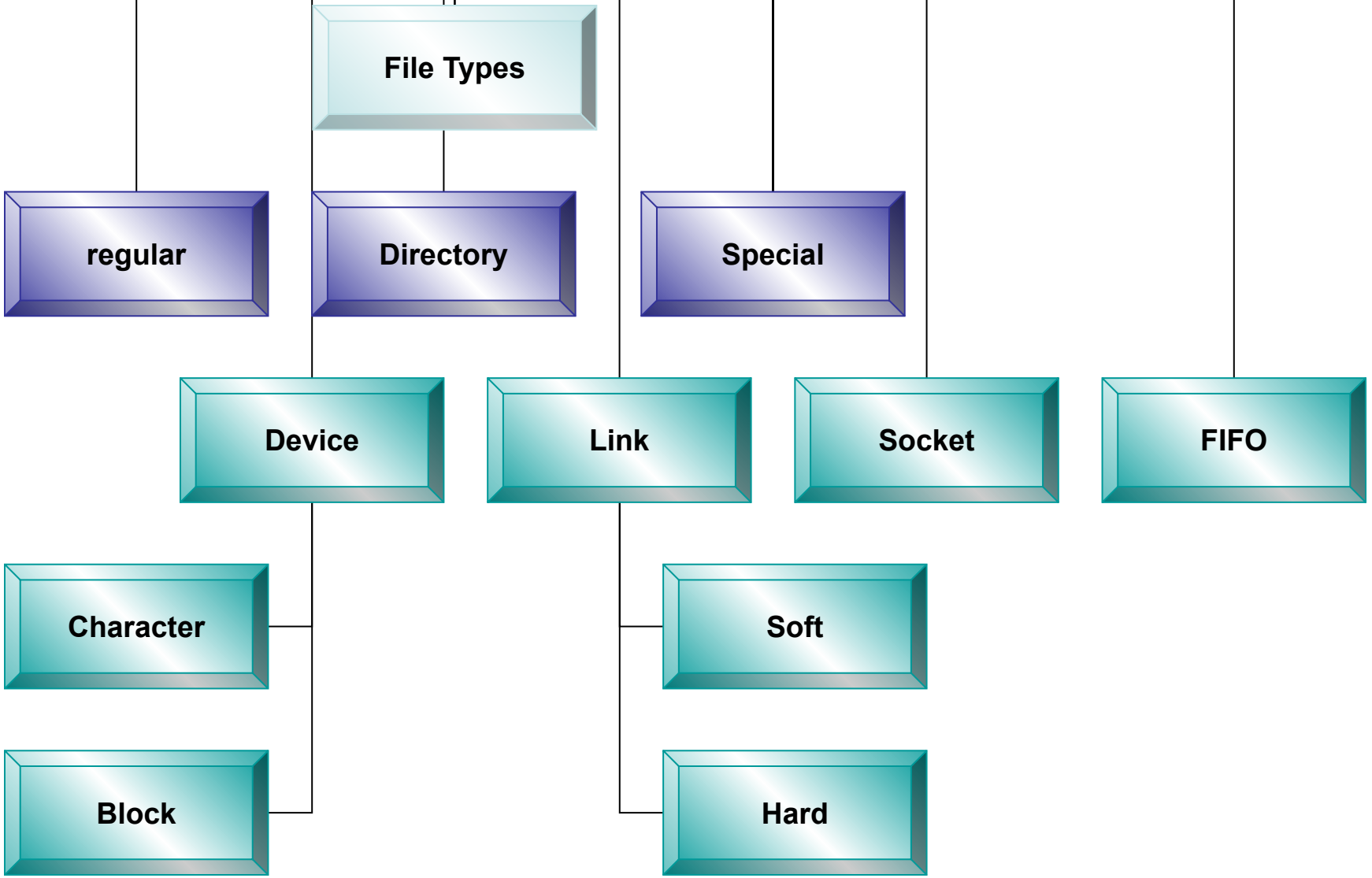
UNIT 2

UNIX FILES

- Files are building blocks in an operating system
- Execution of command causes file to be searched in file system and loading instruction text to the memory.
- Design of an os begins with efficient file management system

File Types


File Types
regular
Directory
Special
Device
Link
Socket
FIFO
Character
Block
Soft
Hard

FILE TYPES

- Regular file
- Directory file
- Fifo file
- Character device file
- Block device file
- Link file
- Socket file

Regular file

- It may be text or binary file
- There is no distinction between these two type of files in UNIX
- Both the files are executable provided execution rights are set
- They can be read or written by users with appropriate permissions
- Can be created with text editors and compilers
- To remove regular files use rm command

Directory file

- It is like a Folder that contains other files and subdirectories
- Provides a means for users to organize files in hierarchical structure based on file relationship or use
- To create a directory file use mkdir command
  mkdir /usr/foo/xyz
- To remove a directory file use rmdir command
  rmdir /usr/foo/xyz
- Every directory contains two special files . And ..

