Technology Advancement in SSDs and Related Ecosystem Changes
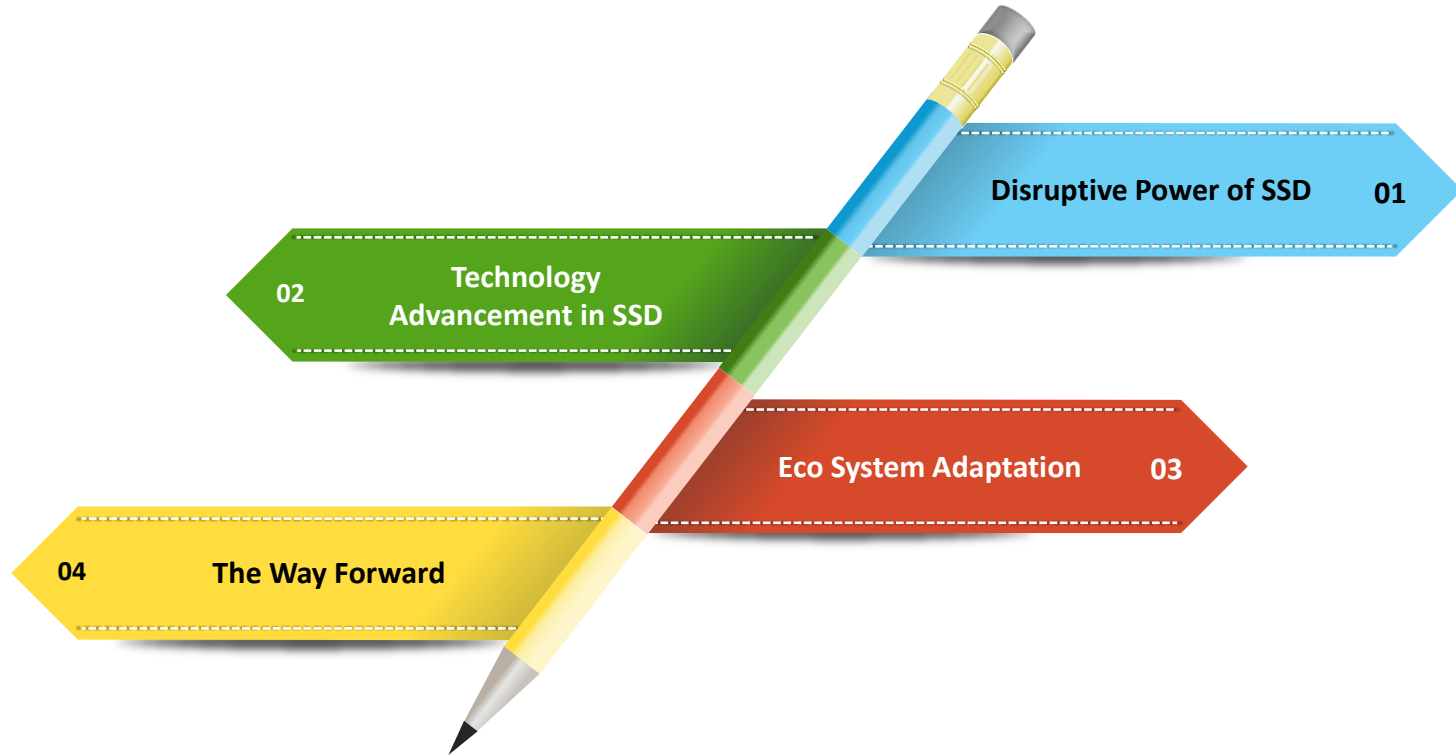
Sanjeev Kumar/ Ravish Sharma

Software Product Engineering, HiTech, Tata Consultancy Services
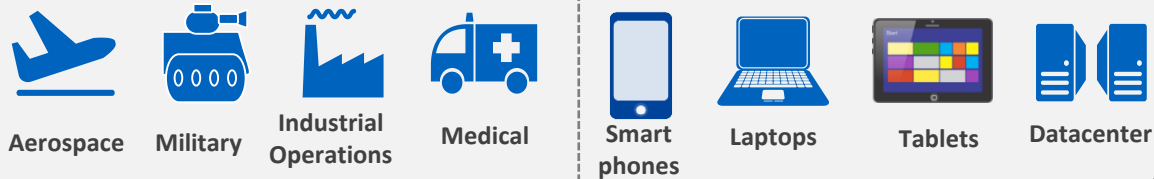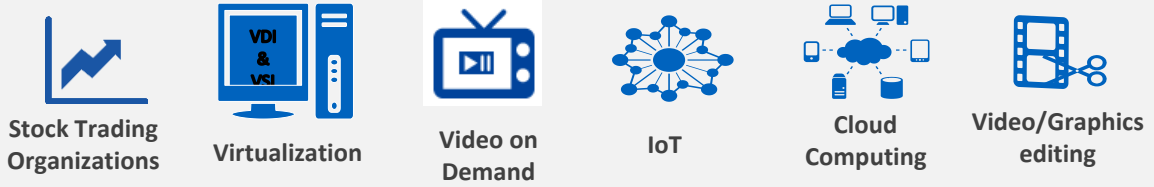
27 May 2016

