UNIT-5

FILE SYSTEM

File System Structure

File System provide efficient access to the disk by allowing data to be stored, located and retrieved in a convenient way. A file System must be able to store the file, locate the file and retrieve the file.

Most of the Operating Systems use layering approach for every task including file systems. Every layer of the file system is responsible for some activities.

Attributes of the File

1)Name

Every file carries a name by which the file is recognized in the file system. One directory cannot have two files with the same name.

2)Identifier

Along with the name, Each File has its own extension which identifies the type of the file. For example, a text file has the extension **.txt,** A video file can have the extension **.mp4.**

3)Type

In a File System, the Files are classified in different types such as video files, audio files, text files, executable files, etc.

4)Location

In the File System, there are several locations on which, the files can be stored. Each file carries its location as its attribute.

5)Size

The Size of the File is one of its most important attribute. By size of the file, we mean the number of bytes acquired by the file in the memory.

6)Protection

The Admin of the computer may want the different protections for the different files. Therefore each file carries its own set of permissions to the different group of Users.

7)Time and Date

Every file carries a time stamp which contains the time and date on which the file is last modified.

Operations on the File

A file is a collection of logically related data that is recorded on the secondary storage in the form of sequence of operations. The content of the files are defined by its creator who is creating the file. The various operations which can be implemented on a file such as read, write, open and close etc. are called file operations.

These operations are performed by the user by using the commands provided by the operating system. Some common operations are as follows:

1)Create operation

This operation is used to create a file in the file system. It is the most widely used operation performed on the file system. To create a new file of a particular type the associated application program calls the file system. This file system allocates space to the file. As the file system knows the format of directory structure, so entry of this new file is made into the appropriate directory.

2)Open operation

This operation is the common operation performed on the file. Once the file is created, it must be opened before performing the file processing operations. When the user wants to open a file, it provides a file name to open the particular file in the file system. It tells the operating system to invoke the open system call and passes the file name to the file system.

3)Write operation

This operation is used to write the information into a file. A system call write is issued that specifies the name of the file and the length of the data has to be written to the file. Whenever the file length is increased by specified value and the file pointer is repositioned after the last byte written.

4)Read operation

This operation reads the contents from a file. A Read pointer is maintained by the OS, pointing to the position up to which the data has been read.

5)Re-position or Seek operation

The seek system call re-positions the file pointers from the current position to a specific place in the file i.e. forward or backward depending upon the user's requirement. This operation is generally performed with those file management systems that support direct access files.

6)Delete operation

Deleting the file will not only delete all the data stored inside the file it is also used so that disk space occupied by it is freed. In order to delete the specified file the directory is searched. When the directory entry is located, all the associated file space and the directory entry is released.

7)Truncate operation

Truncating is simply deleting the file except deleting attributes. The file is not completely deleted although the information stored inside the file gets replaced.

8)Close operation

When the processing of the file is complete, it should be closed so that all the changes made permanent and all the resources occupied should be released. On closing it deallocates all the internal descriptors that were created when the file was opened.

9)Append operation

This operation adds data to the end of the file.

10)Rename operation

This operation is used to rename the existing file.

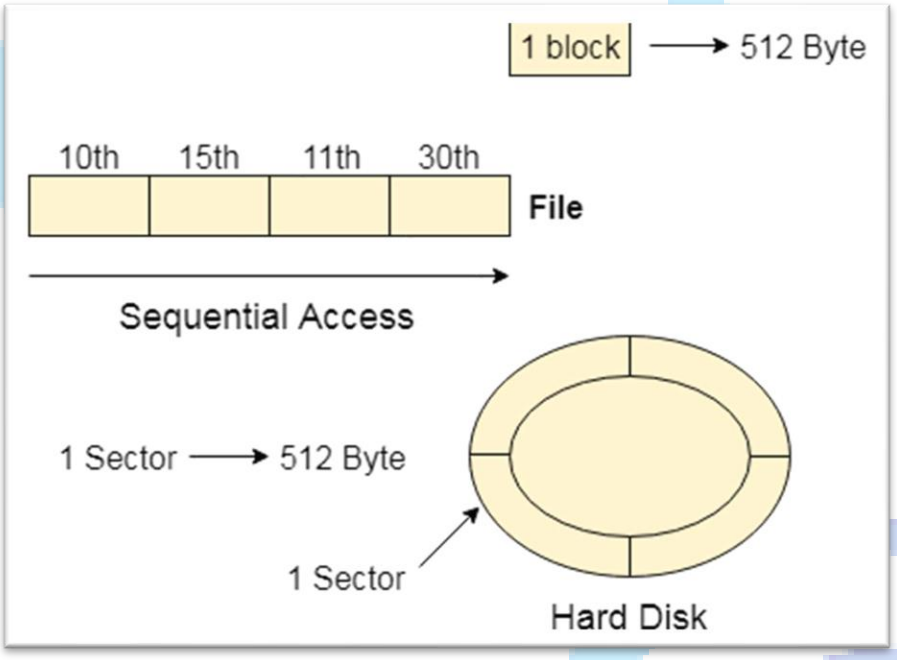
File Access Methods

Let's look at various ways to access files stored in secondary memory.

Those are :

1) Sequential Access
2) Direct Access
3) Index Access

Sequential Access



Most of the operating systems access the file sequentially. In other words, we can say that most of the files need to be accessed sequentially by the operating system.

