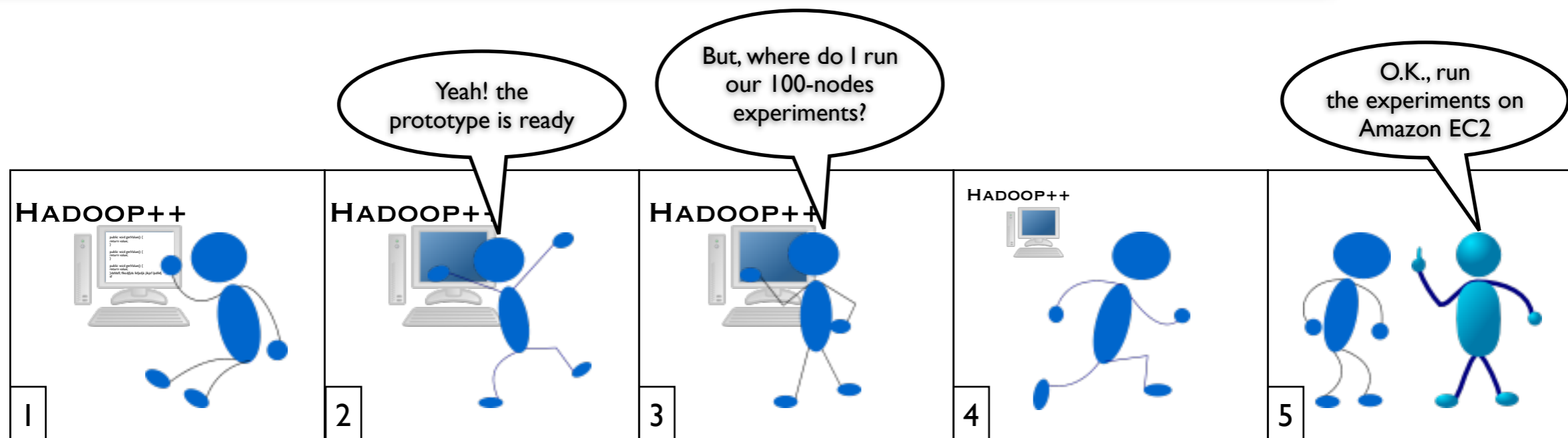
O.K., run the experiments on Amazon EC2

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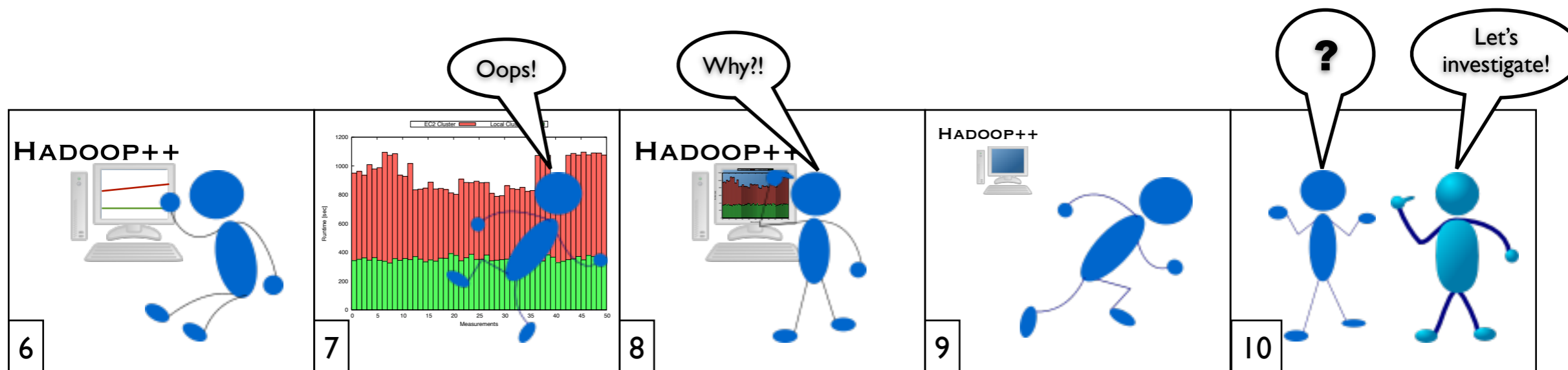
1 HADOOP++ `public void getHadoop() {  
 return null;  
}`

2 HADOOP++ Yeah! the prototype is ready

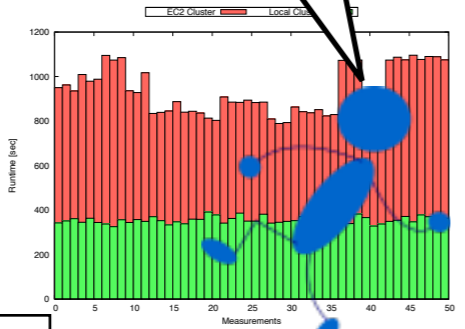
3 HADOOP++ But, where do I run our 100-nodes experiments?

4 HADOOP++

5 O.K., run the experiments on Amazon EC2



6 HADOOP++

7 HADOOP++  Oops!

8 HADOOP++ Why?!

9 HADOOP++

10 ? Let's investigate!

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# Related Work

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**Summary:** cost and performance evaluation of different distributed databases architectures and cloud providers.

[Appeared after VLDB'10 deadline]

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## Variability in Performance

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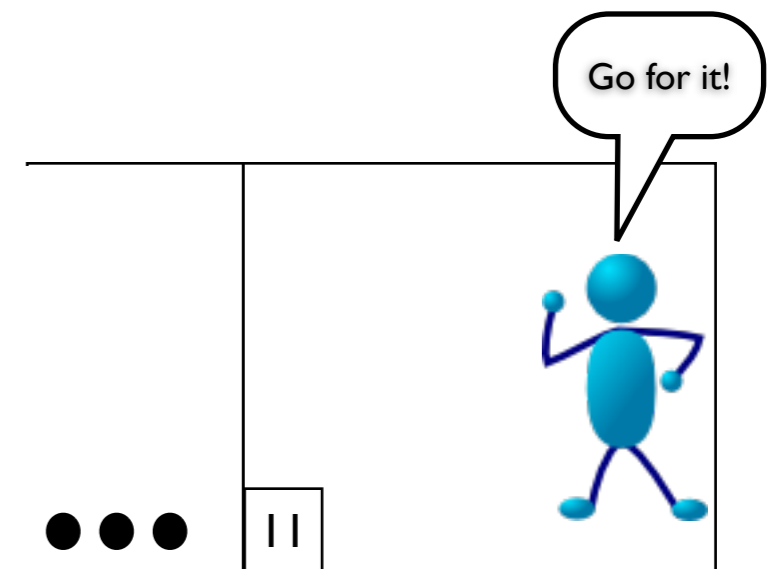
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## Variability in Performance



# Agenda

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- Motivation
- Related Work
- ➔ ● Background
- Methodology
- Results & Analysis
- Conclusion



# Amazon EC2

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- Most **popular** Cloud infrastructure
- Three **locations**: US, EU, and ASIA [after VLDB'10 deadline]
- Different **availability zones** for US
- Linux-based virtual machines (**instances**)
- Five EC2 **Instance types**: standard, micro [from September 9th], high-memory, high-cpu, and cluster-compute [after VLDB'10 deadline]

# Standard Instances

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- **Small size instance**
  - 1.7 GB of main memory
  - 1 EC2 Compute Unit
  - 160 GB of local storage
- **Large size instance**
  - 7.5 GB of main memory
  - 4 EC2 Compute Units
  - 850 GB of local storage
- **Extra Large size instance**
  - 15 GB of main memory
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*“one EC2 compute unit (ECU) provides the equivalent CPU capacity of a 1.0-1.2 GHz 2007 Opteron or 2007 Xeon processor.”*

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## Microbenchmarks



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## Microbenchmarks

### In this talk:

- CPU performance
- Memory performance
- Disk I/O (sequential and random)
- Internal network bandwidth
- External network bandwidth
- Instance startup

# How to Measure?

## Microbenchmarks

### In this talk:

- CPU performance:
- Memory performance:
- Disk I/O (sequential and random):
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# How to Measure?

## Microbenchmarks

### In this talk:

- CPU performance: **Ubench**
- Memory performance: **Ubench**
- Disk I/O (sequential and random): **Bonnie++**
- Internal network bandwidth
- External network bandwidth
- Instance startup

# Goal of Our Study

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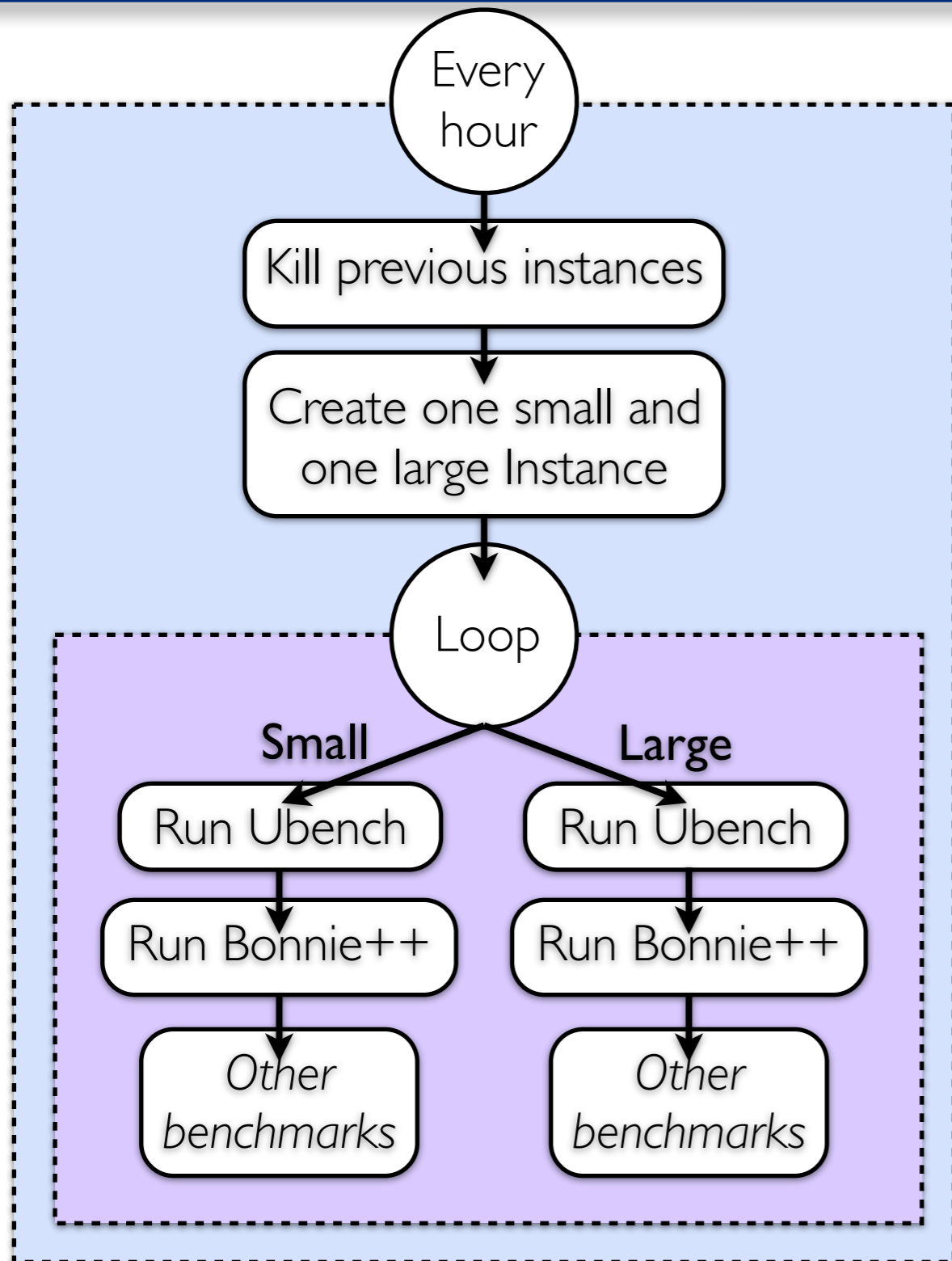
- Do different **Instance types** have different variations in performance?
- Do different **locations** or **availability zones** impact performance?
- Does performance depend on the **time** of the day, weekday, or week?

- **Small** and **large** Instances in **US** and **EU** locations
- **Default** settings for Ubench and Bonnie++
- Results reported in **CET** time
- **Baseline:** our team's cluster at Saarland University
  - 50 Xeon-based virtual nodes
  - 2.66 GHz Quad Core Xeon CPU
  - 16 GB of main memory
  - 6x750 GB SATA hard disks

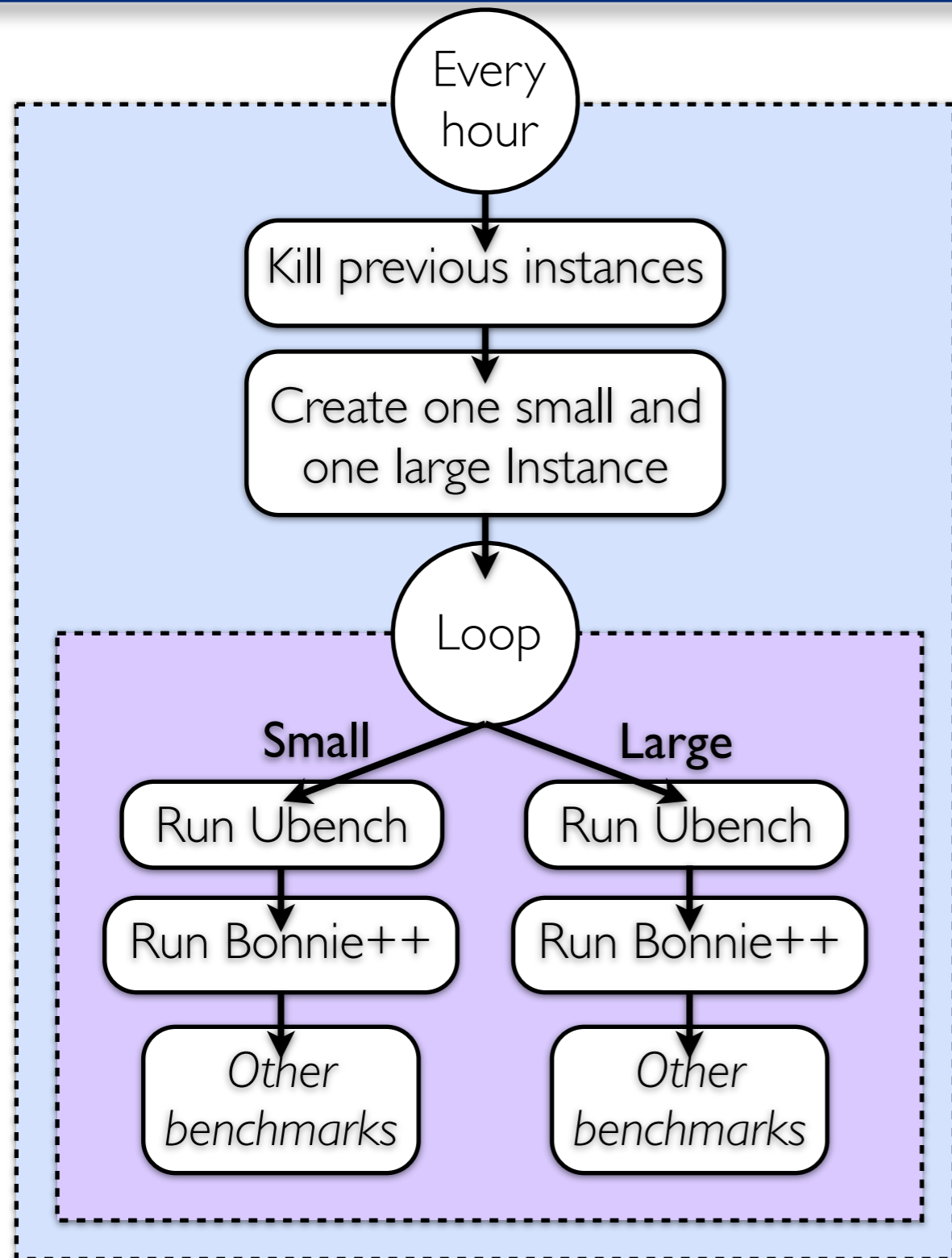
[**ASIA** location was introduced after VLDB deadline]

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# Methodology



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**Start:** December 14, 2009  
**End:** January 12, 2010  
**Duration:** 31 days

[Results for one additional month, but without any additional pattern]

# Measure of Variation

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- Different ones: **range, variance, standard deviation, ...**

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- Need to **compare** data series in different **scales**



# Measure of Variation

- Different ones: **range**, **variance**, **standard deviation**, ...
- Need to **compare** data series in different **scales**
- **Coefficient of Variation (COV)**: ratio of the standard deviation to the mean

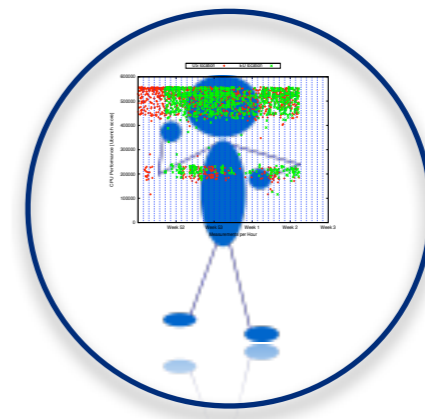
$$COV = \frac{1}{\bar{x}} \cdot \sqrt{\frac{1}{N-1} \cdot \sum_{i=1}^N (x_i - \bar{x})^2}$$

The diagram illustrates the formula for the Coefficient of Variation (COV). The term  $\frac{1}{\bar{x}}$  is highlighted in a light green box, with an arrow pointing to it from the label "mean ( $\bar{x}$ )". The square root term is highlighted in a light blue box, with an arrow pointing to it from the label "standard deviation ( $s$ )".

