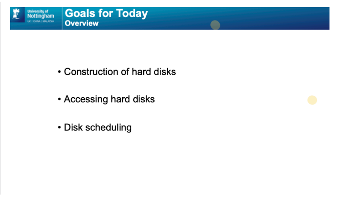
Disk management

2

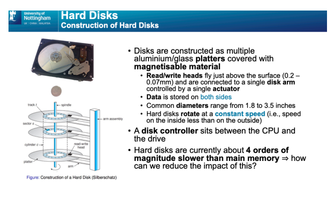


Goals for Today
Overview

- Construction of hard disks
- Accessing hard disks
- Disk scheduling

Construction of Hard Disks

3



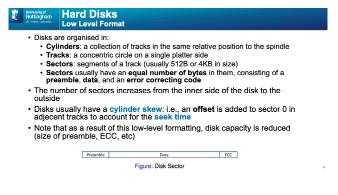
Hard Disks
Construction of Hard Disks

- Disks are constructed as multiple aluminium/glass **platters** covered with **magnetisable material**
  - **Read/write heads** fly just above the surface (0.2 – 0.07mm) and are connected to a single **disk arm** controlled by a single **actuator**
  - **Data** is stored on both sides
  - Common **diameters** range from 1.8 to 3.5 inches
  - Hard disks **rotate** at a **constant speed** (i.e., speed on the inside less than on the outside)
- A **disk controller** sits between the CPU and the drive
- Hard disks are currently about **4 orders of magnitude slower than main memory** ⇒ how can we reduce the impact of this?

Figure: Construction of a Hard Disk (Silberschatz)

Hard Disks: low level format

4



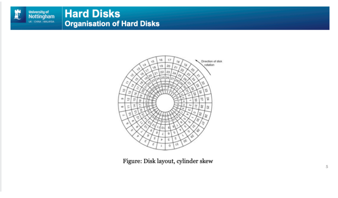
Hard Disks
Low Level Format

- Disks are organised in:
  - **Cylinders**: a collection of tracks in the same relative position to the spindle
  - **Tracks**: a concentric circle on a single platter side
  - **Sectors**: segments of a track (usually 512B or 4KB in size)
  - **Sectors** usually have an **equal number of bytes** in them, consisting of a **preamble**, **data**, and an **error correcting code**
- The number of sectors increases from the inner side of the disk to the outside
- Disks usually have a **cylinder skew**: i.e., an **offset** is added to sector 0 in adjacent tracks to account for the **seek time**
- Note that as a result of this low-level formatting, disk capacity is reduced (size of preamble, ECC, etc)

Figure: Disk Sector

Cylinder skew

5

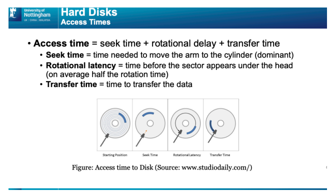


Hard Disks
Organisation of Hard Disks

Figure: Disk layout, cylinder skew

Accessing Hard Disks

6



Hard Disks
Access Times

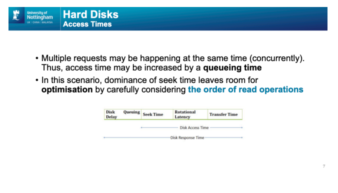
- **Access time** = seek time + rotational delay + transfer time
  - **Seek time** = time needed to move the arm to the cylinder (dominant)
  - **Rotational latency** = time before the sector appears under the head (on average half the rotation time)
  - **Transfer time** = time to transfer the data

Starting Position
Seek Time
Rotational Latency
Transfer Time

Figure: Access time to Disk (Source: www.studiodaily.com/)

Access time: room for management/optimization

7



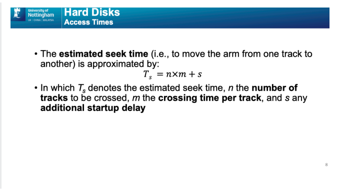
Hard Disks
Access Times

- Multiple requests may be happening at the same time (concurrently). Thus, access time may be increased by a **queueing time**
- In this scenario, dominance of seek time leaves room for **optimisation** by carefully considering **the order of read operations**

Disk Delay
Queuing
Seek Time
Rotational Latency
Transfer Time
Disk Access Time
Disk Response Time

Access time: Seek time

8



Hard Disks
Access Times

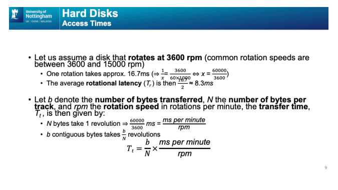
- The **estimated seek time** (i.e., to move the arm from one track to another) is approximated by:

$$T_s = n \times m + s$$

- In which T_s denotes the estimated seek time, n the **number of tracks** to be crossed, m the **crossing time per track**, and s any **additional startup delay**

