Chapter 12: Mass-Storage Systems

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- Overview of Mass Storage Structure
- Disk Structure
- Disk Attachment
- Disk Scheduling
- Disk Management
- RAID Structure

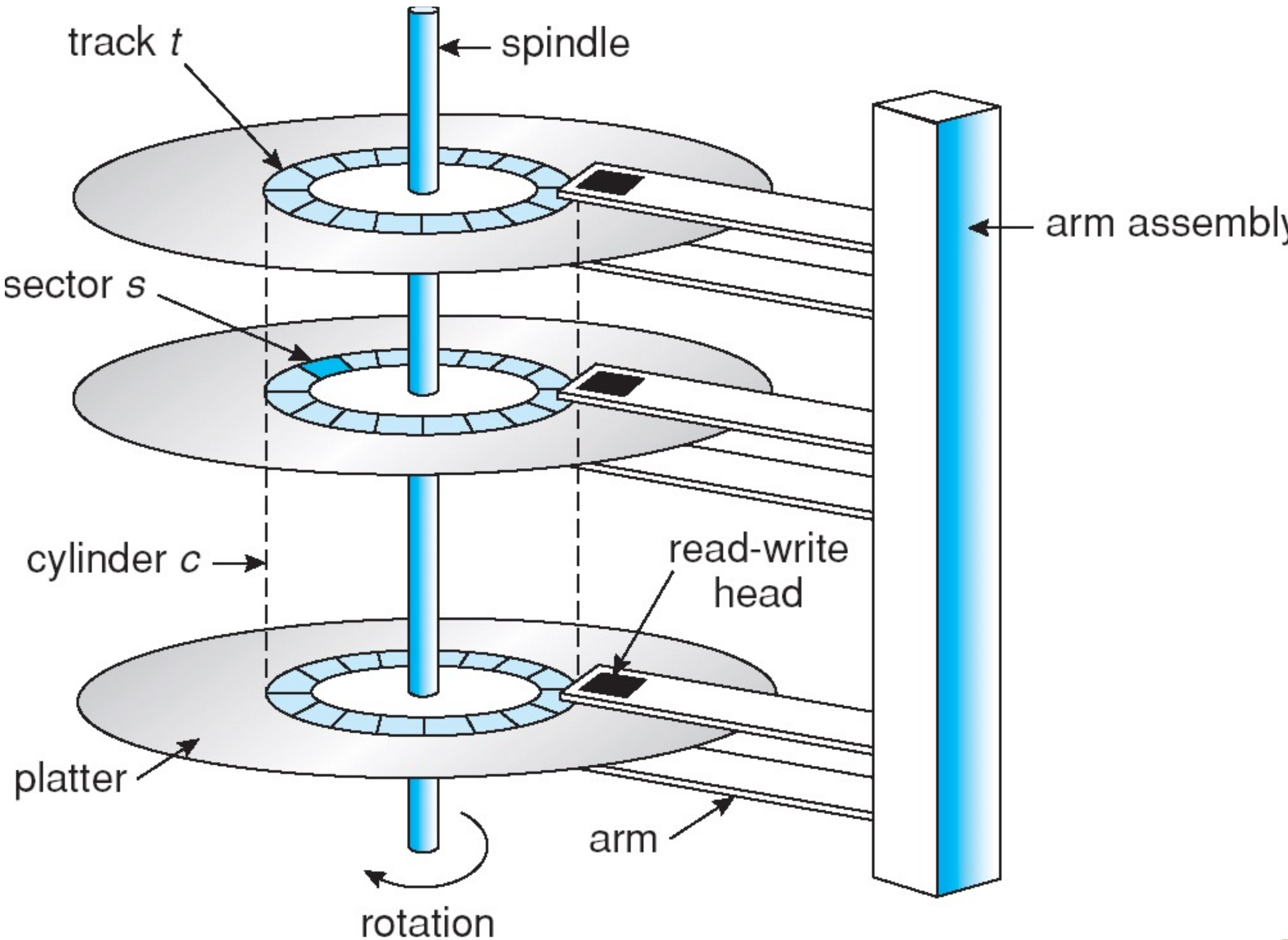
Objectives

- 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

Moving-head Disk Mechanism



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

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

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 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

