Mass Storage Structure

Practice Exercises

12.1 The accelerating seek described in Exercise 12.3 is typical of hard-disk drives. By contrast, floppy disks (and many hard disks manufactured before the mid-1980s) typically seek at a fixed rate. Suppose that the disk in Exercise 12.3 has a constant-rate seek rather than a constant-acceleration seek, so the seek time is of the form $t = x + yL$, where t is the time in milliseconds and L is the seek distance. Suppose that the time to seek to an adjacent cylinder is 1 millisecond, as before, and is 0.5 milliseconds for each additional cylinder.

a. Write an equation for this seek time as a function of the seek distance.

b. Using the seek-time function from part a, calculate the total seek time for each of the schedules in Exercise 12.2. Is your answer the same as it was for Exercise 12.3(c)?

c. What is the percentage speedup of the fastest schedule over FCFS in this case?

12.2 Is disk scheduling, other than FCFS scheduling, useful in a single-user environment? Explain your answer.

12.3 Explain why SSTF scheduling tends to favor middle cylinders over the innermost and outermost cylinders.

12.4 Why is rotational latency usually not considered in disk scheduling? How would you modify SSTF, SCAN, and C-SCAN to include latency optimization?

12.5 How would use of a RAM disk affect your selection of a disk-scheduling algorithm? What factors would you need to consider? Do the same considerations apply to hard-disk scheduling, given that the file system stores recently used blocks in a buffer cache in main memory?

12.6 Why is it important to balance file system I/O among the disks and controllers on a system in a multitasking environment?

12.7 What are the tradeoffs involved in rereading code pages from the file system versus using swap space to store them?

12.8 Is there any way to implement truly stable storage? Explain your answer.

12.9 The term "fast wide SCSI-II" denotes a SCSI bus that operates at a data rate of 20 megabytes per second when it moves a packet of bytes between the host and a device. Suppose that a fast wide SCSI-II disk drive spins at 7200 RPM, has a sector size of 512 bytes, and holds 160 sectors per track.

a. Estimate the sustained transfer rate of this drive in megabytes per second.

b. Suppose that the drive has 7000 cylinders, 20 tracks per cylinder, a head switch time (from one platter to another) of 0.5 millisecond, and an adjacent cylinder seek time of 2 milliseconds. Use this additional information to give an accurate estimate of the sustained transfer rate for a huge transfer.

c. Suppose that the average seek time for the drive is 8 milliseconds. Estimate the I/Os per second and the effective transfer rate for a random-access workload that reads individual sectors that are scattered across the disk.

d. Calculate the random-access I/Os per second and transfer rate for I/O sizes of 4 kilobytes, 8 kilobytes, and 64 kilobytes.

e. If multiple requests are in the queue, a scheduling algorithm such as SCAN should be able to reduce the average seek distance. Suppose that a random-access workload is reading 8-kilobyte pages, the average queue length is 10, and the scheduling algorithm reduces the average seek time to 3 milliseconds. Now calculate the I/Os per second and the effective transfer rate of the drive.

12.10 More than one disk drive can be attached to a SCSI bus. In particular, a fast wide SCSI-II bus (see Exercise 12.9) can be connected to at most 15 disk drives. Recall that this bus has a bandwidth of 20 megabytes per second. At any time, only one packet can be transferred on the bus between some disk's internal cache and the host. However, a disk can be moving its disk arm while some other disk is transferring a packet on the bus. Also, a disk can be transferring data between its magnetic platters and its internal cache while some other disk is transferring a packet on the bus. Considering the transfer rates that you calculated for the various workloads in Exercise 12.9, discuss how many disks can be used effectively by one fast wide SCSI-II bus.

12.11 Remapping of bad blocks by sector sparing or sector slipping could influence performance. Suppose that the drive in Exercise 12.9 has a total of 100 bad sectors at random locations and that each bad sector is mapped to a spare that is located on a different track, but within the same cylinder. Estimate the number of I/Os per second and the effective transfer rate for a random-access workload consisting of 8-kilobyte reads, with a queue length of 1 (that is, the choice of scheduling algorithm is not a factor). What is the effect of a bad sector on performance?

12.12 In a disk jukebox, what would be the effect of having more open files than the number of drives in the jukebox?

12.13 If magnetic hard disks eventually have the same cost per gigabyte as do tapes, will tapes become obsolete, or will they still be needed? Explain your answer.

12.14 It is sometimes said that tape is a sequential-access medium, whereas magnetic disk is a random-access medium. In fact, the suitability of a storage device for random access depends on the transfer size. The term *streaming transfer rate* denotes the data rate for a transfer that is underway, excluding the effect of access latency. By contrast, the *effective transfer rate* is the ratio of total bytes per total seconds, including overhead time such as the access latency.

Suppose that, in a computer, the level-2 cache has an access latency of 8 nanoseconds and a streaming transfer rate of 800 megabytes per second, the main memory has an access latency of 60 nanoseconds and a streaming transfer rate of 80 megabytes per second, the magnetic disk has an access latency of 15 millisecond and a streaming transfer rate of 5 megabytes per second, and a tape drive has an access latency of 60 seconds and a streaming transfer rate of 2 megabytes per seconds.

a. Random access causes the effective transfer rate of a device to decrease, because no data are transferred during the access time. For the disk described, what is the effective transfer rate if an average access is followed by a streaming transfer of 512 bytes, 8 kilobytes, 1 megabyte, and 16 megabytes?

b. The utilization of a device is the the ratio of effective transfer rate to streaming transfer rate. Calculate the utilization of the disk drive for random access that performs transfers in each of the four sizes given in part a.

c. Suppose that a utilization of 25 percent (or higher) is considered acceptable. Using the performance figures given, compute the smallest transfer size for disk that gives acceptable utilization.

d. Complete the following sentence: A disk is a random-access device for transfers larger than ______ bytes, and is a sequential-access device for smaller transfers.

e. Compute the minimum transfer sizes that give acceptable utilization for cache, memory, and tape.

f. When is a tape a random-access device, and when is it a sequential-access device?

12.15 Suppose that we agree that 1 kilobyte is 1,024 bytes, 1 megabyte is $1,024^2$ bytes, and 1 gigabyte is $1,024^3$ bytes. This progression continues through terabytes, petabytes, and exabytes ($1,024^6$). There are currently several new proposed scientific projects that plan to record and store a few exabytes of data during the next decade. To answer the following questions, you will need to make a few reasonable assumptions; state the assumptions that you make.

a. How many disk drives would be required to hold 4 exabytes of data?

b. How many magnetic tapes would be required to hold 4 exabytes of data?

c. How many optical tapes would be required to hold 4 exabytes of data (see Exercise 12.21)?

d. How many holographic storage cartridges would be required to hold 4 exabytes of data (see Exercise 12.20)?

e. How many cubic feet of storage space would each option require?