Experimental Study of Virtual Machine Migration in Support of Reservation of Cluster Resources

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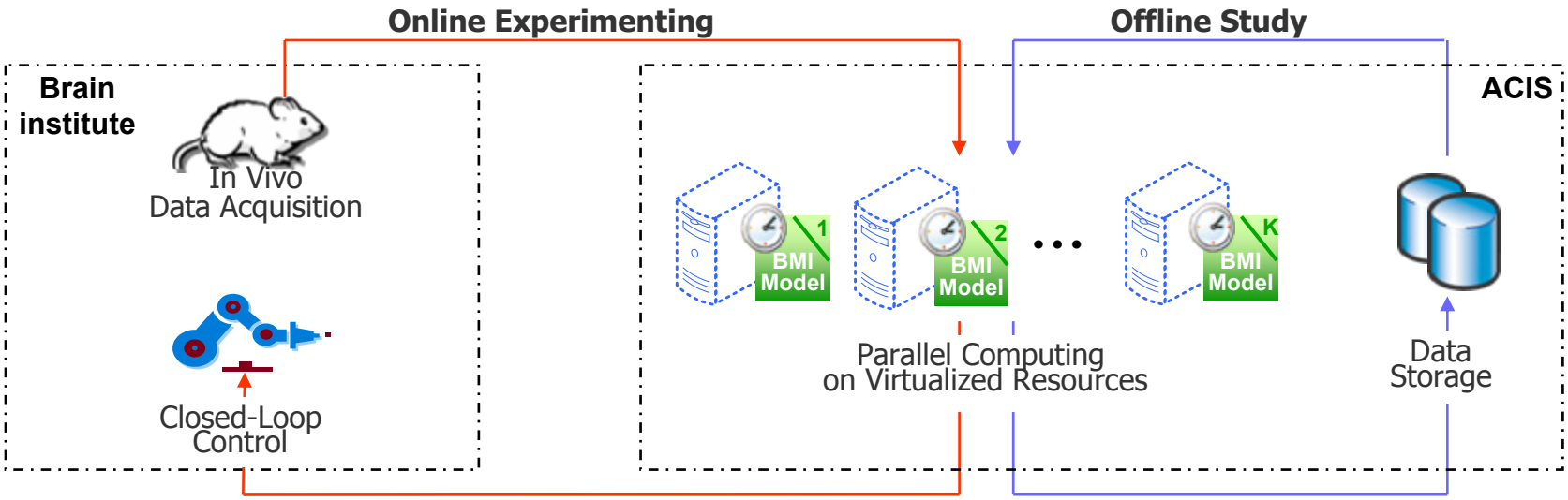
Motivating Application

- Dynamic Data-driven Brain-machine Interface
  - Resource demanding parallel application
  - Time-critical during online experiments
    - Must finish each closed loop within 100ms
  - No stringent time requirement for offline study

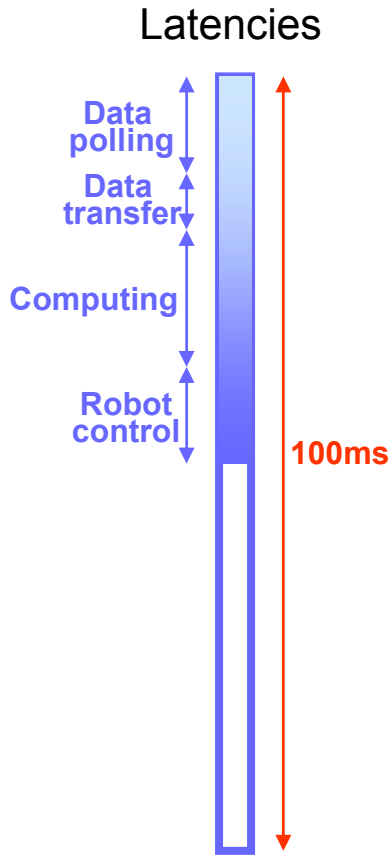


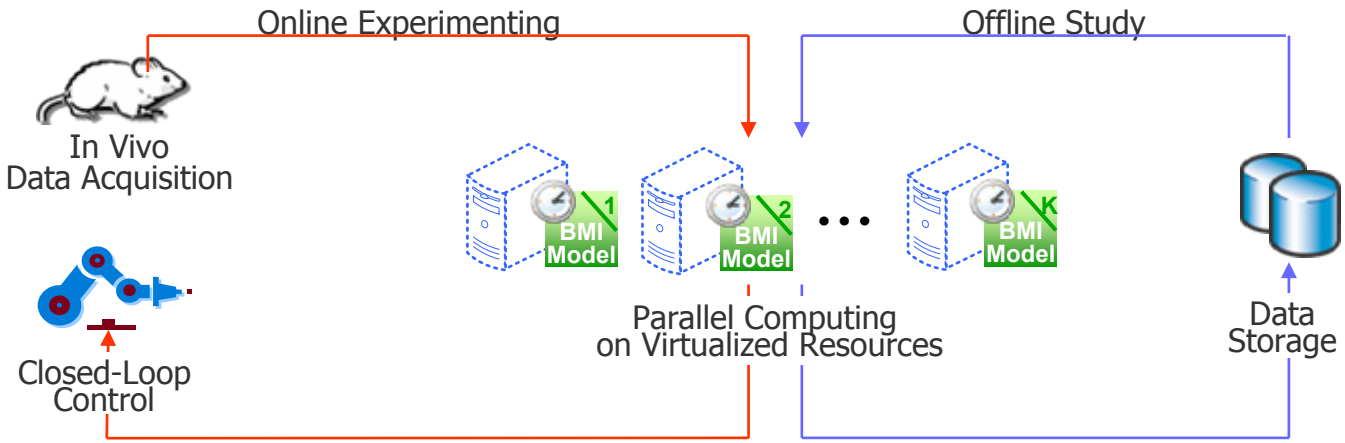
Dynamic Data-driven Brain-machine Interfaces

(http://www.acis.ufl.edu/dddasbmi)

Motivating Application

- Motivation for VM-based resource reservation
  - Online experiments
    - Dedicate cluster resources for VMs running BMI models
    - Without reservation, deadline is often violated
  - Offline study
    - Share cluster resources with VMs running other workloads
  - Cluster reservation
    - Migrating exiting VMs to other resources





