Teknologi pita yang dominan saat ini adalah sistem kartrid yang dikenal sebagai linear tape-open (LTO). LTO was developed in the late 1990s as an open-source alternative to the various proprietary systems on the market. Table 6.6 shows parameters for the various LTO generations. See Appendix J for details.

[JACO08] provides solid coverage of magnetic disks.[MEE96a] provides a good survey of the underlying recording technology of disk and tape systems. [MEE96b] focuses on the data storage techniques for disk and tape systems. [COME00] is a short but instructive article on

6.5 / RECOMMENDED READING AND WEB SITES

current trends in magnetic disk storage technology. [RADD08] and [ANDE03] provide a more recent discussion of magnetic disk storage technology.

An excellent survey of RAID technology, written by the inventors of the RAID concept, is [CHEN94].A good overview paper is [FRIE96].A good performance comparison of the RAID architectures is [CHEN96].

[MARC90] gives an excellent overview of the optical storage field. A good survey of the underlying recording and reading technology is [MANS97].

[ROSC03] provides a comprehensive overview of all types of external memory systems, with a modest amount of technical detail on each. [KHUR01] is another good survey.

[HAEU07] provides a detailed treatment of LTO.

ANDE03 Anderson, D. “You Don't Know Jack About Disks.” *ACM Queue*, June 2003.

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MARC90 Marchant,A. *Optical Recording.* Reading, MA:Addison-Wesley, 1990.

MEE96a Mee, C., and Daniel, E. eds. *Magnetic Recording Technology.* New York: McGraw-Hill, 1996.

MEE96b Mee, C., and Daniel, E. eds. *Magnetic Storage Handbook.* New York: McGrawHill, 1996.

RADD08 Radding,A.“Small Disks, Big Specs.” *Storage Magazine*, September 2008

ROSC03 Rosch, W. *Winn L. Rosch Hardware Bible.* Indianapolis, IN: Que Publishing, 2003.

Recommended Web sites:

• **Optical Storage Technology Association:** Good source of information about optical storage technology and vendors, plus extensive list of relevant links

• **LTO Web site:** Provides information about LTO technology and licensed vendors

Key Terms

access time	DVD-RW	pit
Blu-ray	fixed-head disk	platter
CD	floppy disk gap head land	SERANGAN
CD ROM	magnetic disk magnetic	removable disk
CD-R	tape magnetoresistive	rotational delay
CD-RW	movable-head disk	sector seek time
constant angular velocity (CAV)	multiple zoned recording	serpentine recording
constant linear velocity (CLV) silinder	nonremovable disk optical	striped data substrate
DVD	memory	track transfer time
DVD-ROM		
DVD-R		

Review Questions

6.1 What are the advantages of using a glass substrate for a magnetic disk?

6.2 How are data written onto a magnetic disk?

6.3 How are data read from a magnetic disk?

6.4 Explain the difference between a simple CAV system and a multiple zoned recording system. **6.5** Define the terms *track*, *cylinder*, and *sector*.

6.6 What is the typical disk sector size?

6.7 Define the terms *seek time*, *rotational delay*, *access time*, and *transfer time*.

6.8 What common characteristics are shared by all RAID levels?

6.9 Briefly define the seven RAID levels.

6.10 Explain the term *striped data*.

6.11 How is redundancy achieved in a RAID system?

6.12 In the context of RAID, what is the distinction between parallel access and independent access? **6.13** What is the difference between CAV and CLV?

6.14 What differences between a CD and a DVD account for the larger capacity of the latter?

6.15 Explain serpentine recording.

Problems

6.1 Consider a disk with N tracks numbered from 0 to (N 1) and assume that requested sectors are distributed randomly and evenly over the disk.We want to calculate the average number of tracks traversed by a seek.

sebuah. First, calculate the probability of a seek of length j when the head is currently positioned over track t. *Hint:* This is a matter of determining the total number of combinations, recognizing that all track positions for the destination of the seek are equally likely.

b. Next, calculate the probability of a seek of length K. *Hint:* this involves the summing over all possible combinations of movements of K tracks.

c. Calculate the average number of tracks traversed by a seek, using the formula for expected value N -1

E[x] = ai * Pr[x = i]

i=0

Hint: Use the equalities: a^n i = n(n ~~+ 1); a^n i~~2 = n(n + 1)(2n + 1).

i=1 2 i=1 6

d. Show that for large values of N, the average number of tracks traversed by a seek approaches N/3. **6.2** Define the following for a disk system: t_S = seek time; average time to position head over track

r = rotation speed of the disk, in revolutions per second

n = number of bits per sector N = capacity of a track, in bits t_A =
time to access a sector

Develop a formula for t_A as a function of the other parameters.

