An Experimental Evaluation of Datacenter Workloads On Low-Power Embedded Micro Servers

Yiran Zhao, Shen Li, Shaohan Hu, Hongwei Wang, Shuochao Yao, Huajie Shao, and Tarek Abdelzaher

University of Illinois at Urbana-Champaign
• What we've done:
  – Evaluate sensor-class micro servers (wearable, IoT device: Intel Edison) running various datacenter workloads, and compare with conventional servers (Dell R620).

• Motivation:
  – Big energy cost: up to 50% of the three-year total cost of datacenters is attributed to power consumption (Google, Microsoft, Yahoo)[50].
  – Low energy efficiency (poor proportionality): commodity servers are less than half efficient when at 30% utilization than at 100% utilization [54].
  – High efficiency and considerable capacity of embedded micro servers.
Contributions

• We show how to comprehensively evaluate and fairly compare between micro servers and conventional brawny servers.

• What benchmark tools? How to choose workloads? How to avoid irrelevant bottlenecks? How to choose parameters for comparison?
Contributions

• We show the lessons learned from this experiment.
• Is it possible to replace all conventional servers with micro servers?
• What type of workload is micro server cluster good at?
• What can't micro servers do?
Overview

• Test bed looks like (35 Edison in total):
Specifications

<table>
<thead>
<tr>
<th></th>
<th>Edison</th>
<th>Dell</th>
<th>Estimated gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>2×500MHz</td>
<td>6×2GHz</td>
<td>12x</td>
</tr>
<tr>
<td>RAM</td>
<td>960MB</td>
<td>16GB</td>
<td>16x</td>
</tr>
<tr>
<td>Ethernet</td>
<td>100Mbps</td>
<td>1Gbps</td>
<td>10x</td>
</tr>
<tr>
<td>Cost</td>
<td>$120</td>
<td>$2500</td>
<td>≈20x</td>
</tr>
<tr>
<td>Power draw</td>
<td>1.4-1.68W</td>
<td>52-109W</td>
<td>≈50x</td>
</tr>
</tbody>
</table>

We first test each system component and compare the 2 types of servers.
## Individual server test

<table>
<thead>
<tr>
<th>Component</th>
<th>Test tool</th>
<th>Gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>Dhrystone</td>
<td>≈100x</td>
</tr>
<tr>
<td></td>
<td>Sysbench</td>
<td></td>
</tr>
<tr>
<td>Memory</td>
<td>Sysbench</td>
<td>16x</td>
</tr>
<tr>
<td>Read/Write speed</td>
<td>dd</td>
<td>4x / 5-9x</td>
</tr>
<tr>
<td>Read/Write latency</td>
<td>ioping</td>
<td>8x / 4x</td>
</tr>
<tr>
<td>Network speed</td>
<td>iperf</td>
<td>10x</td>
</tr>
<tr>
<td>Network latency</td>
<td>ping</td>
<td>5x</td>
</tr>
</tbody>
</table>

Cluster tests: online + offline applications.
Cluster tests

• Online application
  – Web service
    • Web server, cache server: Edison vs. Dell
    • Database, load balancer, client: Dell
    • Different cluster sizes: full, 1/2, 1/4, 1/8
Web service test

• What's web content?
  – Fetch 1 text or 1 image per request
  – Texts and images from WikiBench [14]

• How to change average http response size?
  – Change image proportion
  – 0% (1.5KB) to 20% (10KB)

• How to change request rate (throughput)?
  – Change Httpperf connection rate

• How to change stress level of backend?
  – Change cache hit ratio (60% to 93%)
  – Adjust cache warm up time
Edison vs. Dell: throughput, power

- 0% image, 93% cache hit ratio.

- Peak throughput is similar for Edison and Dell.
- Peak throughput scales linearly with cluster size.
- Edison is 3.5 times more energy efficient.
Edison vs. Dell: latency

- 0% image, 93% cache hit ratio.

- Under low throughput, Edison latency is much larger than Dell.
- Under high throughput, Dell latency explodes.
Edison vs. Dell: throughput, power

- 20% image, 93% cache hit ratio.
Edison vs. Dell: latency

- 20% image, 93% cache hit ratio.
Edison vs. Dell: throughput

- 6%, 10% image, 60%, 77% cache hit, full cluster size.

- Dell can handle 2048 connection rate before server error (5xx) occurs.
- Edison can handle 1024 conn/s.
Edison vs. Dell: latency

- 6%, 10% image, 60%, 77% cache hit, full cluster size.