Disruptive Power of SSD   01

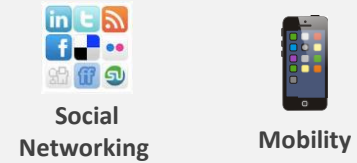Technology Advancement in SSD   02

Eco System Adaptation   03

The Way Forward   04

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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

Cloud

AI / Robotics • Analytics & Big Data

Social Networking • Mobility

Digital 5 Forces
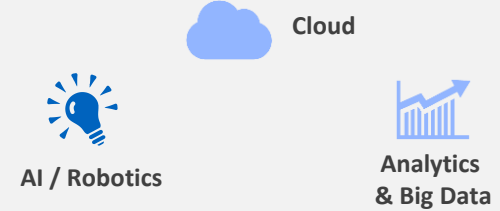
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SSD Market Growth and Business Implications

Global market for SSDs

- Growth at CAGR of 40.7%
- Market share to reach around $229.5 billion

2015   2022

PCIe SSD growth

- Growth at CAGR of 61.2%

2015   2022

NVDIMM growth

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

2015   2021
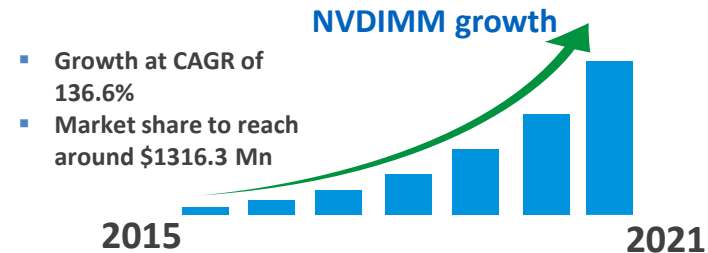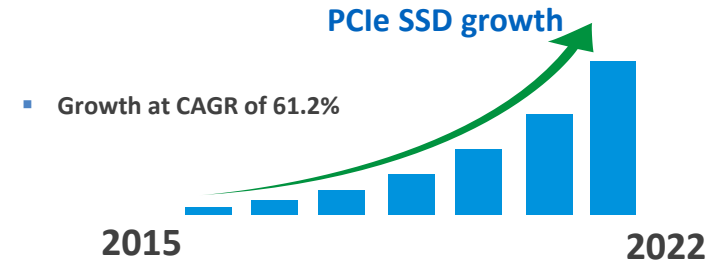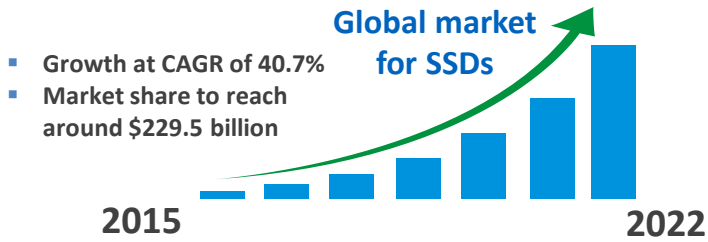
Major Target areas	**SSD Market Players**	**Business approach**
Storage Appliances	Conventional HDD vendors	Developing new technology/products
Server	Semiconductor vendors (Having no HDD experience)	Acquisitions
Mobile/Laptop/ Desktop/Tablets	Startup vendors	Joint venture to develop new technology

Targeted areas, major players and their business approach

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Technology Advancements in SSD

