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Understanding and Minimizing Disk Contention Effects for Data-Intensive Processing in Virtualized Systems

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Agenda

- **Introduction**
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- **Data-intensive Processing and Virtualization**
- **Disk I/O Characterization**
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  - Proposal, evaluation and results
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- References

Introduction

“The information attracts a great deal of attention in recent years and led organizations to find out ways to handle data processing in an efficient, reliable and cost-effective way”

“The emergence of many data-processing frameworks”

Introduction

Problem Statement

- **Virtual datacenters**
  - Hosts many virtual machines
- **Shared environment**
  - Shared pool of resources: CPU, Memory, Network and disk
- **Resource contention**
  - Applications requesting resources at the same time
- **Resource contention**
  - **Disk contention problem**

Introduction

Disk contention problem

Interference implications

- Performance degradation for applications and frameworks
- Inter-VM resource interference
- Unexpected completion time of applications

Related Works

Some investigated works

- CPU and memory solutions
- Hypervisor based virtualization
- YARN (CPU and memory)
- Instrumented frameworks and applications

Opportunities

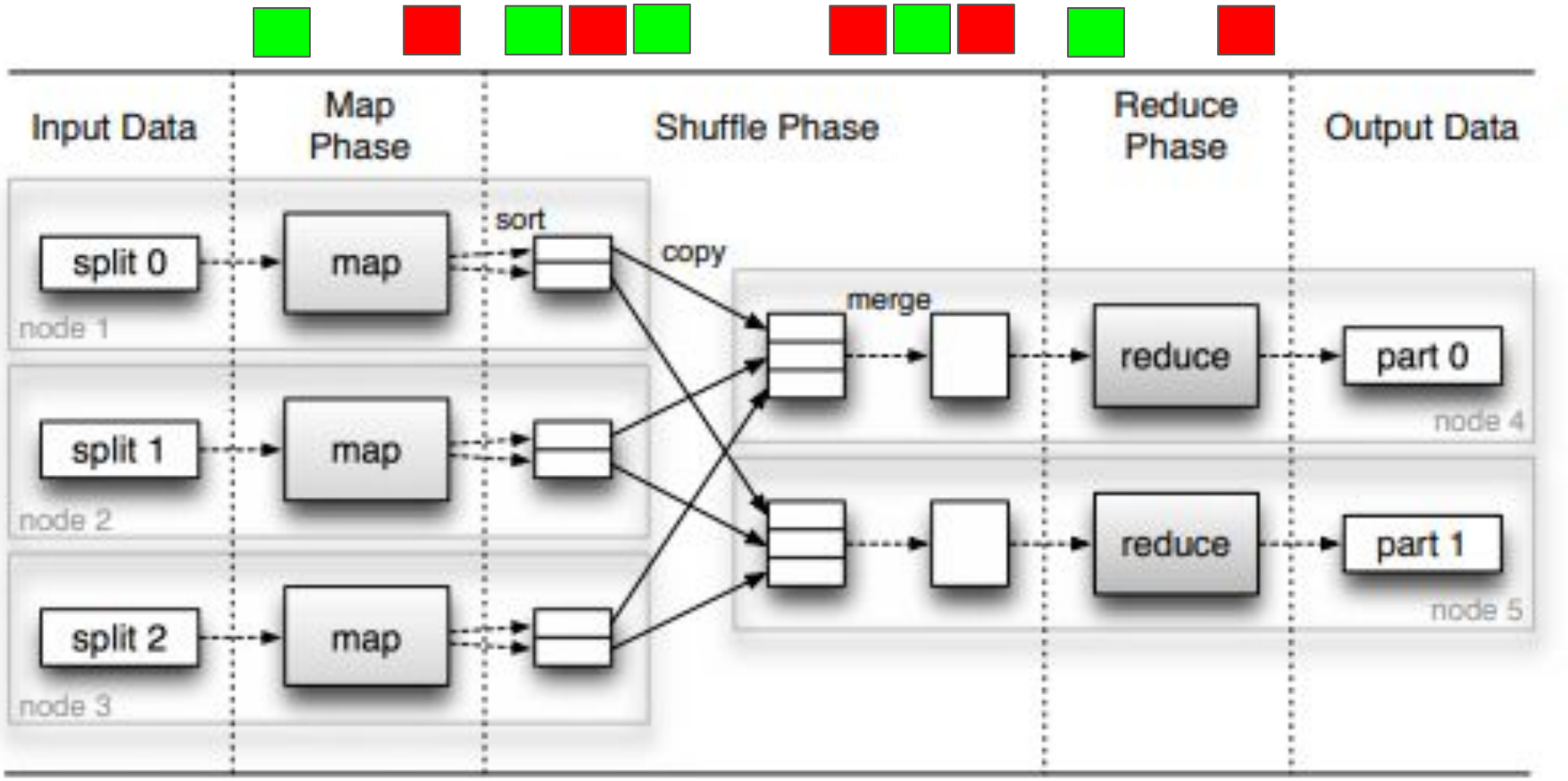
- Container-based virtualization
- Already solved problems in hypervisor-based virtualization are open again!

