WORKLOAD-AWARE LIVE MIGRATION OF VIRTUAL MACHINES

SCS 4224 FINAL YEAR PROJECT IN COMPUTER SCIENCE

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INTRODUCTION

Workload-aware live migration dynamically detects the nature of the workload running in the VM and migrates it by choosing the most efficient migrating method out of live migration techniques (namely pre-copy, post-copy and hybrid approaches).

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BACKGROUND

- **Live Migration of VMs**

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BACKGROUND

Google

1,000,000 Migrations Per Month

Ruprecht, A., Jones, D., Shiraev, D., Harmon, G., Spivak, M., Krebs, M., Baker-Harvey, M. & Sanderson, T. (2018), 'Vm live migration at scale', ACM SIG-PLAN Notices 53(3), 45–56.

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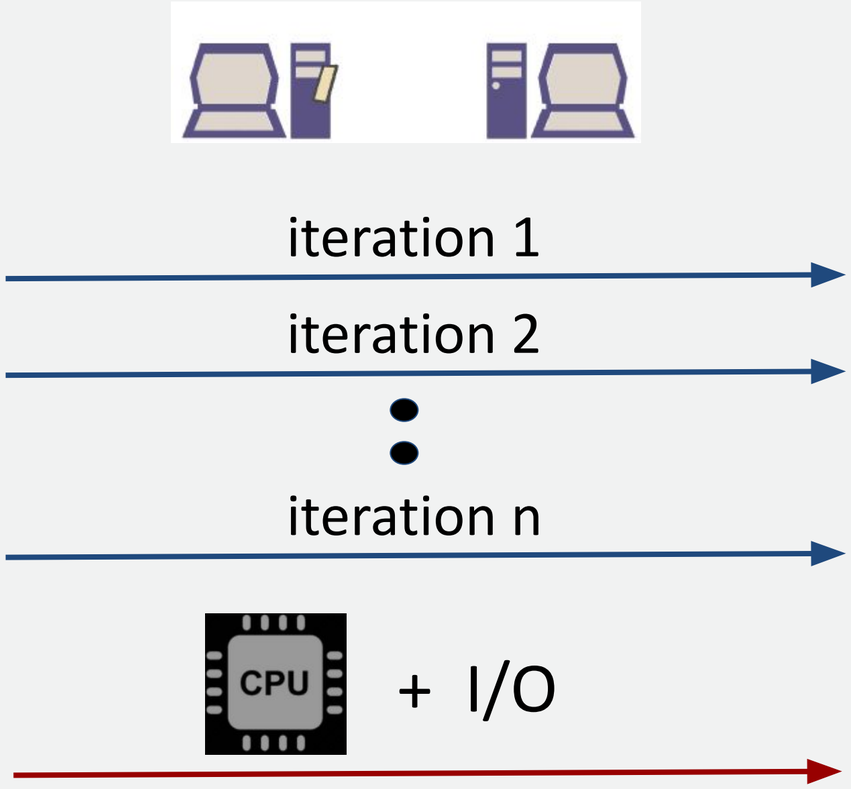
BACKGROUND

- **Pre-copy Migration**



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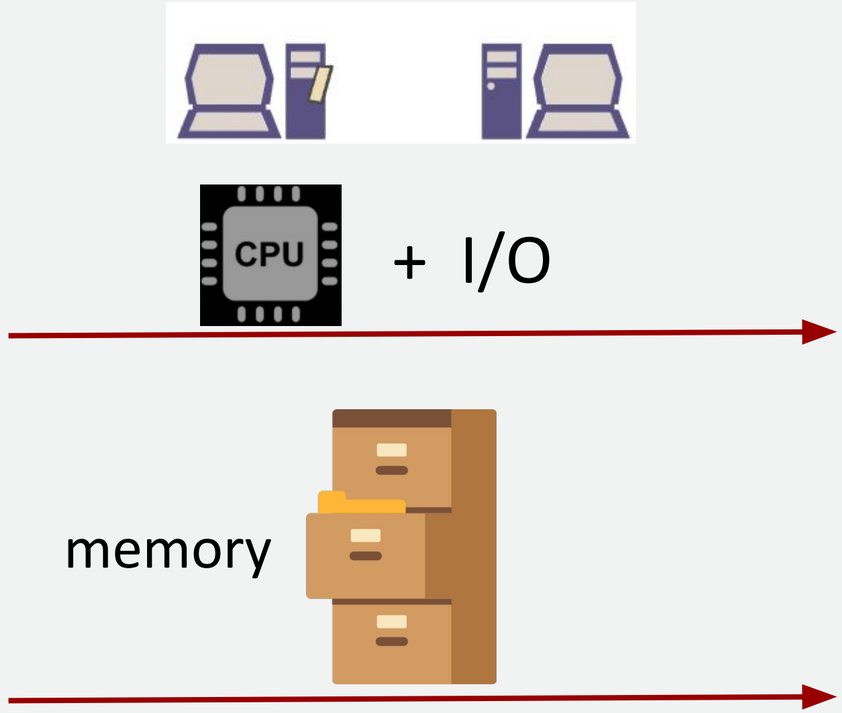
BACKGROUND

