Lecture 12

File System Implementation

Lecture Information

Ceng328 *Operating Systems* at May 11, 2010

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- The file system itself is generally composed of many different levels.

File-System Structure II

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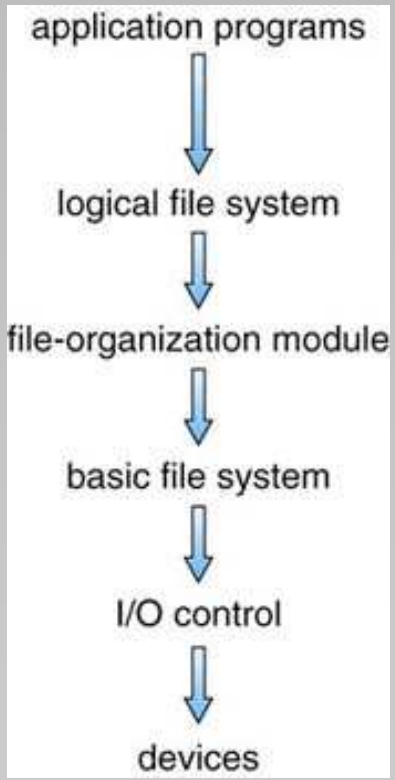

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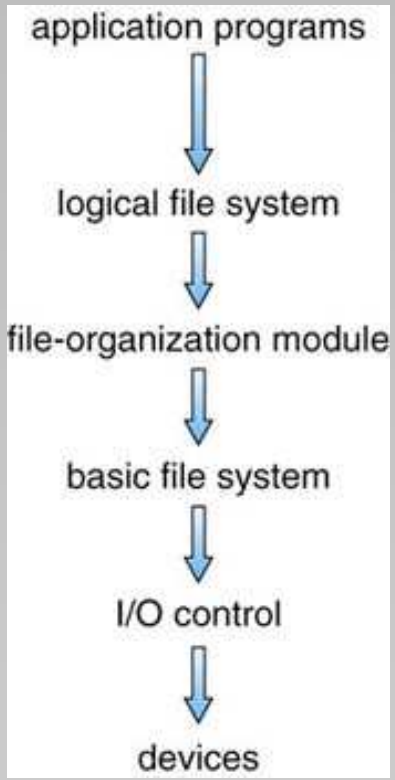

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- Each level in the design uses the features of lower levels to create new features for use by higher levels.

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- Many file systems are in use today; ISO 9660, UNIX file system (UFS), FAT, FAT32, NTFS, ext2, ext3, ext4.

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- Often the file system will contain some of the items shown in Fig. 2.

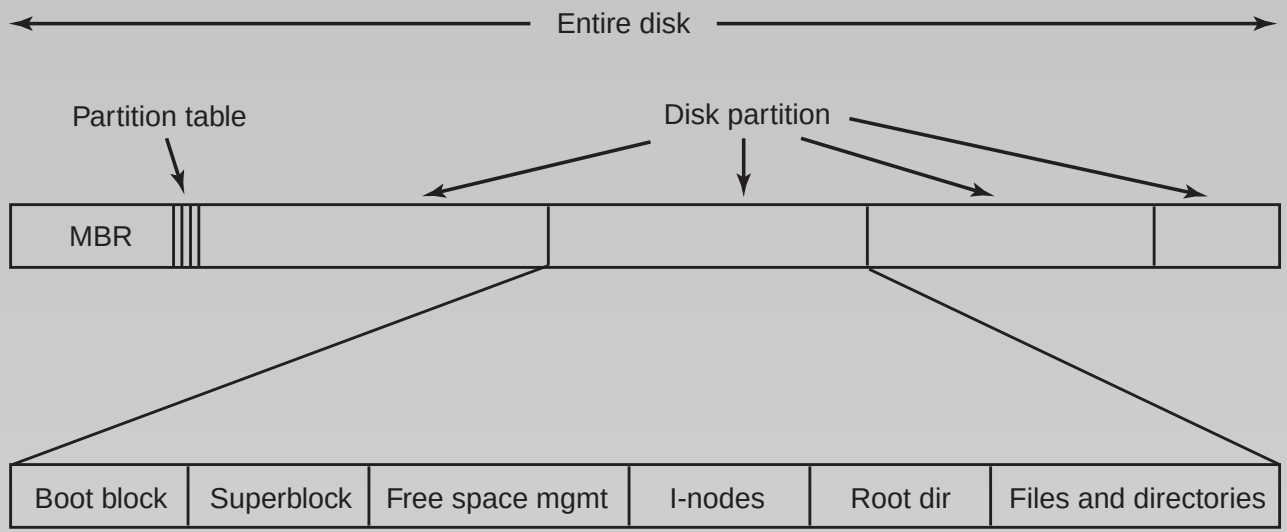

Figure: A possible file system layout.

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- Finally, the remainder of the disk typically contains all the other directories and files.

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- A typical FCB is shown in Fig. 3.

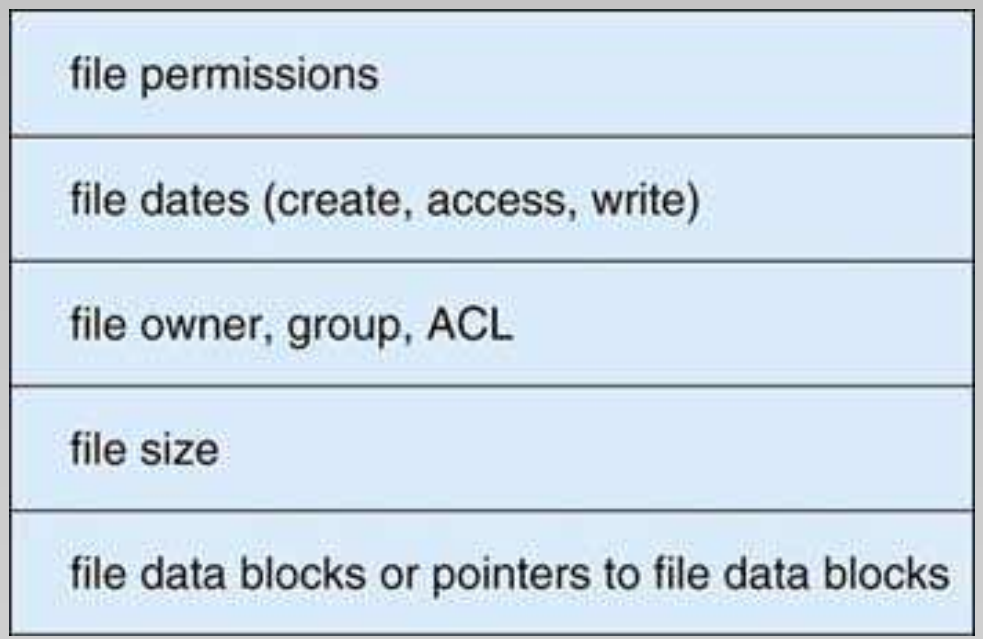

Figure: A typical file-control block.

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- The operating structures of a file-system implementation are summarized in Fig. 4.