Introduction

Proposal

This work proposes a technique to minimize disk contention effects in order to improve applications' performance in virtualized systems.

Data-intensive Processing and Virtualization

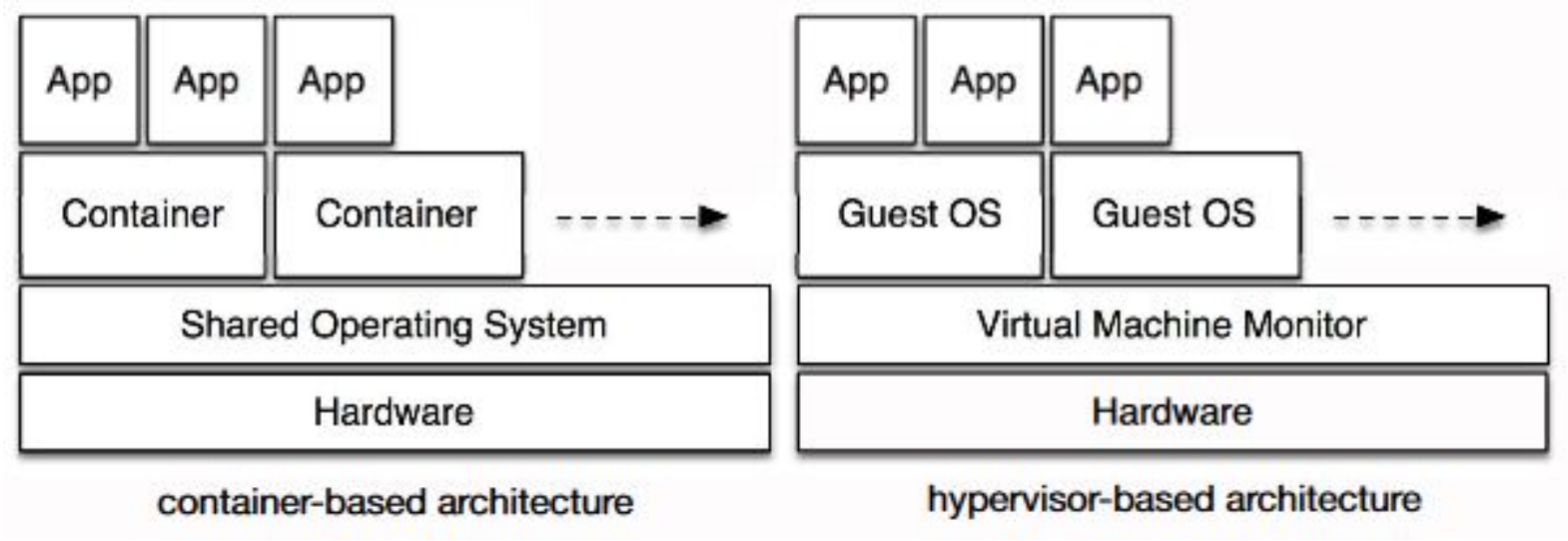


MapReduce data flow [1]

Read Operations

Write Operation

Data-intensive Processing and Virtualization



Comparison of container- and hypervisor-based virtualization architectures [2]

Today, the container-based virtualization is widely used for data-intensive processing

Disk I/O Characterization

Metrics

We observed some I/O characteristics such as data generation process, disk read/write bandwidth, data access patterns and application completion time.

Disk I/O Characterization

Testbed

- A real cluster consisting of 4 identical servers, each equipped with 8 x86 64 cores at 2.27 GHz, 16GB of RAM and one disk (160GB) per node.
- Hadoop MapReduce (1.1.2), the most popular open-source implementation for Big Data analysis.
- HiBench, a realistic benchmark suite based on the MapReduce programming model with real-world applications.

