UNIT VIII

MASS-STORAGE STRUCTURE

Mass-Storage Systems

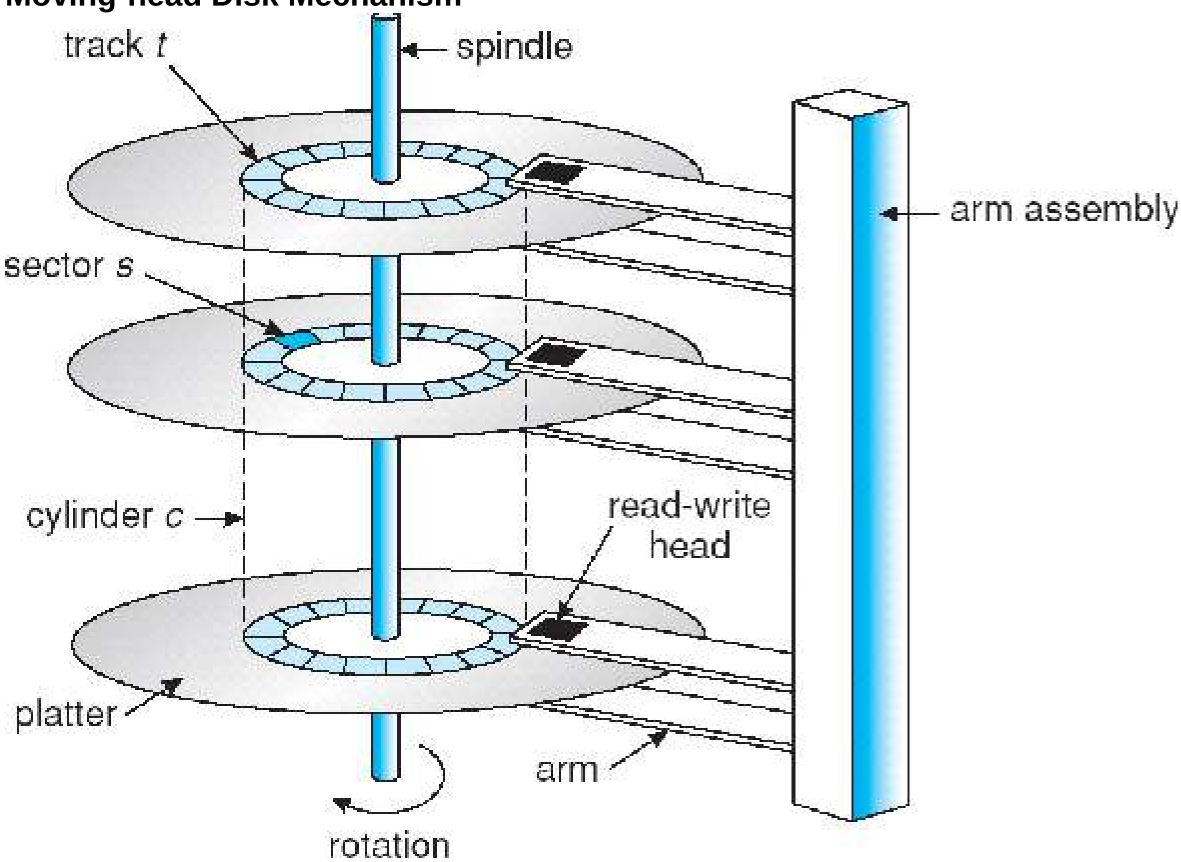
nDescribe the physical structure of secondary and tertiary storage devices and the resulting effects on the uses of the devicesnExplain the performance characteristics of mass-storage devicesnDiscuss operating-system services provided for mass storage, including RAID and HSM

