Amirkabir University of Technology
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Department of Computer Engineering

Mass Storage Systems

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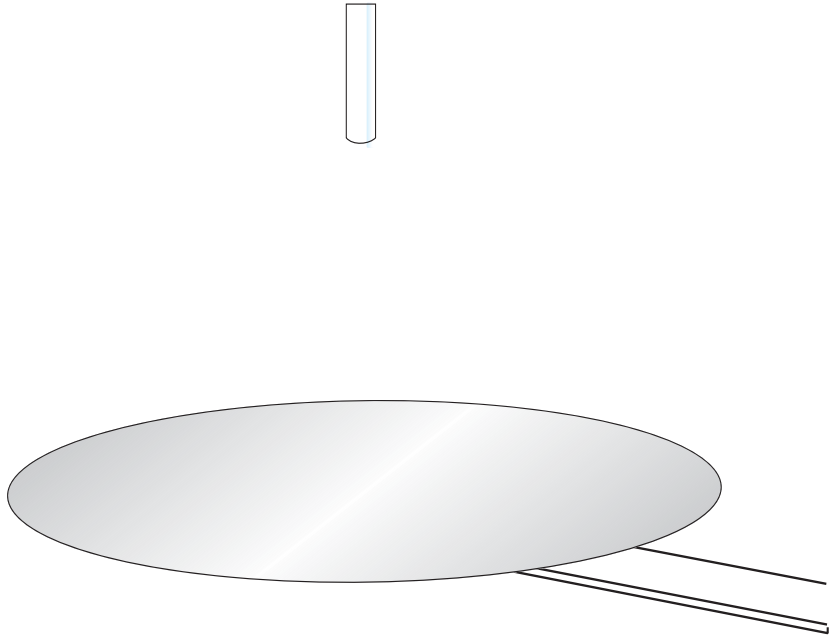
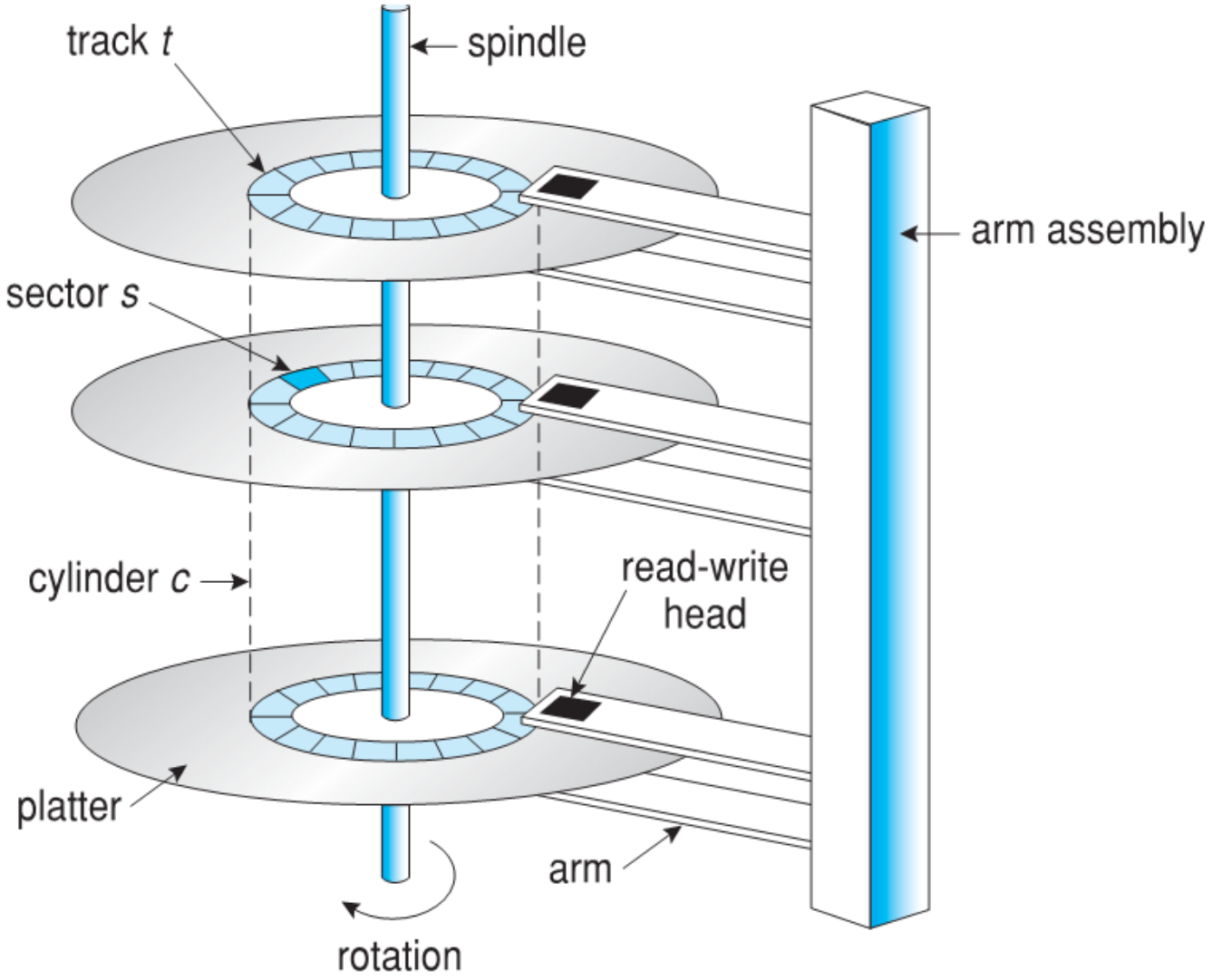
Magnetic disk structure



