Internal Organization of a High-Density Flexible ("Floppy") Disk and of a Fixed ("Hard") Disk

1. Summary: We shall first calculate an initial estimate for the size of the File Allocation Table (FAT) of a Floppy ("Flexible") Disk, or Diskette. Based upon the results of that estimate, we shall then proceed to refine the calculation to determine the exact size of the FAT. We shall then confirm that the exact calculation does not require any change in the number of sectors that must be allocated to the FAT from that determined in the initial estimate. Next, we shall calculate the size of the Root Directory. Then, we shall determine exactly how much space in a diskette is usable for recording the contents of files. Finally, we shall see how the organization of FAT-based disks applies not only to the FAT-12 of the Flexible Disk, but also to FAT-16 and FAT-32 that are used for Rigid ("Hard" or "Fixed") Disks.

2. To calculate an initial value for the size of the File Allocation Table (FAT), first determine how many entries are needed in the FAT. The FAT contains one entry per cluster. The cluster size for the Diskette is one (512-Byte) sector per cluster. Thus, the number of clusters on the Diskette is the same as the number of sectors.

(18 sectors/track) * (80 tracks/side) * (2 sides/Diskette)

= 2,880 total sectors/Diskette

Since each sector is ½ kByte in size,

2,880 sectors/Diskette * ½ kByte/sector = 1,440 kBytes/Diskette

Therefore, the raw size of the diskette is usually quoted as 1.44 Mbytes. As we shall see, however, not all of the space on the diskette is available for the storage

08 Feb 2001; revised 13 Mar 2002

of data. Some space is taken up by the Master Boot Record, by the two copies of the File Allocation Table (FAT) that must be stored on the diskette, and by the various directories that may be present.

3. Initially, we must assume that we need 2,880 entries in the FAT, which is one entry/cluster. The purpose of the FAT entry is to identify what is the next cluster in the file. Therefore, each FAT entry must be able to point to any of the 2,879 other clusters on the disk. Based upon this information, we can calculate what is the minimum size possible for a single FAT entry. To be able to accommodate all 2,880 clusters on the Diskette, the size of each entry must be at a minimum:

$$\lceil (\log_2 2{,}880) \rceil = 12 \text{ bits/FAT entry} = 1.5 \text{ Bytes/FAT entry}$$

It is for this reason that the Diskette is, in fact, organized via what is known as "FAT-12", namely, 12 bits/FAT entry.

4. Thus, our initial calculation for the size of the FAT is:

$$(2{,}880 \text{ entries/FAT}) * (1.5 \text{ Bytes/entry})$$

$$= 4{,}320 \text{ Bytes in FAT to accommodate 2,880 cluster entries}$$

5. The size of an allocation unit for the Diskette is one sector. Thus, the number of clusters that must be allocated to the FAT is:

$$\lceil (4{,}320 \text{ Bytes/FAT}) \div (512 \text{ Bytes/sector}) \rceil = 9 \text{ sectors/FAT}$$

6. Now, let's refine the calculations. Originally, we had estimated 2,880 entries/FAT, one for each cluster (sector) on the disk. HOWEVER, in fact we have found that

08 Feb 2001; revised 13 Mar 2002

nine clusters of the diskette are occupied up by the FAT itself, and therefore are not available for use in storing the contents of files. FAT entries are therefore neither needed nor appropriate for these nine clusters, since the purpose of the FAT entries is to provide the links for successive clusters associated with each file, and the FAT is situated in a fixed and constant location on the disk, and therefore its location does not need to be registered within itself. Furthermore, each disk contains two copies of the FAT, as a safety precaution should one copy of the FAT become corrupted. Thus, there are eighteen sectors on the Diskette, which are equivalent to 18 clusters, for which there will be no FAT entries. In addition, one sector of the disk is occupied by the Main Boot Record (MBR). Thus, we can subtract from the total of 2,880 clusters on the disk a total of 19 clusters, for which FAT entries are not needed. This leaves:

(2,880 clusters — 19 clusters) = 2,861 FAT entries/Diskette

7. Thus, the final calculation for the FAT size is:

(2,861 entries/FAT) * (1.5 Bytes/entry)

= 4,291.5 Bytes of cluster entries/FAT

To this, we must add 2 Bytes to mark the beginning of the FAT, plus one Byte for the medium descriptor entry:

4,291.5 + 2 + 1 = 4,294 Bytes total size of the FAT

Note that although this final size is a little smaller than the original estimate, nevertheless this reduced size still requires nine sectors for the FAT ($\lceil(4,294/512)\rceil$, because there is no use for a fractional part of a cluster or sector.

8. Next, we shall take a look at the size of the Root directory. In the Diskette, this holds a maximum of 224 records, with each record occupying a space of 32 Bytes. Thus, the size of the Root directory is:

   (224 records) * (32 Bytes/record) = 7,168 Bytes total size of the Root directory

   The allocation unit is one cluster, which is also one sector, and so the space occupied by the Root directory is:

   $$\lceil (7{,}168 \text{ Bytes} / 512 \text{ Bytes/sector}) \rceil = \lceil 14.0 \rceil = 14 \text{ sectors}$$

9. To summarize, out of the total of 2,880 sectors on a Diskette, 1 sector is taken up by the Main Boot Record (MBR), 18 sectors by the two copies of the FAT, and 14 sectors by the Root Directory. Thus, the space on the disk that is usable for recording file contents is not more than:

   $$2{,}880 - (1 + 18 + 14) = 2{,}847 \text{ sectors}$$

   This corresponds to:

   2,847 sectors * 512 Bytes/sector

   = 1,457,624 Bytes usable space/Diskette

   Converting this to kilobytes (kB):

   1,457,624 Bytes ÷ 1,024 Bytes/kByte = 1,423.46 kBytes

   = 1.42 MB usable space/Diskette

08 Feb 2001; revised 13 Mar 2002

Thus, we have seen that a 1.44 MB diskette will contain no more than 1.42 MB of data. If there are more directories underneath the Root Directory, then the amount of usable space might be even less.

10. There is a similar organizational structure applicable to a Rigid or "Fixed" Disk (commonly referred to as a "Hard" Disk). Two types of organization available for such disks in conjunction with either Microsoft operating systems or *Linux* are FAT-16, which is an older Microsoft-origination system, and FAT-32. These are in vivid contrast to the FAT-12 organization used on the flexible disk. We can now ask several questions:

    Q1: What is the maximum number of allocation units ("clusters") that can be accommodated in FAT-12?

    Q2: In FAT-16?

    Q3: In FAT-32?

    Q4: Unlike the diskette, whose size and capacity have been standardized for more than 10 years, the size and capacity of a drive for Rigid Disk assembly is separately determined through the design process for each model of disk drive by the manufacturer.

08 Feb 2001; revised 13 Mar 2002