Device Files

- Two types

1. Block device file

- Physical device which transmits data a block at a time

EX: hard disk drive, floppy disk drive

2. Character device file :

- Physical device which transmits data in a character- based manner

EX: line printers, modems, consoles

- Application program may perform read and write operations on device file in the same manner as on regular file

Device Files

- **A physical device can have both character and block device file**
- **To create a device file use mknod command**
  mknod /dev/cdsk c 115 5
  /dev/cdsk : name of the device
  c ---character device b --- block device
  115 — major device number
  5 — minor device number
- **Major device number : an index to the kernel's file table that contains address of all device drivers**
- **Minor device number : tells the driver function what actual physical device it is talking to and I/O buffering scheme used for data transfer**

FIFO file

- Special pipe device file which provides a temporary buffer for two or more processes to communicate by writing data to and reading data from the buffer.
- The size of the buffer associated with a FIFO file is fixed to PIPE_BUF
- The buffer associated with a FIFO file is allocated when the first process opens the FIFO file for read or write
- The buffer is discarded when all the processes referencing the FIFO close their reference .hence the data storage is temporary
- The file exists as long as there is one process which has a direct connection to the FIFO file for data access

FIFO file

- To create a FIFI file use mkfifo OR mkfifo

  mkfifo /usr/prog/fifo_pipe

  mknod /usr/prog/fifo_pipe p

- A fifo file can be removed like any other regular file

Symbolic link file

- A symbolic link file contains a pathname which references another file in either the local or a remote file system

- To create : ln command with –s option

  ln –s /usr/satish/original /usr/ravi/slink

  cat -n /usr/ravi/slink

  /*will print contents of /usr/satish/original file*/

UNIX and POSIX file systems

- They have a tree-like hierarchical file system

- "/" – denotes the root
- "." – current directory
- ".." – parent directory

- NAME_MAX – max number of characters in a file name

- PATH_MAX -- max number of characters in a path name

- The pathname of a file is called hard link

Common UNIX files

- /etc : Stores system administrative files & programs
- /etc/passwd : Stores all user information
- /etc/shadow : Stores user passwords
- /etc/group : Stores all group information
- /bin : Stores all system programs
- /dev : Stores all character and block device files
- /usr/include : Stores standard header files
- /usr/lib : Stores standard libraries
- tmp : Stores all temporary files created by programs

UNIX and POSIX file attributes

- File type : type of file
- Access permission :the file access permission for owner group and others
- Hard link count : number of hard links of a file
- UID : the file owner user ID
- GID : the file group ID

- File size : the file size in bytes
- Last access time : the time the file was last accessed
- Last modify time : the time the file was last modified
- Last change time : the time the file access permission UID GID or hard link count was last changed

UNIX and POSIX file attributes

- Inode number : the system inode number of the file
- File system ID : the file system ID where the file is stored
- File attributes can be listed with ls –l
- File size is not having any meaning for device files
- File attributes are assigned by the kernel when the file is crated

Attributes of a file that remain unchanged

- File type
- File inode number
- File system ID
- Major and minor device number

File attributes that are changed using UNIX commands or system calls

UNIX command	System call	Attributes changed
chmod	chmod	Changes access permission, last change time
chown	chown	Changes UID, last change time
chgrp	chown	Changes GID, last change time

File attributes that are changed using UNIX commands or system calls

touch	**utime**	**Changes last access time, modification time**
ln	**link**	**Increases hard link count**
rm	**unlink**	**Decreases hard link count .If the hard link count is zero ,the file will be removed from the file system**
vi, emacs		**Changes file size,last access time, last modification time**

Inodes in UNIX system

- UNIX system V has an inode table which keeps track of all files
- Each entry in inode table is an inode record
- Inode record contains all attributes of file including inode number and physical disk address where the data of the file stored
- Information of a file is accessed using its inode number.
- Inode number is unique within a file system
- A file is identified by a file system ID and inode number
- Inode record does not contain the name of the file
- The mapping of filenames to inode number is done via directory files

mapping of filenames to inode number

To access a file for example /usr/abc, the kernel knows "/" directory inode number of any process (U-area), it will scan "/" directory to find inode number of "usr" directory it then checks for inode number of abc in usr . The entire process is carried out taking into account the permissions of calling process.

inode number	filename
114	.
65	..
95	abc
234	a.out

Application Program Interface to Files

- Both UNIX and POSIX systems provide an application interface to files as follows

- Files are identified by path names
- Files must be created before they can be used.
- Files must be opened before they can be accessed by application programs .
- open system call is used for this purpose, which returns a file descriptor, which is a file handle used in other system calls to manipulate the open file
- A process may open at most OPEN_MAX number of files
- The read and write system calls can be used to read and write data to opened files
- File attributes are queried using stat or fstat system calls
- File attributes are changed using chmod, chown, utime and link system calls
- Hard links are removed by unlink system call

Struct stat data type<sys/stat.h>

- **Struct stat**

```
{  dev_ts     st_dev;       /* file system ID */
   ino_t      st_ino;       /* File inode number */
   mode_t     st_mode;      /* file type and access flags */
   nlink_t    st_nlink;     /*Hard link count */
   uid_t      st_uid;       /* File user ID */
   gid_t      st_gid;       /* File group ID */
   dev_t      st_rdev;      /* Major and Minor device numbers  */
   off_t      st_size;      /*File size in number of bytes */
   time_t     st_atime;     /* Last access time */
   time_t     st_mtime;     /* last modofication time */
   time_t     st_ctime      /* Last status change time */
};
```

UNIX KERNEL SUPPORT FOR FILES

- Whenever a user executes a command, a process is created by the kernel to carry out the command execution.
- Each process has its own data structures: file descriptor table is one among them.
- File descriptor table has OPEN_MAX entries, and it records all files opened by the process.

