Operating System Practice

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Advanced Operating System Concepts

- Chapter 10: File System
- Chapter 11: Implementing File-Systems
- Chapter 12: Mass-Storage Structure
- Chapter 13: I/O Systems
- Chapter 14: System Protection
- Chapter 15: System Security

Study Items

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

Overview of Mass Storage Structure

- Magnetic disks provide bulk of secondary storage of modern computers
  - Drives rotate at 60 to 250 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)
- Drive attached to computer via I/O bus
  - Busses vary, including ATA, SATA, USB, SCSI, SAS, Firewire
  - Host controller in computer uses bus to talk to disk controller

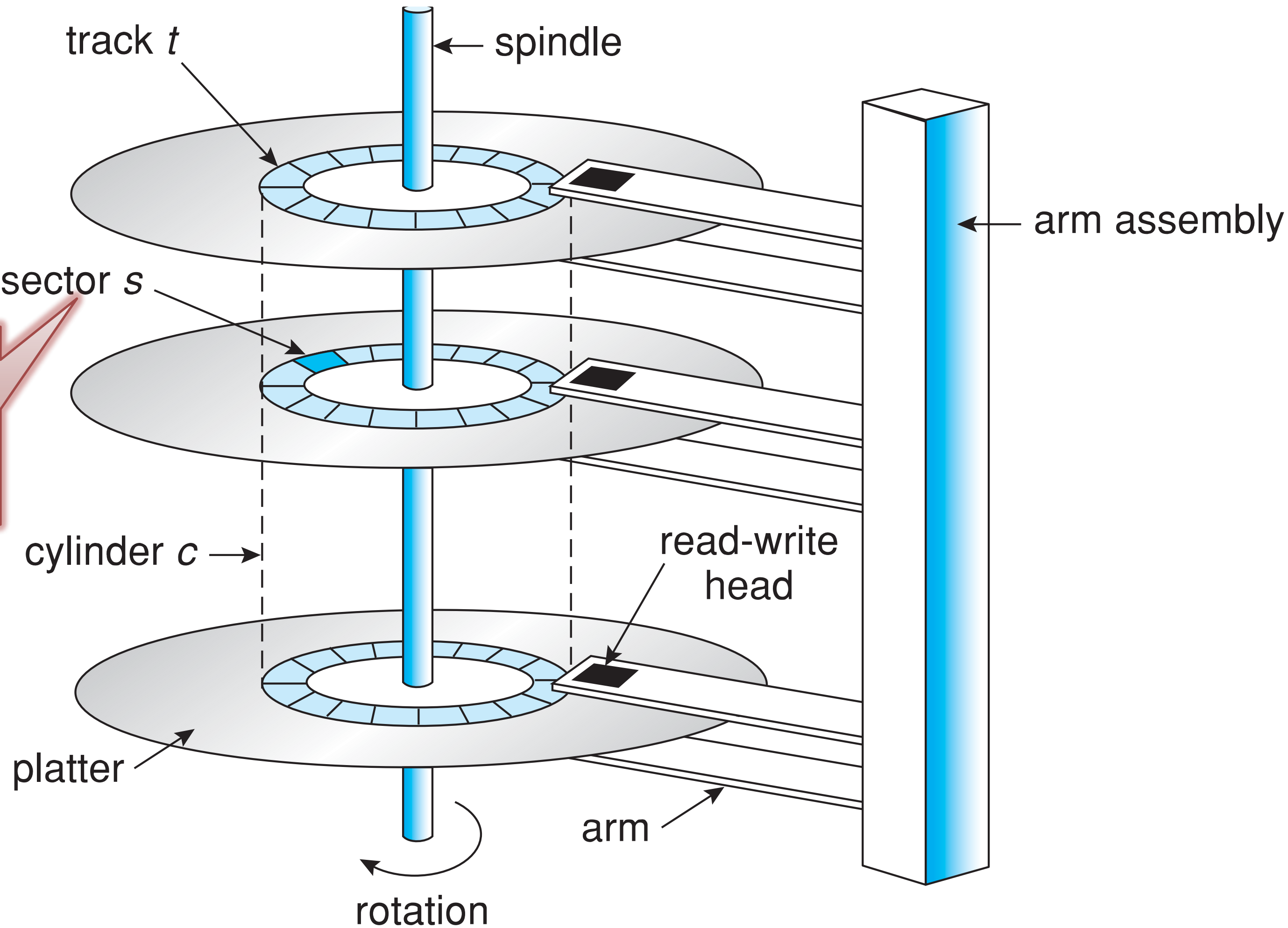
Solid-State Disk

- Nonvolatile memory used like a hard drive
  - Many technology variations
- Can be more reliable than HD
- More expensive than HD
  - Less capacity
  - But much faster
- May have shorter life span
- Busses can be too slow
- No moving parts, so no seek time or rotational latency

Magnetic Tape

- Early secondary-storage medium
- Relatively permanent and holds large quantities of data
- Random access ~1000 times slower than disk
- Mainly used for backup, storage of infrequently-used data, transfer medium between systems
- Once data under head, transfer rates comparable to disk
  - 140MB/sec or greater