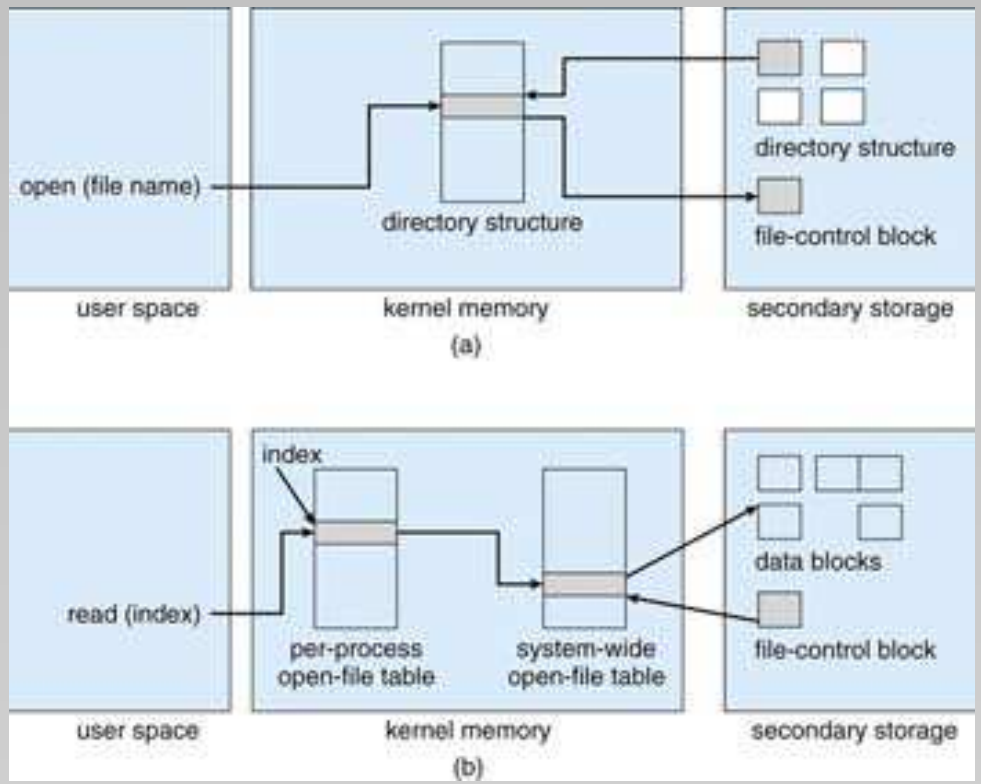

Figure: In-memory file-system structures. (a) File open. (b) File read.

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- The mount table entry contains a pointer to the superblock of the file system on that device.

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1 The first layer is the file-system interface, based on the *open*(), *read*(), *write*(), and *close*() calls and on file descriptors.

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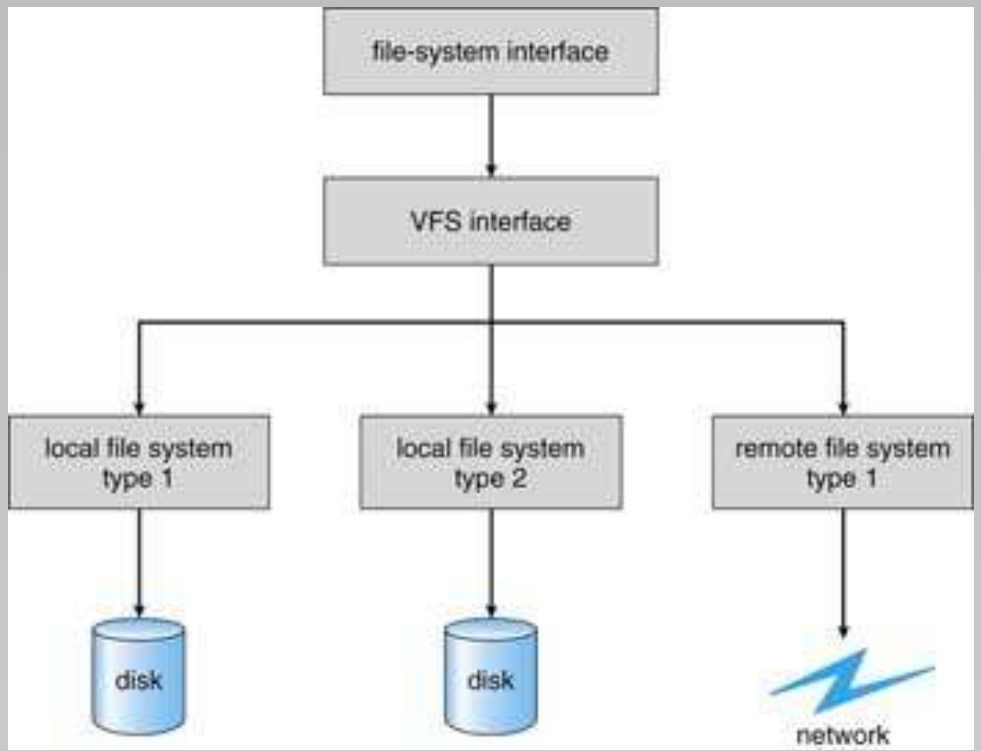

Figure: Schematic view of a virtual file system.

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- The VFS distinguishes local files from remote ones, and local files are further distinguished according to their file-system types.

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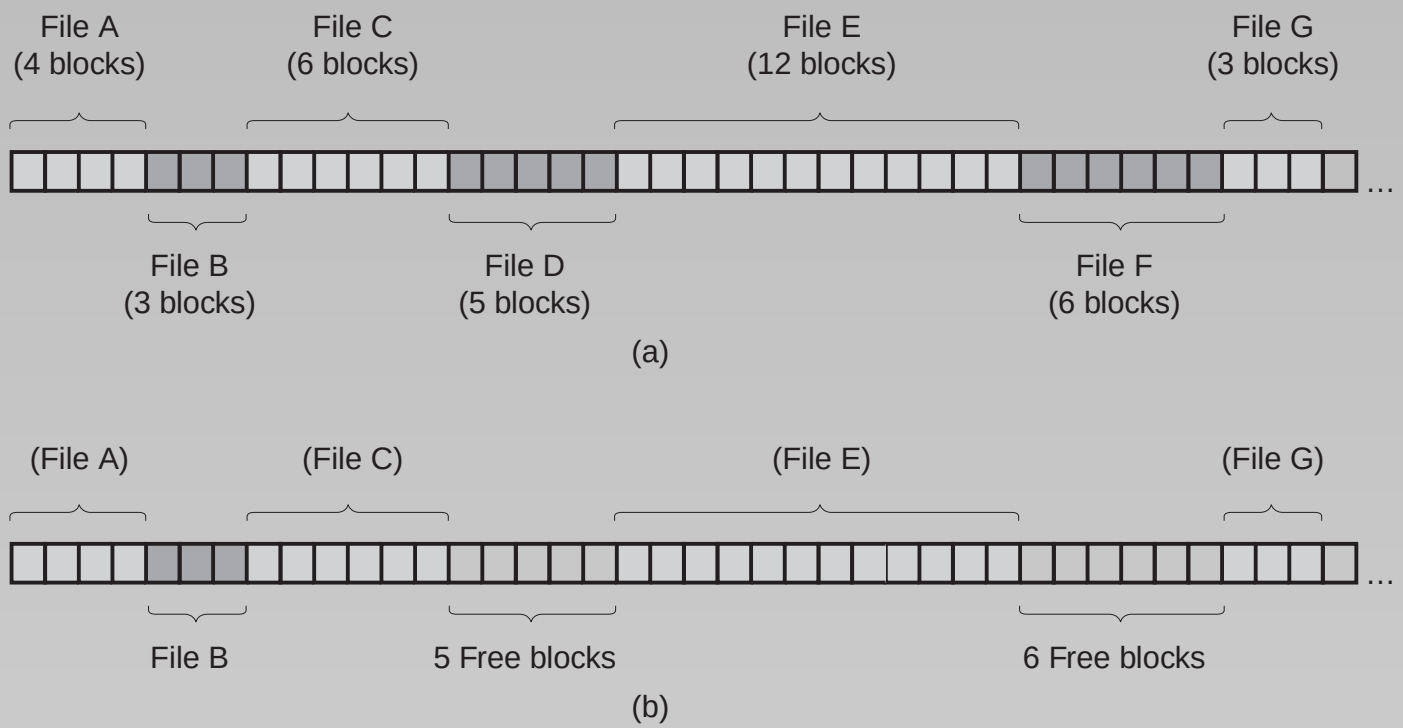

