Need for Datacenter Power Management

- Cost Savings
  - $5M to $1M
  - Power Savings (%) vs. Cost Savings

- Rack Utilization
  - 100% to 20%
  - Cooling Capability (W/Ft²) vs. Rack Utilization
ACPI exports hardware states (e.g. Px states), with increasingly manageable components beyond CPU.

Investment into application specific power management (PM) policies.

Explicit awareness/modification of hardware states directly impacts platform power consumption.
Goal: Continue leveraging existing ecosystem/PM policies

<table>
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<th>Problem</th>
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<td>What manageability to expose?</td>
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# VirtualPower Solutions and Opportunities

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<td>How to obtain power benefits with VM resource sharing?</td>
<td>VPM mechanisms</td>
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![Graph showing 34% Power improvement with VPM support](image)

34% Power improvement with VPM support
Heterogeneity in Modern Datacenters

Platform heterogeneity
- Caused by upgrade cycles/failures
- Variations in power, performance, and manageability

[ICAC2007]
Problem: VM Management View with Heterogeneity
Solution: VPM States

VPM States
- Virtualized “soft” states
- Provide consistent view of manageability across migrations
Problem: PM Policies and Isolation + Independence
Solution: VPM Channels

VPM Channel
- Forward VM policy actions to management domain
- Virtualization layer policies manage hardware power states
Problem: Limited Hardware PM Benefits

- **PM Policy**
- **Application**
- **OS**
- **Hypervisor**
- **Hardware**

**Multicore Processor Frequencies**

**Power (W)**

**Frequency Scaling**

**Voltage and Frequency Scaling**

- **Freq Volt**
- **CPU**
- **Freq Volt**
- **CPU**

**Graph:**

- X-axis: Multicore Processor Frequencies
- Y-axis: Power (W)

- 3.2GHz/3.2GHz
- 3.2GHz/2.8GHz
- 2.8GHz/2.8GHz

- Power values: 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250
Solution: VPM Mechanisms

VPM Mechanisms

- Soft scaling restricts resource allocations
Solution: VPM Mechanisms

VPM Mechanisms

- Soft scaling restricts resource allocations
- Multiple soft scaled virtual resources can be consolidated
VirtualPower Architecture

- Dom0
  - VPM Rules
- PM Policy
- Application
- VPM States
- OS
- VPM Channel
- Hypervisor
- Hardware
Key Idea: State Based Guidance for VPM Rules

- Transparently leverage application specific policies
  - VPM state requests from VMs drive virtualization layer policies: Implicit feedback loop
  - Requests based upon application specific policies: Feedback allows for SLA compliance under PM
**Example: PM-L Rule with State Based Guidance**

<table>
<thead>
<tr>
<th>VPM State</th>
<th>CPU Freq</th>
<th>Soft Scaling</th>
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<tbody>
<tr>
<td>3.2GHz</td>
<td>3.2GHz</td>
<td>100%</td>
</tr>
<tr>
<td>2.8GHz</td>
<td>2.8GHz</td>
<td>100%</td>
</tr>
<tr>
<td>2.0GHz</td>
<td>2.8GHz</td>
<td>71%</td>
</tr>
<tr>
<td>1.6GHz</td>
<td>2.8GHz</td>
<td>57%</td>
</tr>
<tr>
<td>800MHz</td>
<td>2.8GHz</td>
<td>29%</td>
</tr>
</tbody>
</table>

**VPM Rules**

- Allows for flexibility in datacenter management: different rules for different types of VMs
- Can be simple (e.g. simple translation), or rely upon more complicated analysis for state based guidance
Example: Reacting to VM Policy Actions
Example: Reacting to VM Policy Actions
### Meeting SLA Constraints with State Based Guidance

#### Workloads

- **Tiered web service (RUBiS)**
  - VM policy: Linux ondemand governor

- **Transactional workloads**
  - VM policy: monitors transaction processing rate and selects state based upon “slack”

- **Web service (Nutch) with Quality of Information metric (based upon actual application --Travelport)**
  - VM policy: monitors “slack” in QoI and processing time of requests across different client classes
Necessary to use different VPM rules for different applications

VPM rules can be sophisticated

- Adaptive
- Complex analysis
- Learning methods
**Transactional Workloads: Meeting Varying Demands**

- **Single VM**: Obvious power benefits for reduced rates
- **Multi-VM**: VPM rules can obtain substantial savings across VMs with identical or different demands

![Graph showing power consumption for single and multi-VM scenarios.](image-url)

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*Additional soft scaling benefits*
Nutch: Flexibility in Application Performance Metrics

- PM driven by Quality of Information (QoI) metric
  - QoI based on Travelport application
- Use of VM policies for state based guidance
- SLA compliance across variety of metrics
Three dual core platforms, four deployed VMs
- Heterogeneous systems
- Workloads require full performance of P4 core
- PM-G policy heuristic: utilize more power efficient hardware (Core2)
Consolidation with Heterogeneous Systems (2)

- Migrate two VMs to Core2 system
- Local PM-L policy on Core2 performs soft scaling based upon observed requests
- Soft scaling provides room for further consolidation
Consolidation with Heterogeneous Systems (3)
Power Results with Heterogeneous Consolidation

Heterogeneity awareness

Soft scale enabled consolidation
Concluding Remarks / Future Work

**Power management in virtualized systems**
- Transparently leverage existing application policies
- Deal with heterogeneity in hardware/manageability
- Maintain isolation and independence
- Obtain power savings with VM resource sharing

**Solutions/contributions**
- Virtualized “soft” PM states
- VPM channels and mechanisms

**Future Work**
- Distributed power throttling: VPM tokens
- Idle power management: Additional VPM C-states
- Efficient soft-scale consolidations: Hardware extensions
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