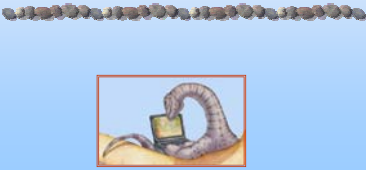


Chapter 12: Mass-Storage Systems

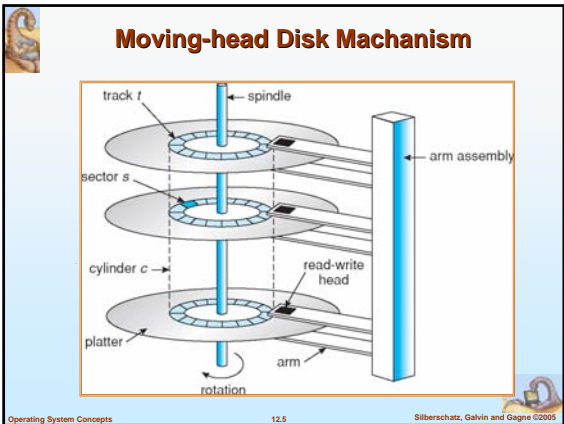


Chapter 12: Mass-Storage Systems

- Overview of Mass Storage Structure
- Disk Structure
- Disk Attachment
- Disk Scheduling
- Disk Management
- Swap-Space Management
- RAID Structure
- Disk Attachment
- Stable-Storage Implementation
- Tertiary Storage Devices
- Operating System Issues
- Performance Issues

- ## Objectives
- Describe the physical structure of secondary and tertiary storage devices and the resulting effects on the uses of the devices
 - Explain the performance characteristics of mass-storage devices
 - Discuss operating-system services provided for mass storage, including RAID and HSM

- ## Overview of Mass Storage Structure
- Magnetic disks provide bulk of secondary storage of modern computers
 - Drives rotate at 60 to 200 times per second
 - **Transfer rate** is rate at which data flow between drive and computer
 - **Positioning time (random-access time)** is time to move disk arm to desired cylinder (**seek time**) and time for desired sector to rotate under the disk head (**rotational latency**)
 - **Head crash** results from disk head making contact with the disk surface
 - That's bad
 - Disks can be removable
 - Drive attached to computer via **I/O bus**
 - Busses vary, including **EIDE, ATA, SATA, USB, Fibre Channel, SCSI**
 - **Host controller** in computer uses bus to talk to **disk controller** built into drive or storage array



- ## Overview of Mass Storage Structure (Cont.)
- Magnetic tape
 - Was early secondary-storage medium
 - Relatively permanent and holds large quantities of data
 - Access time slow
 - Random access ~1000 times slower than disk
 - Mainly used for backup, storage of infrequently-used data, transfer medium between systems
 - Kept in spool and wound or rewound past read-write head
 - Once data under head, transfer rates comparable to disk
 - 20-200GB typical storage
 - Common technologies are 4mm, 8mm, 19mm, LTO-2 and SDLT

Disk Structure

- Disk drives are addressed as large 1-dimensional arrays of *logical blocks*, where the logical block is the smallest unit of transfer.
- The 1-dimensional array of logical blocks is mapped into the sectors of the disk sequentially.
 - Sector 0 is the first sector of the first track on the outermost cylinder.
 - Mapping proceeds in order through that track, then the rest of the tracks in that cylinder, and then through the rest of the cylinders from outermost to innermost.

