Mass-Storage Systems

Amir H. Payberah
payberah@kth.se

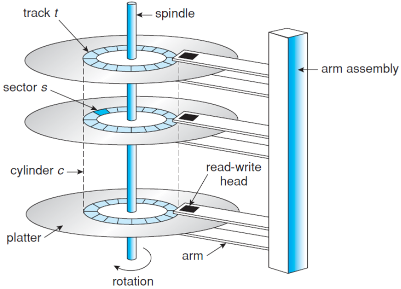
2022

Motivation

- Main memory is usually too small.
- Computer systems must provide secondary storage to back up main memory.

Mass Storage Structure (1/2)

- Magnetic disks: bulk of secondary storage
- Disk platter is a flat circular shape, covered with a magnetic material.
- Heads are attached to a disk arm.
- The surface of a platter is logically divided into circular tracks, which are subdivided into sectors.
- The set of tracks that are at one arm position makes up a cylinder.



Mass Storage Structure (2/2)

- Drives rotate at 60 to 250 times per second.
- Transfer rate: the rate at which data flow between drive and computer.
- Positioning time: the time to move disk arm to desired cylinder (seek time) and time for desired sector to rotate under the disk head (rotational latency).

The First Commercial Disk Drive

- IBM, 1956
- 5M
- Access time ≤ 1 second

Solid-State Disks (SSDs)

- Non-volatile memory used like a hard drive.
- More expensive per MB.
- Maybe have shorter life span.
- Less capacity, but much faster.
- No moving parts, so no seek time or rotational latency.

Magnetic Tape

- Early secondary-storage medium.
- Relatively permanent and holds large quantities of data.
- Access time slow.
- Random access $\sim$ 1000 times slower than disk.
- Mainly used for backup, storage of infrequently-used data.
- Once data under head, transfer rates comparable to disk.

Disk Structure

Disk Structure (1/2)

- Disk drives are addressed as large 1-dimensional arrays of logical blocks.
- The logical block is the smallest unit of transfer.
- Low-level formatting creates logical blocks on physical media.

Disk Structure (2/2)

- The 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.
- Logical to physical address should be easy.

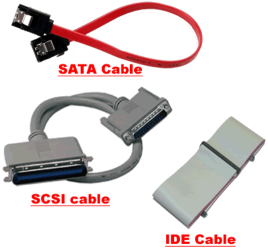
Disk Attachment

Disk Attachment

- Host-attached storage
- Network-attached storage (NAS)
- Storage-area network (SAN)

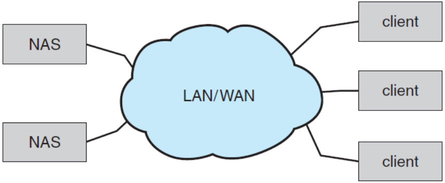
Host-Attached Storage

- Host-attached storage accessed through I/O ports talking to I/O buses.
- IDE or SATA support max. two drives per I/O bus.
- SCSI, up to 16 devices on one cable.
- Fiber Channel (FC) is high-speed serial architecture.



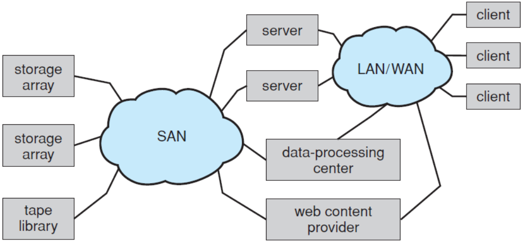
Network-Attached Storage (NAS)

- Network-attached storage is storage made available over a network.
- Remotely attaching to file systems.
- FTP, NFS and SMB are common protocols.

