VIRTUALPOWER: COORDINATED POWER MANAGEMENT IN VIRTUALIZED ENTERPRISE SYSTEMS
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SOSP '07: PROCEEDINGS OF TWENTY-FIRST ACM SIGOPS SYMPOSIUM ON OPERATING SYSTEMS PRINCIPLES
STEVENSON, WASHINGTON, 2007

Summarized by:
Chris Everett
CS 895 – Autonomous Computing
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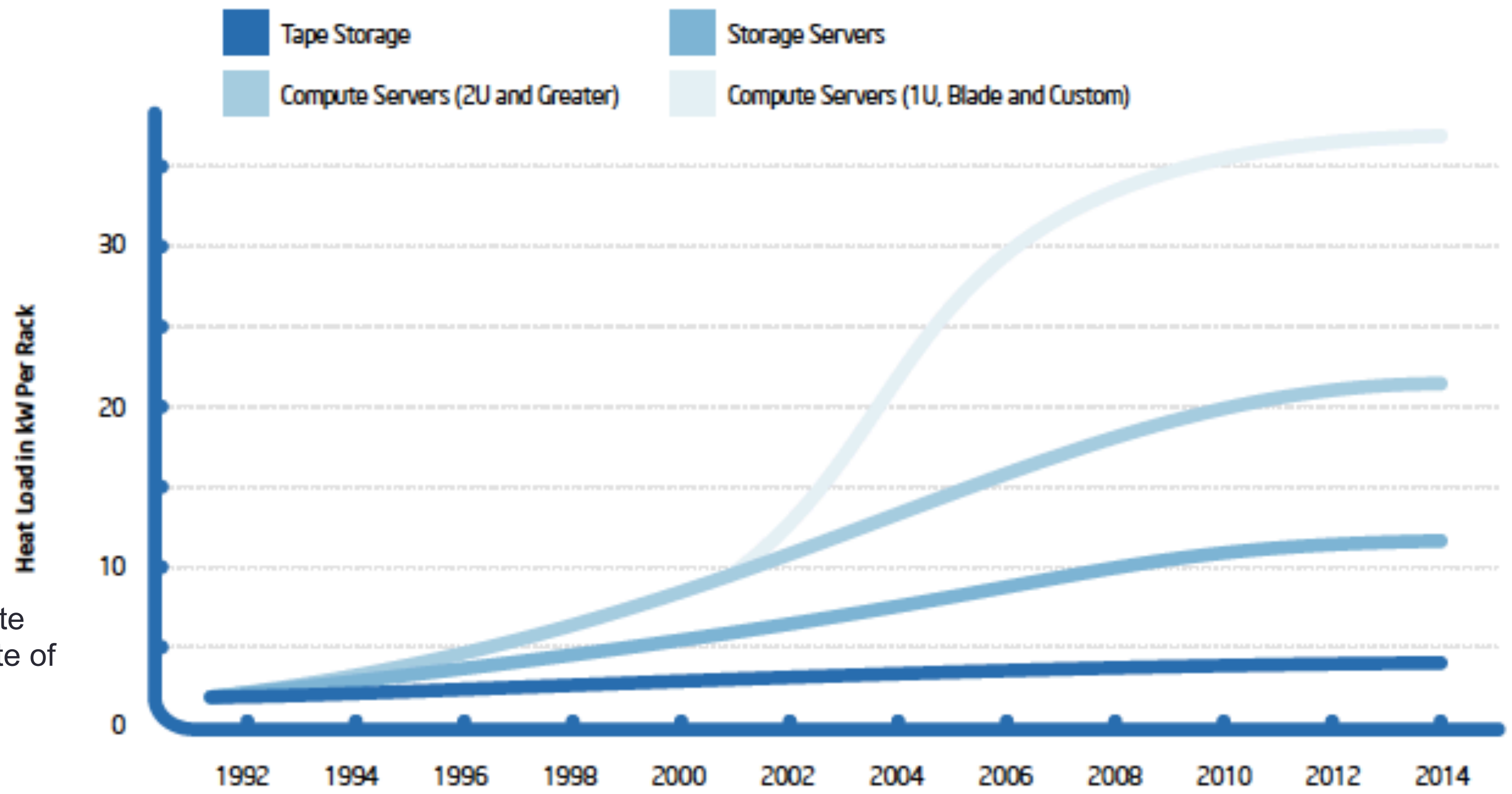
From: Intel White Paper, The State of Data Center Cooling, March 2008