- At peak throughput (512 connections/sec), latency is similar.
Edison vs. Dell: delay distribution

- At peak throughput

- Dell: spikes due to re-connection delay.
- Edison: fewer re-connection, no large back off.
Summary

• Micro cluster achieves similar throughput, much higher efficiency,
• Larger latency,
• Linear scalability due to parallel nature of web service,
• Easier to establish connections due to abundant network resources (e.g. ports).
Cluster tests

- Offline processing
  - MapReduce
    - Name node, resource manager: Dell
    - Data node, node manager: Edison vs. Dell
    - Jobs: wordcount, logcount [10], estimate pi, terasort
Cluster tests

• Map/reduce task number?
  – Each vcore gets 1-2 containers
  – Edison: 2-4 tasks, Dell: 12-24 tasks

• Hadoop block size?
  – Same number of input splits
  – Proportional to container size

• HDFS replication number?
  – Same data-local map task percentage on both platforms
  – Edison: 2, Dell: 1

• Manual fine tuning --sort_mb, --sort_record_percent, etc.
• Wordcount:
  – Data-intensive, lots of map output records
  – 200 input files, 1GB
  – Resource utilization log shows both platforms are fully utilized

  – Edison 2.3 times higher energy efficiency
• Optimized wordcount (wordcount2):
  – Combine input files to so each vcore gets only 1 map task
  – Significant execution time reduction
  – Edison cluster achieves 11% more work-done-per-joule
• Logcount [10]:
  – Count <date, debug level> pairs
  – 500 input files, 1GB
  – Huge container allocation overhead
  – Edison has 2.6 times more work-done-per-joule

• Optimized logcount (logcount2):
  – Combine input files to reduce containers
  – Still large overhead, large friction loss
  – Edison shows 45% more work-done-per-joule
• Estimate Pi:
  – CPU-intensive
  – CPU and RAM both fully utilized

– Edison cannot win: 23% less energy efficient
• Terasort:
  – Data-intensive, 10GB
  – HDFS block size is the same (64MB), ensure same total input data splits
  – Edison shows 32% higher energy efficiency
Lessons

+ Parallelizable applications: much higher energy efficiency on micro servers.
+ Data-intensive batch-processing workloads: more work-done-per-joule on micro servers.
+ Infrastructure: less power, less cooling.
  – Computationally intensive workloads: brawny servers win!
  – Execution time: micro servers spend much more time on data-processing jobs.
  – Micro server cannot be the master (resource manager).
Total cost of ownership

• Simple model: equipment cost + electricity cost [38].
• Equipment cost: Edison $120, Dell $2500.
• Electricity cost: $0.10/kWh [22].
• Cluster lifespan: 3 years [22].
• Web service, server utilization:
  – Low: 10%, high: 75% [22].
• MapReduce, server utilization:
  – Edison: 100%, Dell: 25% to 74%.
TCO

• Web service:
  – 35 Edison vs. 3 Dell
  – Edison: $4329-$4346
  – Dell: $7948-$8236

• MapReduce:
  – 35 Edison vs. 2 Dell
  – Edison: $4352
  – Dell: $5348-$5495
Conclusion

• Build 35-node micro cluster.
• Evaluate both online/offline applications.
• Show how to configure and run fair tests.
• Identify (dis)advantages of micro servers.
• Inspire future work of a hybrid datacenter that combines the strength of both brawny servers and micro servers.
Reference


Acknowledgement

This work was sponsored in part by NSF grants CNS 13-45266 and CNS 16-18627.
Scalability test

• Scale up cluster size:
  – Average speed up when doubling size: Edison 2.07x, Dell 1.9x.
  – Large number of input files, map containers: larger cluster is better.
  – Combine input files into fewer containers, large coordination overhead: smaller cluster is better.

<table>
<thead>
<tr>
<th></th>
<th>Edison cluster</th>
<th>Dell cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster size</td>
<td>35</td>
<td>17</td>
</tr>
<tr>
<td>Wordcount</td>
<td>310s,17670J</td>
<td>1065s,29485J</td>
</tr>
<tr>
<td>Wordcount2</td>
<td>182s,10370J</td>
<td>270s,7475J</td>
</tr>
<tr>
<td>Logcount</td>
<td>279s,15903J</td>
<td>601s,16860J</td>
</tr>
<tr>
<td>Logcount2</td>
<td>115s,6555J</td>
<td>118s,3267J</td>
</tr>
<tr>
<td>Pi</td>
<td>200s,11445J</td>
<td>334s,9247J</td>
</tr>
<tr>
<td>Terasort</td>
<td>750s,43440J</td>
<td>1364s,37763J</td>
</tr>
</tbody>
</table>

<execution time (s), energy (J)>