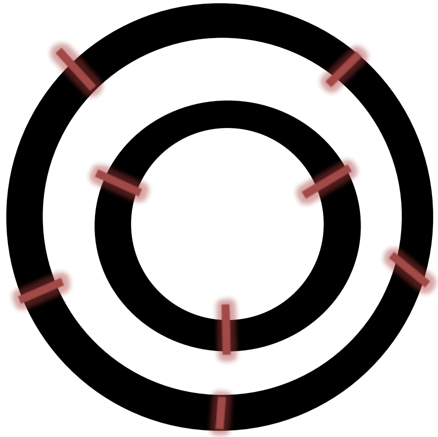
Moving-Head Disk Mechanism



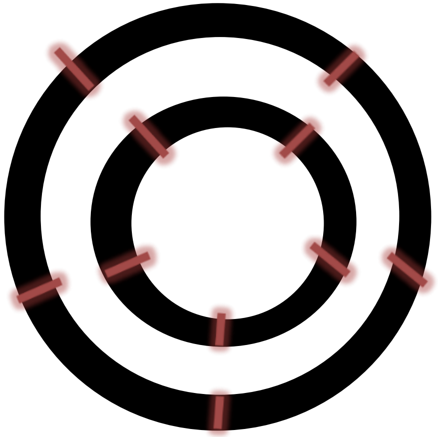
The size of a sector is from 512B to 4KB

Disk Structure

- Constant Linear Velocity (CLV)
  - The outermost track typically hold 40 percent more sectors than the innermost track
  - The drive increases its rotation speed as the head moves from the outer to the inner tracks
  - The same rate of data moving is kept
  - CD and DVD adopt this approach

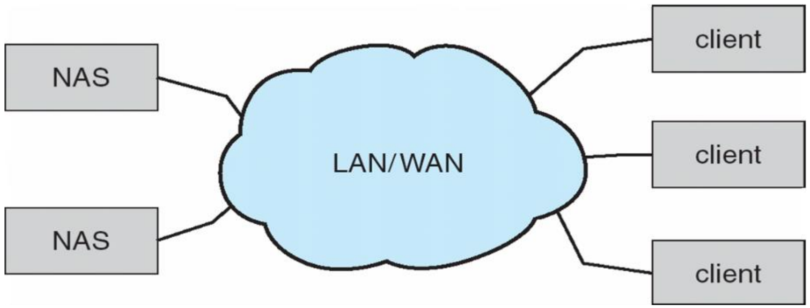


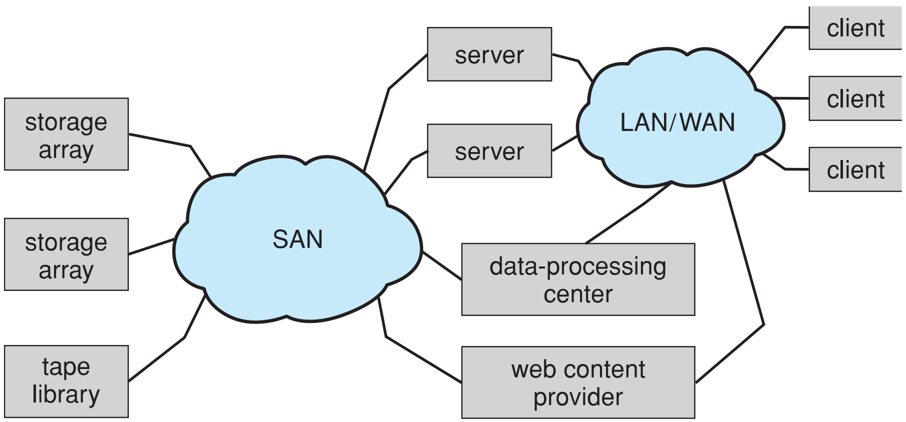
- Constant Angular Velocity (CAV)
  - All tracks have the same number of sectors
  - Tracks have different densities of sectors
  - The same rate of data moving is kept
  - HD adopts this approach



Disk Attachment

- Host-Attached Storage
  - Storage is accessed through I/O ports talking to I/O busses
- Network-Attached Storage (NAS)
  - NAS is storage made available over a network rather than over a local connection (such as a bus)
- Storage-Area Network (SAN)
  - SAN is a private network using storage protocols rather than networking protocol connecting servers and storage units





Disk Scheduling

- The disk I/O request specifies several pieces of information:
  - Whether this operation is input or output
  - What the disk address for the transfer is
  - What the memory address for the transfer is
  - What the number of sectors to be transferred is
- When there are multiple request pending, a good disk scheduling algorithm is required
  - Fairness: which request is the most urgent one
  - Performance: sequential access is preferred