Magnetic disk structure



Overview of mass storage structure

- **Magnetic disks**
  - Bulk of secondary storage of modern computers
  - **Transfer rate** is rate at which data flow between drive and computer
  - **Positioning time** (random-access time)
    - **Seek time**: time to move disk arm to desired cylinder
    - **Rotational latency**: time for desired sector to rotate under the disk head
  - **Head crash** results from disk head making contact with the disk surface -- That's bad

- **Some drives attached to computer via I/O bus**
  - Busses vary, including EIDE, ATA, SATA, USB, Fiber Channel, SCSI, SAS, Firewire
  - **Host controller** in computer uses bus to talk to **disk controller** built into drive or storage array

Magnetic disk performance

- Access Latency = Average access time = average seek time + average rotation latency
  - For fastest disk 3ms + 2ms = 5ms
  - For slow disk 9ms + 5.56ms = 14.56ms

- Average I/O time = average access time
  + (amount to transfer / transfer rate)
  + controller overhead

1st commercial disk drive

1956
IBM RAMDAC computer included the IBM Model 350 disk storage system

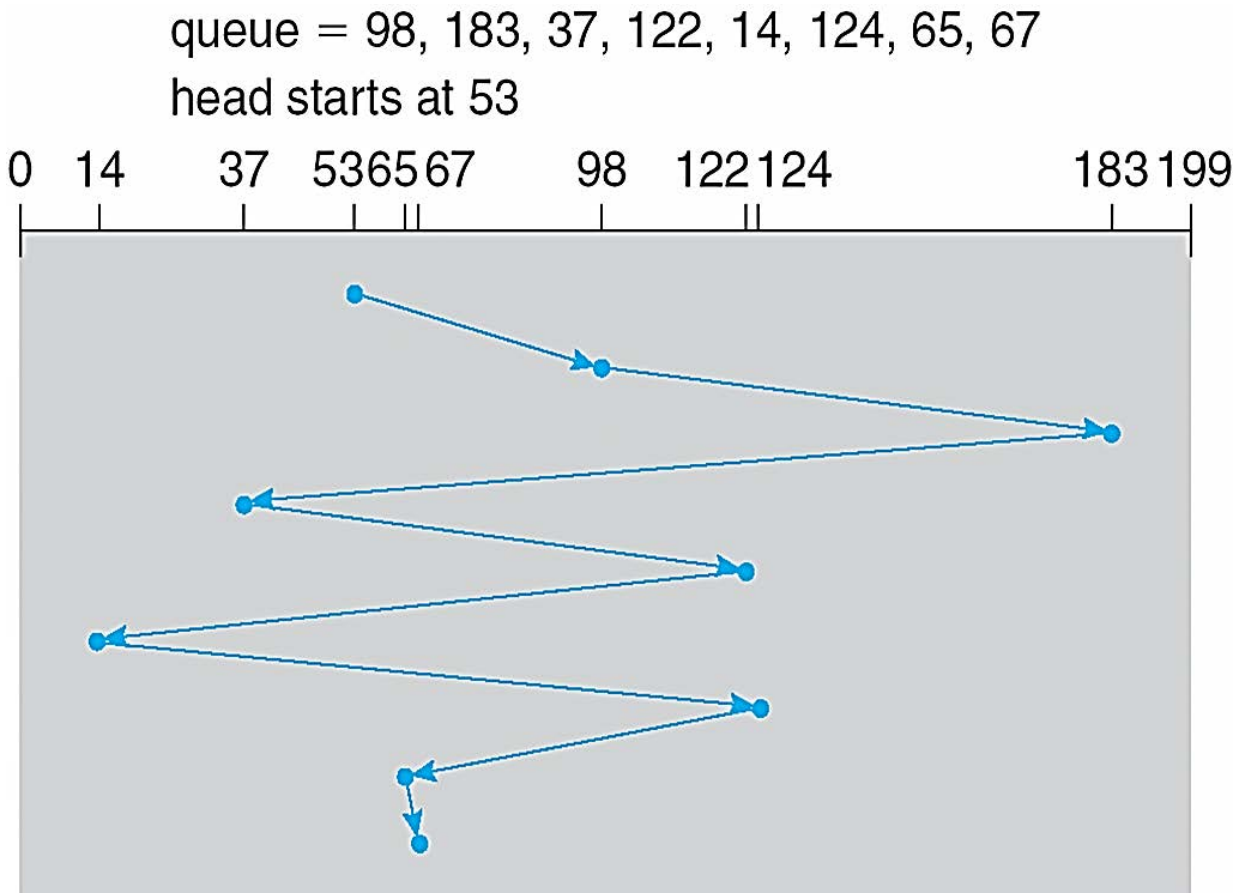
5M (7 bit) characters
50 x 24” platters
Access time = < 1 second