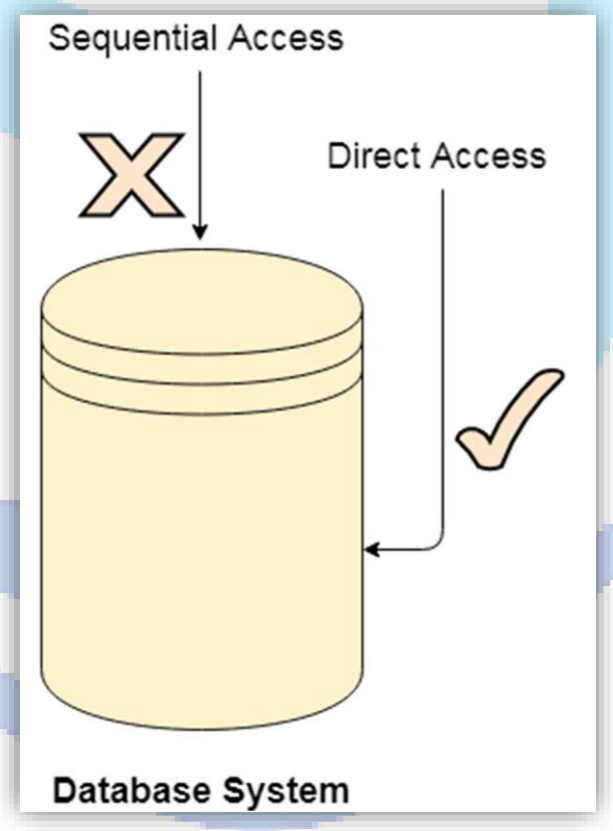
- In sequential access, the OS read the file word by word. A pointer is maintained which initially points to the base address of the file. If the user wants to read first word of the file then the pointer provides that word to the user and increases its value by 1 word. This process continues till the end of the file.
- Modern word systems do provide the concept of direct access and indexed access but the most used method is sequential access due to the fact that most of the files such as text files, audio files, video files, etc need to be sequentially accessed.

Direct Access

The Direct Access is mostly required in the case of database systems. In most of the cases, we needfiltered information from the database. The sequential access can be very slow and inefficient in such cases.

Suppose every block of the storage stores 4 records and we know that the record we needed is stored in 10th block. In that case, the sequential access will not be implemented because it will traverse all the blocks in order to access the needed record.

Direct access will give the required result despite of the fact that the operating system has to perform some complex tasks such as determining the desired block number. However, that is generally implemented in database applications.



Indexed Access

If a file can be sorted on any of the filed then an index can be assigned to a group of certain records. However, A particular record can be accessed by its index. The index is nothing but the address of a record in the file.

In index accessing, searching in a large database became very quick and easy but we need to have some extra space in the memory to store the index value.

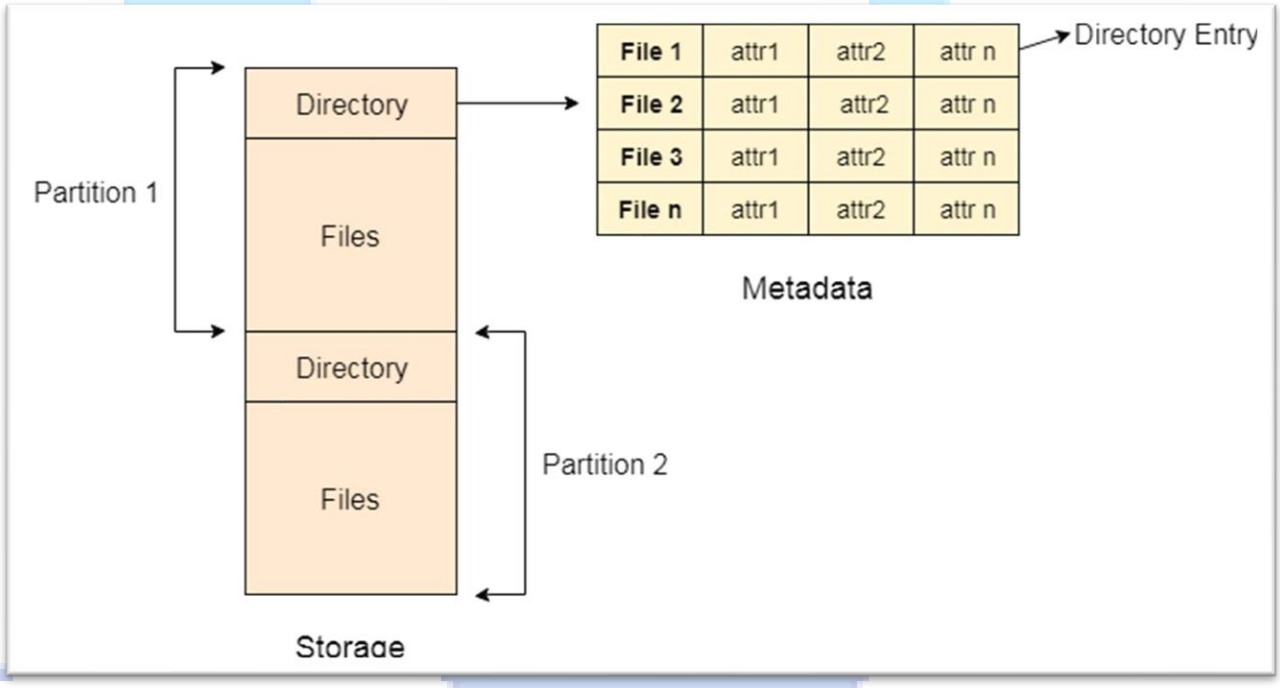
Directory Structure

What is a Directory?

