Exercise Session 1

Disk Performance, Disk Striping and RAID

1.1 Amdahl's Law and Disk Performance

Amdahl's law for the effective performance speedup states:

$$S = \frac{1}{\frac{f}{k} + (1 - f)}$$

S	= effective speedup (in times)
f	= fraction of work in faster mode
k	= speedup while in faster mode (in times)

a) A DBMS Server spends 20% of its processing time in I/O operations. What speedup can be achieved if CPU speed is doubled (increased 10 times)?

b) Given is a computer with 3000 MIPS and a hard drive with the following technical characteristics:

- avg. seek time = 8.5ms
- min. seek time = 2ms
- transfer rate = 444 MB/sec
- rot. speed = 7200 rpm
- block size = 512 bytes

How many instructions on average can the CPU execute during a block access? What if the block is on adjacent track (min. seek time needed)?

c) How can *I/O bandwidth* (amount of data accessible per unit time) be increased? In general, how can *I/O costs* (time spent accessing disk) be minimized?

1.2 The 80-20 Rule and the Need for Disk Striping

The load on a transaction processing system is typically made of read-modify-write operations which are mapped to corresponding *I/O requests*, normally having the size of a disk block. The data is stored in files, distributed over the available physical disks, where each file is completely stored on one physical disk. The so-called 80-20 rule states that 80% of the accesses concern only 20% of the data files. It is observed in practice that the potential hardware parallelism (the joint bandwidth) of the I/O system is not utilized efficiently in order to provide the expected *throughput* (number of requests processed per unit time).

a) To what extent can this observation be explained using the 80-20 Rule?

b) How can the efficiency of the secondary storage system be improved in order to achieve better overall bandwidth and I/O throughput?

1.3 Choosing the Right Striping Unit

We will now examine the effect of the size of the striping unit (the maximum amount of logically contiguous data that is stored on a single disk) on the processing of disk requests. Data is stored and addressed in units of a disk **block**. We assume that 2 disks are available. The following three configurations will be considered (see Figure 1.1):

1.) No striping: store on disk 1 until filled and then continue on disk 2
2.) Striping with a striping unit of 1 block
3.) Striping with a striping unit of 2 blocks

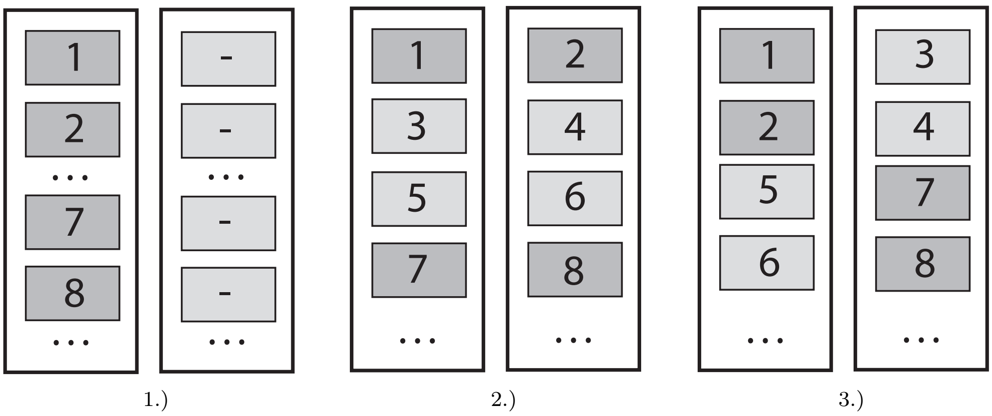

Figure 1.1:

The access time for reading a block is determined by: $T_{acc} = kT_{pos} + T_{trans}$

The **positioning time** $(k.T_{pos})$ accounts for the seek time and rotational delay. We assume that the mean positioning time for random accesses is obtained with $k = 10$ and for adjacent blocks with $k = 1$. We will now examine the following 2 workloads (where Ri stands for request i):

a) 2 read requests sent sequentially:

R1:readBlocks(1,2)
R2:readBlocks(7,8)

b) 2 read requests sent at the same time (concurrent requests):
R1:readBlocks(1,2)
R2:readBlocks(7,8)

Calculate the mean *request response time* (queuing time + service time) and the mean *throughput* (requests processed per unit time) for configurations 1.),2.), and 3.).

For example, for case b) with configuration 2.) we have the following sequence of operations:

Disk 1	***Disk 2***
R1: position[1] R2: queue up	
R1: read[1]	
R1: position[2]	
R1: read[2]	
R2: position[7]	
R2: read[7]	
R2: position[8]	
R2: read[8]	

This leads us to the following results:

$$Mean\ Response\ Time = \frac{(11\ T_{pos} + 2\ T_{trans}) + 2(11\ T_{pos} + 2\ T_{trans})}{2}$$

$$Mean\ Throughput = \frac{2}{(11\ Tpos + 2\ Ttrans) + (11\ Tpos + 2\ Ttrans)}$$

1.4 Evaluation of the different RAID levels

a) Describe the main differences between RAID levels 1, 4 and 5.

b) We will now evaluate the cost/performance differences between RAID levels 1, 4 and 5. We will be comparing configurations with the same usable disk capacity, namely:

- RAID level 4 and 5 arrays with D *data disks* - labeled disks 1 through D, and 1 *check (parity) disk* -labeled disk D+1.
- RAID level 1 arrays with D data disks and D additional mirror disks.

For the sake of simplicity, we will assume that the average positioning time for parallel accesses of D blocks is not substantially different from the average positioning time for a single block access. We will be using the following performance metrics as a basis for our comparison:

$$speedup = \frac{array\ throughput}{single\ disk\ throughput}$$

$$efficiency = \frac{speedup}{number\ of\ disks\ used}$$

Compare the speedups and efficiencies of RAID levels 1, 4 and 5 when processing requests of the following types:

- small read (r) and small write (w) operations (1 striping unit)
- large read (R) and large write (W) operations (accessing all data disks - full stripe)
- small read-modify-write (m) operations

Note 1: To determine speedup, consider the maximum number of disks that can be utilized at a point in time for processing operations of the respective type. Ignore disks executing parity operations.

Note 2: The "number of disks used" in the efficiency equation includes all additional check (parity) disks used for storing redundant information.

c) Summarize the pros and cons of RAID levels 1 and 5.