Cylinders	1	2	3	4	5	6	7
Requests	**5**	**7**	**2**	**6**	**4**	**1**	**3**

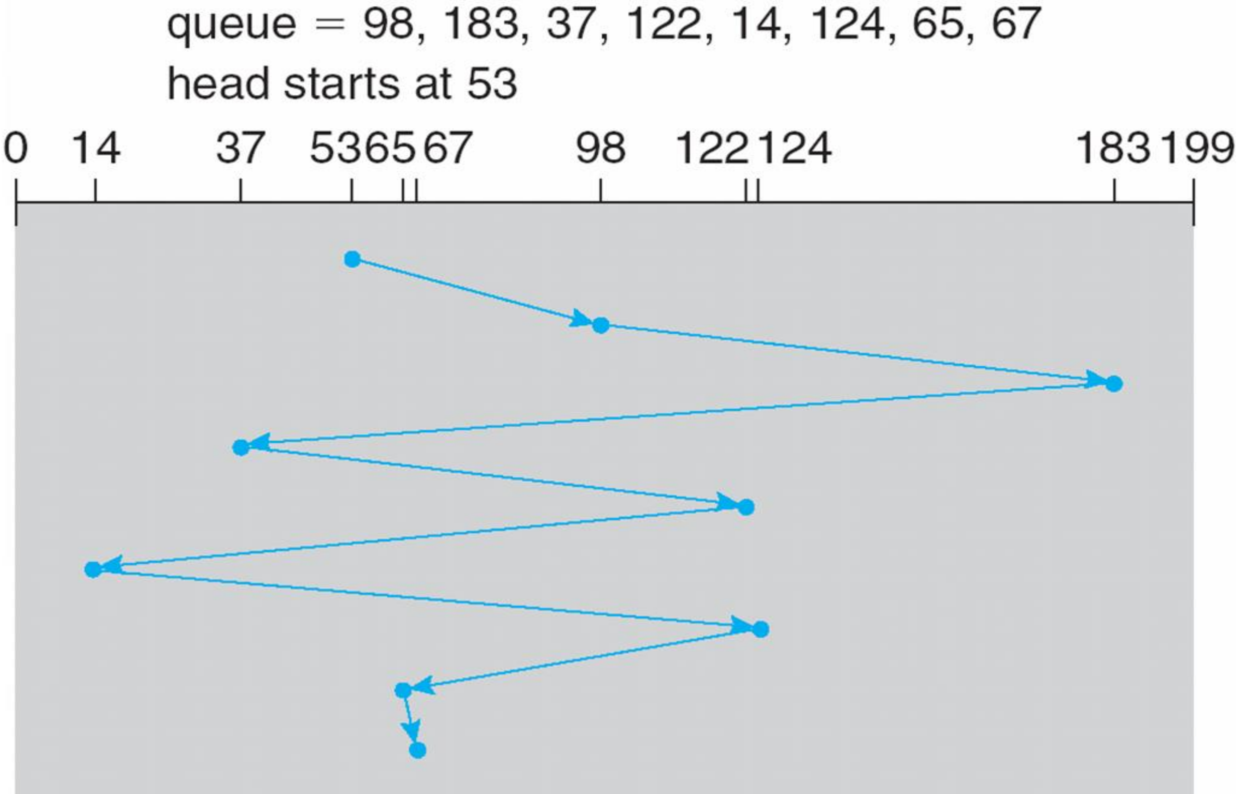
Resort the requests?

