



Education

# Overview and Current Topics in Solid State Storage

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- Goal of this tutorial:
  - Overview of Solid State Storage
    - ◆ Leading into more detailed Tutorials
- What is Solid State Storage?
- The economics of Solid State Storage
- A survey through various Solid State Storage designs
- Current topics, especially related to enterprise use
  
- Q&A

# SNIA Shared Storage Model *A Layered View*

IV. Application

III. File/record layer

IIIa. Database

IIIb. File system

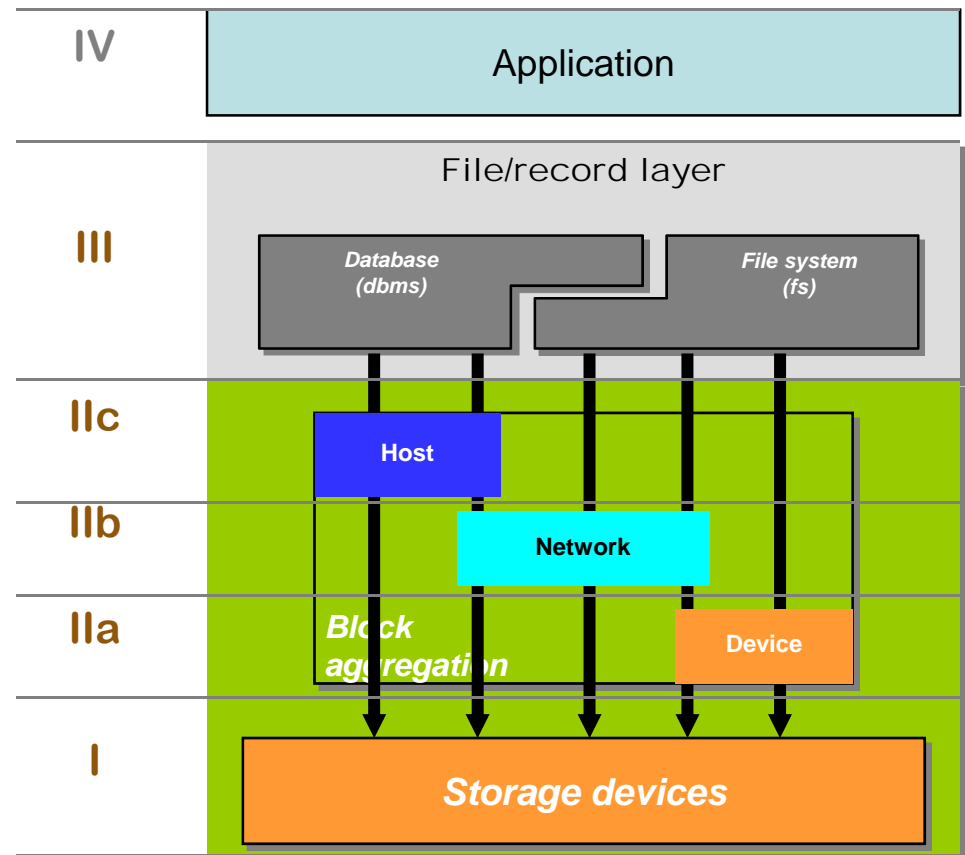
II. Block aggregation

IIa. Host

IIb. Network

**IIc. Device**

**I. Storage devices**



The SNIA Shared Storage Model uses the term “aggregation” instead of “virtualization”

# A Blast from the Past – August 1981



# Machine Specifications

Processor	8088
Speed	4.77 MHz
RAM	16KB
Storage	Cassette Tape, optionally 5.25" 160KB floppy drives
Expansion	5 expansion slots
Bus	Industry Standard Architecture (ISA)
Video	Initially CGA (320x200x16 color, 640x200x2 color) or monochrome (80x25 text only)
I/O	Parallel, Serial
OS	Basic 1 (ROM)
Killer App	VisiCalc

# Fast Forward – to Today

- Today, we have CPUs which are 1,000x faster
  - ◆ Instead of MHz, we have GHz
  - ◆ Instead of one core, we have multi-core
- Today, we have RAM which is 1,000,000x larger
  - ◆ Instead of KB, we have GB
  - ◆ Some machines are approaching TB (!)
- Today, we have storage which is 1,000,000x deeper
  - ◆ Instead of MB, we have TB
- So what's the problem?