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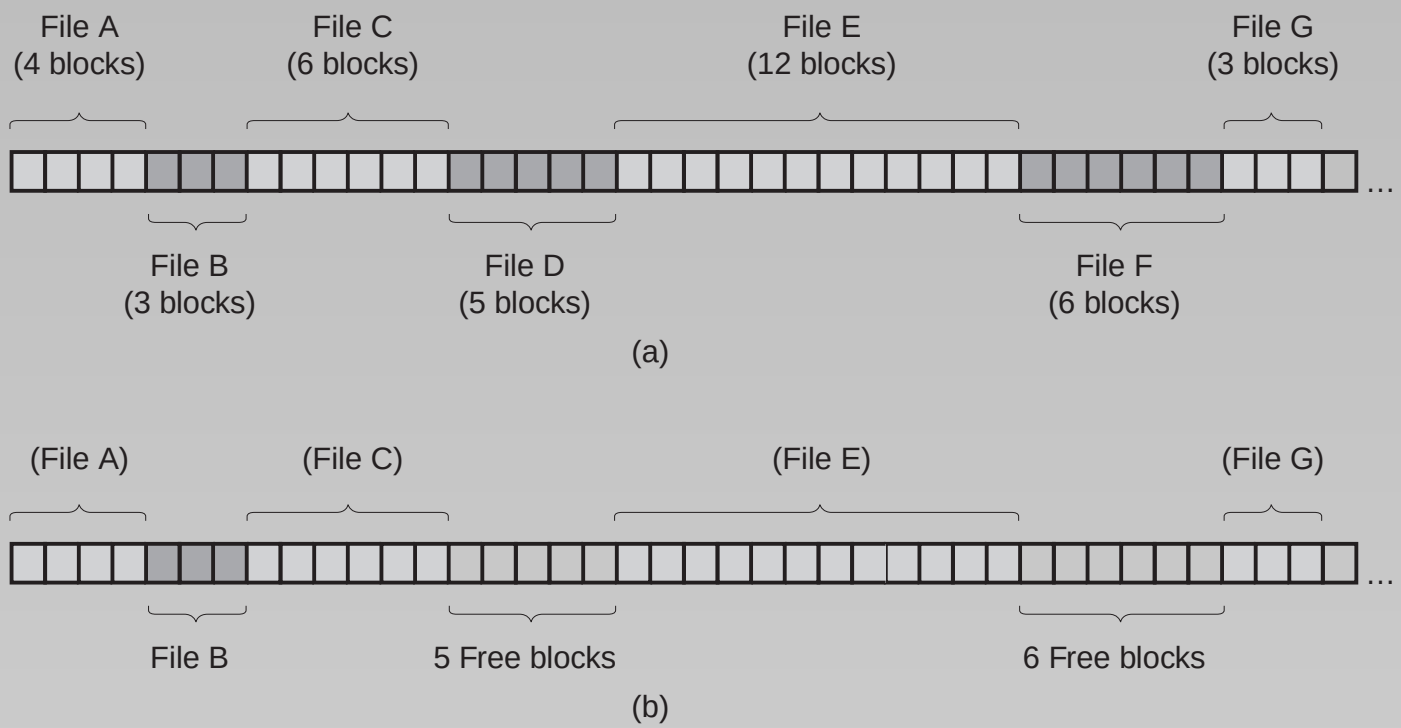

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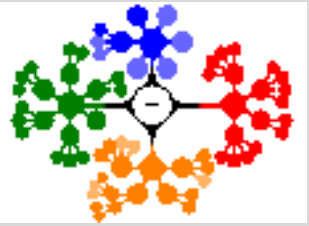
- Contiguous allocation is widely used on CD-ROMs.
- Here all the file sizes are known in advance and will never change during subsequent use of the CD-ROM file system.



Contiguous Allocation III

- The directory entry for each file indicates the address of the starting block and the length of the area allocated for this file (see Fig. 7).

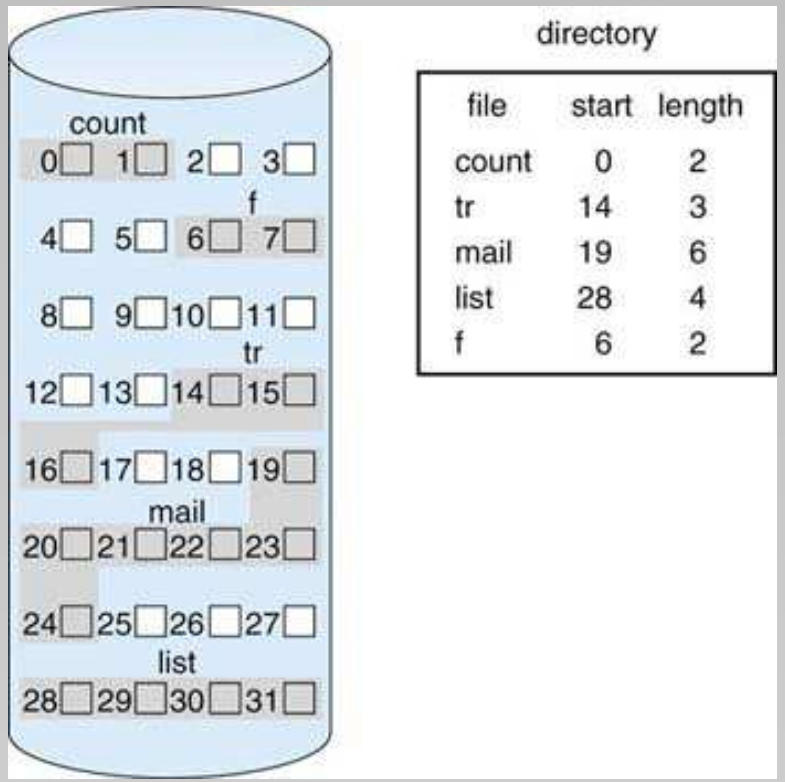


Figure: Contiguous allocation of disk space.

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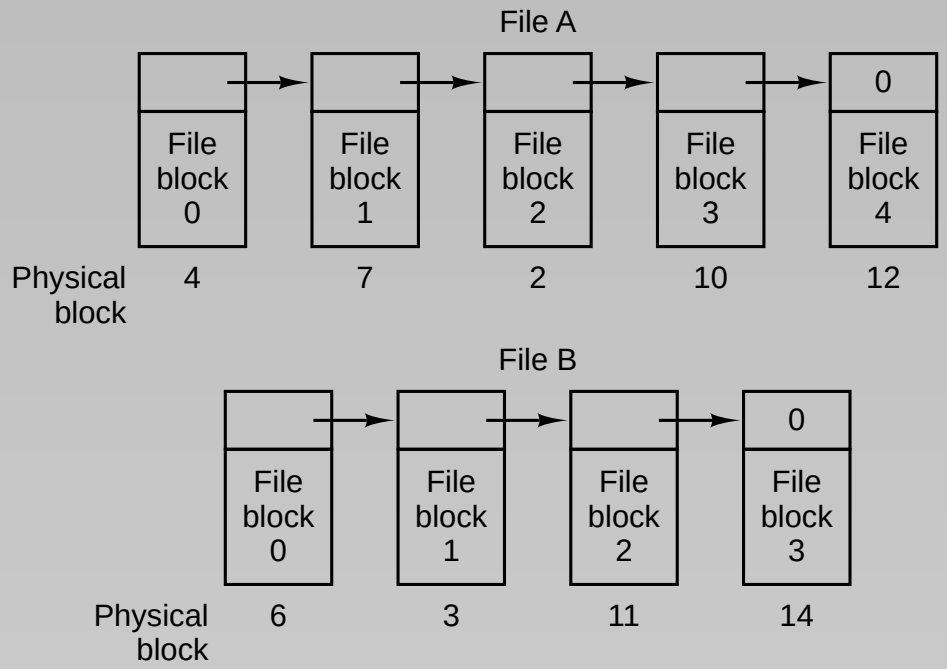
- Even if the total amount of space needed for a file is known in advance, preallocation may be inefficient.

Linked Allocation I

- The second method for storing files is to keep each one as a linked list of disk blocks, as shown in Fig. 8.



