Persistence and Energy Savings

Tom Coughlin, Coughlin Associates, Inc.
Jim Handy, Objective Analysis
Outline

• Findings from Last Year
• Why Persistence will Move into the CPU
• How this improves Applications
• Summary
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SSDs in PCs

- 14% of total power went to HDD
- SSD’s speed helped it power down more
  - HDD Powered down 10% of time
  - SSD powered down 96%
- Savings
  - Storage power 13%
  - Mother board power 2%

<table>
<thead>
<tr>
<th></th>
<th>SSD</th>
<th>HDD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sustained Read</strong></td>
<td>230MB/s</td>
<td>60MB/s</td>
</tr>
<tr>
<td><strong>Sustained Write</strong></td>
<td>130MB/s</td>
<td>50MB/s</td>
</tr>
<tr>
<td><strong>Random Read IOPS</strong></td>
<td>2,500</td>
<td>70</td>
</tr>
<tr>
<td><strong>Random Write IOPS</strong></td>
<td>25</td>
<td>115</td>
</tr>
<tr>
<td><strong>Ave. File Access</strong></td>
<td>0.12ms</td>
<td>19.0ms</td>
</tr>
<tr>
<td><strong>Read latency</strong></td>
<td>&lt;1ms</td>
<td>15ms</td>
</tr>
<tr>
<td><strong>Active Power – Read</strong></td>
<td>0.5W</td>
<td>2.1W</td>
</tr>
<tr>
<td><strong>Idle Power</strong></td>
<td>0.1W</td>
<td>1.0W</td>
</tr>
<tr>
<td><strong>Standby Power</strong></td>
<td>0.06W</td>
<td>0.20W</td>
</tr>
<tr>
<td><strong>Hibernate Resume</strong></td>
<td>&lt;5s</td>
<td>40s</td>
</tr>
</tbody>
</table>
## SNIA SSD TCO Model

<table>
<thead>
<tr>
<th>Storage Type</th>
<th>Power</th>
<th>Read IOPS</th>
<th>mW/IOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>146GB 3.5: Enterprise Fibre Channel SSD</td>
<td>16.4W</td>
<td>10,000</td>
<td>1.6</td>
</tr>
<tr>
<td>64GB 2.5&quot; Enterprise SATA SSD</td>
<td>6.5W</td>
<td>3,500</td>
<td>1.9</td>
</tr>
<tr>
<td>146GB 2.5&quot; 15k RPM SAS HDD</td>
<td>11.0W</td>
<td>420</td>
<td>26.2</td>
</tr>
<tr>
<td>300GB 2.5&quot; 10k RPM SAS HDD</td>
<td>10.2W</td>
<td>270</td>
<td>37.8</td>
</tr>
<tr>
<td>600GB 3.5&quot; 15k RPM Fibre Channel HDD</td>
<td>24.3W</td>
<td>380</td>
<td>63.9</td>
</tr>
<tr>
<td>600GB 3.5&quot; 10k RPM Fibre Channel HDD</td>
<td>18.1W</td>
<td>280</td>
<td>64.6</td>
</tr>
<tr>
<td>2TB 3.5&quot; 7.2k RPM Enterprise SATA HDD</td>
<td>19.6W</td>
<td>133</td>
<td>147.4</td>
</tr>
</tbody>
</table>

From the perspective of mW/IOPS SSDs are a slam-dunk! (Even WITHOUT) considering the savings elsewhere in the system.
Faster Performance Reduces Energy Use

- Allows other parts of the system to enter their own idle states sooner
- Further reduces energy consumption
- HUGI: “Hurry Up, Go Idle.”

Source: Intel & Objective Analysis, July 2017
PM Energy Savings

PM Energy Savings Projection

- Assumptions:
  - XPoint adoption follows Objective Analysis forecast
  - XPoint-based energy savings
    - 10% in Memory Mode
    - 30% in App Direct Mode
  - PM-Aware Software doesn’t take off until 2023
  - Does not estimate reduced server requirements
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NOR Flash Stopped Scaling at 28nm
Something Else Will Replace It
Candidates for NOR Replacement

MRAM

PCM

ReRAM

FRAM
SRAM Is Similarly Challenged
It May Have Already Stopped Scaling

Cell Area

0.01\(\mu m^2\)  0.10\(\mu m^2\)  1.00\(\mu m^2\)

Process Geometry

90nm  65nm  45nm  32nm  22nm  14nm
Putting Things in Perspective

Logic

SRAM
Putting Things in Perspective

Logic

SRAM
What Becomes Persistent?
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Benefits of Persistent Caches

• Energy consumption
• Faster transactions
• This provides significant value for data center and embedded system applications
Energy Savings from Persistence

Relative Energy Consumption

Justin Meza et al, *A Case for Efficient Hardware/Software Cooperative Management of Storage and Memory*
Justin Meza et al, *A Case for Efficient Hardware/Software Cooperative Management of Storage and Memory*
Intermittent Data Centers

Image from Lancium
Maximize Sleep
More Sleep = Lower Energy

- Going in / out of sleep burns energy
  - Mostly storing / reloading RAM
- Only sleep when:

$$\text{EnergySavings}_{\text{Sleep}} > \text{EnergyCost}_{\text{LoadStore}}$$

\[ \Rightarrow \text{Limits sleep to few, long periods} \]

Using Persistent Memory instead of RAM:
- Simply power memory off!
- Eliminates store/reload energy cost
- Enables frequent “Micro-Naps”
  - Save significant additional energy

Jeff Lewis, Spin Memory Presentation, 2019 MRAM Developers Day
Advantages for Embedded Electronics

All images from Wikimedia Commons
Persistent Caches Need Development Support

- BIOS Support
- Operating system support
- Application program support
- Standards
- Hardware support
After That, Expect Persistent Registers!
New Report:
Emerging Memories Find Their Direction

Now Available!
http://www.tomcoughlin.com/techpapers.htm
https://Objective-Analysis.com/reports/#Emerging
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Summary

• SSDs provide faster performance, lowering power use
• Persistent memory offers additional energy savings
• Persistent caches are on their way
  • Persistent registers will follow
• Persistent Memory will decrease energy demand in industrial, civic and consumer applications
• Buy our report!