- In a perfect world, I/O would not be necessary
  - ◆ 1<sup>st</sup> level store would hold everything, forever
- Access Density – IOPS/GB
  - ◆ Getting WORSE over time for rotating magnetic
  - ◆ Will it get worse over time for non-rotating SSD?
- Access Density Example (more is better):
  - ◆ August 1981 – 625 KB/s, 8.33 ms, 3,600 RPM, 20 IOPS
    - ›  $\text{IOPS/GB} = 20 / .001 = \mathbf{20,000}$
  - ◆ Today – 170,000 KB/s, 2.9 ms, 15,000 RPM, 250 IOPS
    - ›  $\text{IOPS/GB} = 250 / 300 = \mathbf{0.833}$

- Storage devices constructed from chips instead of rotating platters or streaming tape
- Various form factors
  - ◆ HDD forms using HDD interfaces (e.g. FC, SATA)
  - ◆ Non-HDD forms such as PCI-Express cards
- Two basic technologies:
  - ◆ DRAM
    - › Usually accompanied by battery/persistent media
  - ◆ NAND Flash
    - › Other Flash types are becoming less viable

# Solid State Storage – Why?

Images of HDD and Representative SSS

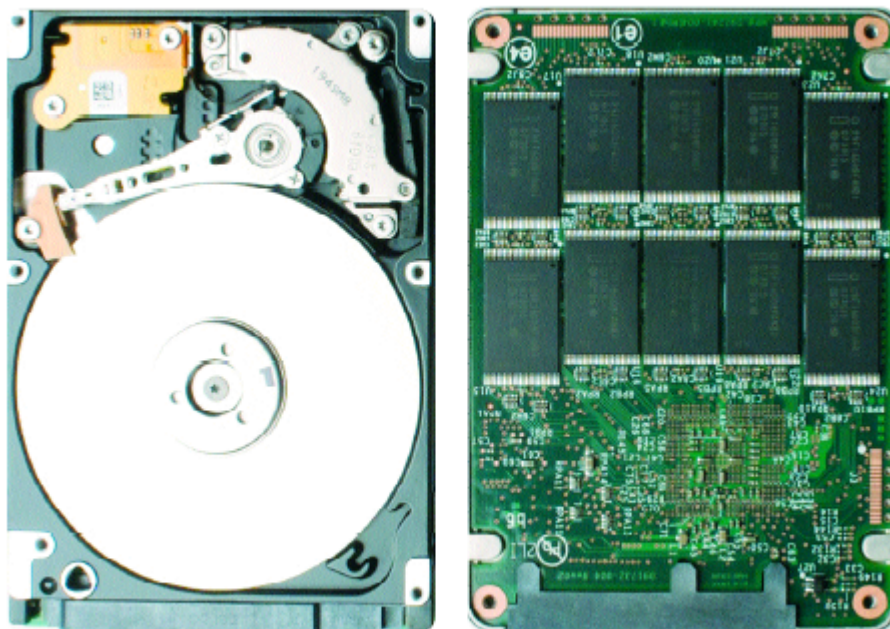


Photo provided by Intel Corp 2008

- Flash as Magnetic Disk Replacement
  - ◆ Write cycles, cost/GB, media lifetime, TCO
- ▶ DRAM as (controller) Cache Replacement
  - ◆ Cost/GB, TCO, expandability/flexibility
- ▶ Consider the Application Workloads
  - ◆ Transactional (random) versus Batch (sequential)
  - ◆ Block versus Files
  - ◆ Structured versus Unstructured