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

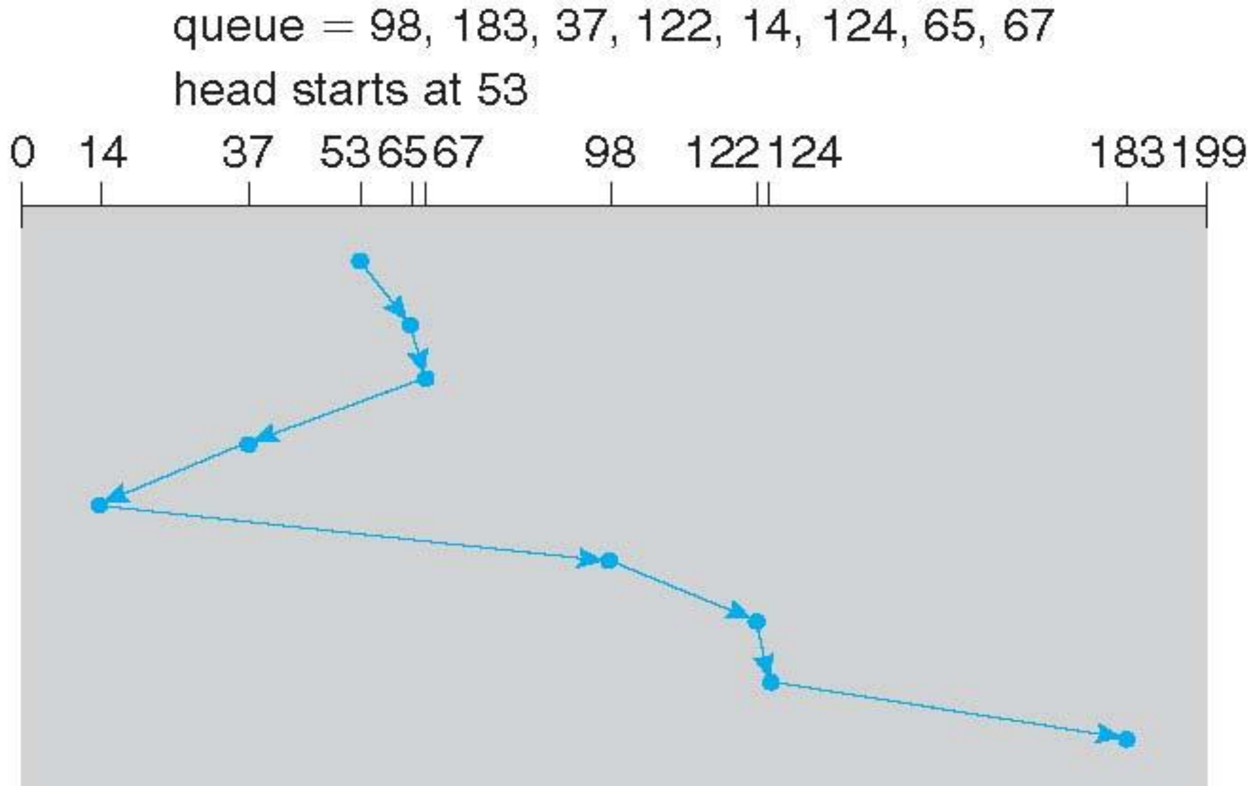
FCFS Scheduling

- FCFS: first come, first serve
- FCFS scheduling is fair but might with low throughput



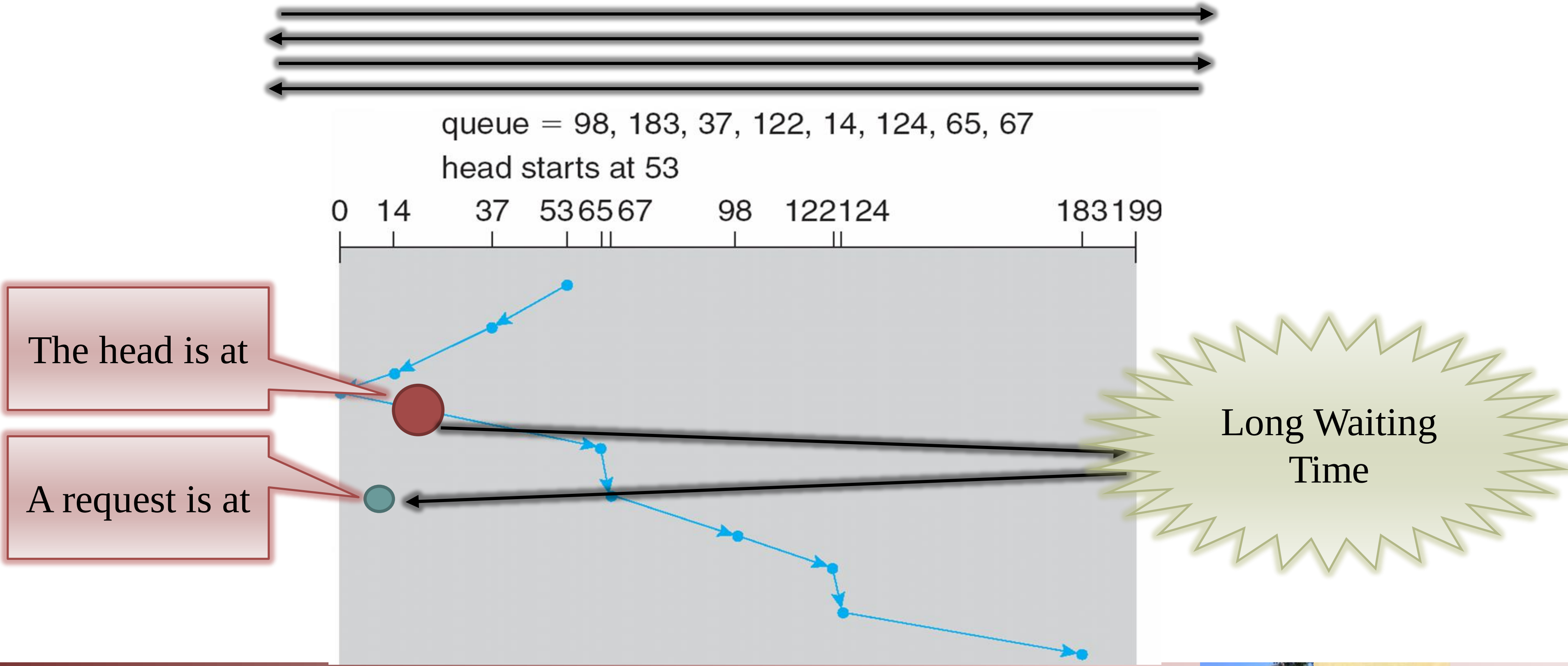
SSTF Scheduling

- SSTF: shortest seek time first
- SSTF scheduling serves the request with shortest seek time



