SAND2010-3174C

Using Cloud Constructs and Predictive Analysis to Enable Pre-Failure Process Migration in HPC Systems

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This work was supported by the United States Department of Energy, Office of Defense Programs. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

Outline

- Motivation
  - Current resource allocation models
  - How resource utilization monitoring and dynamic configuration can improve performance
- System
  - Virtualization for HPC (MPI) Apps
  - Resource Characterizations
  - Resource Manager
  - Orchestration
- Examples
  - Resource health degradation
  - Resource contention

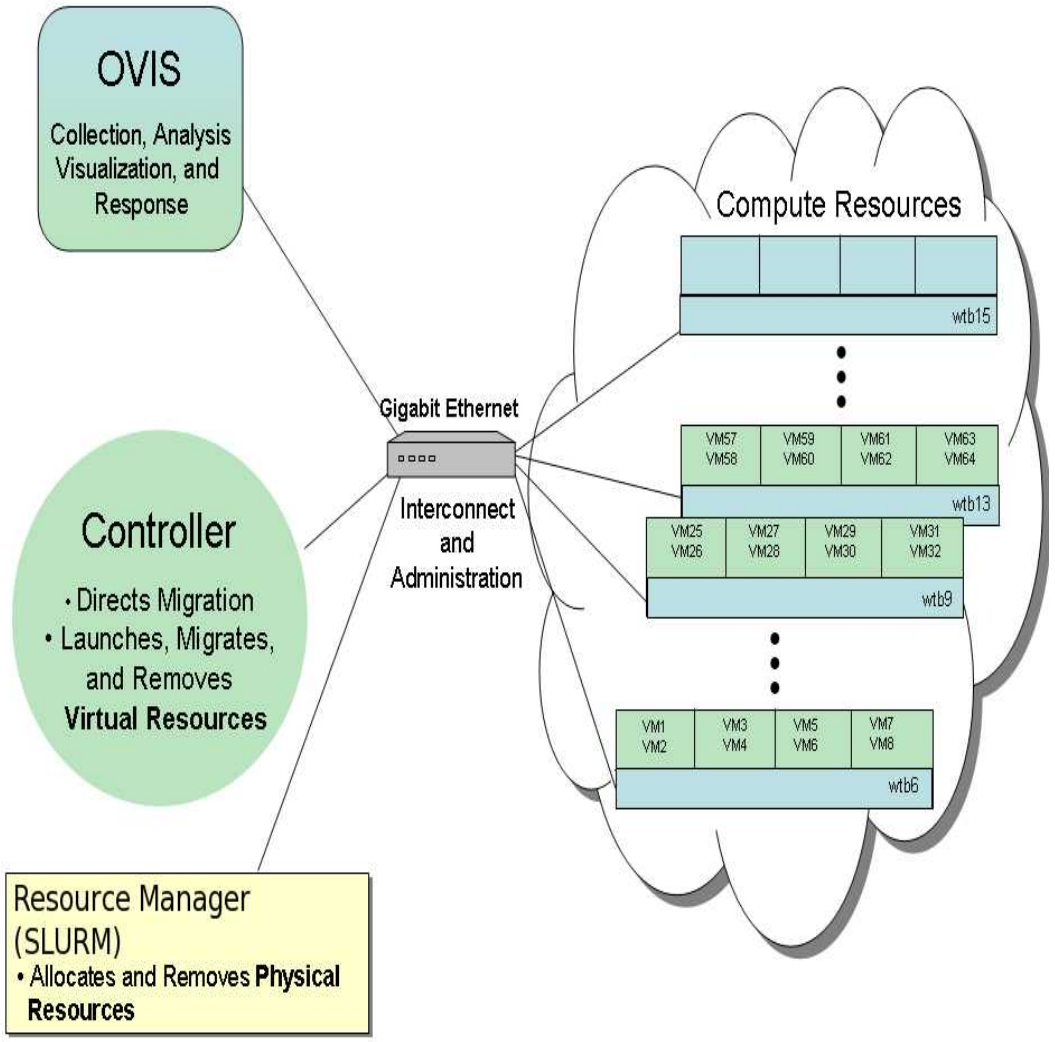
Motivation

- Future architectures will have vastly increased numbers of processing elements per node and more shared subsystem resources (e.g. cache, main memory bus, network)
  - Increased likelihood of contention (e.g. memory and communication buses) within an applications processes and among multiple applications
- Dynamic reconfiguration could enable increased system performance
  - Progress in the face of resource failure