Disk Scheduling (Cont)

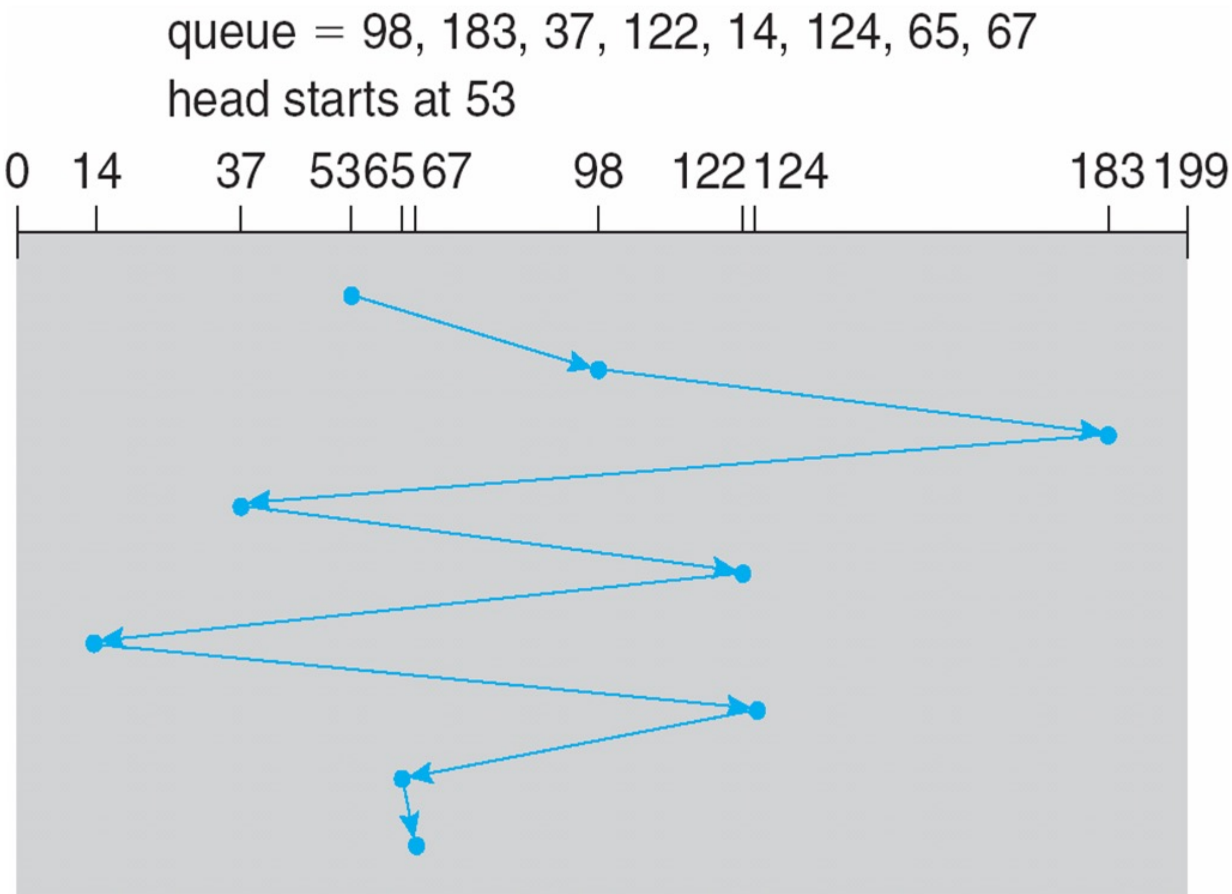
- Several algorithms exist to schedule the servicing of disk I/O requests
- We illustrate them with a request queue (0-199)