Dynamic Data-driven Brain-machine Interfaces

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Overview

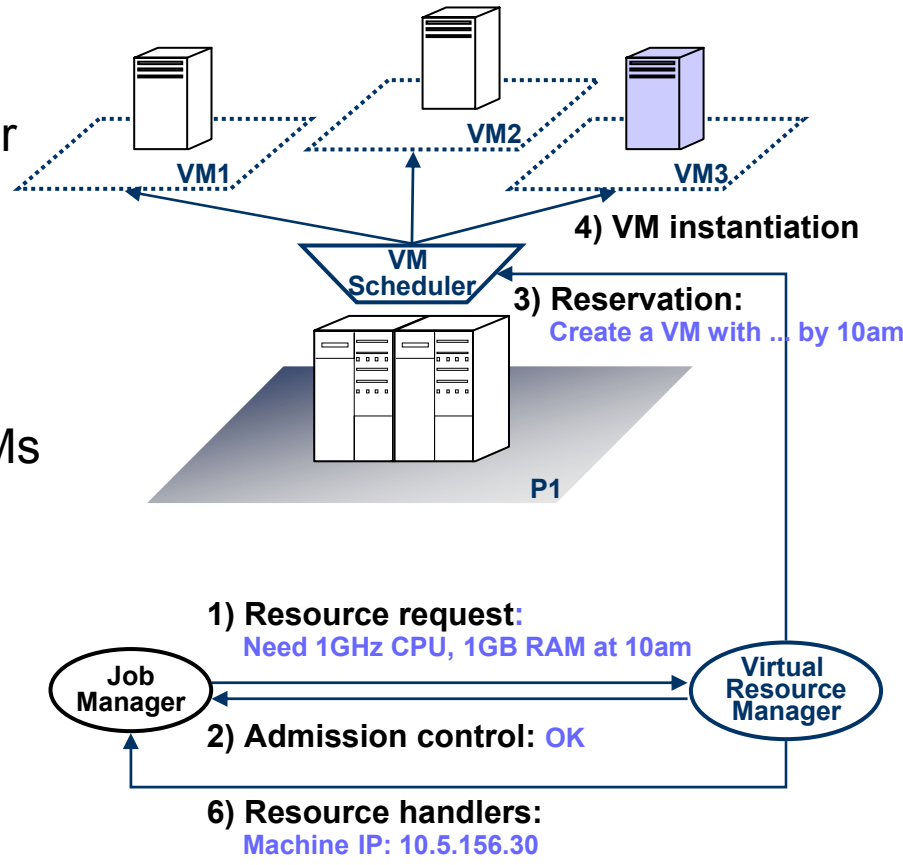
- Goal:
  - Efficient VM-based cluster resource reservation
- Challenge:
  - Vacate resources in time (to meet schedule) but not too early (to fully utilize resources)
- Solution:
  - Build a migration overhead model through experimental analysis

Outline

- Architecture
- Experimental analysis
  - Methodology
  - Migrating a single VM
  - Migrating a sequence of VMs
  - Migrating VMs in parallel
- Summary

VM-based Resource Reservation

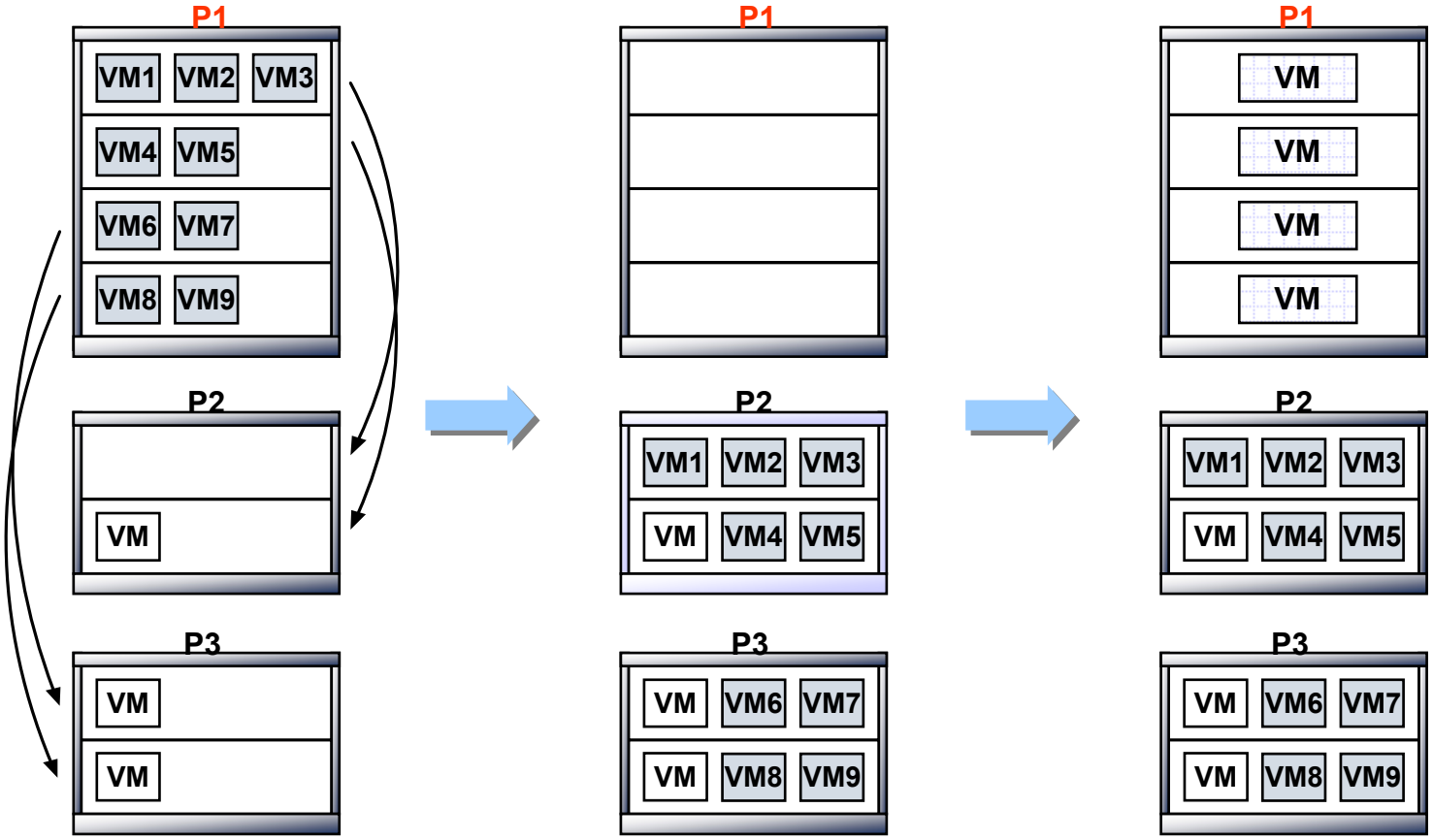
- Virtual resource manager
  - Global management of virtualized resources
  - Presents an abstracted interface for resource requests
  - Hides the complexity of using virtualized resources
  - Coordinates with VM schedulers to reserve, allocate resources with VMs



