File System

- Users make use of computers to create, store, retrieve and manipulate information.
- The file abstraction provides a uniform logical view of physical contents from a wide variety of storage devices that have different characteristics.
- A file in a computer system has a name for its identification, space to store data, a location for convenient access, access restrictions and other attributes and support mechanisms.

- OS implements a software layer on top of the I/O subsystem (device drivers) for users to access data with ease from storage devices. The software layer is called the file management system or file system.
- The file management system contains files, directories and control information (metadata) and supports convenient and secured access on files and directories.

The functions of file system are

- Organization of files
- Execution of file operations
- Synchronization of file operations
- Protection of file contents
- Management of space in the file system.

File concepts

File

- A file is a named collection of related information that is recorded on secondary storage such as magnetic disks, magnetic tapes and optical disks which normally represents programs and data.
- In general, a file is a sequence of bits, bytes, lines or records whose meaning is defined by the files creator and user.

Naming

- A symbolic file name given to a file, for the convenience of users, is a string of characters. When a file is named, it is independent of the process, the user and the system it created. It is the only information kept in human readable form.

File structure

- A file has a certain defined structure, which depends on its type of information stored in the file, like source program, object programs, executable programs, numeric data, text, payroll records, graphic images etc.
    - A text file is a sequence of characters organized into lines.
    - A source file is a sequence of procedures and functions.
    - An object file is a sequence of bytes organized into blocks that are understandable by the machine.
    - When operating system defines different file structures, it also contains the code to support these file structure.

Attributes define the characteristics of a file varying with respect to OS and useful for protection, security and usage monitoring.

The following are the file attributes:

- *Name*: The symbolic file name is the only information kept in human readable form
- *Type*: This information is needed for those systems that support different types.
- *Location*: It is a pointer to a device used to the location of the file on that device.
- *Size*: The current size of the file (in bytes, words or blocks) and possibly the maximum allowed size are included in this attribute.
- *Protection*: Access control information controls who can do reading, writing, executing and so on.
- *Time*, *Date* and *User Identification*: This information may be kept for creation, last modification and last use.

Logical file structure

There are three possible forms of atomic units in a file.

- *Bytes*: File is a sequence of bytes called as flat file. (No internal structure)
- *Fixed length record*: Many OS require files to be divided into fixed length records. Each record is a collection of information about one thing. Easy to deal with but do not reflect the realities of data.
- *Variable length records*: These are used to meet the various workload lengths but the problem is unless the location of the file is known it is hard to perform search operation. To overcome this problem keyed file is used. Each record has a specified field which is the key field which is used for finding the location of the file.

File Meta data

- A file contains information, but the file system also keeps information about the file,
- i.e. meta data (information about information) such as Name, Type, Size and Owner of the file; Group(s) of users that have special access to the file; Access rights; Last Read time; Last Written time; The time of the file was created; which disk the file is stored on and where the file is stored on disk.

File Types

File type refers to the ability of the operating system to distinguish different types of file such as text files source files and binary files etc. The file system supports various classes of file types. A file may or may not have certain internal structure depending on its type.

Many operating systems support many types of files. Operating system like MS-DOS and UNIX have the following types of files −

Ordinary files

  - These are the files that contain user information.
  - These may have text, databases or executable program.
  - The user can apply various operations on such files like add, modify, delete or even remove the entire file.

- Directory files
  - These files contain list of file names and other information related to these files.

Special files

- These files are also known as device files.
- These files represent physical device like disks, terminals, printers, networks, tape drive etc.
- These files are of two types −
    - **Character special files** − data is handled character by character as in case of terminals or printers.
    - **Block special files** − data is handled in blocks as in the case of disks and tapes.