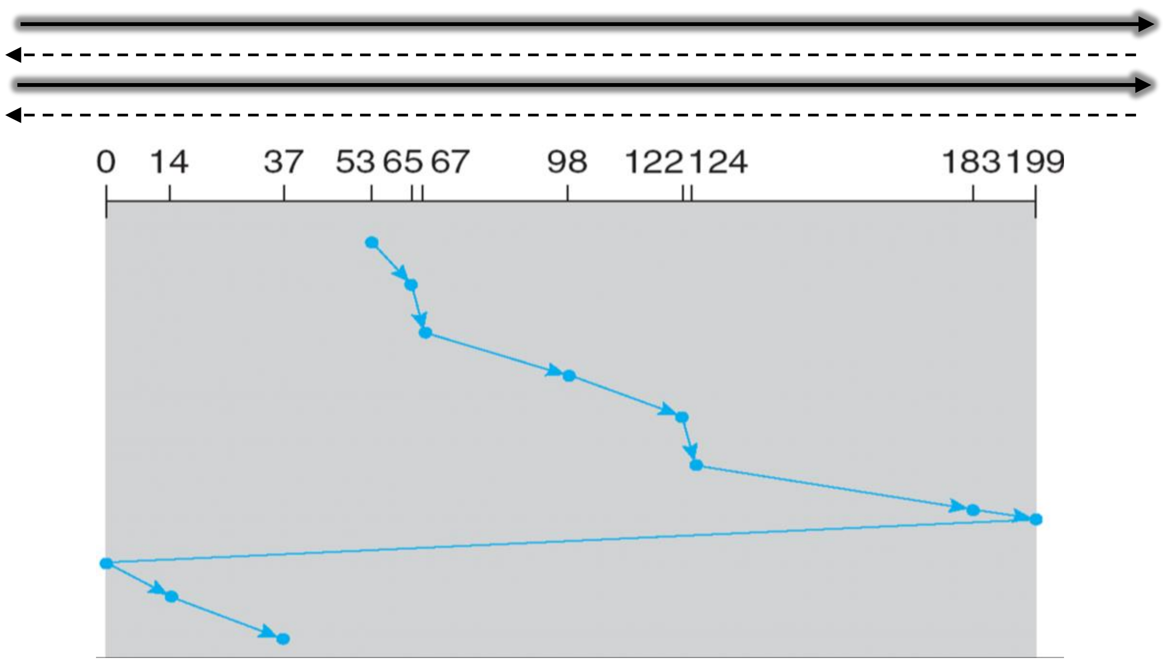
SCAN Scheduling

- SCAN scheduling (also called the elevator algorithm) starts at one end and moves toward the other end



C-SCAN Scheduling

- C-SCAN (Circular SCAN) scheduling starts at only one end and provides a more uniform wait time than SCAN scheduling

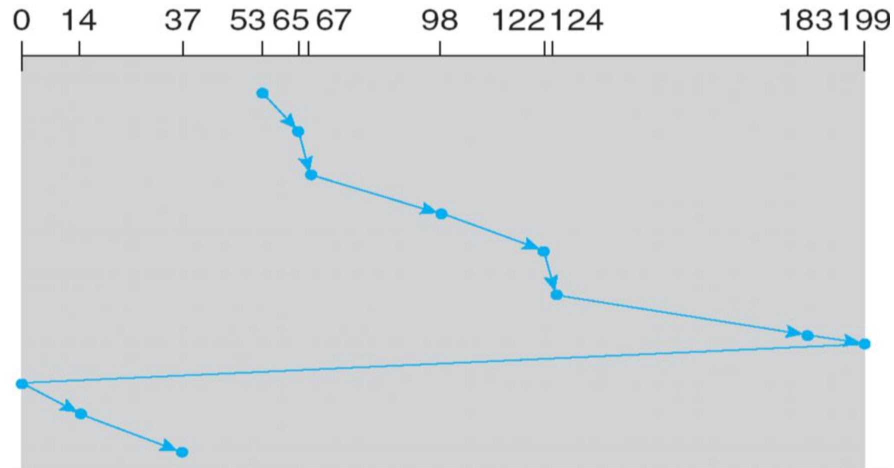


LOOK and C-LOOK Scheduling

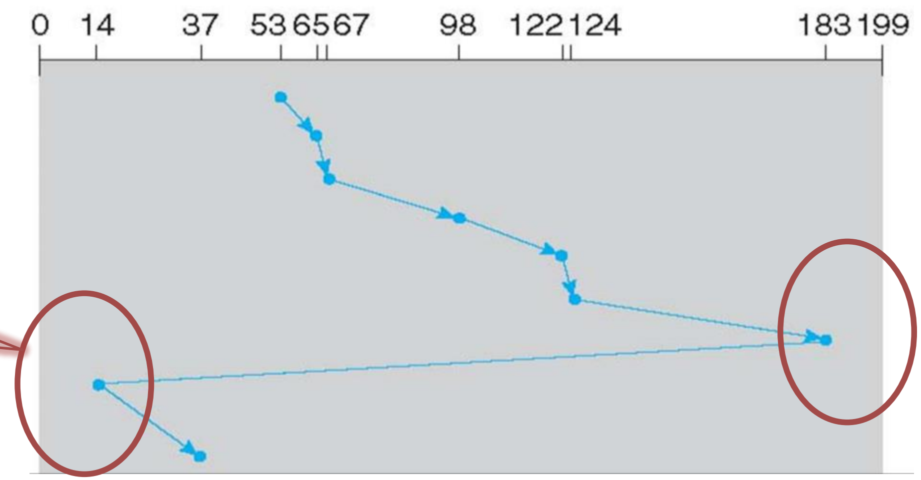
- LOOK scheduling starts at one end and moves toward the other end, and looks for a request before continuing to move in a given direction
- C-LOOK scheduling starts at only one end, and looks for a request before continuing to move in a given direction
- Arm only goes as far as the last request in each direction, then reverses direction immediately, without first going all the way to the end of the disk