- Virtual machine scheduler
  - Per-host management of VMs
  - Presents a unified interface for managing VMs
  - Hides the complexity of using different VM software

VM Migration based Cluster Vacating

- Example



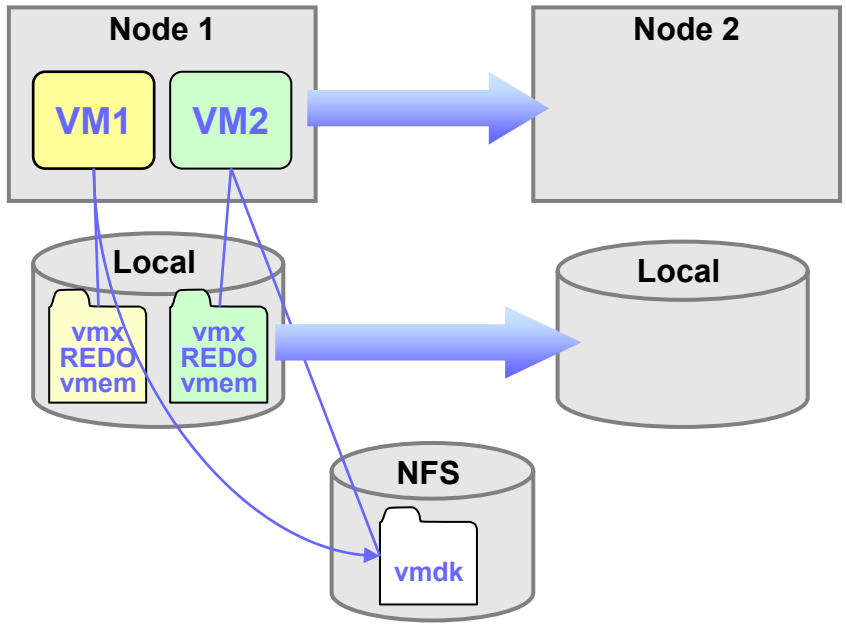
(I) P1 is shared by VMs running various workloads

(II) P1 is reserved by migrating the existing VMs to P2 and P3

(III) P1 is dedicated to the VMs created for a parallel application

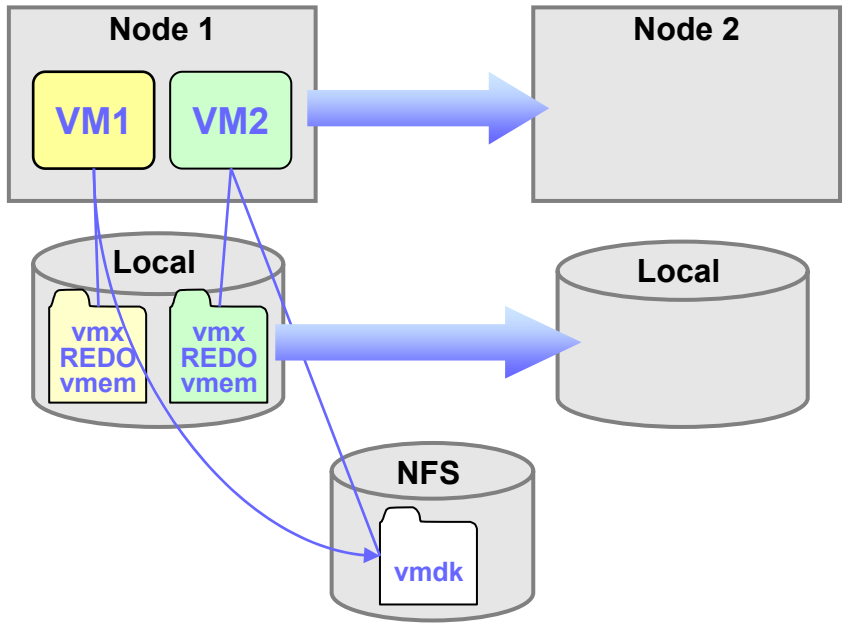
Experimental Setup

- Physical cluster
  - Each node has four CPUs (2.33GHz), 4GB memory
  - Gigabit Ethernet
- Virtual machines
  - VMware Server based
  - VM disk
    - Shared read-only image on NFS (.vmdk)
    - Independent changes (redo logs) on local disks (.REDO)
  - VM memory
    - Mapped to file (.vmem)
    - Stored on local disks



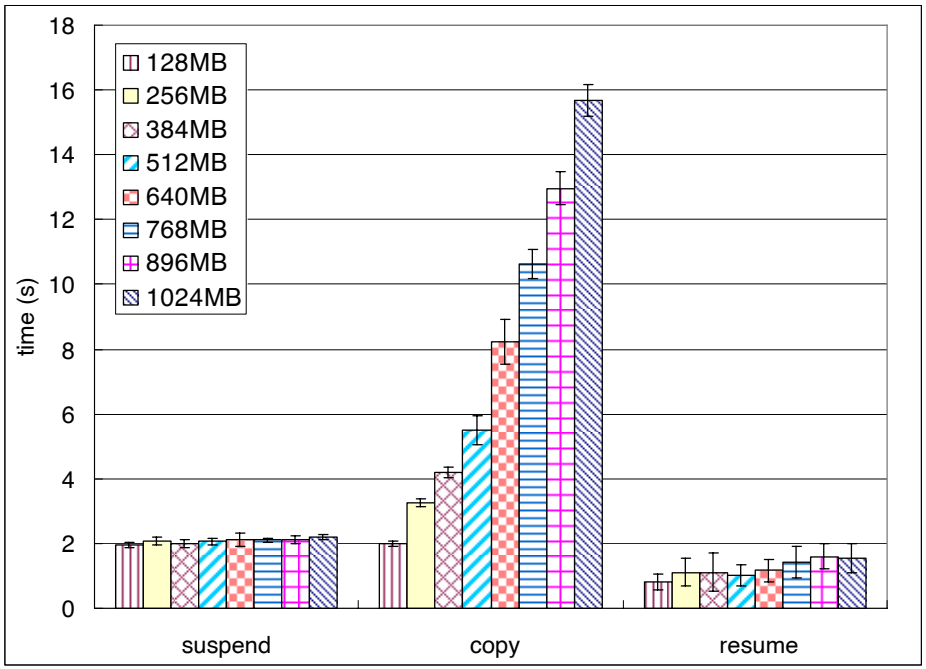
Experimental Setup

- Migration strategy
  - Suspend
    - Synchronizes memory state to file
  - Copy
    - Uses FTP to transfer memory state file, disk redo files
    - Maximum throughput is about 100MB/s
  - Resume
    - Restores memory state from file in foreground
  - Not based on VMware solutions (VMotion)