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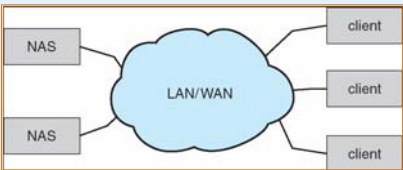
Disk Attachment

- Host-attached storage accessed through I/O ports talking to I/O busses
- SCSI itself is a bus, up to 16 devices on one cable, **SCSI initiator** requests operation and **SCSI targets** perform tasks
 - Each target can have up to 8 **logical units** (disks attached to device controller)
- FC is high-speed serial architecture
 - Can be switched fabric with 24-bit address space – the basis of **storage area networks (SANs)** in which many hosts attach to many storage units
 - Can be **arbitrated loop (FC-AL)** of 126 devices

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Network-Attached Storage

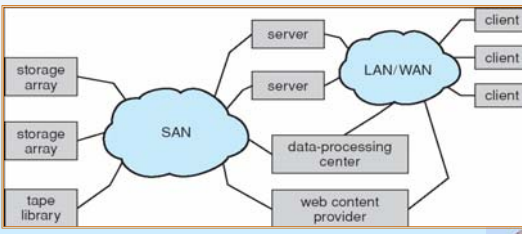
- Network-attached storage (**NAS**) is storage made available over a network rather than over a local connection (such as a bus)
- NFS and CIFS are common protocols
- Implemented via remote procedure calls (RPCs) between host and storage
- New iSCSI protocol uses IP network to carry the SCSI protocol



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Storage Area Network

- Common in large storage environments (and becoming more common)
- Multiple hosts attached to multiple storage arrays - flexible



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Disk Scheduling

- The operating system is responsible for using hardware efficiently — for the disk drives, this means having a fast access time and disk bandwidth.
- Access time has two major components
 - *Seek time* is the time for the disk are to move the heads to the cylinder containing the desired sector.
 - *Rotational latency* is the additional time waiting for the disk to rotate the desired sector to the disk head.
- Minimize seek time
- Seek time \approx seek distance
- Disk bandwidth is the total number of bytes transferred, divided by the total time between the first request for service and the completion of the last transfer.

