Disks: Structure and Scheduling

COMS W4118

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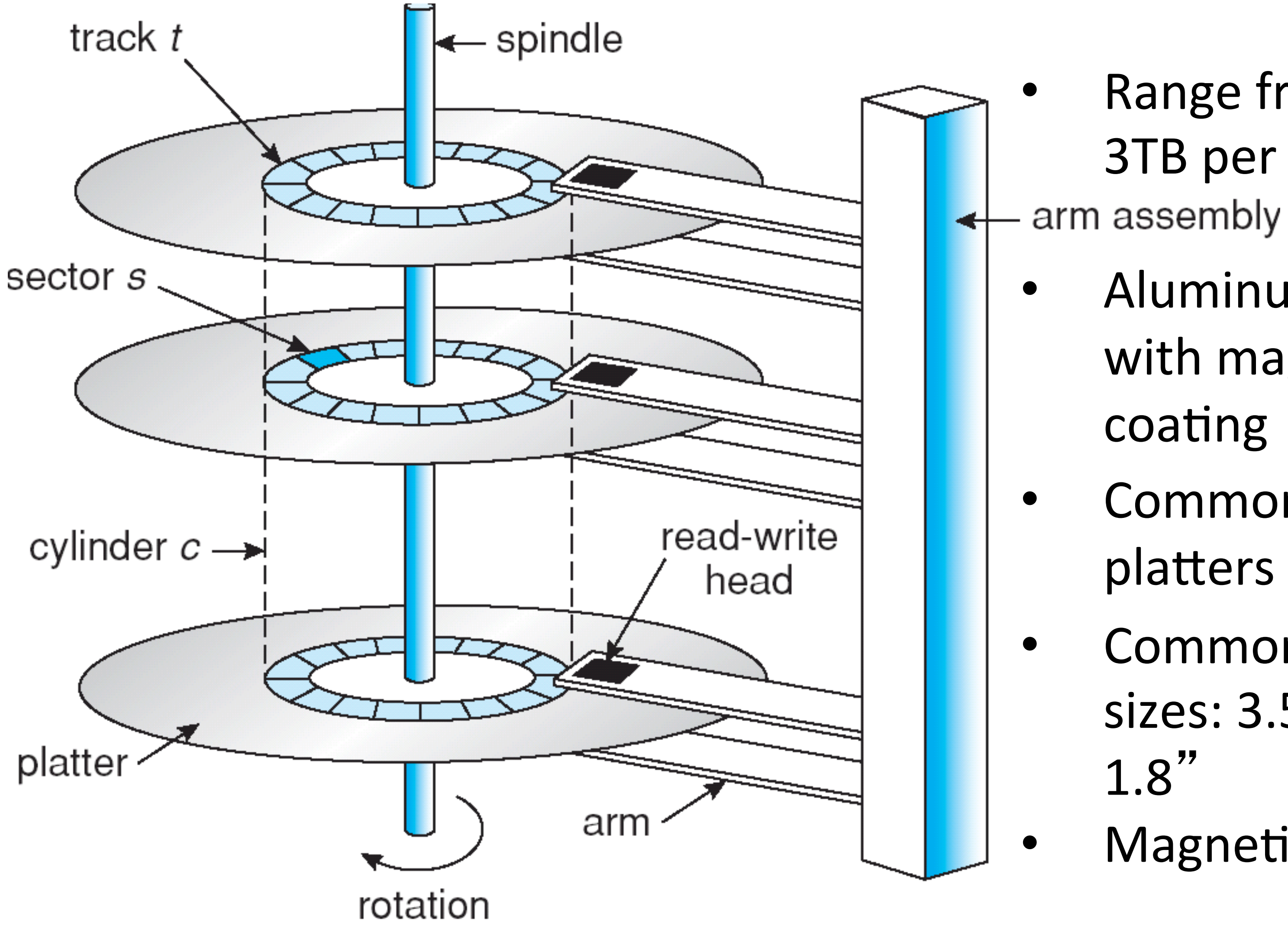
References: Operating Systems Concepts (9e), Linux Kernel Development, previous W4118s

Outline

- Basic: enough to understand FS (now)
  - Disk characteristics
  - Disk scheduling
- Advanced (after studying file systems)
  - Disk Reliability
  - RAID
  - SSDs/Flash

Disk Structure



- Range from 30GB to 3TB per drive
- Aluminum platters with magnetic coating
- Commonly, 2-5 platters per drive
- Common platter sizes: 3.5", 2.5", and 1.8"
- Magnetic heads

