CS5600 Spring
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Week_10 Block Storage device:
Assignment: Estimate Storage Reliability and Performance!

**Question 1:** A disk rotates at 7200 RPM and can transfer 150 MB/s of data from its outer track. What is the maximum number of bytes of data that a single outer track can hold?

**We have the following data:**

- **Disk Rotation Speed:** 7200 RPM (Revolutions Per Minute)
- **Data Transfer Rate:** 150 MB/s (Megabytes per second)
- **1 MB = 10^6 bytes (1,000,000 bytes, assuming decimal MB)**
- **1 minute = 60 seconds**

**Assumptions are the following:**

- The disk transfers data **continuously** while reading a full revolution of the outer track.
- We use **decimal MB** (1 MB = 1,000,000 bytes).
- **1 minute = 60 seconds**

- **Step 1: First we Convert RPM (Revolutions Per Minute) to RPS (Revolutions Per Second)**
  - The disk rotates at 7200 RPM, so we convert it to RPS:
    - Calculation → Revolutions per second = 7200 RPM / 60 = 120 RPS

**Answer: The disk completes 120 revolutions per second**.

- **Step 2: Then we Find the Time for One Revolution**
  - Since the disk completes **120 revolutions per second**, the time taken for **one** full revolution is:
    - Calculation → Time per revolution = 1 / 120 seconds = 0.00833 s

**Answer: 0.00833 seconds per revolution.**

- **Step 3: Finally we Compute Maximum Bytes per Track**

Since the disk can transfer data at **150 MB/s**, to find how much data can be transferred in one full revolution, we multiply the transfer rate by the time per revolution

Calculation → Data per revolution = Transfer rate × Time per revolution = 150,000,000 bytes/sec × 0.00833 sec = 1,250,000 bytes

**Conclusion: The maximum number of bytes of data that a single outer track can hold is 1.25 MB (1,250,000 bytes).**

**Question 2:** Given an average seek time of 5ms, a rotational speed of 10,000 RPM, and a transfer rate of 200 MB/s, how long does a 65536-byte random read request take, in milliseconds, on average? What if the average seek time is 12ms and the rotational speed is 5400 RPM?

We need to determine the **average time** it takes to complete a **65536-byte (64 KB) random read request** under two different sets of conditions by considering:

- **Seek time** (time taken for the read/write head to reach the correct track)
- **Rotational latency** (time taken for the sector to rotate into position)
- **Transfer time** (time taken to actually read the requested data)

**We have the following given data:**

**Case 1:**

- **Average Seek Time:** 5 ms
- **Rotational Speed:** 10,000 RPM
- **Data Transfer Rate:** 200 MB/s
- **Requested Data Size:** 65536 bytes (64 KB)

**Case 2:**

- **Average Seek Time:** 12 ms
- **Rotational Speed:** 5,400 RPM
- **Data Transfer Rate:** 200 MB/s
- **Requested Data Size:** 65536 bytes (64 KB)

**Assumptions are the following:**

1. The **seek time** refers to the **average** seek time taken to position the read/write head.
2. The **rotational latency** is assumed to be **half** the time for a full revolution since, on average, the disk must wait for half a rotation to access the requested sector.
3. The **transfer time** is based on a **continuous transfer rate**.
4. **1 MB = 1,000,000 bytes**.
5. **1 minute = 60 seconds** for time conversions.

## ➢ Step 1: Let's Compute Rotational Latency:

- The **rotational latency** is the time, it takes for the disk to rotate halfway on average before the desired sector reaches the read head.

**Calculation →** Rotational Latency = 1 / 2 × Time per full revolution

**Case 1:** 10,000 RPM

Time per full revolution = 60 seconds / 10,000 RPM = 0.006 seconds = 6 ms

- [ ] **Rotational Latency 6 / 2 = 3 ms**

**Case 2:** 5,400 RPM

Time per full revolution = 60 seconds / 5,400 RPM = 0.0111 = seconds=11.11 ms

- [ ] **Rotational Latency = 11.11 / 2 = 5.56 ms**

### ➢ Step 2: Then we Compute Transfer Time

- The **transfer time** is the time required to read **65536 bytes (64 KB)** from the disk at the given transfer rate.