Access time: Rotational latency and transfer time calculation

9



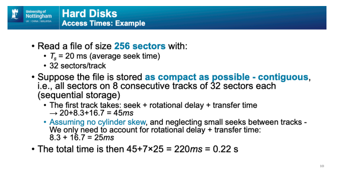
Hard Disks
Access Times

- Let us assume a disk that **rotates at 3600 rpm** (common rotation speeds are between 3600 and 15000 rpm)
  - One rotation takes approx. 16.7ms ($\Rightarrow \frac{1}{x} = \frac{3600}{60 \times 1000} \Leftrightarrow x = \frac{60000}{3600}$)
  - The average **rotational latency** (T_r) is then $\frac{16.7}{2} \approx 8.3ms$
- Let b denote the **number of bytes transferred**, N the **number of bytes per track**, and rpm the **rotation speed** in rotations per minute, the **transfer time**, T_t, is then given by:
  - N bytes take 1 revolution $\Rightarrow \frac{60000}{3600} ms = \frac{ms\ per\ minute}{rpm}$
  - b contiguous bytes takes $\frac{b}{N}$ revolutions

$$T_t = \frac{b}{N} \times \frac{ms\ per\ minute}{rpm}$$

Example: contiguous sectors store

10

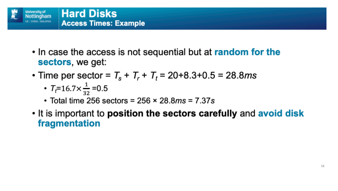


Hard Disks
Access Times: Example

- Read a file of size **256 sectors** with:
  - T_s = 20 ms (average seek time)
  - 32 sectors/track
- Suppose the file is stored **as compact as possible - contiguous**, i.e., all sectors on 8 consecutive tracks of 32 sectors each (sequential storage)
  - The first track takes: seek + rotational delay + transfer time → 20+8.3+16.7 = 45*ms*
  - Assuming no cylinder skew, and neglecting small seeks between tracks - We only need to account for rotational delay + transfer time: 8.3 + 16.7 = 25*ms*
- The total time is then 45+7×25 = 220*ms* = 0.22 s

Example: random sector store

11

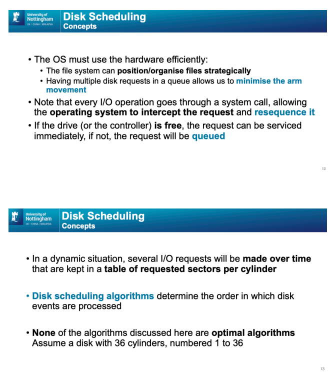


Hard Disks
Access Times: Example

- In case the access is not sequential but at **random for the sectors**, we get:
- Time per sector = $T_s + T_r + T_t$ = 20+8.3+0.5 = 28.8*ms*
  - T_t=16.7×$\frac{1}{32}$ =0.5
  - Total time 256 sectors = 256 × 28.8*ms* = 7.37*s*
- It is important to **position the sectors carefully** and **avoid disk fragmentation**

Disk Scheduling: concept

12



Disk Scheduling
Concepts

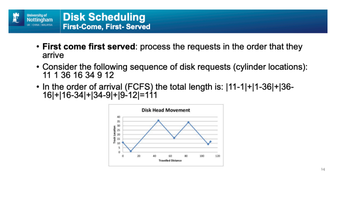
- The OS must use the hardware efficiently:
  - The file system can **position/organise files strategically**
  - Having multiple disk requests in a queue allows us to **minimise the arm movement**
- Note that every I/O operation goes through a system call, allowing the **operating system to intercept the request** and **resequence it**
- If the drive (or the controller) **is free**, the request can be serviced immediately, if not, the request will be **queued**

Disk Scheduling
Concepts

- In a dynamic situation, several I/O requests will be **made over time** that are kept in a **table of requested sectors per cylinder**
- **Disk scheduling algorithms** determine the order in which disk events are processed
- **None** of the algorithms discussed here are **optimal algorithms** Assume a disk with 36 cylinders, numbered 1 to 36

First Come First Served

14



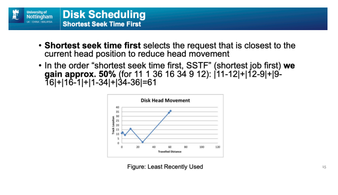
Disk Scheduling
First-Come, First- Served

- **First come first served**: process the requests in the order that they arrive
- Consider the following sequence of disk requests (cylinder locations): 11 1 36 16 34 9 12
- In the order of arrival (FCFS) the total length is: |11-1|+|1-36|+|36-16|+|16-34|+|34-9|+|9-12|=111

Disk Head Movement
Track Location
Travelled Distance
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100
120

Shortest Seek Time First

15



Disk Scheduling
Shortest Seek Time First

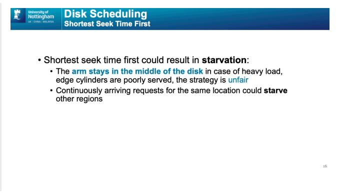
- **Shortest seek time first** selects the request that is closest to the current head position to reduce head movement
- In the order “shortest seek time first, SSTF” (shortest job first) **we gain approx. 50%** (for 11 1 36 16 34 9 12): |11-12|+|12-9|+|9-16|+|16-1|+|1-34|+|34-36|=61

