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Chapter 14

Tertiary Storage Structure

Tertiary Storage Structure

- Tertiary storage devices
- Operating system issues
- Performance issues
Tertiary Storage Devices

- Defining characteristic: low cost
- Generally built using *removable media*
- Examples: floppy disks, CD-ROM, …
  - Floppy disks: thin flexible disk coated with magnetic material, enclosed in a protective plastic case
  - Optical disks: materials that are altered by laser light to have spots that are relatively light and dark
    - Phase-change disk: crystalline or amorphous state
    - Dye-polymer disk: laser heat makes bumps, warms bumps to remove them

Magneto-optic disk

- Magnetic material covered with protective layer of plastic or glass; head much farther from disk than with magnetic disk; less susceptible to head crashes
- Laser heat makes spot susceptible to magnetic field (records)
- Laser light polarization when bouncing off of magnetic spot used for reading (Kerr effect)
Removable disks

- Read-write disks
  - Magnetic disks, magneto-optic disks, optical disks
- Write-once, read many (WORM)
  - One example: thin aluminum film sandwiched between two glass or plastic platters; holes burnt through aluminum; information can be destroyed but not altered
  - Another example: CD-R
- Read-only disks
  - Examples: CD-ROM and DVD

Robotic jukebox for Magneto-optical disks
Magnetic tape

• Compared to disk:
  – Less expensive, holds more data, random access much slower
  – Robotic tape installations
    • Stacker: library that holds a few tapes
    • Silo: library that holds thousands of tapes
  – Archive disk resident tapes for low-cost storage. Stage back into disk storage for active use
Magnetic tape

- Tape silo at Jefferson Lab (http://www.jlab.org/ccc/silo/info/)
  - One terabyte of data a day received
  - 6000 tapes
  - 50 gigabytes per tape at present
  - 300 terabytes total storage
  - Expected enhancements up to over a petabyte (1,000 terabytes) of “near-line” storage
STK Personnel set up central robotics arm.

The robot's "head" contains two cameras and two hands for information retrieval.
Operating System Issues

- Major OS jobs
  - Manage physical devices
  - Present a virtual machine abstraction to applications
- Hard disk abstractions
  - Raw device: an array of data blocks
  - File system: OS queues and schedules the interleaved requests from several applications

Application interface

- Most OSs handle removable disks almost exactly like fixed disks—a new cartridge is formatted and an empty file system is generated on the disk.
  - Tape drive reserved for exclusive use of application
  - Application decides how to use the array of blocks
  - Tape’s format is generally specific to the program that created it
Tape drives

- Basic operations for tape drives differ from those of a disk drive
- **Locate**: position tape to specific logical block (instead of seek)
  - Locate 0 is the same as rewinding
- **Read position**: current logical block
- **Space**: relative movement over logical blocks
  - Space -2: go back two logical blocks
- Append-only devices. Update effectively erases everything past that block
- EOT mark follows last block on tape

Speed

- Tertiary storage aspects of speed: *bandwidth* and *latency*
- Bandwidth: measured in bytes per second
  - *Sustained bandwidth*: average data rate during a large transfer; number of bytes/transfer time (this is the data rate when the data stream is actually flowing)
  - *Effective bandwidth*: average over the entire I/O time, including seek or locate, and cartridge switching (this is the drive’s overall data rate)
Speed

- Access latency--amount of time needed to locate data
  - Access time for a disk--move the arm to the selected cylinder and wait for the rotational latency; generally less than 35 milliseconds
  - Access time on tape requires winding tape reels until the selected block reaches the tape head; tens or hundreds of seconds.
  - Generally say that random access within a tape cartridge is about a thousand times slower than random access on disk.
- Access times on jukebox or tape silo (robotic arm) also requires time to remove (including possibly a return to a consistent state), locate, and load media. Hence removable library best for infrequently used data.

Reliability

- Fixed disk drive is likely to be more reliable than removable disk or tape drive
- Optical cartridge is likely to be more reliable than a magnetic disk or tape
- Head crash in a fixed hard disk generally destroys the data whereas the failure of a tape drive or optical disk drive often leaves the data cartridge unharmed
- Recently, much controversy over lifetimes of CD-ROM
  - Manufactured CD-ROMs versus CD-R (predictions in both directions)
  - Years or decades?
Cost

- Main memory is much more expensive than disk storage
- The cost per megabyte of hard disk storage is competitive with magnetic tape if only one tape is used per drive
- The cheapest tape drives and the cheapest disk drives have had about the same storage capacity over the years
- Tertiary storage gives a cost savings only when the number of cartridges is considerably larger than the number of drives