Transfer Time = Requested Data Size / Transfer Rate = 65,536 bytes / 200,000,000 bytes/sec
0.00032768 seconds = 0.33 ms

### ➢ Step 3: Finally We Compute Total Read Time

The total time for a **random read request** is the sum of:

- **Seek Time**
- **Rotational Latency**
- **Transfer Time**

Total Read Time = Seek Time + Rotational Latency + Transfer Time

### Case 1: (5 ms Seek, 10,000 RPM)

Total Read Time = 5 + 3 + 0.33 = 8.33 ms

### Case 2: (12 ms Seek, 5,400 RPM)

Total Read Time = 12 + 5.56 + 0.33 = 17.89

**Final Answers:**

| Case | Seek Time (ms) | Rotational Speed (RPM) | Rotational Latency (ms) | Transfer Time (ms) | Total Read Time (ms) |
|---|---|---|---|---|---|
| **1** | 5 ms | 10,000 RPM | 3 ms | 0.33 ms | **8.33 ms** |
| **2** | 12 ms | 5,400 RPM | 5.56 ms | 0.33 ms | **17.89 ms** |

**Conclusion:**

When the disk **spins faster**, the time it takes for the right section of data to come around is **shorter**, leading to **faster read times**. Now, if the **seek time increases** which is the time it takes for the read/write head to move to the right track, that **delay adds up significantly**, especially for **random reads**, where the head is constantly moving to different locations. However, once the head **reaches the correct position**, the actual **data transfer happens extremely fast**. This means that when analyzing **total read time**, **seek time and rotational latency have a much bigger impact than the data transfer rate**.

## Question 3: If a system has an estimated mean time between failures of 20,000 days, what is its expected annual reliability expressed as a probability?

**Based on formula : The reliability is $R(t) = e^{-t/mtbf}$**

### Given Data:

- **MTBF (Mean Time Between Failures):** 20,000 days
- **Time period (t):** 1 year = **365 days**

**$R(365) = e^{-365/20000}$**

$= e^{-0.01825}$

$\approx 0.9819$

**Final Answer:** The expected **annual reliability** of the system is **0.9819** or **98.19%**. This means that after **one year**, there is a **98.19% probability** that the system will still be functioning without failure.

## Question 4: A power control system is required to have an availability of at least 99.995% in accordance with regulations. The systems development team has conducted empirical testing and derived an mean time to restore of 1.5 hours and an mean time between failure of 3.1667 years. Will the system meet the expected availability?

We have the following given data:

- **Mean Time to Restore (MTTR) = 1.5 hours**
- **Mean Time Between Failures (MTBF) = 3.1667 years**

**Availability (A) is calculated based on the below formula:**

Formula

$$A = \frac{MTBF}{MTBF + MTTR}$$

$A$ = availability
$MTBF$ = mean time between failure
$MTTR$ = mean time to repair

## ➢ Step 1: Let's Convert MTBF to Hours

Since **1 year = 8766 hours**, we convert MTBF:

MTBF = 3.1667 × 8766 = 27,774 hours

## ➢ Step 2: Then we Apply the Formula

A = 27,774 / 27,774 + 1.5 = 27,774 / 27,775.5 ≈ 0.999946

## ➢ Step 3: Then we Convert to Percentage

A × 100 = 99.9946%

**Conclusion:**

**The required Availability is** 99.995%, and we arrived at the **Calculated Availability of** 99.9946%. Since **99.9946% < 99.995%**, the system **does not meet** the required availability. The system falls slightly short of the **99.995% availability requirement** by **0.0004%**.