Figure 3: NMSC, the world's third fastest supercomputer hosted by Intel in Rio Rancho, NM.

Motivations

- Data center delivery limitations
  - Power
  - Cooling
- Data center cost limitations
  - Power
  - Cooling



From: Intel White Paper, The State of Data Center Cooling, March 2008

Figure 1: Adapted from ASHRAE's projected density loads (kW per Rack) for IT equipment.[4]

Virtualization with Power Management

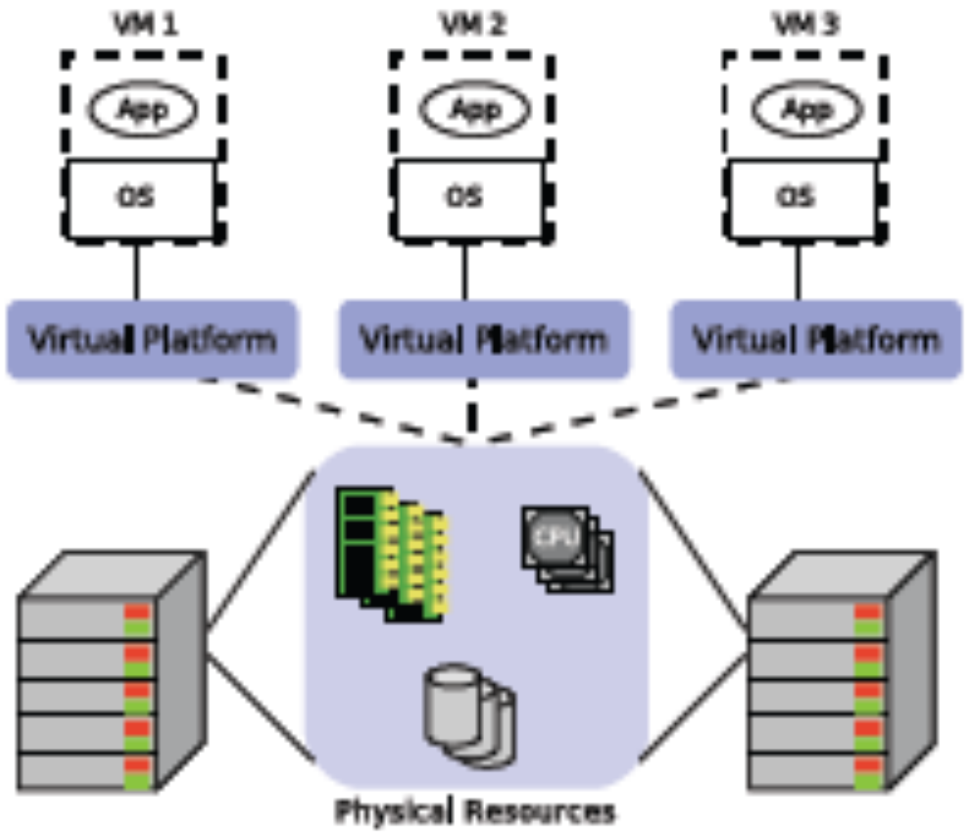
- Soft and hard power scaling
  - Soft → limit hardware usage by guest virtual machines
  - Hard → hardware support (e.g., processor frequency scaling)
- Independence and coordination
  - Independence → each guest virtual machine performs power management
  - Coordination → global coordination of individual guest virtual machine and global goals
- Flexibility in management
  - Heterogeneous hardware in data centers
  - Applications with different SLAs

Contributions

- Study of power management in virtualization
- VPM channels and states for power/ performance trade-offs
- Multiple management actuators using VPM channels and states
- Evaluation of VPM channels and states
  - 31% reduction in power consumption using VPM rules
  - 17% reduction in power consumption using tiered VPM rules
  - 34% reduction in power consumption using runtime consolidation

Infrastructure

- Fault isolation
- Independence
- Performance isolation
- Easy migration across different physical machines



From: Figure 1 of VirtualPower Paper

Figure 1: Scalable Enterprise Infrastructure.