- **Post-copy Migration**



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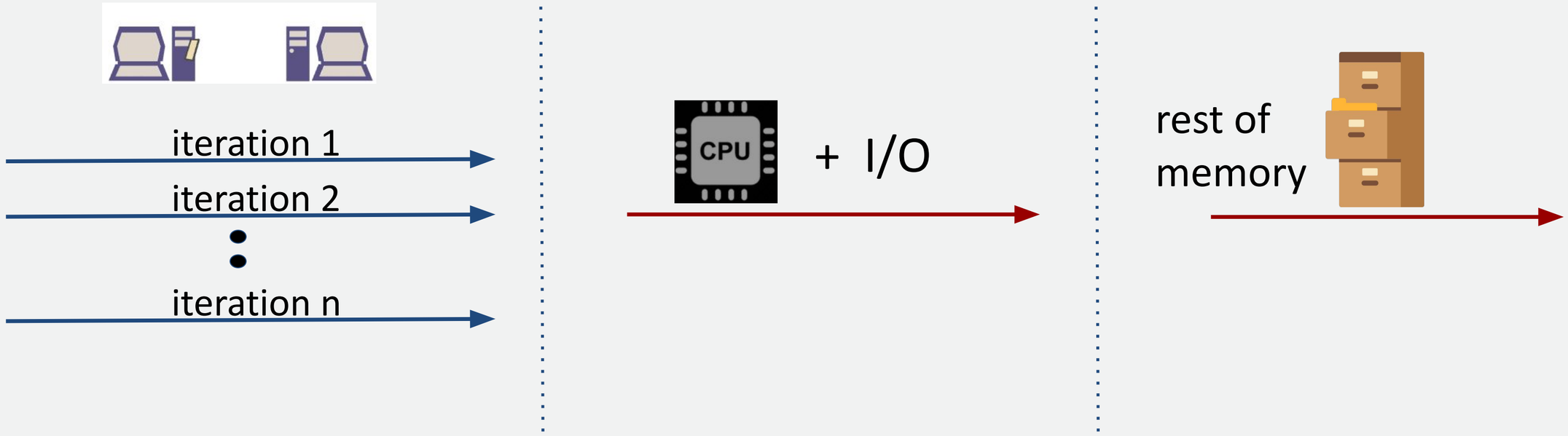
BACKGROUND