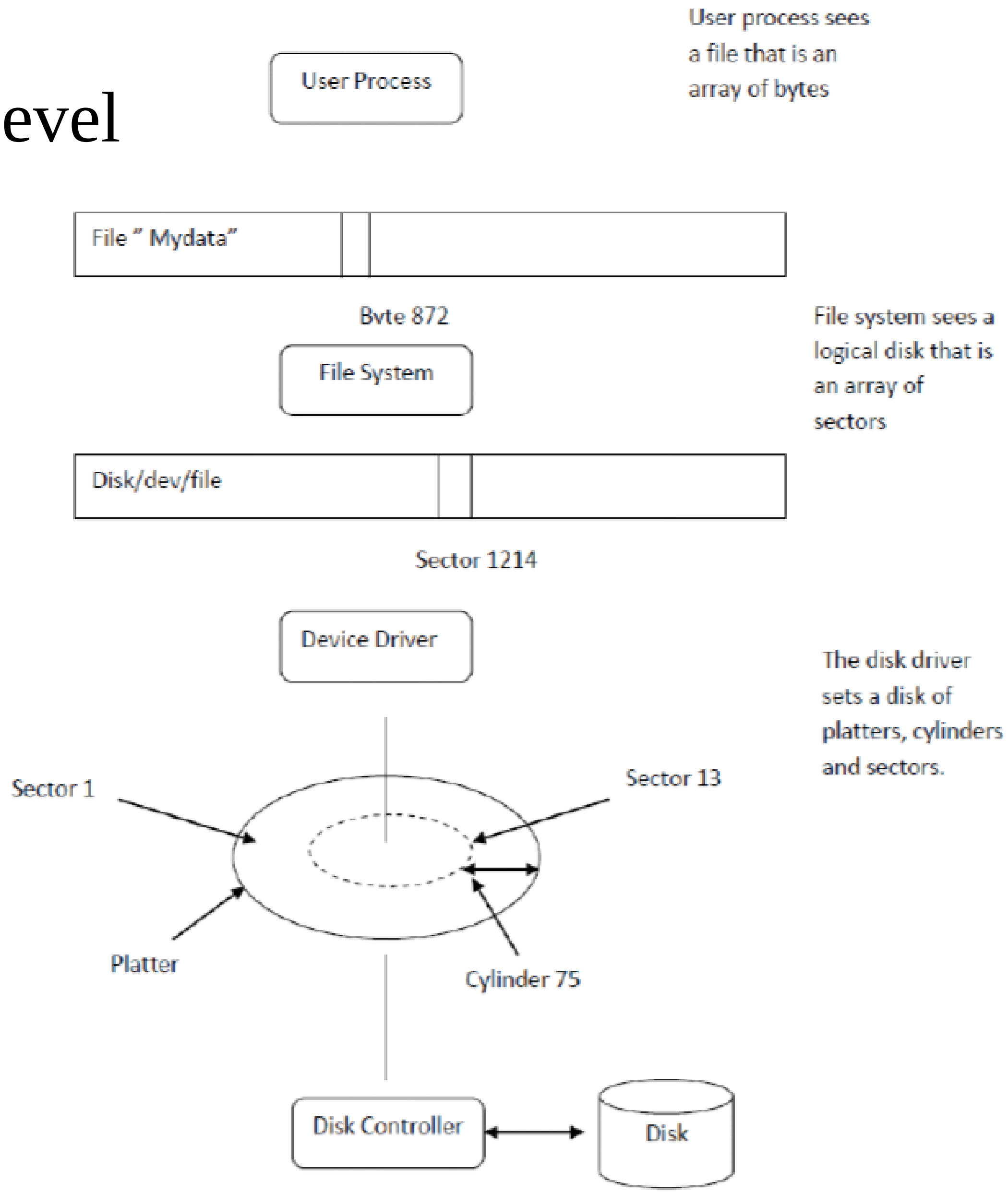
File System

The file system consists of two distinct parts:

i) a collection of files, each storing related data and

ii) a directory structure which organizes and provide information about all the files in the system.

view of a file at each level



User process sees a file that is an array of bytes

File system sees a logical disk that is an array of sectors

The disk driver sets a disk of platters, cylinders and sectors.

File operations

Create:

- Essential if a system is to add files. Need not be a separate system call (can be merged with open).
- Requires the name of the file/directory being created, the name of the directory and some file attributes. Two steps are necessary to create a file:
- space in the file system must be found for the file.
- an entry for the new file must be made in the directory i.e. the directory entry records the name of the file and the location in the file system.

Delete:

- Essential if a system is to delete files.
- Requires the file/directory name to be deleted. To delete a file, the directory is searched for the named file and having found the associated directory entry, all file spaces are released and the directory entry is erased.

Open

- Not essential. An optimization in which the translation from file name to disk locations is perform only once per file rather than once per access.
- Open operation requires a filename to be opened. File system checks for permission to access the file and if the user has the permission, it creates a file descriptor that will be used by the application for future reference.

Close:

- Not essential. Free resources.
- The close operation requires a file descriptor that was obtained in the open operation. It releases the file descriptor and other related resources allocated for the open file session.

Read

- Essential. Must specify filename, file location, number of bytes, and a buffer into which the data is to be placed. Several of these parameters can be set by other system calls and in many OS's they are.
- A system call is issued that specifies the name of the file and where in the memory the file should be put for reading.
- A read operation takes as parameters file descriptor, a positive integer number and a buffer address.
- The operation copies into the buffer those many number of consecutive bytes starting at the current file pointer position from the file. It repositions the file pointer past the last byte it read.

Write

- Essential if updates are to be supported.
- A system call is made specifying both the name of the file and the information to be written to the file.
- A write operation takes as parameters a file descriptor, a byte string and the size of the string. The byte string is written in the file identified by the file descriptor.
- It overwrites the file content starting at the current file pointer position within the file. It allocates more space to the file when it needs to write past the current last byte in the file. It repositions the file pointer after the last byte written.

Truncate

- To erase the contents of the file but keep attributes same, truncating can be used i.e. attributes of the file remain same but the length of the file is reset to zero.
- A truncate operation takes as its parameters a file descriptor and a positive integer number. It reduces the size of the corresponding file to the specified number. If needed, it frees up space from the file.