VPM Architecture

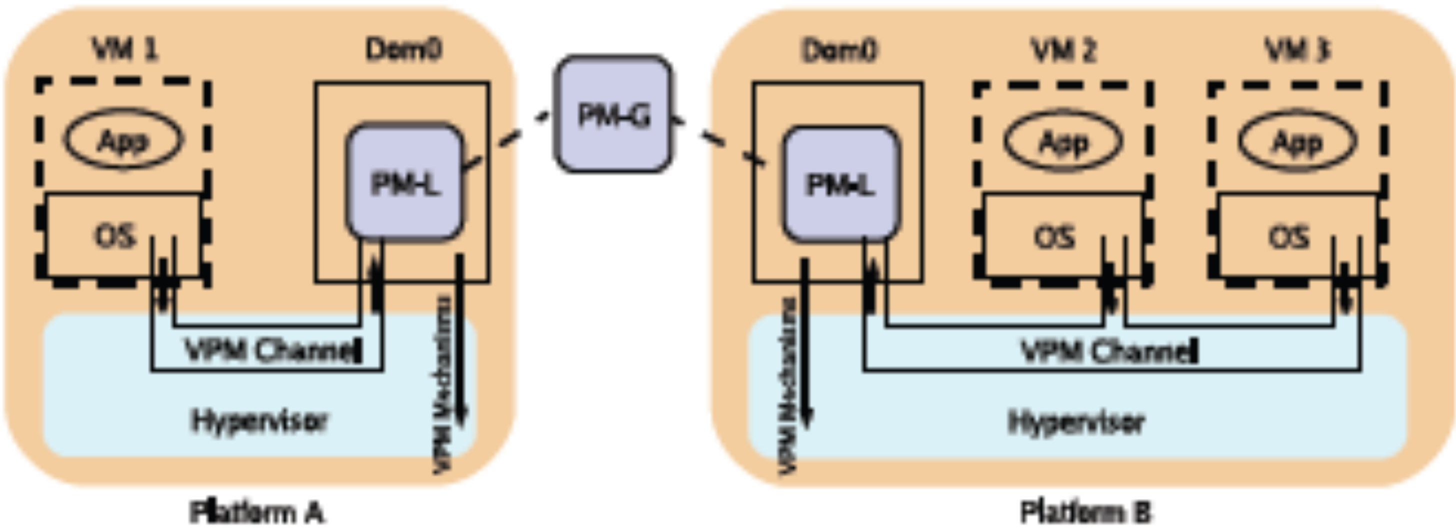


Figure 3: VirtualPower Management Architecture.

- VPM states
- VPM channels
- VPM rules
- VPM mechanisms

States

Table 1: VPM State Definitions.

VPM State	Hardware	Soft (Scheduler)	
	CPU	Work-conserving	Slice
3.2GHz	3.2GHz	Yes	-
2.8GHz	2.8GHz	Yes	-
	3.2GHz	No	88ms
2.0GHz	2.8GHz	No	71ms
	3.2GHz	No	63ms
1.6GHz	2.8GHz	No	57ms
	3.2GHz	No	50ms
800MHz	2.8GHz	No	29ms
	3.2GHz	No	25ms