8.1: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

Moving-head Disk Mechanism



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

8.2:Disk Structure

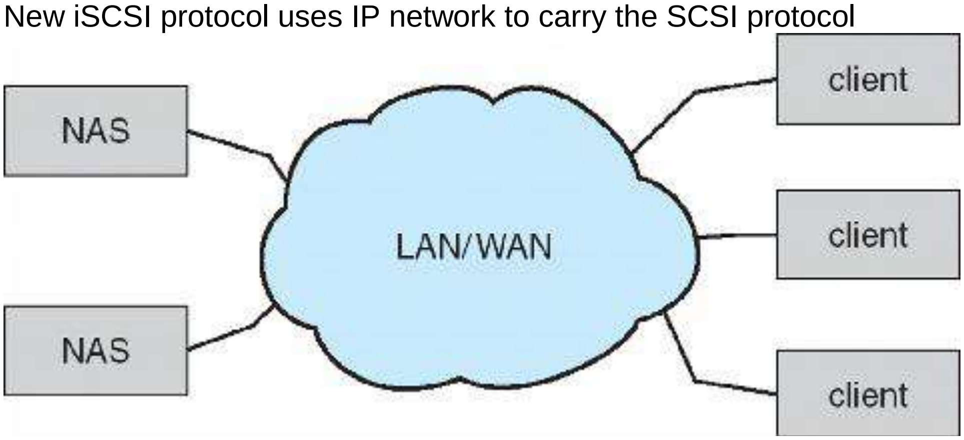
Disk drives are addressed as large 1-dimensional arrays of logical blocks, where the logical block is the smallest unit of transfernThe 1-dimensional array of logical blocks is mapped into the sectors of the disk sequentially
Sector 0 is the first sector of the first track on the outermost cylinder
Mapping 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

8.3: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

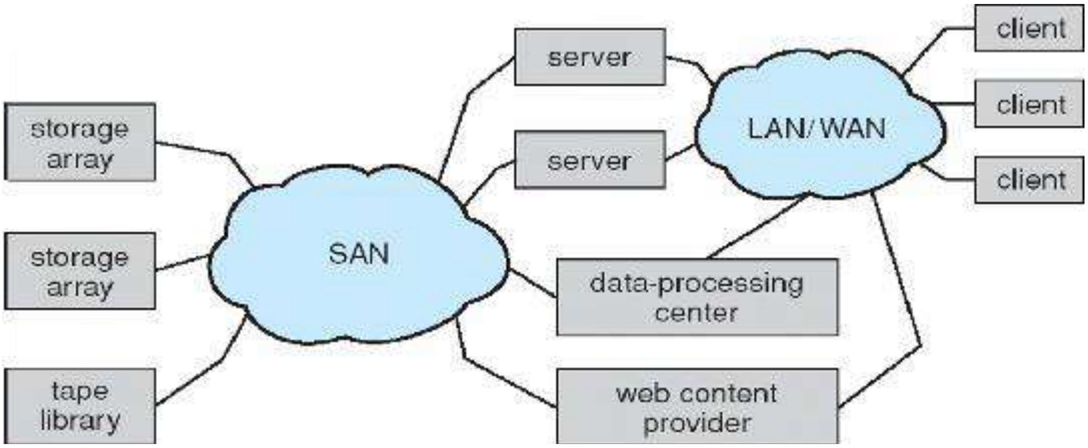
Network-Attached Storage

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



Storage Area Network

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

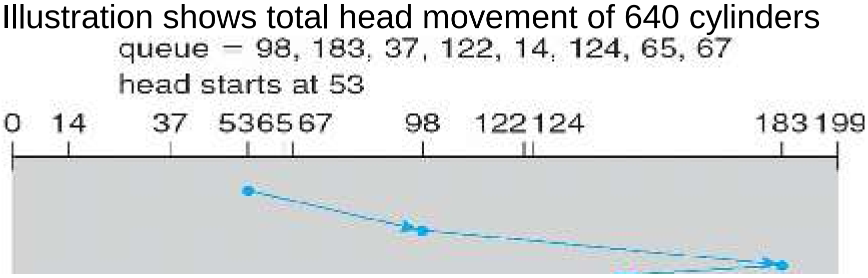


8.4:Disk Scheduling

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 » 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
Several algorithms exist to schedule the servicing of disk I/O requests nWe illustrate them with a request queue (0-199)
98, 183, 37, 122, 14, 124, 65, 67
Head pointer 53