Software

HMS

FILE SYSTEM

nvm EXPRESS

SCSI EXPRESS

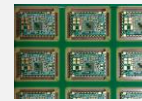## Hardware

NVMe based PCIe SSD

CFM

NVDIMM

3D NAND based SSD

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SSD Hardware Developments

NVDIMM

NVDIMM

| NAND Flash Module | NVDIMM controller | DRAM module |

DRAM slot

3D NAND based SSD

Cells Stacked vertically
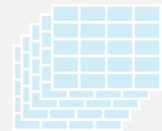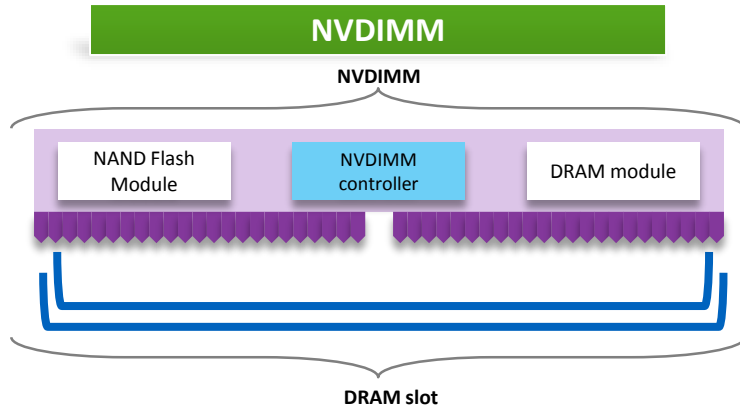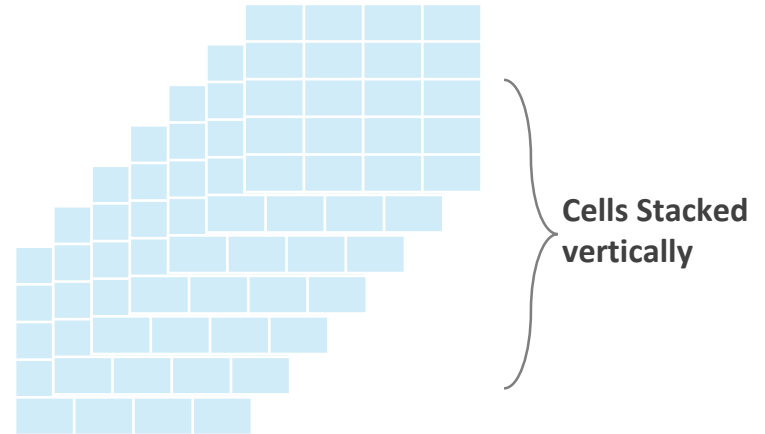
- Single memory sub system combines the technology of DRAM and NAND flash placed on unused DRAM slots
- Bridge the gap between SSD and DRAM
- Available in three variants as
  - NVDIMM-N: Memory mapped DRAM. Flash is not system mapped. Byte and Block oriented access.
  - NVDIMM-F: Memory mapped Flash 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

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SSD Hardware Developments (Contd..)

PCIe based SSDs

NAND Flash Interface   Device Interface   Host Bus

NAND Flash — **Host Bus Adaptor** — **Controller** — **Host System (OS)**

PCIe based SSD   PCIe Slot
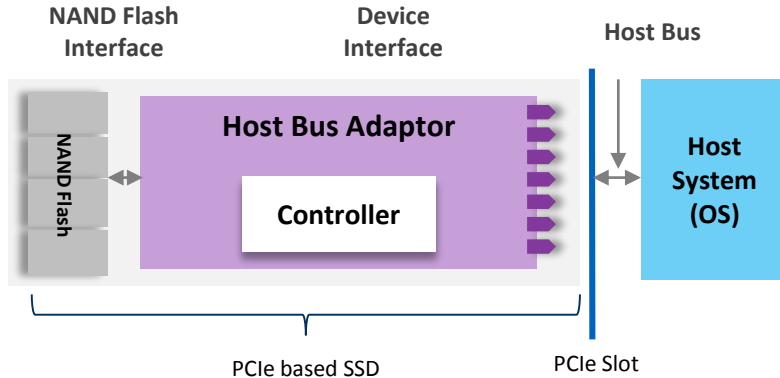
- Storage devices connected to PCIe slot providing improved performance and low latency
- Storage is more closer to CPU
- Host bus adapter controller portion has been embedded in the drive

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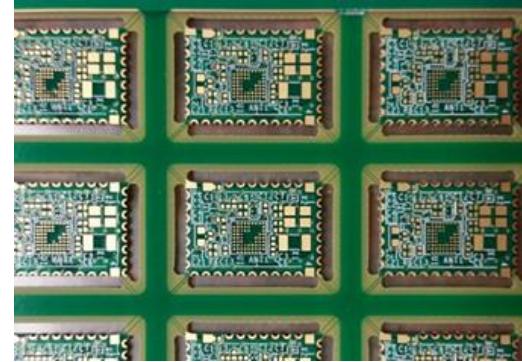
- Storage vendors using CFM in all flash appliance for 100% guaranteed response time I/O.
- Higher density and higher performance
- Require to design Storage architecture from scratch and customized OS.

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SSD Software Developments (Contd..)