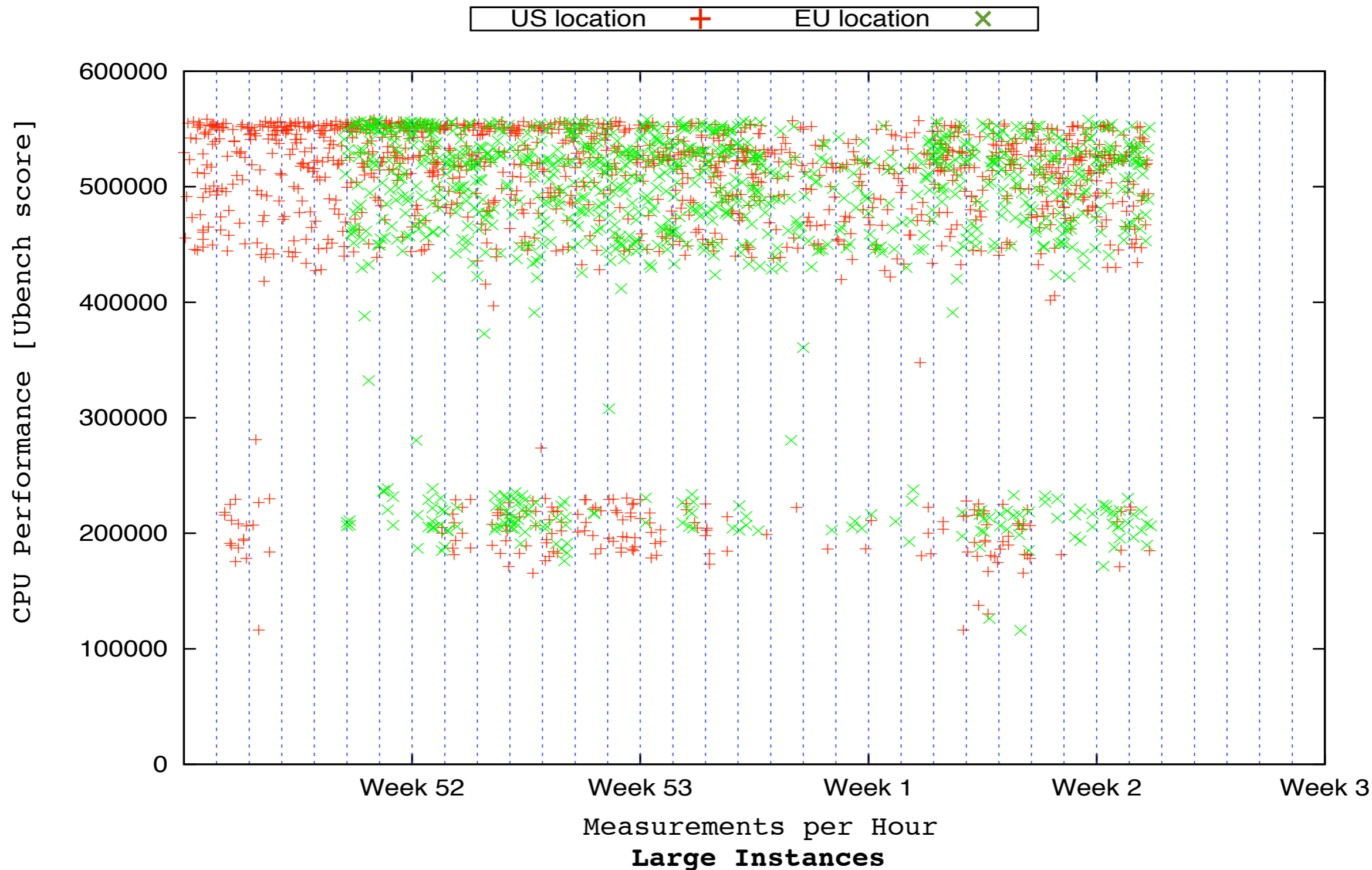
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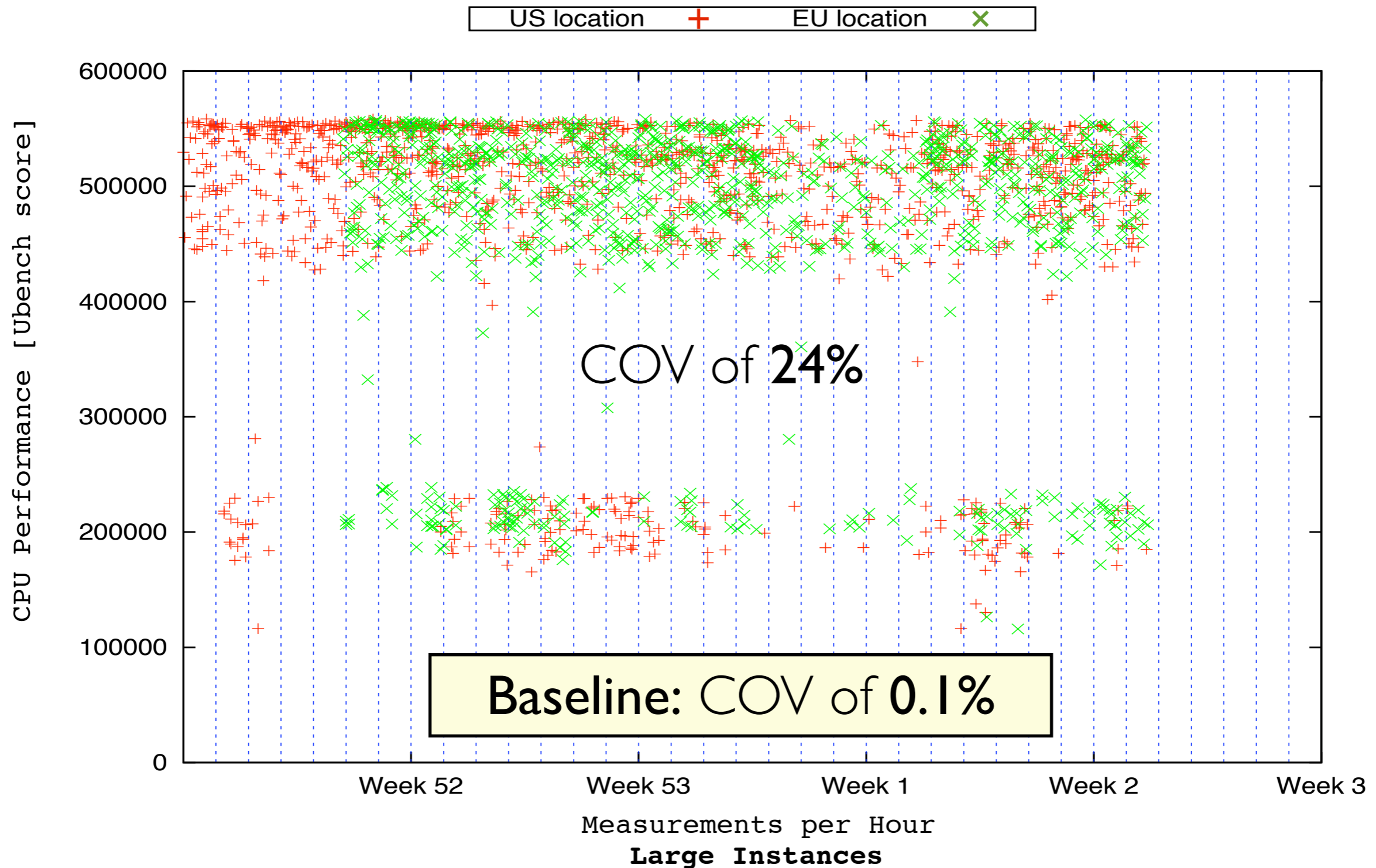
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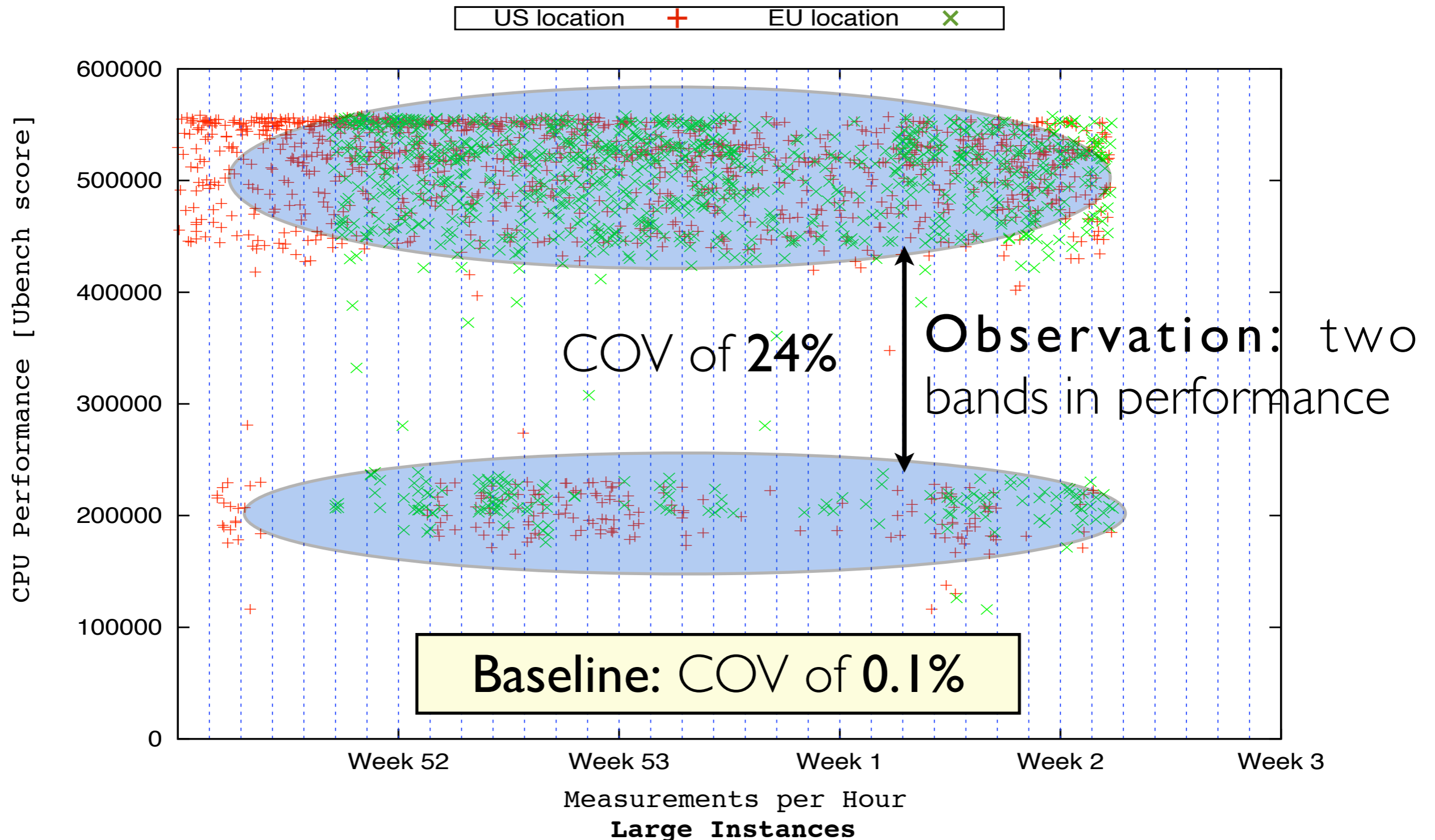
# CPU Performance