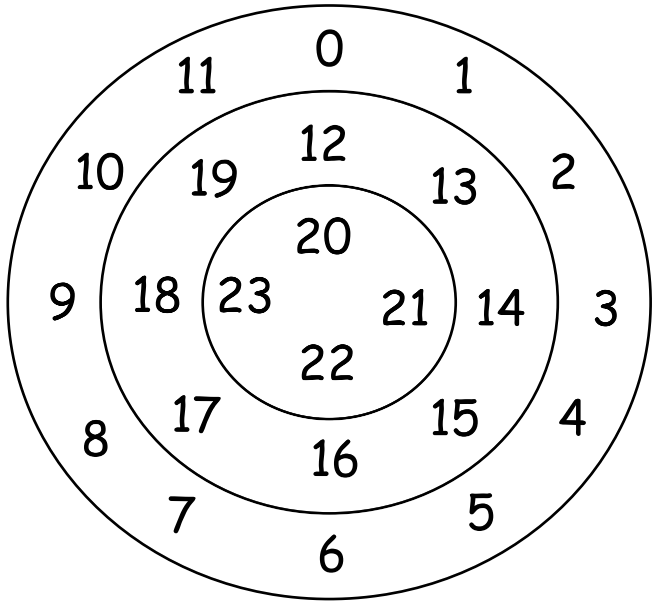
The First Commercial Disk Drive

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 Interface

- From FS perspective: disk is addressed as a one dimension array of logical sectors
- Disk controller maps logical sector to physical sector identified by track #, surface #, and sector #



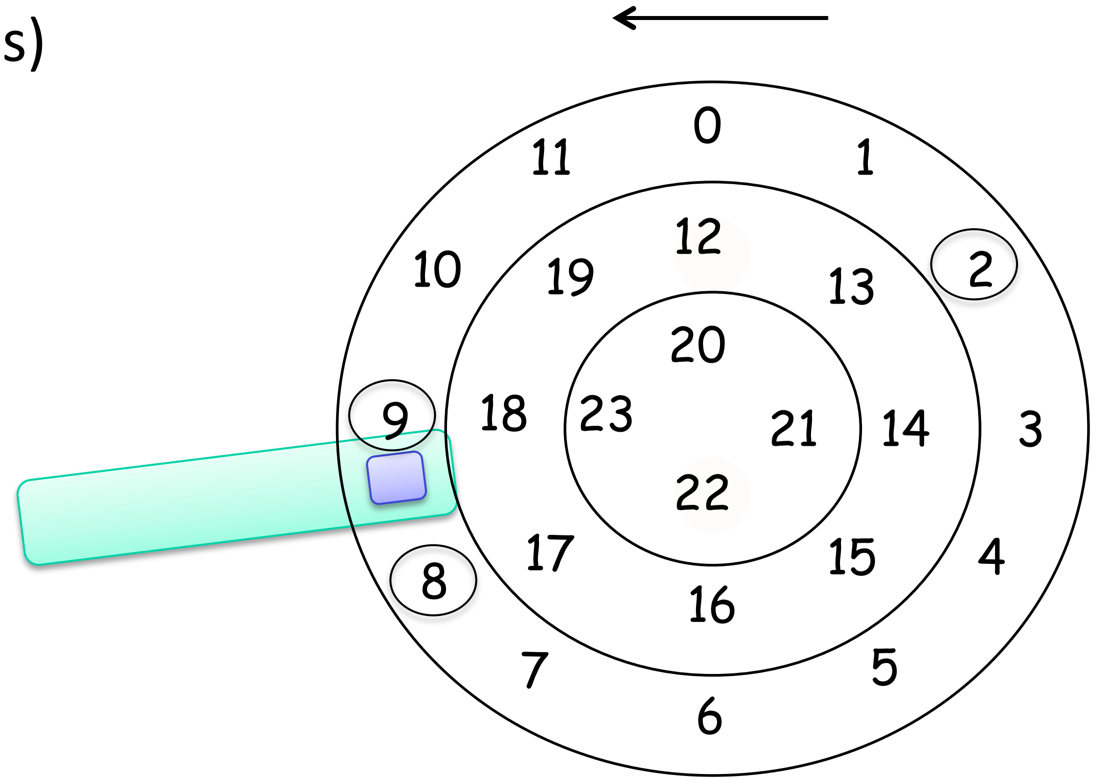
- Note: Old drives allowed direct C/H/S (cylinder/head/sector) addressing by OS. Modern drives export LBA (logical block address) and do the mapping to C/H/S internally.

