# Disk I/O Management

Chapter 5

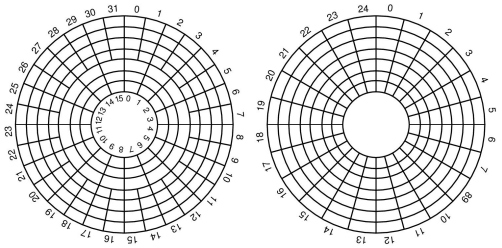


# Disk Management

- Management and ordering of disk access requests is important:
  - Huge speed gap between memory and disk
  - Disk throughput is extremely sensitive to
    - Request order ⇒ Disk Scheduling
    - Placement of data on the disk ⇒ file system design
  - Disk scheduler must be aware of *disk geometry*



# Disk Geometry



- Physical geometry of a disk with two zones
  - Outer tracks can store more sectors than inner without exceed max information density
- A possible virtual geometry for this disk



# Evolution of Disk Hardware

| Parameter | IBM 360-KB floppy disk | WD 18300 hard disk |
|---|---|---|
| Number of cylinders | 40 | 10601 |
| Tracks per cylinder | 2 | 12 |
| Sectors per track | 9 | 281 (avg) |
| Sectors per disk | 720 | 35742000 |
| Bytes per sector | 512 | 512 |
| Disk capacity | 360 KB | 18.3 GB |
| Seek time (adjacent cylinders) | 6 msec | 0.8 msec |
| Seek time (average case) | 77 msec | 6.9 msec |
| Rotation time | 200 msec | 8.33 msec |
| Motor stop/start time | 250 msec | 20 sec |
| Time to transfer 1 sector | 22 msec | 17 µsec |

Disk parameters for the original IBM PC floppy disk and a Western Digital WD 18300 hard disk

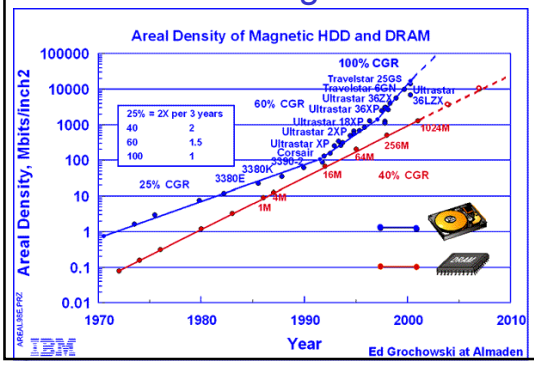


# Things to Note

- Average seek time is approx 12 times better
- Rotation time is 24 times faster
- Transfer time is 1300 times faster
  - Most of this gain is due to increase in density
- Represents a gradual engineering improvement



# Storage Capacity is 50000 times greater



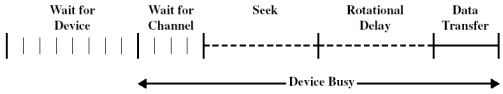
# IBM 3380 – First Gigabyte Disk

Circa.early 1981
Approx: $100,000



# Disk Performance

- Disk is a moving device ⇒ must be positioned correctly for I/O
- Execution of a disk operation involves
  - Wait time: the process waits to be granted device access
    - Wait for device: time the request spend in wait queue
    - Wait for channel: time until a shared I/O channel is available
  - Access time: time hardware need to position the head
    - Seek time: position the head at the desire track
    - Rotational delay (latency): spin disk to the desired sector
  - Transfer time: sectors to be read/written rotate below head




# Estimating Access Time

- *Seek time* $T_s$: Moving the head to the required track
  - not linear in the number of tracks to traverse:
    - ➜ startup time
    - ➜ settling time
  - Typical average seek time: a few milliseconds
- *Rotational delay:*
  - rotational speed, $r$, of 5,000 to 10,000rpm
  - At 10,000rpm, one revolution per 6ms ⇒ average delay 3ms
- *Transfer time:*
  to transfer $b$ bytes, with $N$ bytes per track: $T = \frac{b}{rN}$

Total average access time: $T_a = T_s + \frac{1}{2r} + \frac{b}{rN}$

# A Timing Comparison

- $T_s = 2$ ms, $r = 10,000$ rpm, 512B sect, 320 sect/track
- Read a file with 2560 sectors (= 1.3MB)
- File stored compactly (8 adjacent tracks):

| Read first track | |
|---|---|
| Average seek | 2ms |
| Rot. delay | 3ms |
| Read 320 sectors | 6ms |
| | 11ms |

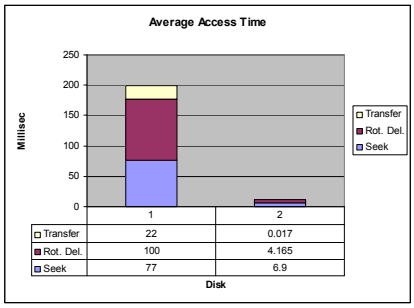
⇒ All sectors: $11 + 7 * 8 = 67\ ms$

- Sectors distributed randomly over the disk:

| Read any sector | |
|---|---|
| Average seek | 2ms |
| Rot. delay | 3ms |
| Read 1 sector | 0.01875ms |
| | 5.01875ms |