Components and Enabling Technologies

- Scalable monitoring and analysis system
  - Provides real-time fine-grained collection and analysis of hardware state information
  - Provides facility for obtaining meaningful real-time, low-level resource utilization information
- Low overhead virtualization technologies
  - Provide simple process level mobility that can enable dynamic resource re-balancing in response to application requirements, system state, and/or failure prediction
- Advanced resource manager/scheduler
  - Manage and allocate both physical and virtual resources
- Controller
  - Orchestrate allocation, evaluation, and re-balancing of resources with respect to the applications running on a system, their resource requirements, and priorities

Prototype HPC System for Pre-failure Process Migration



- Resource monitoring and characterization – OVIS
- Resource Manager – SLURM
- Controller
  - Dynamic mapping of virtual to physical resources
  - Orchestrates and controls launch and migration of virtual resources
  - Requests and releases physical resource allocations
- Compute Resources
  - Base physical infrastructure on which virtual resources are hosted and applications run
- Gigabit Ethernet interconnect
  - Communication infrastructure for both application and system administration

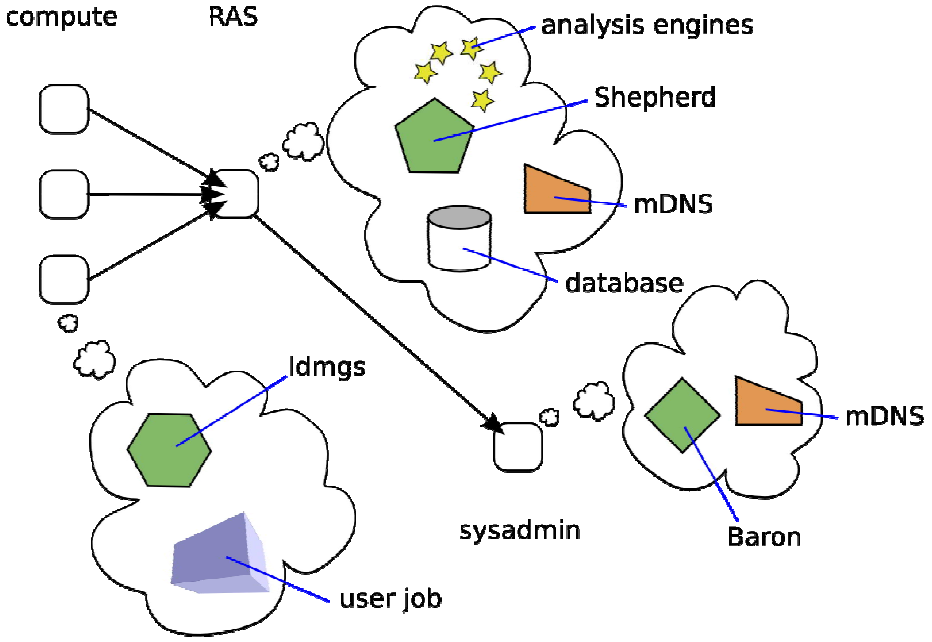
Running HPC (MPI) Applications in a Virtualized Environment