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

Head pointer 53

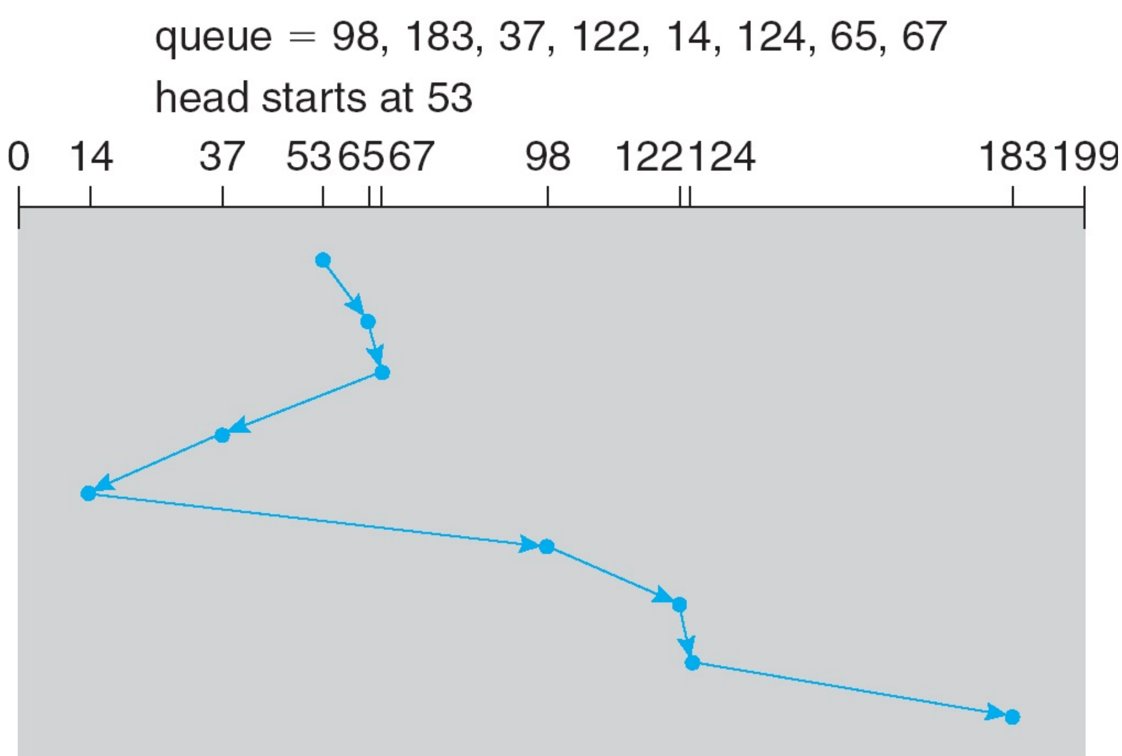
First-come, first-served (FCFS)

Illustration shows total head movement of **640 cylinders**



Shortest seek time first (SSTF)