⇒ All: $2560 * 5.01875 = 20,328ms$

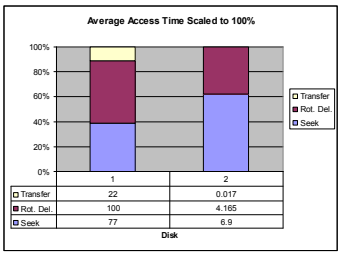
# Disk Comparative Performance






# Disk Performance is Entirely Dominated by Seek and Rotational Delays

- Will only get worse as capacity increases much faster than increase in seek time and rotation speed
  - Note it has been easier to spin the disk faster than improve seek time
- Operating System should minimise mechanical delays as much as possible



## Low-level Disk Formatting

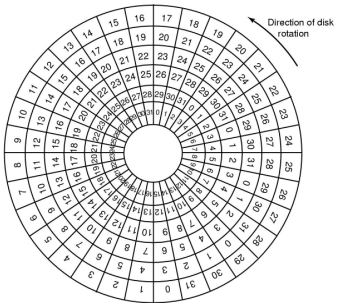
| Preamble | Data | ECC |
|---|---|---|

A disk sector



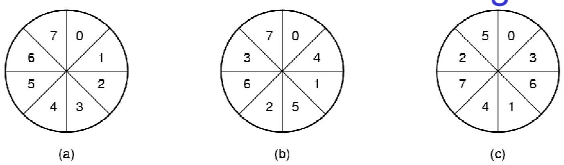
## Low-level Disk Formatting

- When reading sequential blocks, the seek time can result in missing block 0 in the next track
- Disk can be formatted using a cylinder *skew* to avoid this






## Low-Level Disk Formatting




- Issue: After reading one sector, the time it takes to transfer the data to the OS and receive the next request results in missing reading the next sector
- To overcome this, we can use interleaving
  a) No interleaving
  b) Single interleaving
  c) Double interleaving



## Low-Level Disk Formatting

- Modern drives can overcome interleaving type issues by simply reading the entire track (or part thereof) into the on-disk controller and caching it.



## Disk Arm Scheduling Algorithms

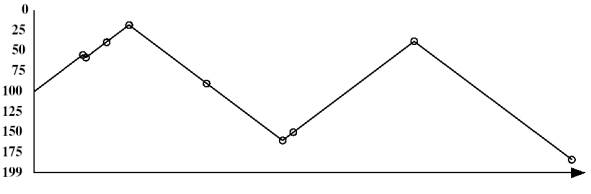
- Time required to read or write a disk block determined by 3 factors
  1. Seek time
  2. Rotational delay
  3. Actual transfer time
- Seek time dominates
- For a single disk, there will be a number of I/O requests
  - Processing them in random order leads to worst possible performance



## First-in, First-out (FIFO)

- Process requests as they come
- Fair (no starvation)
- Good for a few processes with clustered requests
- Deteriorates to random if there are many processes

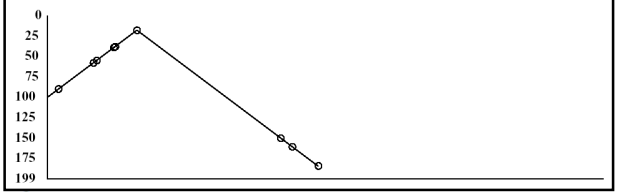
Request tracks: 55, 58, 39, 18, 90, 160, 150, 38, 184



## Shortest Seek Time First

- Select request that minimises the seek time
- Generally performs much better than FIFO
- May lead to starvation

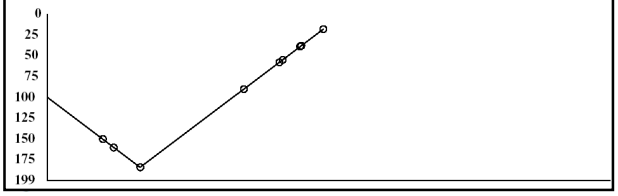
Request tracks: 55, 58, 39, 18, 90, 160, 150, 38, 184




## Elevator Algorithm (SCAN)

- **Move head in one direction**
  - Services requests in track order until it reaches the last track, then reverses direction
- **Better than FIFO, usually worse than SSTF**
- **Avoids starvation**
- **Makes poor use of sequential reads (on down-scan)**
- **Less Locality**

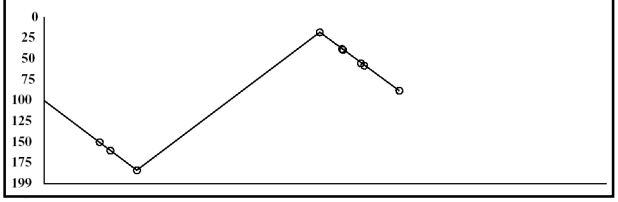
Request tracks: 55, 58, 39, 18, 90, 160, 150, 38, 184



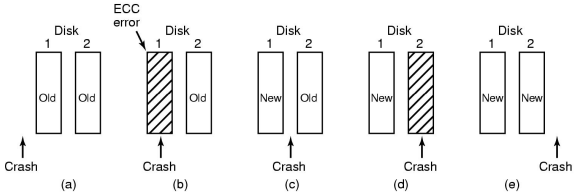

## Modified Elevator (Circular SCAN, C-SCAN)

- Like elevator, but reads sectors in only one direction
  - When reaching last track, go back to first track non-stop
- Better locality on sequential reads
- Better use of read ahead cache on controller
- Reduces max delay to read a particular sector

Request tracks: 55, 58, 39, 18, 90, 160, 150, 38, 184




## Implementing Stable Storage




- Use two disks to implement stable storage
  - Problem is when a write (update) corrupts old version, without completing write of new version
  - Solution: Write to one disk first, then write to second after completion of first