Directory can be defined as the listing of the related files on the disk. The directory may store some or the entire file attributes.

To get the benefit of different file systems on the different operating systems, A hard disk can be divided into the number of partitions of different sizes. The partitions are also called volumes or mini disks.

Each partition must have at least one directory in which, all the files of the partition can be listed. A directory entry is maintained for each file in the directory which stores all the information related to that file.

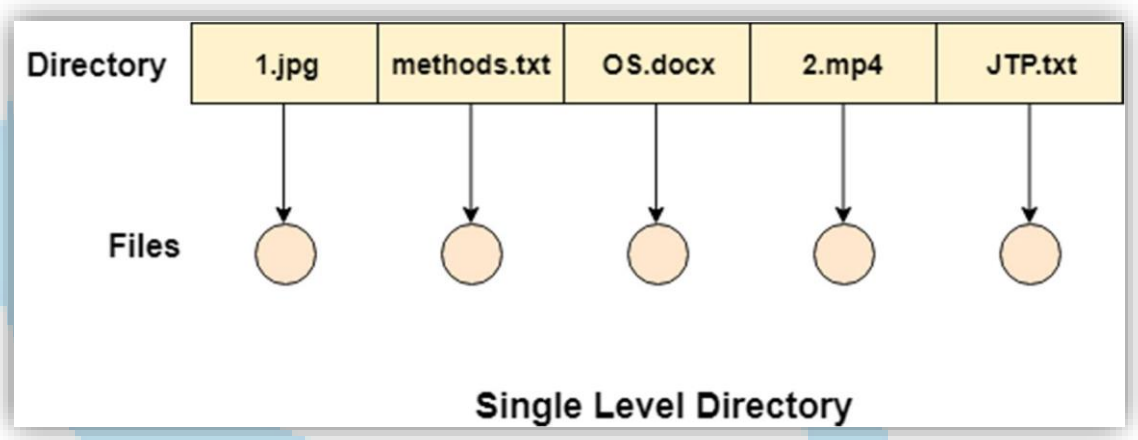


A directory can be viewed as a file which contains the Meta data of the bunch of files. Every Directory supports a number **of common operations** on the file

1) File Creation
2) Search for the file
3) File deletion
4) Renaming the file
5) Traversing Files
6) Listing of files

Single Level Directory

The simplest method is to have one big list of all the files on the disk. The entire system will contain only one directory which is supposed to mention all the files present in the file system. The directory contains one entry per each file present on the file system.



This type of directories can be used for a simple system.

Advantages

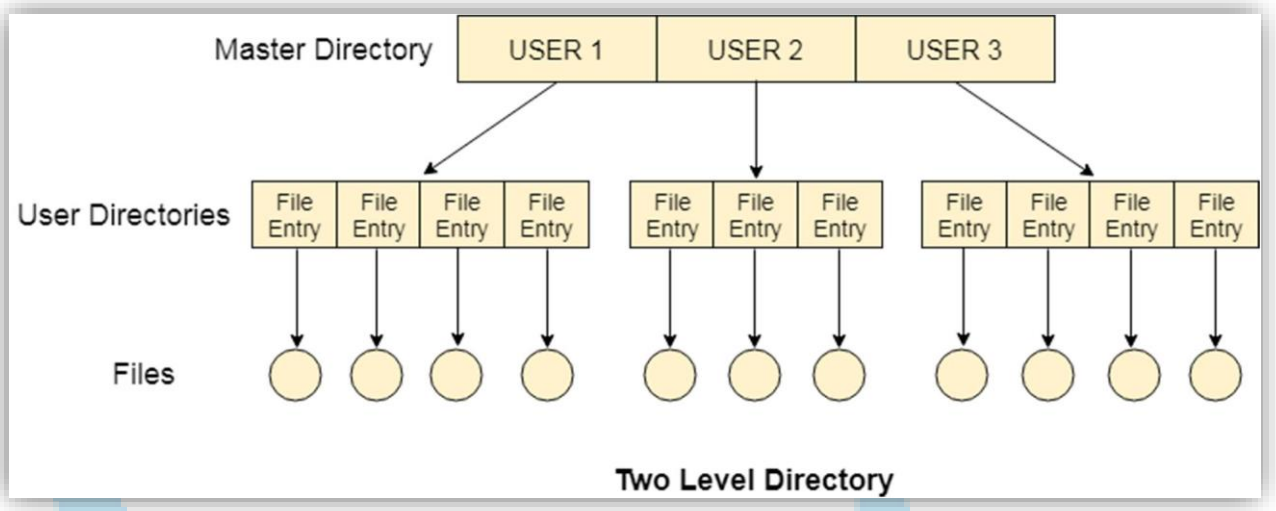
1) Implementation is very simple.
2) If the sizes of the files are very small then the searching becomes faster.
3) File creation, searching, deletion is very simple since we have only one directory.

Disadvantages

1) We cannot have two files with the same name.
2) The directory may be very big therefore searching for a file may take so much time.
3) Protection cannot be implemented for multiple users.
4) There are no ways to group same kind of files.
5) Choosing the unique name for every file is a bit complex and limits the number of files in the system because most of the Operating System limits the number of characters used to construct the file name.

Two Level Directory

In two level directory systems, we can create a separate directory for each user. There is one master directory which contains separate directories dedicated to each user. For each user, there is a different directory present at the second level, containing group of user's file. The system doesn't let a user to enter in the other user's directory without permission.