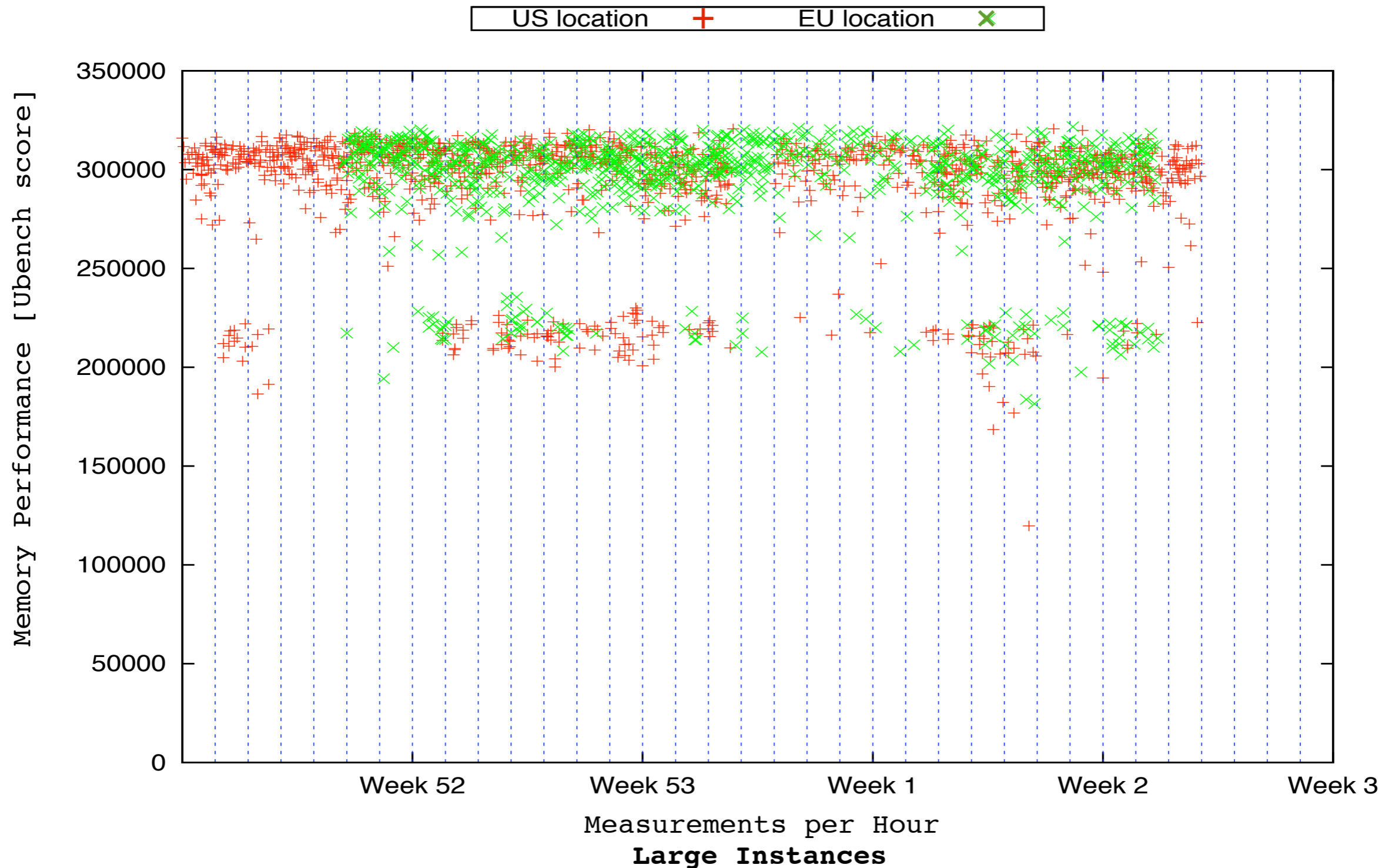
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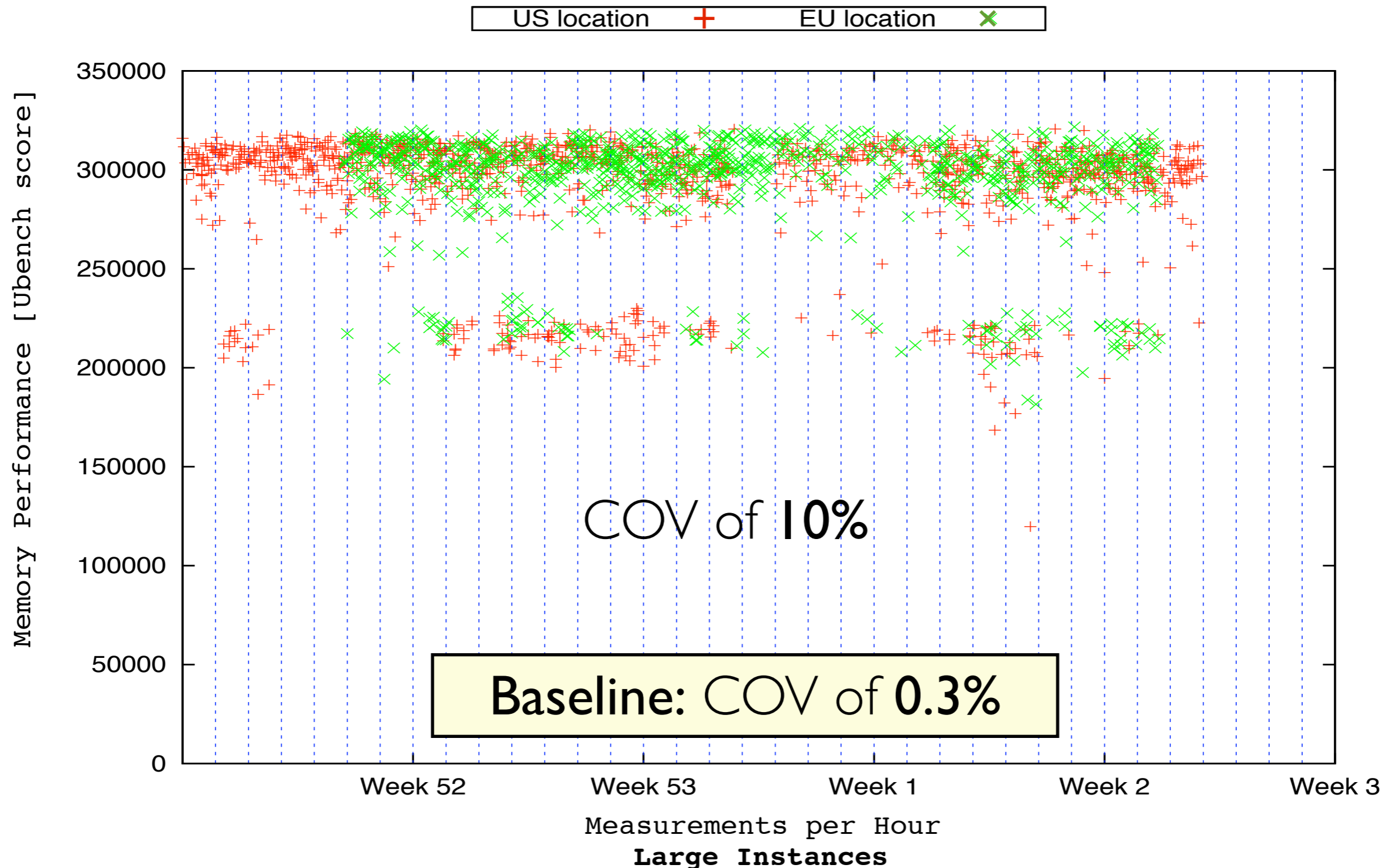
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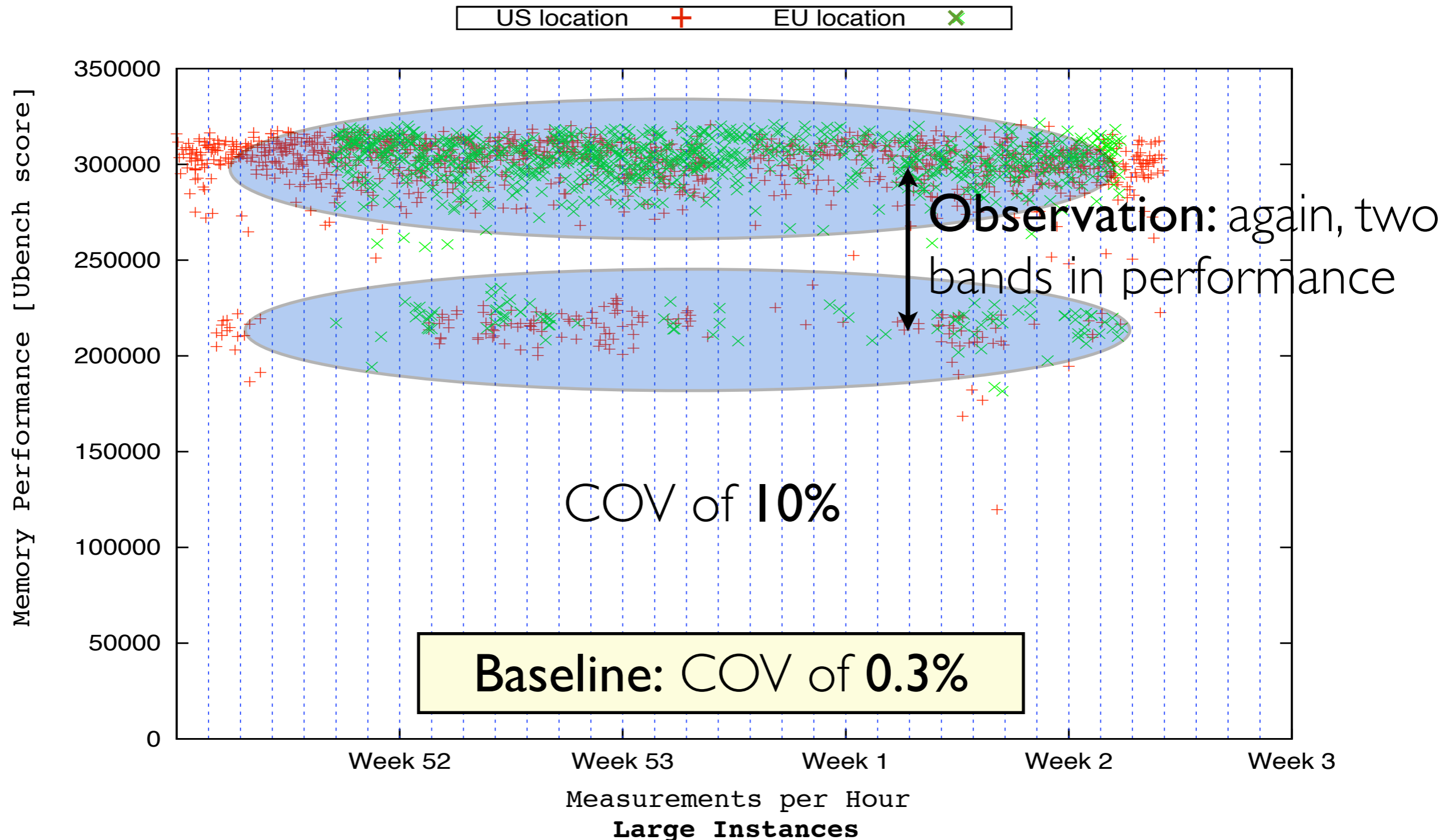
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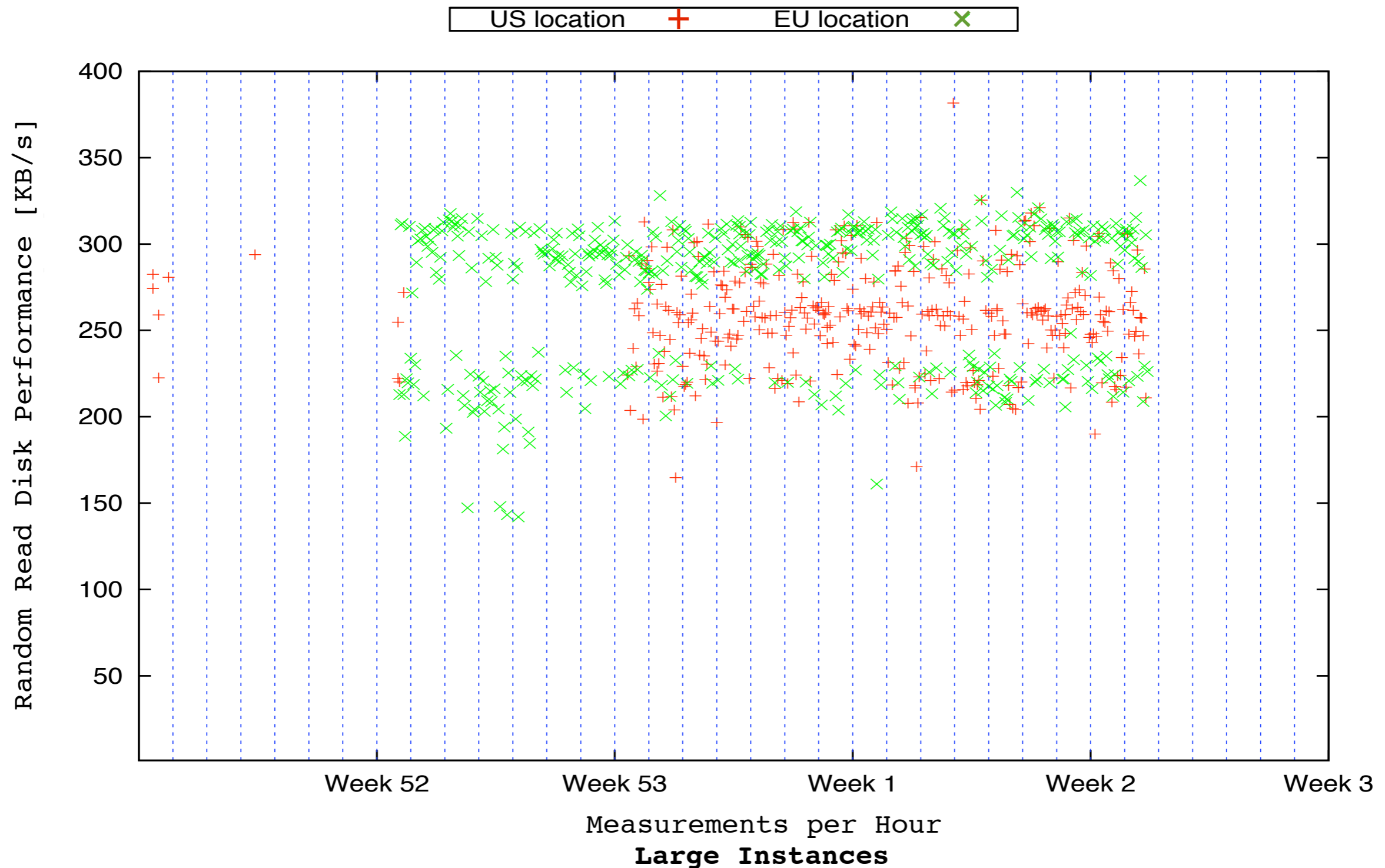


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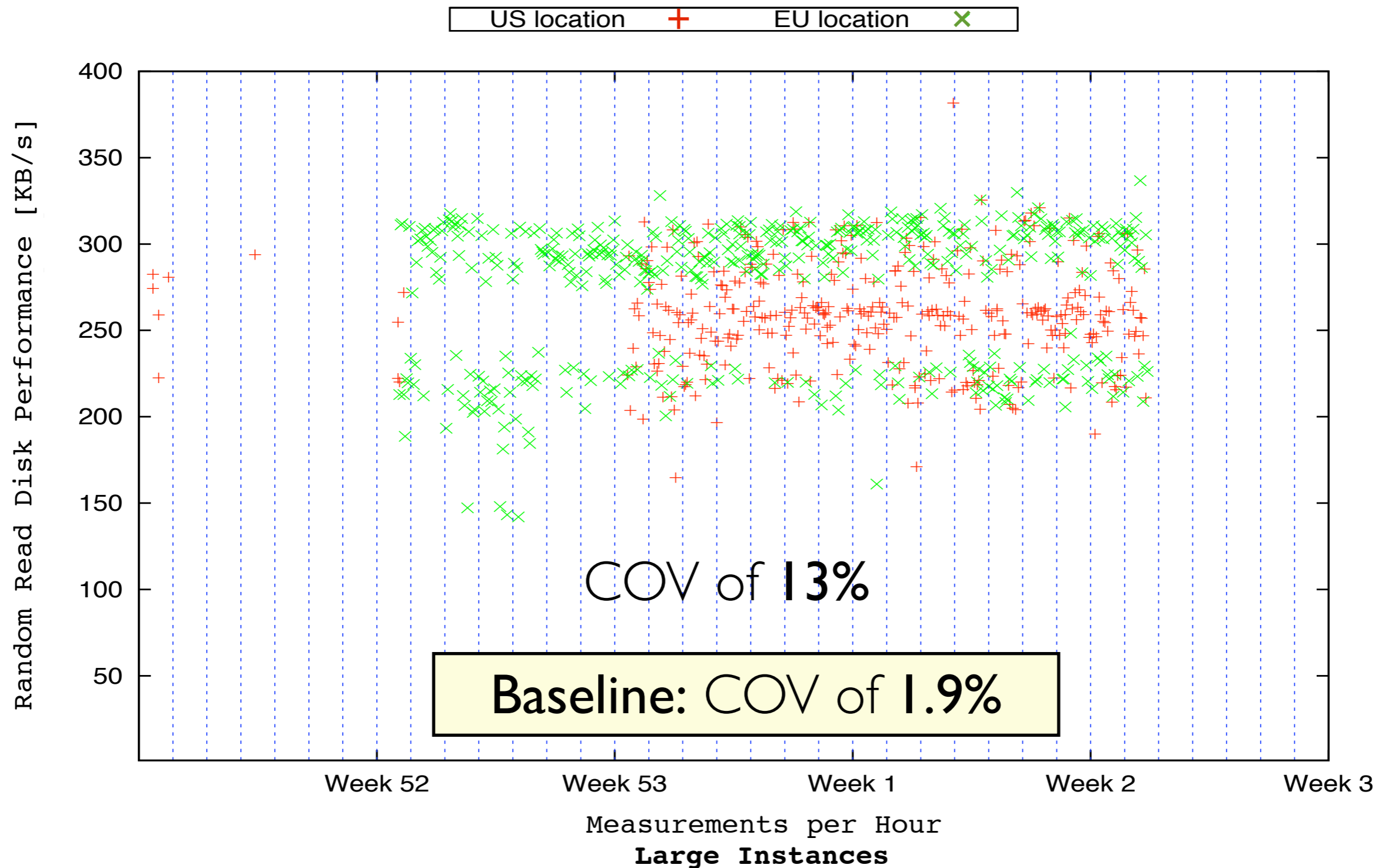




