Solid State Storage for the Enterprise

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Abstract

Solid State Storage for the Enterprise

This presentation will discuss the types of solid state storage systems directed at enterprise. The presentation will look at DDR-RAM and Flash based storage devices and their technical differences. The presentation will provide some examples of the variance in the operational characteristics among different flash based SSD. The presentation will discuss the fit of various memory based storage devices with enterprise applications.

Learning Objectives

- Understand types of solid state storage available for enterprise applications.
- Understand that not all Flash SSDs are the same.
- Discuss applications for solid state storage in the enterprise.
Agenda Topics

- Solid State Disk Overview
- Flash SSD in a HDD Form Factor
Solid State Disk Overview

- What is a Solid State Disk?
- Flash and DDR Memory Characteristics
- Why Solid State Disk?
- SSD Killer Applications
- SSD and ILM
What is a Solid State Disk?

“A solid state drive (SSD) is a semiconductor-based block storage device that behaves as a virtual HDD and appears to the host device as a disk drive.”

What is a Solid State Disk?

- **Flash Memory Based**
  - Same class of memory used in consumer electronics
  - Inherently non-volatile
  - Best known for ruggedness and good random read performance.

- **DDR Memory Based**
  - Same memory used in enterprise servers
  - Requires batteries and backup hard disks for non-volatility
  - Best known for outstanding performance and high cost.

- **Cached Flash**
  - Mix of DDR RAM and NAND Flash.
Flash Memory Characteristics

Two types of NAND Flash Memory

- **SLC – single layer**
  - 100,000 writes per cell
  - Primarily used in industrial and military applications
  - Higher cost
  - 1.5 millisecond erase times; 200 microsecond write times; 25 microsecond read times
  - Maximum density – 16Gbit with 32Gbit on the way
  - SLC memory is best suited for the enterprise

- **MLC – multi layer**
  - 10,000 writes per cell
  - Primarily used in consumer electronics
  - Lower cost
  - Half the performance of SLC
  - Maximum density – 32Gbit with 64Gbit on the way.

- Expect mixed SLC – MLC flash SSDs in the near future.
The process to write data to flash follows these steps:

- Determine “block” to update. NAND flash is typically divided into 128KB blocks and further subdivided into 2KB pages.
- Copy data from the existing “block” (if necessary)
- Erase the “block” and reset cell to all “1’s”
- Rewrite the “block”, only 0’s can be written to a flash cell.
DDR RAM Characteristics

- Unlimited writes per cell
- Primarily used as computer memory
- Higher cost and lower density than NAND flash
- Inherently volatile
- Highly reliable chip design
- 10-15 nanoseconds read and write times
- Maximum density 1Gbit (2Gbit is being sampled)
- DDR RAM is well suited for the enterprise.
What is a Solid State Disk?

<table>
<thead>
<tr>
<th>1.8”</th>
<th>2.5”</th>
<th>3.5”</th>
<th>JBOD</th>
<th>Rack Mount</th>
</tr>
</thead>
</table>

- **Flash**
  - SATA
  - IDE

- **SATA**
  - IDE
  - IDE
  - SCSI
  - Fibre Channel

- **SCSI**
  - Fibre Channel
  - SAS

- **SAS**
  - InfiniBand
  - SAS

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Why Solid State Disks?
Converging Trends
Why Solid State Disks?
Latency Matters

“Money can buy bandwidth, but latency is forever”

John R. Mashey, Chief Scientist SGI,
“Big Data and the Next Wave of InfraStress”, USENIX, 1999
Why Solid State Disks?
Little Change in HDD RPM

- 1956 RAMAC
  - the first disk drive
  - 5 MB storage
  - 1,200 RPM

- 2007 SCSI Hard Drive
  - 400 GB storage
  - 15,000 RPM

- From 1956 to 2007:
  - 12.5 times increase in RPM
  - 80,000 times increase in capacity
Why Solid State Disks?
Data Access Times

Data Access Times
(assumes a cache-miss)

Milliseconds

<table>
<thead>
<tr>
<th></th>
<th>Read</th>
<th>Write</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDD</td>
<td>4</td>
<td>0.2</td>
</tr>
<tr>
<td>Flash</td>
<td>2</td>
<td>0.02</td>
</tr>
<tr>
<td>DDR RAM</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Why Solid State Disks? Random I/O’s

Random I/O's Per Second
(assumes a cache-miss)