Disk Latencies

- Rotational delay: rotate disk to get to the right sector
- Seek time: move disk arm to get to the right track
- Transfer time: get bits off the disk

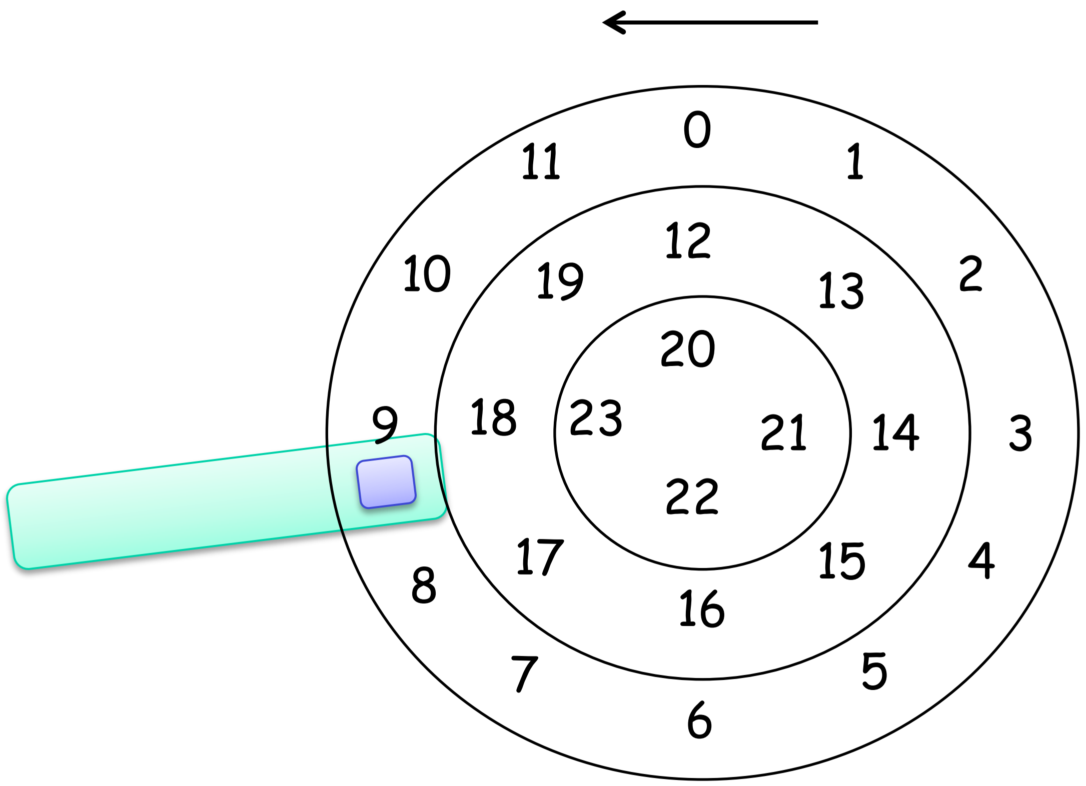
Seek Time

- Must move arm to the right track
- Can take a while (e.g., 5– 10ms)
  - Acceleration, coasting, settling (can be significant, e.g., 2ms)



Transfer Time

- Transfer bits out of disk
- Actually pretty fast (e.g., 125MB/s)



I/O Time (T) and Rate (R)

- T = Rotational delay + seek time + txfer time
- R = Size of transfer / T
- Workload 1: large sequential accesses?
- Workload 2: small random accesses?

Example: I/O Time and Rate

	Barracuda	**Cheetah 15K.5**
Capacity	1TB	300GB
Rotational speed	7200 RPM	15000 RPM
Rotational latency (ms)	4.2	2.0
Avg seek (ms)	9	4
Max Transfer	105 MB/s	125 MB/s
Platters	4	4
Connects via	SATA	SCSI

- Random 4KB read
  - Barracuda: T = 13.2ms, R = 0.31MB/s
  - Cheetah: T = 6ms, R = 0.66MB/s
- Sequential 100 MB read
  - Barracuda: T = 950ms, R = 105 MB/s
  - Cheetah: T = 800ms, R = 125 MB/s

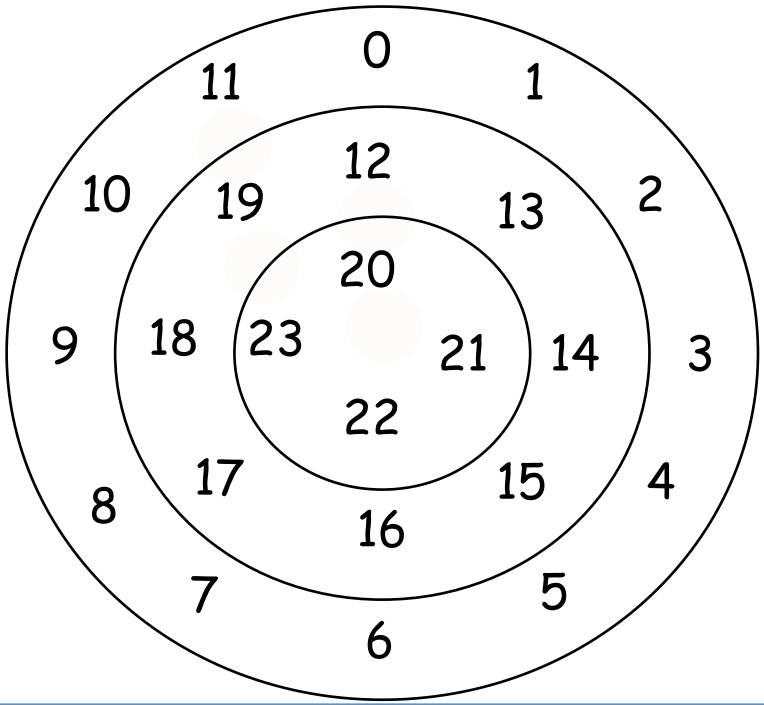
Design tip: Use Disks Sequentially!