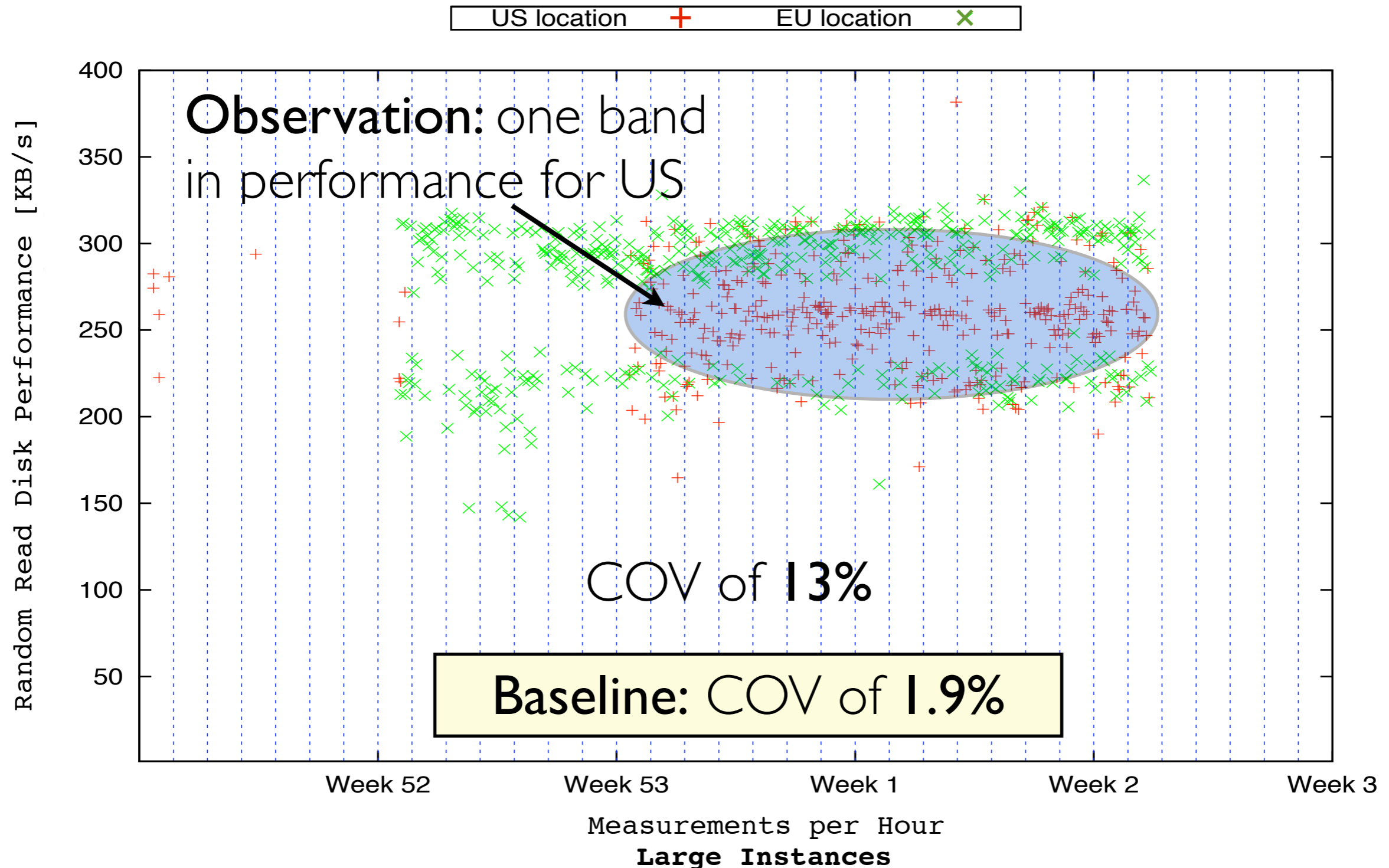
# Random I/O Performance



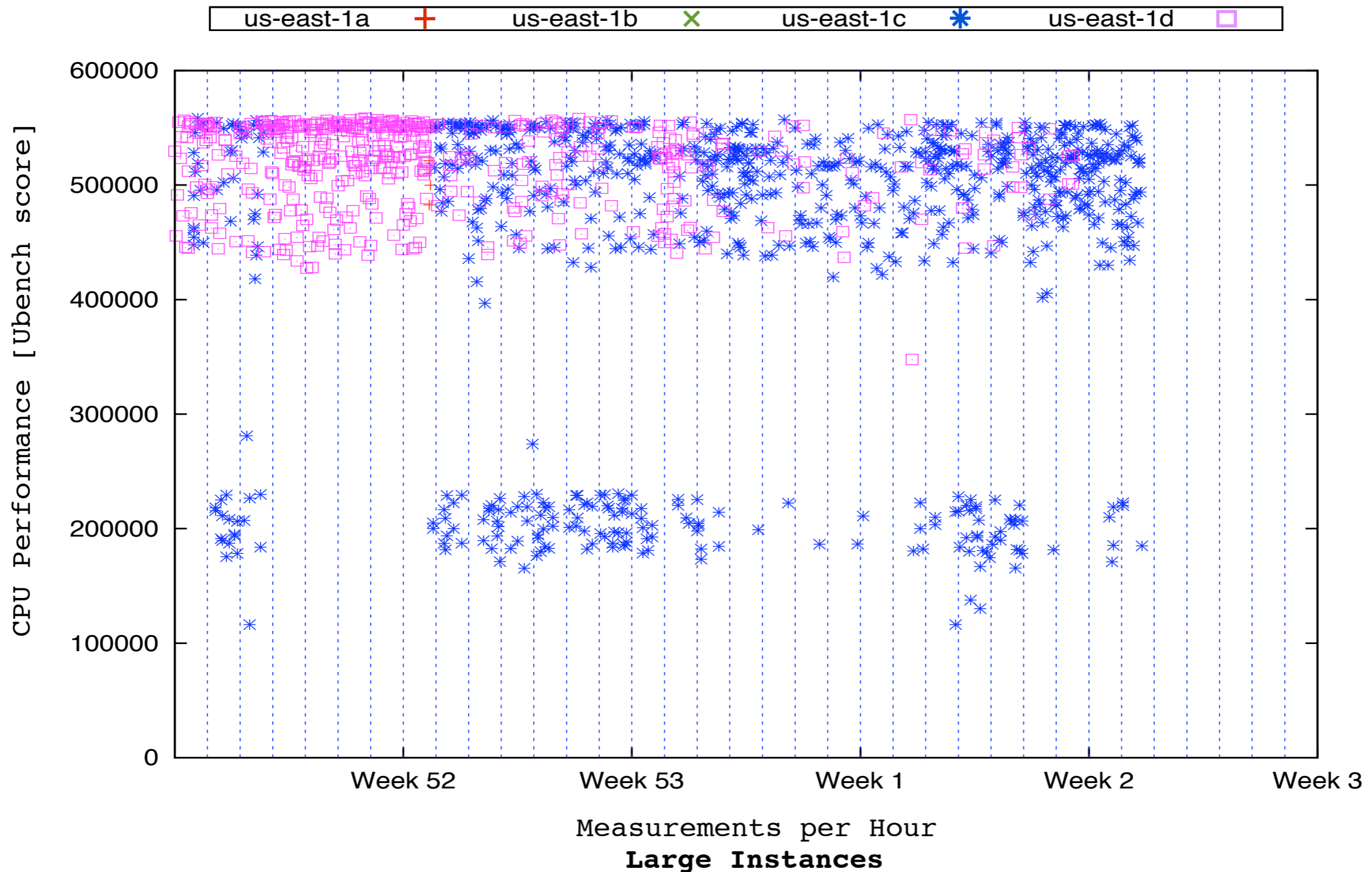
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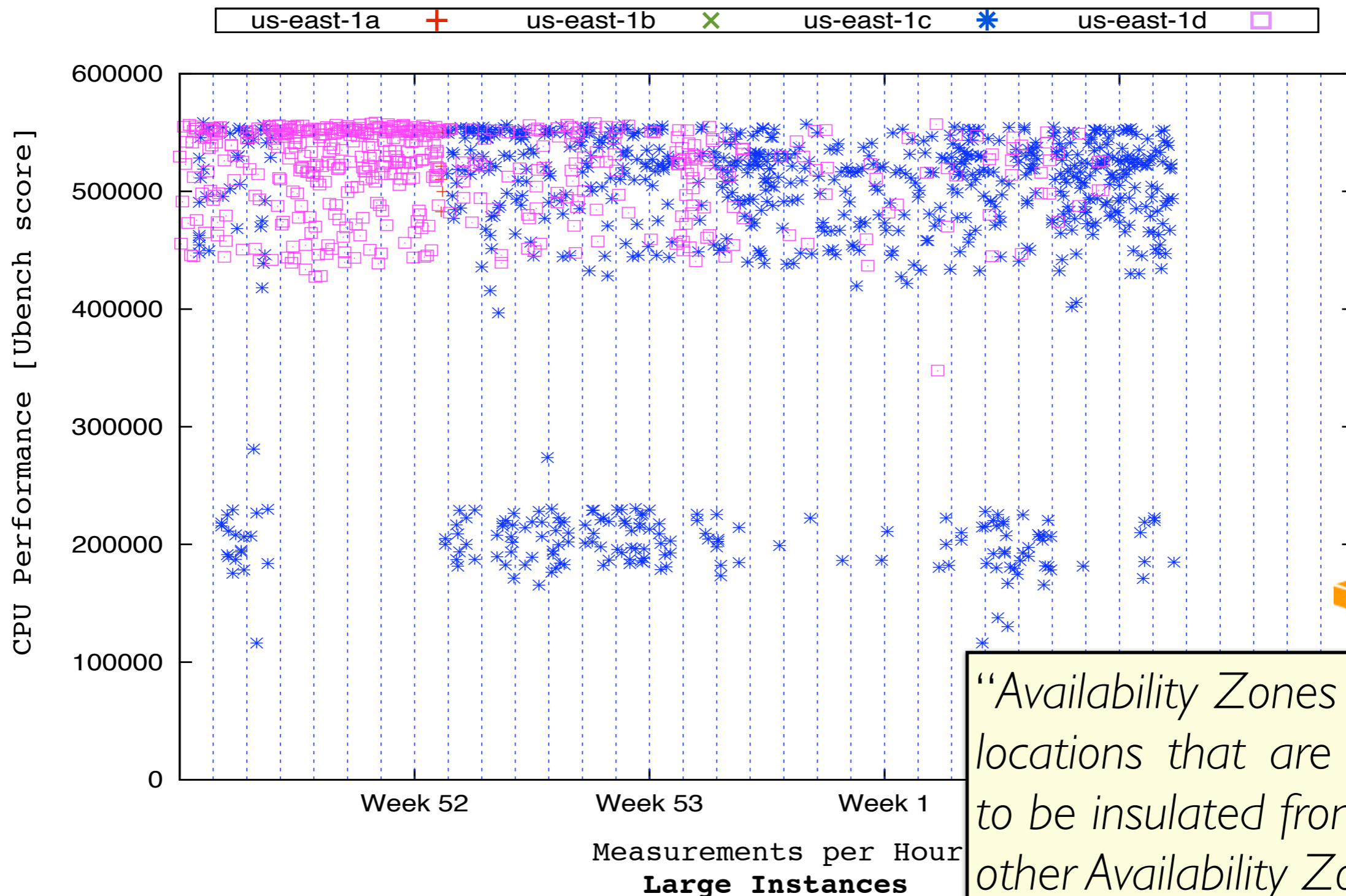
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# Availability Zones

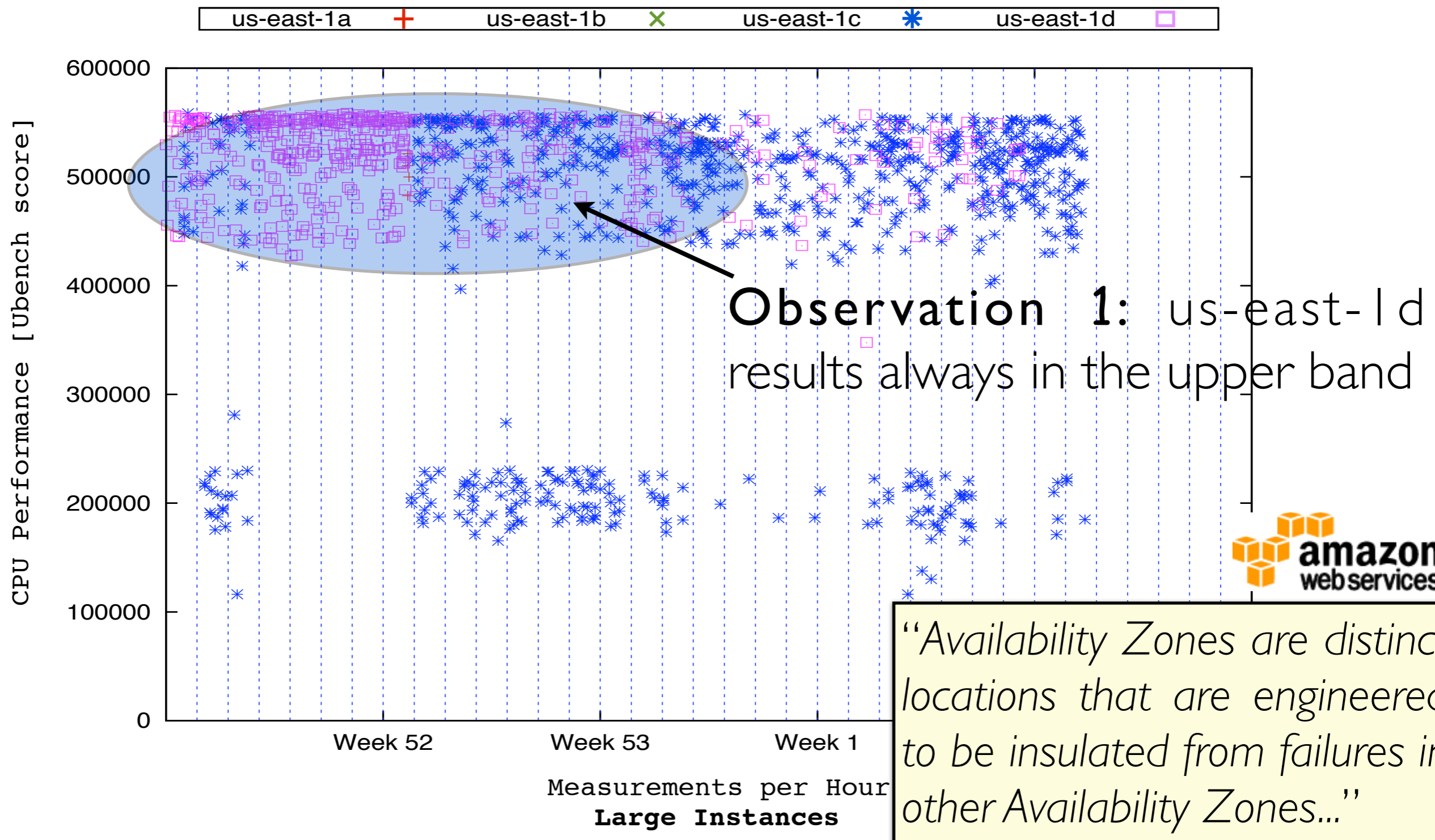


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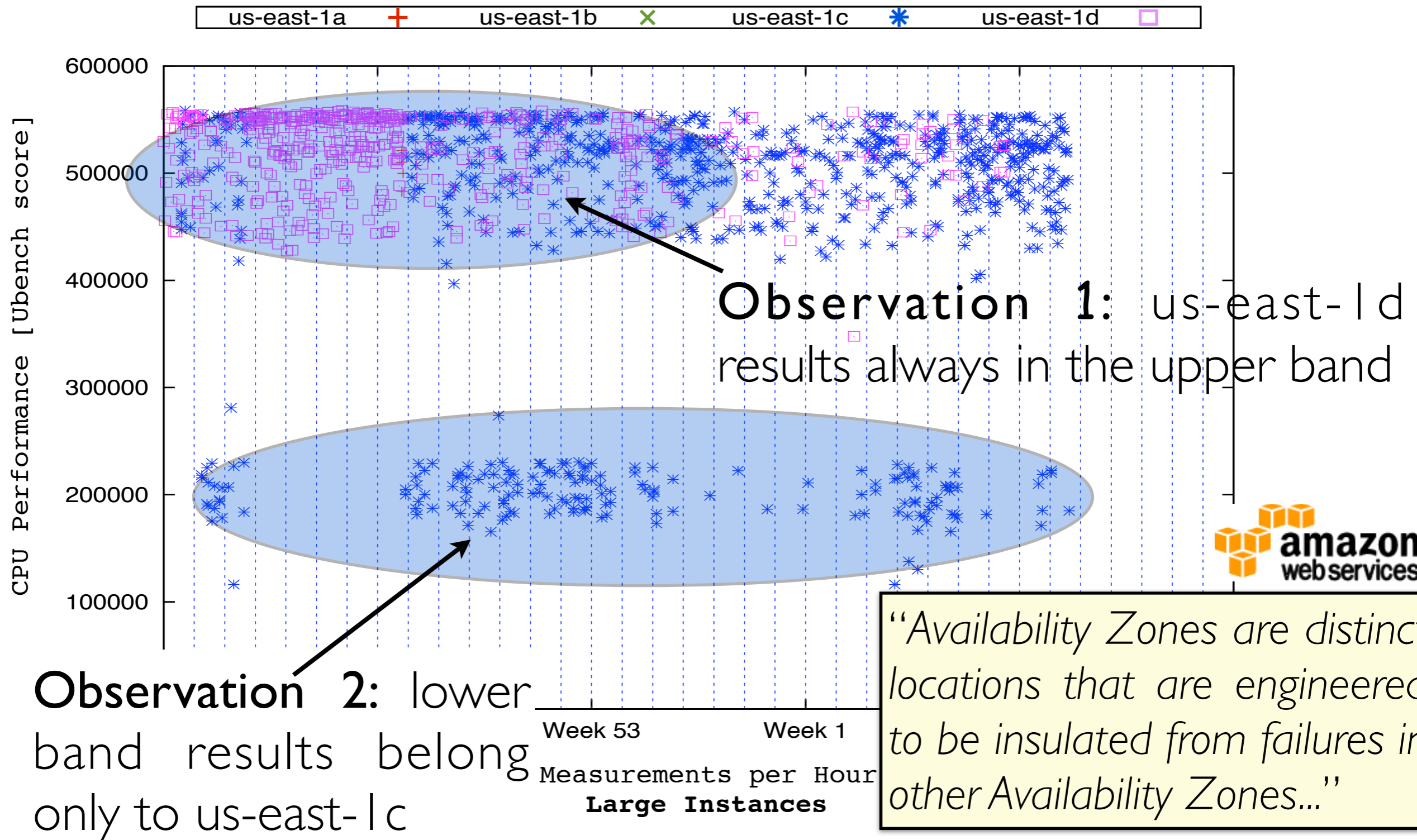