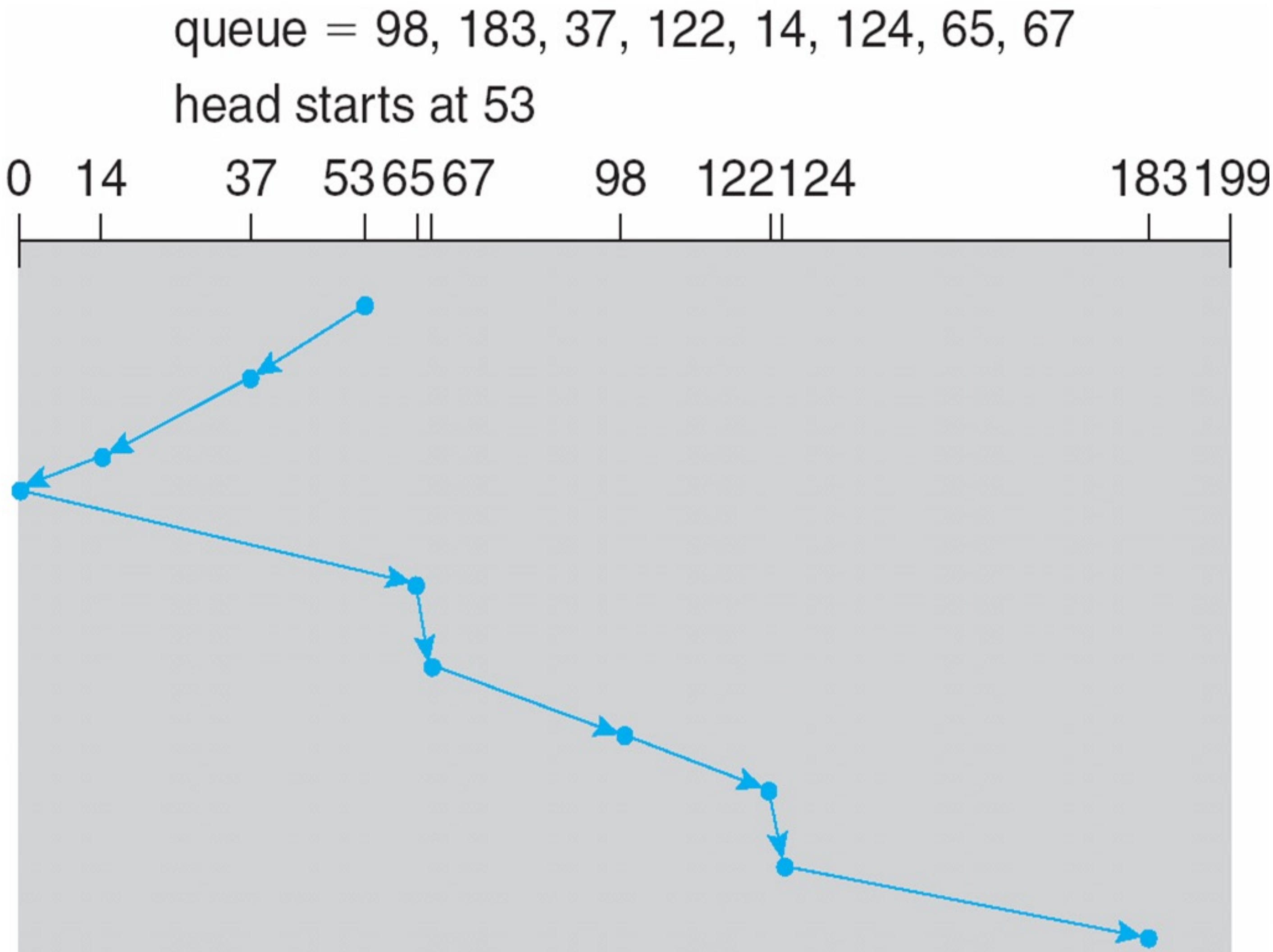
- Selects the request <u>with the minimum seek time</u> from the current head position
- SSTF scheduling is a form of SJF scheduling; may cause starvation of some requests
- Illustration shows total head movement of <u>236 cylinders</u>



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
- Illustration shows total head movement of **208 cylinders**

SCAN (Cont.)


queue = 98, 183, 37, 122, 14, 124, 65, 67
head starts at 53
0 14 37 53 65 67 98 122 124 183 199