- HDD: 200 I/Os/Sec (Read 200, Write 0)
- Flash: 100,000 I/Os/Sec (Read 20,000, Write 80,000)
- DDR RAM: 400,000 I/Os/Sec (Read 400,000, Write 0)
Why Solid State Disks?
Low Power

Relative Comparison of Storage Mediums (Tiers) For Similar Capacities

Why Solid State Disks?  
Dropping Prices

Average Price per GB Comparison - SSD and HDD by Form Factor


Note: DRAM SSD include additional components (i.e. batteries, etc)
Why Solid State Disks?
Low Price for Performance

Price / IOPS

- DDR: $0.20
- Flash: $0.84
- HDD: $2.00
Flash SSD
Killer Applications

- Business notebook computer storage
  - Faster OS startup
  - Improved notebook read performance
  - Low power
  - Rugged
Data warehousing

- Terabytes of capacity needed as hot files are difficult to isolate to a small amount of data
- Very read intensive applications
- Cache will preserve write performance at levels the enterprise is accustomed to receiving

Rendering

- Small block random I/O application
- Very read intensive application
- Hot files are difficult to isolate
Cached Flash RAID SSD
Killer Applications

- **Video on demand**
  - Storing frequently accessed movies requires 1TB plus capacity
  - Very read intensive applications
  - Less frequently accessed content still stored in HDD RAID

- **Seismic processing**
  - Large capacity of data (4TB plus), broadly and randomly accessed
  - Very read intensive application
DDR RAM SSD
Killer Applications

➤ Write intensive OLTP environments
   ◦ Heavy writes make these environments unsuitable for flash systems
   ◦ Store transaction logs, temporary space, and undo segments on SSD

➤ Web transaction databases
   ◦ Extreme concurrency
   ◦ High read and write volumes

➤ Single-threaded applications
   ◦ The ultimate latency sensitive application
   ◦ Often found in the financial industry
Mission critical data warehousing

- When company profitability or lives are on the line, nothing is faster than a DDR RAM based solution
- Data Warehouses with simultaneous high ingest rates and high query rates
Growth in the Enterprise SSD Market


Units (kU)

Revenue ($M)

2007 2008 2009 2010 2011 2012

80% CAGR

217% CAGR
Flash SSD in an HDD Form Factor

Moving from HDD to SSD
- Flash SSD Characteristics
- Market Segmentation
- Performance Comparisons
- Wear Life
- System Design Considerations
Consistent Characteristics

- Small block random read performance is excellent versus HDD
- Read / write performance is asymmetric
  - Writes slower than reads
- Sequential performance today not much better than enterprise HDD
- Power less than HDD
- More expensive per capacity than HDD / less expensive per IOP
Flash SSD Market Segments

Flash SSD pricing

Flash SSD vs. HDD Performance

- **HDD Performance**
  - Roughly correlated to rotational speed

- **SSD Performance**
  - Varies widely between drives
  - Varies with work load in surprising ways
  - Varies with previous access patterns
Flash SSD vs. HDD Performance

<table>
<thead>
<tr>
<th>SSD Random 512 byte IOPs Performance</th>
<th>Read</th>
<th>Write</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSD A</td>
<td>45000</td>
<td>16000</td>
</tr>
<tr>
<td>SSD B</td>
<td>19000</td>
<td>130</td>
</tr>
<tr>
<td>SSD C</td>
<td>7000</td>
<td>15</td>
</tr>
<tr>
<td>SSD D</td>
<td>6300</td>
<td>926</td>
</tr>
<tr>
<td>15K rpm HDD*</td>
<td>185</td>
<td>170</td>
</tr>
<tr>
<td>7.2K rpm HDD*</td>
<td>79</td>
<td>73</td>
</tr>
<tr>
<td>5.4K rpm HDD*</td>
<td>60</td>
<td>57</td>
</tr>
</tbody>
</table>

* calculated from data sheet seek time
• Be careful about performance assumptions when dealing with asymmetrical read and write performance
## Flash SSD vs. HDD Performance

<table>
<thead>
<tr>
<th>SSD Sequential Performance MB/sec</th>
<th>Read</th>
<th>Write</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSD A</td>
<td>220</td>
<td>115</td>
</tr>
<tr>
<td>SSD B</td>
<td>130</td>
<td>120</td>
</tr>
<tr>
<td>SSD C</td>
<td>57</td>
<td>38</td>
</tr>
<tr>
<td>SSD D</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>15K rpm HDD</td>
<td>171</td>
<td>171</td>
</tr>
<tr>
<td>7.2K rpm HDD</td>
<td>105</td>
<td>105</td>
</tr>
<tr>
<td>5.4K rpm HDD</td>
<td>61</td>
<td>61</td>
</tr>
</tbody>
</table>
SSD Performance Surprises

- Mixing reads & write slower than writes

![4K IOPS Performance Chart]

- The chart shows the performance of SSDs and HDDs under different read/write mixes (100/0, 90/10, 80/20, 70/30, 60/50, 50/50, 0/100).

