Runtime Measurements in the Cloud

Observing, Analyzing, and Reducing Variance

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

Information Systems Group
Saarland University

VLDB 2010
September 14th, Singapore
Motivation
Motivation

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
Motivation

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Yeah! the prototype is ready

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

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1. Hadoop++
2. Hadoop++
3. Hadoop++
4. Hadoop++
5. Hadoop++
6. Hadoop++

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

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Yeah! the prototype is ready
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O.K., run the experiments on Amazon EC2
Motivation

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Hadoop++

Motivation

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Oops!

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VLDB 2010

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Motivation

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

![Bar chart comparing Amazon EC2 and Local Cluster runtime measurements](image)

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

**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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1. Yeah! the prototype is ready
2. But, where do I run our 100-nodes experiments?
3. O.K., run the experiments on Amazon EC2

Hadoop++

4. Hadoop++
5. Hadoop++

6. Oops!
7. Why?!?

Hadoop++

8. Hadoop++

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

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Yeah! the prototype is ready

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

O.K., run the experiments on Amazon EC2

Motivation

Hadoop++

0

200

400

600

800

1000

1200

0

5

10

15

20

25

30

35

40

45

50

Runtime [sec]

Measurements

EC2 Cluster

Local Cluster

Hadoop++

Oops!

Why?!

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

VLDB 2010

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Research track: Cloud computing session
Related Work
Related Work


Summary: performance unpredictability is mentioned as one of the major obstacles for Cloud computing.
Related Work

Research Challenges


Summary: performance unpredictability is considered as one of the major challenges of cloud computing.


Summary: evaluation of different Cloud services of Amazon in terms of cost and performance.
Related Work

Research Challenges

Absolute Performance


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

[Appeared after VLDB’10 deadline]
Related Work

Research Challenges


Summary:
- Cost and performance evaluation of different distributed databases and cloud providers.
- Performance unpredictability is mentioned as one of the major obstacles for Cloud computing.

Absolute Performance

Summary:
- Evaluation of different Cloud services of Amazon in terms of cost and performance.

Application Performance

Summary:
- Cost and performance evaluation of different distributed database architectures and cloud providers.

Variability in Performance

?
Related Work

Research Challenges


Absolute Performance


Application Performance


Summary:
- Evaluation of different Cloud services of Amazon in terms of cost and performance.
- Focus on performance unpredictability as a major obstacle for Cloud computing.
- Evaluation of different Cloud services for scientific computing.

Variability in Performance

Go for it!
Agenda

- Motivation
- Related Work
- Background
- Methodology
- Results & Analysis

Information Systems Group
Amazon EC2

- 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

- **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
  - 8 EC2 Compute Unit
  - 1690 GB of local storage
Standard Instances

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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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What to Measure?
What to Measure?

Microbenchmarks
What to Measure?

Microbenchmarks

- CPU performance
- Memory performance
What to Measure?

Microbenchmarks

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

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):

• Internal network bandwidth
• External network bandwidth
• Instance startup
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
Goal of Our Study

- Do different Instance types have different variations in performance?
Goal of Our Study

• Do different **Instance types** have different variations in performance?

• Do different **locations** or **availability zones** impact performance?
Goal of Our Study

In this talk:

• 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?
Setup

- **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
Setup

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[ASIA location was introduced after VLDB deadline]
Methodology

- Every hour
- Kill previous instances
- Create one small and one large instance
- Loop
  - Small
    - Run Ubench
    - Run Bonnie++
    - Other benchmarks
  - Large
    - Run Ubench
    - Run Bonnie++
    - Other benchmarks
Methodology

Every hour:

- Kill previous instances
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  - Large:
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    - Run Bonnie++
    - Other benchmarks

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

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

• Different ones: range, variance, standard deviation, ...
Measure of Variation

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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

\[ COV = \frac{1}{\overline{x}} \cdot \sqrt{\frac{1}{N-1} \cdot \sum_{i=1}^{N} (x_i - \overline{x})^2} \]
Agenda

- Motivation
- Related Work
- Background
- Methodology

Results & Analysis
CPU Performance

CPU Performance [Ubench score]

US location + EU location ×

Measurements per Hour

Large Instances

Week 52  Week 53  Week 1  Week 2  Week 3

Runtime Measurements in the Cloud, J. Schad, J. Dittrich, and J. Quiané
CPU Performance