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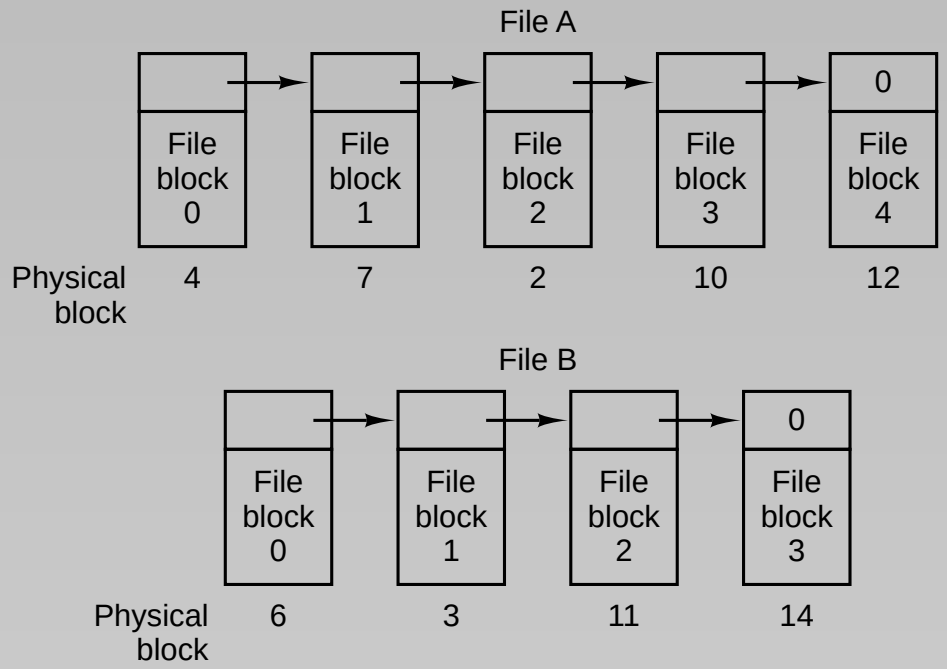

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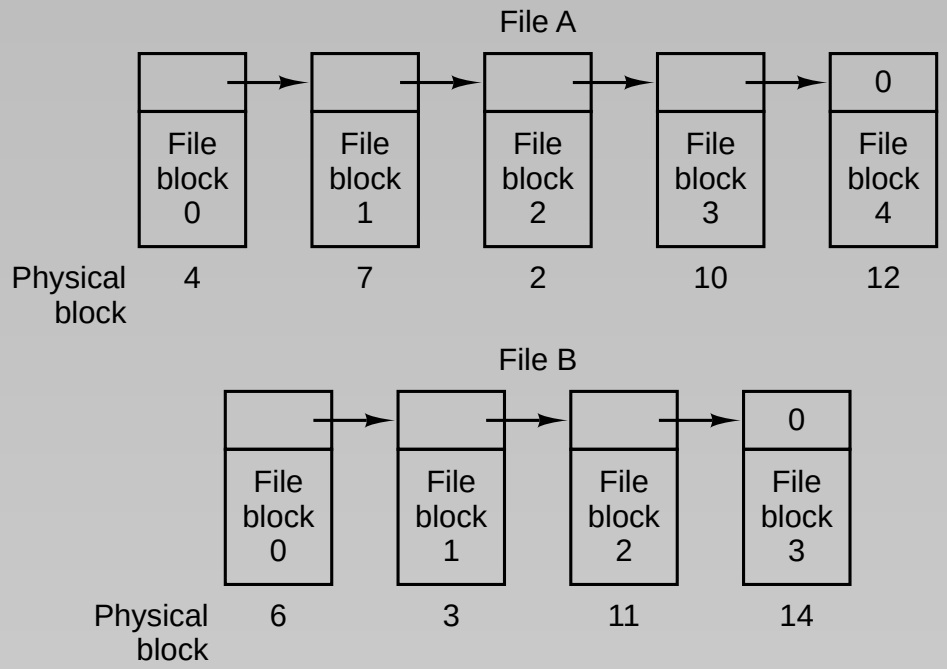

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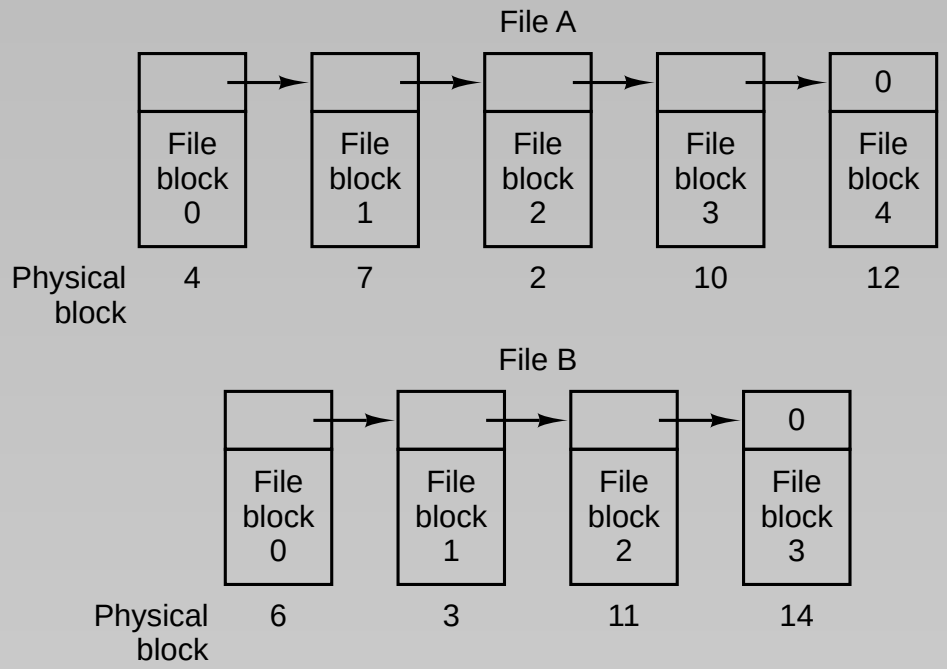

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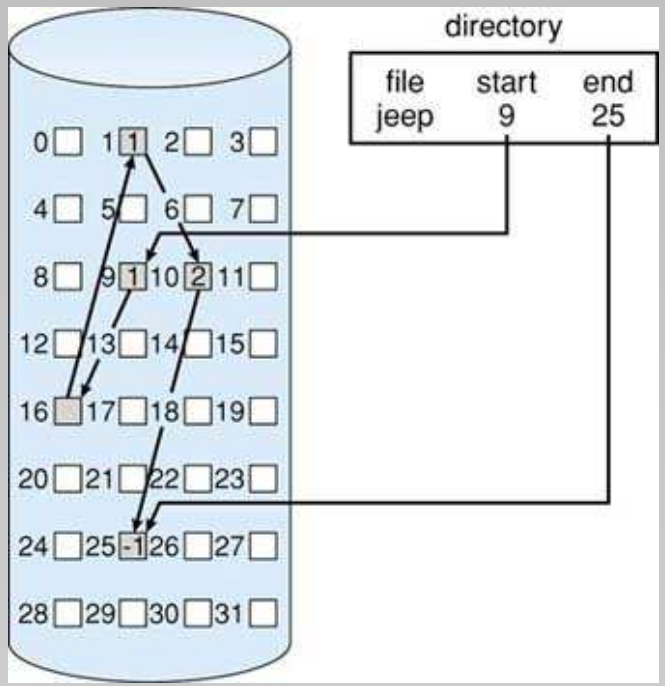
  - The directory contains a pointer to the first and last blocks of the file.

Linked Allocation II

For example, a file of five blocks might start at block 9 and continue at block 16, then block 1, then block 10, and finally block 25 (see Fig. 9).



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  - What would happen if a pointer were lost or damaged?
  - A bug in the OS software or a disk hardware failure might result in picking up the wrong pointer.

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- An illustrative example is the FAT structure shown in Fig. 10 for a file consisting of disk blocks 217, 618, and 339.