# What functionality do users need?

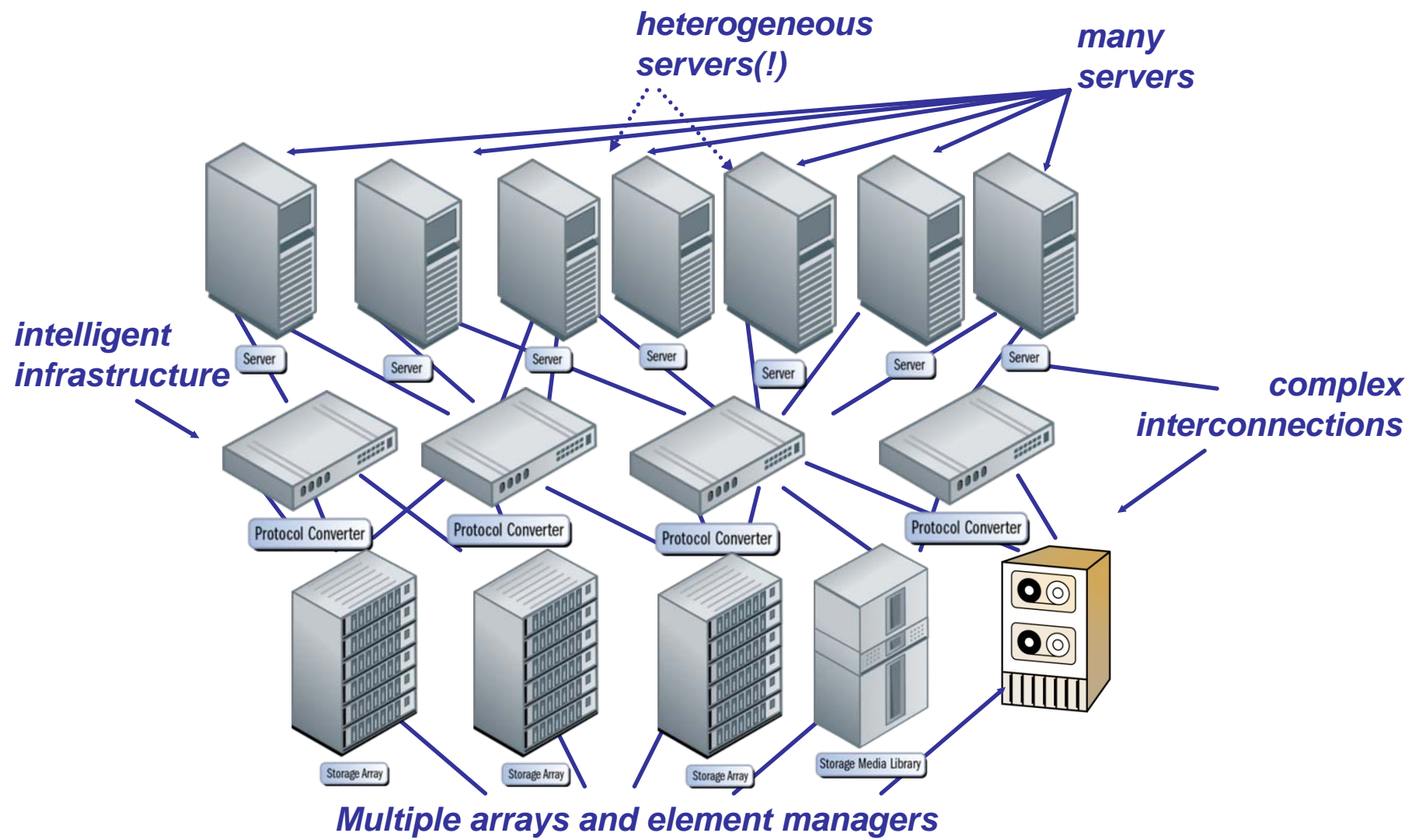
## *Application aspects of storage*

- **Capacity**
  - ◆ Application requirements
  - ◆ Structured / unstructured
  - ◆ Growth potential
- **Performance**
  - ◆ Throughput / IOPS
  - ◆ Responsiveness
- **Availability**
  - ◆ Failure resistance
  - ◆ Recovery time/point
    - **RTO/RPO**
  - ◆ Simplification of change

## *Physical aspects of storage*

- **Capacity**
  - ◆ Disk or Tape Size
  - ◆ Number of disks/channel
  - ◆ Number of tape devices
- **Performance**
  - ◆ Disk latency & seek time
  - ◆ Cache size & hit rate
  - ◆ Media rotation rate (RPM)
  - ◆ Responsiveness
- **Availability**
  - ◆ MTBF/MTTR (Rebuild time)
  - ◆ Path redundancy
  - ◆ Path bandwidth

# Where does Solid State Fit?



- Applications don't want disks
  - ◆ They want space (more is better)
- Applications don't want IOPS
  - ◆ They want time (less is better)
- Applications do I/O because they *have* to
  - ◆ But they don't really *want* to
- The problem is not applications, it's application programmers and the OSes

## ➤ Unstructured data

- ◆ Unstructured data access is a poor fit for SSD
- ◆ Exception – small, non-growing tagged files
- ◆ OS images – boot-from-flash, page-to-DRAM

## ➤ Structured data

- ◆ Structured data access is an excellent fit for SSD
- ◆ Exception – large, growing table spaces

## ➤ Databases have key elements

- ◆ Commit files – logs, redo, undo, tempDB

## Physical disc drive



Disc Drive



### Logical data layout

- Logical Block Addresses (LBA)
- 'Defect-Free'