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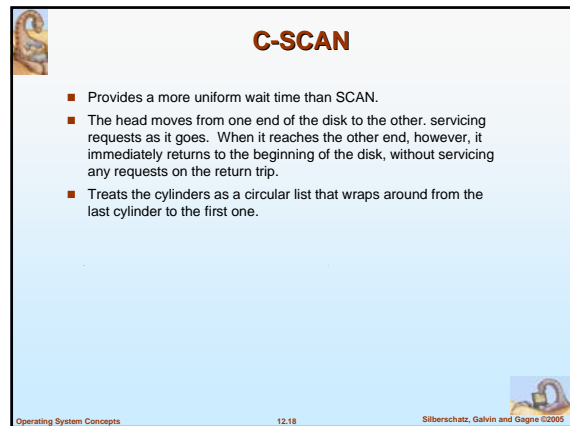
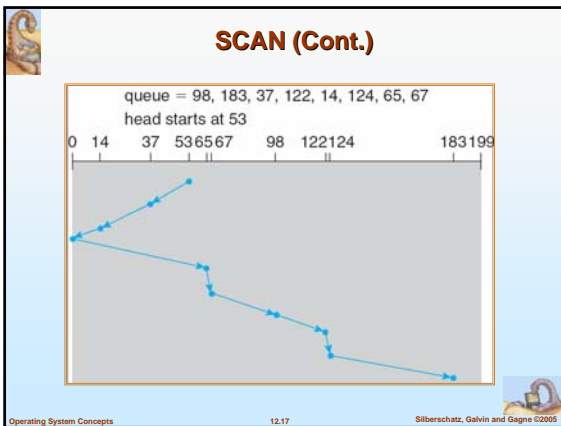
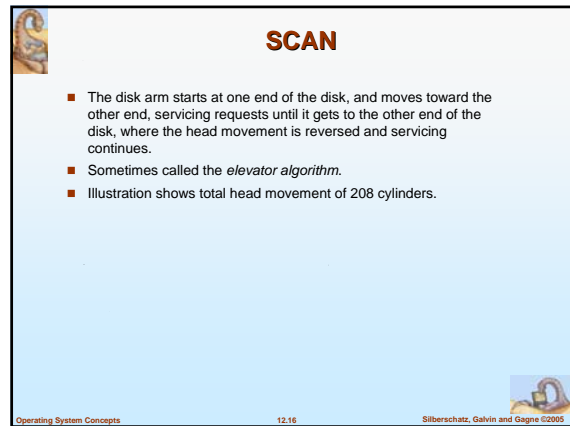
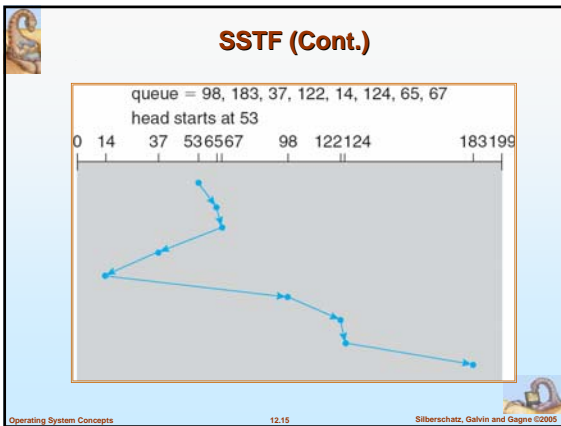
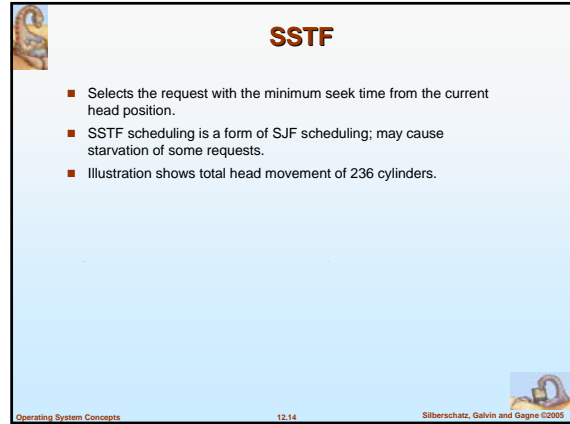
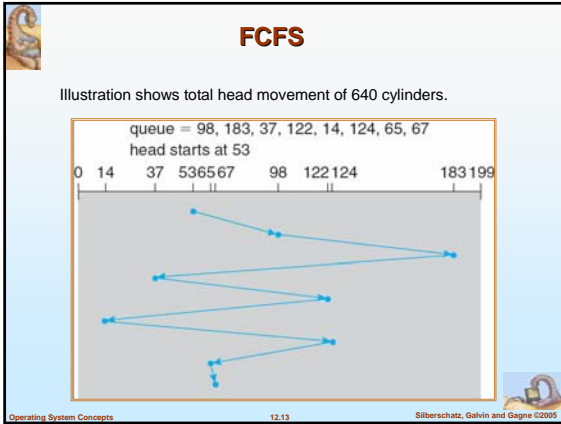
Disk Scheduling (Cont.)

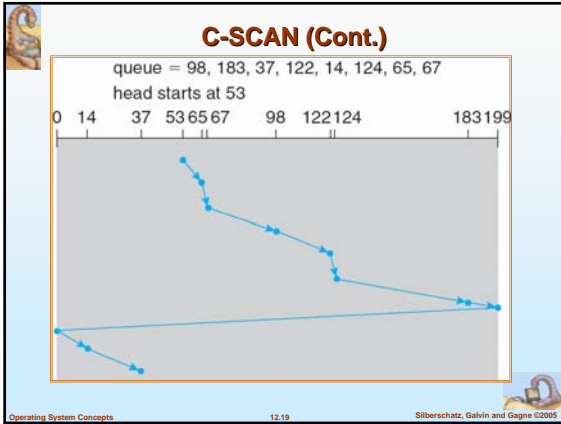
- Several algorithms exist to schedule the servicing of disk I/O requests.
- We illustrate them with a request queue (0-199).

