Power, Energy and Thermal Considerations in SSD-Based I/O Acceleration

Jie Zhang, Mustafa Shihab and Myoungsoo Jung
Computer Architecture and Memory System Lab
Department of Electrical Engineering
The University of Texas at Dallas
Summary

**Challenges:** State-of-art SSD integrates much more internal resources compared to traditional ones. No one consider how growing internal resource impact **power, energy and thermal factor** on SSD.
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**Goals:** invokes the importance of power, energy, and temperature issues in high-end SSD and addresses the critical issues related with growing internal resources.
**Challenges:** State-of-art SSD integrates much more internal resources compared to traditional ones. No one considers how growing internal resource impact **power, energy and thermal factor** on SSD.

**Goals:** invoke the importance of power, energy and temperature issues in high-end SSD and address the critical issues related with growing internal resource.

**Contributions:** we quantitatively analyze challenges of SSDs in integrating more resources:

- Operating temperature
- Dynamic power behaviors
- Energy consumption
- Overheating and power throttling issues
Outline

• Motivation

• Evaluation Setup

• Findings
  • Operating temperature
  • Dynamic power behavior
  • Energy consumption
  • Overheating problem and power throttling issue

• Conclusions
Increased Resources in SSDs

- Huge bandwidth gap between single chip/channel and host interface
- Many chips to utilize chip-level parallelism
- Many channels to utilize channel-level parallelism
- Many controllers/cores to handle multiple tasks
- Overall, more and more resources are integrated in state-of-art SSDs
In past 12 years, the number of chips and channels has been increased by 64 times.

Following this trend, there are more internal resources in the future.

Massive integrated power contributors cause potential power concern.

Essential to study power, energy, and thermal factor of modern SSDs.
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## Evaluation Setup: SSD Testbeds

<table>
<thead>
<tr>
<th>Feature</th>
<th>SP-SSD</th>
<th>MC-SSD</th>
<th>MR-SSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface</td>
<td>SATA 6Gbps</td>
<td>PCIe 2.0</td>
<td>PCIe 2.0</td>
</tr>
<tr>
<td>Core</td>
<td>3</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td># of Channels</td>
<td>8</td>
<td>8</td>
<td>32</td>
</tr>
<tr>
<td># of Chips</td>
<td>64</td>
<td>64</td>
<td>128</td>
</tr>
<tr>
<td>DRAM Sizes</td>
<td>256MB</td>
<td>2GB</td>
<td>2.25GB</td>
</tr>
<tr>
<td>Storage Cap.</td>
<td>512GB</td>
<td>400GB</td>
<td>512GB</td>
</tr>
</tbody>
</table>

**Baseline SSD**

- Multi-core SSD vs. SP-SSD: more cores, larger DRAM size
- MR-SSD vs. SP-SSD: more channels, more chips
Evaluation Setup: Workload & Dev. Status

<table>
<thead>
<tr>
<th>Data Type</th>
<th>SEQ</th>
<th>RND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Size</td>
<td>4KB</td>
<td>8KB</td>
</tr>
<tr>
<td>Device Status</td>
<td>Pristine</td>
<td>Aged</td>
</tr>
</tbody>
</table>

- **Data type**: sequential data and random data
- **Data size**: from 4KB to 4MB
- **Device status**:
  - Pristine device: SSD with default factory setting
  - Aged device: mimic actual aged SSD
- **Based on these, there are 192 different configurations**
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Operating Temperature

Write Access on Pristine Device

- Various request sizes have little impact on SP-SSD’s temperature

95~120 F
Various request sizes have little impact on SP-SSD’s temperature.

MR-SSD has higher temperature than SP-SSD.

Write Access on Pristine Device:

- Temperature range: 95~120°F
- 58% temperature increase
- 119~182°F
Operating Temperature

Write Access on Pristine Device

- Various request sizes have little impact on SP-SSD’s temperature
- MR-SSD has higher temperature than SP-SSD
- As for MR-SSD, temperature increases when data size increases
Various request sizes have little impact on SP-SSD’s temperature.
MR-SSD has higher temperature than SP-SSD.
As for MR-SSD, temperature increases when data size increases.
Temperature saturates when data size increases to a certain level.
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Dynamic Power Behavior

- Various request sizes have little impact on power of SP-SSD
- MC/MR-SSD consume 3.5X and 4.5X more power than SP-SSD
- As for MC/MR-SSD, power increases when data size increases
- Power saturates when data size increases to a certain level
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Energy Consumption

- Common presumption, MR/MC-SSD save energy because of bandwidth.

![Energy Consumption Graph](image)

- Energy of Read Operation

- 95% energy savings
Energy Consumption

- Common presumption, MR/MC-SSD save energy because of bandwidth

- MC/MR-SSDs cost more energy than SP-SSDs
- MC/MR-SSDs require more power to feed its internal resources
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Overheating Problem

- Overheating problem: heat output exceeds certain level which may lead to malfunction of SSDs
- Device-level protection mechanism dynamically reduces heat output

180°F not reached
• Overheating problem: heat output exceeds certain level which may lead to malfunction of SSDs
• Device-level protection mechanism dynamically reduces heat output
• Devices with larger data sizes reach overheating points earlier
• How is the temperature controlled?
Power throttling: power is automatically decreased at overheating point to control heat output.

This decrement is carried out by a device-level mechanism.

Is simply decreasing power good enough?
• Huge performance decreases at the overheating point
• protection mechanism throttles power by turning off active resources
• Less power reduces temperature, but also limit active resources
• Overheating problem and power throttling issue hinders SSDs from integrating more resources
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Critical Findings:

• MC/MR-SSDs generate higher temperature, consume larger power and energy than conventional SSDs-not acceptable for many work conditions

• Overheating problem and power throttling issues are holding back state-of-the-art SSDs from achieving potential performance gains

Future Work:

• HW/SW optimization studies are required to improve power and energy efficiency of SSDs
Thank you!