6.3 Consider a magnetic disk drive with 8 surfaces, 512 tracks per surface, and 64 sectors per track. Sector size is 1 KB.The average seek time is 8 ms, the track-to-track access time is 1.5

ms,and the drive rotates at 3600 rpm.Successive tracks in a cylinder can be read without head movement. sebuah. What is the disk capacity?

b. What is the average access time? Assume this file is stored in successive sectors and tracks of successive cylinders, starting at sector 0, track 0, of cylinder i.

c. Estimate the time required to transfer a 5-MB file.

d. What is the burst transfer rate?

6.4 Consider a single-platter disk with the following parameters: rotation speed: 7200 rpm; number of tracks on one side of platter: 30,000; number of sectors per track: 600; seek time: one ms for every hundred tracks traversed. Let the disk receive a request to access a random sector on a random track and assume the disk head starts at track 0.

a. What is the average seek time?

b. What is the average rotational latency?
c. What is the transfer time for a sector?

d. What is the total average time to satisfy a request?

6.5 A distinction is made between physical records and logical records.A **logical record** is a collection of related data elements treated as a conceptual unit,independent of how or where the information is stored.A **physical record** is a contiguous area of storage space that is defined by the characteristics of the storage device and operating system. Assume a disk system in which each physical record contains thirty 120-byte logical records. Calculate how much disk space (in sectors, tracks, and surfaces)

will be required to store 300,000 logical records if the disk is fixed-sector with 512 bytes/sector, with 96 sectors/track, 110 tracks per surface, and 8 usable surfaces. Ignore any file header record(s) and track indexes, and assume that records cannot span two sectors. 6.6 Consider a disk that rotates at 3600 rpm.The seek time to move the head between adjacent tracks is 2 ms. There are 32 sectors per track, which are stored in linear order from sector 0 through sector 31.The head sees the sectors in ascending order.Assume the read/write head is positioned at the start of sector 1 on track 8. There is a main memory buffer large enough to hold an entire track. Data is transferred between disk locations by reading from the source track into the main memory buffer and then writing the date from the buffer to the target track.

sebuah. How long will it take to transfer sector 1 on track 8 to sector 1 on track 9?

b. How long will it take to transfer all the sectors of track 8 to the corresponding sectors of track 9? 6.7 It should be clear that disk striping can improve data transfer rate when the strip size is small compared to the I/O request size. It should also be clear that RAID 0 provides improved performance relative to a single large disk, because multiple I/O requests can be handled in parallel. However, in this latter case, is disk striping necessary? That is, does disk striping improve I/O request rate performance compared to a comparable disk array without striping? 6.8 Consider a 4-drive, 200GB-per-drive RAID array. What is the available data storage capacity for each of the RAID levels, 0, 1, 3, 4, 5, and 6?

6.9 For a compact disk, audio is converted to digital with 16-bit samples, and is treated a stream of 8-bit bytes for storage.One simple scheme for storing this data,called direct recording, would be to represent a 1 by a land and a 0 by a pit. Instead, each byte is expanded into a 14-bit binary number. It turns out that exactly 256 (2^8) of the total of 16,134 (2^{14}) 14-bit numbers have at least two 0s between every pair of 1s, and these are the numbers selected for the

expansion from 8 to 14 bits. The optical system detects the presence of 1s by detecting a transition for pit to land or land to pit.It detects 0s by measuring the distances between intensity changes. This scheme requires that there are no 1s in succession; hence the use of the 8-to-14 code.

The advantage of this scheme is as follows. For a given laser beam diameter, there is a minimum-pit size, regardless of how the bits are represented. With this scheme, this minimum pit size stores 3 bits, because at least two 0s follow every 1. With direct recording, the same pit would be able to store only one bit. Considering both the number of bits stored per pit and the 8-to-14 bit expansion, which scheme stores the most bits and by what factor?

6.10 Design a backup strategy for a computer system.One option is to use plug-in external disks,which cost $150 for each 500 GB drive.Another option is to buy a tape drive for $2500, and 400 GB tapes for $50 apiece. (These were realistic prices in 2008.) A typical backup strategy is to have two sets of backup media onsite, with backups alternately written on them so in case the system fails while making a backup,the previous version is still intact. There's also a third set kept offsite, with the offsite set periodically swapped with an on-site set.

sebuah. Assume you have 1 TB (1000 GB) of data to back up. How much would a disk backup system cost? **b.** How much would a tape backup system cost for 1 TB?

c. How large would each backup have to be in order for a tape strategy to be less expensive? **d.**

What kind of backup strategy favors tapes?