Kernel support to open system call

- Whenever an open function is called the kernel will resolve the pathname to file inode.
- Open call fails and returns -1 if the file inode does not exist or the process lacks appropriate permissions.

- Else a series of steps follow:

1. The kernel will search the file descriptor table and look for first unused entry and index to the entry is returned as file descriptor of the opened file.
2. The kernel will scan the file table in its kernel space , to find an unused entry that can be assigned to reference the file
3. If an unused entry is found in the file table,then the following events will occur:

Kernel support to open system call

a. **The process's file descriptor table entry will be set to point to file table entry.**

b. **The file table entry will be set to point to inode table entry where the inode record of file is present.**

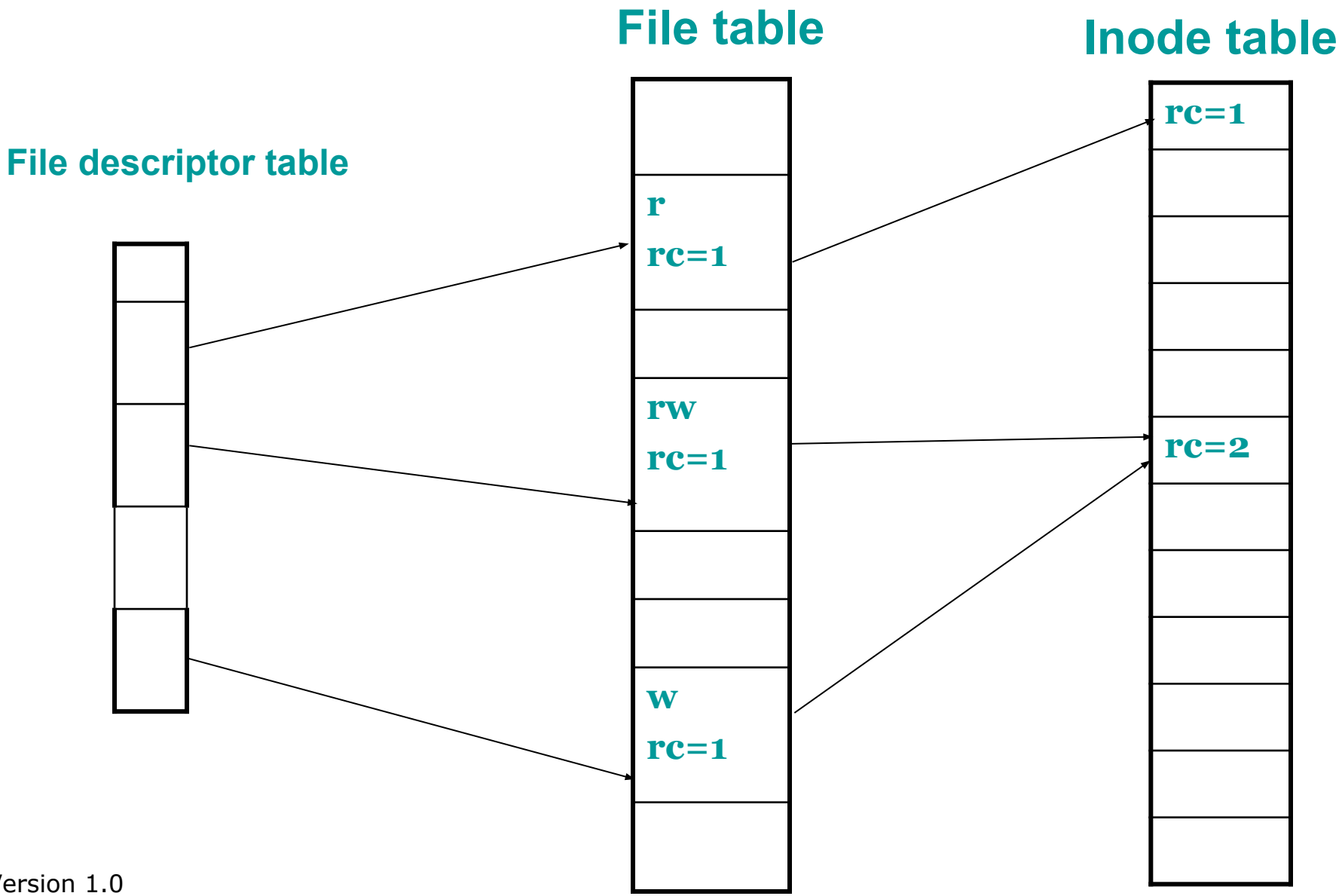
c. **The file table entry will contain the current file pointer of the open file.**

d. **The file table entry will contain an open mode which specifies the file is opened for read- only ,write-only etc,.**