Disk I/O Characterization

WORKLOAD CHARACTERISTICS

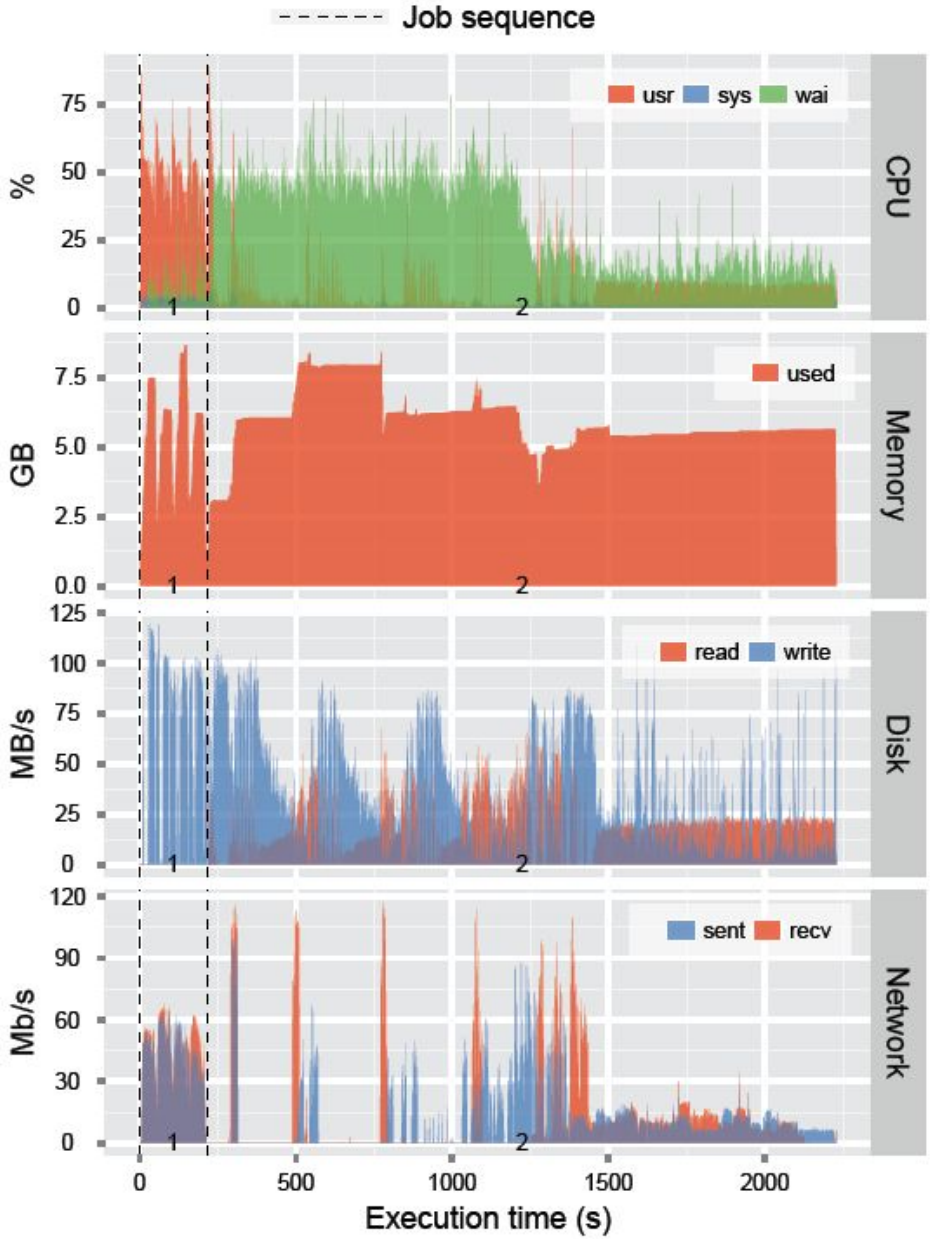
Application	Load in	Load out	Time (s)
Sort	15,9Gb	15,1Gb	2225
Terasort	37,2Gb	37,2Gb	1265
WordCount	11,4Gb	1Mb	2286
Nutch	509Mb	208,4Mb	266
Pagerank	1,3Gb	476Mb	160
K-means	46,4Gb	57Gb	3038
Bayes	352Mb	1Mb	401
Hive	5Gb	1,7Gb	788