- **Hybrid Migration**



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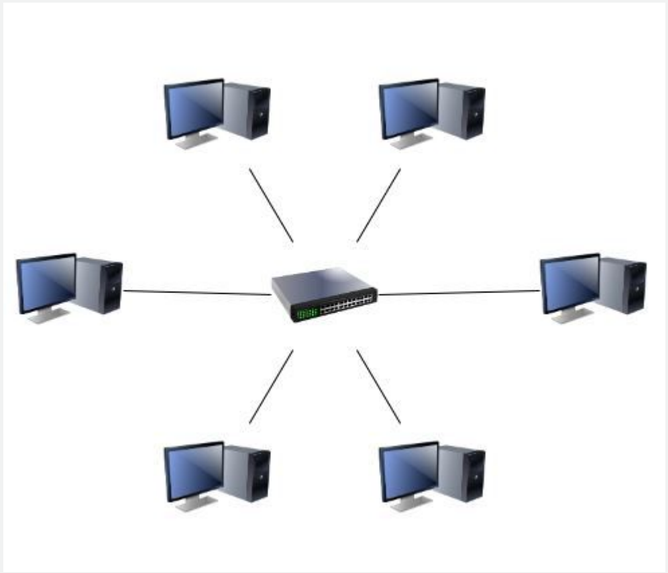
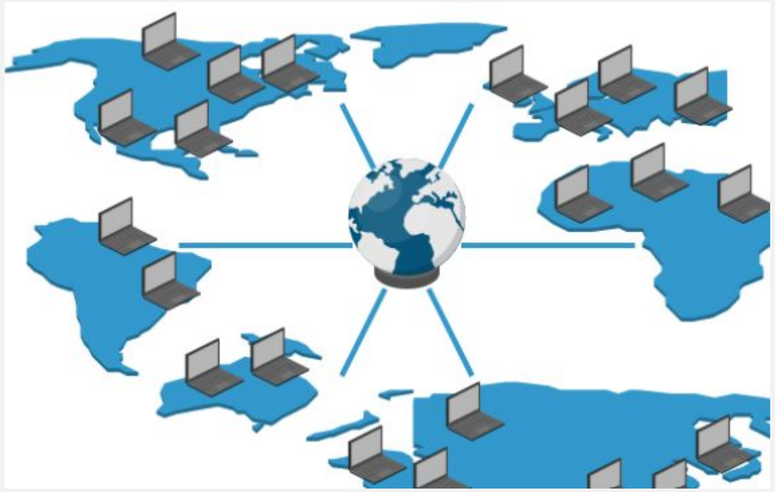
BACKGROUND

- **LAN Migration**



- **WAN Migration**



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BACKGROUND

- Performance Metrics
  - Downtime
  - Total Migration Time
  - Bandwidth Utilization
  - Performance Degradation
  - Eviction Time

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MOTIVATION

- **Migrating VMs with minimal migration duration.**
- **Decrease performance degradation.**

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RESEARCH GAP

- **Less focus on how the type of VM workload impacts the migration process.**
- **Less focus on dynamically changing migration aspects.**

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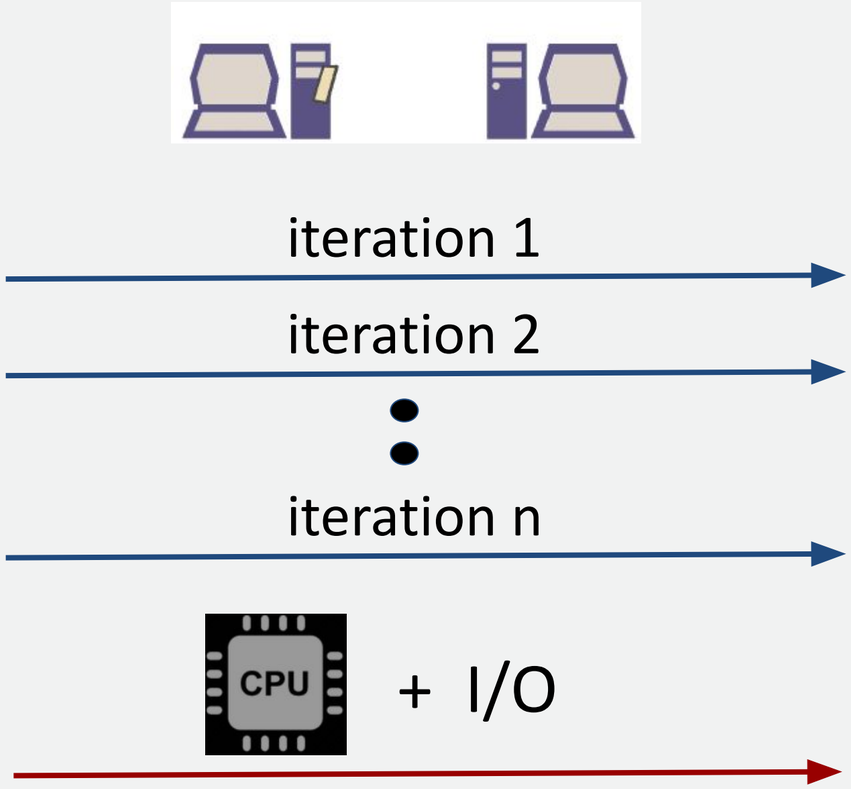
- **Pre-copy Migration**



“...even moderately write-intensive workloads can reduce precopy’s effectiveness during migration”

- Hines, M. R., Deshpande, U. & Gopalan, K. (2009), ‘Post-copy live migration of virtual machines’, ACM SIGOPS operating systems review 43(3), 14–26.