- Disk performance differs by a factor of 200 or 300 for random v.s. sequential accesses

- When possible, access disks sequentially

Mapping of logical sectors to physical

- Logical sector 0: the first sector of the first (outermost) track of the first surface
- Logical sector address incremented within track, then tracks within cylinder, then across cylinders, from outermost to innermost
- Track skew



Parallel Reading from Heads

- All heads should point to same place on track
  - Why not read from all heads in parallel?
- Need perfectly aligned heads
  - Hard to do in practice
  - Heads not perfectly aligned because of
    - Mechanical vibrations
    - Thermal gradients
    - Mechanical imperfections
  - High density makes problem worse
  - Needs high throughput read/write circuitry
- Consequence: most drives have a single active head at a time

Pros and cons of default mapping

- Pros
  - Simple to program
  - Default mapping reduces seek time for sequential access
- Cons
  - FS can't precisely see mapping
  - Reverse-engineer mapping in OS is difficult
    - # of sectors per track changes
    - Disk silently remaps bad sectors

Disk cache

- Internal memory (8MB-32MB) used as cache
- Read-ahead: "track buffer"
  - Read contents of entire track into memory during rotational delay
- Write caching with volatile memory
  - Write back or immediate reporting: claim written to disk when not
    - Faster, but data could be lost on power failure
  - Write through: ack after data written to platter

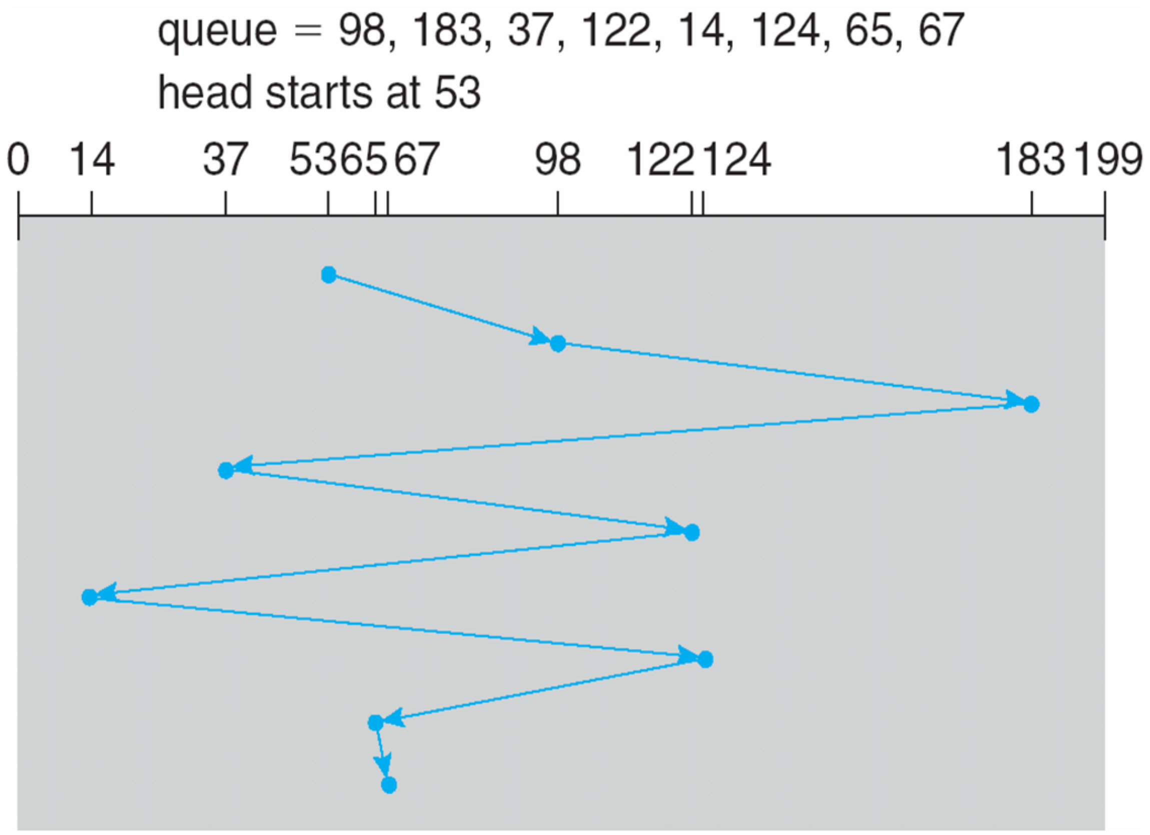
Disk scheduling

- Goal: minimize positioning time
  - Performed by both OS and disk itself
  - Why?
- OS can control:
  - Sequence of workload requests
- Disk knows:
  - Geometry, accurate positioning times