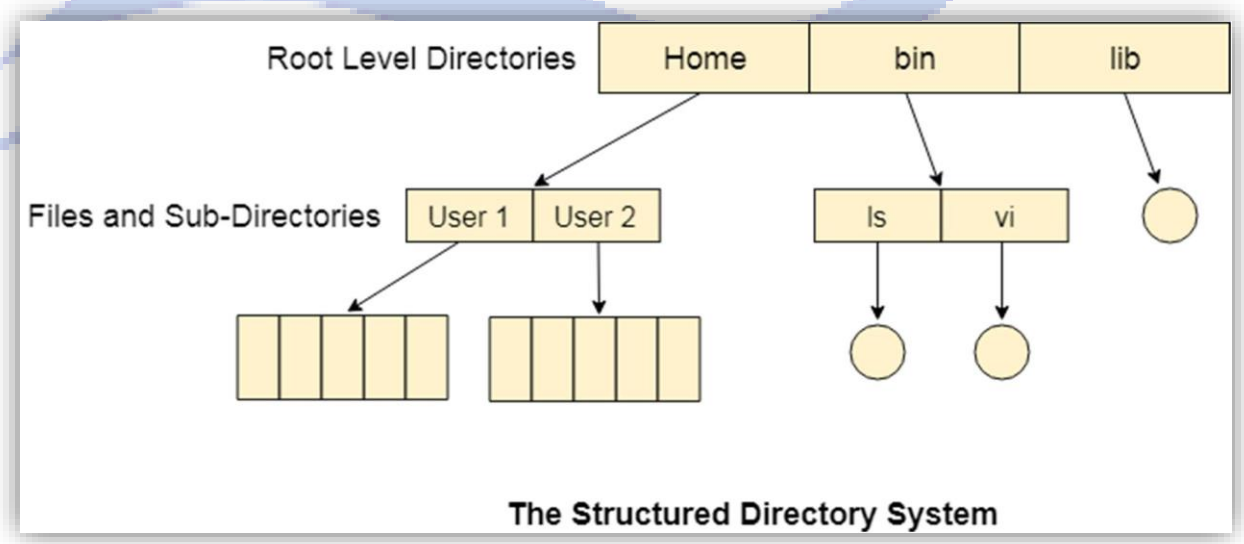
Characteristics of two level directory system

1) Each files has a path name as */User-name/directory-name/*
2) Different users can have the same file name.
3) Searching becomes more efficient as only one user's list needs to be traversed.
4) The same kind of files cannot be grouped into a single directory for a particular user.

Every Operating System maintains a variable as **PWD** which contains the present directory name (present user name) so that the searching can be done appropriately.

Tree Structured Directory

In Tree structured directory system, any directory entry can either be a file or sub directory. Tree structured directory system overcomes the drawbacks of two level directory system. The similar kind of files can now be grouped in one directory.

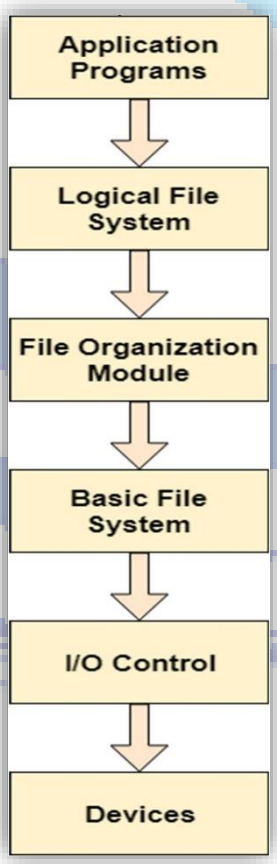


- Each user has its own directory and it cannot enter in the other user's directory. However, the user has the permission to read the root's data but he cannot write or modify this. Only administrator of the system has the complete access of root directory.
- Searching is more efficient in this directory structure. The concept of current working directory is used. A file can be accessed by two types of path, either relative or absolute.
- Absolute path is the path of the file with respect to the root directory of the system while relative path is the path with respect to the current working directory of the system. In tree structured directory systems, the user is given the privilege to create the files as well as directories.

File System Structure

File System provide efficient access to the disk by allowing data to be stored, located and retrieved in a convenient way. A file System must be able to store the file, locate the file and retrieve the file.

Most of the Operating Systems use layering approach for every task including file systems. Every layer of the file system is responsible for some activities.



The image shown above, elaborates how the file system is divided in different layers, and also the functionality of each layer.

- When an application program asks for a file, the first request is directed to the logical file system. The logical file system contains the Meta data of the file and directory structure. If the application program doesn't have the required permissions of the file then this layer will throw an error. Logical file systems also verify the path to the file.
- Generally, files are divided into various logical blocks. Files are to be stored in the hard disk and to be retrieved from the hard disk. Hard disk is divided into various tracks and sectors. Therefore, in order to store and retrieve the files, the logical blocks need to be mapped to physical blocks. This mapping is done by File organization module. It is also responsible for free space management.
- Once File organization module decided which physical block the application program needs, it passes this information to basic file system. The basic file system is responsible for issuing the commands to I/O control in order to fetch those blocks.

File Allocation Methods

The allocation methods define how the files are stored in the disk blocks. There are three main disk space or file allocation methods.

1) Contiguous Allocation
2) Linked Allocation
3) Indexed Allocation

The main idea behind these methods is to provide:

- Efficient disk space utilization.
- Fast access to the file blocks.