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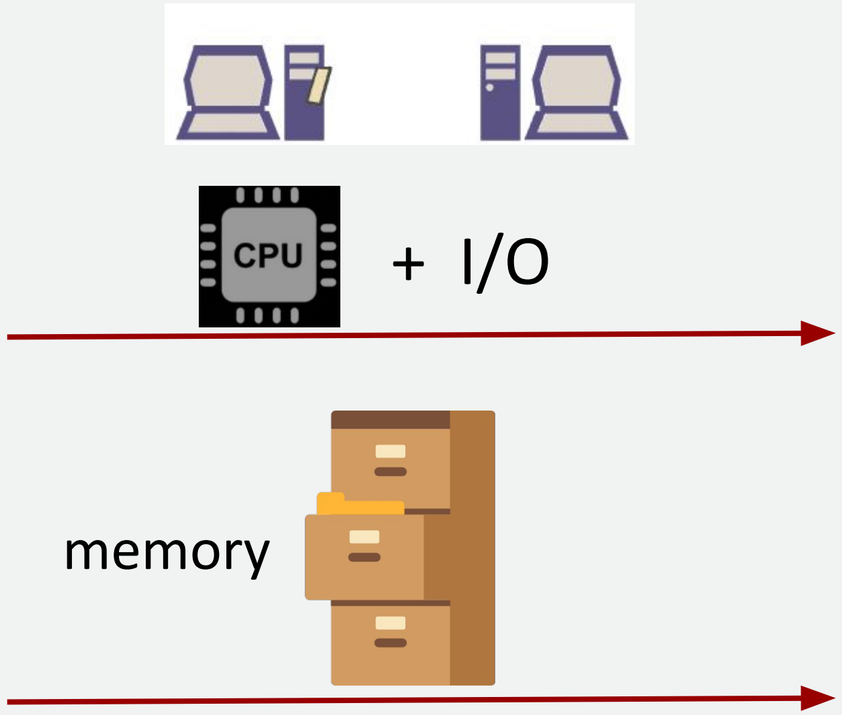
- **Post-copy Migration**



“... post-copy doesn’t perform well with read intensive loads. A read intensive VM will lead to an increase in the number of page faults ”

- Sahni, S. and Varma, V., 2012, October. A hybrid approach to live migration of virtual machines. In 2012 IEEE international conference on cloud computing in emerging markets (CCEM) (pp. 1-5). IEEE.

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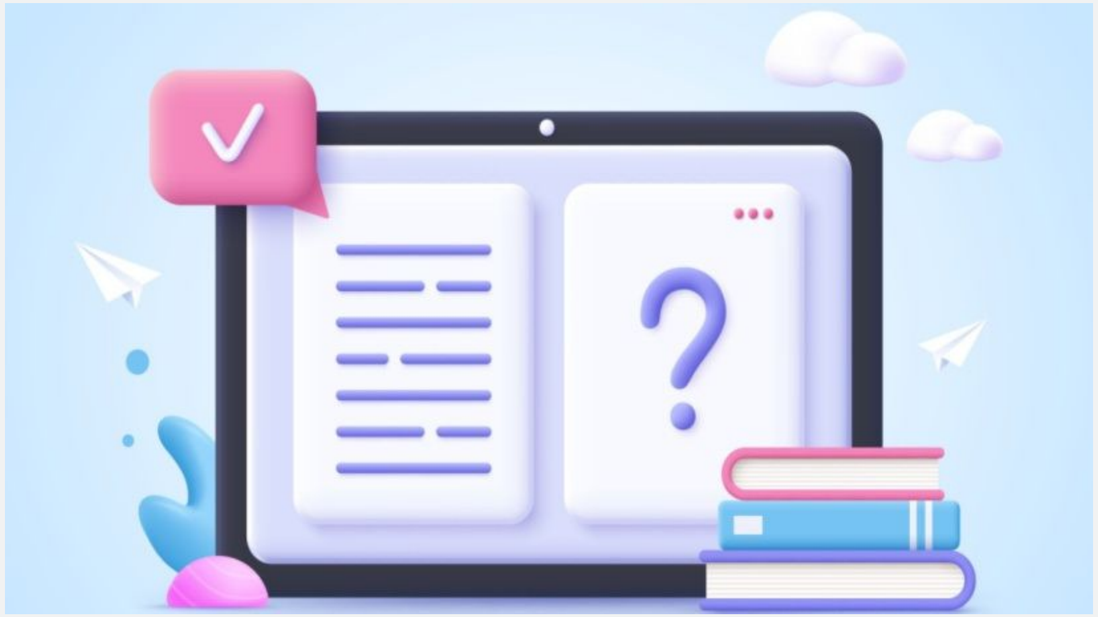
RELATED WORK