Disk Head Movement
Track Location
Travelled Distance
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100
120

Figure: Least Recently Used

Shortest Seek Time First evluation

16

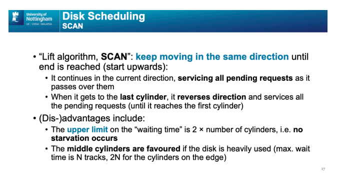


Disk Scheduling
Shortest Seek Time First

- Shortest seek time first could result in **starvation**:
  - The **arm stays in the middle of the disk** in case of heavy load, edge cylinders are poorly served, the strategy is unfair
  - Continuously arriving requests for the same location could **starve** other regions

SCAN (lift algorithm)

17

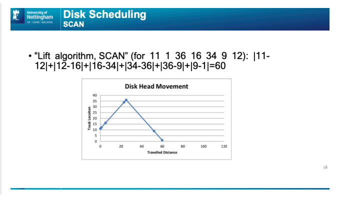


Disk Scheduling
SCAN

- “Lift algorithm, **SCAN**”: **keep moving in the same direction** until end is reached (start upwards):
  - It continues in the current direction, **servicing all pending requests** as it passes over them
  - When it gets to the **last cylinder**, it **reverses direction** and services all the pending requests (until it reaches the first cylinder)
- (Dis-)advantages include:
  - The **upper limit** on the “waiting time” is 2 × number of cylinders, i.e. **no starvation occurs**
  - The **middle cylinders are favoured** if the disk is heavily used (max. wait time is N tracks, 2N for the cylinders on the edge)

example

18



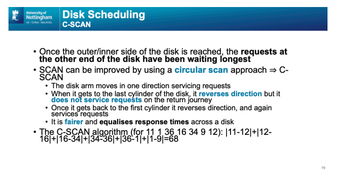
Disk Scheduling
SCAN

- “Lift algorithm, SCAN” (for 11 1 36 16 34 9 12): |11-12|+|12-16|+|16-34|+|34-36|+|36-9|+|9-1|=60

Disk Head Movement
Track Locaiton
Travelled Distance
0
5
10
15
20
25
30
35
40
0
20
40
60
80
100
120

C-SCAN

19

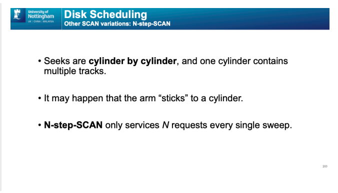


Disk Scheduling
C-SCAN

- Once the outer/inner side of the disk is reached, the **requests at the other end of the disk have been waiting longest**
- SCAN can be improved by using a **circular scan** approach ⇒ C-SCAN
  - The disk arm moves in one direction servicing requests
  - When it gets to the last cylinder of the disk, it **reverses direction** but it **does not service requests** on the return journey
  - Once it gets back to the first cylinder it reverses direction, and again services requests
  - It is **fairer** and **equalises response times** across a disk
- The C-SCAN algorithm (for 11 1 36 16 34 9 12): |11-12|+|12-16|+|16-34|+|34-36|+|36-1|+|1-9|=68

N-step-SCAN

20

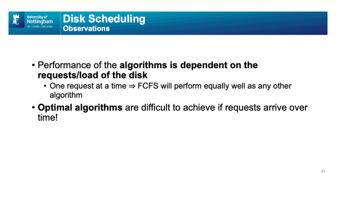


Disk Scheduling
Other SCAN variations: N-step-SCAN

- Seeks are **cylinder by cylinder**, and one cylinder contains multiple tracks.
- It may happen that the arm “sticks” to a cylinder.
- **N-step-SCAN** only services *N* requests every single sweep.

Performance dependent on request

21

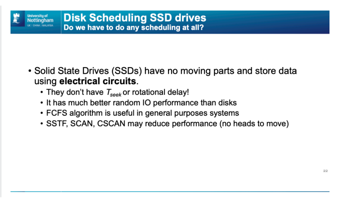


Disk Scheduling
Observations

- Performance of the **algorithms is dependent on the requests/load of the disk**
  - One request at a time ⇒ FCFS will perform equally well as any other algorithm
- **Optimal algorithms** are difficult to achieve if requests arrive over time!

SSD doesn’t need scheduling

22



Disk Scheduling SSD drives
Do we have to do any scheduling at all?

- Solid State Drives (SSDs) have no moving parts and store data using **electrical circuits**.
  - They don’t have T_{seek} or rotational delay!
  - It has much better random IO performance than disks
  - FCFS algorithm is useful in general purposes systems
  - SSTF, SCAN, CSCAN may reduce performance (no heads to move)