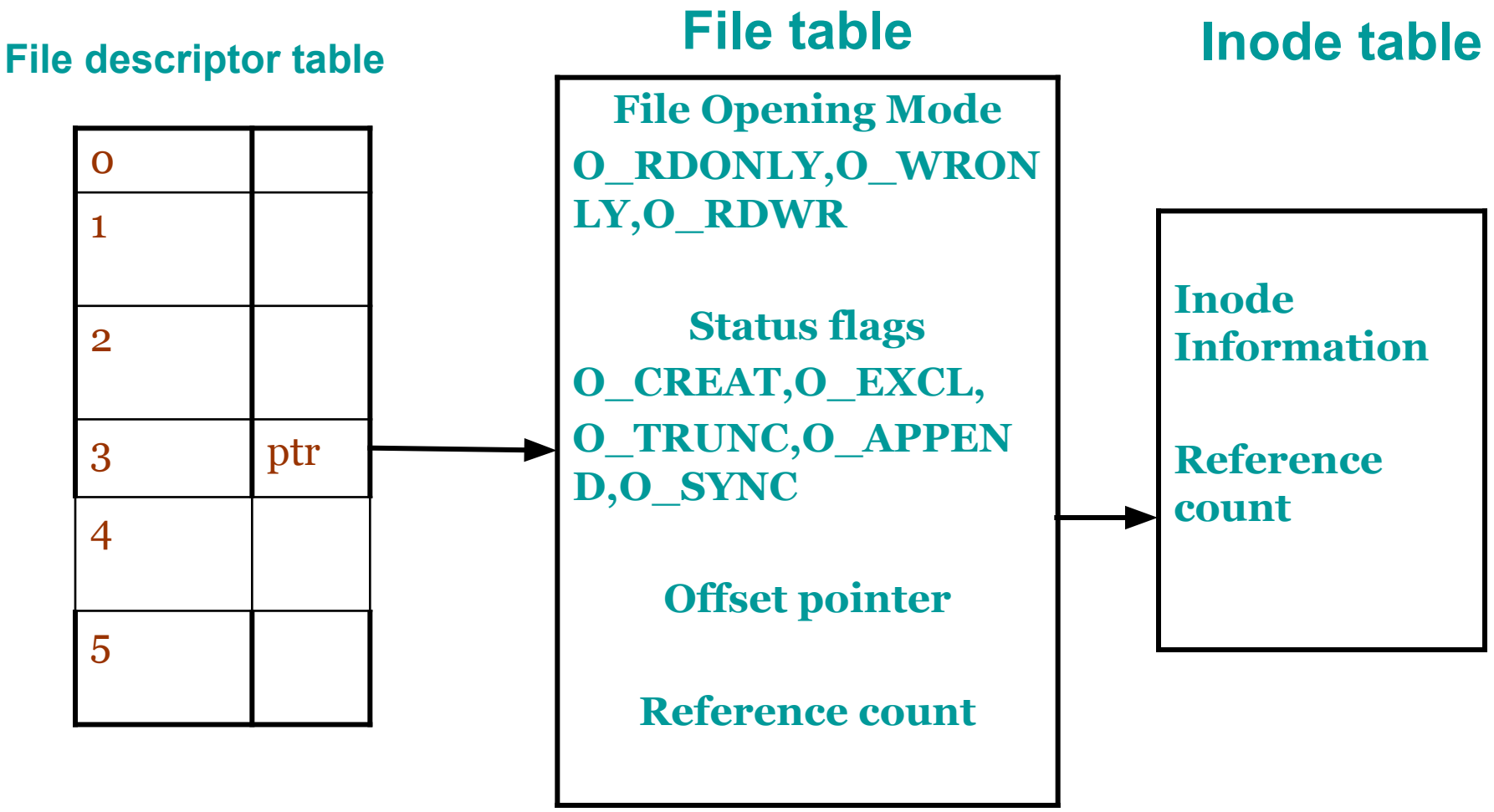
e. **Reference count of file table is set to 1.**

f. **The reference count of the in-memory inode of file is increased by 1.**

Data Structure for File Manipulation



Data Structure for File Manipulation



Close-on Exec flag is one bit flag which specifies Whether a file to be closed on exec call is also Present in file descriptor table

Kernel support : read system call

- The kernel will use the file descriptor to index the process's file descriptor table to find file table entry to opened file.
- It checks the file table entry to make sure that the file is opened with appropriate mode.
- If the read/write operation is found comaptible with the file's open mode, the kernel will use the pointer specified in the file table entry to access the file's inode record.

Kernel support : read system call

- The kernel will check the type of file in the inode record and invokes an appropriate driver function to initiate the actual data transfer with a physical file.

- If the process calls lseek function then the changes are made to the file pointer in file table, provided the file is not a character device file, a FIFO file, or a symbolic link file as they follow only sequential read and write operations.

Kernel support : close system call

When a process calls close function ,the sequence of events are as follows

- The kernel will set the corresponding descriptor table entry to unused.
- It decrements the reference count in file table entry by 1.if reference count !=0 then go to 6
- File table entry is marked unused
- The reference count in file inode table entry is decremented by 1.if reference count !=0 then go to 6
- If hard link count is non zero, it returns a success status, otherwise marks the inode table entry as unused and allocates all the physical disk storage.
- It returns the process with a 0 (success) status.

Directory files

- Directory is a record oriented file.
- Each record contains the information of a file residing in that directory.
- Record data type is struct dirent in UNIX V and POSIX.1, and struct direct in BSD UNIX.
- The usage of the directory file is to map filenames to corresponding inode numbers

Directoryfunction	Purpose
opendir	Opens a directory file (returns DIR *)
readdir	Reads next record from file
closedir	closes a directory file
rewinddir	Sets file pointer to beginning of file

- Unix system also provides telldir and seekdir function for random access of different records in a directory file

UNIX File APIs

- creat — create a file
- open — Open/create a file for data access
- read — Reads data from a file
- write — Writes data to a file
- lseek — Allows random access of data in a file
- close — Terminates connection to a file
- stat, fstat — Queries attributes of a file
- chmod — Changes access permissions of a file
- chown — Changes UID and/or GID of a file
- utime — Changes last modification time and access time stamps of a file
- link — creates a hard link to a file
- unlink — Deletes a hard link of a file
- umask — Sets default file creation mask

