Solid State Drive Architecture

A comparison and evaluation of data storage mediums

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Outline

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Introduction

• To gain a full understanding of solid state drives (SSDs), one must be knowledgeable of the current generation of platter based drives
• SSDs mirror the functionality of the existing standard of hard disk drives (HDDs)
Storage Devices as Limiting Factor

- CPU Performance has improved approximately 60% every year
- I/O Sub-System Performance has improved less than 10% each year due to limitations imposed by the mechanical components
- Amdahl’s Law dictates that the disk I/O bottleneck diminishes the improvements introduced by increased RAM and CPU speed to the overall system performance
  - “Only as strong as your weakest link”
HDD vs. SSD

- Same form factors
  - 1.8”, 2.5”, and 3.5”
- Interface
  - SATA, PCIe, SCSI
  - Computer doesn’t necessarily know which is connected
HDD

• Rotating Magnetic Media
  – On a disk called a platter
  – Platter rotates several hundred times a second
    • 5400, 7200, 10000, 15000 rpm
  – Platter contains magnetic domains on which data is written
HDD

- Always contain more than one platter
- There is a head for each platter, but the heads cannot move independently
- Cylinder – All tracks accessible without moving the head assembly
- Head – The device that writes data to and reads the surface of one side of a platter
HDD Data Structure

• Sector – A slice of the platter that contains the minimum addressable read/write portion
  – Typically 512 bytes
• Track – Thin concentric circular strips that contain portions of multiple sectors
  – Head can access all data on a track without moving
HDD Data Structure

- Blocks – The intersection of a track and a sector
  - Minimum addressable size in the HDD
  - Addresses are specified by providing the cylinder, head, and sector number
Logical Block Addressing (LBA)

- A way of addressing blocks that simply numbers them linearly rather than providing a cylinder, head, and sector number
- This scheme is generally replacing the legacy block addressing scheme although both are supported on current SSDs and HDDs
HDD vs. SSD

• Sectors of concentric circles in HDDs represent the LBAs in the system

• In an SSD the LBAs are actually inside of the flash media
  – They represent individual addresses
Interface

• Serial ATA (SATA)
  – Serial: 4 Pin + grounds
  – Reduced 40 pins of parallel ATA (PATA) to 4 pins to increase speed

• Speeds (Maximum)
  – PATA: 133 MB/s
  – SATA-I: 125 MB/s
  – SATA-II: 250 MB/s
  – SATA-III: 500 MB/s
Interface

• PCI Express (PCIe) v2.0
  – 500 MB/s per lane
    • Up to 16 lanes
  – Very low power and broad hardware support

• Regarding SSD
  – PCIe SSDs are used only for extremely high performance applications due to their enormous cost
Latencies

- **HDD**
  - Seek time – amount of the necessary to move the head to the desired cylinder
  - Rotational time – amount of time needed for the media to rotate to the correct sector
- **SDD**
  - Single fetch latency that is orders of magnitude less than HDDs latency
Latency

• Video Demonstration
  – 6:40 -> 7:54
SSD Architecture

• SSDs contain a number of NAND flash components
  – 10 to upwards of 60 or 70
SSD Architecture

• Controller
  – Takes the raw data storage in the NAND flash and makes it look and act like hard disk drive
  – Contains the micro controller, buffer, error correction, and flash interface modules
Controller Components

• Flash interface modules (FIMs) physically and logically connect the controller to the NAND flash devices
  – FIMs have the ability to communicate with multiple NAND flash devices and therefore performance can be increased by adding additional FIMs

• Micro Controller – a processor inside the controller that takes the incoming data and manipulates it
  – Stripping any errors
  – Making sure it is correctly mapped
  – Putting it into the flash or retrieving it from the flash

• DRAM Cache – Reasonable amount of very low latency memory that gives the processor some room to work
NAND Flash Media

• NAND Flash Media contains NAND cells arranged in multiple planes
  – The planes allow for parallel access to the NAND
  – They also allow for interleaving

• The data moves in and out through a cache element
SSDs MLC vs. SLC

• MLC (Multi-Level Cell) – Cheaper yet slower and slightly less reliable
• SLC (Single Level Cell) – Faster and more reliable, yet more expensive than SLC
• Advantages of SLC are dwindling due to advancements in controller design, which mitigate the disadvantages of MLC
Advantages Summary

• Super low latency
  – Zero seek time
• Very fast read and write speeds
• Physically more robust
  – Shock resistance (1500Gs+)
  – Zero moving parts
    • Completely silent
    • Low power consumption
• Excel at small/short reads and writes
• Immune to data fragmentation
Performance Comparison
Performance Comparison

ZoneBench: 10K Random Accesses [KB/s]

- 10K random reads:
  - Raptor 32GB: 563
  - MemoRight GT SSD: 676
  - VelociRaptor 32GB: 424
  - VelociRaptor: 495

- 10K random writes:
  - Raptor 32GB: 1384
  - MemoRight GT SSD: 1530
  - VelociRaptor 32GB: 1622
  - VelociRaptor: 1067
  - Raptor: 1356
Disadvantages

- Cost per GB is much higher than HDDs
  - 64GB SSD $125-$150
  - 2TB HDD $90-100
- General Size
  - 3TB consumer 3.5” HDDs are available (relatively common)
  - 1TB consumer 3.5” SSDs are available (very rare and expensive)
- Limited write cycles
  - 1 to 2 million write cycles before wear out for MLC
  - Up to 5 million write cycles before wear out for SLC
Conclusions

• Although cost prohibitive, for performance applications SSDs hold a great advantage over platter drives

• Common consumer setups take advantage of SSDs for program files while using larger cheaper platter drives to store media and other general storage
  – Hybrid drives

• SSDs represent the evolution toward alleviating the bottleneck that is data storage in present day systems
Questions?