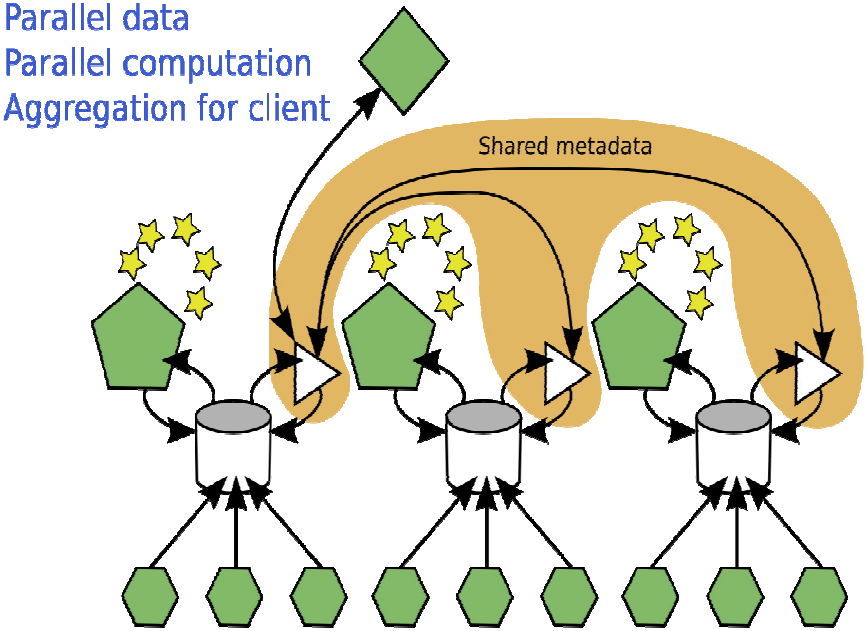
- Overhead
  - Claims of from zero to 3% depending on which flavor is being used and tuning
  - We ignore this aspect in this work as studies show it is currently viable and getting better
- Provisioning and Mobility for MPI Applications
  - MPI_Barrier wrapper as an easy way to ensure against in-flight message loss
    - Only Migrate at a barrier
  - Dr. Panda has included facility for addressing this in the context of Xen Para-virtualization in MVAPICH

Dynamic Reconfiguration using Live Migration

- Migration of virtual machine while application processes are still running
  - Migration time bounded by Gigabit Ethernet interconnect speed
- Use simple MPI_Barrier wrapper to coordinate migration with application
  - Only perform migration at MPI_Barrier
  - Checks for flags written by the Controller
  - Coordination across all MPI ranks so no in-flight messages lost
  - Minimize changing process state

Scalable Resource Monitoring and Analysis Architecture (OVIS)





Actionable Pre-failure Resource Characterizations

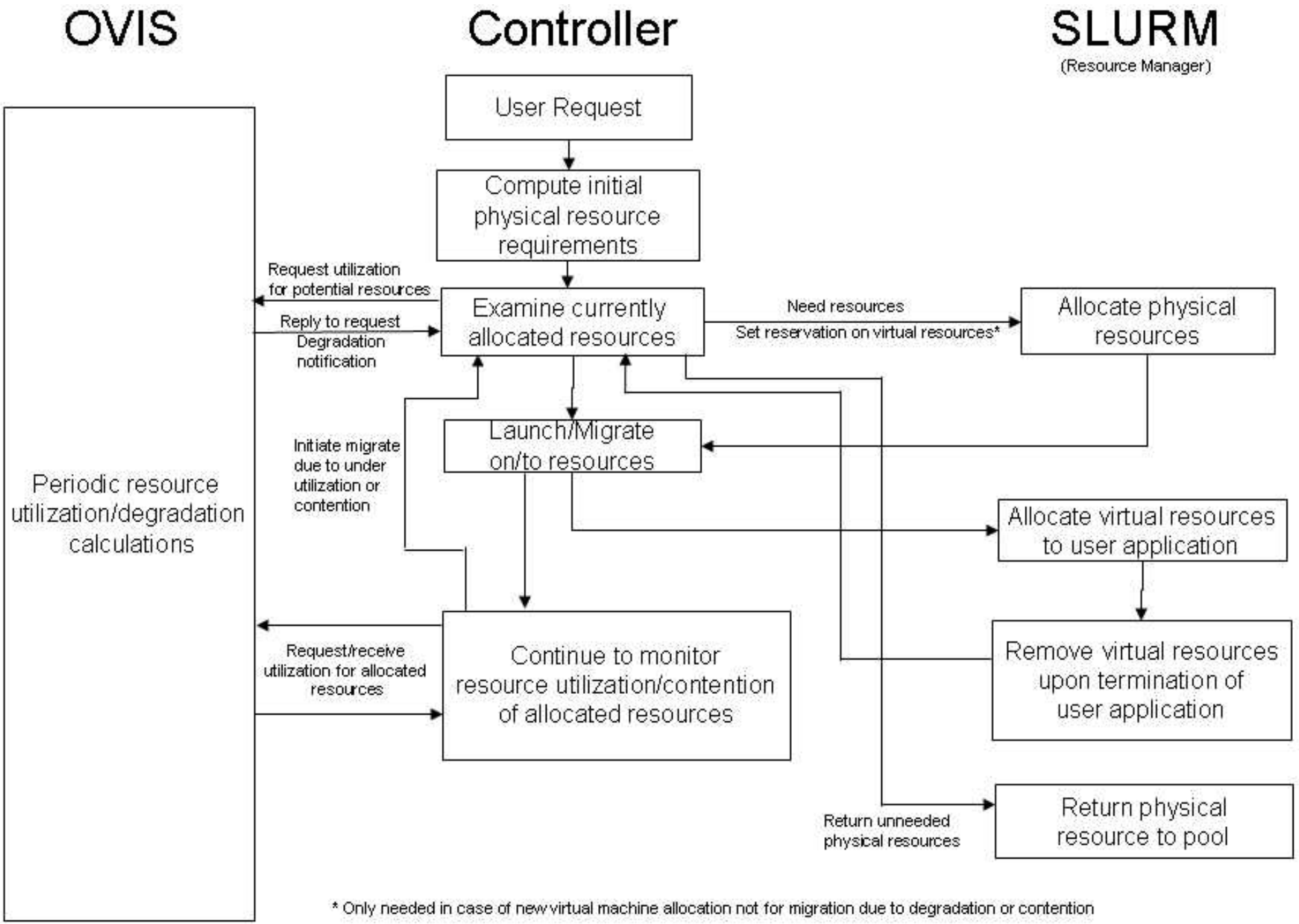
- Understand dynamic application resource characteristics
- Provide run-time profiling to detect performance issues and state change (e.g. increasing active memory utilization)
- Identify possible pre-failure conditions
  - CPU utilization, memory (including caches), internal buses, network
- Identify anomalous behavior
  - Relative to other resources hosting similar processes in similar environment
- Determine efficacy of reconfiguration: frequency, overhead, impact