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Optimization Mechanisms

- **Dynamic Self Ballooning** (Hines et al., ACM SIGOPS operating systems review, 2009)
- **Compression** (Deshpande et al., Proceedings of the 20th international symposium on High performance distributed computing, 2011)
- **Quick Eviction** (Fernando et al., IEEE International Conference on Cluster Computing (CLUSTER), 2016)
- **Deduplication** (Deshpande et al., IEEE 7th International Conference on Cloud Computing, 2014)

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SOLive (Fernando et al., IEEE INFOCOM 2020-IEEE conference on computer communications, 2020)

- **Aims to minimize the total migration time.**
- **Considers different VM workloads.**
  - **CPU Intensive**
  - **Network Intensive**
  - **Memory Intensive**
- **Dynamically categorizes VMs.**

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SOLive (Fernando et al., IEEE INFOCOM 2020-IEEE conference on computer communications, 2020)

- **Migrating multiple VMs.**
- **Workload analysis.**
- **Order the VMs according to their workload types.**

- **Migrating a single VM.**
- **Workload analysis.**
- **Choose the most optimal migration method according to the VM workload types.**

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AdaMig (Li et al., Proceedings of the 17th ACM SIGPLAN/SIGOPS International Conference on Virtual Execution Environments, 2021)

- **Adaptive Live Migration.**
- **Prioritizing pre-copy.**
- **Halts inefficient migration and dynamically switches to another method.**
- **"Migration Speed < Page Dirtying Rate"**
  - **CPU Throttling**
  - **Compression**

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AdaMig (Li et al., Proceedings of the 17th ACM SIGPLAN/SIGOPS International Conference on Virtual Execution Environments, 2021)

- **Prioritizing pre-copy migration.**
- **Consider only non-demanding workloads.**

- **No priority among the migration methods.**
- **Consider general workloads which can be demanding or non-demanding.**

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RESEARCH QUESTIONS

1. How can workload characteristics be effectively analyzed and classified to determine the most suitable migration method for a given virtual machine?

CPU Usage

Memory Usage,
Page Dirtying rate

Network Usage

2. What are the performance implications of different migration methods (pre-copy, post-copy, hybrid) in workload-aware live migration?

Total Migration Time

Application Overhead

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OBJECTIVES

- **Identify workload metrics that can capture the characteristics of different types of workloads.**
- **Identify the methods to capture the workload metrics dynamically while the VM is running.**
- **Create a classification model that can classify the workloads according to the workload metrics.**
- **Determine the correlation between migration methods and workload characteristics.**
- **Establish an algorithm that can select the most suitable migration method based on the workload analysis.**

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SCOPE

IN SCOPE

- Workload analysis.
- Analyzing migration methods with respect to different workloads.
- Developing an algorithm for workload-aware live migration.

OUT SCOPE

- Dynamic workloads.
- WAN migrations.
- Multi-tier VM applications.
- Multiple VM migrations.

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RESEARCH METHODOLOGY & DESIGN

- Design Science Research Methodology.
- Investigating and creating different VM workloads.
- Classifying the workloads.
- Evaluating migration methods.
- Identifying the correlation of workloads-migration methods.
- Developing an algorithm.

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EVALUATION

- **The developed algorithm would be evaluated against vanilla pre-copy, post-copy and hybrid migration methods as baselines in terms of total migration time.**

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PROGRESS SO FAR

- **Setting up two physical servers with Gigabit ethernet.**
- **Investigating different types of VM workloads.**

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REFERENCES

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- http://www.animated-gifs.fr/category_computing/internet-1/
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- Deshpande, U., Wang, X. & Gopalan, K. (2011), Live gang migration of virtual machines, in 'Proceedings of the 20th international symposium on High performance distributed computing', pp. 135–146.
- Fernando, D., Bagdi, H., Hu, Y., Yang, P., Gopalan, K., Kamhoua, C. & Kwiat, K. (2016), Quick eviction of virtual machines through proactive snapshots, in '2016 IEEE International Conference on Cluster Computing (CLUSTER)', IEEE, pp. 156–157.