*“Availability Zones are distinct locations that are engineered to be insulated from failures in other Availability Zones...”*

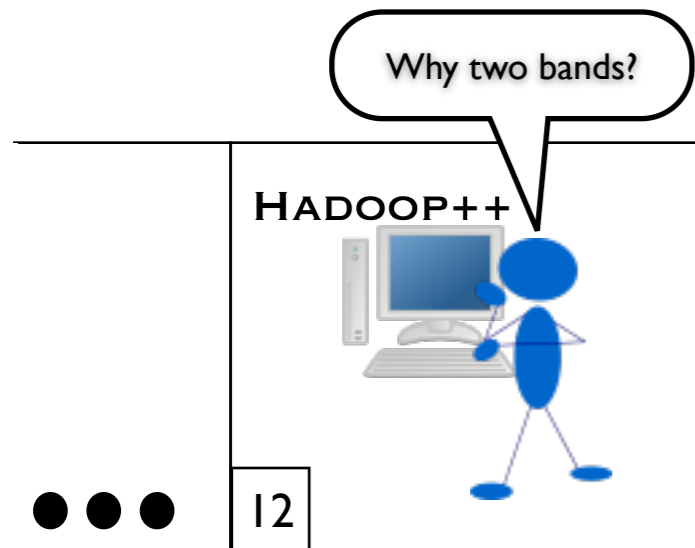
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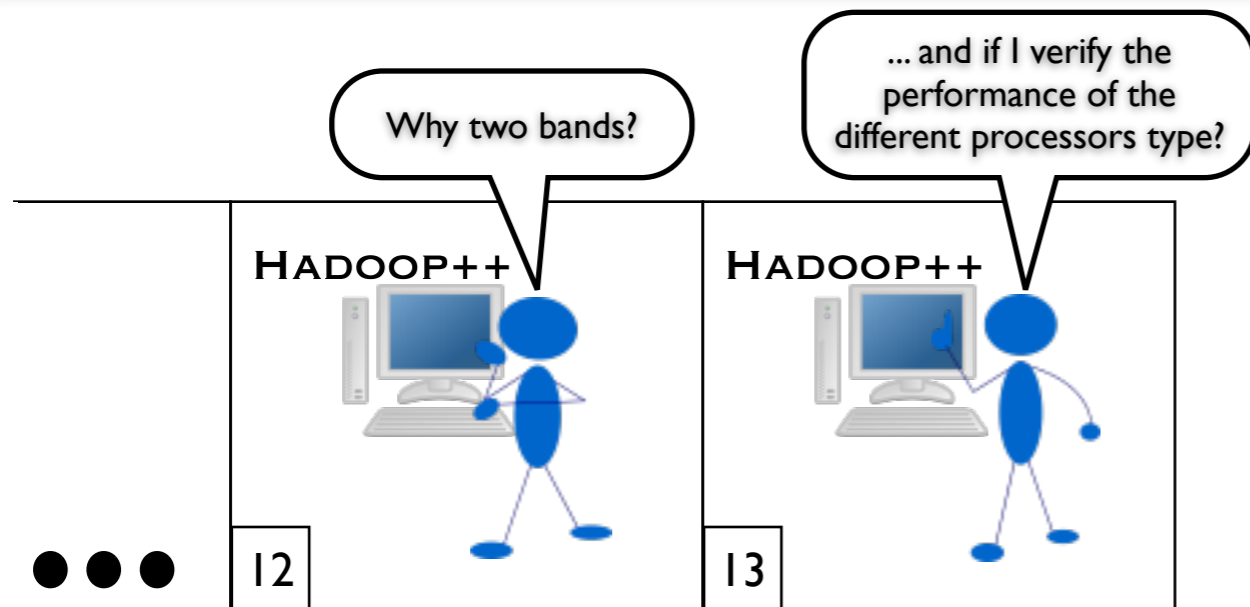


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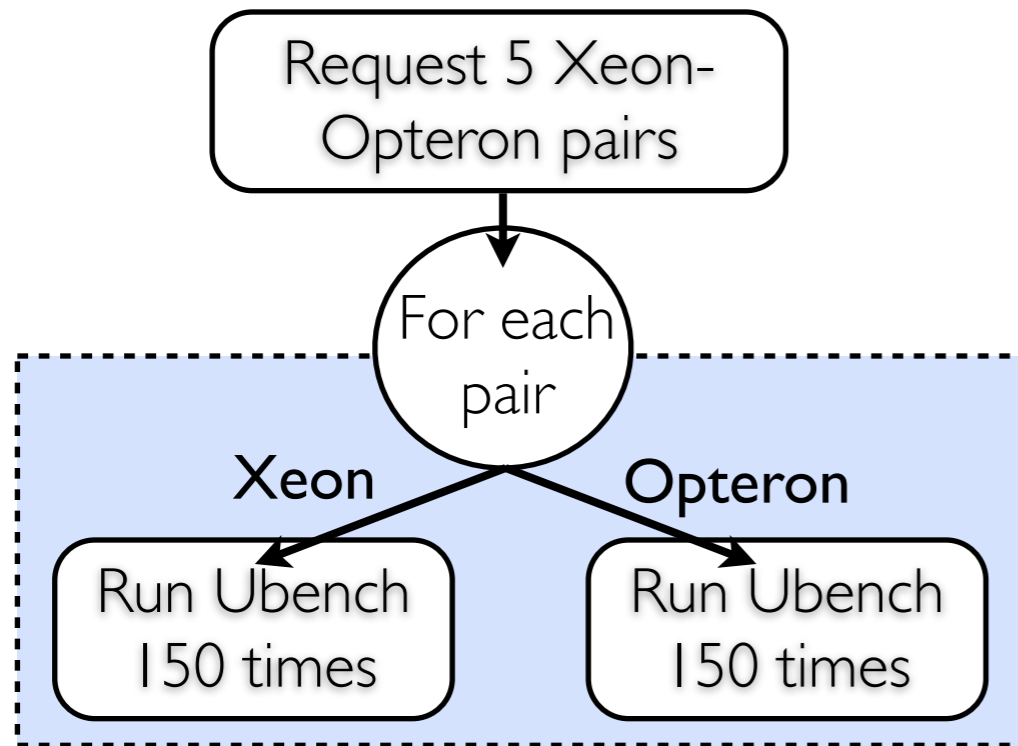
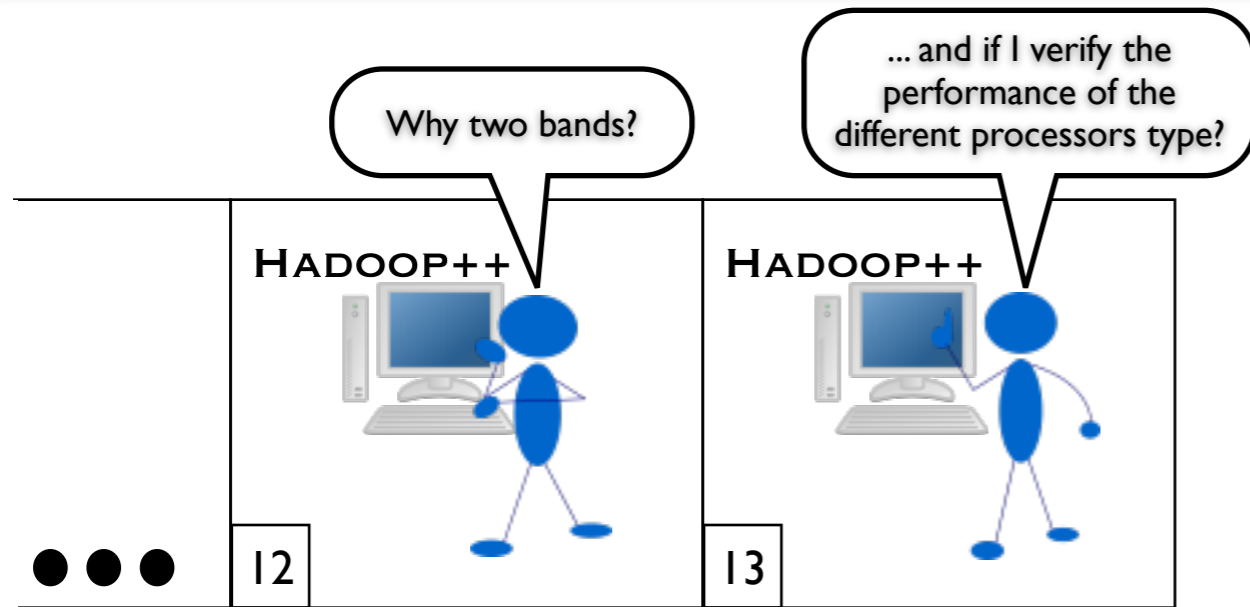