Host managed SSDs

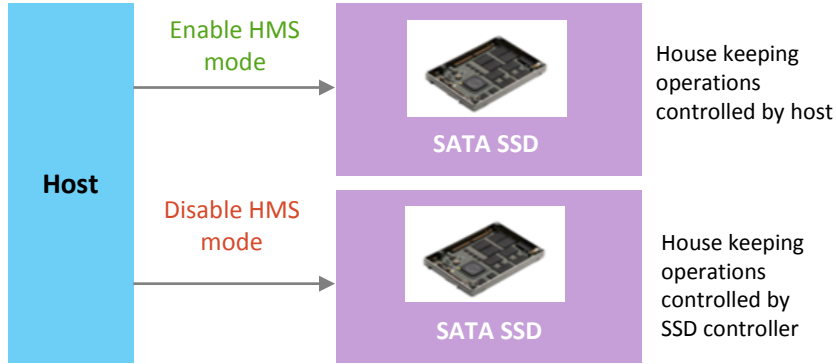**Enable HMS mode** → SATA SSD

House keeping operations controlled by host

Disable HMS mode → SATA SSD

House keeping operations controlled by SSD controller

Host

NVMe over PCIe and SCSI over PCIe

- 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

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

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SSD Software Developments (Contd..)

BIOS

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

File system optimized

FILE SYSTEM

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
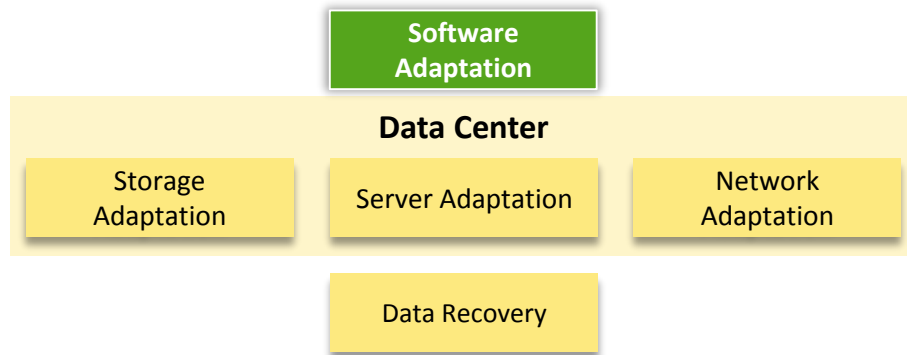 - Reduces the number of erase cycles on the flash memory providing higher performance during writes

- 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

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Eco-System Adaptation Towards SSD Technology Growth

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.

Software Adaptation

Data Center

| Storage Adaptation | Server Adaptation | Network Adaptation |

Data Recovery

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Eco System Adaptation (Contd..)
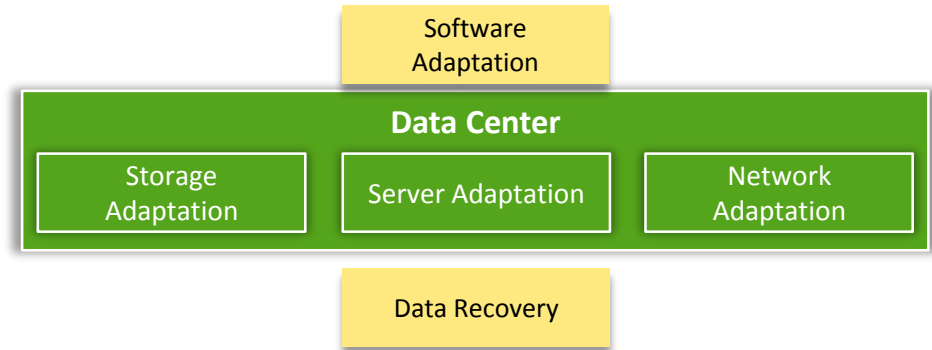
Storage Adaptation

- 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.
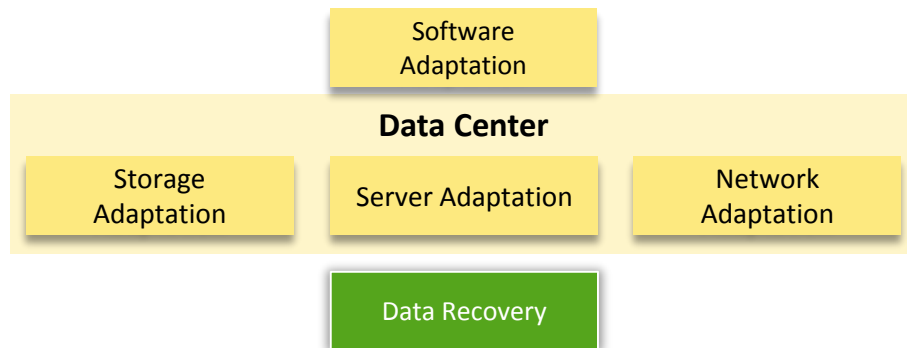
Software Adaptation

Data Center

Storage Adaptation	Server Adaptation	Network Adaptation

Data Recovery

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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

Software Adaptation

Data Center

| Storage Adaptation | Server Adaptation | Network Adaptation |

Data Recovery

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The Way Forward

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.

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Q&A
mail us @ sanjeev24.k@tcs.com

Thank You