Performed applications

Disk I/O Characterization

Sort - a disk intensive application

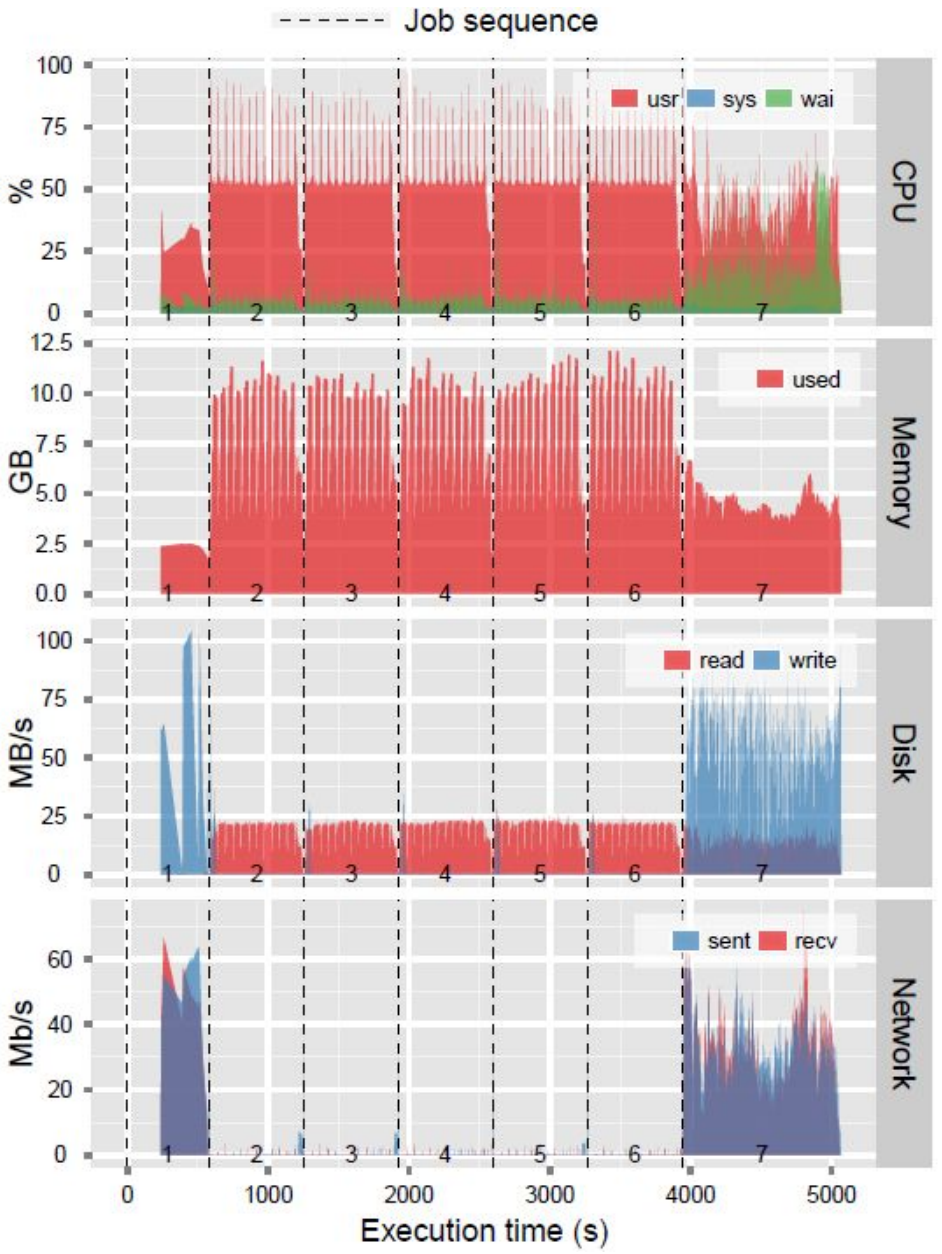
- Well-defined resource patterns
- Overlapping
- Resource correlation



Disk I/O Characterization

Kmeans - a non-disk intensive application

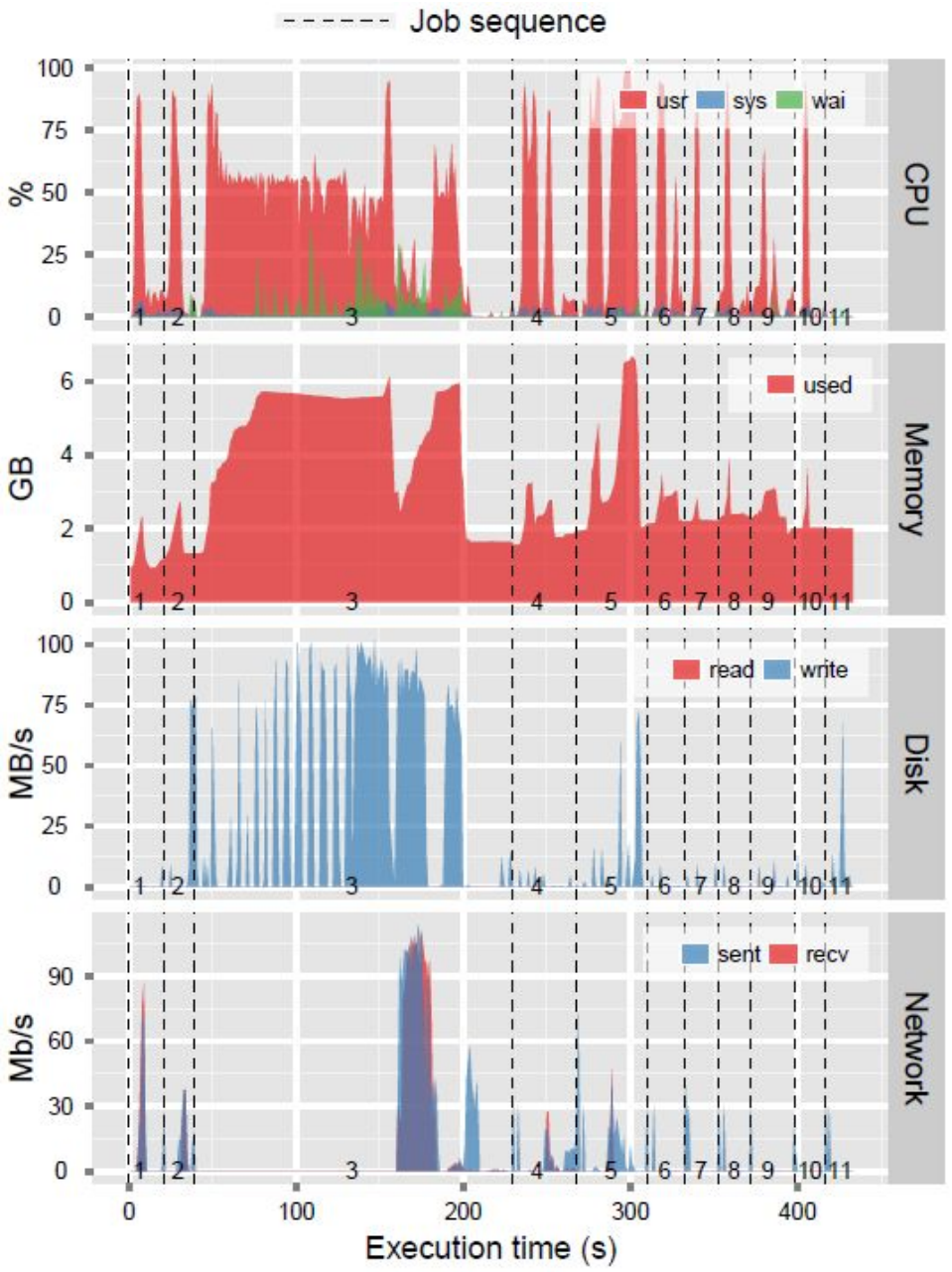
- Well-defined resource patterns
- Resource correlation
- A long period with no disk write operations
- Sub utilization of resources
- Other applications can run during this time slice