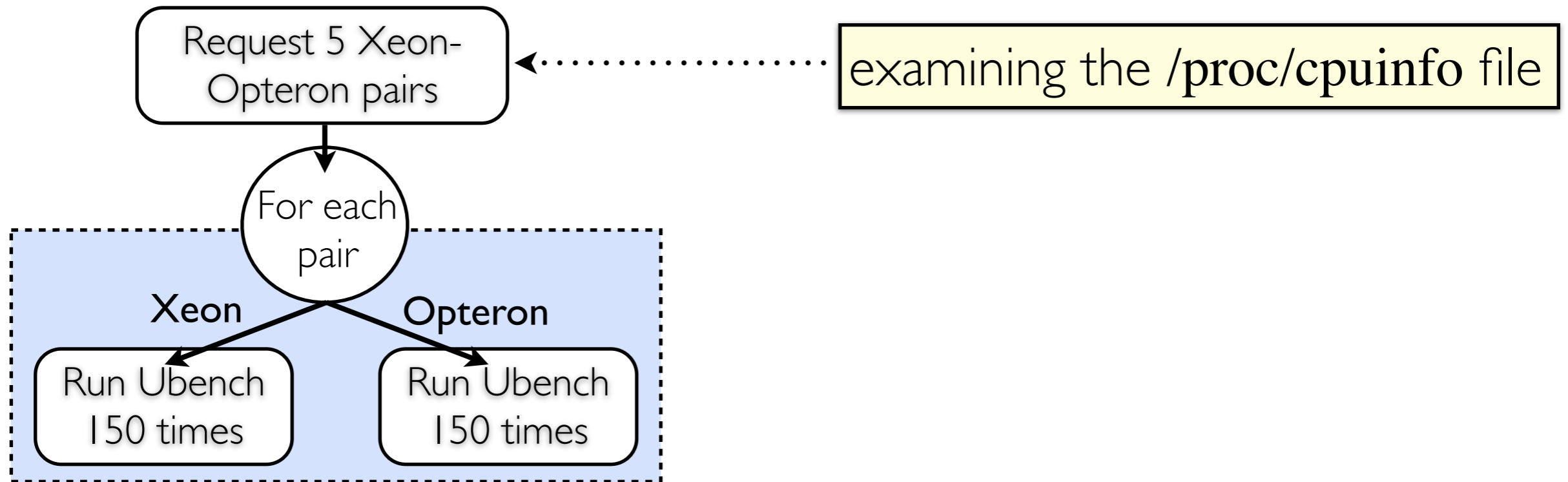
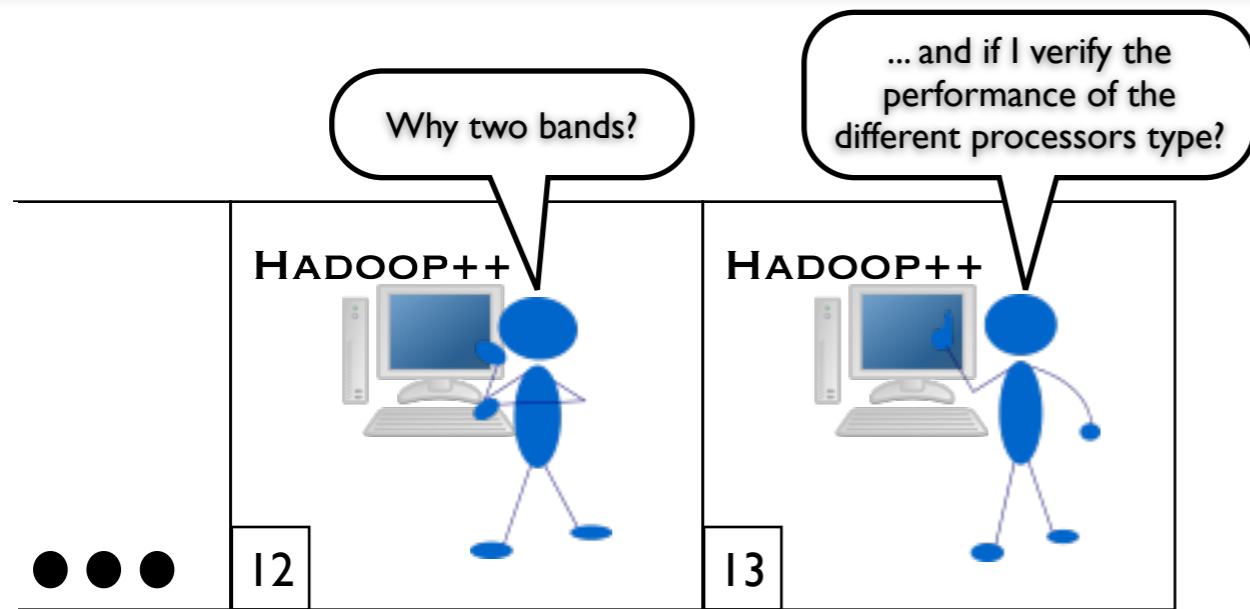
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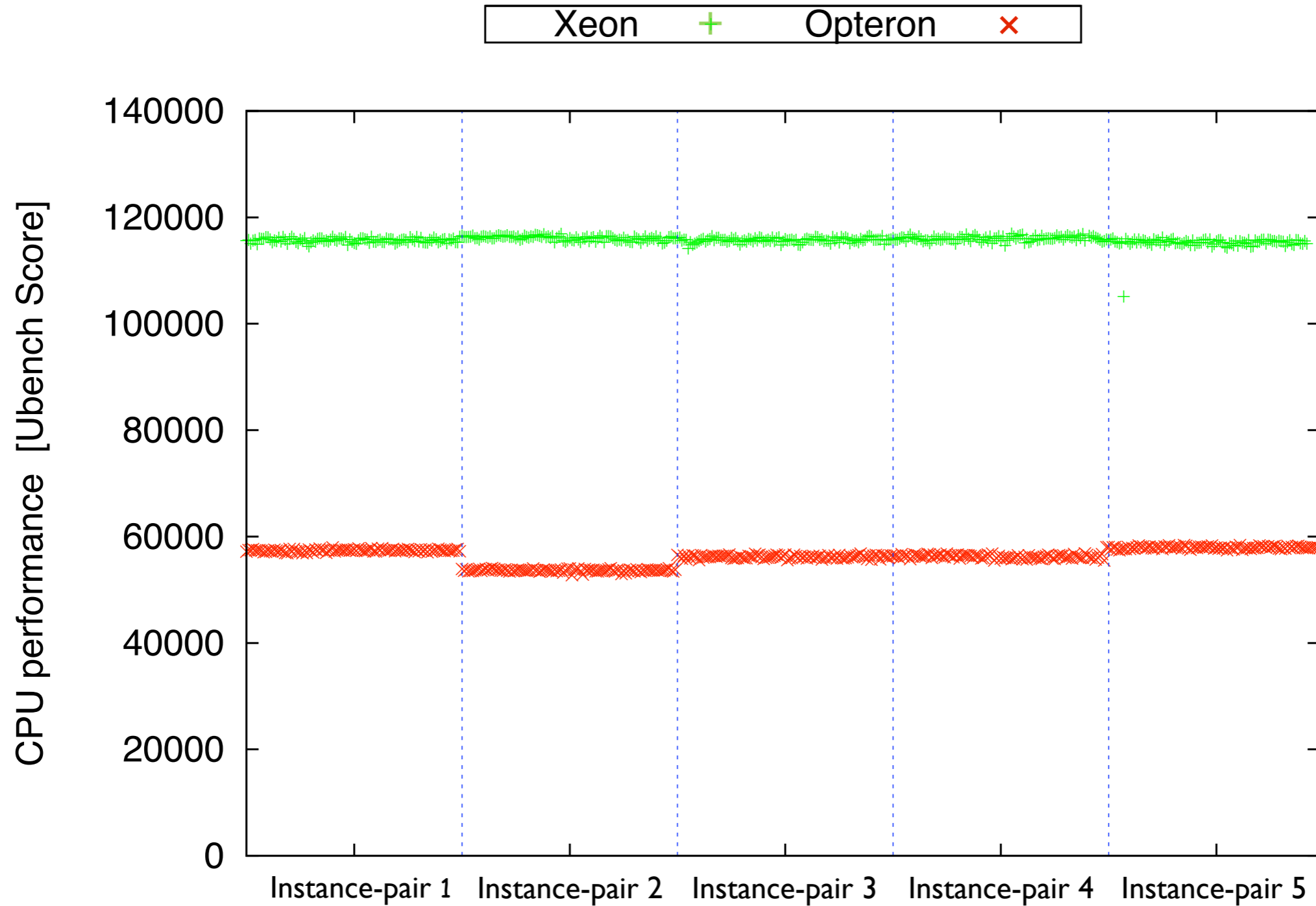
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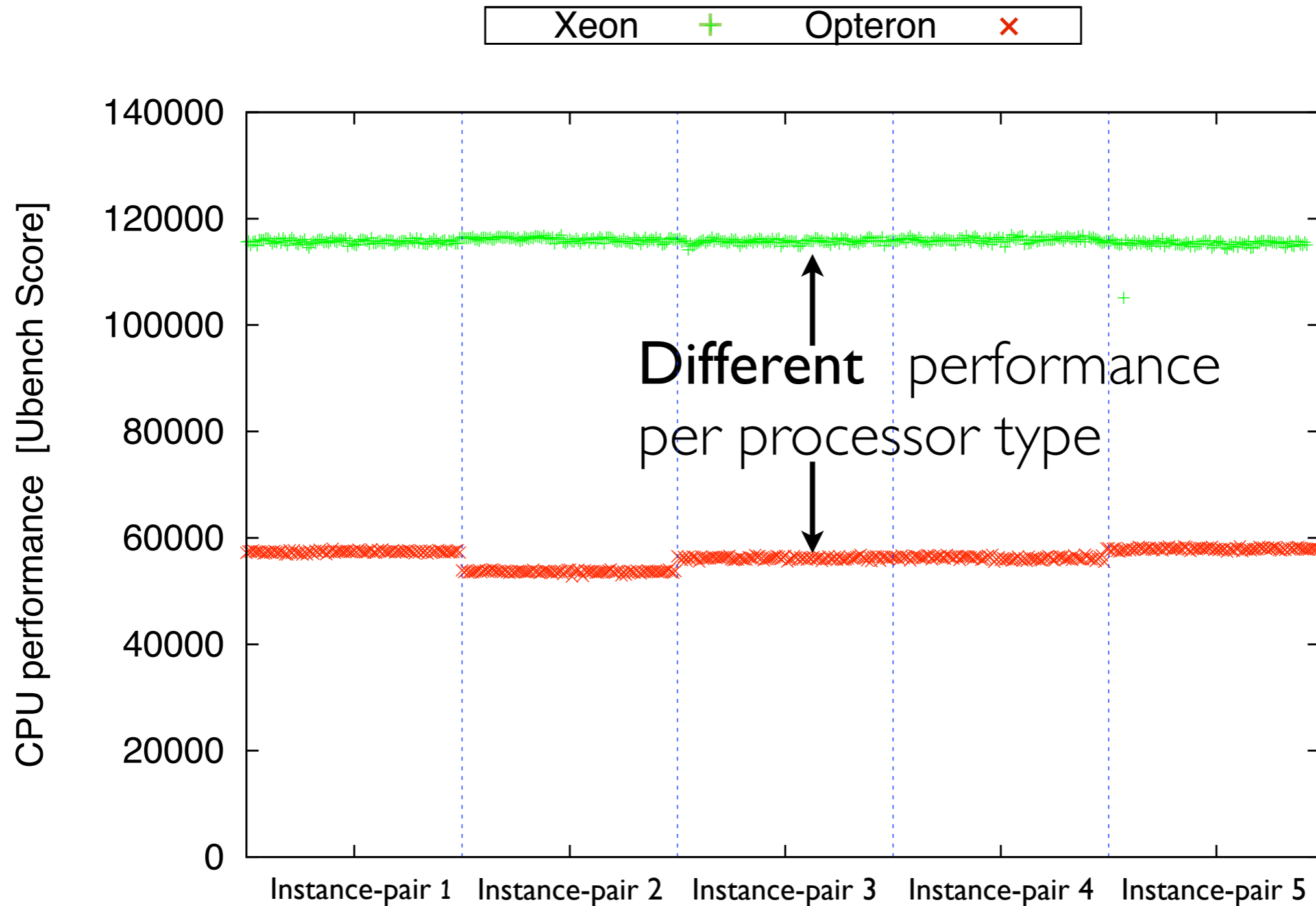
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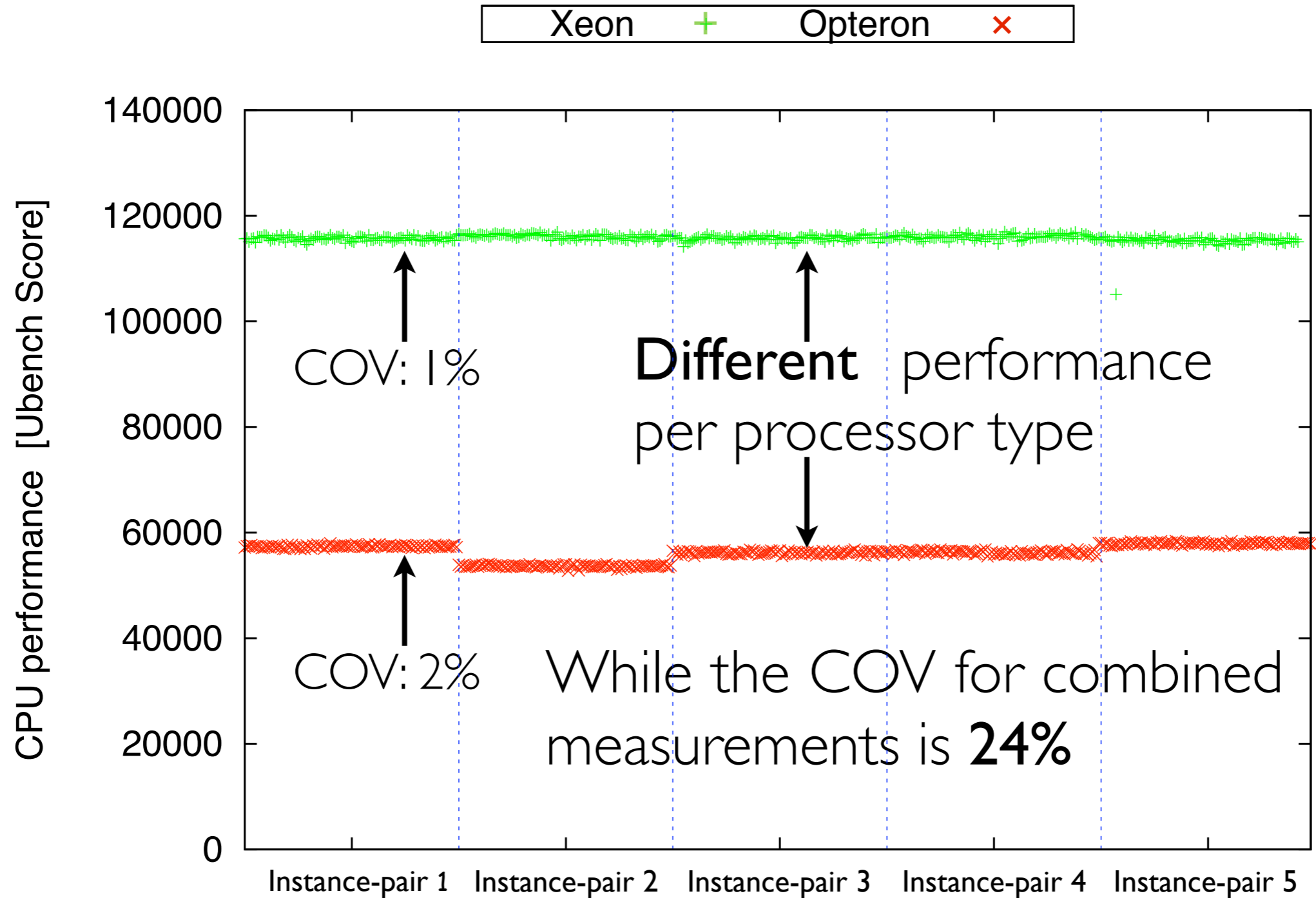
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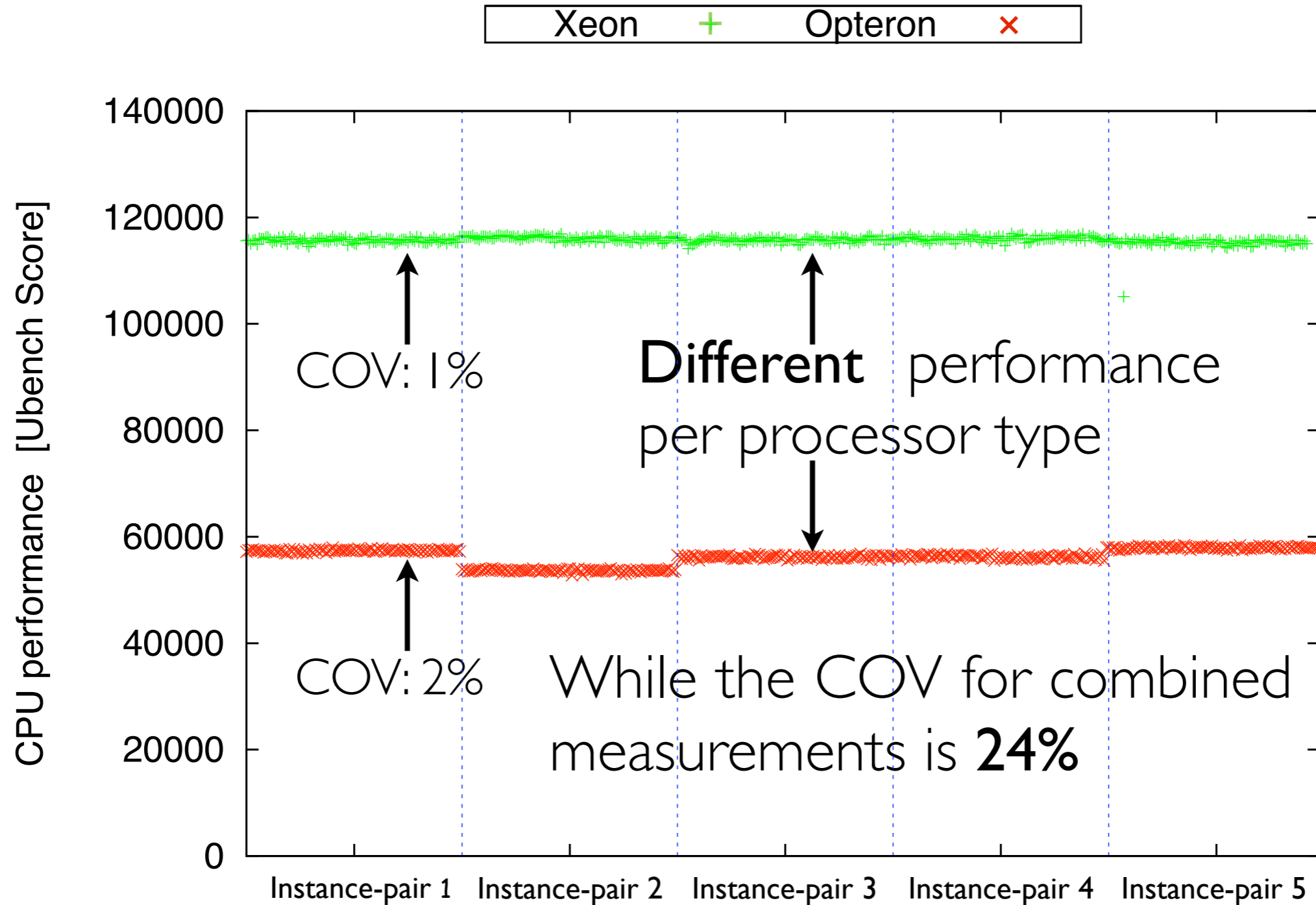
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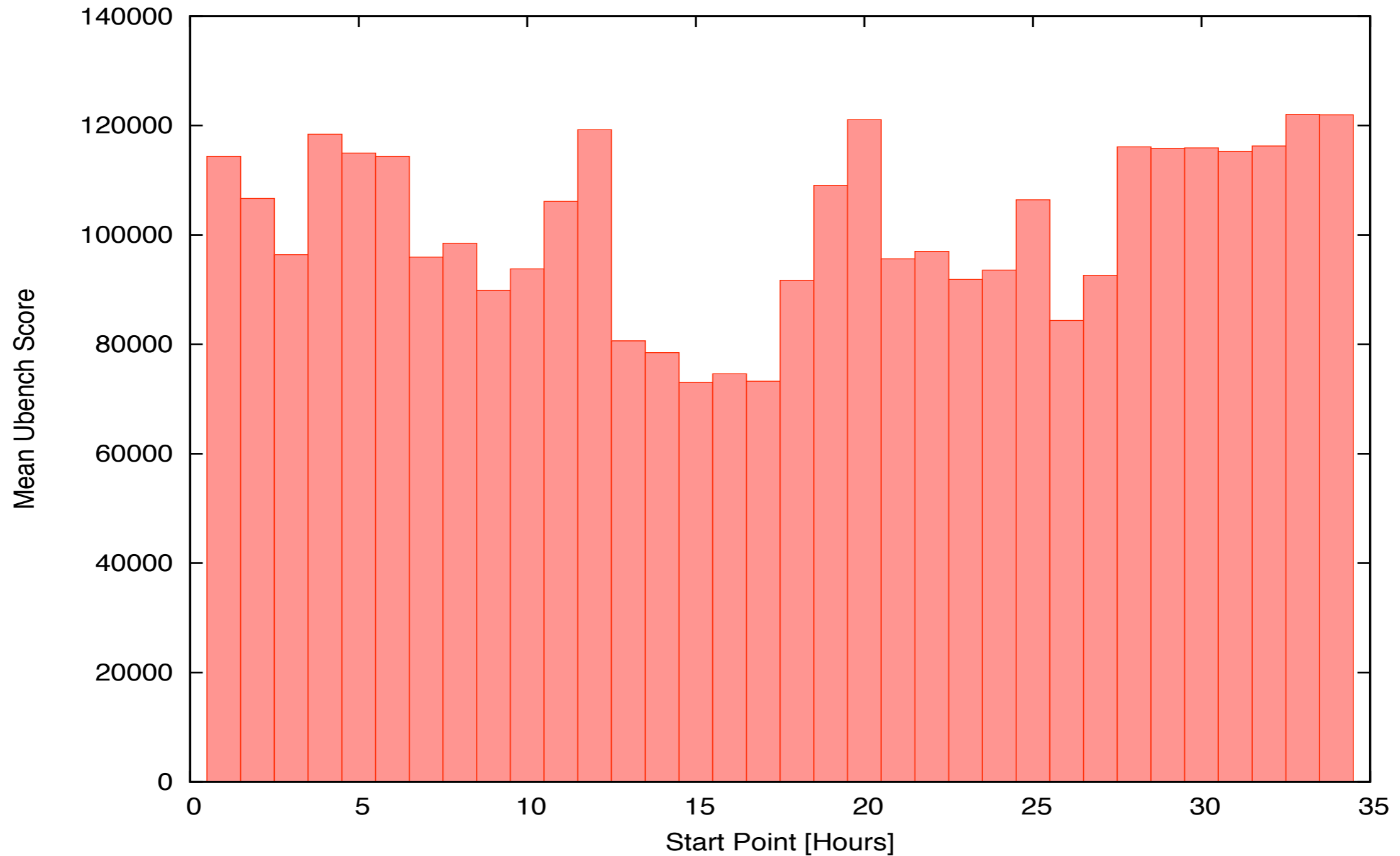


# CPU Distribution (2/2)



Observation: 1 cpu → 1 underlying system [memory and I/O follows this pattern]