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- Deshpande, U., You, Y., Chan, D., Bila, N. & Gopalan, K. (2014), Fast server deprovisioning through scatter-gather live migration of virtual machines, in '2014 IEEE 7th International Conference on Cloud Computing', IEEE, pp. 376–383.
- Fernando, D., Yang, P. & Lu, H. (2020), Sdn-based order-aware live migration of virtual machines, in 'IEEE INFOCOM 2020-IEEE conference on computer communications', IEEE, pp. 1818–1827.
- Li, H., Xiao, G., Zhang, Y., Gao, P., Lu, Q. & Yao, J. (2021), Adaptive live migration of virtual machines under limited network bandwidth, in 'Proceedings of the 17th ACM SIGPLAN/SIGOPS International Conference on Virtual Execution Environments', pp. 98–110.

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Q & A

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BENCHMARKS

Sysbench	CPU Intensive	
Kernbench	CPU Intensive	Synthetic (not completely)
Quick Sort	CPU Intensive	
Lookbusy	CPU Intensive	Synthetic
OpenMP	CPU Intensive	Real-world, Matrix multiplication, Used in scientific workloads
SPEC-CPU 2017	CPU Intensive	
SPEC-CPU 2006	CPU Intensive	100% CPU Usage
Freebench Distray	CPU Intensive	100% CPU Usage
Scientific	CPU Intensive	90%-80% CPU Usage

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BENCHMARKS

Pagedirtier	Memory Intensive	90% Memory Usage (3.6GB), Writes in memory pages in random order
Working set	Memory Intensive	Synthetic
Appmembench	Memory Intensive	Synthetic
SAP-HANA	CPU & Memory Intensive	Real-world, Database System, Simulates users logging in and executing queries
Httperf	Network Intensive	
iPerf	Network Intensive	

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RESULT

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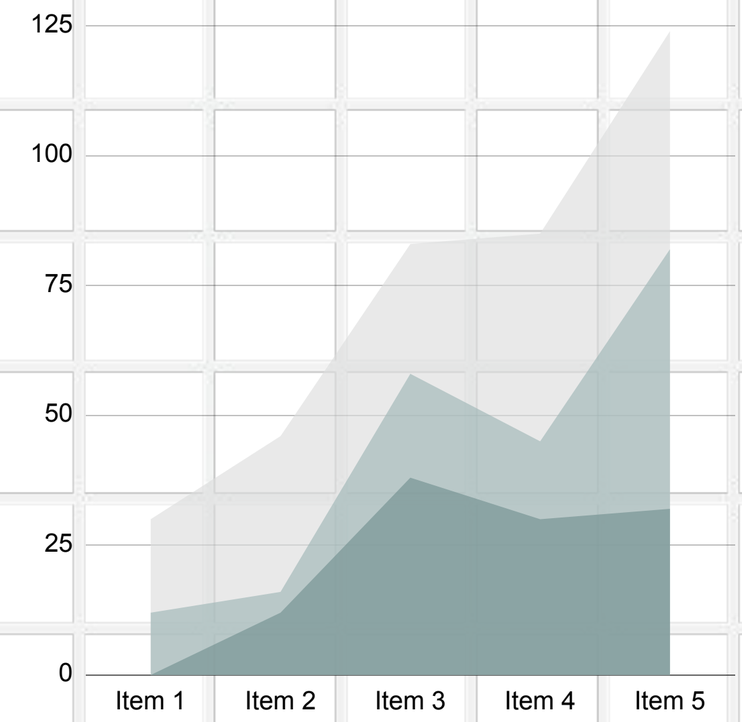

SOLUTION

SOLUTION 1

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SOLUTION 2

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SOLUTION 3

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CONCLUSION

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RECOMMENDATIONS

RECOMMENDATION 1

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RECOMMENDATION 2

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APPROACH

Creating Workloads	**Lorem ipsum dolor sit amet, consectetur adipiscing elit.**	**Lorem ipsum dolor sit amet, consectetur adipiscing elit.**	**Lorem ipsum dolor sit amet, consectetur adipiscing elit.**	**Lorem ipsum dolor sit amet, consectetur adipiscing elit.**