Open system call

- This function establishes connection between a process and a file.
- It can also be used to create a file.
- This system call returns a file descriptor which can be used is read or write system calls
- The prototype of the function

```
#include <sys/types.h>
#include <fcntl.h>
int open (const char *pathname, int access mode ,
                                    , mode_t permission);
```

- **Pathname : It can be absolute path name or a relative path name**
- **Access_mode : An integer which specifies how file is to be accessed by calling process**

- Access mode flag Use

- O_RDONLY : Opens file for read-only
- O_WRONLY : Opens file for write only
- O_RDWR : Opens file for read & write
- Along with these access mode flags one or more of the access modifier flags can be specified by bit-wise ORing

- Access modifier flags

- O_APPEND
- O_CREAT
- O_EXCL
- O_TRUNC
- O_NONBLOCK
- O_NOCTTY
- O_SYNC

Access modifier flags

- O_APPEND : appends data to end of file
- O_TRUNC : if the file already exists, discards its contents and sets file size to zero
- O_CREAT : creates the file if it does not exist
- O_EXCL : used with O_CREAT only. This flag causes open to fail if the file exists
- O_NONBLOCK : specifies that any subsequent read or write on the file should be non blocking

- O_NOCTTY :specifies not to use the named terminal device file as the calling process control terminal
- O_SYNC :have each write to wait for physical I/O to complete

Ex : int fd;
fd=open("/etc/passwd",O_RDONLY);
fd=open("foo.txt",O_WRONLY|O_APPEND); like cat>>temp.c
fd=open("../foo.txt",O_WRONLY|O_TRUNC); like cat> temp.c

- Third argument Permission is required only when O_CREAT is specified and can be specified by using octal numbers or symbolic constants

fd=open("foo.txt",O_WRONLY|O_CREAT|O_TRUNC,0644)
fd=open("foo.txt",O_WRONLY|O_CREAT|O_TRUNC,
S_IRUSR|S_IWUSR|S_IRGRP|S_IOTH

permission	User	Group	Others	All
Read	S_IUSR	S_IGRP	S_IOTH	S_IRWXU
Write	S_IWUSR	S_IWGRP	S_IOTH	S_IRWXG
Execute	S_IXUSR	S_IXGRP	S_IXOTH	S_IRWXO

Umask

- An umask value specifies some access rights to be masked off(or taken away) automatically on any files created by the process
- A process can query or change its umask value by using umask system call

- Prototype:

```
mode_t      umask ( mode_t  new_umask);
mode_t      old_mask = umask (S_IXGRP|S_IWOTH|S_IXOTH);
```

/*removes execute permission from group and write&execute permission from others*/

- the file is created with bit wise ANDing the ones compliment of the calling process umask value
- Actual_permission = permission & ~umask_value
- Actual_permission=0557&(~031)=0546

Creat

- It is used to create new regular files
- Retained only for the backward-compatibility
- its prototype is

```
#include <sys/types.h>
#include <unistd.h>
Int creat (const char* pathname, mode_t mode)
```

- The file can be created by using open as
- #define create(path_name,mode)
  Open(path_name,O_WRONLY|O_CREAT|O_TRUNC,mode);

Read system call

- This function fetches a fixed size block of data from a file referenced by a given file descriptor.

```
#include <sys/types.h>
#include <unistd.h>
ssize_t read (int fdesc ,void* buf, size_t size);
```

- read attempts to read nbyte characters from the file descriptor filedes into the buffer buf.
- fdesc is an integer descriptor that references the opened file
- buf is the address of the buffer holding the data.
- Size specifies how many bites to read
- Read can read from text/binary file, that is why buf data type is universal pointer void *(which could be any of the primitive data).
- The return value of read is the number of bytes of data successfully read and stored in buf argument

Read system call contd

- If read is interrupted by the signal then read returns number of bytes successfully read before the system call is interrupted by signal
- Some unix systems return -1 and discard the contents of the buffer and some restart the system call automatically.
- The read function may block the calling process if it is reading a FIFO or device file and the data is not yet available to satisfy the request (so specify O_NONBLOCK /O_NDELAY flag for open).
- Ex :

```
#define BUFSIZE     100
int n; char buf[BUFSIZE];
while((n=read(fd,buf,BUFSIZE) >0)
```

Write system call

- The write function puts a fixed size block of data to a file referenced by a file descriptor

```
#include <sys/types.h>
#include <unistd.h>
 ssize_t write (int fdesc ,void* buf, size_t size);
```

- fdesc is an integer file descriptor that refers to the opened file
- Buf is the address of a buffer which contains data to be written to file
- Size specifies how many bytes of data are in the buf argument
- Write can write text or binary files
- Write function writes nbyte number of bytes from the generic buffer buf to the file descriptor filedes.