COV of 24%

Baseline: COV of 0.1%
CPU Performance

Baseline: COV of 0.1%

Observation: two bands in performance

COV of 24%

Results & Analysis

September 14th, 2010

Runtime Measurements in the Cloud, J. Schad, J. Dittrich, and J. Quiané
Memory Performance

US location
EU location

Memory Performance [Ubench score]

Measurements per Hour
Large Instances

Week 52
Week 53
Week 1
Week 2
Week 3

September 14th, 2010
Runtime Measurements in the Cloud, J. Schad, J. Dittrich, and J. Quiané
Memory Performance

COV of 10%

Baseline: COV of 0.3%

Measurements per Hour
Large Instances

US location
EU location

Week 52
Week 53
Week 1
Week 2
Week 3

COV of 10%

Baseline: COV of 0.3%
Observation: again, two bands in performance

COV of 10%

Baseline: COV of 0.3%
Random I/O Performance

Measurements per Hour

Large Instances

Random Read Disk Performance [KB/s]

US location + EU location ×

Week 52
Week 53
Week 1
Week 2
Week 3

Results & Analysis
Random I/O Performance

Random Read Disk Performance [KB/s]

Baseline: COV of 1.9%

COV of 13%

US location + EU location ×
Random I/O Performance

**Observation:** one band in performance for US

**COV of 13%**

**Baseline:** COV of 1.9%

Measurements per Hour
Large Instances
Availability Zones

Results & Analysis

CPU Performance [Ubench score]

Measurements per Hour

Large Instances
Availability Zones

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

Observation 1: us-east-1d results always in the upper band

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

Observation 1: us-east-1d results always in the upper band

Observation 2: lower band results belong only to us-east-1c

“Availability Zones are distinct locations that are engineered to be insulated from failures in other Availability Zones…”
CPU Distribution (1/2)

Why two bands?

HADOOP++
CPU Distribution (1/2)

Why two bands?

... and if I verify the performance of the different processors type?
CPU Distribution (1/2)

Why two bands?

... and if I verify the performance of the different processors type?

Hadoop++

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Hadoop++

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Request 5 Xeon-Opteron pairs

For each pair

Xeon

Run Ubench 150 times

Opteron

Run Ubench 150 times

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CPU Distribution (1/2)

Why two bands?

... and if I verify the performance of the different processors type?

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For each pair

Xeon

Run Ubench 150 times

Opteron

Run Ubench 150 times

examining the /proc/cpuinfo file

Request 5 Xeon-Opteron pairs
CPU Distribution (2/2)

![Graph showing CPU performance for Xeon and Opteron instances, withInstance-pairs 1 to 5 plotted.](image-url)
Different performance per processor type

CPU Distribution (2/2)
Results & Analysis

CPU Distribution (2/2)

Different performance per processor type

While the COV for combined measurements is 24%

COV: 1%

COV: 2%

CPU performance [Ubench Score]

Xeon + Opteron
Different performance per processor type

While the COV for combined measurements is 24%

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

![Chart showing Mean Ubench Score for 50 Large Instances Cluster against start point in hours. The chart indicates variability in performance over time.]
Larger Clusters

Observation: 30% of the measurements fall into the low performance band.

Still, two bands in performance
MapReduce Job

- **Application:** a MapReduce aggregation job
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![Bar chart comparing runtime measurements between Amazon EC2 and Local Cluster](chart.png)
MapReduce Job

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**Results & Analysis**
**Application**: a MapReduce aggregation job

**Number of virtual nodes**: 50

**Repetitions**: once every hour

**Observation**: upper band results from virtual clusters composed of 80% of Xeon processors (of 20% for the lower band).
Lessons Learned
Lessons Learned

Ah O.K.! So...

Hadoop++

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Lessons Learned

• Be careful!
Lessons Learned

• Be careful!
• High variance in performance: COV up to 24%
• Hard to interpret results
• Repeatability to limited extent
Lessons Learned

- Be careful!
- High variance in performance: COV up to 24%
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- Repeatability to limited extent

- Two bands in performance
Lessons Learned

• Be careful!
• High variance in performance: COV up to 24%
• Hard to interpret results
• Repeatability to limited extent

• Two bands in performance
• Partially due to different physical CPU types
Conclusion

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

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• Researchers should
  • use **equivalent** virtual clusters to **compare** systems
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By the way...

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

[after VLDB’10 deadline]
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