98, 183, 37, 122, 14, 124, 65, 67

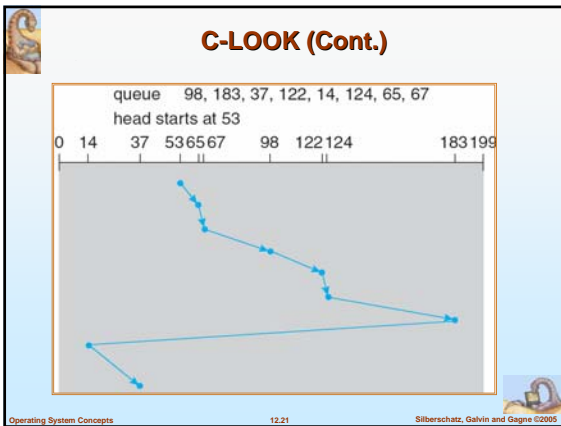
Head pointer 53

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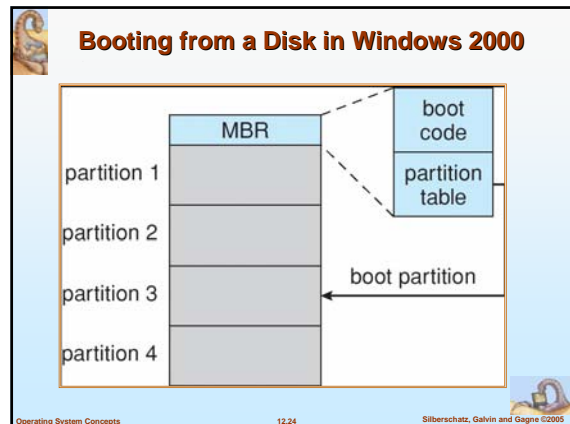


- ### C-LOOK
- Version of C-SCAN
 - Arm only goes as far as the last request in each direction, then reverses direction immediately, without first going all the way to the end of the disk.
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- ### Selecting a Disk-Scheduling Algorithm
- SSTF is common and has a natural appeal
 - SCAN and C-SCAN perform better for systems that place a heavy load on the disk.
 - Performance depends on the number and types of requests.
 - Requests for disk service can be influenced by the file-allocation method.
 - The disk-scheduling algorithm should be written as a separate module of the operating system, allowing it to be replaced with a different algorithm if necessary.
 - Either SSTF or LOOK is a reasonable choice for the default algorithm.
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- ### Disk Management
- *Low-level formatting, or physical formatting* — Dividing a disk into sectors that the disk controller can read and write.
 - To use a disk to hold files, the operating system still needs to record its own data structures on the disk.
 - *Partition* the disk into one or more groups of cylinders.
 - *Logical formatting* or "making a file system".
 - Boot block initializes system.
 - The bootstrap is stored in ROM.
 - *Bootstrap loader* program.
 - Methods such as *sector sparing* used to handle bad blocks.
- Operating System Concepts 12.23 Silberschatz, Galvin and Gagne ©2005



Swap-Space Management

- Swap-space — Virtual memory uses disk space as an extension of main memory.
- Swap-space can be carved out of the normal file system, or, more commonly, it can be in a separate disk partition.
- Swap-space management
 - 4.3BSD allocates swap space when process starts; holds *text segment* (the program) and *data segment*.
 - Kernel uses *swap maps* to track swap-space use.
 - Solaris 2 allocates swap space only when a page is forced out of physical memory, not when the virtual memory page is first created.

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Data Structures for Swapping on Linux Systems

Operating System Concepts 12.26 Silberschatz, Galvin and Gagne ©2005

RAID Structure

- RAID – multiple disk drives provides **reliability** via **redundancy**.
- RAID is arranged into six different levels.

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RAID (cont)

- Several improvements in disk-use techniques involve the use of multiple disks working cooperatively.
- Disk striping uses a group of disks as one storage unit.
- RAID schemes improve performance and improve the reliability of the storage system by storing redundant data.
 - *Mirroring or shadowing* keeps duplicate of each disk.
 - *Block interleaved parity* uses much less redundancy.