Examples of C-SCAN and C-LOOK

C-SCAN



C-LOOK



Reduce the moving time

Selecting a Disk-Scheduling Algorithm

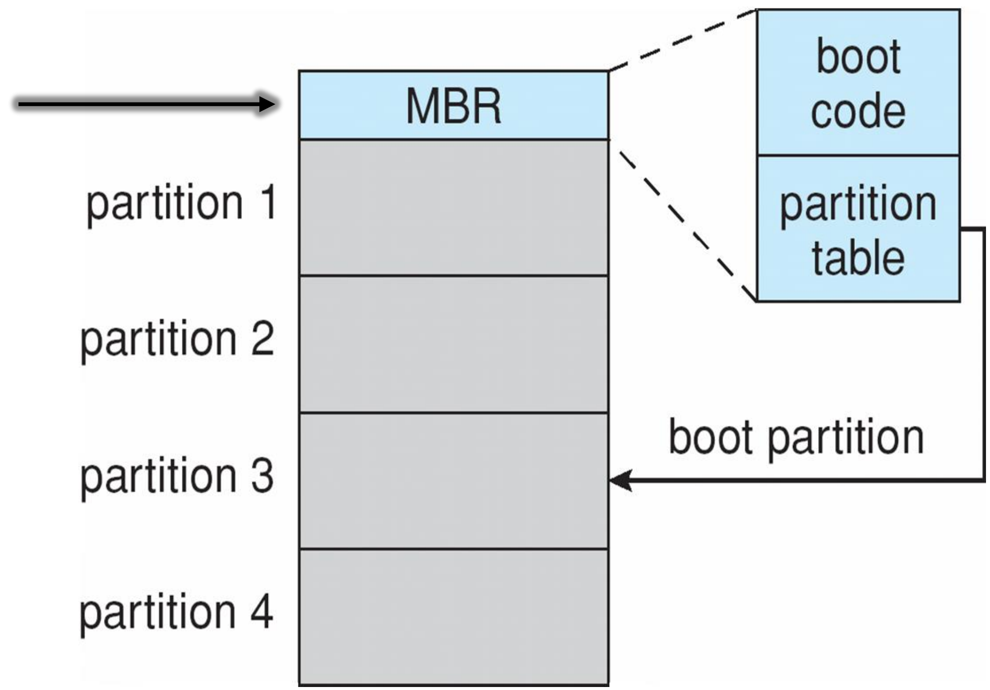
- SSTF is common and has a natural appeal
- SCAN and C-SCAN perform better for systems that place a heavy load on the disk
  - Less starvation
- Requests for disk service can be influenced by the file-allocation method
- The disk-scheduling algorithm should be written as a separate module of the operating system, allowing it to be replaced with a different algorithm if necessary
- Either SSTF or LOOK is a reasonable choice for the default algorithm
- FCFS is good for SSD

Disk Management

- Low-level formatting, or physical formatting — Dividing a disk into sectors that the disk controller can read and write
  - Each sector can hold header information, plus data, plus error correction code (ECC)
  - Usually 512 bytes of data but can be selectable
- Partition the disk into one or more groups of cylinders, each treated as a logical disk
- Logical formatting — 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
- Raw disk access for apps that want to do their own block management, keep OS out of the way (databases for example)