FCFS Disk Scheduling

Schedule requests in order received (FCFS)

- Advantage: fair
- Disadvantage: high seek cost and rotation



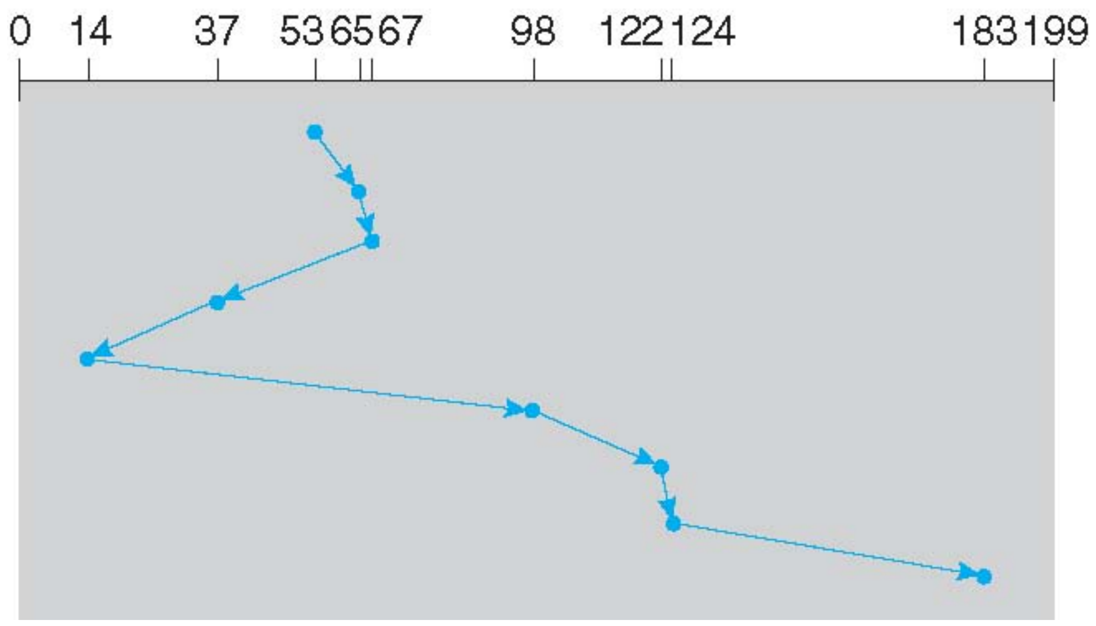
Total head movement of 640 cylinders

SSTF: Shortest Seek Time First

- Shortest seek time first (SSTF):
  - Form of Shortest Job First (SJF) scheduling
  - Handle nearest cylinder next
  - Advantage: reduces arm movement (seek time)
  - Disadvantage: unfair, can starve some requests