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
- Minimize seek time
- Seek time ≈ seek distance
- Disk bandwidth
  - The total number of bytes transferred, divided by the total time between the first request for service and the completion of the last transfer

FCFS (First come first serve)

Response to request queue based on FCFS
Head movement = 640 cylinders

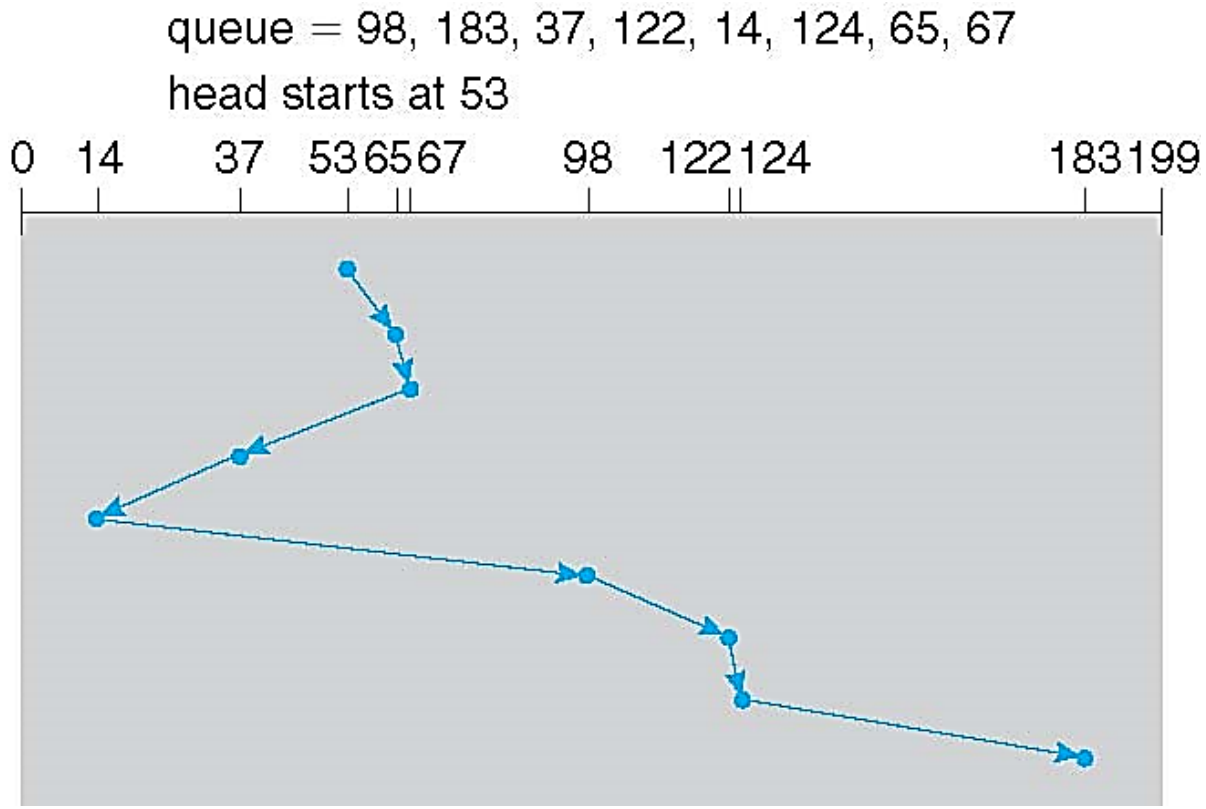


SSTF (Shortest Seek Time First)

