CSE 321b: Computer Organization (II)
Third Year, Computer & Systems Engineering

Solution to Assignment #2

1. A hard disk drive has 10 surfaces, 10240 tracks per surface, …

(a) What is the total capacity of hard disk drive (in GB)?

Total capacity = (10 surf.) * (10240 tr./surf.) * (512 sect./tr.) * (4*1024 B/sect.)
= 214748364800 B = 200 GB

(b) What is the physical address of the sector whose logical block address (LBA) is 2312349?

HPC = 10 and SPT = 512
C = LBA $\div_{\text{int}}$ (SPT * HPC) = 2312349 $\div_{\text{int}}$ (512 *10) = 451
H = (LBA $\div_{\text{int}}$ SPT) mod HPC = (2312349 $\div_{\text{int}}$ 512) mod 10 = 6
S = (LBA mod SPT) + 1 = (2312349 mod 512) + 1 = 158
The physical address = (451, 6, 158)

(c) What is the longest time needed to read any sector anywhere on the disk?

Longest time to read sector
= max. seek time + (max. rot. delay + transfer time of one sector)
= time to seek over all tracks + time of one revolution
= (10240 tr.) / (1280 tr./ms) + (60*1000 ms/min) / (5400 rev/min)
= 19.11 ms

2. Suppose each layer of the DVD can store 3.5 GB of data.

(a) What is the maximum amount of data that can be stored on the DVD (in GB)?

Maximum amount stored on a DVD = (2 sides) * (2 layers/side) * (3.5 GB/layer) = 14 GB

(b) Suppose the DVD is used to store a video with 30 frames/s …:

i. What is the maximum number of minutes that can be stored on the DVD?

Data required to encode one minute of video
= (60 s) * (30 frames/s) * (720*480 pixels/frame) * (24 bit/pixel)
= 14,929,920,000 b
= 1.738 GB
Maximum number of minutes stored on a DVD = (14 GB) / (1.738 GB/min) = 8.06 min

ii. What is the compression ratio required to fit a 133-minute movie in 1 layer of the DVD?

Data required to encode a 133-minute movie = 133 min * (1.738 GB/min) = 231.164 GB
Compression ratio = 1 : ((231.164 GB)/(3.5GB)) ≈ 1 : 66

3. A RAID level 2 array is built using 7 disk drives. Each drive can store 4 TB.

(a) What is the overall data storage capacity of this array (in TB)?

Suppose m disks store data and k disks store Hamming code
Knowing that: $m + k = 7$ and $m + k + 1 \leq 2^k$
Then: k=3 and m=4
The overall data storage capacity = (4 disks) * (4 TB/disk) = 16 TB

(b) Suppose disks #3, #5 and #7 in the array fail. Show how their data can be restored.

For any arbitrary stripe value "$D_7D_6D_5C_4D_3C_2C_1$", we know that:
$C_1 = D_3 \oplus D_5 \oplus D_7$ -- (1)
$C_2 = D_3 \oplus D_6 \oplus D_7$ -- (2)
$C_4 = D_5 \oplus D_6 \oplus D_7$ -- (3)
So, if D_3, D_5 and D_7 are unknown, we can calculate their values by solving equations (1), (2) and (3) together as follows:

- From equations (1) and (2), we can calculate D_5 as follows: $D_5 = C_1 \oplus C_2 \oplus D_6$
- Then from equation (3), we can calculate D_7 as follows: $D_7 = C_4 \oplus D_5 \oplus D_6$
- Then from equation (1), we can calculate D_3 as follows: $D_3 = C_1 \oplus D_5 \oplus D_7$

So, for example if the stripe value = "?1?0?01":

- $D_5 = 1 \oplus 0 \oplus 1 = 0$
- $D_7 = 0 \oplus 0 \oplus 1 = 1$
- $D_3 = 1 \oplus 0 \oplus 1 = 0$

4. An I/O device transfers 2500 independent data blocks each second over a system bus, … What fraction of the processor's time is spent handling the data transfer with and without DMA?

- Without DMA:
  Processor is busy during the whole transfer window
  Processor time spent in transfer each second =
  (2500 block) * (4000 B/block) / ($100*10^6$ B/s) = 0.1 s
  Fraction of processor time spent in transfer = (0.1 s) / (1 s) = 0.1
- With DMA:
  For each block, processor initiates DMA and handles interrupt when transfer completes.
  Processor time spent in transfer each second =
  (2500 block) * (2500 cycle/block) / ($200*10^6$ cycle/s) = 0.03125 s
  Fraction of processor time spent in transfer = (0.03125 s) / (1 s) = 0.03125

5. A given CPU requires 1000 cycles to perform a context switch and start interrupt handler …
(a) How many cycles per second does CPU spend in I/O with the device if interrupts are used?

Number of CPU cycles spend in I/O each second (with interrupts)
= number of requests per second * number of cycles per request
= (150 request/s) * (1000 + 10000 + 1000 cycles/request) = 1800000 cycles/s

(b) How many cycles per second are spent on I/O if polling is used?

Number of polls per second = (1 s) / ($0.5*10^{-3}$ s) = 2000 poll/s
In each of the 2000 polls, CPU spends 500 cycle to poll the device.
In 150 of the 2000 polls, CPU spends and additional 10000 cycles to handle I/O.

Number of CPU cycles spend in I/O each second (with polling)

= (number of polls per second * number of polling cycles per poll) +
(number of requests per second * number of handling cycles per request)

= ((2000 polls/s) * (500 cycle/poll)) + ((150 request/s) * (10000 cycle/request))

= 2500000 cycles/s

(c) How often would CPU have to poll for polling to take as many cycles per sec. as interrupts?

Suppose the number of polls per second = x

We need to solve the following equation for x:

((x polls/s) * (500 cycle/poll)) + ((150 request/s) * (10000 cycle/request)) = 1800000 cycles/s

Number of polls per second = x = 600 polls/s

Time between polls = 1/x = 1.667 ms