### LBA

000
001
002
003
004
005
006
.. nnn

### Physical data layout

- C-H-S Addresses
- Media defects



**Check out SNIA Tutorial:  
Virtualization I – How, ...?**

# Economics of Solid State Storage

- Memory densities 64x what they were 3 years ago
- \$/GB is decreasing rapidly
  - ◆ But still nowhere near where rotating disk is \$/GB
- Key metrics are now \$/IOP, \$/IOP/U, \$/IOP/W
- SSS is 100-1000x faster access time
- Bandwidth:
  - ◆ Read bandwidth typically limited only by interface
  - ◆ Write bandwidth typically limited only by controller design
- Read/Random is typically the best use case (existing SSD)
  - ◆ Very consistent I/O response time



**Check out SNIA  
Tutorial:  
Economics of Solid  
State Storage:  
Perception and Reality**

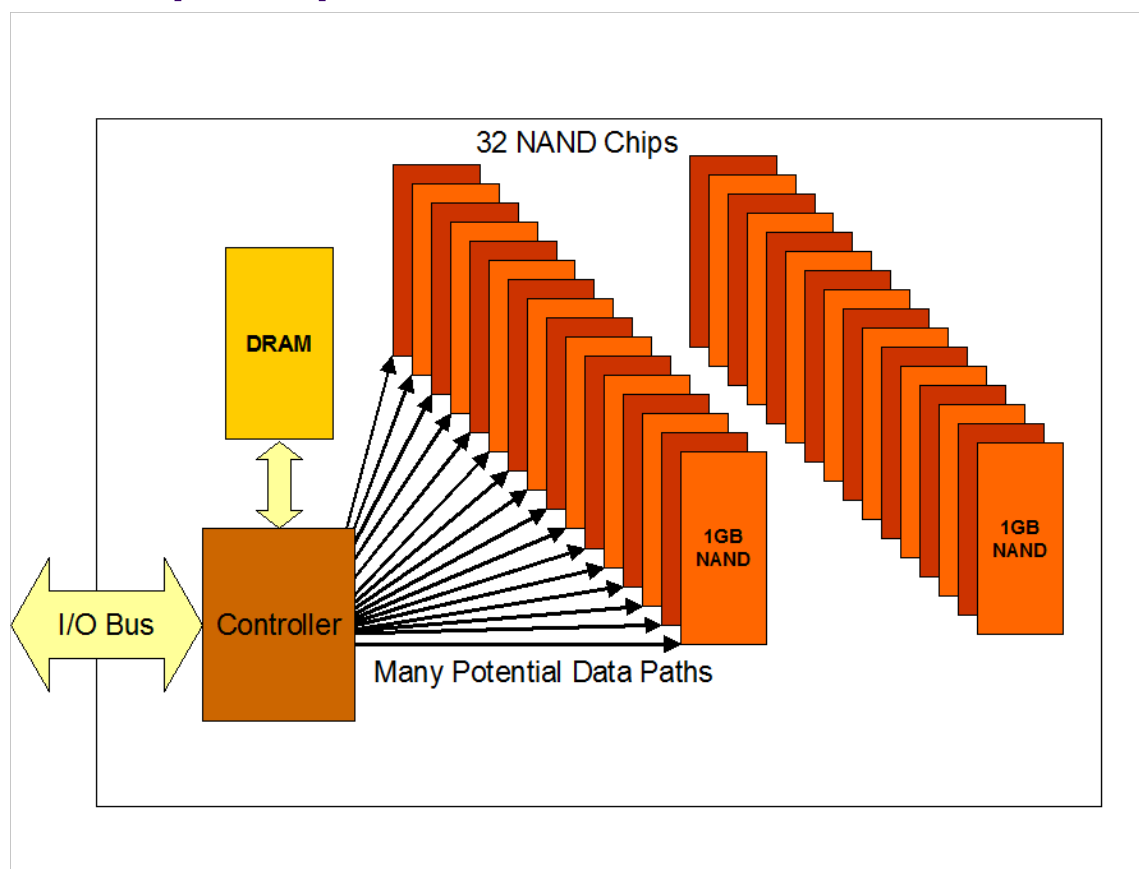
# Impact of Solid State Storage

- Server CPUs today are multicore, GHz
- Millions of CPU cycles during just one HDD seek
- SSS can potentially eliminate waste:
  - ◆ Server infrastructure – reduce CPU load/wait time
  - ◆ Storage infrastructure – reduce short-stroking HDDs
  - ◆ Applications – reduce I/O bounded-ness
  - ◆ Humans – reduce wait time, screen refreshes, queries
  - ◆ Data Centers – reduce power, cooling load, rackspace
- Reliability – a whole ‘nother topic ...