Write system call

- Write returns the number of characters successfully written.
- On its failure (disk is full or file size limit exceeds) returns -1.
- If write is interrupted by the signal then it retuns the number of bytes successfully written before write is interrupted.
- Some systems may restart the system call automatically or return -1.
- The non blocking operation can be specified by using O_NONBLOCK or O_NDELAY flag

Ex:

```
# define BUFSIZE  8192
Int n; cahr buf[BUFSIZE];
N=write(fd,buf,BUFSIZE);
```

Close system call

- Disconnects a file from a process

```
#include <unistd.h>
int close (int fdesc);
```

- Close function will de allocate system resources(file table entries and memory buffer allocated to hold read/write file data).
- If a process terminates without closing all the files it has opened ,the kernel will close those files for the process.
- Returns 0 on success or -1 on failure and errno contains the error code

fcntl system call

- This system call can be used to query or set access control flags and the close-on-exec flag of any file descriptor.
- This function can also be used to assign multiple file descriptors to reference the same file (to inplement du &dup2 system calls).
- This function can also be used to lock the files.

```
#include <fcntl.h>
int fcntl (int fdesc ,int cmd,.....);
```

- cmd argument specifies which operation to perform on a file referenced by the fdesc argument .

fcntl system call CONTD

- The possible values for cmd can be
- F_GETFL : returns the access control flags of a file descriptor fdesc.
- F_SETFL : sets or clears control flags that are specified in the third argument (allowed flags are O_APPEND & O_NDELAY).
- F_GETFD : returns the close-on-exec flag of a file referenced by fdesc.
- F_SETFD : sets or clears close-on-exec flag of a file descriptor fdesc.
- F_DUPFD : duplicates the file descriptor fdesc with another file descriptor

fcntl system call CONTD

- Fcntl function is useful in changing the access control flag of a file descriptor
- After a file is opened for blocking read-write access and the process needs to change the access to nonblocking and in write-append mode, it can call fcntl on the file's descriptor as

```
int cur_flags=fcntl(fdesc,F_GETFL);
int fcntl(fdesc,F_SETFL,cur_flag|O_APPEND|O_NONBLOCK);
```

- The close-on-exec flag of file descriptor specifies that if a process that owns the descriptor calls the exec API to execute a different program, the file descriptor should be closed by the kernel before the new program runs.

```
cout <<fdesc <<"close-on-exec :"<<fcntl(fdesc,F_GETFD);
(void) fcntl(fdesc,F_SETFD,1);
```

fcntl system call CONTD

- The fcntl function can also be used to duplicate a file descriptor fdesc with another file descriptor.
- the results are two file descriptors referencing the same file with same access mode and sharing the same file pointer to read or write the file.
- This feature is useful in redirection of std i/p and o/p.

```
int   fdesc=open("foo.txt",O_RDONLY);   //open foo.txt for read
close(0);                    // close standard input
if (fcntl(fdesc, F_DUPFD,0) ==-1)  //stdin from  foo.txt now
        perror( "fcntl error \n");
char buf[256];
int rc=read(0,buf,256);                //read data from foo.txt
```

fcntl system call CONTD

- Fcntl can be used to implement dup and dup2 system calls as follows
- the dup function duplicates a file descriptor fdesc with the lowest unused file descriptor of the calling process.

```
#define    dup(fdesc)      fcntl(fdesc,F_DUPFD,0);
```

- The dup2 function will duplicate a file descriptor fd1 using fd2 file descriptor, regardless of whether fd2 is used to reference another file

```
#define          dup2(fd1,fd2)   close(fd2), fcntl(fd1,F_DUPFD,fd2)
```

- The return value of fcntl is dependent on the cmd value, but it is -1 if the function fails.

lseek system call

- The read and write system calls are always relative to the current offset within a file.
- the lseek system call is used to change the file offset to a different value
- Lseek allows a process to perform random access of data on any opened file.
- lseek is incompatible with FIFO files,character device files and symlink files.
- Prototype :

```
#include <sys/types.h>
#include <unistd.h>
Off_t lseek (int fdesc , off_t pos, int whence)
```

The return value of lseek is the new file offset address where the next read or write operation will occur

lseek system call

- the first argument *fdesc* is an integer file descriptor that refers to an opened file.

- the second argument *Pos* specifies a byte offset to be added to a reference location in deriving the new file offset value.
- The reference location is specified by the whence argument. The possible values for whence are

- SEEK_CUR current file pointer address
- SEEK_SET the beginning of a file (pos cannot be negative)
- SEEK_END the end of a file

- The iostream class defines the tellg and seekg functions to allow users to do random data access of any iostream object.
- Ex: lseek(fd,10,SEEK_CUR); lseek(fd,-10,SEEK_END);

lseek system call

```
/* Program: to read contents of file in reverse order */
#include<fcntl.h>
#include<unistd.h>
int main ( )
 {
  char     buf;      int   size, fd;
  fd=open( “foo.txt”,O_RDONLY);
  size=lseek(fd,-1,SEEK_END);
  while(size  >0)  {
            read (fd,&buf,1);
            write(STDOUT_FILENO,&buf,1);
            lseek(fd,-2,SEEK_CUR);
            }
   exit(0);
}
```

link system call

- The link function creates a new link for existing file.
- The function does not create a new file ,rather it creates a new pathname for an existing file.
- Prototype :

```
#include <unistd.h>
int link (const char* cur_link , const char* new_link) ;
```

On success hard link count attribute of the file will be incremented by 1

- The first argument cur_link is a path name of an existing file
- The second argument new_link is a new path name to be assigned to the same file.

