Performance in Virtual Environments
Stefan Appel
Virtualization is used heavily nowadays (cloud computing)
Physical resources are shared between virtual machines
Are resources shared fairly when virtual resources exceed physical resources?

- CPU: yes
- Memory Bandwidth: yes
- Disk I/O: it depends
Test Setup

- **Hardware**
  - IBM x3850 Server
  - 4 x Dual-Core Xeon 7150N 3.5GHz
  - 16GB RAM
  - 6 x 10,000 RPM SAS HD, RAID 10

- **Software**
  - Host OS: Debian Linux, etch
  - Hypervisor: VMWare Server 2.0
  - Guest OS: Ubuntu Linux, 8.04

- **Scenario:**
  1–7 Virtual Machines (VMs) in parallel
Testing CPU Performance in Parallel Running VMs

- Benchmark
  - SPECjvm2008 Benchmark Suite
  - 11 Applications / Workloads
  - Composite score & separate scores

- Virtual Machine Setup
  - 2 vCPUs
  - 1024MB RAM
  - 512MB JVM Heap Size

- CPU overbooking with 5+ VMs in parallel (8 cores available)
- SPECjvm2008 started simultaneously in 1-7 VMs
Fair CPU Sharing Between VMs

<table>
<thead>
<tr>
<th>Number of Virtual Machines</th>
<th>1</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard Deviation</strong></td>
<td>-</td>
<td>0.121</td>
<td>0.084</td>
<td>0.118</td>
<td>0.118</td>
</tr>
<tr>
<td><strong>Accumulated Score</strong></td>
<td>14.770</td>
<td>56.240</td>
<td>58.930</td>
<td>58.240</td>
<td>56.668</td>
</tr>
</tbody>
</table>

- Fair distribution of CPU time among VMs
  - Low standard deviation

- Overhead increases slightly with increasing number of VMs
  - Accumulated score decreases
Different behavior of benchmarks due to amount of parallelism

- 1 Virtual Machine vs. 4 Virtual Machines
  - No performance difference for some benchmarks: compress, mpegaudio, scimark.small
  - Significant performance difference for other benchmarks: compiler, xml
- Different amount of parallelism
CPU not Fully Utilized During Benchmark Run

- Parts of SPECjvm2008 do not utilize two CPU cores
- 5+ Virtual Machines necessary to fully utilize host system

![CPU Idle Percentage over Time, 2 vCPUs, 10sec Measurement Intervals](chart.png)
Testing Memory Throughput in Parallel Running VMs

- **Benchmark**
  - RAMSPEED: Memory throughput, one thread
  - RAMSMP: Memory throughput, multiple threads
  - COPY (A=B), SCALE (A=m*B), ADD (A=B+C) and TRIAD (A=m*B+C) operations

- **Virtual Machine Setup**
  - 2 vCPUs, 2048MB RAM
  - Transfer of 8GB of data, 5 runs

- CPU overbooking with 5+ VMs in parallel
- Physical amount of RAM (16GB) sufficient, no swapping
- RAMSPEED/RAMSMP started simultaneously in 1-7 VMs
Full Memory Bandwidth only with 3+ VMs in Parallel

- Max. throughput requires utilization of multiple CPUs
  - Utilization of all memory controllers and caches

- Low overhead in highly utilized system
  - Overall throughput decreases slowly with increasing number of VMs

![Ramsmp, 2 Processes per VM: Accumulated Throughput over VMs](image_url)
Memory Bandwidth is Distributed fairly among VMs

- Hypervisor distributes available memory bandwidth uniformly
  - Low standard deviations when comparing throughput per VM

- Slightly increasing std. dev. with increasing number of VMs
  - Fair distribution of resources more difficult with more VMs
Testing IO Performance in Parallel Running VMs

- Benchmark
  - Bonnie++: `putc()`, `writec()`, `write()`, `read()`; Character- and Blockwise
  - Iozone: Write, Re-Write, Read, Random Read; different Blocksizes

- Virtual Machine Setup
  - 2 vCPUs
  - 1024MB RAM
  - 40GB disk, Benchmark file size: 2GB

- Scenarios
  - Bonnie++ and Iozone in 1, 3 and 5 VMs in parallel: sufficient CPUs für 3 VMs, sufficient RAM
The Average IO Throughput per VM is Constant

- Repeated Iozone and Bonnie++ runs
  - Average throughput to and from hard disk is constant
  - Different values of Bonnie++ and Iozone due to different mechanisms
High Differences in IO Throughput between Runs

- Standard deviation almost always exceed 10%
  - No uniform distribution of IO bandwidth throughout a single run
  - Same for Iozone runs with different block sizes and Bonnie++ runs
Accumulated Throughput Exceeds Throughput of Single VM

- Accumulated throughput (r/w) exceeds single VM throughput
  - Write: Effect small, but can be measured
  - Read: Effect huge, throughput doubled
- Possible explanations:
  - Caching effects, serialization of writes

![Throughput Accumulated over all VMs](image)
Summary:
CPU ok, Mem ok, IO depends

- CPU sharing works
  - SPECjvm2008 in 1-7 VMs in parallel

- Memory Bandwidth sharing works
  - RAMSPEED/RAMSMP in 1-7 VMs in parallel

- Disk I/O
  - Iozone and Bonnie++ in 1,3 and 5 VMs in parallel
  - Bandwidth shared fairly **on average**
  - But differences between VMs for single runs
  - Accumulated throughput exceeds single VM throughput
Thank You for Your Attention!

- Questions?

- Comments?