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

Head movement = 236 cylinders

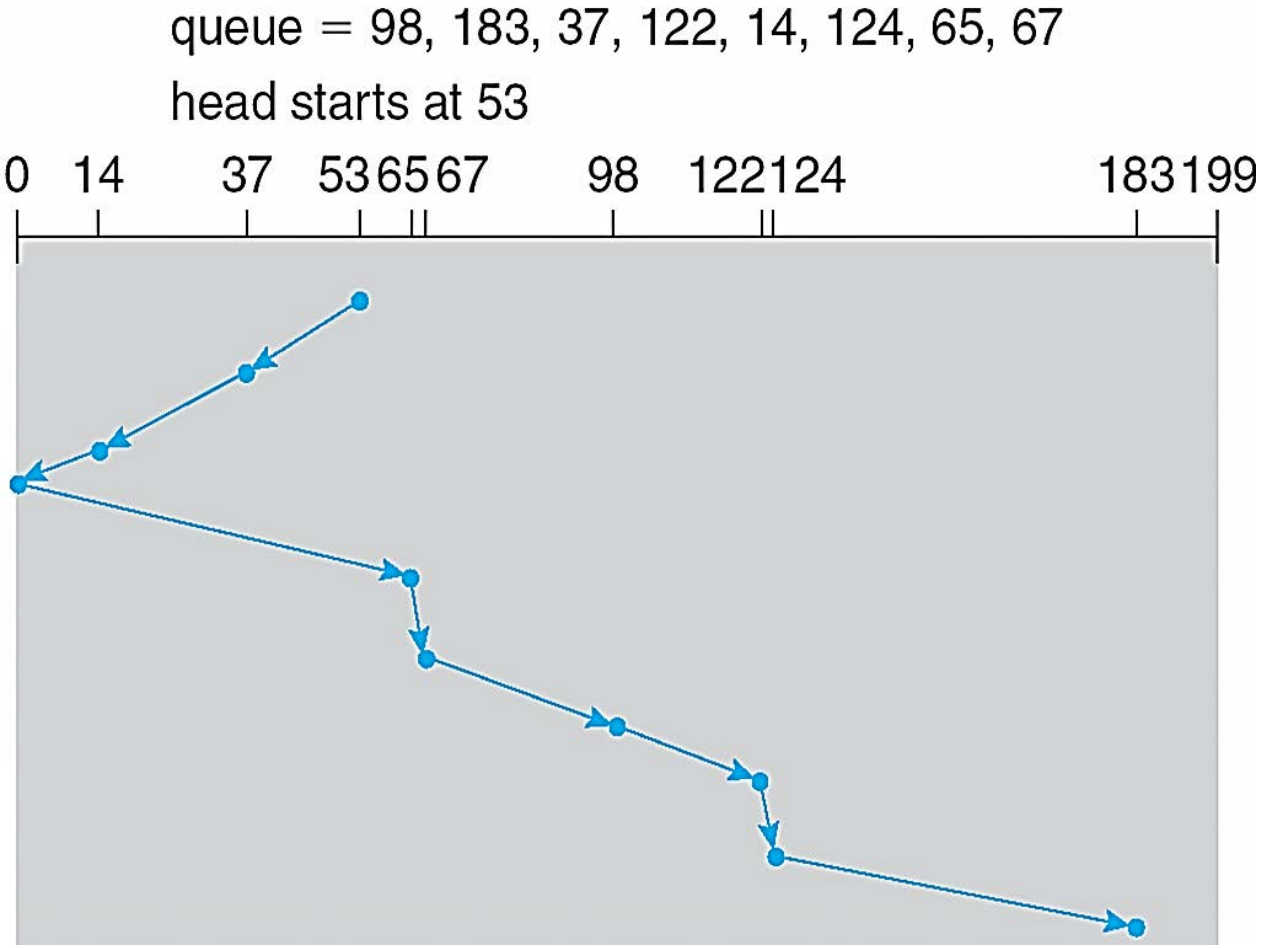


SCAN

- 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.

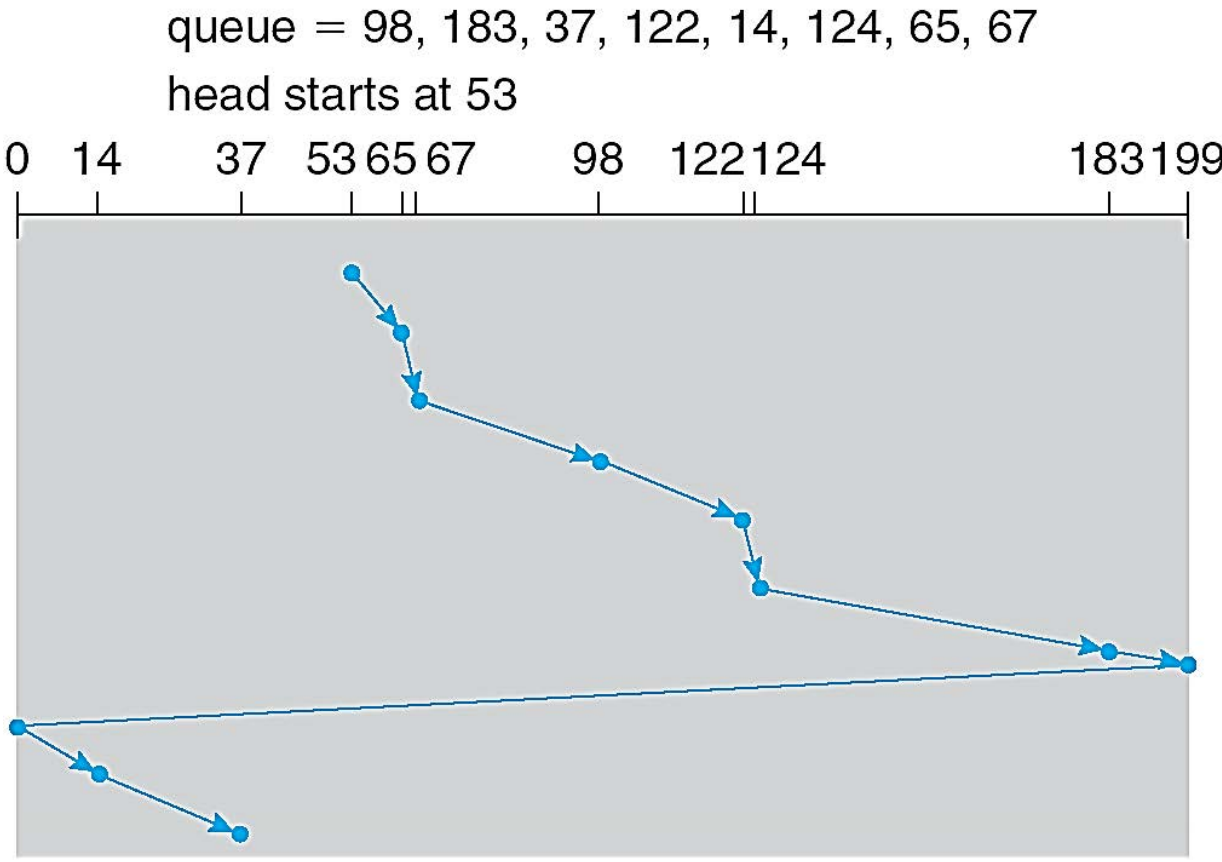
- SCAN algorithm sometimes called the elevator algorithm