From: Table 1 of VirtualPower Paper

Channel

From: Figure 3 of VirtualPower Paper

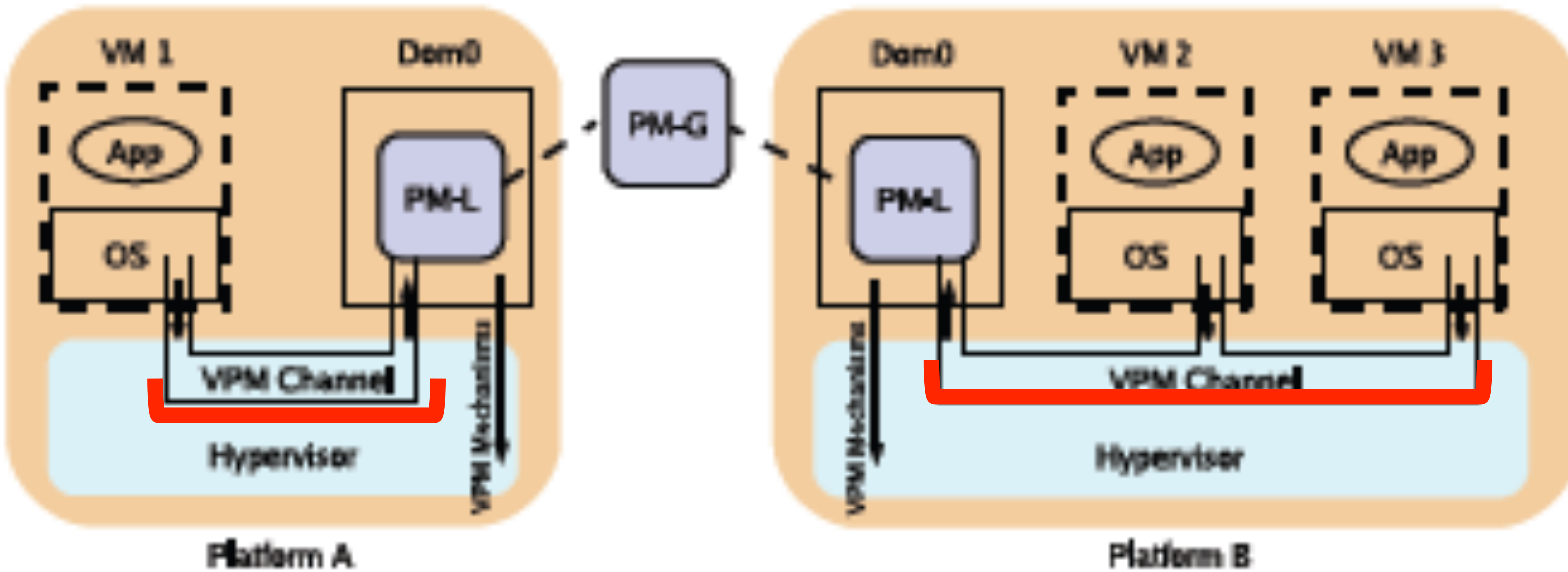


Figure 3: VirtualPower Management Architecture.

- Communication channel between virtual machines and controller
- Captures requests from virtual machines

Rules

- Tiered policy approach
  - Local
    - Perform actions corresponding to resources on local platforms
    - Resides in controller of local machine
  - Global
    - Responsible for coordinating global decisions
    - Example: VM migration
- For example: throttle power consumption for period of time

