Technology Advancement in SSDs and Related Ecosystem Changes
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27 May 2016
Disruptive Power of SSDs

Enterprise applications

Stock Trading Organizations
Virtualization
Video on Demand
IoT
Cloud Computing
Video/Graphics editing

Aerospace
Military
Industrial Operations
Medical
Smart phones
Laptops
Tablets
Datacenter

Industries
Solid State Drives
Devices and Systems

Digital 5 Forces

Cloud
AI / Robotics
Analytics & Big Data
Social Networking
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SSD Market Growth and Business Implications

- **Global market for SSDs**
  - Growth at CAGR of 40.7%
  - Market share to reach around $229.5 billion

- **PCle SSD growth**
  - Growth at CAGR of 61.2%

- **NVDIMM growth**
  - Growth at CAGR of 136.6%
  - Market share to reach around $1316.3 Mn

**Targeted areas, major players and their business approach**

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Technology Advancements in SSD

Software
- HMS
- FILE SYSTEM
- nvm EXPRESS
- SCSI EXPRESS

Hardware
- NVMe based PCIe SSD
- CFM
- NVDIMM
- 3D NAND based SSD
- Single memory sub system combines the technology of DRAM and NAND flash placed on unused DRAM slots
- Bridge the gap between SSD and DRAM
- Available in three variants as
  - NVDIMM-N: Memory mapped DRAM. Flash is not system mapped. Byte and Block oriented access.
  - NVDIMM-F: Memory mapped Flash with no DRAM. Block oriented access.
  - NVDIMM-P: A combination of NVDIMM-N and NVDIMM-F
- Vertically Stacked NAND. Instead of scaling in x-y direction it scales up
- Provides high capacity in smaller space and improve electrical performance due to reduction in interconnect length among cells
- 3-D NAND based on 32, 48, 64 layers
Storage devices connected to PCIe slot providing improved performance and low latency
- Storage is more closer to CPU
- Host bus adapter controller portion has been embedded in the drive

Storage vendors using CFM in all flash appliance for 100% guaranteed response time I/O.
- Higher density and higher performance
- Require to design Storage architecture from scratch and customized OS.
Host managed SSDs

- SSD controller is aware of the internal operations going inside through flash translation layer
- Through HMS, host computer will be aware of to drive internal operations
- Host will be controlling through the command (extension in ATA command set), which has support in firmware of SSDs

NVMe over PCIe and SCSI over PCIe

- Non Volatile Memory Express (NVMe)
  - New high performance software interface over PCIe based storage
  - Designed from ground to harness the performance benefit of PCIe
  - NVMe provides high degree of parallelism, manage up to 64K commands at a time having queue depth of 64K

- SCSI Express (SCSi)
  - SCSI Express (SCSi) is an emerging interface that is used to execute SCSI commands over PCIe
  - Handle higher IOPS associated with SSD due to SCSi multi-core architecture and optimized driver stack.
SSD Software Developments (Contd..)

**BIOS**
- OEM vendors are providing support as NVDIMM enabled platform by changing their BIOS to detect the device as NVDIMM

**Drivers/utility programs**
- Drivers for server solutions like NVDIMM and NVMe based PCIe SSD
- Manageability software for end devices like health monitoring suite
- Implementation of TRIM utility for SSD
  - Enables the SSD’s Garbage Collection to avoid moving the invalid/deleted data blocks, saving time and write cycles by not rewriting the invalid data
  - Reduces the number of erase cycles on the flash memory providing higher performance during writes

**File system optimized**
- Traditional file systems have been optimized such as PM aware file system that have features supporting SSDs/Flash/NVDIMM such as
  - JFFS2
  - YAAFS
  - UBIFS
  - F2FS
  - ZFS
  - BTRFS
  - NVDIMM aware FS
Software Adaptation

- Re-designing application and tools keeping flash architecture in focus
  - Atomic write API on SSD helps database application to accelerate
  - Flash aware demand paging
  - Performance test suite/framework will need to be completely redesigned for All Flash Array

- Customizing component like file system, operating system and drivers which will utilize the potential of persistent memory.

- For support of NVDIMM in their server products vendors needs to update BIOS/Memory Reference Code (memory map update, memory allocation table) and operating system.

- Vendor specific or vendor neutral (open source) needs to be upgraded to accommodate the new SSDs changes such as NVMe based PCIe SSDs, NVDIMM.
**Eco System Adaptation (Contd..)**

**Storage Adaptation**
- All Flash Array/Hybrid Flash Array
  - HDD replaced by SSD
  - Storage Architecture written from scratch
  - OS customized to completely leverage the SSD
  - CFM, NVMe over PCIe and 3D NAND based SSD are being used in AFA with proper modification
- Converged and Hyper converged Infrastructure
  - SSD based CI and HCI are coming in market

**Server Adaptation**
- NVDIMM solutions
- PCIe based direct attached storage
- Saving on Server up-gradation cost by replacing HDD with SSD

**Network Adaptation**
- Earlier bottleneck was on compute, then it shifted to storage and now with mature and advance technology in storage like SSD, bottleneck has shifted to network.
  - Vendors are providing support for 10GbE connectivity in their servers and storage products to completely utilize the SSD.
Data recovery on SSD

Data recovery companies are developing solutions to recover data on SSD which is completely new and difficult due to IP protection of SSDs.

- Major challenges are encrypted devices, decoding Flash Transition Layer, Getting the correct NAND page layout and creating the useful data out of Raw NAND pages.
- SSD vendors are designing the self recoverable drive
SSD is in mainstream and affecting almost all the industries and trends. Recent development in SSD are providing the increased capacity, better endurance, higher IOPS and low power consumption with the same form factor.

There are multiple technology evolving which can be adapted instead of NAND based SSD. But most of them are on design/development phase. Some of them are

- **3D XPoint Technology**: New technology will fill a gap in the storage market between DRAM and NAND flash, claiming it is up to 1,000 times faster than NAND flash. It will have much greater endurance and storage density than NAND.
- **Resistive RAM including Memristors (RRAM)**
- **Magneto-resistive RAM including spin-transfer torque (MRAM)**

But none of these technology will beat SSD until they will match it by cost and capacity.
Q&A
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Thank You