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

Solution to Assignment #2

1. Consider a 256 GB hard disk drive with the following parameters: 6.5 ms average seek time, ...
   (a) What is the spindle speed (in r.p.m)?

   Average rotational delay = 1 / (2 * spindle speed)
   2.5 ms = 1 / (2 * r)
   Spindle speed = r = 1 / (2 * (2.5 * 10^{-3}) s) = 200 r.p.s = 200 * 60 r.p.m = 12000 r.p.m

   (b) What is the number of sectors per track?

   Maximum data rate = tracks per second * track capacity
   100 MB/s = (200 track/s) * SPT * (2048 B/sector)
   Number of sectors per track = SPT = (100 * 2^{20} B/s) / ((200 track/s) * (2048 B/sector)) = 256

   (c) What is the number of heads per cylinder?

   Disk capacity = number of surfaces * tracks per surface * sectors per track * bytes per sector
   256 GB = HPC * (65536 tr./surf.) * (256 sect./tr.) * (2048 B/sect.)
   Number of heads per cylinder = HPC = (256 * 2^{30} B) / (65536 * 256 * 2048 B/surf.)) = 8

   (d) Estimate the average percentage of the total time occupied by seek operations and rotational delays.

   Average transfer time = average file size / (track capacity * spindle speed)
   = (0.1 * 2^{20} B) / ((256 sect./tr.) * (2048 B/sect.) * (200 tr./s)) = 1 ms
   Average % of sk. & rot. times = (sk. time + rot. time) / (sk. time + rot. time + tr. time) * 100%
   = (6.5 ms + 2.5 ms) / (6.5 ms + 2.5 ms + 1 ms) * 100% = 90%

2. A CD-ROM drive operates at a constant linear velocity of 1.2 m/s and a constant data rate of 150 KB/s.
   (a) What is the linear data density of the CD-ROM disk (in B/mm)?

   Linear data density = data transfer rate / linear velocity
   = (150*2^{10} B/s) / (1.2*10^{3} mm/s) = 128 B/mm

   (b) What is the storage capacity of the CD-ROM disk (in MB)?

   CD-ROM disk capacity = linear data density * track length
   = (128 * 2^{-20} / 10^{-6} MB/Km) * (5.38 Km) = 556.74 MB

3. A RAID array is to be built using 12 disk drives. The storage capacity of each drive is 2 TB.
   (a) Block-level stripping with distributed parity.
   RAID level: 5
   Number of data drives = 12 – 1 = 11
   Total data capacity = 11 * (2 TB) = 22 TB

   (b) Bit-level stripping with Hamming error correction codes (ECC).

   RAID level: 2

Number of ECC drives = k (where $12+k \leq 2^k \Rightarrow k = 4$)
Number of data drives = $12 - k = 8$
Total data capacity = 8 * (2 TB) = 16 TB

(c) Mirroring without stripping or parity.

RAID level: 1
Number of data drives = 12 / 2 = 6
Total data capacity = 6 * (2 TB) = 12 TB

4. A computer collects characters from n input devices while executing a program called PROG.
(a) Express the maximum value of n as a function of t.

n is maximum when all the time is spent in polling!
CPU keeps executing POLL over and over 100% of the time!
$t = 0.2 + 0.1 * n_{max}$
$n_{max} = 10 * t - 2$

(b) Express the maximum value of r as a function of t.

r is maximum when each device produces one character every polling round!
r_{max} = (1 char) / (t ms) = 1000 / t char/s

(c) Express the percentage of time spent in servicing the devices as a function of n and t.

$\%T_{serv}$ = (time to poll n devices) / (time between pooling rounds) * 100%
$= (0.2 + 0.1 * n) / t * 100\% = (20 + 10 * n) / t\ \%$

(d) Which conditions need to be satisfied in order to prevent any loss of characters …?

$n = 8$ and $\%T_{serv} \leq 10\%$
$(20 + 10 * 8) / t \leq 10$
$t \geq 10$ ms
r_{max} = 1000 / t char/s
Conditions: $t \geq 10$ ms and $r \leq 1000 / t$ char/s

5. Consider a system in which each bus cycle takes 200 ns. Transfer of bus control in either direction, from processor to I/O device or vice-versa, takes 75 ns. One of the I/O devices has a data transfer rate of 250 KB/s and employs DMA. Data are transferred one byte at a time.
(a) Suppose the DMA is employed in a burst mode. That is, the DMA controller gains bus mastership prior to the start of a block transfer and maintains control of the bus until the whole block is transferred. For how long would the DMA controller gain mastership of the bus in order to transfer a block of 1 KB?

DMA time = time to gain bus + time to transfer block + time to release bus
= 75 ns + (1 KB) / (250 KB/s) + 75 ns = 4000.15 µs

(b) Repeat the calculation (from part (a)) for cycle-stealing mode.

DMA time = (time to gain bus + time to transfer byte + time to release bus) * block size
= (75 ns + 200 ns + 75 ns) * 1024 = 358.4 µs