Disk I/O Characterization

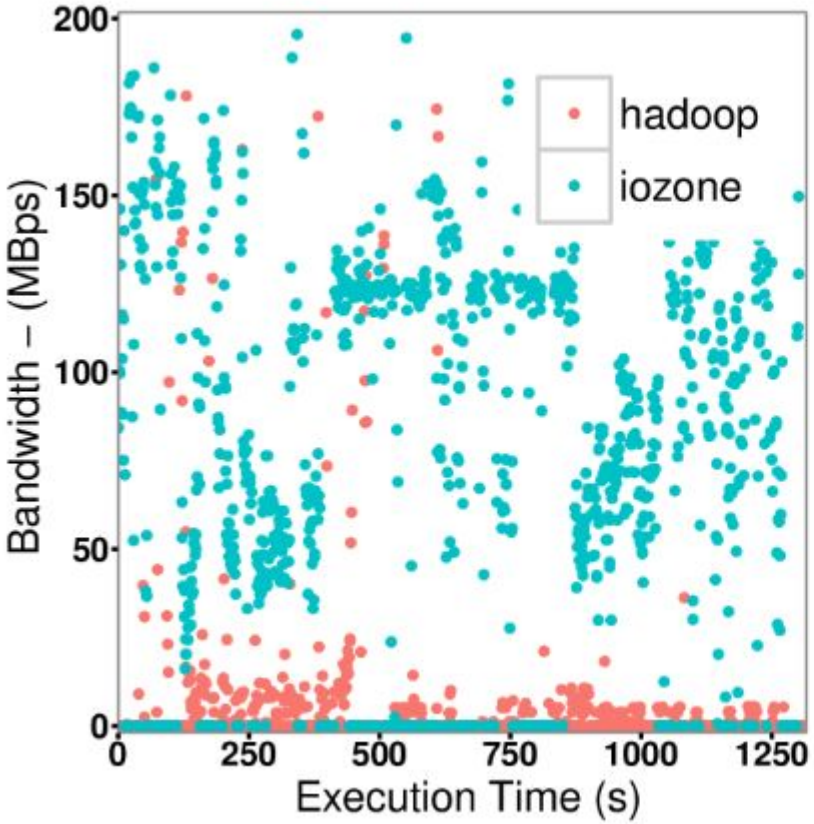
Bayes- a moderate disk application

- Resource usage variation/fluctuation
- Write operations are more intensive than read operations.