- **If requests are uniformly dense, largest density at other end of disk and those wait the longest**



C-SCAN (Circular SCAN)

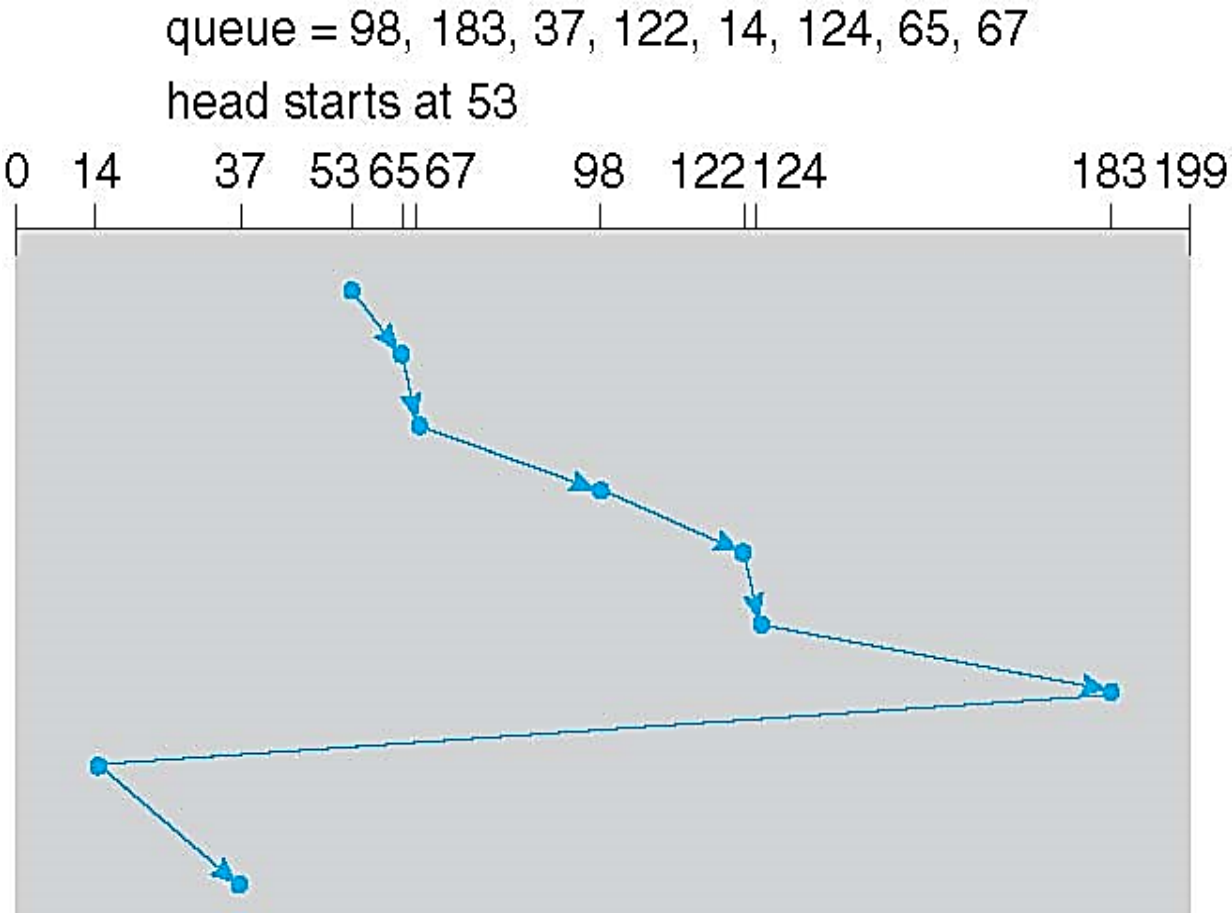
- Provides a more uniform wait time than SCAN
- The head moves from one end of the disk to the other, servicing requests as it goes
  - When it reaches the other end, however, it immediately returns to the beginning of the disk, without servicing any requests on the return trip
- Treats the cylinders as a circular list that wraps around from the last cylinder to the first one



LOOK and C-LOOK (Circular LOOK)

- LOOK a version of SCAN
- C-LOOK 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



Which one is better?