Mechanisms

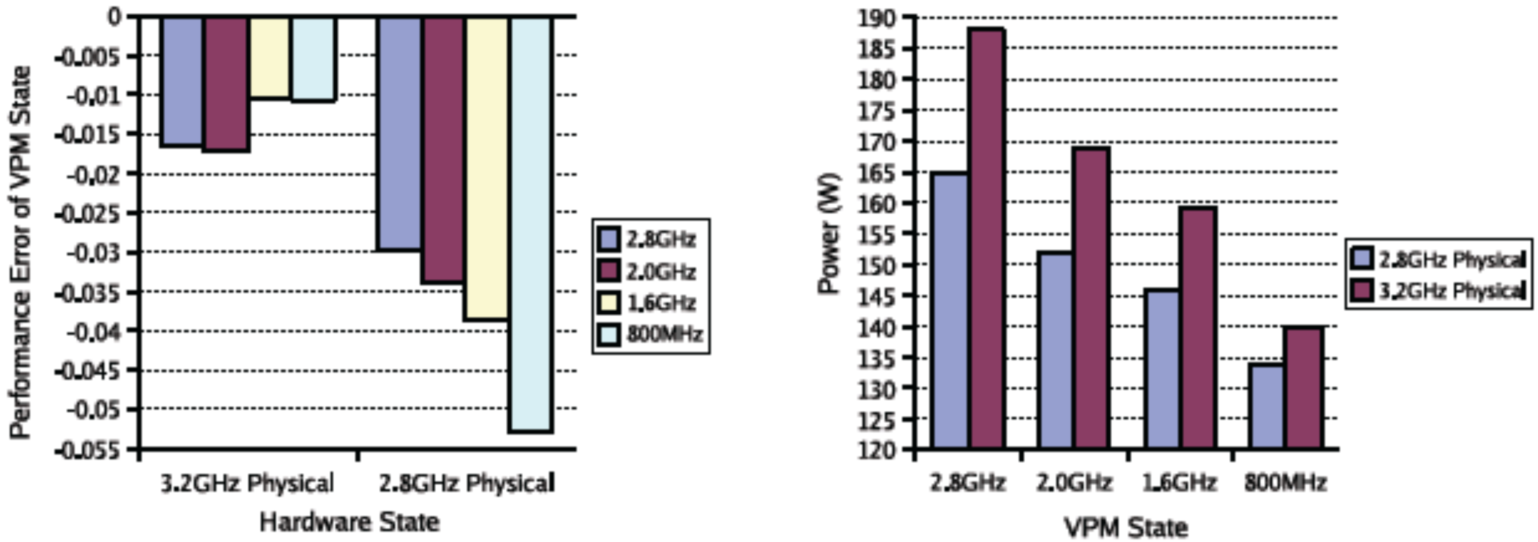
- Hardware scaling
  - Vary across platforms and devices
  - VPM rules set hardware states
- Soft scaling
  - Scheduling management
  - Uses feedback loops
- Consolidation
  - Based on soft scaling to fully utilize hardware
  - VM re-mapping or migration

Experimental Setup

Figure 4: Power Measurement Setup.