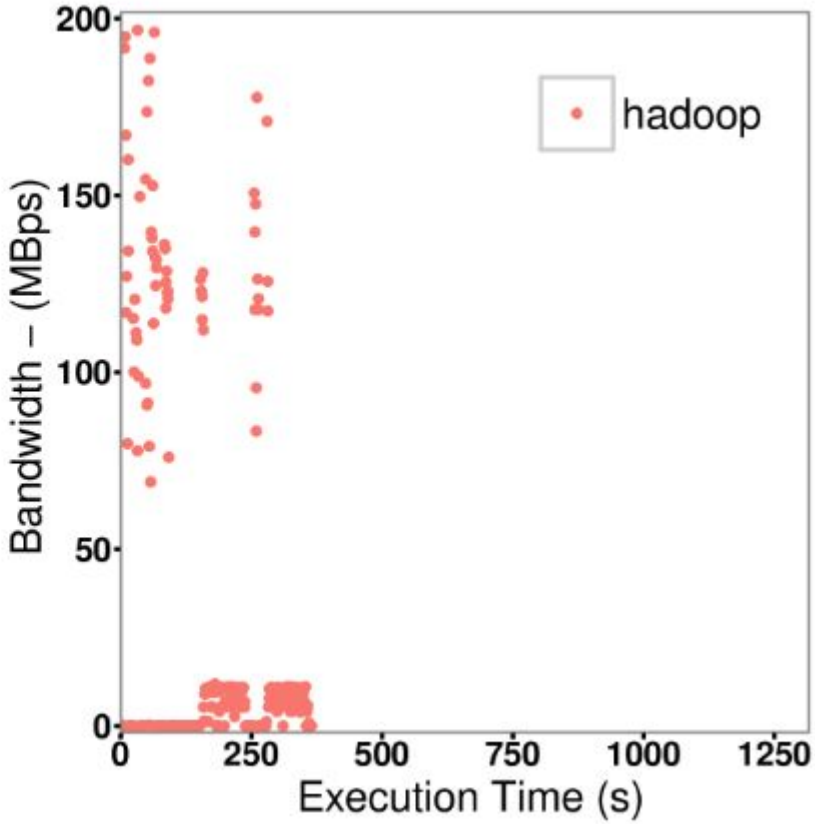
Disk I/O Contention and Resource Allocation