- As the read/write mix changes, the IOPs (I/O operations per second) decrease, indicating slower performance.

- The chart highlights the performance advantages of SSDs in mixed workloads compared to HDDs.
SSD Performance Surprises

- Comparative performance between drives differs based on IO profile

![Graph showing IOPs performance vs. command transfer length for Drive X and Drive Y](image-url)
SSD Performance Surprises

- Previous access patterns can dramatically affect current performance

### 8K IOPs over several Runs

- Run 1: 2500 IOPs
- Run 2: 4000 IOPs (peaks)
- Run 3: 500 IOPs (dramatic drop)
- Run 4: 4500 IOPs (recovery)

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Flash SSD Wear Life

**Factors affecting wear life**

- **Flash Technology**
  - SLC – 100,000 P/E cycle
  - MLC – 10,000 P/E cycles

- **Controller Design**
  - Average Flash Writes Per Host Write
  - Efficiency of Wear Leveling
  - SSD Rated Capacity
  - SSD Flash Capacity Above Rated Capacity

- **Use**
  - Write rate at IO profiles
  - Duty Cycle
Flash SSD Wear Life

- Wear Leveling Efficiency: 1.1
- Write Efficiency: 1.1
- Over Provisioning: 30%
- Duty Cycle: 80%
- R/W: 80/20
- User Capacity: 64GB
System Design Considerations

○ System Design Example
  ▶ IO Workload
    ▶ 75/25 R/W Mix at 4K Transfer lengths
    ▶ 16 commands queued
  ▶ SSD A IOPs = 16000
  ▶ FC HDD IOPs = 310

○ Prices
  ▶ 73 GB FC HDD - $250 – price from web search
  ▶ 64 Gb SSD A - $60/GB from IDC chart for enterprise drive price

<table>
<thead>
<tr>
<th>Drive</th>
<th>Cap (GB)</th>
<th>IOPs</th>
<th>Price / GB</th>
<th>Drive Cost</th>
<th>$$ / IOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>15K RPM HDD</td>
<td>73</td>
<td>310</td>
<td>$5.00</td>
<td>$250.00</td>
<td>$0.81</td>
</tr>
<tr>
<td>SSD A</td>
<td>64</td>
<td>16000</td>
<td>$60.00</td>
<td>$3,840.00</td>
<td>$0.24</td>
</tr>
</tbody>
</table>
System Design Considerations

- **System 1 – Match IOPs**
- **System 2 – Match Price**
- **System 3 – Match Capacity with 20% of Capacity Fast**

<table>
<thead>
<tr>
<th></th>
<th>HDD System</th>
<th>Match IOPs</th>
<th>Match Price</th>
<th>20% SSD</th>
</tr>
</thead>
<tbody>
<tr>
<td># SSD</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>23</td>
</tr>
<tr>
<td># HDD</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>80</td>
</tr>
<tr>
<td>System IOPs @ profile</td>
<td>31000</td>
<td>32000</td>
<td>96000</td>
<td>392800</td>
</tr>
<tr>
<td>Drive Cost</td>
<td>$25,000.00</td>
<td>$7,680.00</td>
<td>$23,040.00</td>
<td>$108,320.00</td>
</tr>
<tr>
<td>System Capacity (GB)</td>
<td>7300</td>
<td>128</td>
<td>384</td>
<td>7312</td>
</tr>
<tr>
<td>SSD % Original Capacity</td>
<td>0.0%</td>
<td>1.8%</td>
<td>5.3%</td>
<td>20.1%</td>
</tr>
<tr>
<td>Drive Power Used (W)</td>
<td>1600</td>
<td>16</td>
<td>48</td>
<td>1464</td>
</tr>
<tr>
<td>% Power Used</td>
<td>100.0%</td>
<td>1.0%</td>
<td>3.0%</td>
<td>91.5%</td>
</tr>
</tbody>
</table>
SSD have a variety of technologies and form factors
Lower SSD pricing has expanded the SSD market potential for higher performance storage tiers
SSD performance characteristics vary widely
Pick the SSD to match the application
Q&A / Feedback

Please send any questions or comments on this presentation to SNIA: trackstorage@snia.org

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