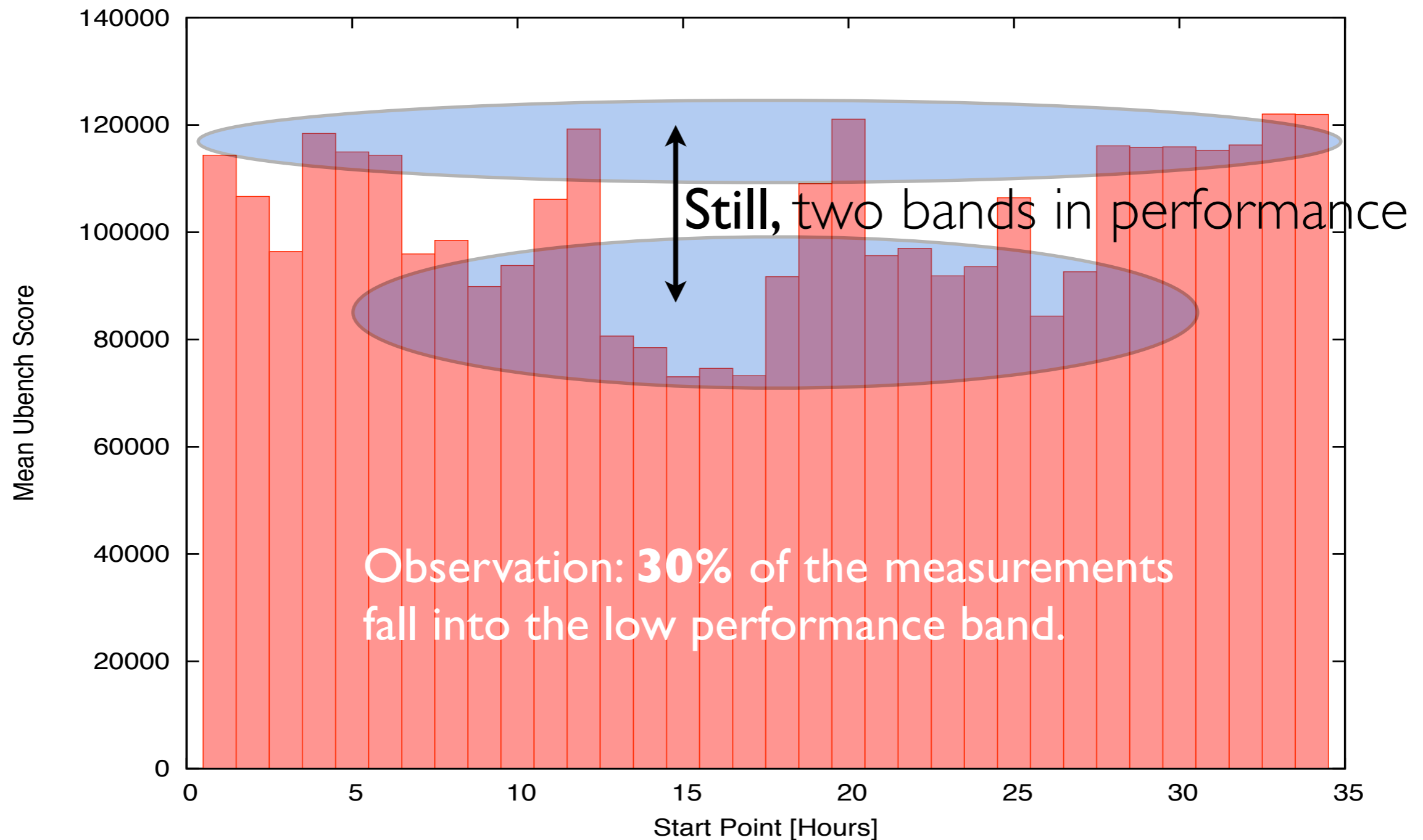
# Larger Clusters



**50 Large Instances Cluster**



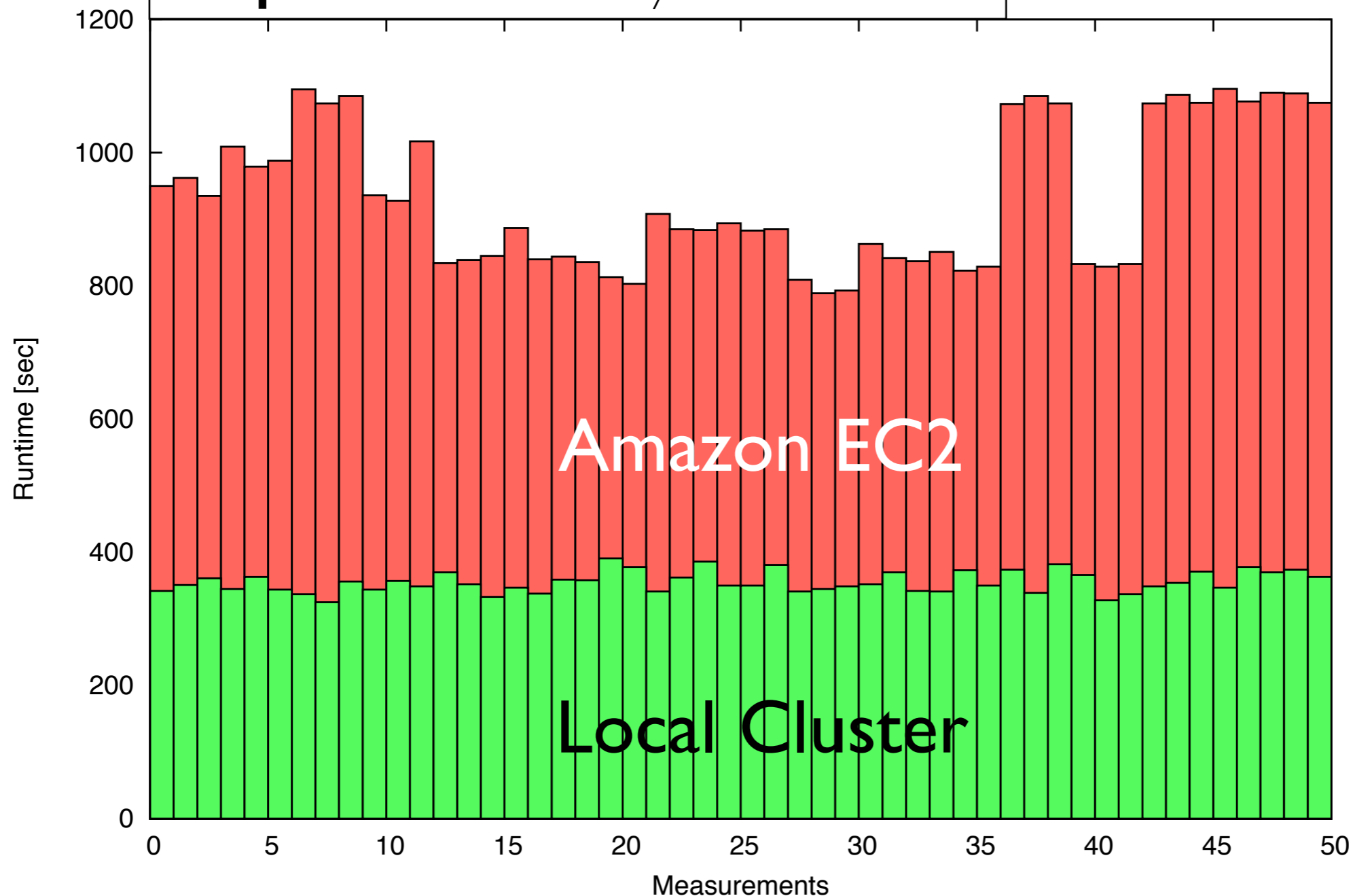
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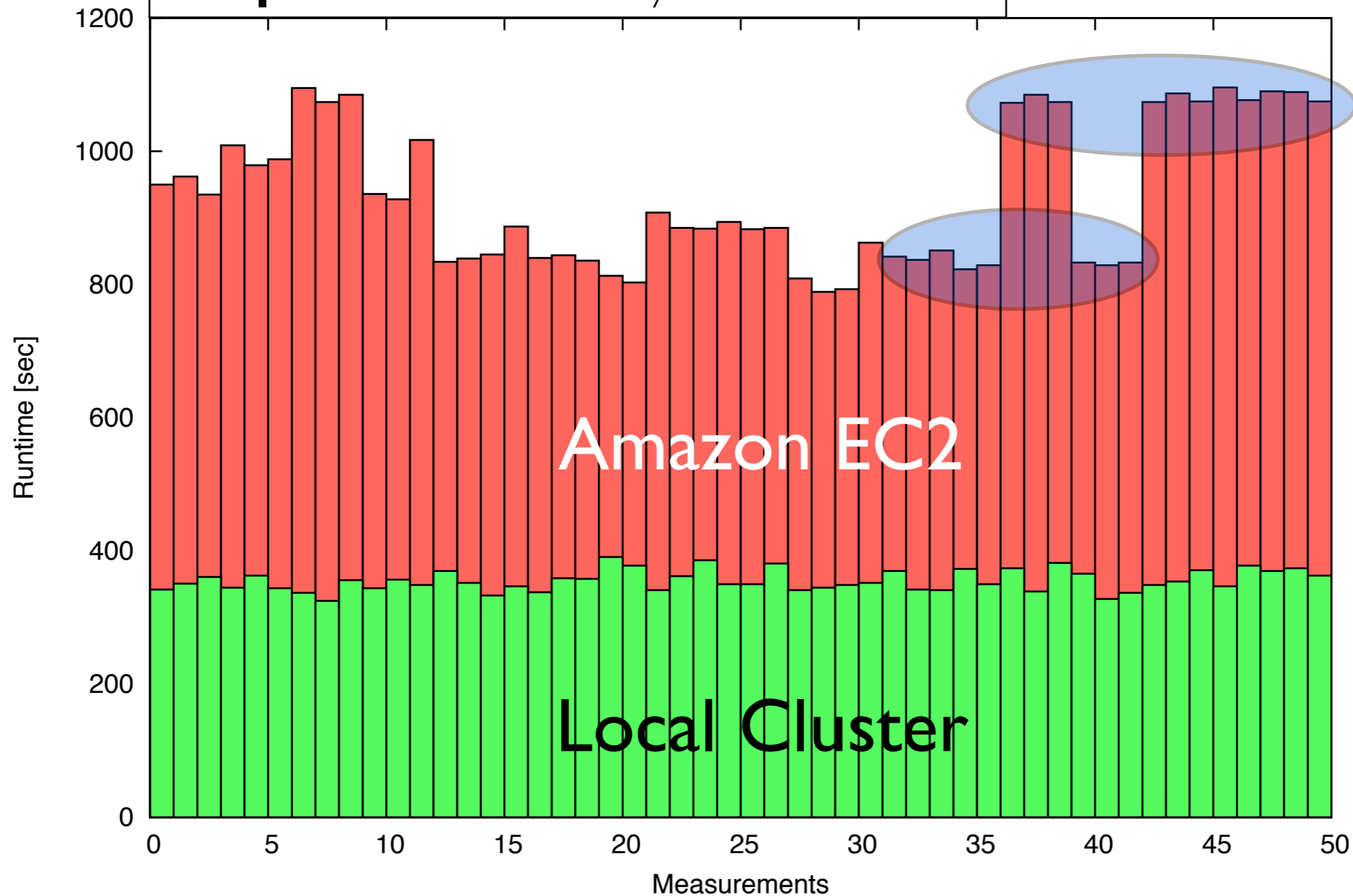
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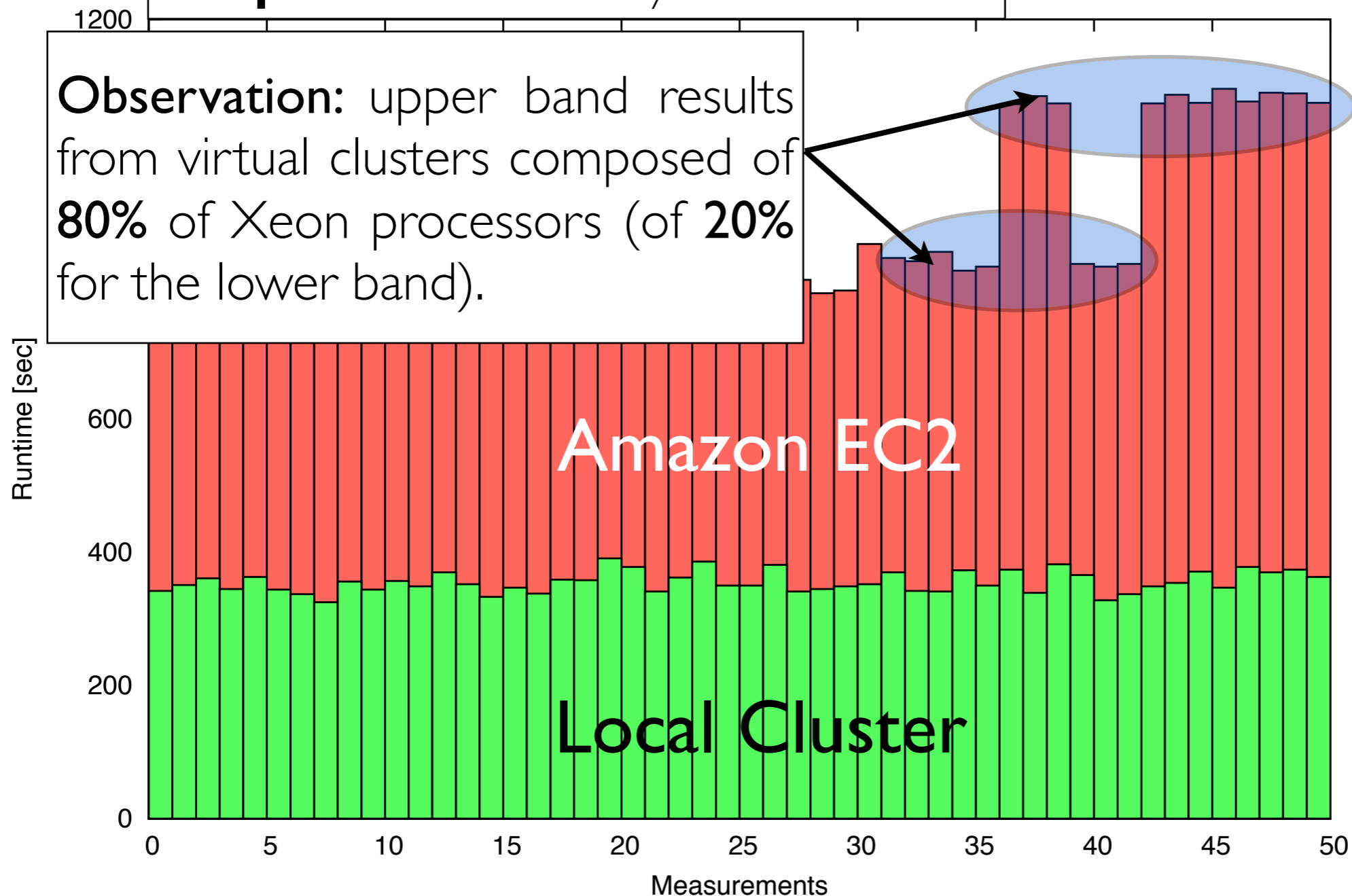
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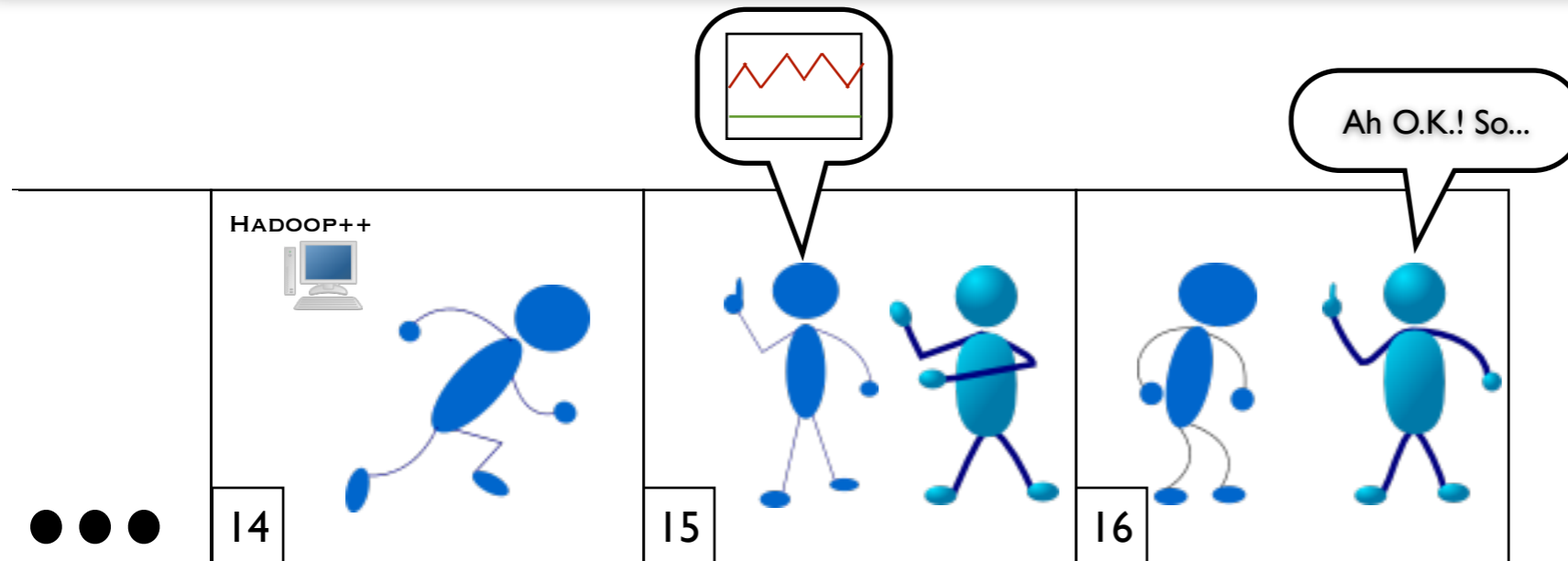
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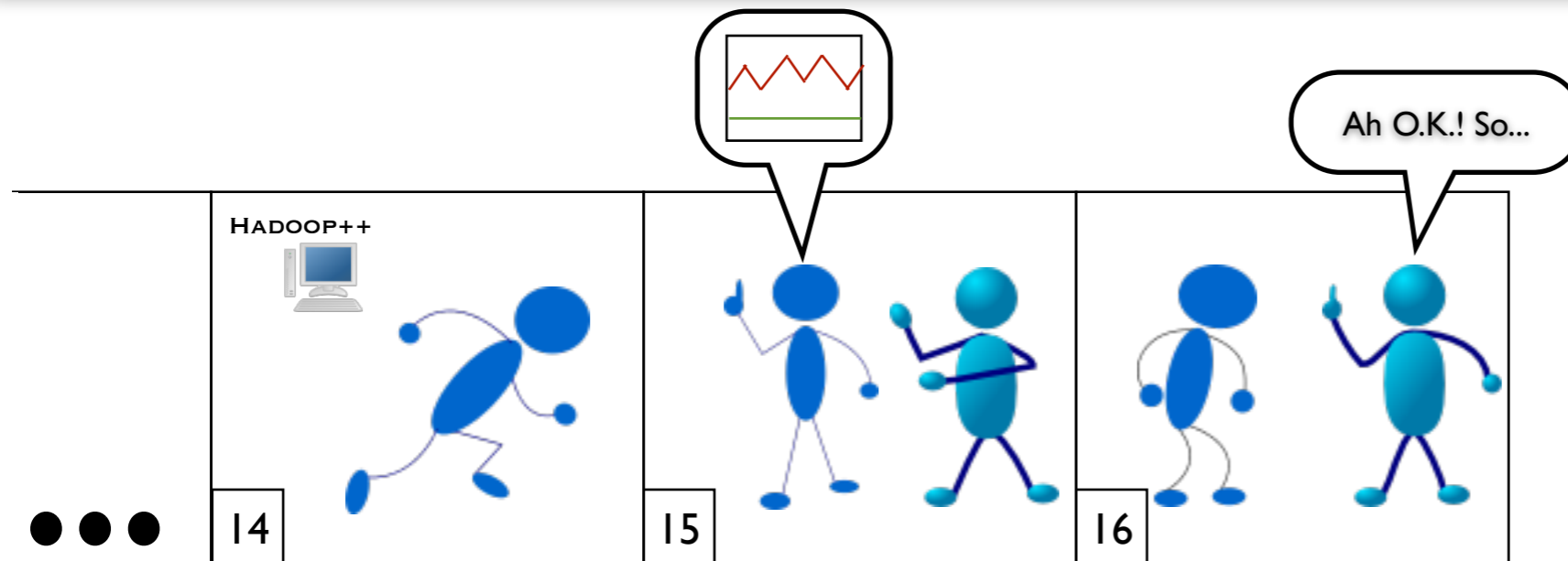
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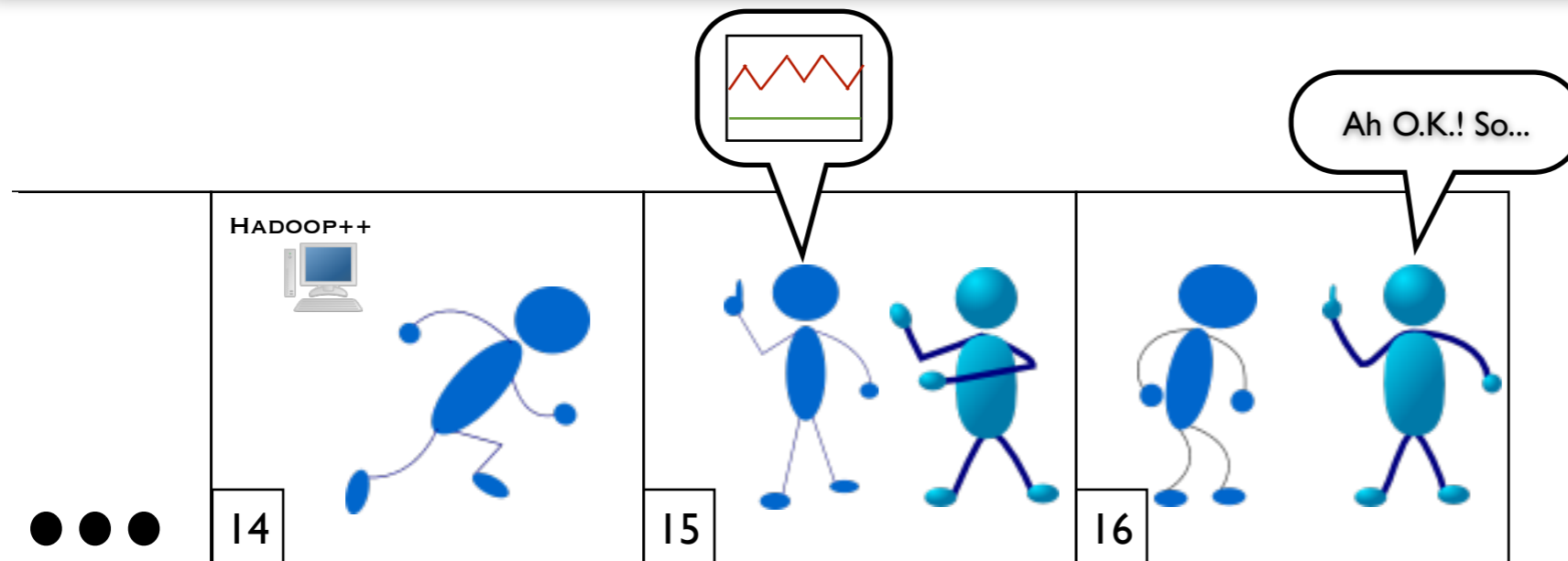