FCFS

Illustration shows total head movement of 640 cylinders



SSTF

Selects the request with the minimum seek time from the current head position
SSTF scheduling is a form of SJF scheduling; may cause starvation of some requests
nIllustration shows total head movement of 236 cylinders

SCAN

The disk arm starts at one end of the disk, and moves toward the other end, servicing requests until it gets to the other end of the disk, where the head movement is reversed and servicing continues.nSCAN algorithm Sometimes called the elevator algorithm

Illustration shows total head movement of 208 cylinders

C-SCAN

Provides a more uniform wait time than SCAN

The head moves from one end of the disk to the other, servicing requests as it goes

When it reaches the other end, however, it immediately returns to the beginning of the disk, without servicing any requests on the return trip

Treats the cylinders as a circular list that wraps around from the last cylinder to the first one

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

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

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”

To increase efficiency most file systems group blocks into clusters

- Disk I/O done in blocks
- File I/O done in clusters

Boot block initializes system

The bootstrap is stored in ROM

Bootstrap loader program

Methods such as sector sparing used to handle bad blocks

Booting from a Disk in Windows 2000

8.5: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

Data Structures for Swapping on Linux Systems

RAID Structure

RAID – multiple disk drives provides reliability via redundancynIncreases the mean time to failurenFrequently combined with NVRAM to improve write performance

RAID is arranged into six different levels

Several improvements in disk-use techniques involve the use of multiple disks working cooperativelynDisk striping uses a group of disks as one storage unitnRAID schemes improve performance and improve the reliability of the storage system by storing redundant data

Mirroring or shadowing (RAID 1) keeps duplicate of each disk

Striped mirrors (RAID 1+0) or mirrored stripes (RAID 0+1) provides high performance and high reliabilitylBlock interleaved parity (RAID 4, 5, 6) uses much less redundancy

RAID within a storage array can still fail if the array fails, so automatic replication of the data between arrays is common

Frequently, a small number of hot-spare disks are left unallocated, automatically replacing a failed disk and having data rebuilt onto them

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

Extensions

RAID alone does not prevent or detect data corruption or other errors, just disk failures

Solaris ZFS adds checksums of all data and metadata

Checksums kept with pointer to object, to detect if object is the right one and whether it changed

Can detect and correct data and metadata corruption

ZFS also removes volumes, partititions

Disks allocated in pools

Filesystems with a pool share that pool, use and release space like “malloc” and “free” memory allocate / release calls

ZFS Checksums All Metadata and Data

Traditional and Pooled Storage

Stable-Storage Implementation

Write-ahead log scheme requires stable storagenTo 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

Tertiary Storage Devices

Low cost is the defining characteristic of tertiary storagenGenerally, tertiary storage is built using removable medianCommon 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 caselMost 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

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 crashesnOptical 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 by not altered
Very durable and reliable
Read-only disks, such ad CD-ROM and DVD, com 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 Support

nMajor OS jobs are to manage physical devices and to present a virtual machine abstraction to applicationsnFor hard disks, the OS provides two abstraction:
Raw device – an array of data blockslFile 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., and 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 latencynBandwidth 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
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 drivenAn optical cartridge is likely to be more reliable than a magnetic disk or tapenA 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 storagenThe cost per megabyte of hard disk storage is competitive with magnetic tape if only one tape is used per drivenThe cheapest tape drives and the cheapest disk drives have had about the same storage capacity over the yearsnTertiary storage gives a cost savings only when the number of cartridges is considerably larger than the number of drives