**Check out SNIA Tutorial:  
SSS Reliability – an In-Depth Look**

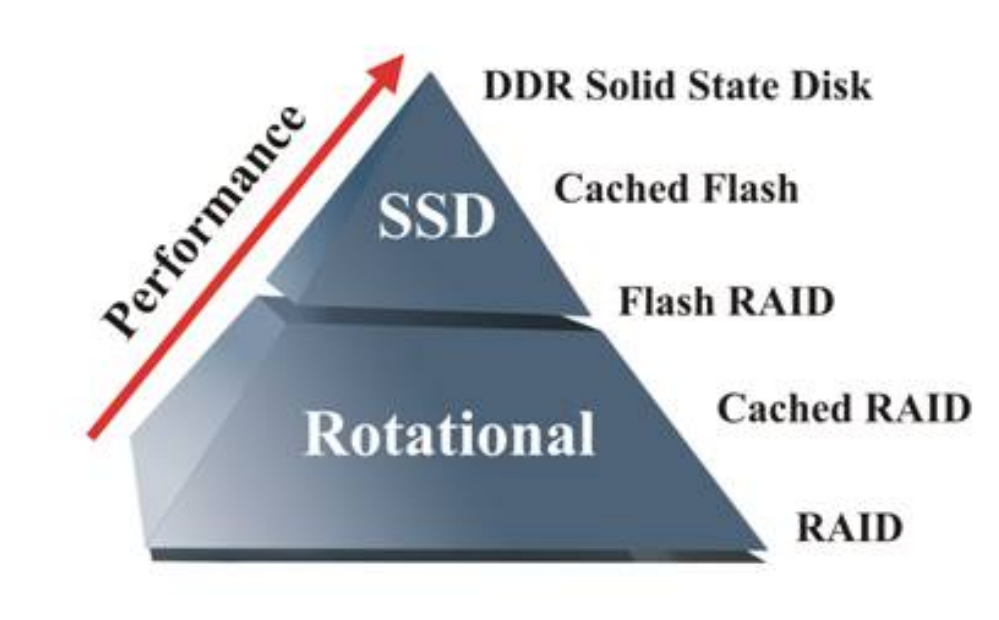
- Use of internal techniques such as striping across multiple chips – parallel access – even more IOPS