- 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

Disk Attachment

Disk attachment

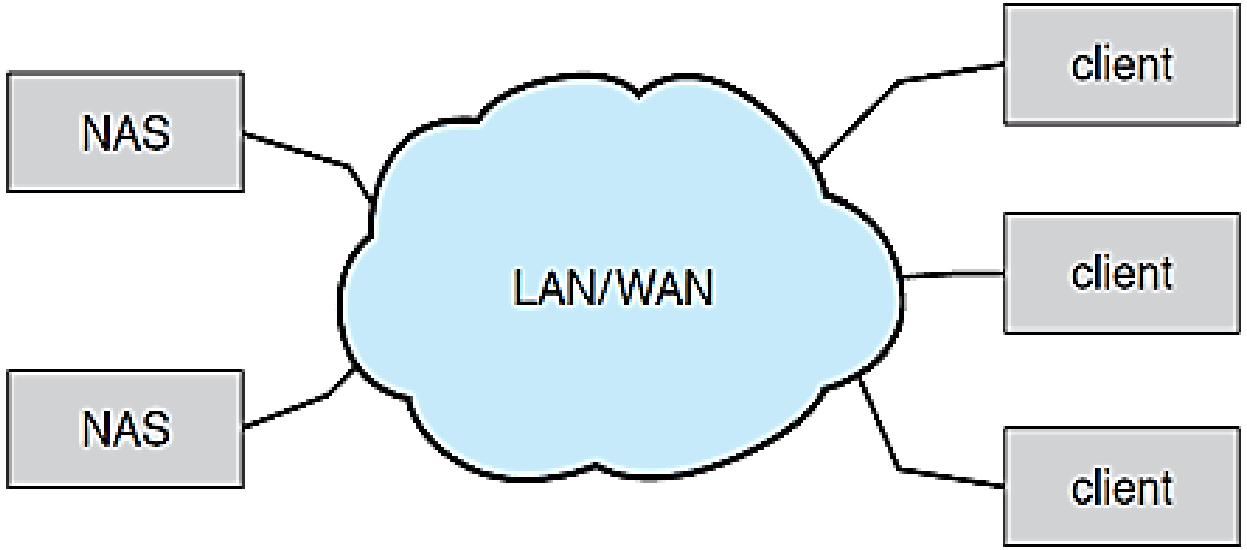
- 1) Host-attached storage
- 2) Network-attached storage (NAS)
- 3) Storage-area network (SAN)

1) Host-attached storage

- Accessed through PC I/O ports talking to I/O busses
- The typical desktop PC uses an I/O bus architecture, called IDE or ATA
  - Maximum of 2 drivers per I/O bus
  - A newer, similar protocol that has simplified cabling is SATA
- SCSI is a bus, up to 16 devices on one cable
- Fiber Channel (FC) is high-speed serial architecture

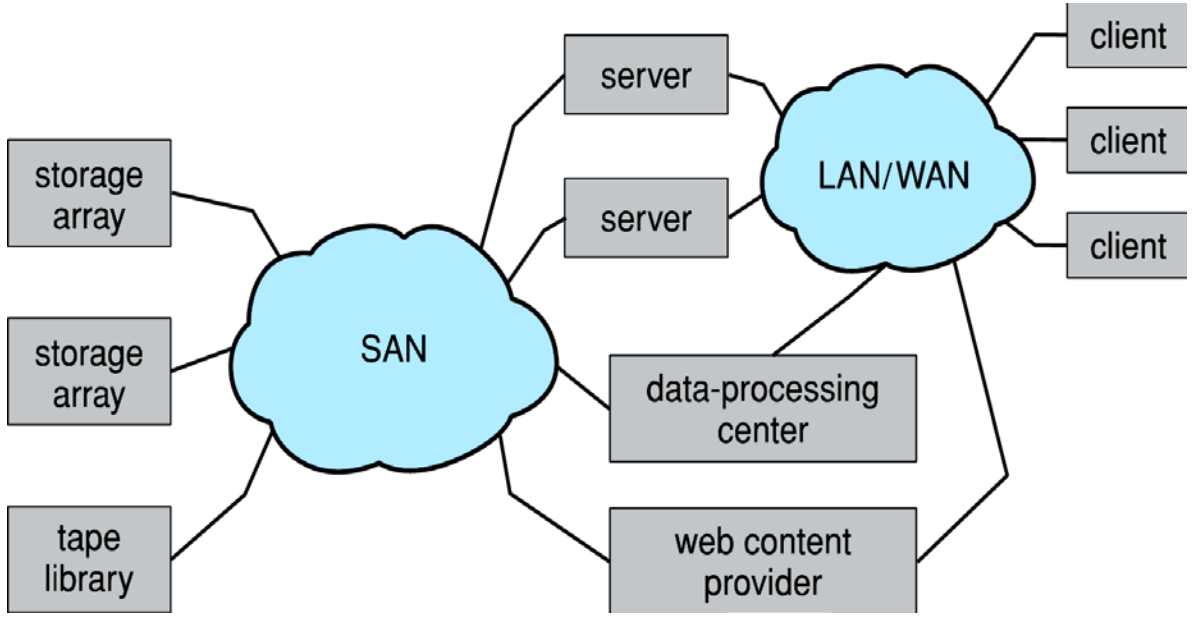
2) Network-attached storage (NAS)