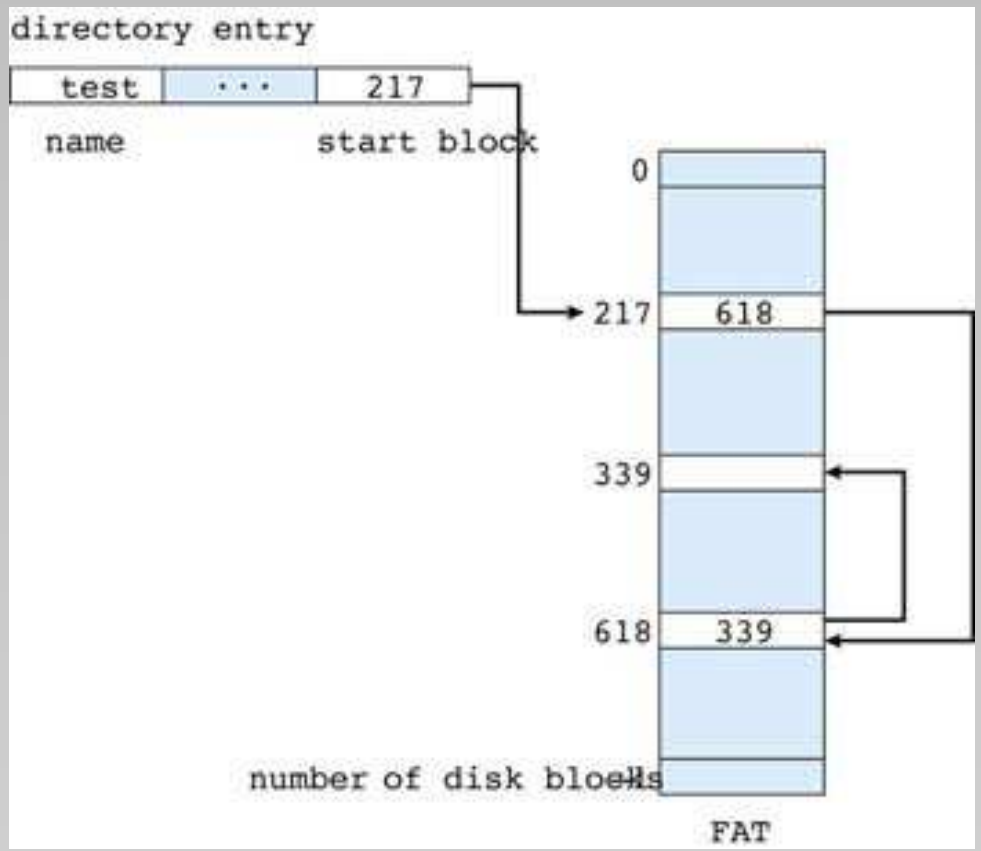

Figure: File allocation table.

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  - With a 20-GB disk and a 1-KB block size, the table needs 20 million entries.
  - Each entry has to be a minimum of 3 bytes. For speed in lookup, they should be 4 bytes.
  - Thus the table will take up 60 MB or 80 MB of main memory all the time.

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- A data structure called an **i-node** (index-node), which lists the attributes and disk addresses of the files blocks (see Fig. 11).

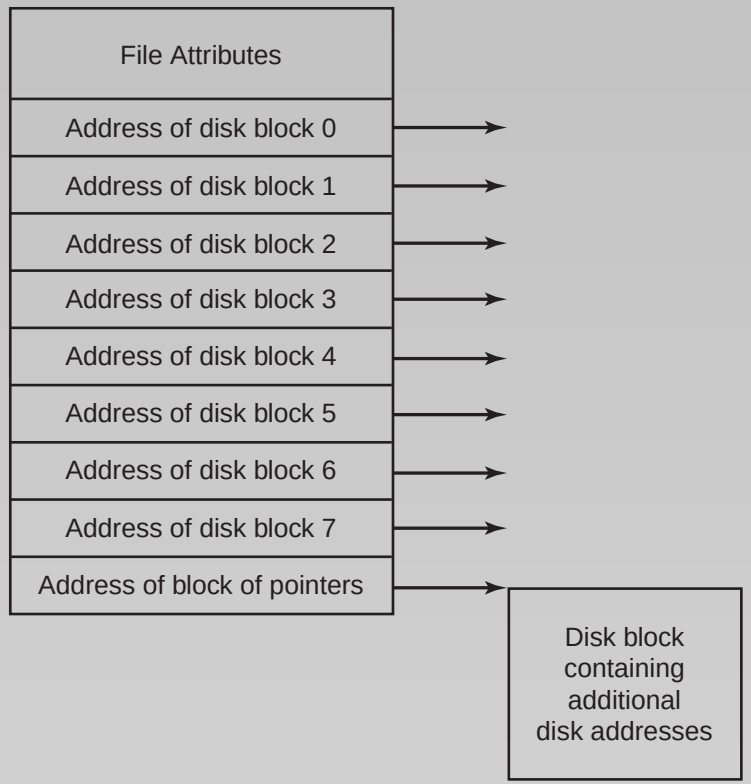

Figure: An example i-node.

Dr. Cem Özdoğan

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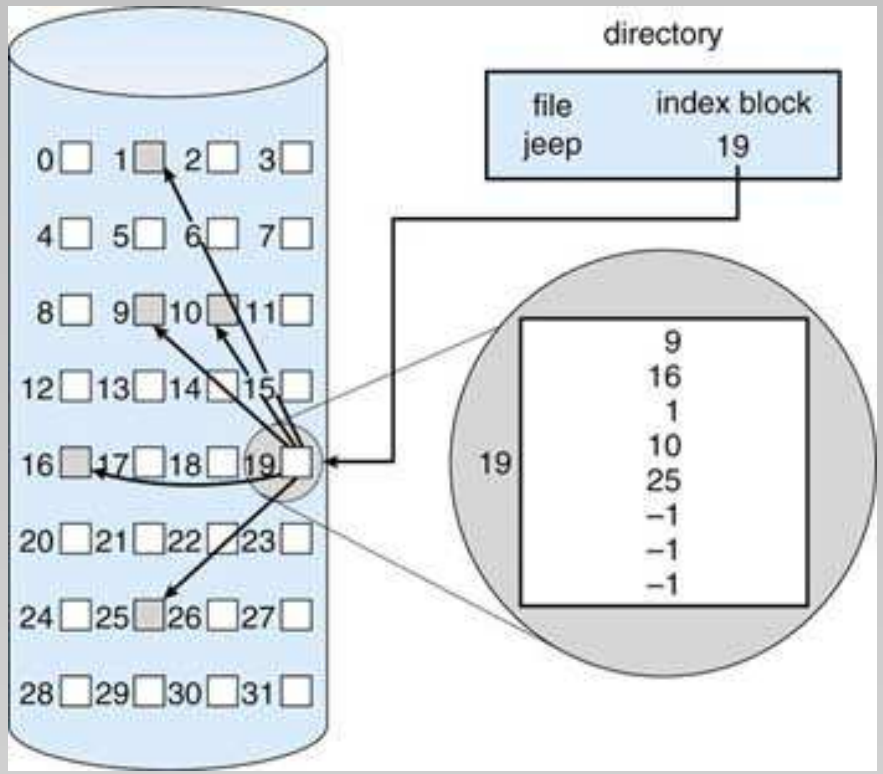
- Each file has its own index block, which is an array of disk-block addresses.
- The i^{th} entry in the index block points to the i^{th} block of the file. The directory contains the address of the index block (see Fig. 12).



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- Let us consider how the path name */usr/ast/mbox* is looked up. The lookup process is illustrated in Fig. 13.