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RAID Levels

Operating System Concepts 12.29 Silberschatz, Galvin and Gagne ©2005

RAID (0 + 1) and (1 + 0)

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Stable-Storage Implementation

- Write-ahead log scheme requires stable storage.
- To implement stable storage:
 - Replicate information on more than one nonvolatile storage media with independent failure modes.
 - Update information in a controlled manner to ensure that we can recover the stable data after any failure during data transfer or recovery.

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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.

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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.

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Removable Disks (Cont.)

- 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.

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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 by not altered.
- Very durable and reliable.
- *Read Only* disks, such as CD-ROM and DVD, come from the factory with the data pre-recorded.

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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.

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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 abstraction:
 - Raw device – an array of data blocks.
 - File system – the OS queues and schedules the interleaved requests from several applications.

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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., and application does 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.

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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.

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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.

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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.

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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.

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Speed (Cont.)

- 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.

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Reliability

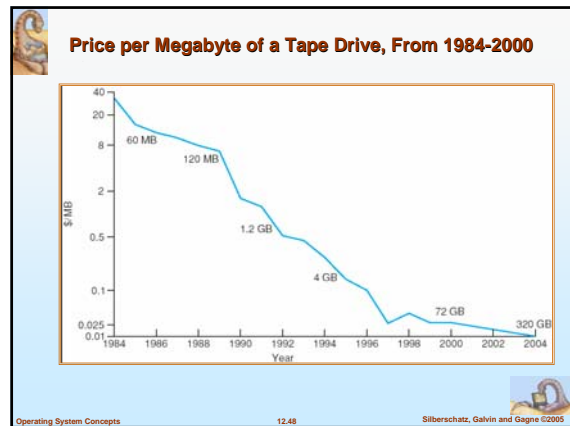
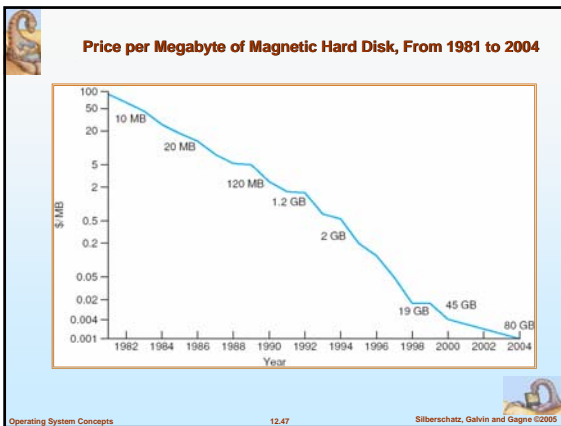
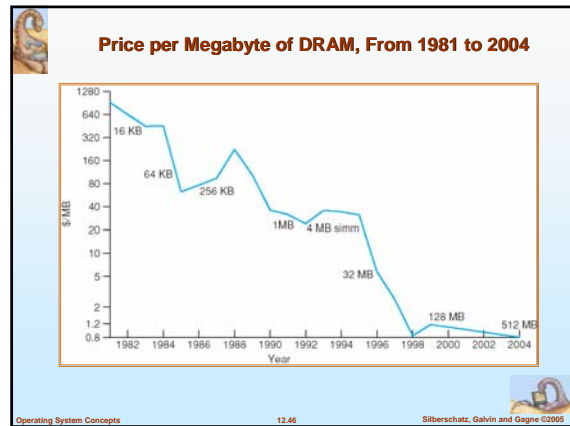
- A fixed disk drive is likely to be more reliable than a removable disk or tape drive.
- An optical cartridge is likely to be more reliable than a magnetic disk or tape.
- A head crash in a fixed hard disk generally destroys the data, whereas the failure of a tape drive or optical disk drive often leaves the data cartridge unharmed.

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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.

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End of Chapter 12