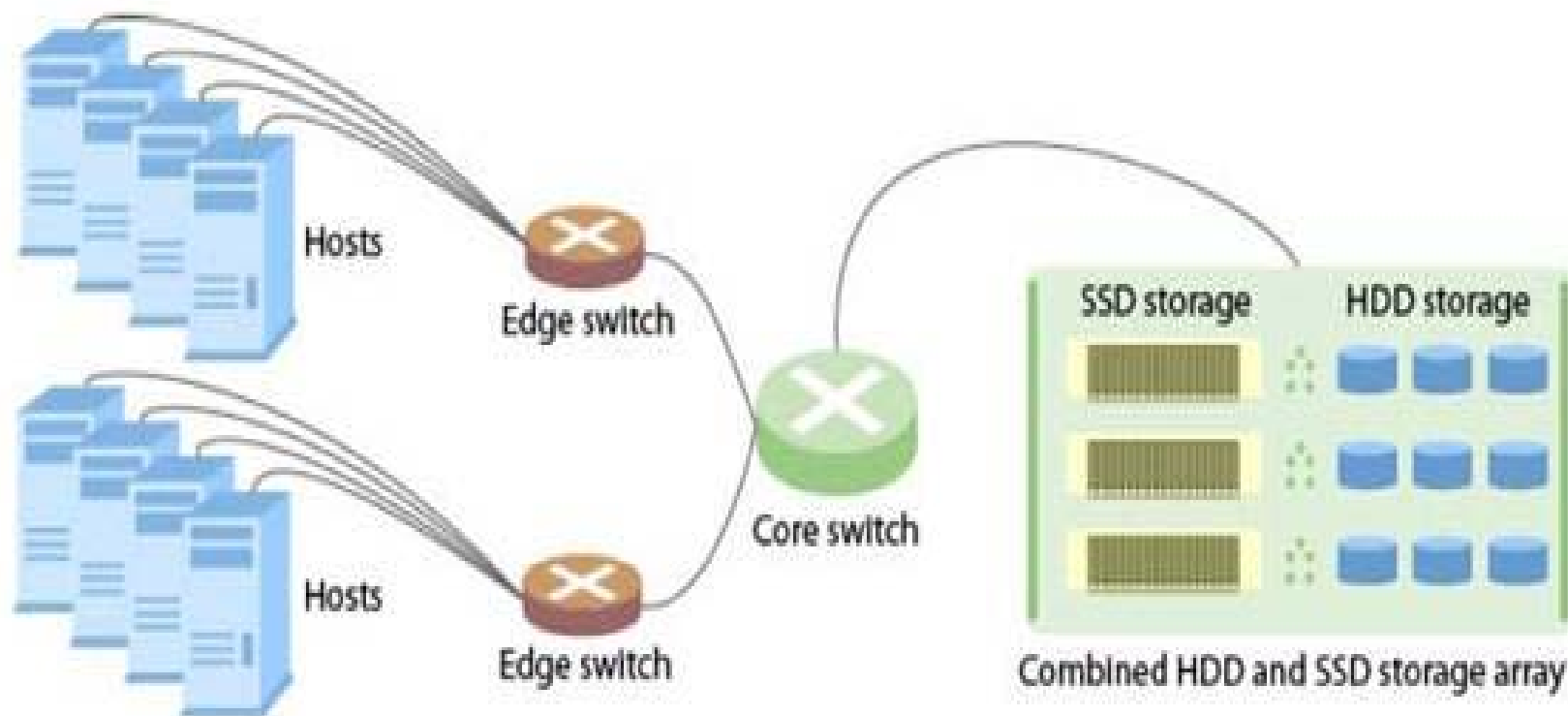
# Tiered Storage and Solid State



- SAN
- NAS
- DAS

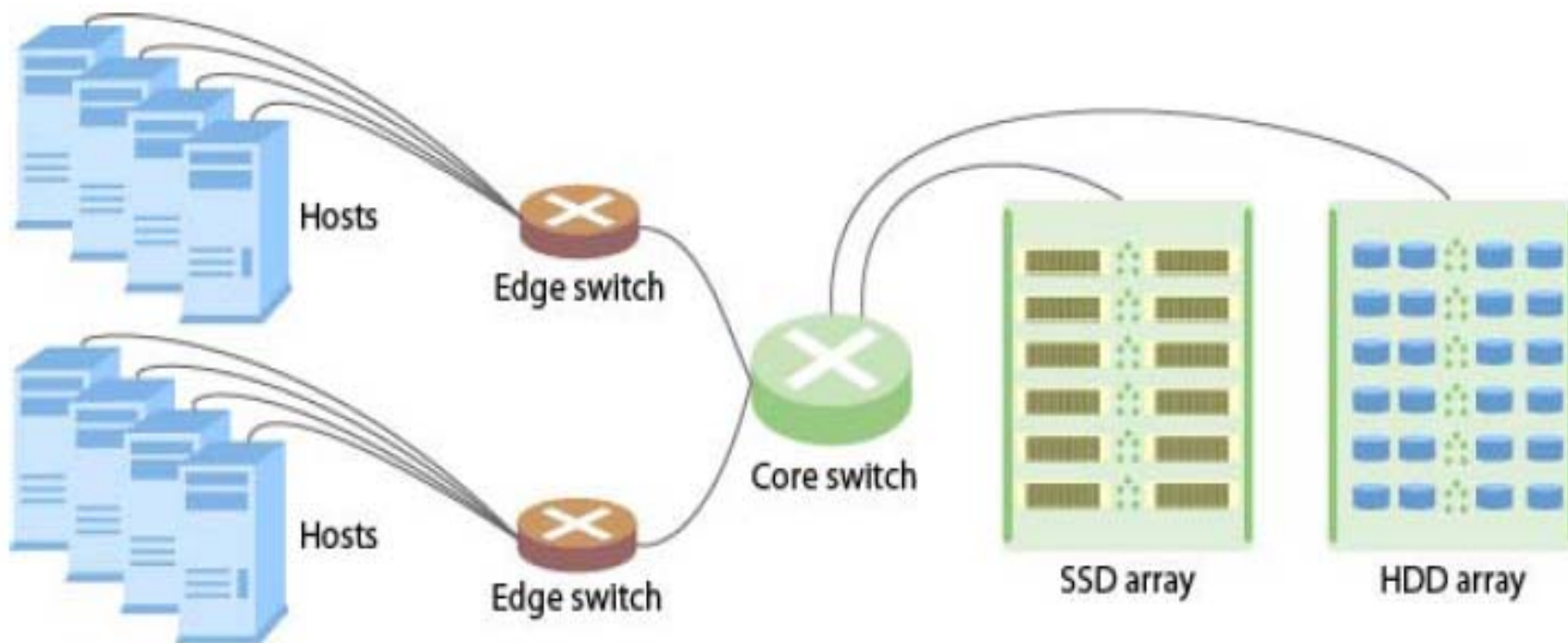


- Arrays – take advantage of existing function
- Hybrid approach – use SSD and HDD in same array