A



Contention Scenario

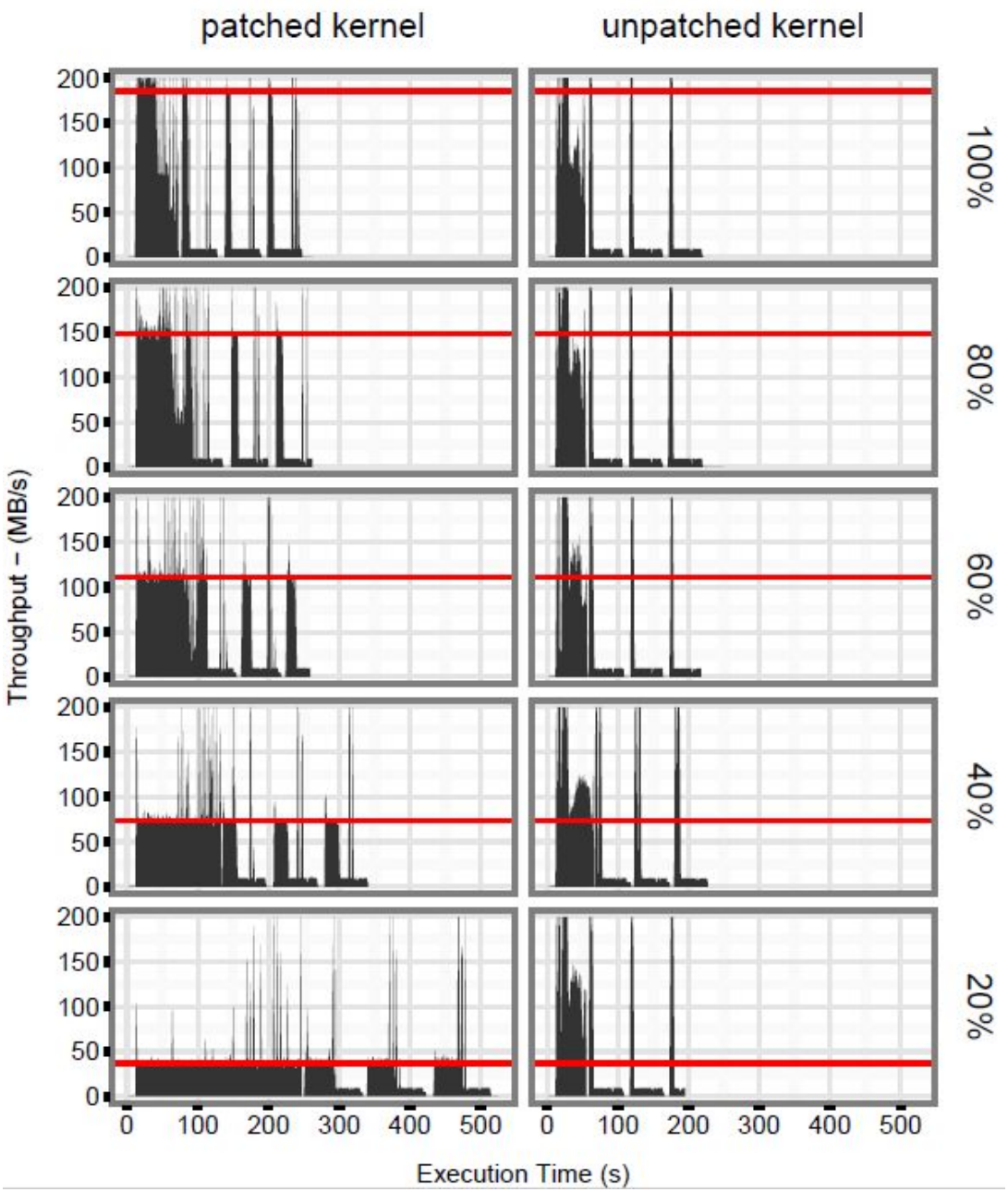
B



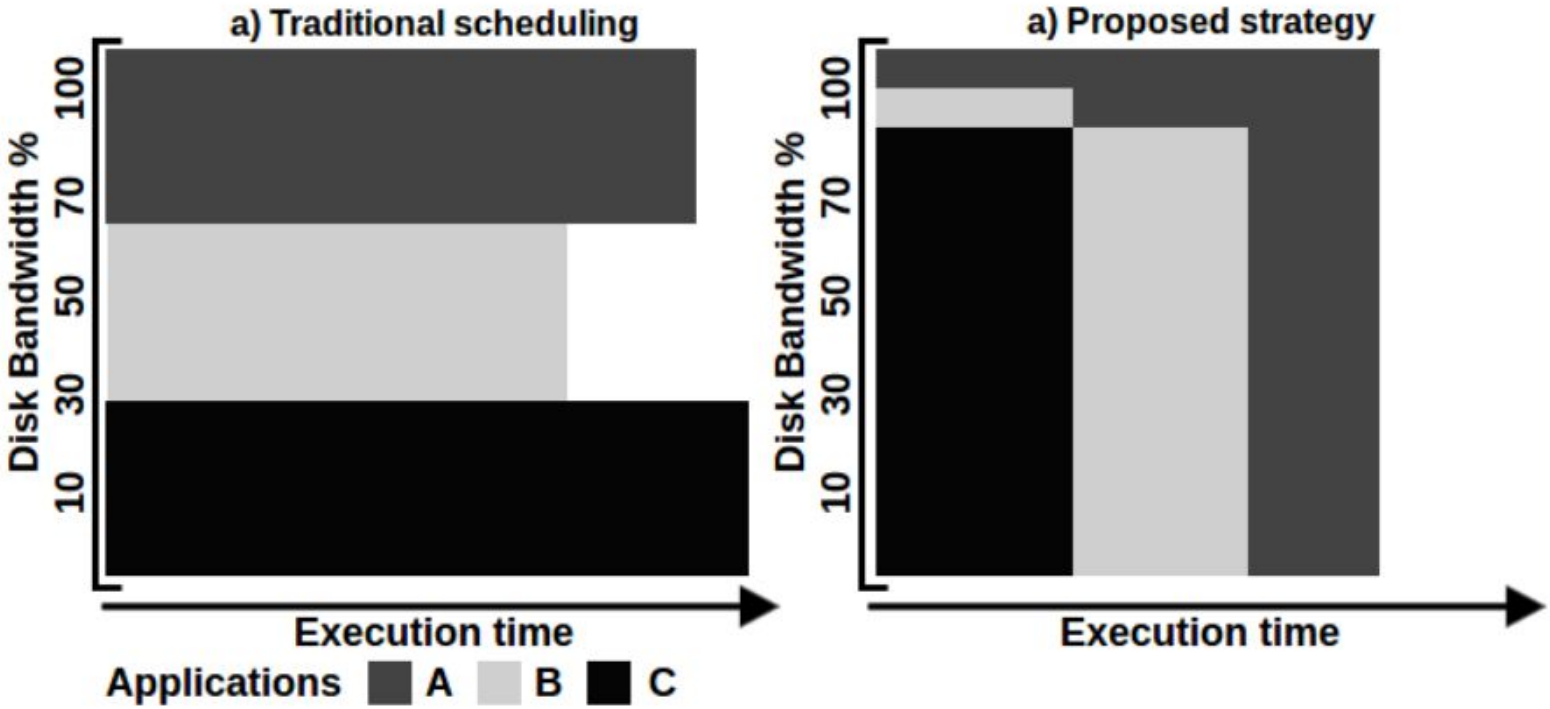
Non-contention scenario

Disk I/O Contention and Resource Allocation

- Cgroups (control groups)
  - Isolate a collection of process (CPU, memory,disk and network)
  - Block I/O controller (blkio)
- Measures Disk bandwidth (average)
- Kernel < 4 need a special patch
- Isolation faults



Towards a Dynamic Disk Resource Allocation



Goal: adjust the disk I/O utilization rates dynamically

Methodology: uses a variation of the Shortest Job First (SJF) algorithm. It is a greedy algorithm that selects the process with the shortest execution time.