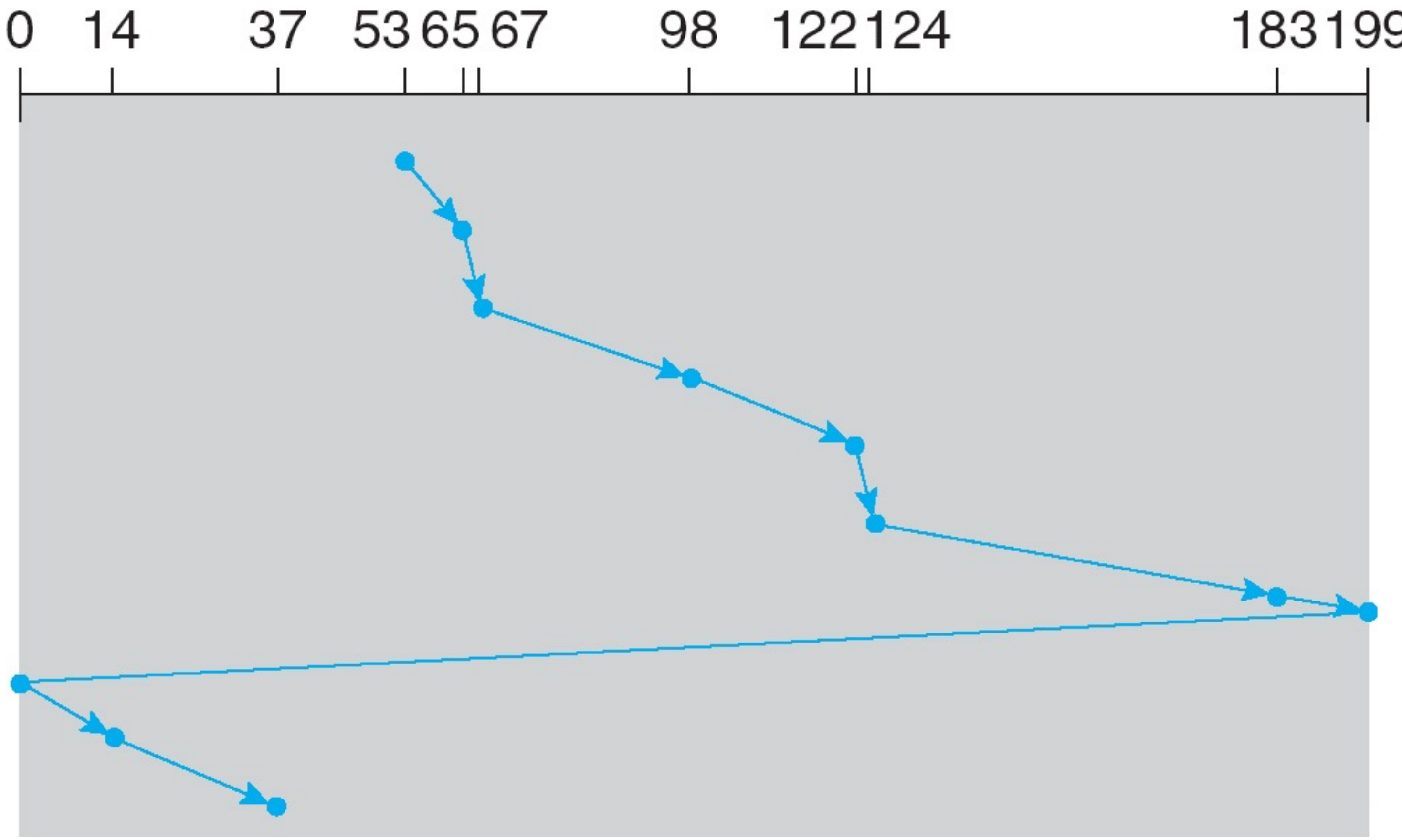
C-SCAN

- 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-SCAN (Cont)

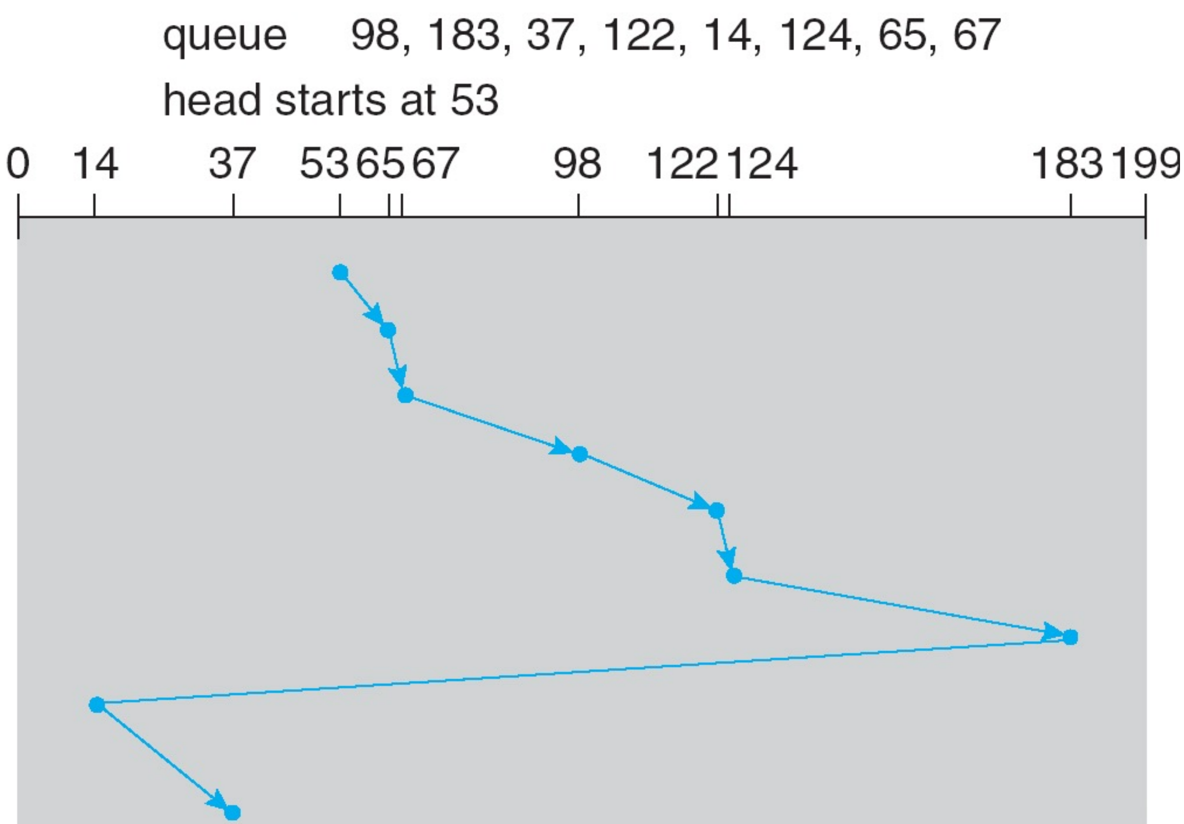
queue = 98, 183, 37, 122, 14, 124, 65, 67