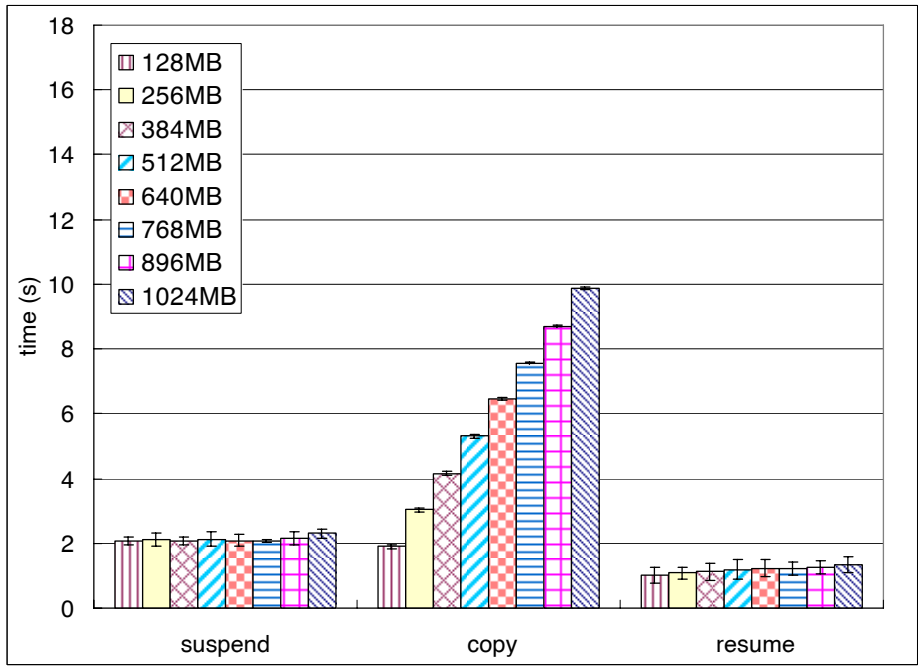


Migration Overhead of a Single VM

- Different memory sizes
  - Suspend and resume phases are fast
  - Copy time grows as memory size increases
- Different methods to store the migrated states
  - RAMFS removes the impact of disk I/Os to the migration process



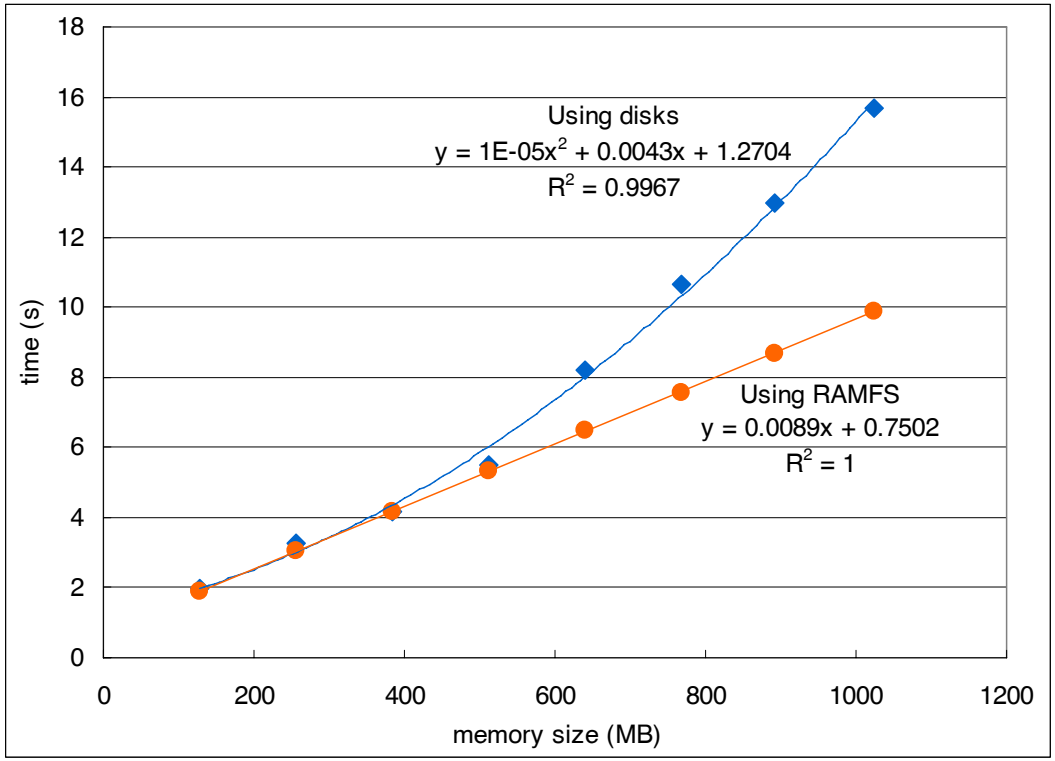
Using disks on the destination host to store migrated VM state files