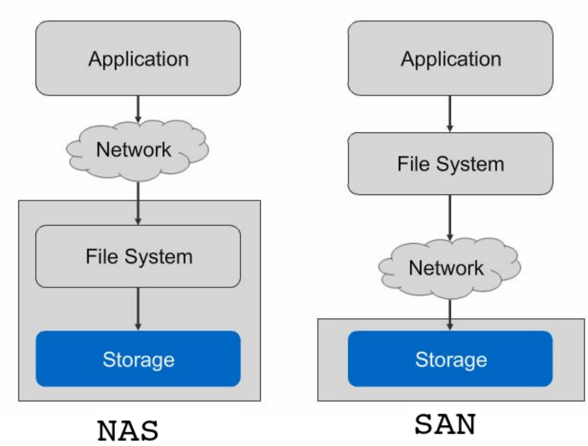


Storage-Area Network (SAN)

- Storage-area network is common in large storage environments.
- Multiple hosts attached to multiple storage arrays.



NAS vs. SAN


Application
Network
File System
Storage
NAS
Application
File System
Network
Storage
SAN

Disk Management

Disk Formatting (Physical)

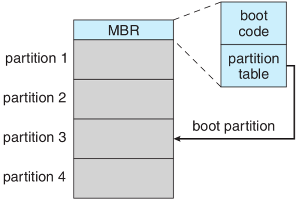
- Physical formatting: dividing a disk into sectors that the disk controller can read and write.
- Each sector can hold header information, data, and error correction code.
- To use a disk to hold files, the OS needs to record its own data structures on the disk.

Disk Formatting (Logical)

- Logical formatting or making a file system.
- Partition: one or more groups of cylinders, each treated as a logical disk.

Boot Block

- The bootstrap program: initializes a computer when it is powered up and starts the OS.
- The bootstrap program is stored in the boot blocks at a fixed location on the disk.



Disk Scheduling

Disk Scheduling

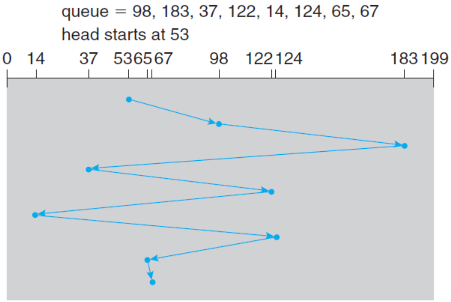
- There are many sources of disk I/O request, e.g., OS, system processes, users processes.
- OS maintains queue of requests, per disk or device.
- Idle disk can immediately work on I/O request, busy disk means work must queue.

Disk Scheduling Algorithms

- First Come First Serve (FCFS)
- Shortest Seek Time First (SSTF)
- SCAN
- C-SCAN
- C-Look

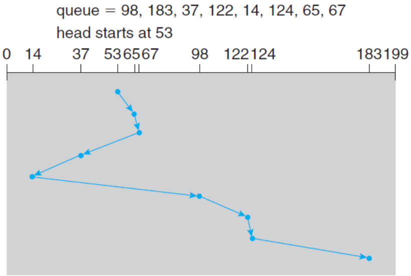
FCFS

- Request queue (0-199): 98, 183, 37, 122, 14, 124, 65, 67
- Head pointer 53
- Total head movement: 640 cylinders



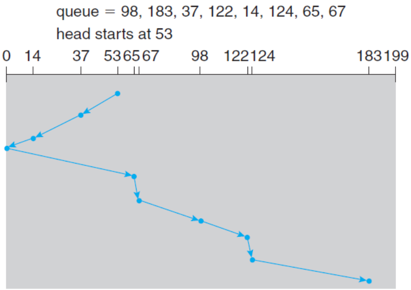
SSTF

- 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.
- Total head movement: 236 cylinders.



SCAN

- Starts from one end of the disk, and moves toward the other end.
  - Servicing requests until it gets to the other end of the disk.
  - At the end of the dist, the head movement is reversed.
- Total head movement: 236 cylinders

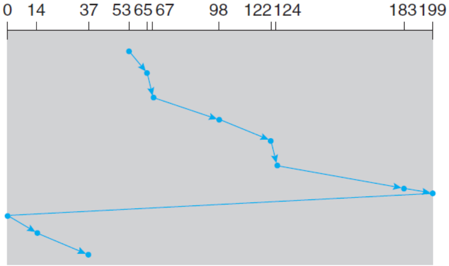


C-SCAN

- Provides a more uniform wait time than SCAN.
- When it reaches the end, it immediately returns to the beginning of the disk without servicing any requests on the return trip.