Towards a Dynamic Disk Resource Allocation

Methodology

- We compared all OS I/O Schedulers (CFQ, noop, deadline)
- The metric observed was makespan (MS) - represents the application completion time considering the beginning and end of a sequence of jobs or tasks.
- Measurements have a confidence interval of at least 95%.
- Two evaluation scenarios
  - Homogeneous: same application and varied workload
  - Heterogeneous: varied applications and workloads
    - Real-world scenario

Towards a Dynamic Disk Resource Allocation

Testbed

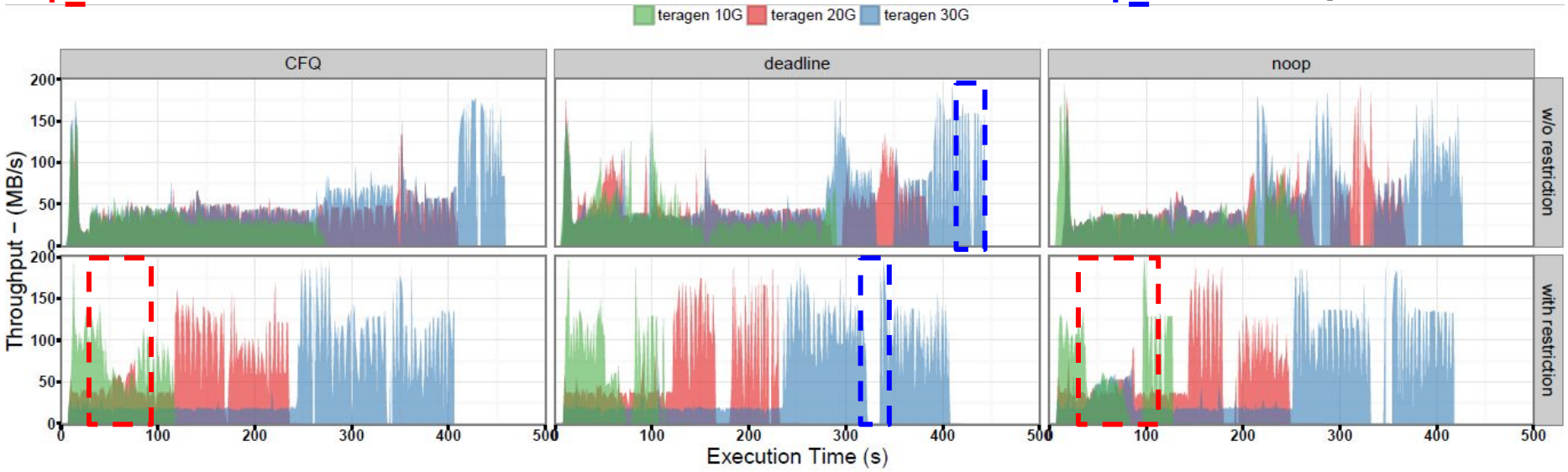
- Two identical Dell PowerEdge M610 servers, 24GB of RAM and one 300GB 10K RPM SAS disk;
- Ubuntu Server 14.04.1 LTS, patched with a custom Kernel (version 3.3) with container-based virtualization (LXC)
- A custom IOtop monitor
- Hadoop MapReduce (1.1.2), the most popular open-source implementation for Big Data analysis.
- HiBench, a realistic benchmark suite based on the MapReduce programming model with real-world applications.

Towards a Dynamic Disk Resource Allocation

Homogeneous evaluation

Isolation faults

Shuffle phase



MAKESPAN IMPROVEMENT BY SCHEDULER

State	CFQ	deadline	noop
w/o restriction (sec)	382	395	422
restriction (sec)	307	297	293
performance improvement (%)	19,6	24,8	30,56

Towards a Dynamic Disk Resource Allocation

Heterogeneous evaluation (real-world scenario)

Terasort (20GB), Sort (1.1GB) and K-means (3GB).

REAL WORLD SCENARIO: MAKESPAN IMPROVEMENT BY SCHEDULERS

State	CFQ	deadline	noop
w/o restriction (sec)	1614	1381	1525
restriction (sec)	1448	1131	1123
performance improvement (%)	10	18	26

DETAILED PERFORMANCE ANALYSIS PER APPLICATION

Schedulers	**CFQ**			**Noop**			**Deadline**		
Applications	**K-means**	**Sort**	**Terasort**	**K-means**	**Sort**	**Terasort**	**K-means**	**Sort**	**Terasort**
w/o restriction (sec)	877	1252	2713	1417	1158	2000	1287	987	1546
Restriction (sec)	737	859	2749	676	564	2131	699	522	1871
Gain (%)	15,9	31,3	-1,6	52,2	51,2	-6	45,6	47,1	-20

Conclusion and Future Work

The proposed strategy is feasible and effective to the presented scenarios.

- The strategy improves the application completion time up to 26%.
- Gains were obtained with all OS-system I/O Schedulers.

As future work, we would like to suggest:

- A fine-grained dynamic model to resize resources (CPU, memory, disk, network) on-demand.
- A Disk I/O scheduler for data-intensive processing.
- Towards a Dynamic Network Resource Allocation for data-intensive processing (batch and stream).

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Thanks!

Any questions?

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