Unlink system call

- Deletes a link of an existing file.
- It decreases the hard link count attributes of the named file and removes the filename entry of the link from a directory file
- On success the file can no longer be referenced by that link.
- The file is removed from thefile system if the hard link count is zero and no process has any file descriptor referencing the file.

```
#include <unistd.h>
int unlink (const char* cur_link );
```

The argument cur_link is a pathname that references an existing file. The return value is 0 on success , -1 on failure

READING THE INODE :Stat,fstat

- Both stat and fstat functions can be used to retrieve attributes of a given file.
- The only difference between these two functions is that stat takes pathname as an argument, where as fstat takes file descriptor as an argument.
- The prototype of these two functions are

```
#include <sys/types.h>
#include <unistd.h>
int stat (const char* path_name, struct stat* statv)
int fstat (const int fdesc, struct stat* statv)
```

READING THE INODE :Stat,fstat contd

- **The second argument to stat and fstat is the address of a struct stat type variable.**

- **Struct stat**

```
{  dev_t      st_dev;
   ino_t      st_ino;
   mode_t     st_mode;
   nlink_t    st_nlink;
   uid_t      st_uid;
   gid_t      st_gid;
   dev_t      st_rdev;
   off_t      st_size;
   time_t     st_atime;
   time_t     st_mtime
   time_t     st_ctime
};
```

- **both the functions return value 0 on success and -1 on fail.**
- **The possible error values are pathname/file descripor is invalid,process lacks the permission,the function interrupted.**

READING THE INODE :Stat,fstat contd

- If a pathname specified to stat is a symbolic link, then the stat will resolve link and access the attributes of the non-symbolic file .
- To avoid this lstat system call is used
- It is used to obtain attributes of the symbolic link file
- Lstat behaves just like stat for non symbolic link files

```
int lstat (const char* path_name , struct stat*  statv);
```

READING THE INODE :Stat,fstat contd

```
/* program:attributes.c –Uses lstat call and struct stat to display file
   attributes */
#include<stdio.h>
#include<sys/stat.h>
int main()
{  struct stat statbuf;
 if(lstat("foo.txt",&statbuf) == -1)
                perror (" stat error \n");
printf("Inode number :%d \n",statbuf.st_ino);
printf("UID:%d",statbuf.st_uid);
printf("GID :%d\n",statbuf.st_gid);
printf("Type and  Permissions :%o \n"statbuf.st_mode);
printf("Number of links:%d \n",statbuf.st_nlink);
printf("Size in bytes : %d \n",statbuf.st_size);
```

READING THE INODE :Stat,fstat contd

```
printf("blocks allocated : %d\n",statbuf.st_blocks);
printf("Last modification time : %s",ctime(&statbuf.st_mtime));
printf("Last access time :%s\n",ctime(&statbuf.st_atime));
exit(0);
}
```

FILE AND RECORD LOCKING

- UNIX systems allow multiple processes to read and write the same file concurrently.
- It is a means of data sharing among processes.
- Why we need to lock files?
- It is needed in some applications like database access where no other process can write or read a file while a process is accessing a data base.
- Unix and POSIX systems support a file-locking mechanism.
- File locking is applicable only to regular files.

Shared and exclusive locks

- A read lock is also called a shared lock and a write lock is called an exclusive lock.
- These locks can be imposed on the whole file or a portion of it.
- A write lock prevents other processes from setting any overlapping read or write locks on the locked regions of a file.
- The intention is to prevent other processes from both reading and writing the locked region while a process is modifying the region.

- A read lock allows processes to set overlapping read locks but not write locks. Other processes are allowed to lock and read data from the locked regions.

- A lock is mandatory if it is enforced by the operating system kernel.

- A mandatory locks can cause problems: If a runaway process sets a mandatory exclusive lock on a file and never unlocks it, no other processes can access the locked region of the file until either a runaway process is killed or the system is rebooted.

- If a file lock is not mandatory, it is an advisory. An advisory lock is not enforced by a kernel at the system call level
- The following procedure is to be followed
- Try to set a lock at the region to be accessed. if this fails, a process can either wait for the lock request to become successful or go to do something else and try to lock the file again.
- After a lock is acquired successfully, read or write the locked region.
- Release the lock after read or write operation to the file.

Advisory locks

- A process should always release any lock that it imposes on a file as soon as it is done.
- An advisory lock is considered safe, as no runaway processes can lock up any file forcefully. It can read or write after a fixed number of failed attempts to lock the file
- Drawback: the programs which create processes to share files must follow the above locking procedure to be cooperative.

FCNTL file locking

- **int fcntl (int fdesc, int cmd_flag, ...);**

Cmd_flag	Use
F_SETLK	Sets a file lock. Do not block if this cannot succeed immediately.
F_SETLKW	Sets a file lock and blocks the calling process until the lock is acquired.
F_GETLK	Queries as to which process locked a specified region of a file.

- For file locking, the third argument is an address of a struct flock-typed variable.
- This flock specifies a region of a file where the lock is to be set, unset or queried.

```
struct flock
{
      short   l_type;
      short   l_whence;
      off_t    l_start;
      off_t    l_len;
      pid_t   l_pid;
};
```

l_type and l_whence fields of flock

l_type value	Use
F_RDLCK	Sets as a read (shared) lock on a specified region
F_WRLCK	Sets a write (exclusive) lock on a specified region
F_UNLCK	Unlocks a specified region

l_whence value	*Use*
SEEK_CUR	The l_start value is added to the current file pointer address
SEEK_SET	The l_start value is added to byte 0 of file
SEEK_END	The l_start value is added to the end (current size) of the file

- The l_len specifies the size of a locked region beginning from the start address defined by l_whence and l_start. If l_len is 0 then the length of the lock is imposed on the maximum size and also as it extends. It cannot have a –ve value.