Using RAMFS on the destination host to store migrated VM state files

Modeling Copy Phase

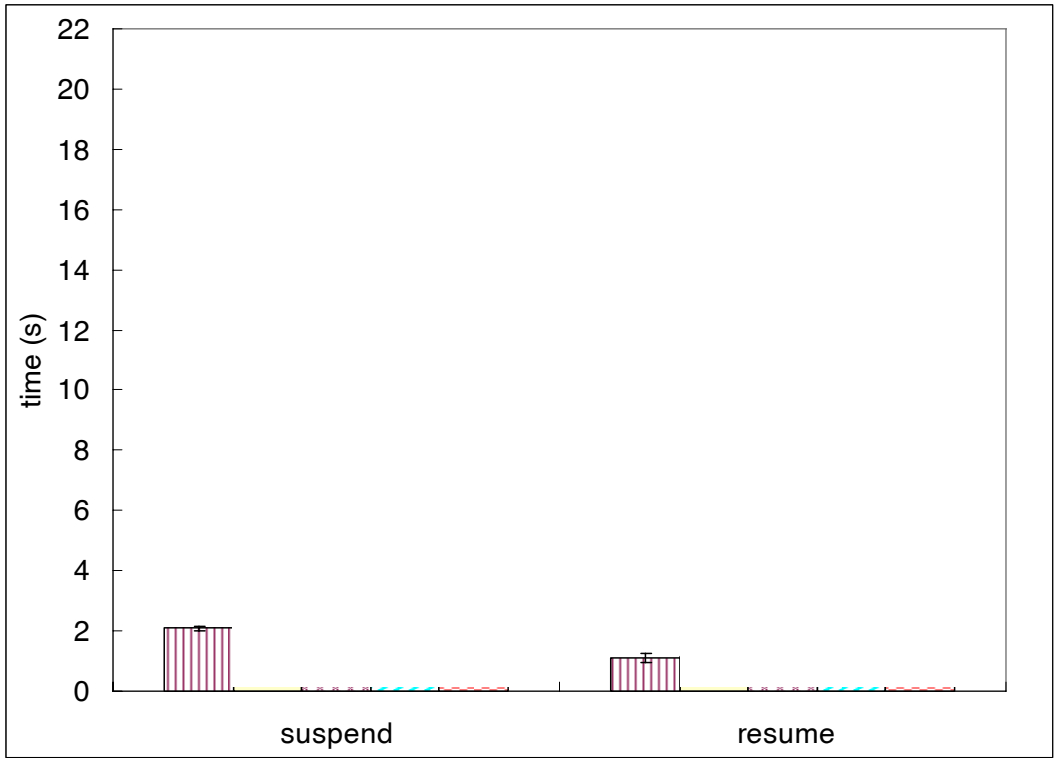
- Using regression methods
  - Polynomial for using disk, linear for using RAMFS
- RAMFS setup is used for all the following experiments



Using regression to model the copy phase

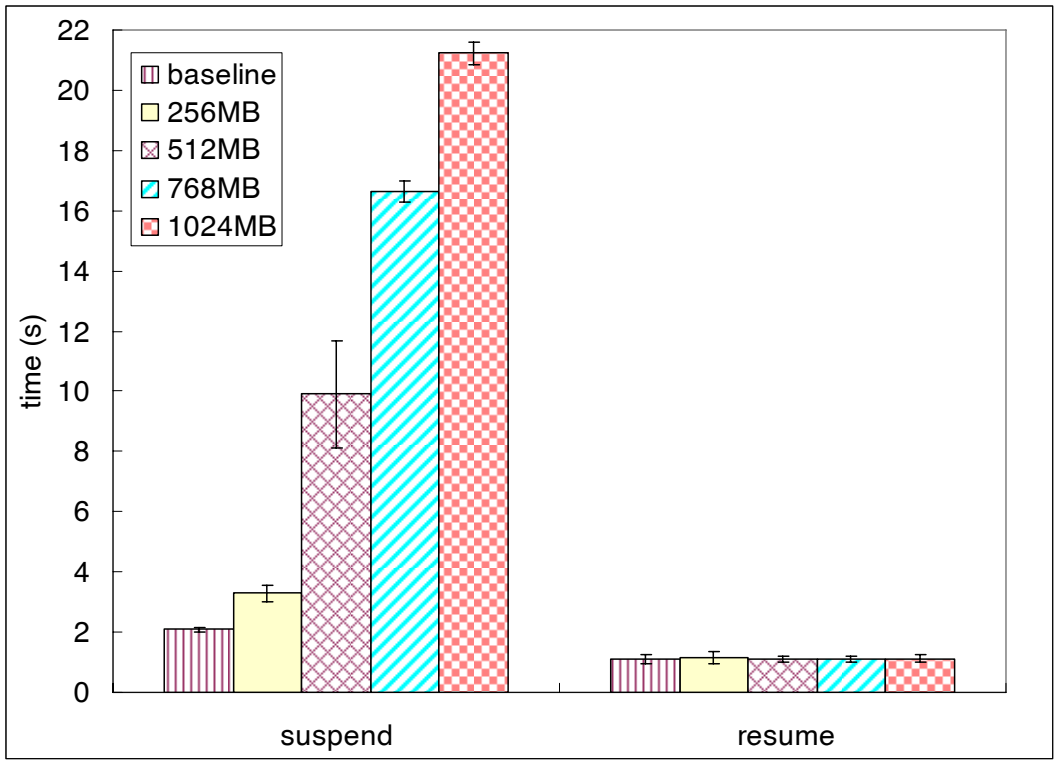
Modeling Suspend and Resume Phases

- Resume
  - Typically short: memory state is buffered after the copy phase
- Suspend
  - Typically short: memory state is frequently synchronized to file



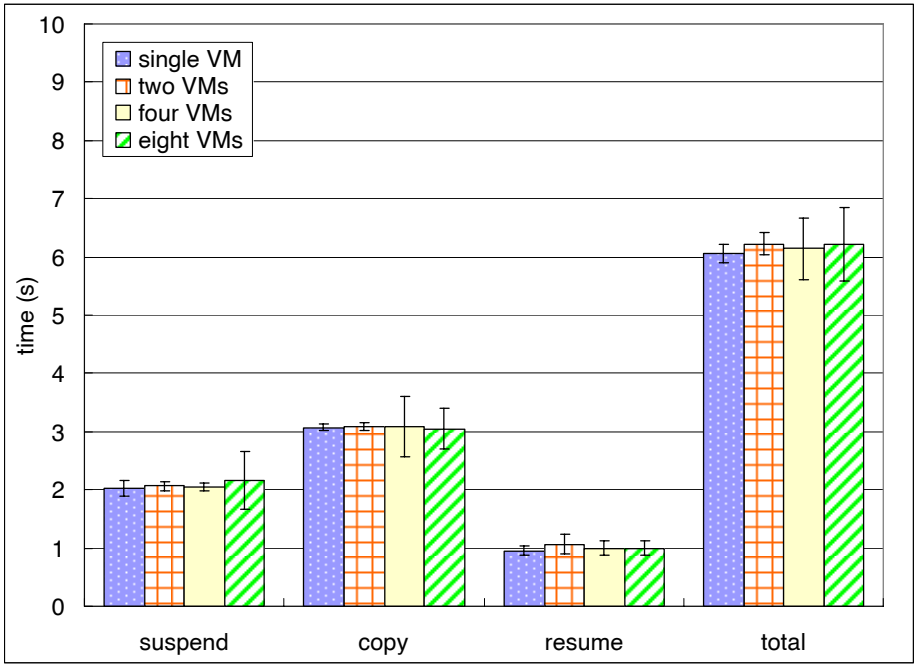
Modeling the Suspend and Resume Phases

- Running memory-intensive workload in the migrated VM
  - A “rogue” program that continuously modifies memory
  - Suspend time increases as more synchronization is needed