head starts at 53



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

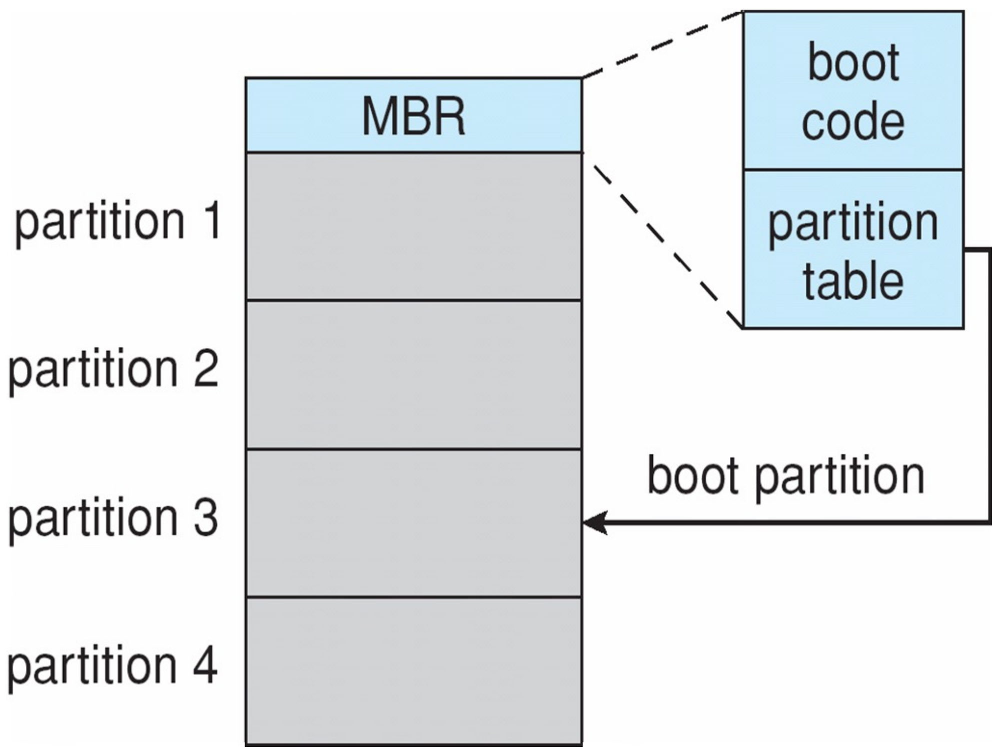
- SSTF is common and has a natural appeal
- SCAN and C-SCAN perform better for systems that place a heavy load on the disk
- Performance depends on the number and types of requests
- Requests for disk service can be influenced by the file-allocation method
- The disk-scheduling algorithm should be written 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

Windows 2000 places its boot code in the first sector on the hard disk (master boot record).
Disk divided into more than one partitions with one as boot partition, which contains OS and device drivers.