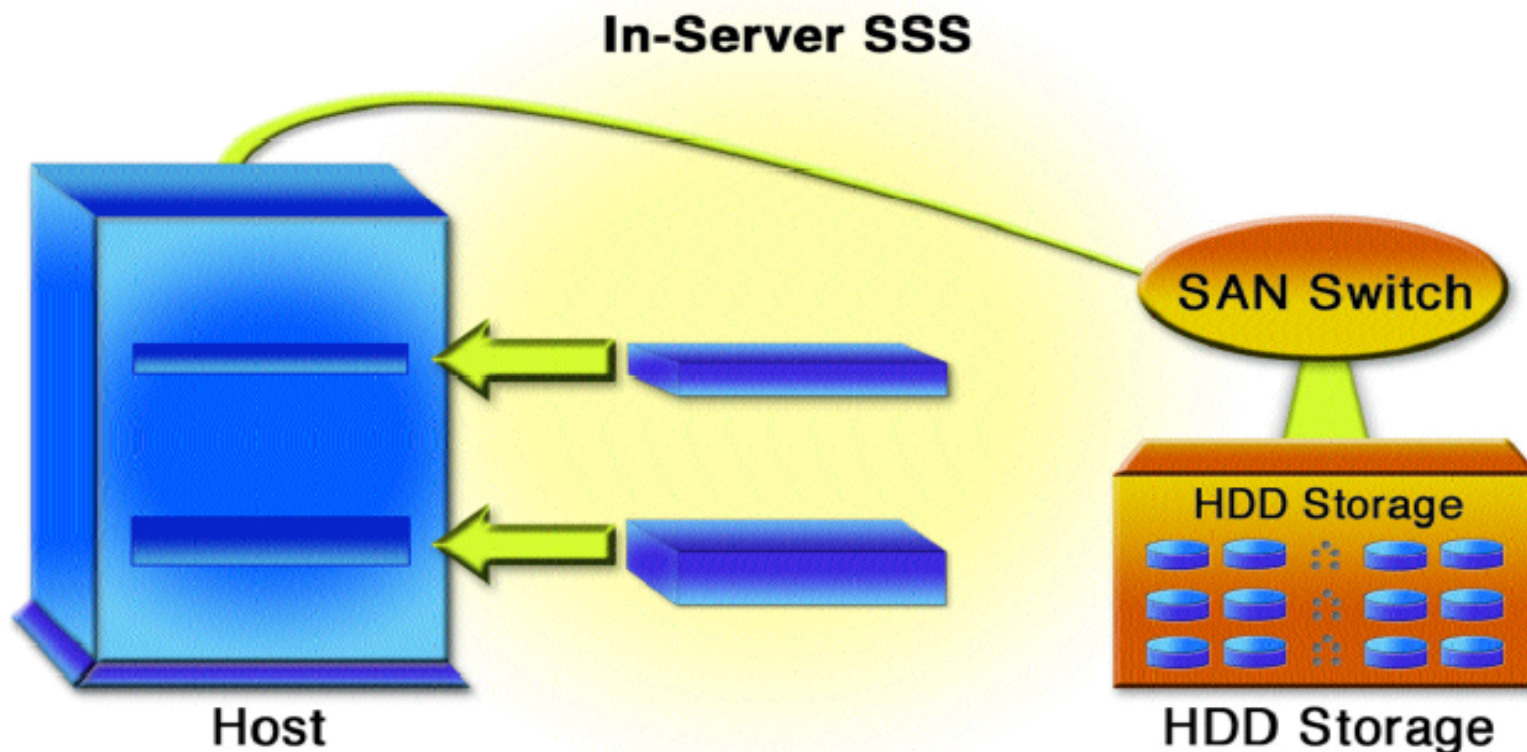


# Architectural Approaches in SSS

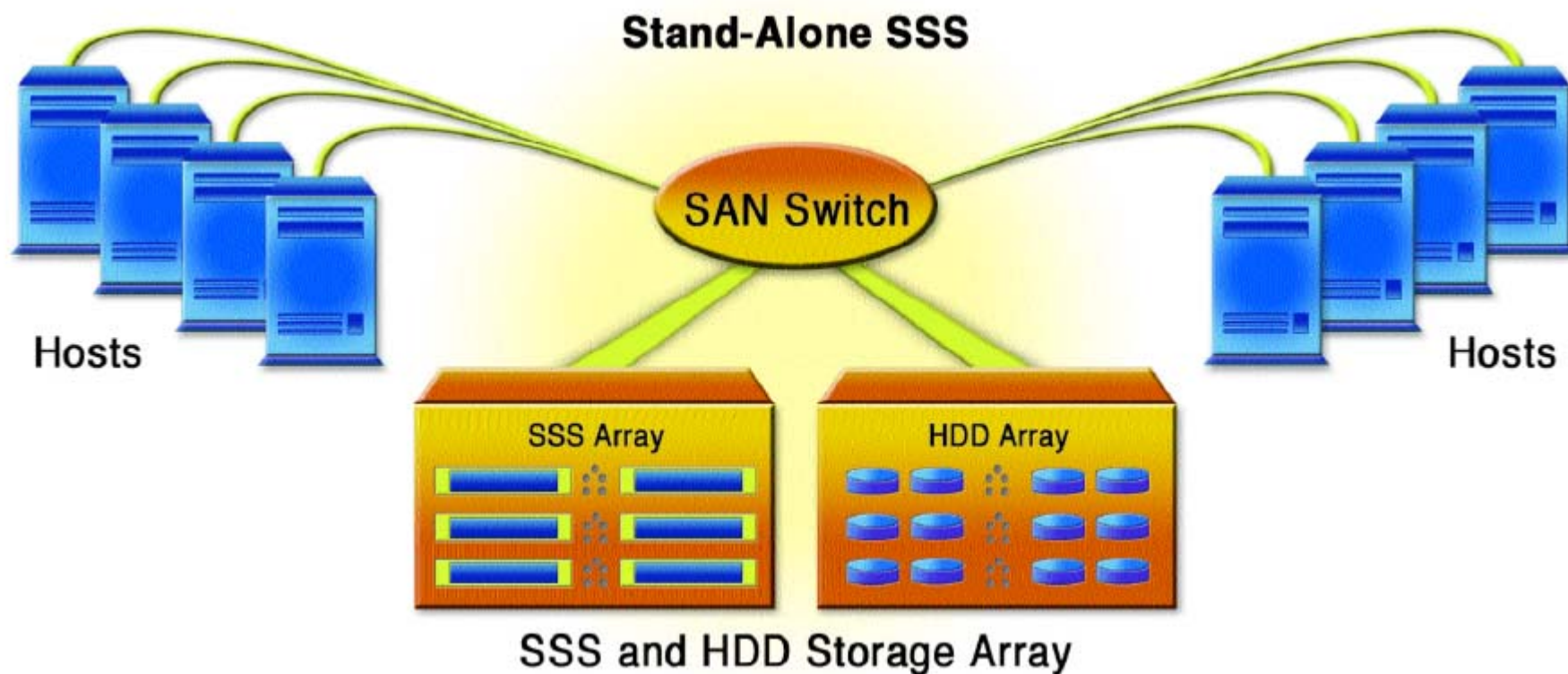
- Arrays – take advantage of existing function
- Hybrid approach – use SSD and HDD in different arrays



- Servers – take advantage of existing busses/interconnect
- Brings SSS closer to the CPU/RAM, architecturally



- Standalone – take advantage of specifically isolating SSS
- Brings SSS to bear on a single server/compute job



# Final Thoughts on Solid State Storage

- What is the impact on application workloads?
  - ◆ SSS may be better → ideal for virtualized workloads
  - ◆ Multiple workloads tend to randomize I/O streams
    - › E.g. two simultaneous sequential workloads = one large random
- What is the impact on server design?
  - ◆ Potential to entertain swap of RAM for SSS
  - ◆ Potential to use bus extension instead of channels
  - ◆ Potential to improve in-box reliability (no moving parts)
- Best practice – use all layers of the storage pyramid
- Application mix may change – layers remain the same



Check out SNIA  
Tutorial: **SSS**  
**Performance**

# Final Thoughts on Solid State Storage

## ➤ What is the 'cost' of storage?

- ◆ Acquisition Cost – very straightforward, a single figure
- ◆ Operational Cost – not straightforward, multiple figures
- ◆ Performance Cost – usually never calculated – but it should!
- ◆ E.g. “if this job ran in 2 hours instead of 10, what’s the \$\$\$?”

## ➤ How to improve Performance Cost?



Check out SNIA  
Tutorial: SSS  
Performance

- ◆ Replace slow components with fast(er) components
  - ◆ Add more components at the same or faster speed
    - › VMs, CPU, RAM, slots, HBAs, channels, controllers, disks, ...
- ## ➤ Best practice – use all layers of the storage pyramid
- ## ➤ Application mix may change – layers remain the same

- Please send any questions or comments on this presentation to SNIA: [tracksolidstate@snia.org](mailto:tracksolidstate@snia.org)

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