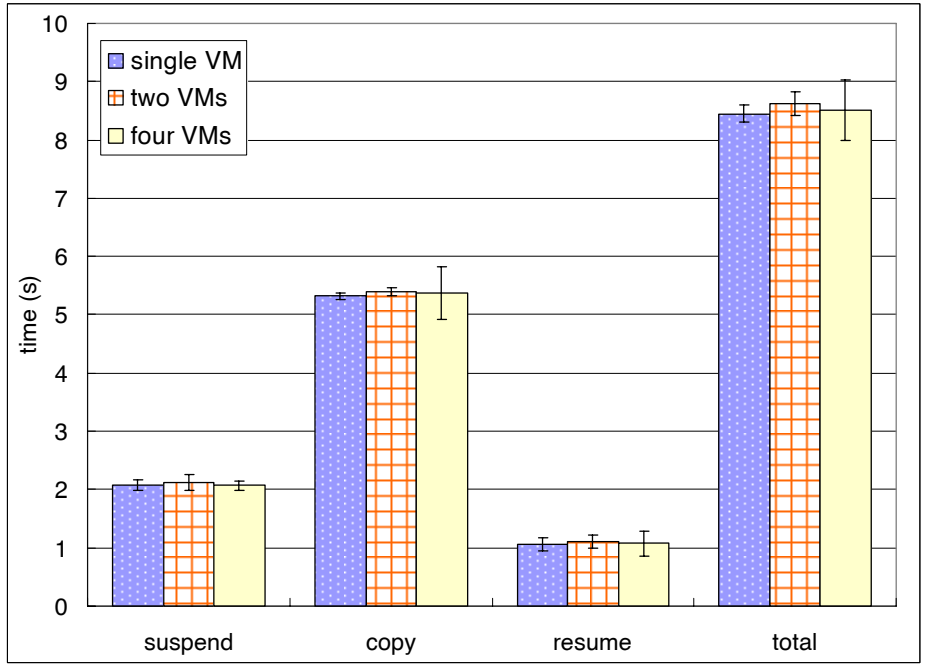


Migrating a Sequence of VMs

- Per-VM migration time is consistent regardless of the number of sequentially migrated VMs



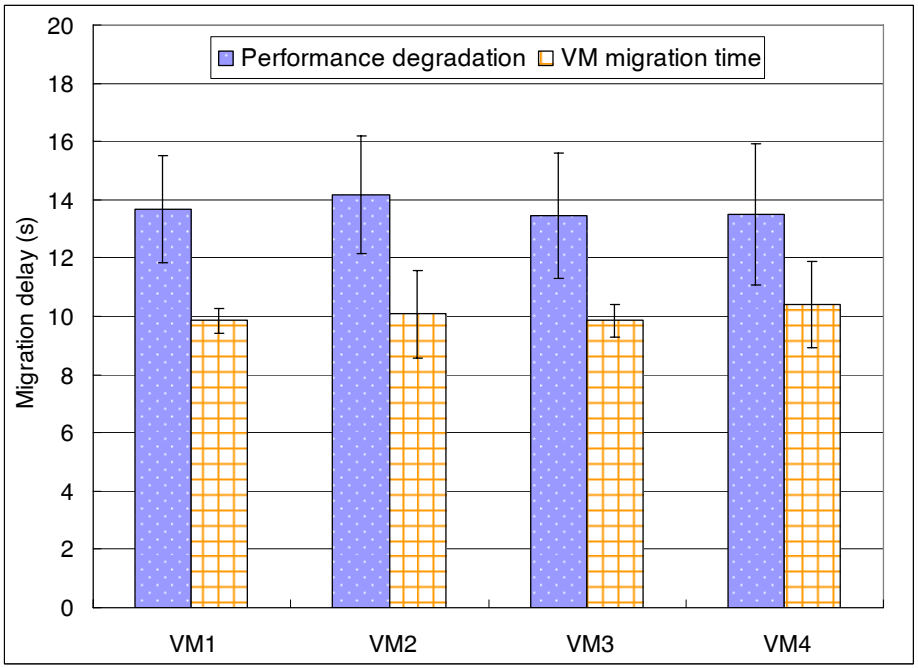
Per-VM migration time when migrating a sequence of 256MB-RAM VMs

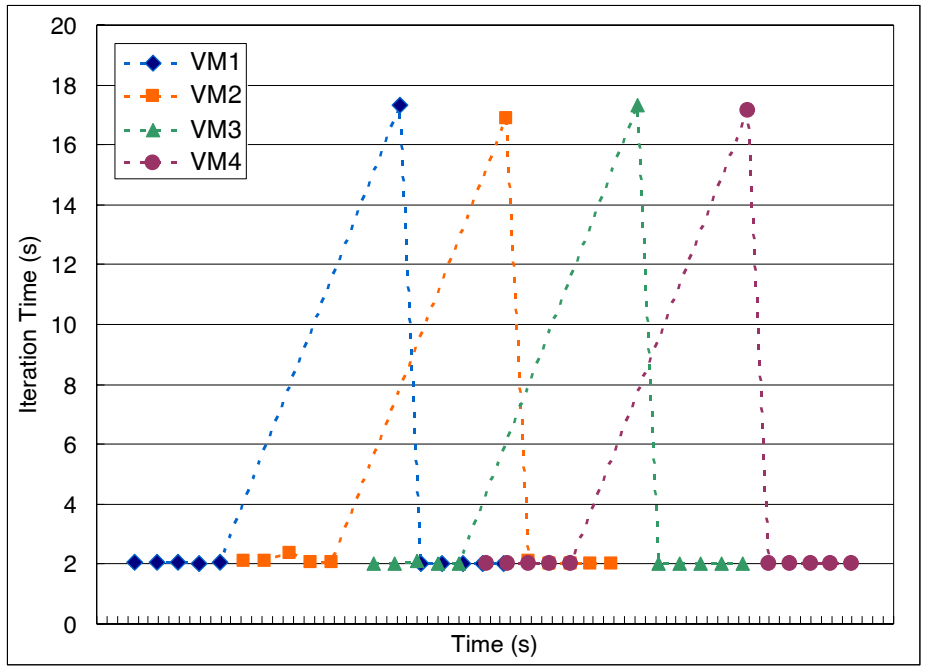


Per-VM migration time when migrating a sequence of 512MB-RAM VMs

Migrating VMs with CPU-intensive Workload

- CPU-intensive workload
  - Runs iteratively, consumes 100% of CPU
- Performance degradation
  - = Impacted iteration time – Regular iteration time
- Takes longer for applications in VMs to recover to full performance