Resource Manager

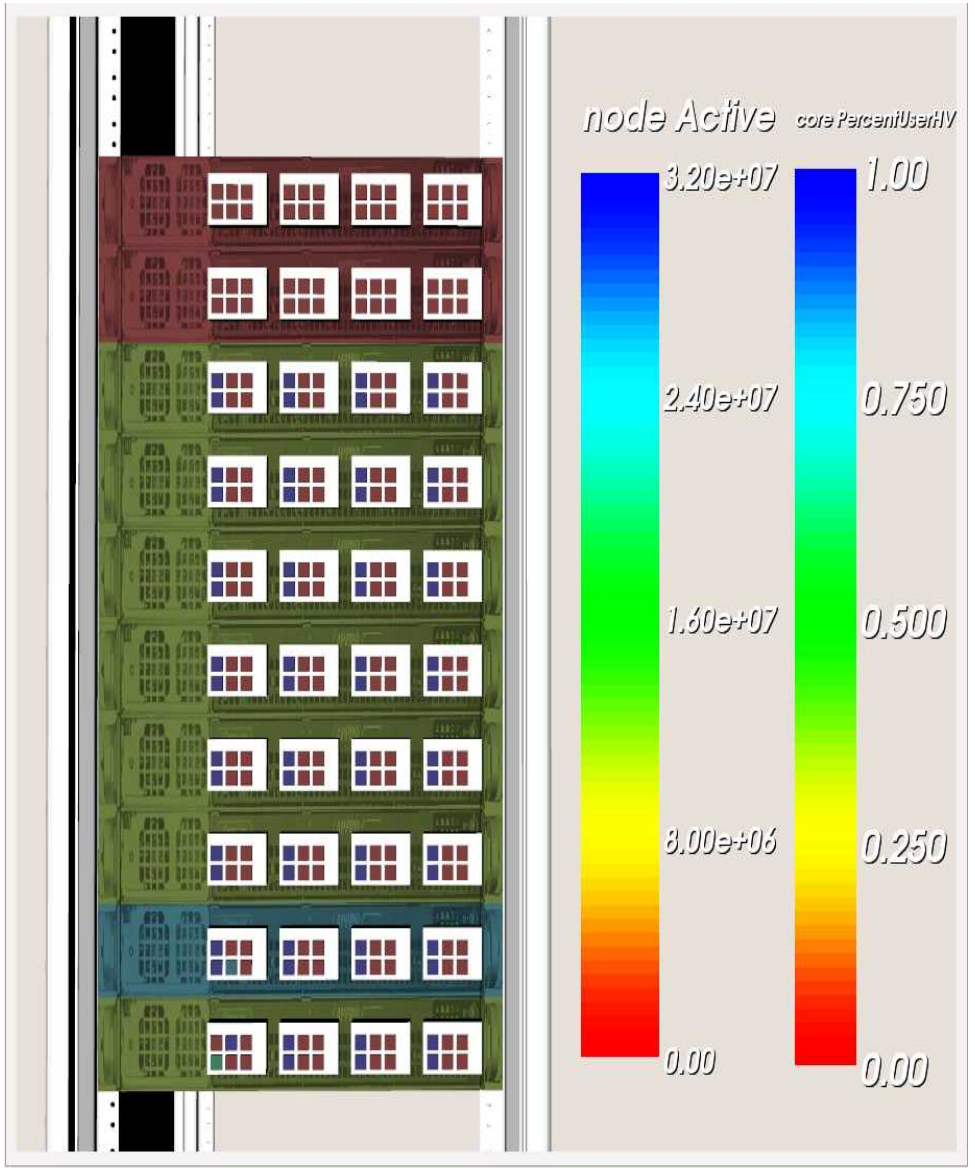
SLURM – Simple Linux Utility for Resource Management