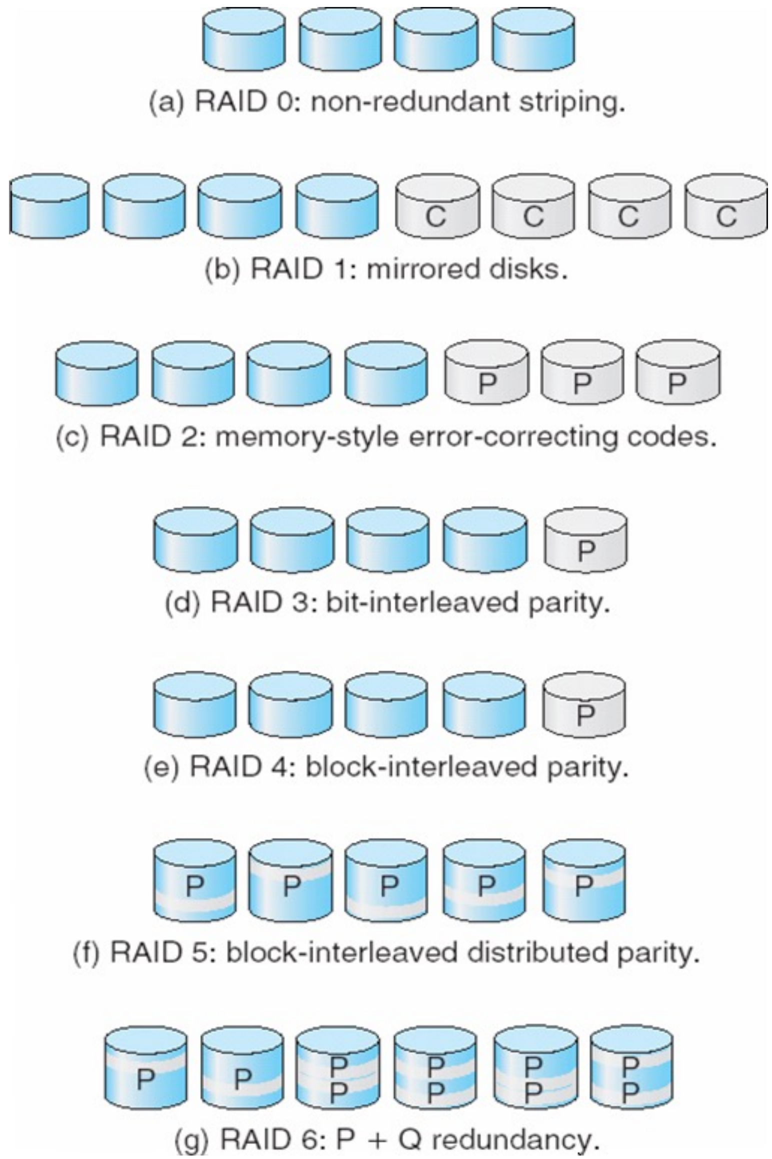
RAID Structure

- RAID – multiple disk drives provides reliability via redundancy
- Increases the mean time to failure
- Frequently combined with nonvolatile RAM (NVRAM) to cache the RAID array. This write-back cache is protected from data loss during power failures.
- RAID is arranged into six different levels

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 (RAID 1) keeps **duplicate of each disk**
  - Striped mirrors (RAID 1+0) or mirrored stripes (RAID 0+1) provides high performance and high reliability
  - Block 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

RAID Levels


(a) RAID 0: non-redundant striping.
C C C C
(b) RAID 1: mirrored disks.
P P P
(c) RAID 2: memory-style error-correcting codes.
P
(d) RAID 3: bit-interleaved parity.
P
(e) RAID 4: block-interleaved parity.
P P P P P
(f) RAID 5: block-interleaved distributed parity.
P P P P P P P P P P
(g) RAID 6: P + Q redundancy.

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