Module 14: Tertiary-Storage Structure

- Tertiary Storage Devices

- Operating System Issues

- Performance Issues

Tertiary Storage Devices

- Low cost is the defining characteristic of tertiary storage.

- Generally, tertiary storage is built using *removable media.*

- Common examples of removable media are floppy disks and CD-ROMs; other types are available.

Removable Disks

- Floppy disk — thin flexible disk coated with magnetic material, enclosed in a protective plastic case.

  – Most floppies hold about 1 MB; similar technology is used for removable disks that hold more than 1 GB.

  – Removable magnetic disks can be nearly as fast as hard disks, but they are at a greater risk of damage from exposure.

Removable Disks (Cont'd)

- A magneto-optic disk records data on a rigid platter coated with magnetic material.

  – Laser heat is used to amplify a large, weak magnetic field to record a bit.

  – Laser light is also used to read data (Kerr effect).

  – The magneto-optic head flies much farther from the disk surface than a magnetic disk head, and the magnetic material is covered with a protective layer of plastic or glass; resistant to head crashes.

- Optical disks do not use magnetism; they employ special materials that are altered by laser light.

WORM Disks

- The data on read-write disks can be modified over and over.

- WORM ("Write Once, Read Many times") disks can be written only once.

- Thin aluminum film sandwiched between two glass or plastic platters.

- To write a bit, the drive uses a laser light to burn a small hole through the aluminum; information can be destroyed but not altered.

- Very durable and reliable.

- *Read Only* disks, such as CD-ROM and DVD, come from the factory with the data pre-recorded.

Tapes

- Compared to a disk, a tape is less expensive and holds more data, but random access is much slower.

- Tape is an economical medium for purposes that do not require fast random access, e.g., backup copies of disk data, holding huge volumes of data.

- Large tape installations typically use robotic tape changers that move tapes between tape drives and storage slots in a tape library.

  – stacker – library that holds a few tapes
  – silo – library that holds thousands of tapes

- A disk-resident file can be *archived* to tape for low cost storage; the computer can *stage* it back into disk storage for active use.

Operating System Issues

- Major OS jobs are to manage physical devices and to present a virtual machine abstraction to applications.

- For hard disks, the OS provides two abstractions:

  - Raw device – an array of data blocks.

  - File system – the 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.

- Tapes are presented as a raw storage medium, i.e., an application does not not open a file on the tape, it opens the whole tape drive as a raw device.

- Usually the tape drive is reserved for the exclusive use of that application.

- Since the OS does not provide file system services, the application must decide how to use the array of blocks.

- Since every application makes up its own rules for how to organize a tape, a tape full of data can generally only be used by the program that created it.

Tape Drives

- The basic operations for a tape drive differ from those of a disk drive.

- **locate** positions the tape to a specific logical block, not an entire track (corresponds to **seek**).

- The **read position** operation returns the logical block number where the tape head is.

- The **space** operation enables relative motion.

- Tape drives are "append-only" devices; updating a block in the middle of the tape also effectively erases everything beyond that block.

- An EOT mark is placed after a block that is written.

File Naming

- The issue of naming files on removable media is especially difficult when we want to write data on a removable cartridge on one computer, and then use the cartridge in another computer.

- Contemporary OSs generally leave the name space problem unsolved for removable media, and depend on applications and users to figure out how to access and interpret the data.

- Some kinds of removable media (e.g., CDs) are so well standardized that all computers use them the same way.

Hierarchical Storage Management (HSM)

- A hierarchical storage system extends the storage hierarchy beyond primary memory and secondary storage to incorporate tertiary storage — usually implemented as a jukebox of tapes or removable disks.

- Usually incorporate tertiary storage by extending the file system.

  - Small and frequently used files remain on disk.

  - Large, old, inactive files are archived to the jukebox.

- HSM is usually found in supercomputing centers and other large installations that have enormous volumes of data.

Speed

- Two aspects of speed in tertiary storage are bandwidth and latency.

- Bandwidth is measured in bytes per second.

  - *Sustained bandwidth* – average data rate during a large transfer; # of bytes/transfer time.
    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.
    Drive's overall data rate.

Speed (Cont'd)

- 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; < 35 milliseconds.

  - Access on tape requires winding the 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.

- The low cost of tertiary storage is a result of having many cheap cartridges share a few expensive drives.

- A removable library is best devoted to the storage of infrequently used data, because the library can only satisfy a relatively small number of I/O requests per hour.

Reliability

- A fixed disk drive is likely to be more reliable than a removable disk or tape drive.

- An optical cartridge is likely to be more reliable than a magnetic disk or tape.

- A 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.

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.