All the three methods have their own advantages and disadvantages as discussed below

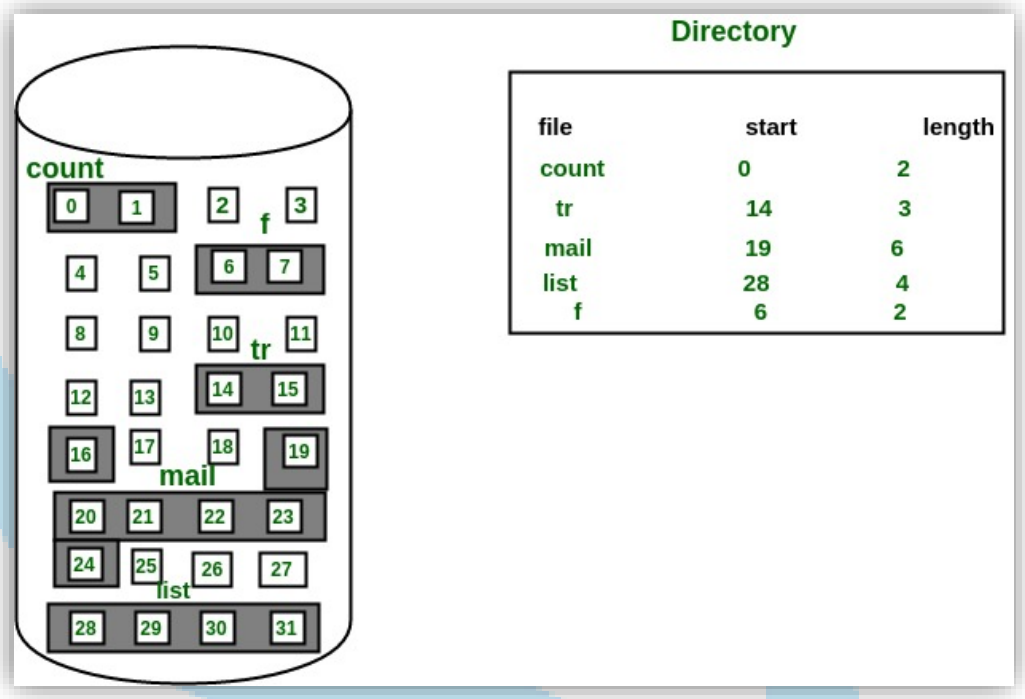
1)Contiguous Allocation

In this scheme, each file occupies a contiguous set of blocks on the disk. For example, if a file requires n blocks and is given a block b as the starting location, then the blocks assigned to the file will be: *b, b+1, b+2,……b+n- 1.* This means that given the starting block address and the length of the file (in terms of blocks required), we can determine the blocks occupied by the file.

The directory entry for a file with contiguous allocation contains

Address of starting block and Length of the allocated portion.

The *file 'mail'* in the following figure starts from the block 19 with length = 6 blocks. Therefore, it occupies 19,20,21,22,23,24 blocks.



Advantages

- Both the Sequential and Direct Accesses are supported by this. For direct access, the address of the kth block of the file which starts at block b can easily be obtained as (b+k).
- This is extremely fast since the number of seeks are minimal because of contiguous allocation of file blocks.

Disadvantages

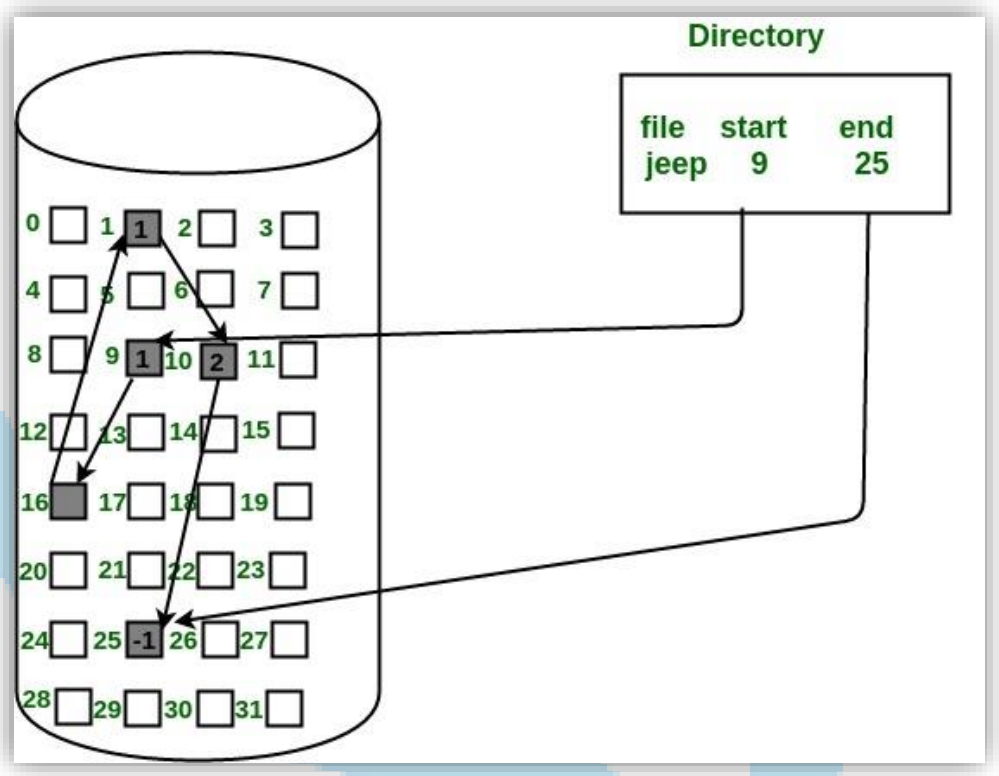
- This method suffers from both internal and external fragmentation. This makes it inefficient in terms of memory utilization.
- Increasing file size is difficult because it depends on the availability of contiguous memory at a particular instance.