From: Figure 4 of VirtualPower Paper

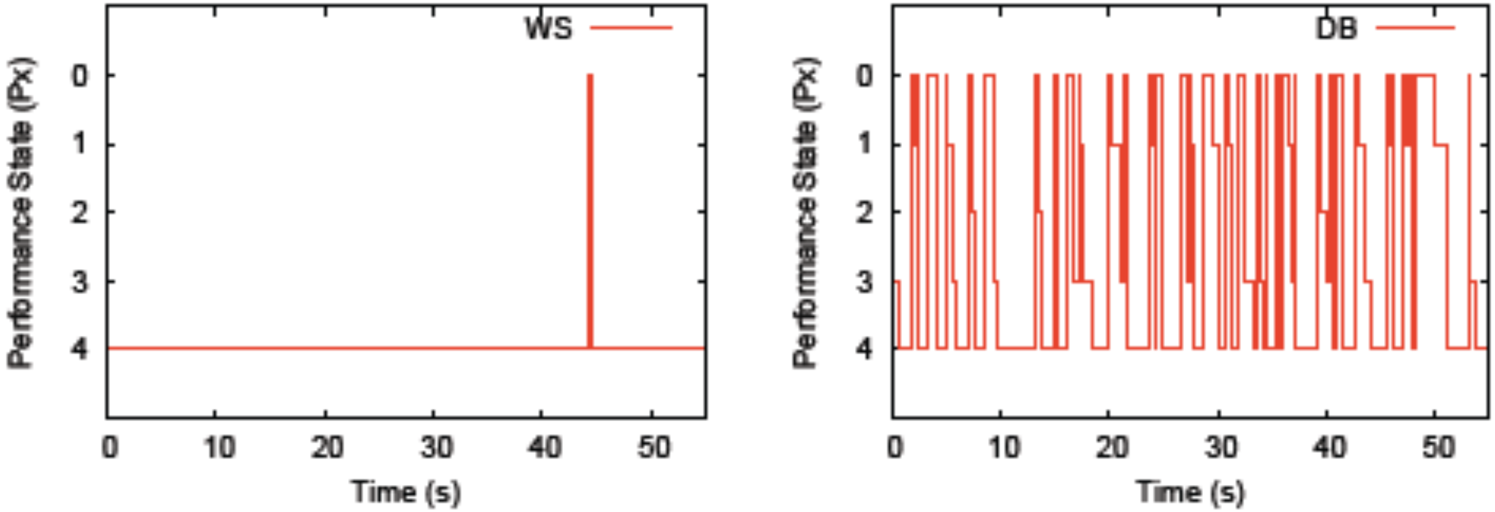
Results



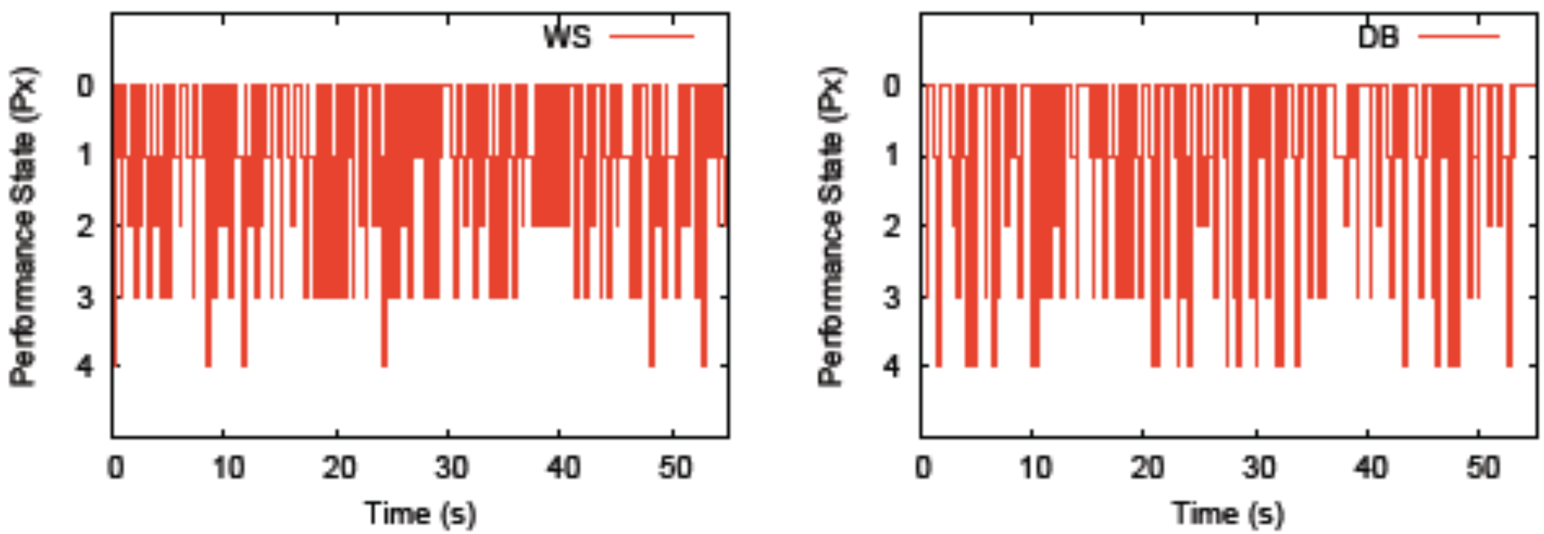
(a) Performance Error (b) Scaling Power Effects

Figure 5: Soft Scaling Characteristics.