- Can maintain separate resource partitions
  - Used separate **physical** and **virtual** resource partitions
- Supports resource allocation on a per-node, per-socket, and per-core granularity
  - Requested physical allocations on a **per-node** granularity
- Does not innately support virtual to physical resource mappings
- Does not currently support additional resource allocations to jobs

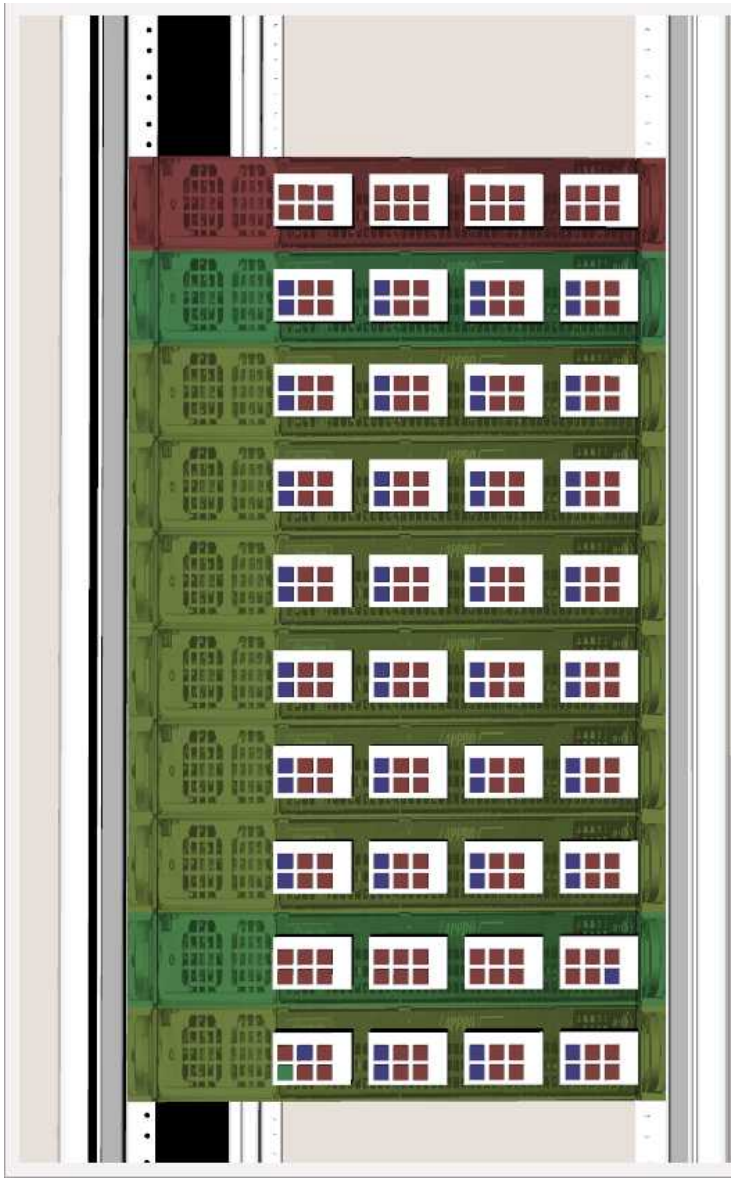
Orchestrating System Interactions



Example: Health Degradation

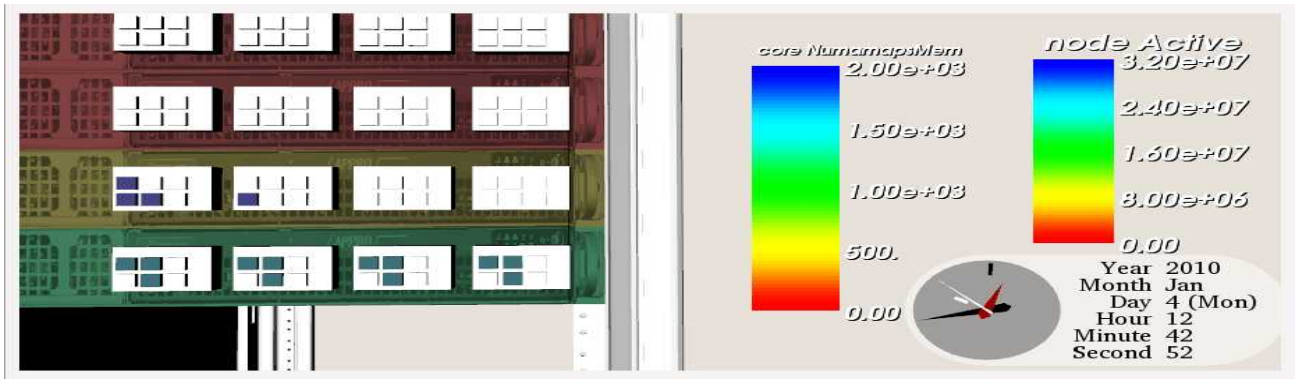


Anomalous condition detected



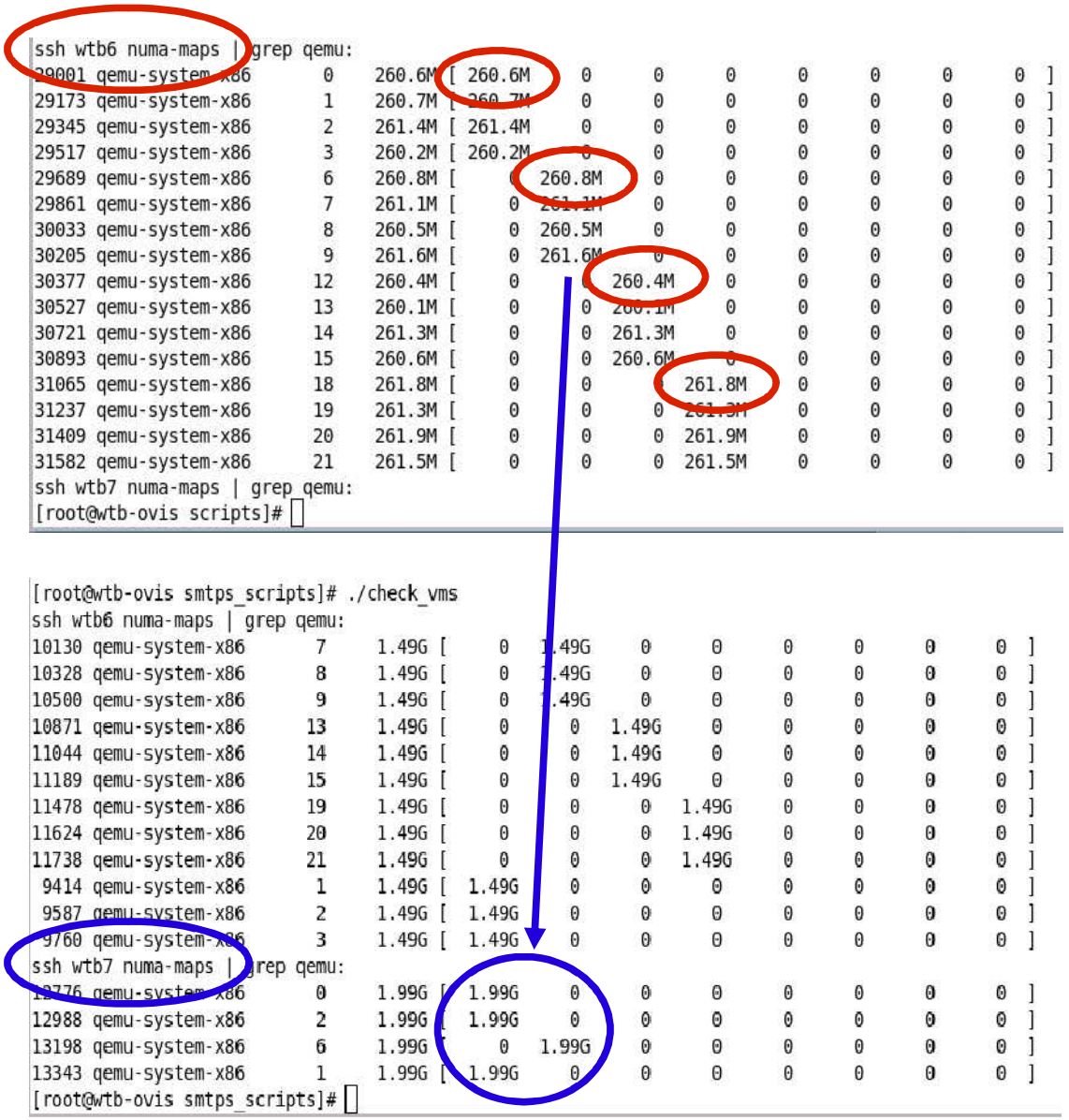
Anomalous condition mitigated via dynamic resource allocation and migration