- Storage over a network rather than a local connection
- Remotely attaching to file systems
- NFS and CIFS are common protocols
- Implemented via remote procedure calls (RPCs) between host and storage over typically TCP or UDP on IP network



3) Storage-area network (SAN)

- A method for large storage environments
- Multiple hosts attached to multiple storage arrays
- Storage arrays and Hosts are connected to one or more Fiber Channel Switches



Disk Management

Disk management

- Disk formatting
- Boot block
- Bad blocks

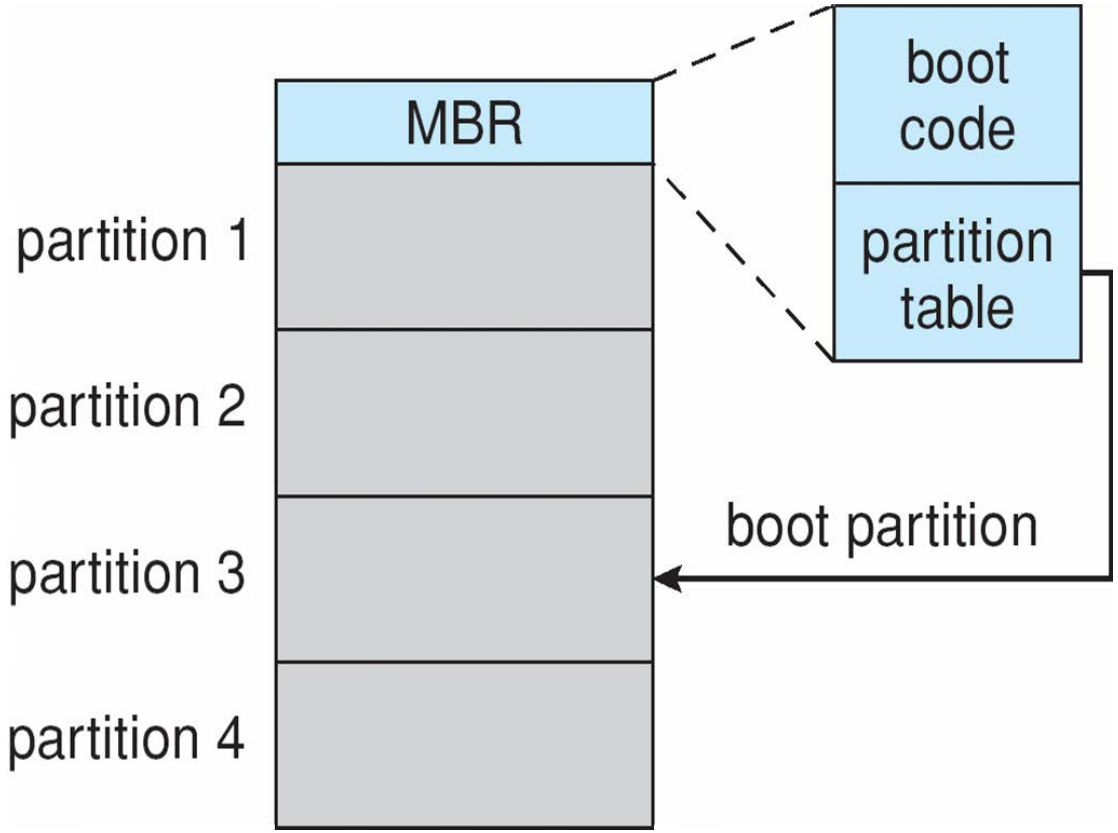
Disk formatting

- Low-level formatting, or physical formatting
  - Dividing a disk into sectors
  - Each sector can hold header information, plus data, plus error correction code (ECC)
  - Usually 512 bytes of data but can be selectable

- OS data structures to save files
  - Partition the disk into one or more groups of cylinders, each treated as a logical disk
  - 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

- Boot block initializes system
  - The bootstrap is stored in ROM
  - Bootstrap loader program stored in boot blocks of boot partition