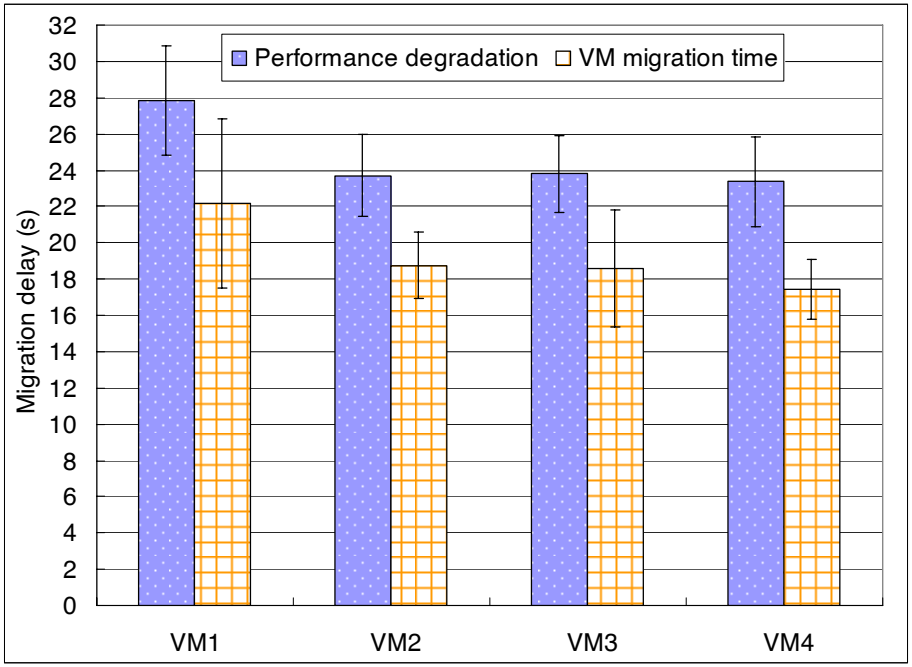


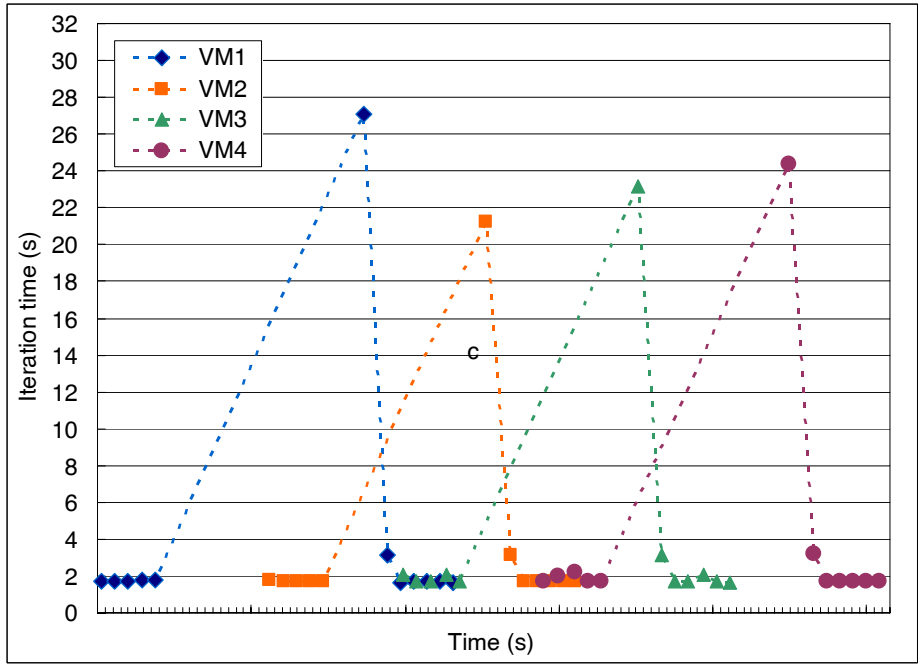


Migrating four VMs in sequence; each has 512MB-RAM and runs a CPU-intensive benchmark

Migrating VMs with Memory-intensive Workload

- Memory-intensive workload
  - Runs iteratively, touches 100% of memory
- Performance degradation
  - = Time of 2 impacted iterations – Regular iteration time * 2
- Migration is a more memory intensive process