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

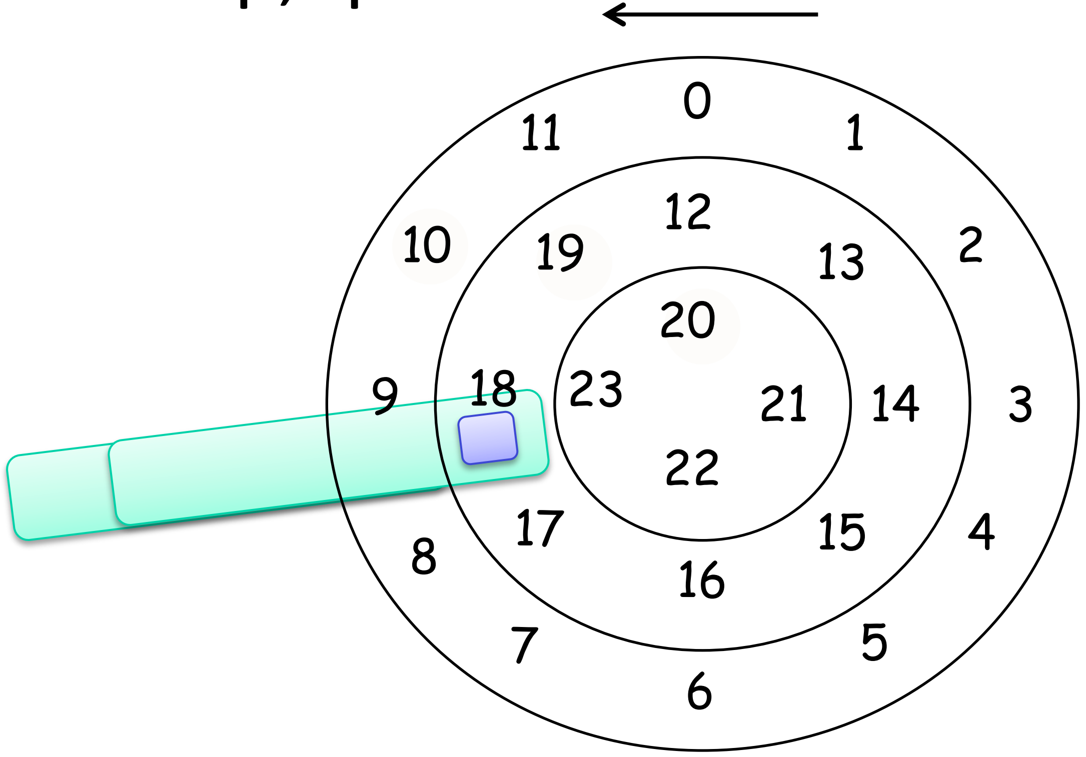
head starts at 53



Total head movement of 236 cylinders

Elevator (aka SCAN or C-SCAN)

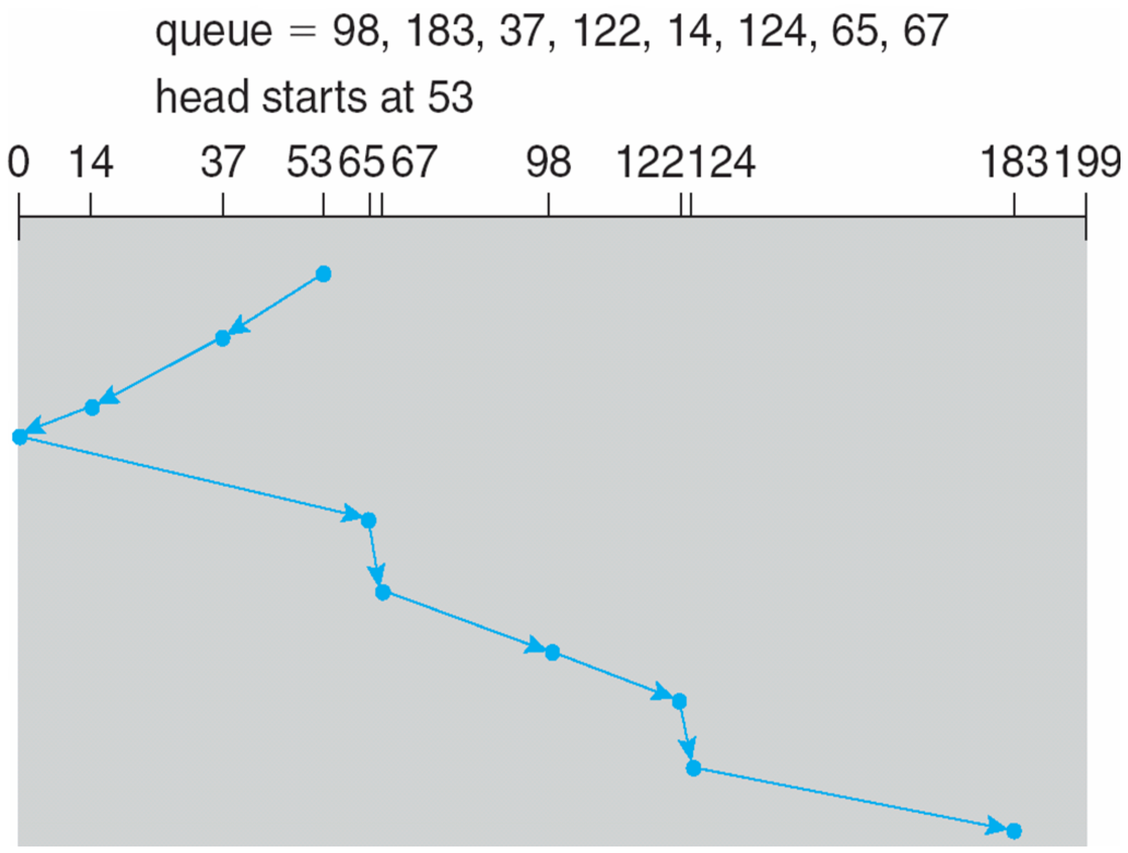
- Disk arm sweeps across disk
- If request comes for a block already serviced in this sweep, queue it for next sweep



SCAN (Elevator) Disk Scheduling

Make up and down passes across all cylinders

- Pros: efficient, simple
- Cons: Unfair. Oldest requests (furthest away) also wait longest.



