SESSION 16
DISK

Reading: Chapter 7
(except 7.3, 7.4.3, 7.5, and
read 7.8 and 7.10 lightly)

ISE218 – Fundamentals of Information Technology

Objectives

• Become familiar with storage media, and the differences in their respective formats
• Understand disk terminology
• Understand disk access to better understand performance issues
• Understand how RAID improves disk performance and reliability
• Understand which RAID systems are most useful today
Magnetic Disks

- Disks contain large amounts of durable storage that can be accessed quickly

Magnetic Disk Technology

- Hard disk platters are mounted on spindles
- Read/write heads are mounted on an arm that swings radially to read the disk
- Disk forms a logical cylinder beneath read/write heads
- Data blocks are addressed by their cylinder, surface, and sector
Disk Layout

- Disk tracks constitute a set of concentric circles on a platter
- Sectors have a unique address, and can be accessed independent of surrounding sectors
- Some disks have more sectors on tracks nearer the edge

Some errors can be corrected in HW

Figure not to scale – typically millions of sectors per disk

Disk Properties

- **Density** (bits per length measure) usually varies based on distance from edge
- **Seek time** - time it takes for a disk arm to move into position over the desired cylinder
- **Rotational delay** is the time that it takes for the desired sector to move into position beneath the read/write head
- Seek time + rotational delay = **access time**
- Access time + read time = **transfer time**
- Mean Time To Failure - statistically-determined
Magnetic Disk Characteristics

- Major advantage – low cost
- Limitations include:
  - Very slow compared to main memory
  - Fragility
  - Moving parts wear out
- Solid state drives, SSDs now available
  - Computers "see" SSDs as just another disk drive, but they store data in non-volatile flash memory
  - Flash memory also found in memory sticks and MP3 players.

Low cost memory make SSDs feasible

SSD

- SSD access time and transfer rates
  - Typically 100 times faster than magnetic disk, but slower than onboard RAM by a factor of 100,000
  - vary widely among manufacturers
- Unlike RAM, flash is block-addressable
- Updates are spread over the entire medium through wear leveling to prolong the life of the SSD.

About 10 times more expensive than mag disk
Typical Disk Performance

<table>
<thead>
<tr>
<th>Measure</th>
<th>HDD</th>
<th>SDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>500GB-8TB</td>
<td>120-512GB</td>
</tr>
<tr>
<td>Rotational speed</td>
<td>5,400-7,200 rotations/minute</td>
<td></td>
</tr>
<tr>
<td>Cache</td>
<td>16MB, 8GB</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>2.5 inch</td>
<td>Usually fits in an HDD drive bay</td>
</tr>
<tr>
<td>Connector</td>
<td>SATA III (6Gbps)</td>
<td>SATA, PCIe, USB</td>
</tr>
<tr>
<td>Average seek time</td>
<td>12ms</td>
<td>Total access time is usually less than .1ms</td>
</tr>
<tr>
<td>Rotational latency</td>
<td>5ms</td>
<td></td>
</tr>
<tr>
<td>Data transfer rate</td>
<td>1Gbs</td>
<td>800Mbs-5Gbs</td>
</tr>
</tbody>
</table>

Optical Disks

- Large storage capacities
- Easily removable
- Very inexpensive
- Examples
  - CD-ROM - .5 GB
  - DVD – 4.7/8.5 GB
  - Blu-ray – 25/50 GB
- Sometimes used for archival storage

Optical disks are estimated to last for a hundred years (compared to 5-10 years for a mag disk)
CD-ROM

- Designed for music - later adapted to data
- Data is recorded in a single spiral track, starting from the center of the disk
- Binary ones and zeros are delineated by bumps in the polycarbonate disk substrate
- The transitions between pits and lands define binary ones

CD-ROM Format

- The logical data format for a CD-ROM is much more complex than that of a magnetic disk
- Different formats are provided for data and music
- Two levels of error correction are provided for the data format (a CD holds at most 650MB of data, but can contain as much as 742MB of music)
**DVD**

- DVDs can be thought of as denser CDs
- DVDs can hold as much as 8.5GB
- Employs a shorter wavelength laser
- Improved formatting and error correction

- Shorter wavelength laser allows pits and lands to be closer together and the spiral track to be wound tighter

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**Blu-Ray Disks**

- Blue violet laser
- The Blu-Ray disc format won market dominance over HD-CD
- Developed by a consortium of nine companies including Sony, Samsung, and Pioneer
RAID

- Redundant Array of Independent Disks
- Storage virtualization
- Addresses problems of disk reliability, cost, and performance
- Data is stored across many disks, with extra disks added to the array to provide error correction (redundancy)
- Accessed by the OS as a single drive

RAID Concepts

- Disks are an inherently unreliable
- Techniques to deal with unreliable disks
  - Mirroring - system automatically maintains multiple copies of data
  - Parity - added data (e.g., one or more bits) to detect, and possibly correct from errors
    - Parity drive
    - Distributed parity
  - Striping – allocation of logical data to multiple physical disk drives (improves bandwidth)
    - lessens interference with read/write head positioning and controller access
    - Striping can be with sequential bits, bytes, or blocks
RAID Taxonomy

- Data is distributed across several disks in various ways – referred to as the RAID taxonomy
- Defined in levels
  - RAID 0 – striping without parity or mirroring (performance, but no fault tolerance)
  - RAID 1 – mirroring without parity or striping
  - RAID 2 – bit-level striping with some parity (not used)
  - RAID 3 – byte-level striping with parity (not often used)
  - RAID 4 – block-level striping with parity
  - RAID 5 – block-level striping with distributed parity
  - RAID 6 – block-level striping with double parity (can tolerate failure of 2 drives)

RAID

- Large systems consisting of many drive arrays may employ various RAID levels, depending on the criticality of the data on the drives.
- A higher RAID level does not necessarily mean a “better” RAID level
  - It all depends upon the needs of the applications that use the disks
The Future of Data Storage

- Technology advances have improved the upper limit for magnetic disk storage
  - In the 1970s, the upper limit was thought to be around 2Mb/in²
  - Today’s disks commonly support 20Gb/in²
- Improvements have occurred in several different technologies including:
  - Materials science
  - Magneto-optical recording heads
  - Error correcting codes

The Future of Data Storage

- As data densities increase, bit cells consist of proportionately fewer magnetic grains.
- Superparamagnetic limit - point at which there are too few grains to hold a binary value
  - In 2006, the superparamagnetic limit is thought to lie between 150Gb/in² and 200Gb/in²
- Greatest gains in magnetic storage have probably already been realized
Have You Met the Objectives?

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