# Conclusion



- Be careful!

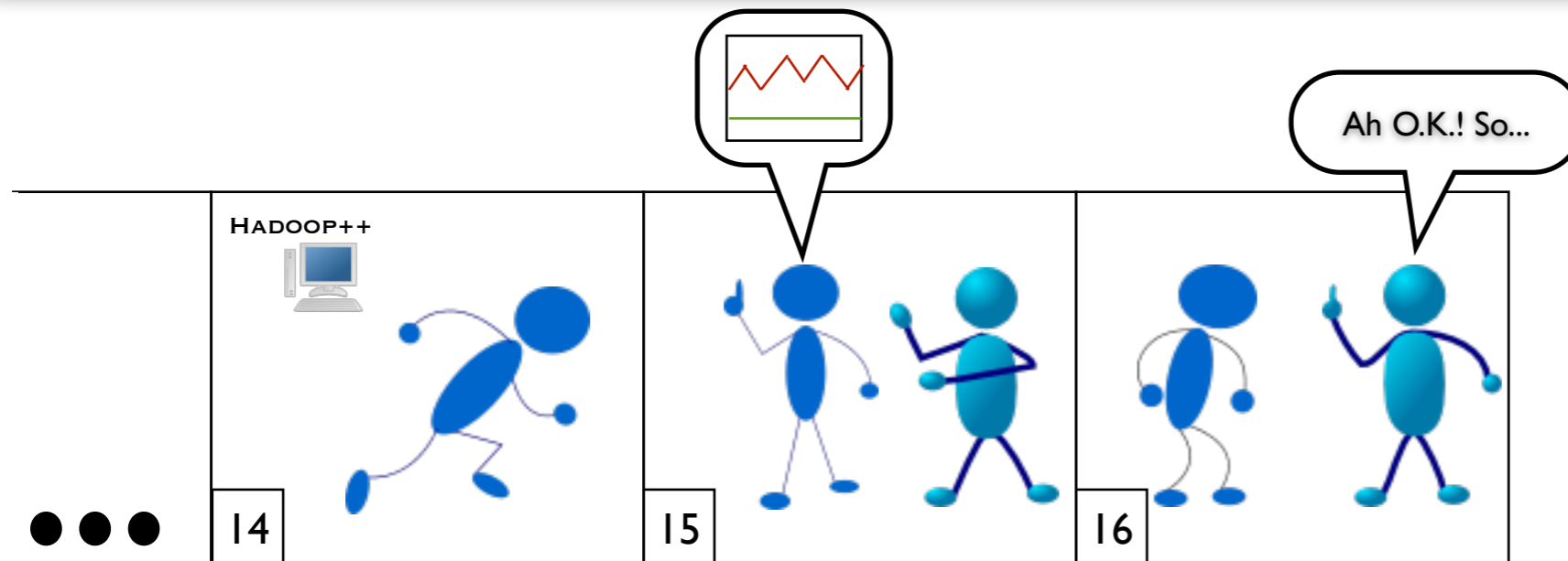
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- Be careful!
- High variance in performance: COV up to **24%**
- Hard to interpret results
- Repeatability to limited extension

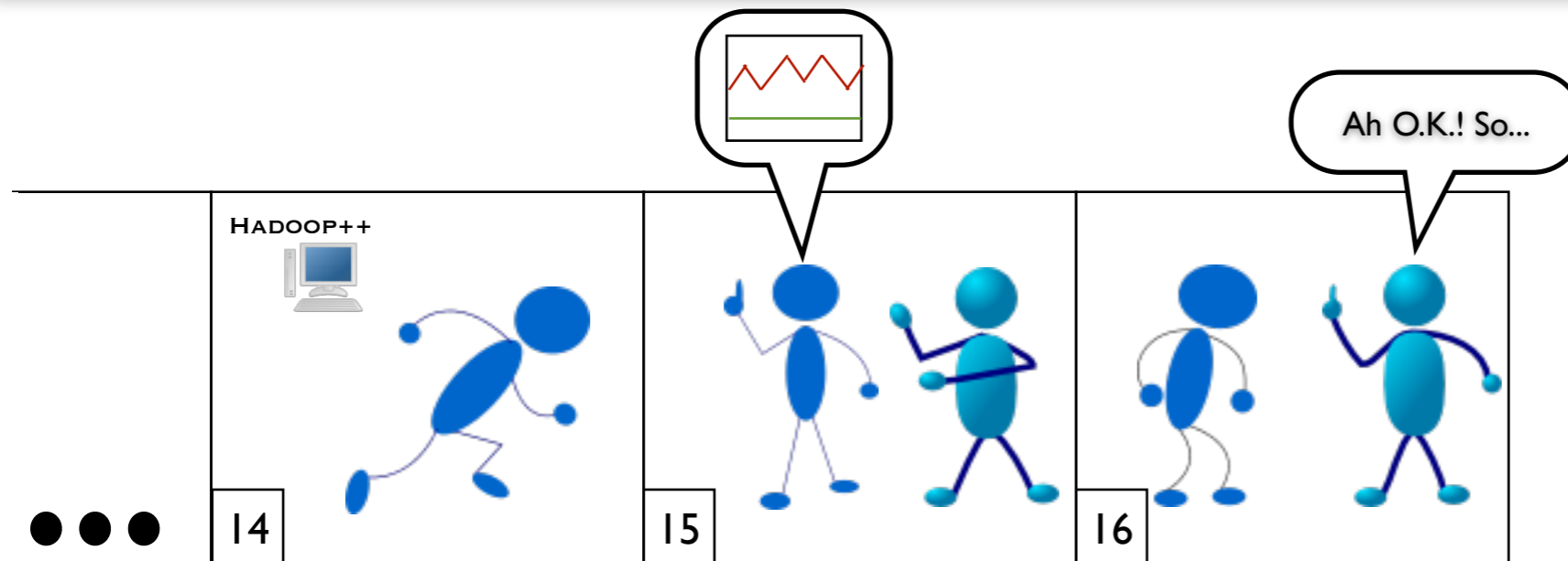


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- **Be careful!**
  - High variance in performance: COV up to **24%**
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- **Two bands** in performance

# Conclusion



- **Be careful!**
- High variance in performance: COV up to **24%**
- Hard to interpret results
- Repeatability to limited extension

- **Two bands** in performance
- Partially due to different physical CPU types

# Final Remarks

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- Amazon should:
  - reveal the **physical** details
  - **allow** users to specify physical characteristics

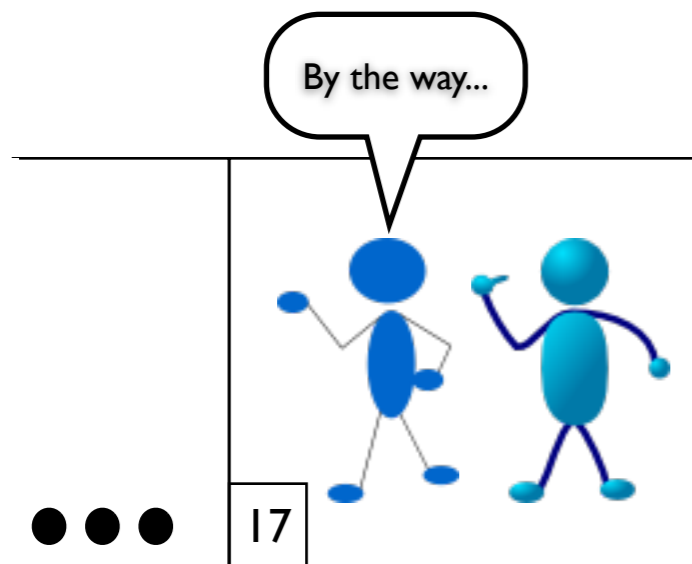
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  - use **equivalent** virtual clusters to **compare** systems
  - report **underlying** system type with the results

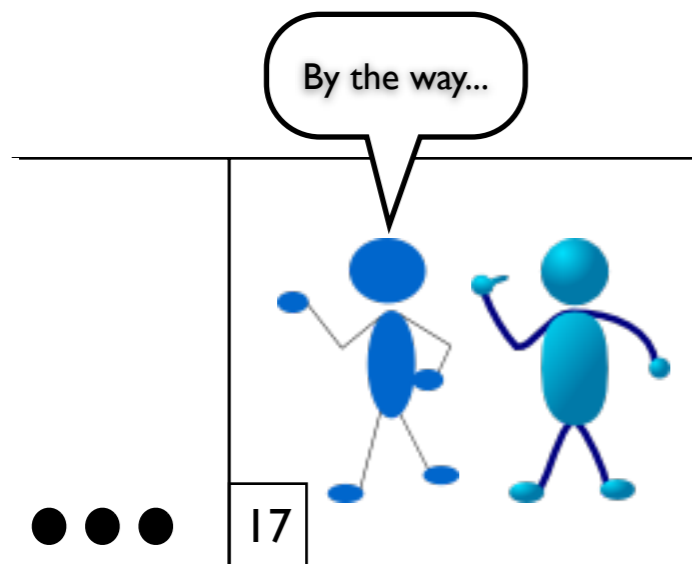


Amazon **recently** introduced the  
**cluster-compute** Instances

[after VLDB'10 deadline]

# Final Remarks

- Amazon should:
  - reveal the **physical** details
  - **allow** users to specify physical characteristics
- Researchers should
  - use **equivalent** virtual clusters to **compare** systems
  - report **underlying** system type with the results



Amazon **recently** introduced the  
**cluster-compute** Instances

[after VLDB'10 deadline]