Total head movement of 208 cylinders

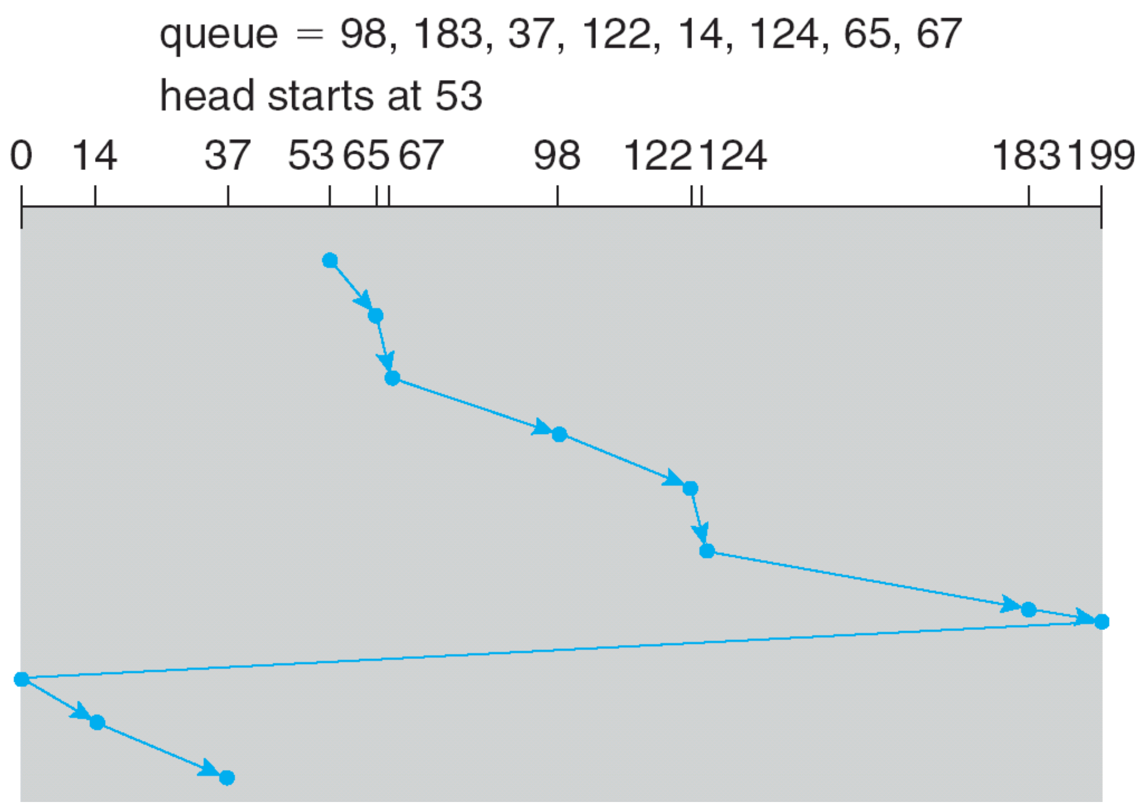
C-SCAN

- 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
- Total number of cylinders?

C-SCAN (Elevator) Scheduling

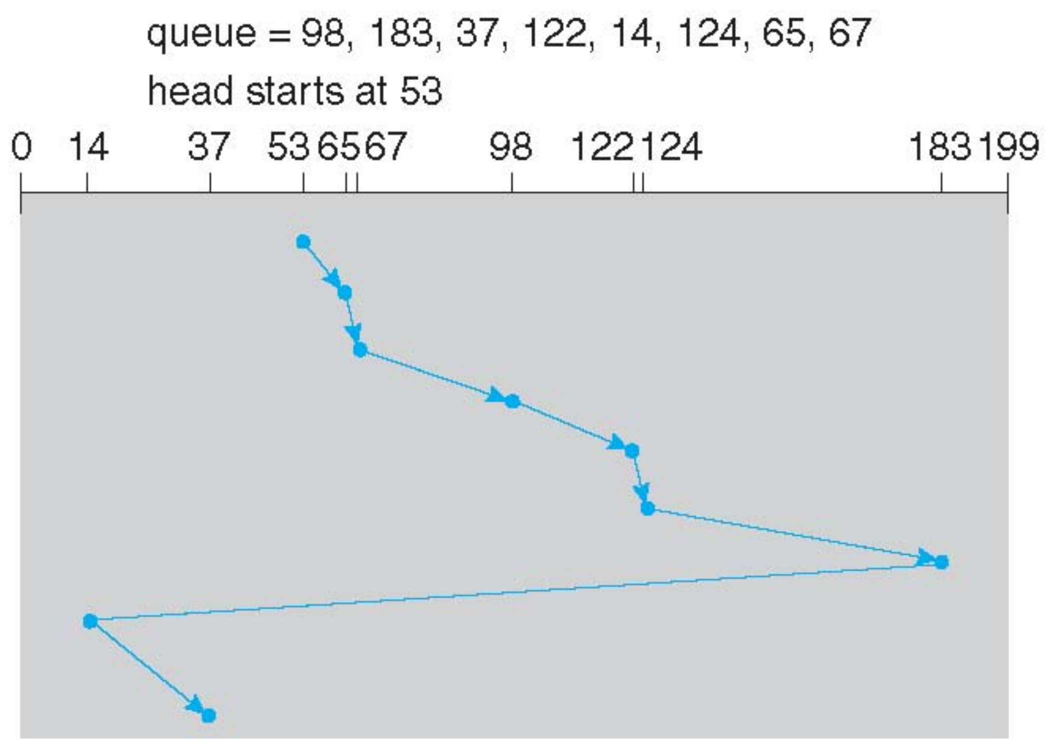
Head reads in one direction only

- Wrap around without reading when end is reached (like circular linked list)
- Provides a more uniform wait time than SCAN



