Power Characterization of Servers in Heterogeneous Cloud Environments

Mascha Kurpicz, Anita Sobe, Pascal Felber
Université de Neuchâtel

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Bigger data centers

More powerful CPUs

Cloud computing requires more energy than India or Germany

Goal:
Reduce energy consumption on multiple levels
Context

- Heterogeneous hardware within a data center is common
- Multi-cloud scenarios: connecting heterogeneous data centers
Study about power consumption for different workloads
- CPU
- Disk
- Real-world application

On heterogeneous hardware

Physical power meter

- PowerSpy device from Alciom
- Setup: power every second (Watt)
Metrics

\[ E = P \times t \]  
Joule = Watt x seconds

\[ \frac{\text{Perf}}{W} = \frac{\text{Throughput}}{P} \]
E.g. for disk workload:
Read Rate / Watt

Workload
OS
Hardware
Idle power
Idle power consumption

<table>
<thead>
<tr>
<th>M1-i3</th>
<th>M2-i5</th>
<th>M3-i7-2gm</th>
<th>M4-i7-4g</th>
<th>M5-xeon</th>
<th>M6-amd</th>
<th>M7-amd tc</th>
<th>M8-via</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop</td>
<td>Desktop</td>
<td>Mobile</td>
<td>Desktop</td>
<td>Desktop</td>
<td>Server</td>
<td>Desktop</td>
<td>Mobile</td>
</tr>
</tbody>
</table>
Idle power consumption

![Graph showing idle power consumption for different processors. M1-i3 to M8-via are listed with their corresponding power consumption values. M5-xeon has the highest power consumption among the listed processors.](image)

<table>
<thead>
<tr>
<th>Processor</th>
<th>M1-i3</th>
<th>M2-i5</th>
<th>M3-i7-2gm</th>
<th>M4-i7-4g</th>
<th>M5-xeon</th>
<th>M6-amd</th>
<th>M7-amdtc</th>
<th>M8-via</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Desktop</td>
<td>Desktop</td>
<td>Mobile</td>
<td>Desktop</td>
<td>Desktop</td>
<td>Server</td>
<td>Desktop</td>
<td>Mobile</td>
</tr>
</tbody>
</table>

16 cores, older architecture, server
CPU workload (factorial)

Best: i7-2gm
Disk workload (Bonnie++)

<table>
<thead>
<tr>
<th>Type</th>
<th>M8-via</th>
<th>M3-i7-2gm</th>
<th>M2-i5</th>
<th>M1-i3</th>
<th>M4-i7-4g</th>
<th>M5-xeon</th>
<th>M7-amdtc</th>
<th>M6-amd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Mobile</td>
<td>Mobile</td>
<td>Desktop</td>
<td>Desktop</td>
<td>Desktop</td>
<td>Desktop</td>
<td>Desktop</td>
<td>Server</td>
</tr>
<tr>
<td>Disk RPM</td>
<td>5400</td>
<td>5400</td>
<td>5900</td>
<td>7200</td>
<td>7200</td>
<td>7200</td>
<td>7200</td>
<td>7200</td>
</tr>
</tbody>
</table>
Impact on energy-aware scheduling

Different scheduling possibilities on the same two machines

<table>
<thead>
<tr>
<th></th>
<th>M1-i3</th>
<th>M4-i7-4g</th>
<th>Total (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placement 1</td>
<td>5xDisk</td>
<td>5xCPU</td>
<td>14'370</td>
</tr>
<tr>
<td>Placement 2</td>
<td>5xCPU</td>
<td>5xDisk</td>
<td>16'110</td>
</tr>
</tbody>
</table>

M1-i3: Desktop
M4-i7-4g: Desktop
Current work: Job and HW profiles

- HW profile on reference machine
- Extrapolation from one machine to another
- Online job profiling
- Estimation of job energy consumption as input for scheduling decision
HW profile

- Profile machine m1 as a reference
- CPU (usr and sys) and disk
- Utilization intervals $u_1, \ldots, u_n$

<table>
<thead>
<tr>
<th>Util</th>
<th>$u_1$</th>
<th>$u_2$</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>usr</td>
<td>10W</td>
<td>20W</td>
<td>...</td>
</tr>
<tr>
<td>sys</td>
<td>10W</td>
<td>15W</td>
<td>...</td>
</tr>
<tr>
<td>disk</td>
<td>3W</td>
<td>5W</td>
<td>...</td>
</tr>
</tbody>
</table>
Extrapolation for other HW

<table>
<thead>
<tr>
<th>Util</th>
<th>$u_1$</th>
<th>$u_2$</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>usr</td>
<td>10W</td>
<td>20W</td>
<td>...</td>
</tr>
<tr>
<td>sys</td>
<td>10W</td>
<td>15W</td>
<td>...</td>
</tr>
<tr>
<td>disk</td>
<td>3W</td>
<td>5W</td>
<td>...</td>
</tr>
</tbody>
</table>

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<th>Util</th>
<th>$u_1$</th>
<th>$u_2$</th>
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<tr>
<td>usr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sys</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>disk</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Utilization mapping between machines

- Utilization mapping tables
  - For CPU (sys and \textit{usr})
  - For disk

<table>
<thead>
<tr>
<th>sys(%)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>m1</td>
<td>10</td>
<td>20</td>
<td>...</td>
</tr>
<tr>
<td>m2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Online job profiling – machine m1

- On job arrival, monitor part of the job on m1
- Measure CPU and disk utilization
- Look up power consumption in HW profile of m1

Expected power consumption on machine m1
Online job profiling – other machines

- Utilization mapping for machines $m_2, \ldots, m_n$
- Look up power values in HW table for mapped utilization values

Expected power consumption on machines $m_2, \ldots, m_n$

- Provide table with expected power consumption for the different machines to the scheduler
Workflow

1. **Job arrival**
2. **Profile m1**
3. **Obtain data for all machines**
4. **Power profile**
5. **Scheduling**

**HW matrix**

**Utilization mapping**

- **m1**: 35W
- **m2**: 40W
...
Scheduler

- Estimated power consumption on each machine
- Estimated execution time

Energy efficient scheduling decision
Open points

- Data locality
- Which subset of the workload to monitor?
- What HW can be covered by the model?
- Exact definition of the mapping functions
Conclusion

Different workload characteristics

Heterogenous hardware

Different energy consumption
Conclusion

- Different workload characteristics
- Heterogeneous hardware
- Different energy consumption

- Workload placement and consolidation
- Pricing model

Energy efficient scheduling!
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