Secondary Storage Devices: Magnetic Tapes

Last Time : Secondary Storage Devices: Magnetic Disks. Up to non data overhead

Today

- Continuing on last week's notes on disks (nondata overhead, the cost of a disk access, disk as a bottleneck)
- Magnetic tapes
  - Characteristics of magnetic tapes
  - Data organization on 9-track tapes
  - Estimating tape length requirements
  - Estimating data transmission times
  - Disk versus tape

Reference: Folk, Zoellick and Riccardi. Sections 3.2.

Characteristics of Magnetic Tapes

- No direct access, but very fast sequential access.
- Resistant to different environmental conditions.
- Easy to transport, store, cheaper than disk.
- Before it was widely used to store application data; nowadays, it's mostly used for backups or archives (terciary storage).

Data Organization on Nine-Track Tapes

In a tape, the **logical position** of a byte within a file is the same as its **physical position** in the file (sequential access).

Nine-track tape:

```
--------------------------------------------------------------
__________|0     0|__________|0|__________|0     0|__________
__________|0     0|__________|1|__________|0     0|__________
__________|0     0|__________|1|__________|0     0|__________
__________|0     0|__________|0|__________|0     0|__________
__________|0     0|__________|1|__________|0     0|__________
__________|0     0|__________|0|__________|0     0|__________
__________|0     0|__________|0|__________|0     0|__________
__________|0     0|__________|1|__________|0     0|__________
__________|0     0|__________|1|__________|0     0|__________
--------------------------------------------------------------
          |<-Gap->|  <-- Data Block -->   |<-Gap->|
```

- **Data blocks** are separated by interblock GAPS.
- 9 parallel tracks (each is a sequence of bits)
- A **frame** is a 1-bit slice of the tape corresponding to 9 bits (one in each track) which correspond to 1 byte plus a **parity bit**.

In the example above, the byte stored in the frame that is shown is: `01101001`
The parity bit is `1`, since we are using **odd parity**, i.e., the total number of bits is odd.

Complete the parity bit in the examples below:

```
11111111
00000000
00100000
```

Since `000000000` cannot correspond to a valid byte, this is used to mark the **interblock gap**.

So, if we say that this tape has 6,250 **bits per inch** (bpi) per track, indeed it stores 6,250 **bytes per inch** when we take into account the 9 tracks.

Estimating Tape Length Requirements

Performance of tape drives can be mesured in terms of 3 quantities:
- Tape density = 6250 bpi (bits per inch per track)
- Tape speed = 200 inches per second (ips)
- Size of interblock gap = 0.3 inch

File characteristics:
- Number of records = 1,000,000
- Size of record = 100 bytes

How much tape is needed?

It depends on the blocking factor (how many records per data block). Let us compute the space requirement in two cases:
A) Blocking factor = 1
B) Blocking factor = 50

Space requirement (s)
b = length of data block (in inches)
g = length of interblock gap (in inches)
n = number of data blocks

s = n x (b + g)

A) Blocking factor = 1

b = block size/tape density = 100/6250 = 0.016 inch
n = 1,000,000
s = 1,000,000 x (0.016 + 0.3) inch = 316,000 inches ~ 26,333 feet
(Absurd to have the length of the data block smaller than the interblock gap!)

B) Blocking factor = 50

b = 50 x 100/6,250 = 0.8 inch
n = 1,000,000/50 = 20,000
s = 20,000 x (0.8 + 0.3) inch = 22,000 inches ≈ 1,833 feet

An enormous saving by just choosing a higher blocking factor.

Effective Recording Density (ERD)

ERD = number of bytes per block / number of inches to store a block

In previous example :

A) Blocking factor =1: E.R.D. = 100/0.316 ~ 316.4 bpi
B) Blocking factor =50: E.R.D. = 5,000/1.1 ~ 4,545.4 bpi

The **Nominal Density** was 6,250 bpi!

Estimating Data Transmission Times

Nominal Rate = tape density (bpi) x tape speed (ips)

In a 6,250 - bpi , 200 - ips tape :
Nominal Rate = 6,250 x 200 = 1,250,000 bytes/sec ~ 1,250 KB/sec

Effective Transmission Rate = E.R.D. x tape speed

In the previous example:
A) E.T.R. = 316.4 x 200 = 63,280 bytes/sec ~ 63.3 KB/sec
B) E.T.R. = 4,545.4 x 200 = 909,080 bytes/sec ~ 909 KB/sec
Note : There is a tradeoff between **increasing** blocking factor for increasing speed & space utilization and **decreasing** it for reducing the size of the I/O buffer.

Disk versus Tape

In the past : Disks and Tapes were used for secondary storage: disks preferred for random access and tapes for sequential access.
Now :
Disks have taken over most of secondary storage (lower cost of disk and lower cost of RAM which allows large I/O buffer). Tapes are mostly used for **tertiary storage**.