From: Figure 5 of VirtualPower Paper



(a) No Active Power Management

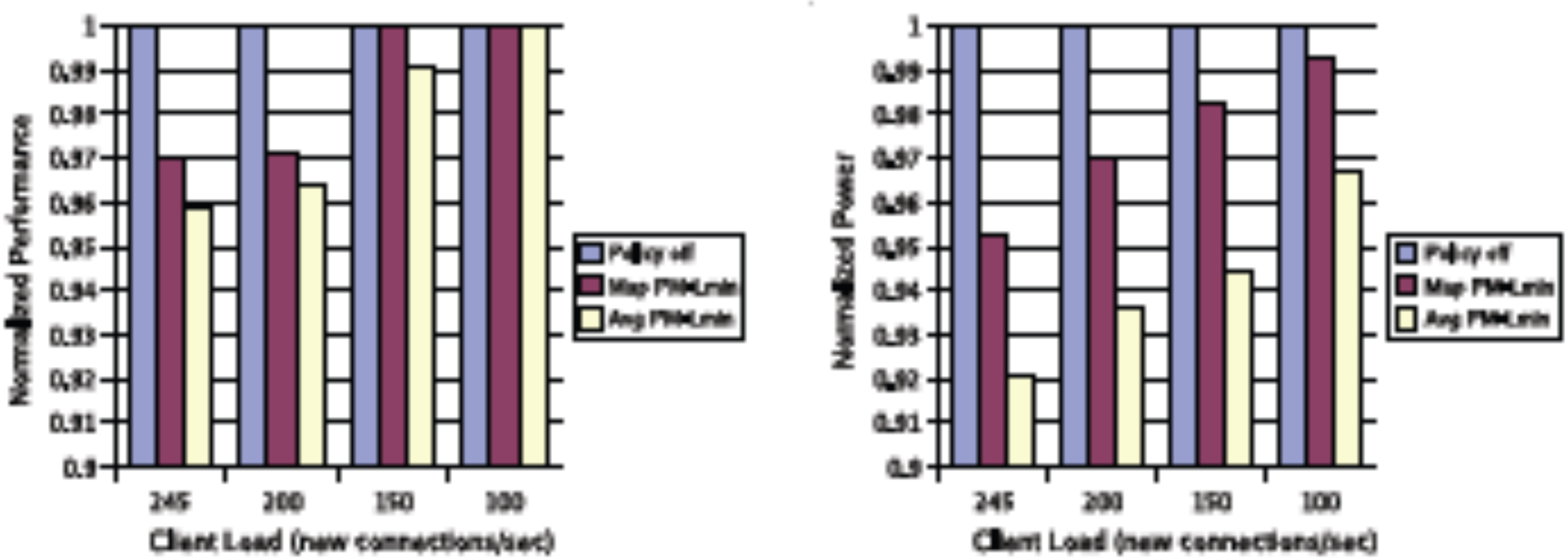


(b) Active Power Management

From: Figure 6 of VirtualPower Paper

Different Policies

From: Figure 9 of VirtualPower Paper



(a) Performance

(b) Power Consumption

Figure 9: RUBiS Experimental Results.

Power Use

Table 2: Managing Two Machines with Four VMs.

Configuration	Power (W)
Two VMs per machine (no PM)	490W
Two VMs per machine (PM-L_{min})	318W
Consolidated with 1 idle machine	362W
Consolidated with 1 sleep/off machine	242W

From: Table 2 of VirtualPower Paper

Discussion

- Performance issues with VPM states
  - Use common denominators for hardware
  - Non-optimized settings
- Feedback mechanisms for hardware specific rules
- Hypervisor overhead
- Use virtual machines to distribute heat production to containerized data centers
  - Heat homes/offices (proposed in Microsoft Research paper)
  - Heat greenhouse (proposed by researchers from Notre Dame)
  - Produce electricity using thermoelectric generators (proposed by researchers from National Taiwan University)