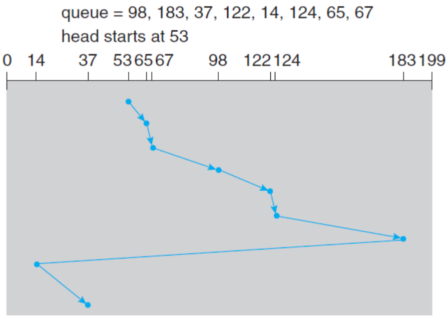
queue = 98, 183, 37, 122, 14, 124, 65, 67

head starts at 53



Look

- LOOK is a version of SCAN, C-LOOK is a 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.



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

head starts at 53

Selecting a Disk-Scheduling Algorithm (1/2)

- Having a fast access time and disk bandwidth.
- Minimize seek time.
- Disk bandwidth is the total bytes transferred, divided by the total time between the first request and the completion of the last transfer.

Selecting a Disk-Scheduling Algorithm (2/2)

- SSTF is common and has a natural appeal: good performance
- SCAN and C-SCAN perform better for systems that place a heavy load on the disk: less starvation
- Performance depends on the number and types of requests.

RAID Structure

Failure and Reliability

- Multiple disk drives provides reliability via redundancy.
- Increases the mean time to failure.
  - E.g., if the mean time to failure of a single disk is 100,000 hours.
  - The mean time to failure of some disk in an array of 100 disks will be $100{,}000/100 = 1{,}000$ hours, or 41.66 days
  - It is not long at all.

Mirroring

- The simplest approach to introducing redundancy is to duplicate every disk, called mirroring.
- A logical disk consists of two physical disks, and every write is carried out on both disks.
- If one of the disks in the volume fails, the data can be read from the other.

Improvement in Performance via Parallelism

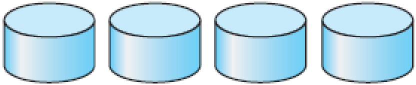
- Disk striping uses a group of disks as one storage unit.
- Bit-level striping: splitting the bits of each byte across multiple disks.
  - E.g., with n disks, bit i of a file goes to disk $(i \bmod n) + 1$.
- Block-level striping: blocks of a file are striped across multiple disks.

RAID Levels

- RAID: redundant array of inexpensive disks
- RAID schemes improve performance and improve the reliability of the storage system by storing redundant data.
- RAID is arranged into six different levels.

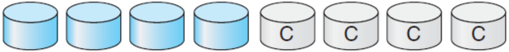
RAID Level 0

- Disk arrays with striping at the level of blocks but without any redundancy.



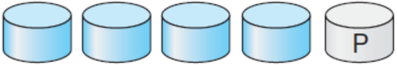
RAID Level 1

- Disk mirroring



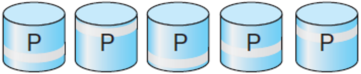
RAID Level 4

- Block-level striping, as in RAID 0.
- Error-correcting code (ECC)
- Keeps ECC on a separate disk for corresponding blocks from N other disks.



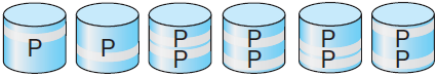
RAID Level 5

- Spreads data and ECC among all N+1 disks, rather than storing data in N disks and parity in one disk.



RAID Level 6

- Like RAID level 5 but stores extra redundant information to guard against multiple disk failures.



Summary

Summary

- Mass storage structure: platter, track, sector, cylinder
- Disk attachment: host-attached, network-attached, storage-area-network
- Disk scheduling: FCFS, SSTF, SCAN, C-SCAN, C-Look
- Disk management: formatting, boot block
- RAID: RAID0-RAID6

Questions?

Acknowledgements

Some slides were derived from Avi Silberschatz slides.