The Future of ARM in HPC

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Background

- The shift from RISC to x86 supercomputers was driven by cost, availability and performance
- Are the same conditions are now present for a shift from x86 to ARM systems?
Rise and Fall of RISC and x86

Source: Supercomputing with Commodity CPUs: Are Mobile SoCs Ready for HPC?, 2013
Performance Trends of ARM and x86

Source: Supercomputing with Commodity CPUs: Are Mobile SoCs Ready for HPC?, 2013
Motivation

- Energy consumption is now the limiting factor for performance
- ARM processors, originally designed for mobile and embedded systems, are very energy efficient
- Makes them an attractive choice for an power efficient HPC cluster
Introducing ARM

- Energy efficient RISC processor
- Architecture developed by ARM Holdings and licensed to manufacturers
- Dominates the large mobile market and starting to reach the server market
- Cheap!
  - $3.40 for a 32b microprocessor running Linux
# Quick Comparison of ARM vs. x86

<table>
<thead>
<tr>
<th></th>
<th>ARM</th>
<th>x86</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Processor</strong></td>
<td>Texas Instruments OMAP4430 (Dual core A9)</td>
<td>Intel Core2 Q9400</td>
</tr>
<tr>
<td><strong>Year Released</strong></td>
<td>2011</td>
<td>2008</td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td>45nm</td>
<td>45nm</td>
</tr>
<tr>
<td><strong>Cores</strong></td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Clock Speed</strong></td>
<td>1GHz</td>
<td>2.66GHz</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td>1GB DDR2</td>
<td>8GB DDR2</td>
</tr>
<tr>
<td><strong>Network</strong></td>
<td>100Mbps</td>
<td>1000Mbps</td>
</tr>
<tr>
<td><strong>TDP</strong></td>
<td>1.9W</td>
<td>95W</td>
</tr>
</tbody>
</table>
Web server performance measured with three different page sizes: 30KB, 50KB and 100KB.

Source: *Energy- and Cost-Efficiency Analysis of ARM-Based Clusters*, 2012
Performance

The energy consumption (inversely proportional to performance) of a simulated ARM system. Shows that performance increases as bottlenecks in the system are identified and addressed.

Source: On Understanding the Energy Consumption of ARM-bases Multicore Servers, 2013
Performance

- ARM processors can’t (yet) compete with x86 processors in raw compute power.
- Depending on how important energy consumption is and the performance needed, they may be an alternative.
- ARM processors are getting more powerful and x86 processors are getting more energy efficient.
DARPA Exascale Computing

- Started in 2008 as a challenge to reach an exaflop of computing power
- Design goals
  - Finish by 2018
  - Achieve 1 Exaflop within 20 MWatts
- Limitations found
  - Power
  - Cost
Limited by Power Requirements

- Exascale goal: 20 MW, 50 GFlops/Watt
- Current Technology: 200 MW
- Most Efficient Supercomputer
  - TSUBAME-KFC - LX 1U-4GPU/104Re-1G Cluster
  - Tokyo Institute of Technology
  - 4,503.17 MFlops/Watt (4.5 GFLOPS/W)
  - Heterogeneous system with Intel processors and NVIDIA GPUs
Attempts to Lower Power

- BlueGene (custom PowerPC processor)
- Other RISC Machines
- Heterogeneous Architectures
  - Xeon Phi Co-Processor - 4 GFlops / W
  - NVIDIA K20x Co-Processor - 18 GFlops / W
Current ARM Clusters

- **Tibidabo (2011)**
  - Proof of Concept ARM based Supercomputer
  - 256 NVIDIA Tegra2 nodes
  - 512 GFLOPS @ 3.4 kW (0.15 GFLOPS/W)

- **Mont-Blanc (2014 - 2016)**
  - Currently 810 processor modules with Samsung Exynos5 SoCs, 4GB DDR3 and 1Gb ethernet
  - 26 TFLOPS @ 18 kW (1.44 GFLOPS/W)
  - Plans to scale higher
Tibidabo

- 256 nodes, 1Gb links
- 9 48-port routers
- 48-ary tree network
  - Network diameter: 4
  - Average distance: 3.7
  - Bisection width: 1
Mont-Blanc

- Level 1: 810 nodes, 1Gb links
- Level 2: 15-port switch, 10Gb links
- Level 3: 9-port switch, 10Gb links
- Top level: 6-port switch
- Fat tree network
  - Network Diameter: 6
  - Average Distance: 5
  - Bisection width: 3
Conclusions

- Not there yet in terms of performance
- Could be solved by heterogeneous systems with a mix of ARM SoCs and GPUs
- Huge mobile market drives ARM cost down and performance up
- Could be the future of HPC
Questions?
Backup Slide - Energy Requirements

Source: *Building Supercomputers from Commodity Embedded Chips*, 2014