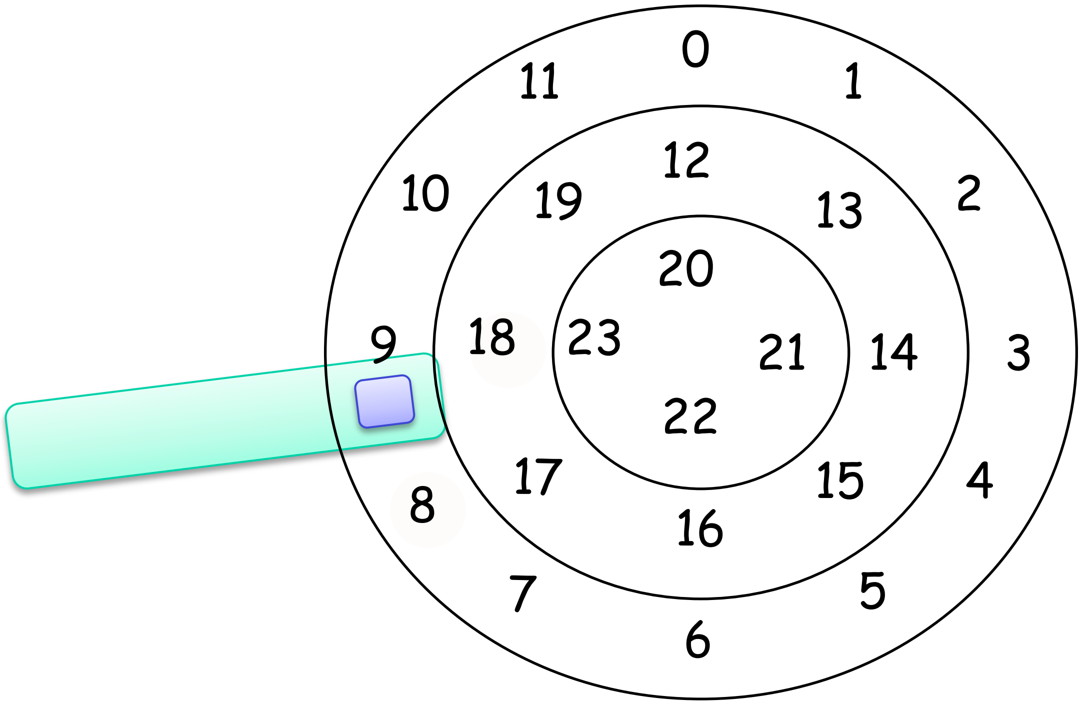
C-LOOK Scheduling

- In practice, don't need to scan to ends of disk
- Wrap around when no more requests
- Wrap to earliest outstanding request



Modern disk scheduling issues

- Elevator (or SSTF) ignores rotation!
- Shortest positioning time first (SPTF)
- OS + disk work together to implement



I/O Scheduling in Practice

- Simple: Linus Elevator scheduler
  - Default until 2.4
  - Variant of C-LOOK algorithm
  - Merge new request with existing where possible
  - Otherwise, insert in sorted order between existing requests
  - If no suitable location found, insert at queue tail
- In practice situation is more complicated due to
  - Interactions with filesystem (data layout)
  - Interactions with caches (write-back vs. write-through)
  - Write and read requests have different priority
  - Delay sensitive applications such as multimedia
  - Additional algorithms: Deadline, Completely Fair Queuing (CFQ)
- Will look in a bit more depth later

Disk technology trends

- Data → more dense
  - More bits per square inch
  - Disk head closer to surface
  - Create smaller disk with same capacity
- Disk geometry → smaller
  - Spin faster → Increase b/w, reduce rotational delay
  - Faster seek
  - Lighter weight
- Disk price → cheaper
- Density improving more than speed (mechanical limitations)

New mass storage technologies

- New memory-based mass storage technologies avoid seek time and rotational delay
  - No moving parts means more reliable, shock resistant
  - NAND Flash: ubiquitous in mobile devices
  - Battery-backed DRAM (NVRAM)
- Disadvantages
  - Price: more expensive than same capacity disk
  - Reliability: more likely to lose data
  - Other significant quirk: cant rewrite easily
- Open research question: how to effectively use flash in commercial storage systems
- Will look in more depth later