Memory map

- Memory mapping a file creates a region in the process address space, and each byte in the region corresponds to a byte in the file.
- Conventional memory read and write operations on the mapped sections by applications are treated by the system as file read and write operations respectively.
- When the mapped file is closed, all the modified data are written back to the file and the file is unmapped from the process address space.

File Pointer

- On systems that do not include a file offset as part of the read and write system calls, the system must track the last read / write location as current file position pointer.
- This pointer is unique to each process operating on the file, and therefore must be kept separate from the disk file attributes.

Reposition

- adjusts a file pointer to a new offset. The operation takes a file descriptor and an offset as parameters and sets the associated file pointer to the offset. The directory is searched for the appropriate entry and current file position is set to a given value.

Seek

- Not essential (could be in read/write). Specify the offset of the next (read or write) access to this file. Repositioning within a file does not needed to involve any actual I/O. This file operation is also known as file seek.

Directory

Directories

Files in an OS are generally named using a hierarchical naming system based on directories. Almost all OS use a hierarchical naming system. In such a system, a path name consists of component names separated with a separator character.

- A directory is a name space and the associated name maps each name into either a file or another directory.
- Directories contain bookkeeping information about files.
- Directories are usually implemented as files and in OS point of view there is no distinction between files and directories.

Directory operations

- Create: Produces an ``empty'' directory. Normally the directory created actually contains . and .., so is not really empty
- Delete: Requires the directory to be empty (i.e., to just contain . and ..). Commands are normally written that will first empty the directory (except for . and ..) and then delete it. These commands make use of file and directory delete system calls.
- Opendir: Same as for files (creates a ``handle'')
- Closedir: Same as for files
- Readdir: In the old days (of unix) one could read directories as files so there was no special readdir (or opendir/closedir). It was believed that the uniform treatment would make programming (or at least system understanding) easier as there was less to learn.
- Rename: As with files
- Link: Add a second name for a file;
- Unlink: Remove a directory entry. But if there are many links and just one is unlinked, the file remains.

- The structure of the directories and the relationship among them are the main areas where file systems tend to differ, and it is also the area that has the most significant effect on the user interface provided by the file system.
- The most common directory structures used by multi-user systems are:
  - **Single-level directory**
  - **Two-level directory**
  - **Tree-structured directory**
  - **Acyclic directory**

Single-Level Directory

- In a single-level directory system, all the files are placed in one directory. This is very common on single-user OS's.
- Limitations
  - Unique name is a problem

    More number of files

    More than one user

Two-Level Directory

- In the two-level directory system, the system maintains a master block that has one entry for each user. This master block contains the addresses of the directory of the users.

Limitations

- This structure effectively isolates one user from another. This is an advantage when the users are completely independent, but a disadvantage when the users want to cooperate on some task and access files of other users.

Tree-Structured Directory

- In the tree-structured directory, the directory themselves are files. This leads to the possibility of having sub-directories that can contain files and sub-subdirectories.

Limitations

- An interesting policy decision in a tree-structured directory structure is how to handle the deletion of a directory.
- If a directory is empty, its entry in its containing directory can simply be deleted.
- However, suppose the directory to be deleted id not empty, but contains several files, or possibly sub-directories.
- Some systems will not delete a directory unless it is empty.

Acyclic-Graph Directory

- The acyclic directory is an extension of the tree-structured directory structure. In the tree-structured directory, files and directories starting from some fixed directory are owned by one particular user.
- In the acyclic structure, this prohibition is taken out and thus a directory or file under directory can be owned by several users.

Path Name

- An absolute path name is a name that gives the path from the root directory to the file that is named.
- When hierarchical file system is used, the absolute path may be long if many levels of subdirectories are present.
- Hierarchical naming system use compound names with several parts. Each part is looked up in a flat name space usually called a directory. If this look up leads to another directory, then the next part of the compound name is looked up in that directory.
- To reduce the length of the path name, working/current directory concept is used. This allows the use of relative path names.
- A relative path name is a path name that starts at the working directory rather than the root directory.

Aliases

- Hierarchical directory systems provide a means for classifying and grouping files.
- All the files in a single directory tend to be related in some way, but sometimes a file is related to several different groups and it is an inconvenient restriction to have no place it in just one group.
- This problem can be handled with the concept of a file alias. It is a file name that refers to a file that also has another name. There may be two or more absolute path names.

File Access Mechanisms

File access mechanism refers to the manner in which the records of a file may be accessed. There are several ways to access files −

Sequential access

Direct/Random access

Indexed sequential access

Sequential access

A sequential access is that in which the records are accessed in some sequence, i.e., the information in the file is processed in order, one record after the other. This access method is the most primitive one. Example: Compilers usually access files in this fashion.

Direct/Random access

Random access file organization provides, accessing the records directly.

Each record has its own address on the file with by the help of which it can be directly accessed for reading or writing.

The records need not be in any sequence within the file and they need not be in adjacent locations on the storage medium.

Indexed sequential access

This mechanism is built up on base of sequential access.

An index is created for each file which contains pointers to various blocks.

Index is searched sequentially and its pointer is used to access the file directly.