2) Linked List Allocation

In this scheme, each file is a linked list of disk blocks which need not be contiguous. The disk blocks can be scattered anywhere on the disk.

The directory entry contains a pointer to the starting and the ending file block. Each block contains a pointer to the next block occupied by the file.

The file 'jeep' in following image shows how the blocks are randomly distributed. The last block (25) contains -1 indicating a null pointer and does not point to any other block.



Advantages

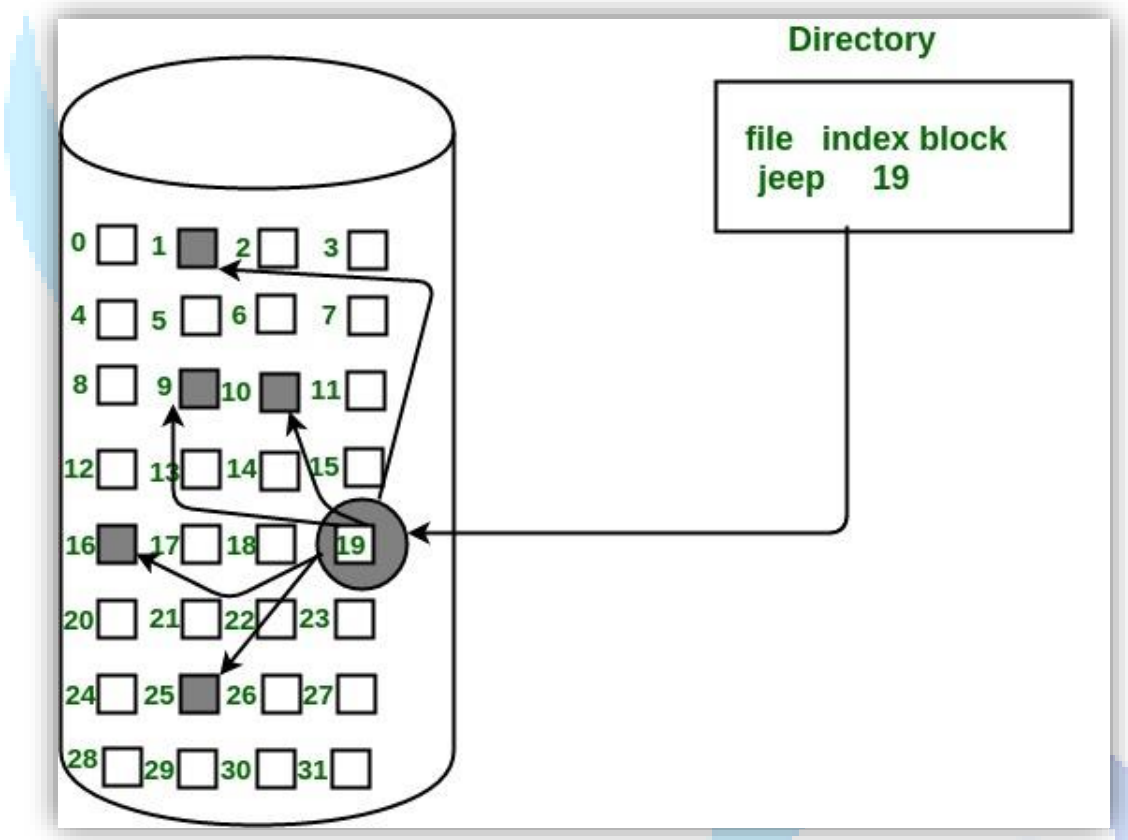
- This is very flexible in terms of file size. File size can be increased easily since the system does not have to look for a contiguous chunk of memory.
- This method does not suffer from external fragmentation. This makes it relatively better in terms of memory utilization.

Disadvantages

- Because the file blocks are distributed randomly on the disk, a large number of seeks are needed to access every block individually. This makes linked allocation slower.
- It does not support random or direct access. We can not directly access the blocks of a file. A block k of a file can be accessed by traversing k blocks sequentially (sequential access) from the starting block of the file via block pointers.
- Pointers required in the linked allocation incur some extra overhead.

3)Indexed Allocation

In this scheme, a special block known as the Index block contains the pointers to all the blocks occupied by a file. Each file has its own index block. The ith entry in the index block contains the disk address of the ith file block. The directory entry contains the address of the index block as shown in the image:



Advantages

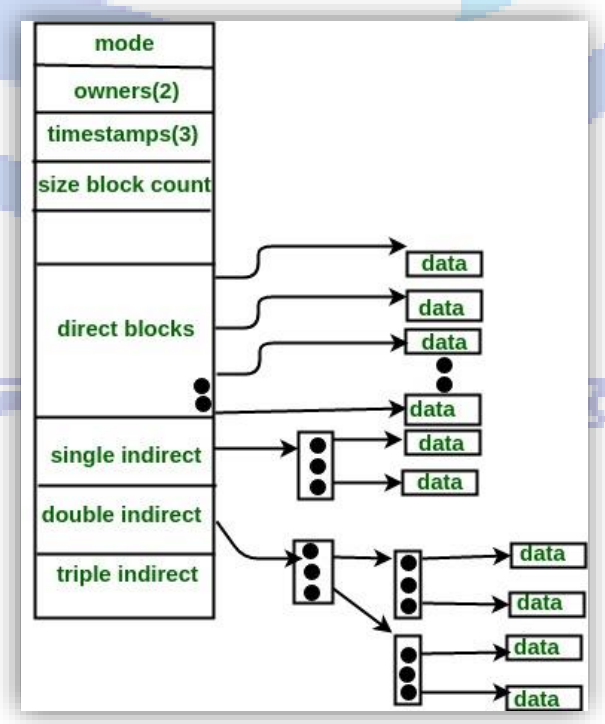
- This supports direct access to the blocks occupied by the file and therefore provides fast access to the file blocks.
- It overcomes the problem of external fragmentation.