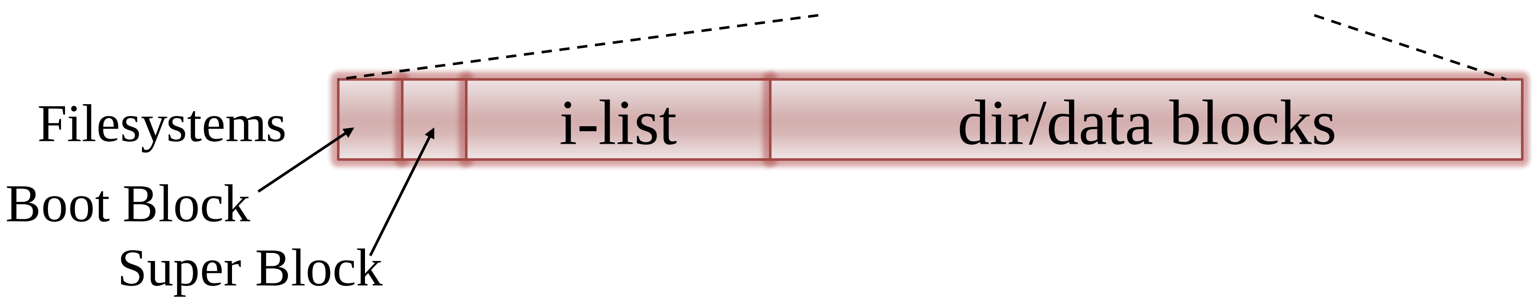
Booting from a Disk

ROM
BIOS/UEFI



BIOS: Basic Input Output System

UEFI: Unified Extensible Firmware Interface



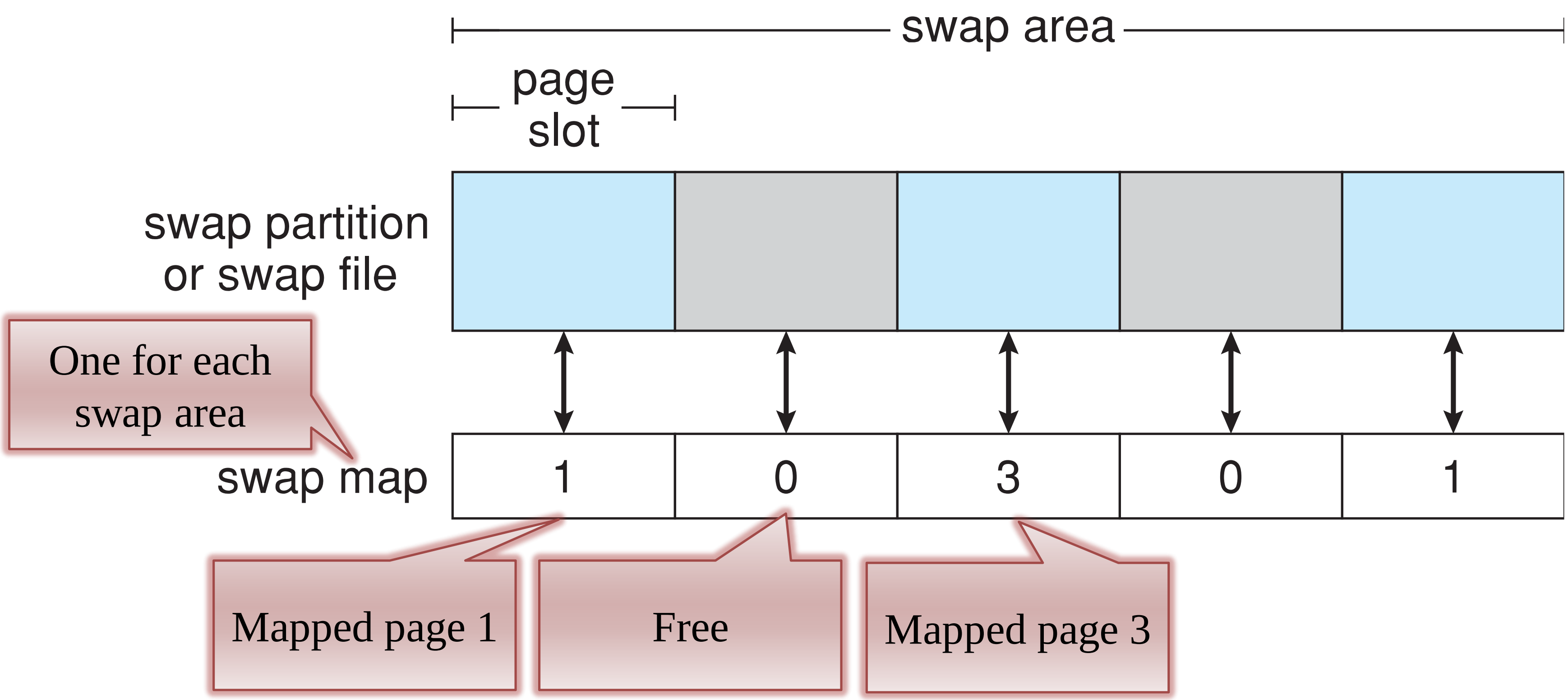
Bad Blocks

- A bad block: some bits of data in the block is corrupted
- Soft error: a bad block can be recovered by ECC
- Hard error: a bad block results in lost data
- Spared sectors are for bad block replacement
  - For example, one spared sector per 100 normal sector, let 97^{th} block is a bad block
  - Sector sparing:
    - Use the spared sector to replace the 97^{th} block
  - Sector slipping:
    - 97→98, 98→99, 99→100, 100→spared sector

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 can be carved out of the normal file system, or, more commonly, it can be in a separate disk partition (raw)
- Some systems allow multiple swap spaces

Data Structures for Swapping on Linux Systems



RAID Structure

- RAID: redundant array of inexpensive disks
  - Multiple disk drives provides reliability via redundancy
  - RAID Increases the mean time to data loss
- Mean time to failure: the average time for the first hard error
- Mean time to repair: the exposure time when another failure could cause data loss
- Mean time to data loss: the average time for the first data loss
- If mirrored disks fail independently, consider each disk with 100,000 hours mean time to failure and 10 hours mean time to repair
  - Mean time to failure of any of the two disks: 100,000/2 = 50,000
  - The possibility for another disk to fail within the 10 hours: 10/100,000
  - Mean time to data loss is $5 * 10^8$ hours, or 57,000 years!