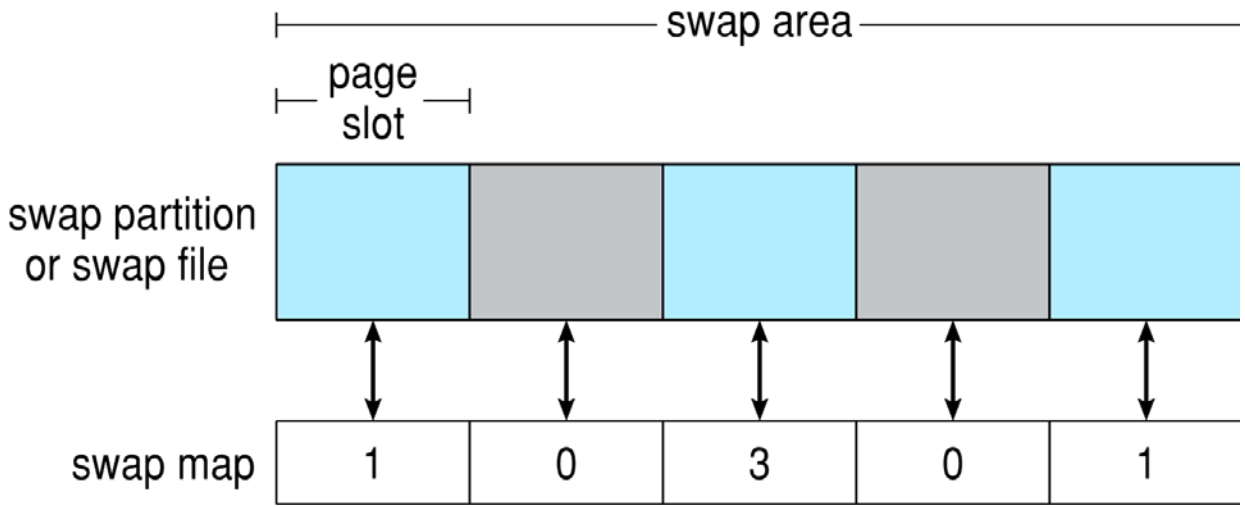
Bad blocks

- The controller maintains a list of bad blocks on the disk
- The list is initialized during the low-level formatting at the factory and is updated over the file of the disk
- Sector sparing or forwarding: replacing each bad sector logically with one of the spare sectors.

Swap space management

Swap-space management

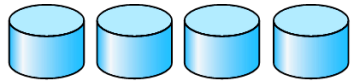
- **Swap-space — Virtual memory uses disk space as an extension of main memory**
- **Less common now due to memory capacity increases**
- **Swap-space**
  - **Normal file system, OR separate disk partition (raw)**



RAID Structures

RAID

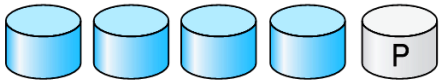
- RAID – Redundant Array of Inexpensive Disks
- Multiple disk drives provides reliability via redundancy
- Increases the mean time to failure



(a) RAID 0: non-redundant striping.

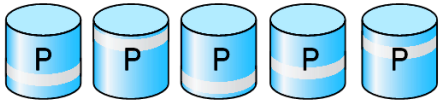
(b) RAID 1: mirrored disks.

(c) RAID 2: memory-style error-correcting codes.

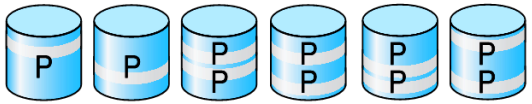


(d) RAID 3: bit-interleaved parity.

(e) RAID 4: block-interleaved parity.

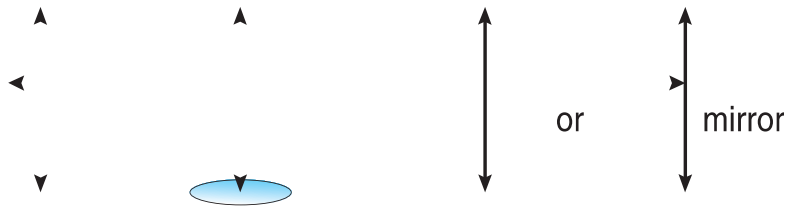


(f) RAID 5: block-interleaved distributed parity.



(g) RAID 6: P + Q redundancy.

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



Stable-Storage Implementation

Stable-storage implementation

- **Stable storage**: data is **never lost** (due to failures, etc)
- **Write-ahead log (WAL)** scheme requires stable storage
- In a system using WAL, all **modifications** are written to a **log before** they are **applied**.

What are failure's effects?

1. **Successful completion**

   The data were written correctly on disk

2. **Partial failure**

   A failure occurred in the midst of transfer, so only some of the sectors were written with the new data, and the sector being written during the failure may have been corrupted

3. **Total failure**

   The failure occurred before the disk write started, so the previous data values on the disk remain intact

How to implement stable storage?

- If failure occurs during block write, recovery procedure restores block to consistent state
  - System maintains 2 physical blocks per logical block
    1. Write to 1st physical
    2. When successful, write to 2nd physical
    3. Declare complete only after second write completes successfully

- Systems frequently use NVRAM (Non-Volatile RAM) as one physical to accelerate

Questions?