Disadvantages

- The pointer overhead for indexed allocation is greater than linked allocation.
- For very small files, say files that expand only 2-3 blocks, the indexed allocation would keep one entire block (index block) for the pointers which is inefficient in terms of memory utilization. However, in linked allocation we lose the space of only 1 pointer per block.

For files that are very large, single index block may not be able to hold all the pointers. Following mechanisms can be used to resolve this:

1) **Linked scheme:** This scheme links two or more index blocks together for holding the pointers. Every index block would then contain a pointer or the address to the next index block.
2) **Multilevel index:** In this policy, a first level index block is used to point to the second level index blocks which in turn points to the disk blocks occupied by the file. This can be extended to 3 or more levels depending on the maximum file size.
3) **Combined Scheme:** In this scheme, a special block called the **Inode (information Node)** contains all the information about the file such as the name, size, authority, etc and the remaining space of Inode is used to store the Disk Block addresses which contain the actual file *as shown in the image below.*
   - The first few of these pointers in Inode point to the **direct blocks** i.e the pointers contain the addresses of the disk blocks that contain data of the file.
   - The next few pointers point to indirect blocks. Indirect blocks may be single indirect, double indirect or triple indirect.
   - **Single Indirect block** is the disk block that does not contain the file data but the disk address of the blocks that contain the file data. Similarly, **double indirect blocks** do not contain the file data but the disk address of the blocks that contain the address of the blocks containing the file data.



Protection in File System

In computer systems, a lot of user's information is stored, the objective of the operating system is to keep safe the data of the user from the improper access to the system. Protection can be provided in number of ways. For a single laptop system, we might provide protection by locking the computer in a desk drawer or file cabinet. For multi-user systems, different mechanisms are used for the protection.

Types of Access :

The files which have direct access of the any user have the need of protection. The files which are not accessible to other users doesn't require any kind of protection. The mechanism of the protection provide the facility of the controlled access by just limiting the types of access to the file. Access can be given or not given to any user depends on several factors, one of which is the type of access required. Several different types of operations can be controlled:

1) Read – Reading from a file.
2) Write – Writing or rewriting the file.
3) Execute – Loading the file and after loading the execution process starts.
4) Append – Writing the new information to the already existing file, editing must be end at the end of the existing file.
5) Delete – Deleting the file which is of no use and using its space for the another data.
6) List – List the name and attributes of the file.

Operations like renaming, editing the existing file, copying; these can also be controlled. There are many protection mechanism. each of them mechanism have different advantages and disadvantages and must be appropriate for the intended application.

Access Control

There are different methods used by different users to access any file. The general way of protection is to associate identity-dependent access with all the files and directories an list called access-control list (ACL) which specify the names of the users and the types of access associate with each of the user. The main problem with the access list is their length. If we want to allow everyone to read a file, we must list all the users with the read access. This technique has two undesirable consequences:

Constructing such a list may be tedious and unrewarding task, especially if we do not know in advance the list of the users in the system.

Previously, the entry of the any directory is of the fixed size but now it changes to the variable size which results in the complicates space management. These problems can be resolved by use of a condensed version of the access list. To condense the length of the access-control list, many systems recognize three classification of users in connection with each file:

- Owner – Owner is the user who has created the file.
- Group – A group is a set of members who has similar needs and they are sharing the same file.
- Universe – In the system, all other users are under the category called universe.

The most common recent approach is to combine access-control lists with the normal general owner, group, and universe access control scheme. For example: Solaris uses the three categories of access by default but allows access-control lists to be added to specific files and directories when more fine-grained access control is desired.

Other Protection Approaches

The access to any system is also controlled by the password. If the use of password is random and it is changed often, this may be result in limit the effective access to a file.

The use of passwords has a few disadvantages:

- The number of passwords are very large so it i difficult to remember the large passwords.
- If one password is used for all the files, then once it is discovered, all files are accessible; protection is on all-or-none basis.

Free Space Management

Free space management is a critical aspect of operating systems as it involves managing the available storage space on the hard disk or other secondary storage devices. The operating system uses various techniques to manage free space and optimize the use of storage devices. Here are some of the commonly used free space management techniques:

1) Linked Allocation: In this technique, each file is represented by a linked list of disk blocks. When a file is created, the operating system finds enough free space on the disk and links the

blocks of the file to form a chain. This method is simple to implement but can lead to fragmentation and wastage of space.