Indexed Allocation IV

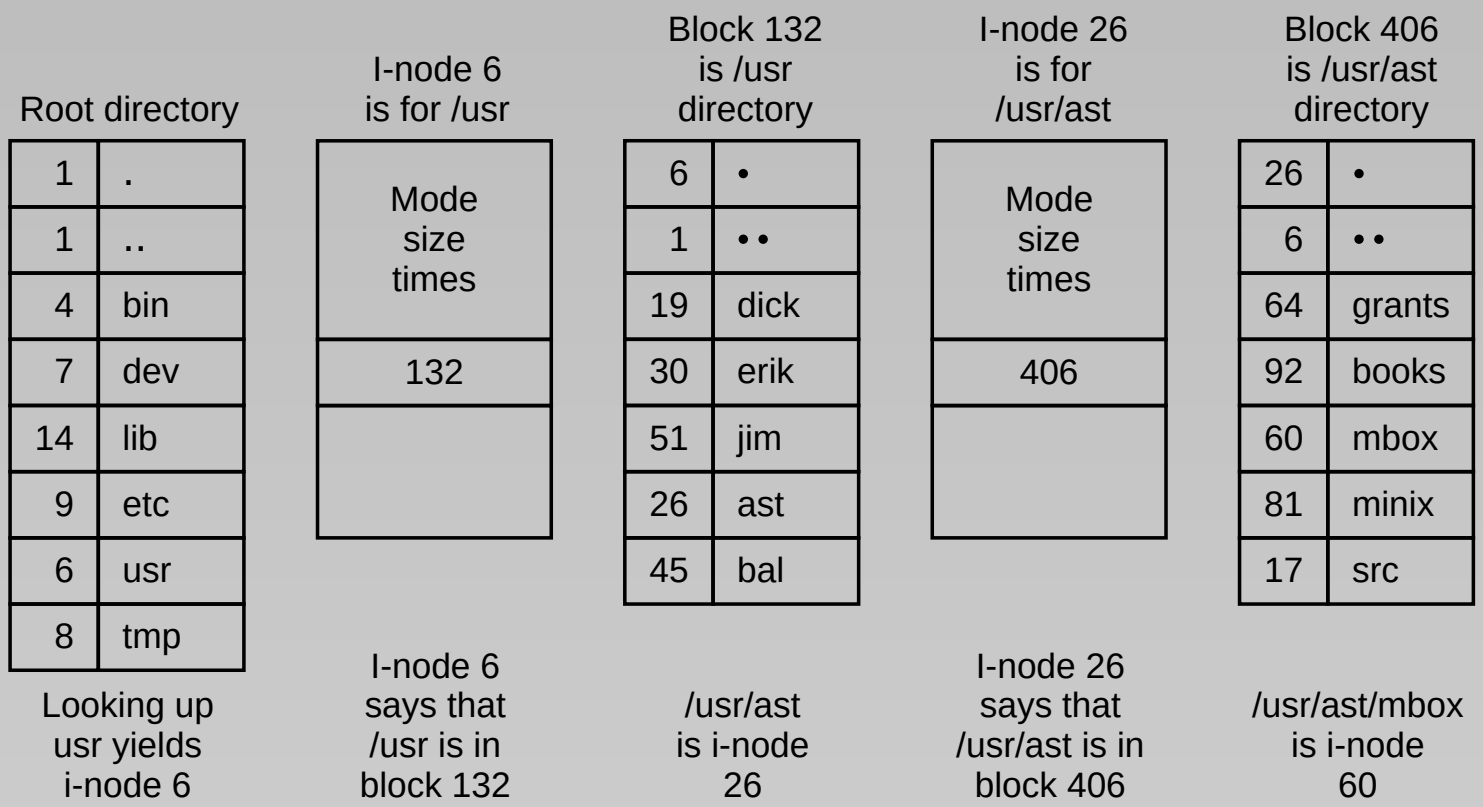

Figure: The steps in looking up */usr/ast/mbox*.

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  - Every file must have an index block, so we want the index block to be as small as possible.
  - If the index block is too small, however, it will not be able to hold enough pointers for a large file, and a mechanism will have to be available to deal with this issue.

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  - With linked allocation, we lose the space of only one pointer per block.
  - With indexed allocation, an entire index block must be allocated, even if only one or two pointers will be *non-nil*.
- This point raises the question of how large the index block should be.
  - Every file must have an index block, so we want the index block to be as small as possible.
  - If the index block is too small, however, it will not be able to hold enough pointers for a large file, and a mechanism will have to be available to deal with this issue.
- Mechanisms for this purpose include the followings.

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  - With 4096-byte blocks, we could store 1024 4-byte pointers in an index block.
  - Two levels of indexes allow 1048576 data blocks and a file size of up to 4 GB.

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  - Under this method, the number of blocks that can be allocated to a file exceeds the amount of space addressable by the 4-byte file pointers used by many OSs (32-bit file pointer: 4 GB).
  - Many UNIX implementations now support up to 64-bit file pointers (terabytes).

Indexed Allocation VIII

A UNIX inode is shown in Fig. 14.

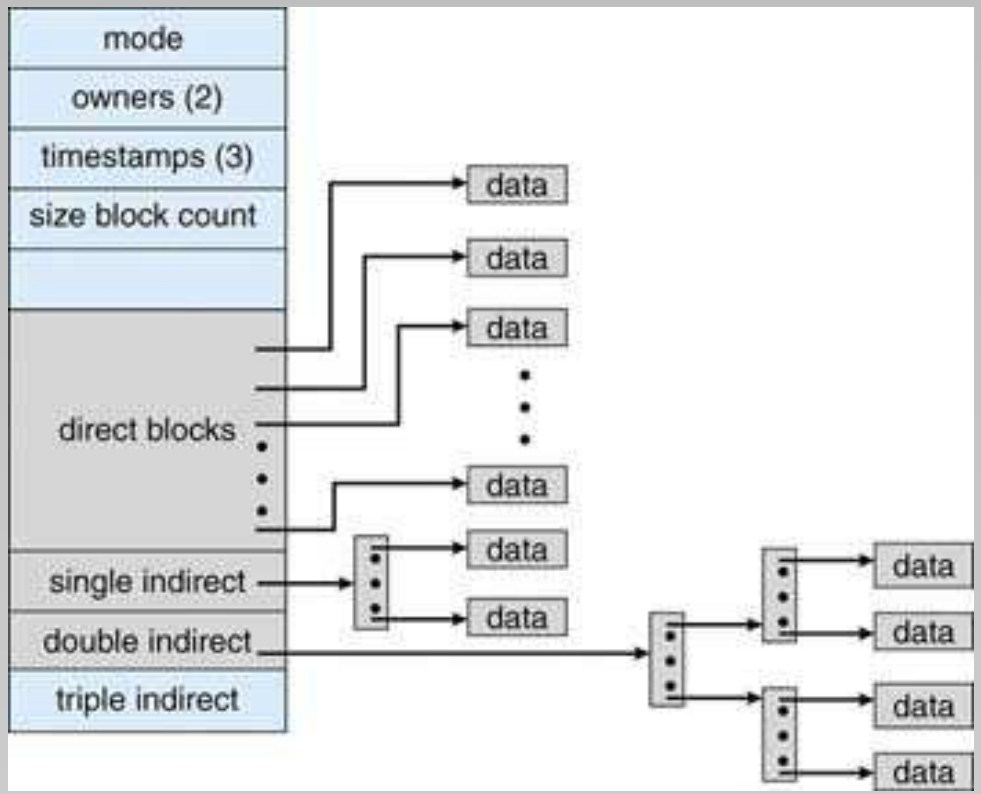

Figure: The UNIX inode.

Bit Vector I

- Frequently, the free-space list is implemented as a **bit map** or **bit vector**.

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  $(40 * 1020 * 1024 * 1024/1024/8/1.024 = 5.12\ MB)$.
- A 500-GB disk with a 1-KB block and a 32-bit (4 bytes) disk block number, we need 488 million bits for the map, which requires just under 60000 1-KB blocks to store $((500x10^9/1KB)/1024/8)$.