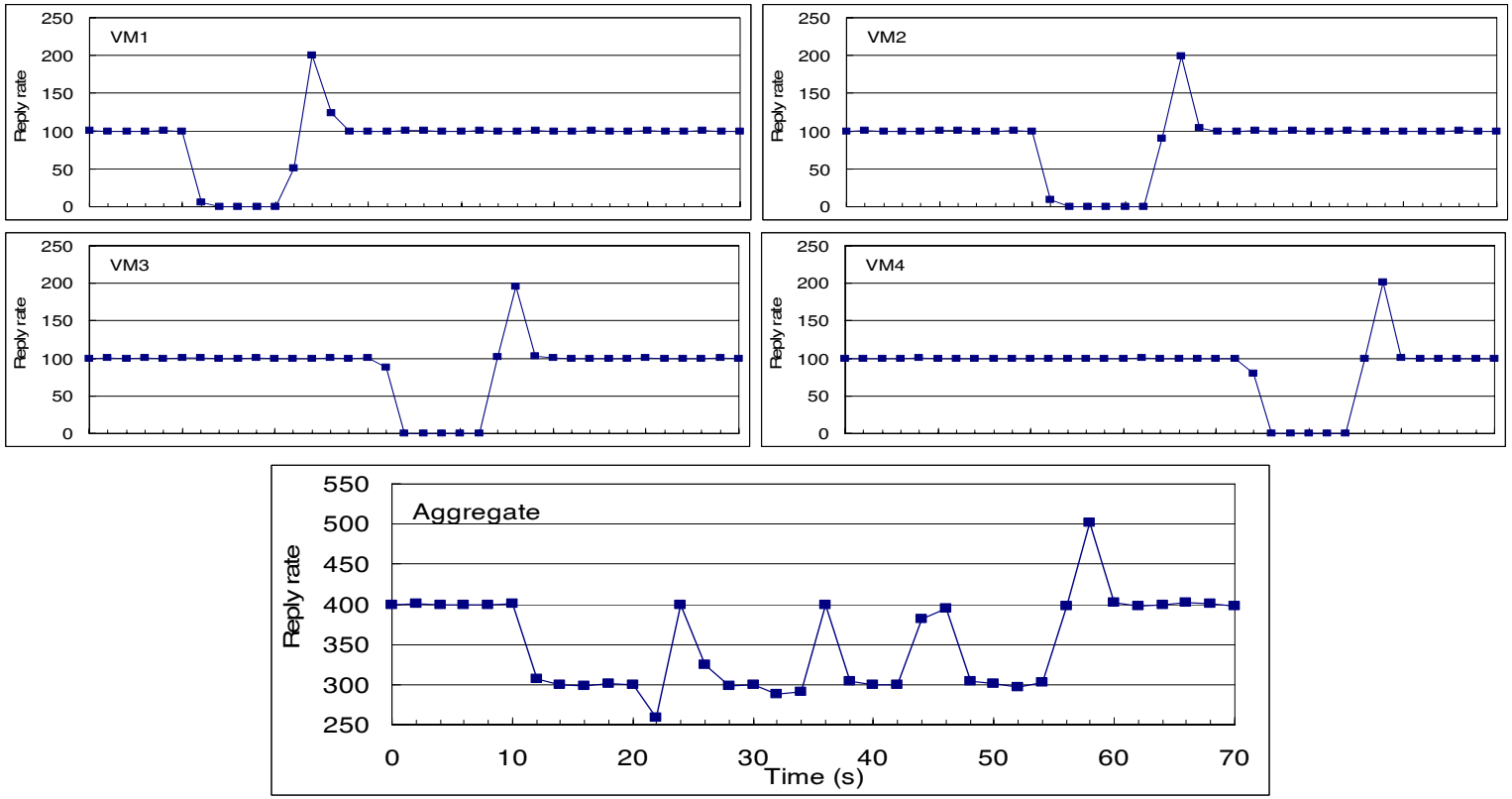




Migrating four VMs in sequence; each has 512MB-RAM and runs a memory-intensive benchmark

Migrating VMs with Web Workloads

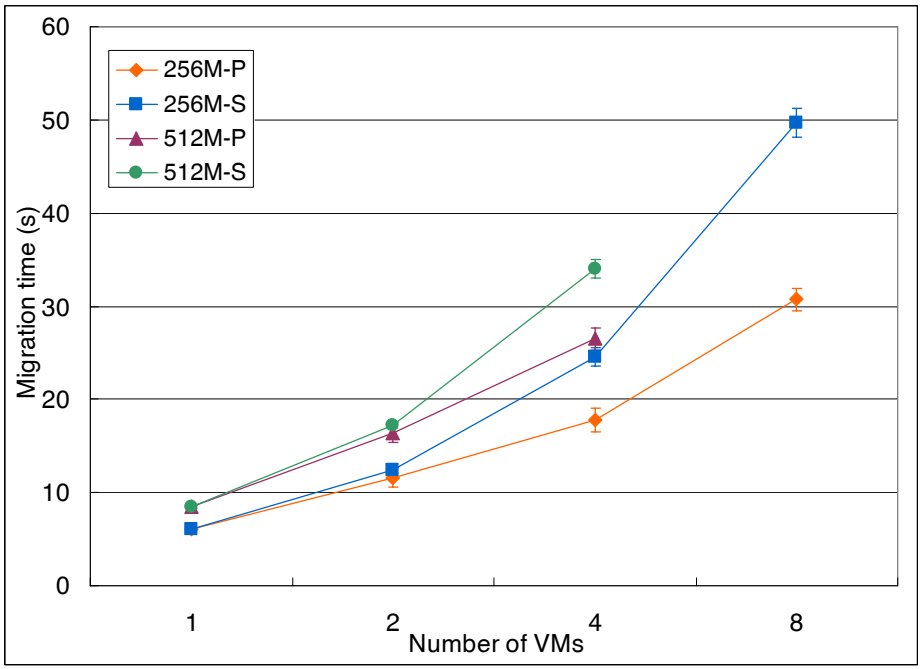
- Apache Web server
  - Serves constant-rate requests from outside clients (100 request/s each)
  - Takes longer for the throughputs to recover



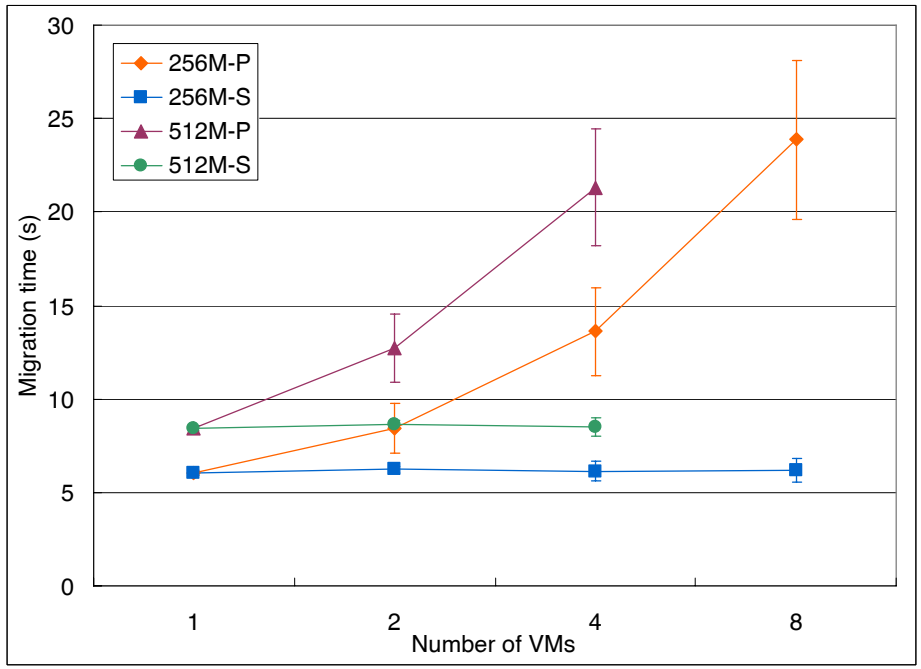
Migrating four VMs in sequence; each has 512MB-RAM and runs a Web server

Migrating VMs in Parallel

- Parallel migration has shorter total migration time
  - Faster vacating of cluster resources
- Sequential migration has shorter per-VM migration time
  - Less impact on the applications in the VMs



Total migration time



Per-VM migration time

Related Work

- VM-based resource management
  - In-VIGO
  - Virtual workspaces
  - Virtuoso
  - Shirako
- VM migration based resource reallocation
  - VIOLIN
  - Sandpiper
- VM migration optimizations
  - VMware VMotion
  - Xen live migration

Summary

- Conclusions:
  - It is feasible to predict the migration time of VMs with different configurations and different numbers
  - It takes longer for a VM's application to recover than the VM migration time
  - Sequential migration has less impact on VMs' applications
  - Parallel migration is faster for migrating multiple VMs

- Future work:
  - Generalizes and validates the model across different physical platforms, with different VM technologies
  - Considers modeling of live migrations

Acknowledgement

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  - http://www.acis.ufl.edu/dddasbmi
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- **Questions?**
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