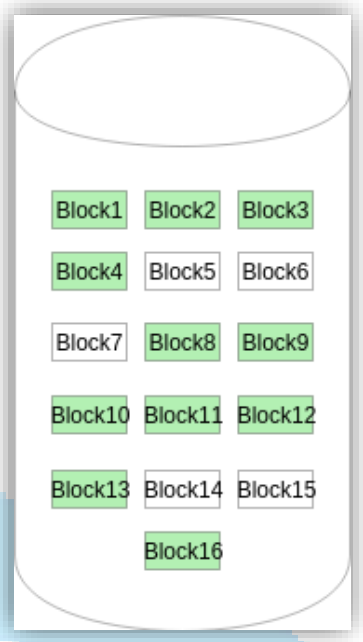
2) Contiguous Allocation: In this technique, each file is stored as a contiguous block of disk space. When a file is created, the operating system finds a contiguous block of free space and assigns it to the file. This method is efficient as it minimizes fragmentation but suffers from the problem of external fragmentation.
3) Indexed Allocation: In this technique, a separate index block is used to store the addresses of all the disk blocks that make up a file. When a file is created, the operating system creates an index block and stores the addresses of all the blocks in the file. This method is efficient in terms of storage space and minimizes fragmentation.
4) File Allocation Table (FAT): In this technique, the operating system uses a file allocation table to keep track of the location of each file on the disk. When a file is created, the operating system updates the file allocation table with the address of the disk blocks that make up the file. This method is widely used in Microsoft Windows operating systems.
5) Volume Shadow Copy: This is a technology used in Microsoft Windows operating systems to create backup copies of files or entire volumes. When a file is modified, the operating system creates a shadow copy of the file and stores it in a separate location. This method is useful for data recovery and protection against accidental file deletion.

Overall, free space management is a crucial function of operating systems, as it ensures that storage devices are utilized efficiently and effectively.

The system keeps tracks of the free disk blocks for allocating space to files when they are created. Also, to reuse the space released from deleting the files, free space management becomes crucial. The system maintains a free space list which keeps track of the disk blocks that are not allocated to some file or directory. The free space list can be implemented mainly as:

1) Bitmap or Bit vector
2) Linked List
3) Grouping
4) Counting

1)Bitmap or Bit vector – A Bitmap or Bit Vector is series or collection of bits where each bit corresponds to a disk block. The bit can take two values: 0 and 1: *0 indicates that the block is allocated* and 1 indicates a free block. The given instance of disk blocks on the disk in *Figure 1* (where green blocks are allocated) can be represented by a bitmap of 16 bits as: **0000111000000110.**



Advantages

- Simple to understand.
- Finding the first free block is efficient. It requires scanning the words (a group of 8 bits) in a bitmap for a non-zero word. (A 0-valued word has all bits 0). The first free block is then found by scanning for the first 1 bit in the non-zero word.

2)Linked List – In this approach, the free disk blocks are linked together i.e. a free block contains a pointer to the next free block. The block number of the very first disk block is stored at a separate location on disk and is also cached in memory.

In *below*, the free space list head points to Block 5 which points to Block 6, the next free block and so on. The last free block would contain a null pointer indicating the end of free list. A drawback of this method is the I/O required for free space list traversal.

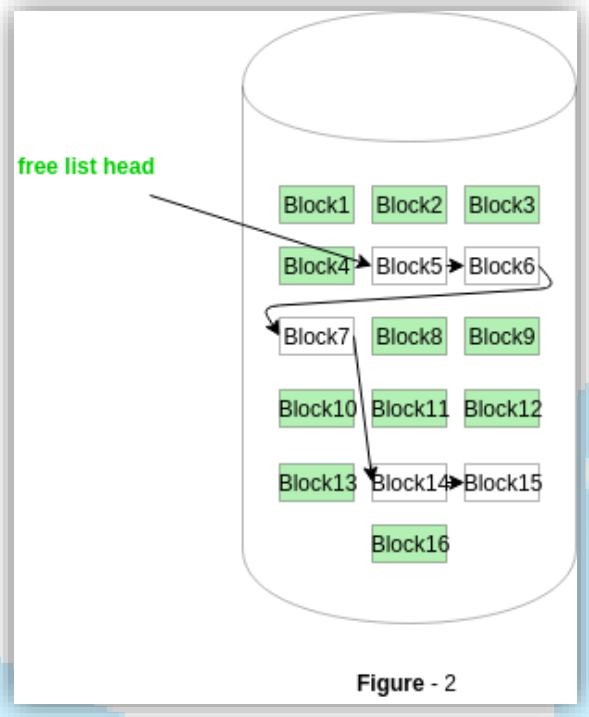


Figure - 2

3)Grouping – This approach stores the address of the free blocks in the first free block. The first free block stores the address of some, say n free blocks. Out of these n blocks, the first n-1 blocks are actually free and the last block contains the address of next free n blocks. An **advantage** of this approach is that the addresses of a group of free disk blocks can be found easily.

4)Counting – This approach stores the address of the first free disk block and a number n of free contiguous disk blocks that follow the first block. Every entry in the list would contain:

1) Address of first free disk block
2) A number n

Here are some advantages and disadvantages of free space management techniques in operating systems:

Advantages

1) Efficient use of storage space: Free space management techniques help to optimize the use of storage space on the hard disk or other secondary storage devices.
2) Easy to implement: Some techniques, such as linked allocation, are simple to implement and require less overhead in terms of processing and memory resources.
3) Faster access to files: Techniques such as contiguous allocation can help to reduce disk fragmentation and improve access time to files.

Disadvantages

1) Fragmentation: Techniques such as linked allocation can lead to fragmentation of disk space, which can decrease the efficiency of storage devices.
2) Overhead: Some techniques, such as indexed allocation, require additional overhead in terms of memory and processing resources to maintain index blocks.
3) Limited scalability: Some techniques, such as FAT, have limited scalability in terms of the number of files that can be stored on the disk.
4) Risk of data loss: In some cases, such as with contiguous allocation, if a file becomes corrupted or damaged, it may be difficult to recover the data.
5) Overall, the choice of free space management technique depends on the specific requirements of the operating system and the storage devices being used. While some techniques may offer advantages in terms of efficiency and speed, they may also have limitations and drawbacks that need to be considered.