Contention Detection Triggers Live Migration



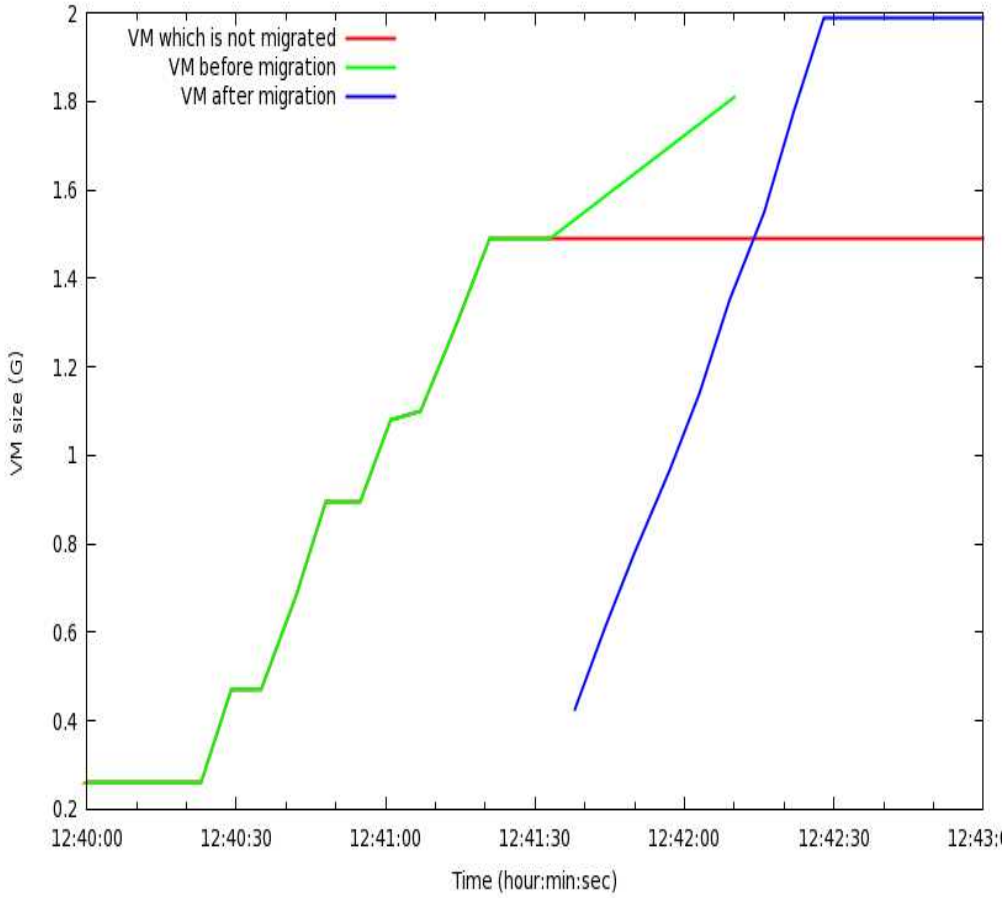
- 1VM/Core, 4VM/Socket
- Bind to 8GB of memory associated with socket
- Migration triggered by run-time detection of impending memory oversubscription
- Triggering (top)
- Migration occurring (middle)
- Migration complete (bottom)