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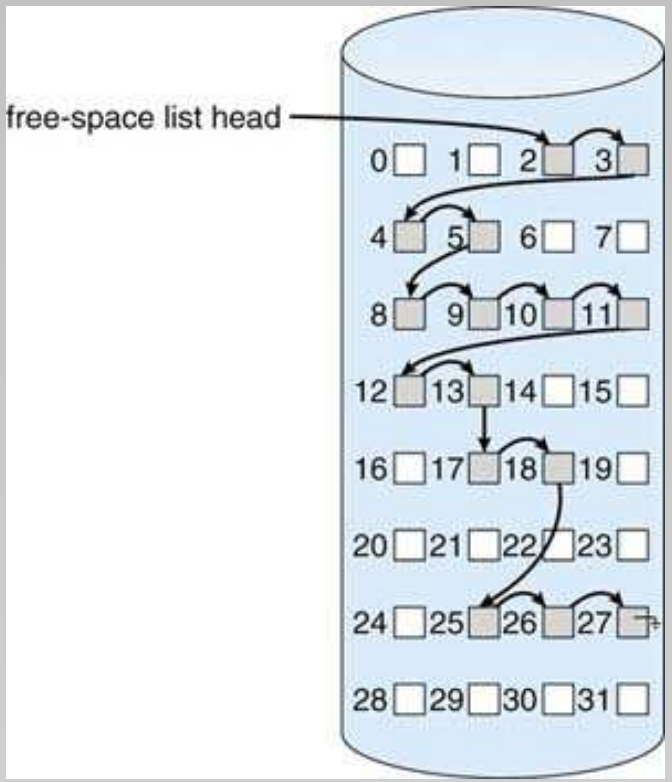

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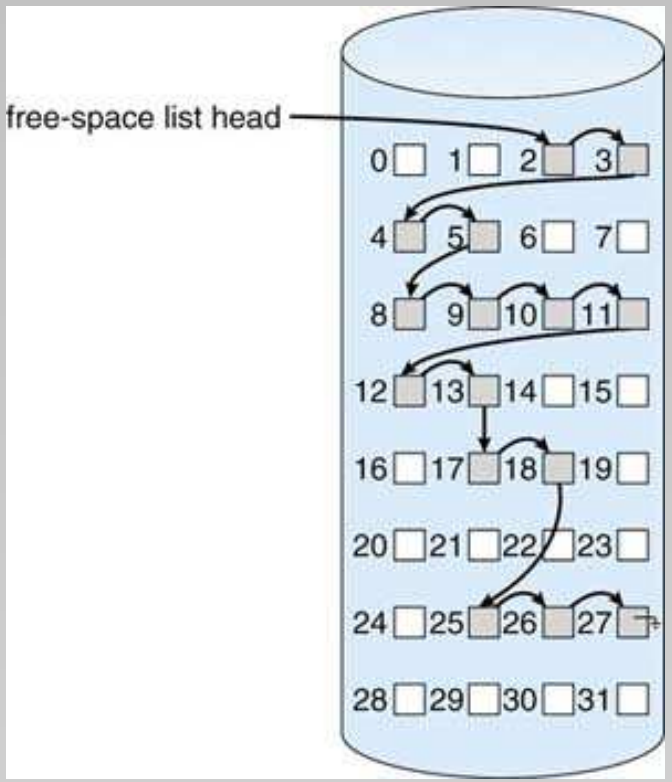

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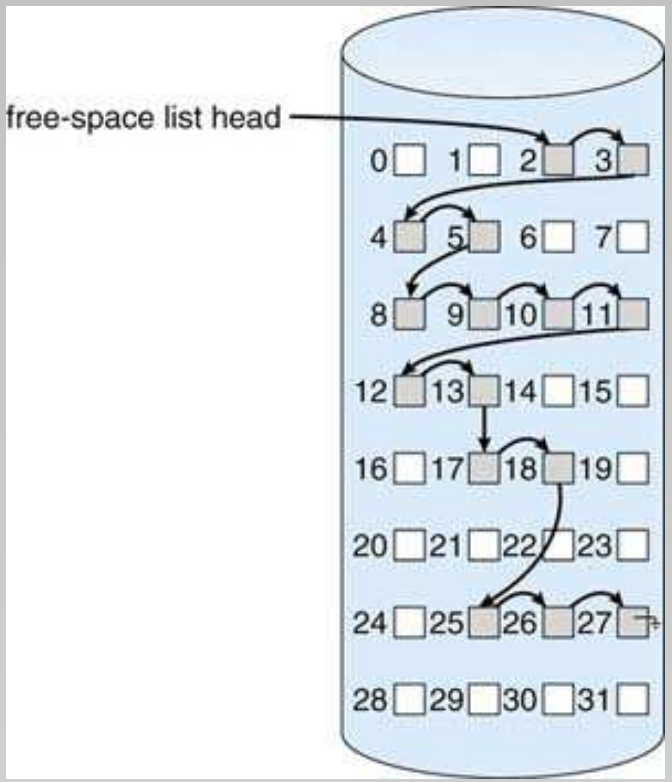

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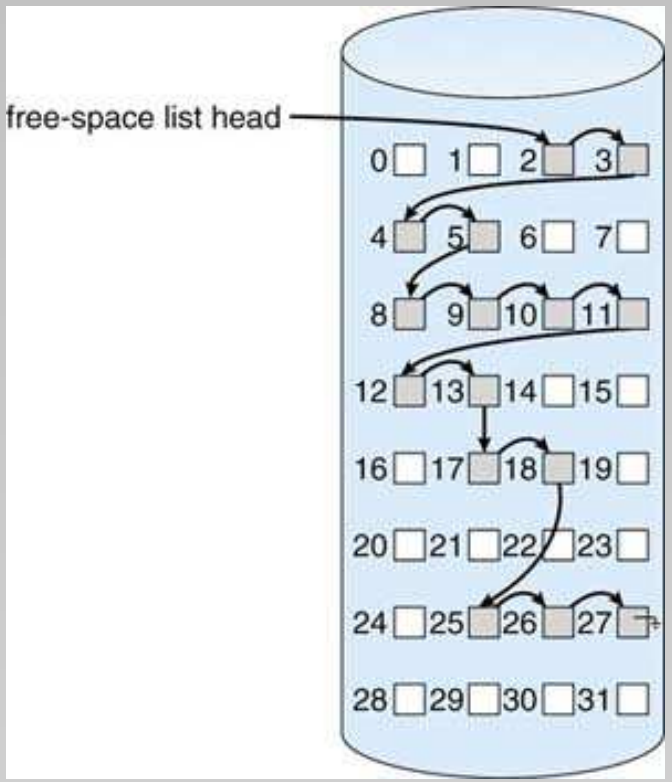

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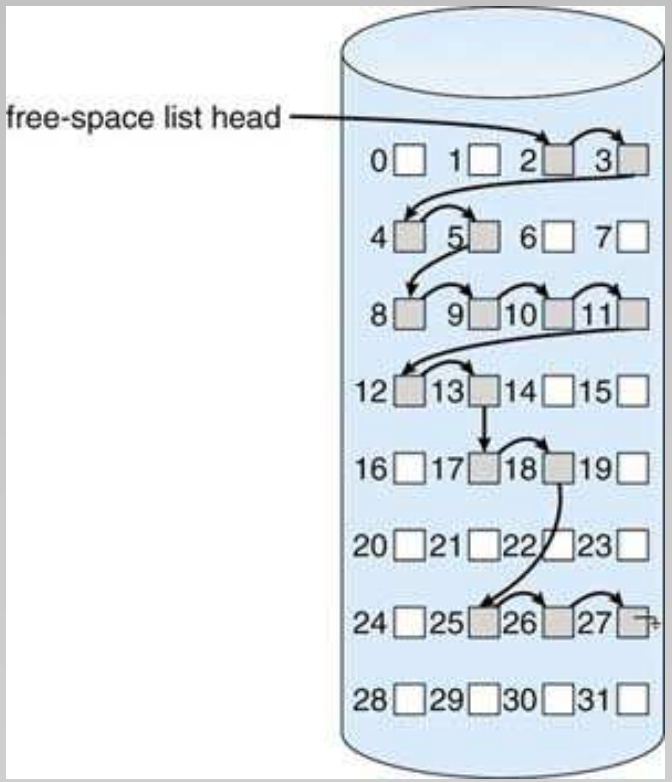

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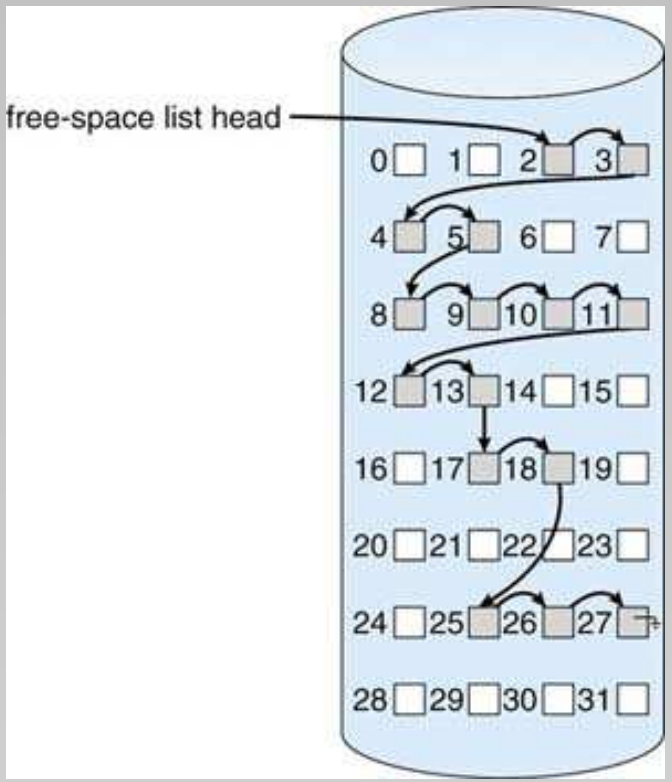

