Computer Science 605.411

Module 11 Example Set 1

1. a) On average what fraction of a rotation must a disk make to get to the beginning of a random sector on a track?
On average it takes ½ revolution to get to the beginning of a random sector on a track.

b) If a disk rotates 500 RPM (revolutions per minute), how long on average is the rotational delay to get to the start of a random sector?

The rotation rate of 500 RPM = 500/60 = 8.333 revolutions per second
So one revolution takes 60/500 = 1/8.333 = 0.12 seconds
The rotational delay = 0.5 * 0.12 seconds = 0.06 seconds

2. Give a concise answer to each of the following questions.
a) What is memory mapped I/O?
This is an I/O scheme in which portions of the address space are assigned to I/O devices so that the I/O device registers (data and control) can be accessed using the normal memory load and store instructions.

b) Why is DMA an improvement over direct programmed controlled I/O?
DMA is a mechanism that provides a device controller the ability to transfer data directly to or from the memory without involving the processor. This allows the CPU to perform arithmetic and other instructions while the DMA is going on in parallel.

c) When would DMA be a poor choice for I/O?
DMA is not useful when the amount of data that needs to be transferred between memory and the I/O device is relatively small (as for a mouse or keyboard). This is because the overhead of setting up the DMA transfer could actually take longer than the actual transfer. So DMA is used for block tranfers.

d) How can DMA cause the CPU to potentially use stale memory data?
Since DMA transfers go directly to memory, they bypass the CPU as well as the cache. This makes it possible for the contents of cache to become inconsistent with the content of memory.

3. Suppose we have a magnetic disk drive with the following parameters:

Average seek time	12 ms
Rotation rate	3600 RPM
Transfer rate	3.5 MB/second
# sectors per track	64
Sector size	512 bytes
Controller overhead	5.5 ms

a) What is the average time to read a single sector?
Disk access time = seek time + rotational delay + transfer time + controller overhead
= 12 + (0.5* 60/3600)*1000 + (512/(3.5*2^{20}))*1000 + 5.5 = 25.97 ms

b) What is the average time to read 16 consecutive sectors in the same track?
The seek time and rotational delay would be the same; the transfer time would correspond to 16*512 = 8192 bytes of data.
Disk access time = seek time + rotational delay + transfer time + controller overhead
= 12 + (0.5* 60/3600)*1000 + (8192/(3.5*2^{20}))*1000 + 5.5 = 28.07 ms

4. The daily computer system processing load for a certain company consists of 60% CPU activity and 40% disk activity. Customers are complaining that the system is too slow. After doing some research, you have learned that you can upgrade the disks for $8000 to make them 2.5 times as fast as they are currently. You have also learned that you can upgrade the CPU to make it 1.4 times as fast for $5000.

a) Which option would you choose to yield the best performance improvement for the least amount of money?
Changing the CPU would provide a speedup = 1/((1-0.60) + (0.60/1.4)) = 1.2069 which is a 20.69% speedup.
Changing the disks would provide a speedup = 1((1-0.40) + (0.40/2.5)) = 1.3158 or a 31.58% speedup.
The cost per 1% speedup for the CPU = $5000/20.69% = $241.66
The cost per 1% speedup for the disks = $8000/31.58% = $253.32
So upgrading the CPU is the better option based on cost.

b) Which option would yield the bigger improvement if cost is no concern?
Upgrading the disks provides the greater speedup but costs more. So this is the better option if cost is of no concern.

5. Answer the following questions:

a) What is the average time to read or write a 512-byte sector for a typical disk rotating at 7200 RPM? The average seek time is 8 ms, the transfer rate is 20 MB/sec, and the controller overhead is 2 ms. Assume that the disk is idle so that there is no need to wait for any previous operation to complete.

Average disk access time =
seek time + rotational delay + transfer time + controller overhead =
8 ((0.5*60*1000/7200) + (512/20*2^{20})*1000 + 2 = 14.17 ms

b) A program repeatedly performs a three-step process: it reads in a 4-KB block of data from disk, does some processing on that data, and then writes out the result as another 4-KB block elsewhere on the disk. Each block is contiguous and randomly located on a single track on the disk. The disk drive rotates at 7200 RPM, has an average seek time of 8 ms, and has a transfer rate of 20 MB/sec. The controller overhead is 2 ms. No other program is using the disk or processor, and there is no overlapping of disk I/O with data processing. The processing step takes 20 million clock cycles and the clock rate is 400 MHz. What is the overall speed of the system in blocks processed per second assuming no other overhead?

Disk read or write time for a 4 KB block
= seek time + rotational delay + transfer time + controller overhead
= 8 + (0.5*60*1000/7200) + (4*1024/20*2^{20})*1000 + 2 = 14.17 ms

Processing time for a 4 KB block = number of clock cycles * cycle time
= 20*10^6 * (1/(400*10^6)) = 50 ms

Total time to process one 4 KB = read time + processing time + write time
= 14.17 + 50 + 14.17 = 78.34 ms

Number of blocks processed per second = 1/(total time to process 1 block)
= 1/78.34 ms = 0.01276 per ms or 12.76 per second