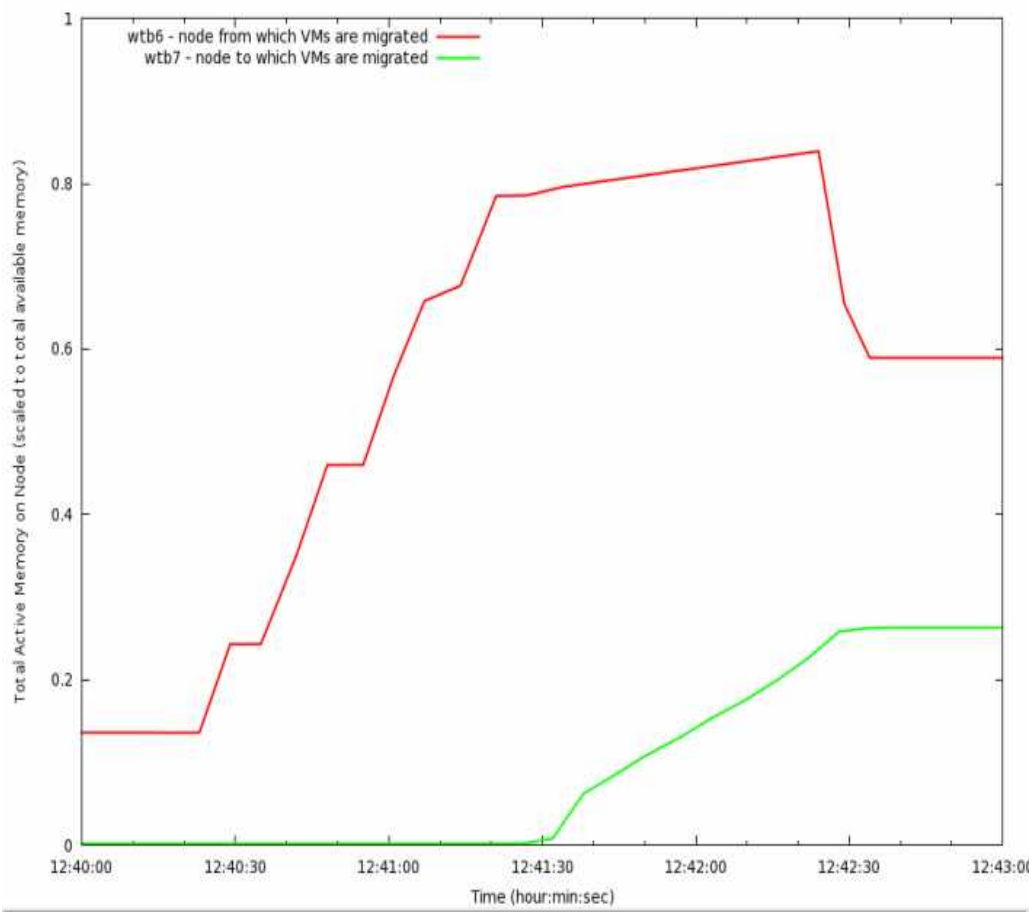
Example HPC Usage Model Leveraging VM Characteristics



- Container size at launch is minimum (top)
- After migration is maximum (bottom)
- Intentional oversubscription of resources
  - Start application on fewer resources and adjust as needs change and resources become available

Memory Utilization Monitoring





Future Work

- Determine resource characterizations of interest
- Decision making – When to migrate and where in environment with many applications running and sharing resources
- Efficacy of response – don't want to migrate too often, don't want to migrate to resources that will result in cascading bad effects
- Robustness of integrated system – Scalability and stability

Questions?

Resource View Considerations in Virtualized Environments

- Resource utilization looks different from the host than from the VM
  - Host view shows actual CPU utilization ----->
  - VM view shows actual memory footprint of application (described later)