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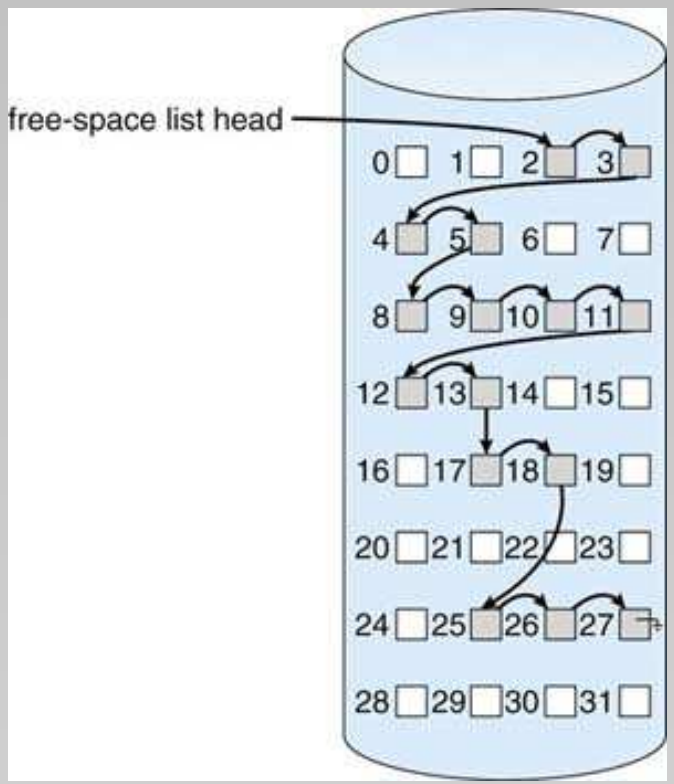

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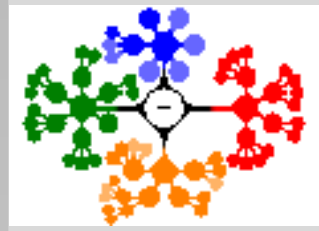

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Keeping it in main memory;

- With a 1-KB block and a 32-bit (4 bytes) disk block number, each block on the free list holds the numbers of 255 free blocks. (1KB/32-bit=256; one slot is needed for the pointer to the next block. The number of blocks that could be addressed:$2^{32} \simeq 4.3x10^{9}$).

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- It is not surprising that the bitmap requires less space (60000 blocks), since it uses 1 bit per block, versus 32 bits in the linked list model. Only if the disk is nearly full (i.e., has few free blocks) will the linked list scheme require fewer blocks than the bitmap.

Linked List III

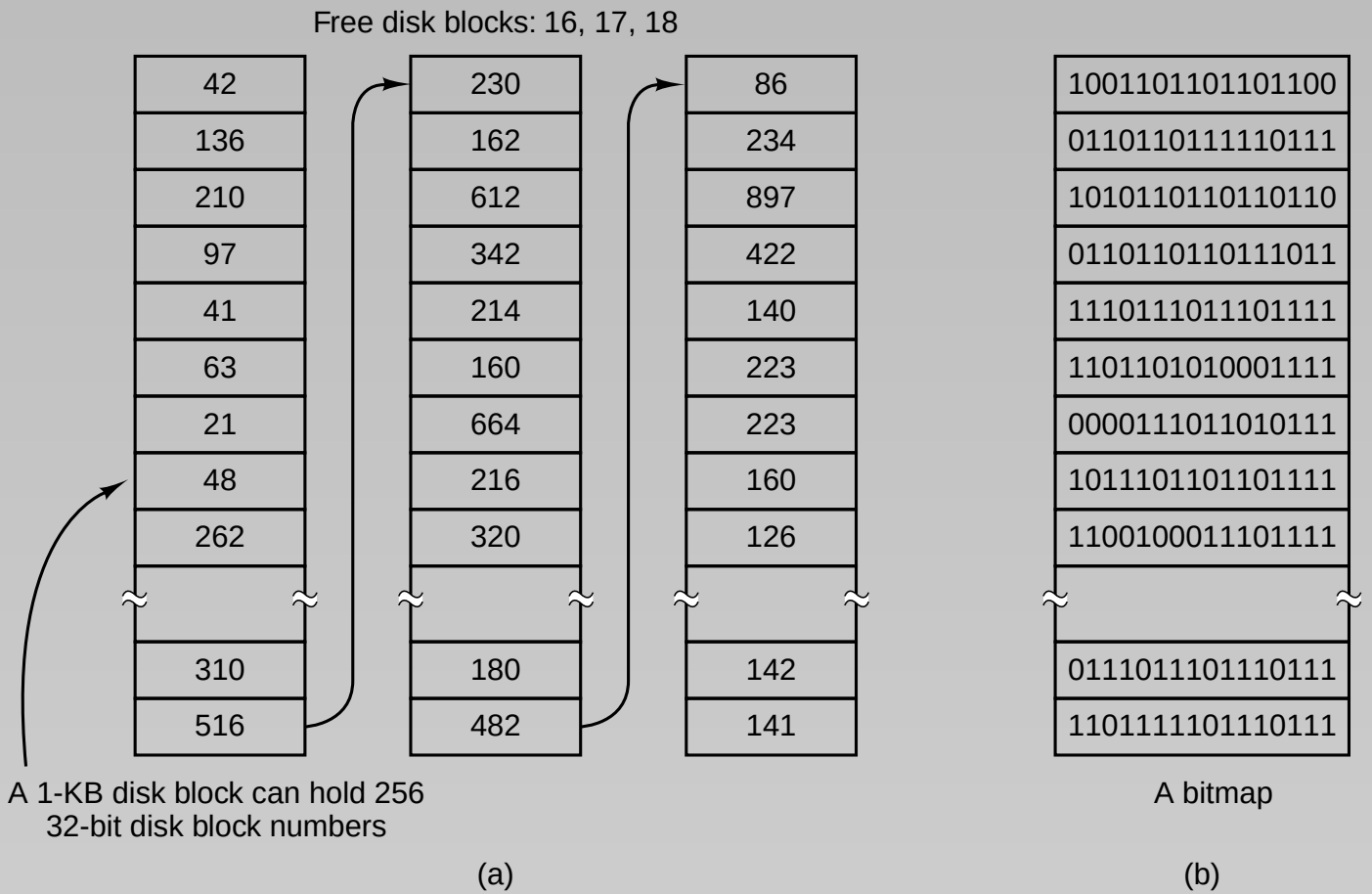

Figure: (a) Storing the free list on a linked list. (b) A bitmap.

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- Small writes are highly inefficient, since a 50-μsec disk write is often preceded by a 10-msec seek and a 4-msec rotational delay.
- With these parameters, disk efficiency drops to a fraction of 1 percent.
- While the writes can be delayed, doing so exposes the file system to serious consistency problems if a crash occurs before the writes are done.

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- Recall that a system crash can cause inconsistencies among on-disk file system data structures, such as directory structures, free-block pointers, and free FCB pointers.

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- For example, the free FCB count might indicate that an FCB had been allocated, but the directory structure might not point to the FCB.

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- Both NTFS and the Veritas (improved UFS) file system use this method, and it is an optional addition to UFS on Solaris 7 and beyond.

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  - This recovery is all that is needed after a crash, eliminating any problems with consistency checking.