Improvement in Performance via Parallelism

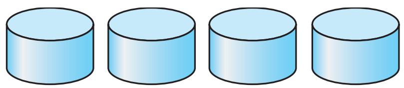
- Bit-level striping
  - Bit-level striping can be generalized to include a number of disks that either is a multiple of 8 or divides 8
  - For example, if we use an array of four disks, bits *i* and 4 + *i* of each byte go to disk *i*
- Block-level striping
  - blocks of a file are striped across multiple disks
  - For example, with n disks, block i of a file goes to disk (i mod n) + 1

RAID

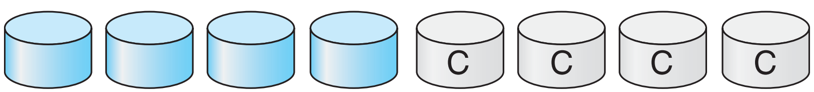
- RAID schemes improve performance and improve the reliability of the storage system by storing redundant data
  - Mirroring or shadowing (RAID 1) keeps duplicate of each disk
  - Striped mirrors (RAID 1+0) or mirrored stripes (RAID 0+1) provides high performance and high reliability
- Block interleaved parity (RAID 4, 5, 6) uses much less redundancy
- Frequently, a small number of hot-spare disks are left unallocated, automatically replacing a failed disk and having data rebuilt onto them

RAID Levels

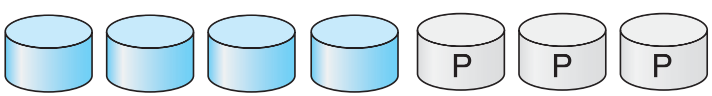
In the figures, P indicates error-correcting bits and C indicates a second copy of the data



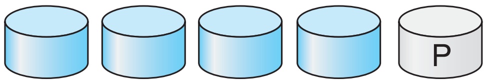
(a) RAID 0: non-redundant striping.



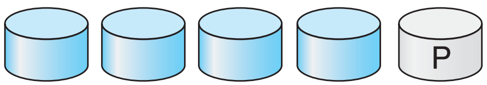
(b) RAID 1: mirrored disks.



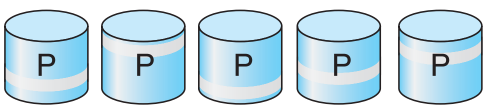
(c) RAID 2: memory-style error-correcting codes.



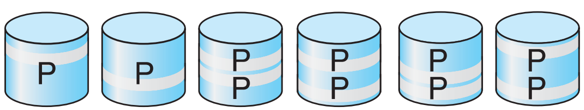
(d) RAID 3: bit-interleaved parity.



(e) RAID 4: block-interleaved parity.



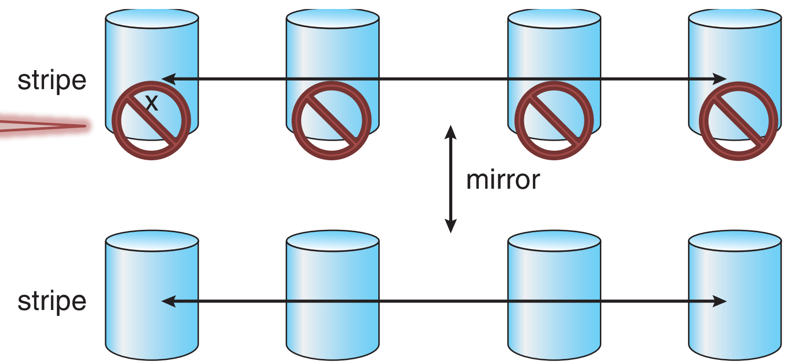
(f) RAID 5: block-interleaved distributed parity.



(g) RAID 6: P + Q redundancy.

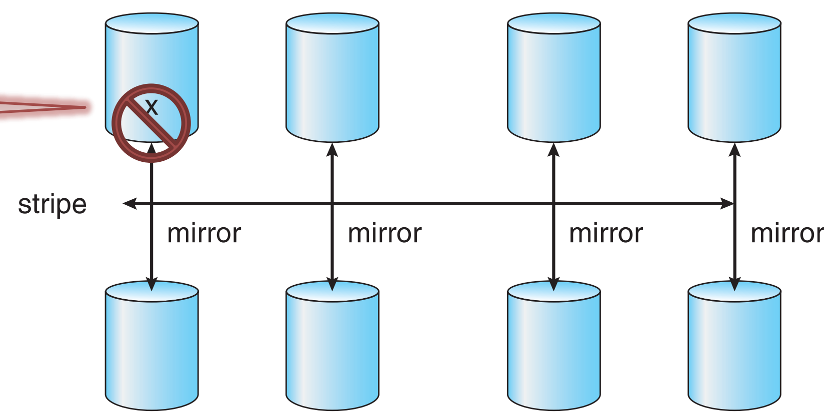
RAID (0+1) and (1+0)

One Fail
Four Offline



a) RAID 0 + 1 with a single disk failure.

One Fail
One Offline



b) RAID 1 + 0 with a single disk failure.