- When fcntl is called, the variable contains the region of the file locked and the ID of the process that owns the locked region. This is returned via the l_pid field of the variable.

LOCK PROMOTION AND SPLITTING

- If a process sets a read lock and then sets a write lock on the file, then process will own only the write lock. This process is called lock promotion.

- If a process unlocks any region in between the region where the lock existed then that lock is split into two locks over the two remaining regions.

Mandatory locks can be achieved by setting the following attributes of a file.

- Turn on the set-GID flag of the file.
- Turn off the group execute right of the file.

- All file locks set by a process will be unlocked when process terminates.

- If a process locks a file and then creates a child process via fork, the child process will not inherit the lock.

- The return value of fcntl is 0 if it succeeds or -1 if it fails.

Program-1 to illustrate the locking mechanism

In the given example program, performed a read lock on a file “sample” from the 50th byte to 150th byte.

```
#include<fcntl.h>
int main ( )
{
int fd;
struct flock lock;
fd=open(“sample”,O_RDONLY);
lock.l_type=F_RDLCK;  lock.l_whence=0;  lock.l_start=50;
lock.l_len=100;  fcntl(fd,F_SETLK,&lock);
}
```

Program-2 to illustrate the locking mechanism

Program

```
#include<fcntl.h>
#include<iostream.h>
#include<stdlib.h>
int main()
{
char buf[50];
int fd=open("b.txt",O_RDWR);
struct flock f1;
f1.l_type=F_WRLCK;
f1.l_whence=SEEK_END;
f1.l_start=0;
f1.l_len=100;
fcntl(fd,F_GETLK,&f1);
```

```
if(f1.l_type==F_RDLCK)
{
cout << f1.l_pid << " has put read lock" << endl;
// exit(0);
}
if(f1.l_type==F_WRLCK)
{
cout << f1.l_pid << " has put write lock" << endl;
//exit(0);
}
```

```
f1.l_type=F_WRLCK;
f1.l_pid=getpid();
fcntl(fd,F_SETLKW,&f1);
sleep(10);
lseek(fd,-50,SEEK_END);
read(fd,buf,50);
cout << buf;
f1.l_type=F_UNLCK;
fcntl(fd,F_SETLK,&f1);
}
```

Program-3 to illustrate the locking mechanism

```
#include <stdio.h>
#include <stdlib.h>
#include <errno.h>
#include <fcntl.h>
#include <unistd.h

int main(int argc, char *argv[])
{           /* l_type   l_whence  l_start  l_len  l_pid*/
 struct flock fl = {F_UNLCK, SEEK_SET,   0,      100,     0 };
 int fd;
 int fsize,offset;
 char buf[50];
```

```
if ((fd = open(argv[1], O_RDWR)) == -1)
 {
  perror("Can't open file");
  exit(1);
 }

 printf("File is Not Locked by any Process\n");
 printf("Press Enter to Lock the File\n");
 printf("------------------------------\n");
 getchar();
```

```
fl.l_type = F_WRLCK;
fl.l_pid = getpid();
 if (fcntl(fd, F_SETLK, &fl) == -1)
 {
  perror("Can't set Exculsive Lock");
  exit(1);
 }
 else if(fl.l_type!=F_UNLCK)
 {
        printf("File has been Exculsively Locked by
    process:%d\n",fl.l_pid);
 }
```

```
else
 {
  printf("File is not Locked\n");
 }
 printf("Press ENTER to Release lock:\n");
 getchar();
 fl.l_type = F_UNLCK;
 printf("File has been Unlocked\n");
fsize=lseek(fd,0,SEEK_END);
 offset=fsize-50;
```

```
lseek(fd,offset,SEEK_SET);
 read(fd,buf,50);
 printf("Last 50 Byte Content in the file is\n");
 printf("=================================\n");
 printf("%s\n",buf);
 return 0;
}
```

To Run Program

Create a file, here we are creating a file with name demo with the following Content:

Consider the last 100 bytes as a region.Write a C/C++ program to check whether the region is locked.

[root@localhost /]# cc lock.c

[root@localhost /]# ./a.out demo

OUTPUT

File is Not Locked by any Process

Press Enter to Lock the File

File has been Exclusively Locked by process:4087

Press Any Key to release lock:

File has been Unlocked

Last 50 Byte Content in the file is

==========

/C++ program to check whether the region islocked

Directory File APIs

- **Why do we need directory files?**

- **To aid users in organizing their files into some structure based on the specific use of files**

- **They are also used by the operating system to convert file path names to their inode numbers**

Directory File APIs

- To create a directory

int n = int **mkdir (const char*** path_name , **mode_t** mode);

- **The mode argument specifies the access permission for the owner, group, and others to be assigned to the file.**

- **int n= mkdir("/usr/demo/abc", 754);**
- **Owner=7**
- **Group=5**
- **Others=4**
- **Read =4 , write =2, execute =1;**

Difference between mkdir and mknod

- **Directory created by mknod API does not contain the "." and ".." links. These links are accessible only after the user explicitly creates them.**
- **Directory created by mkdir has the "." and ".." links created in one atomic operation, and it is ready to be used.**
- **One can create directories via system API's as well.**

Directory File APIs

- A newly created directory has its user ID set to the effective user ID of the process that creates it.

- Directory group ID will be set to either the effective group ID of the calling process or the group ID of the parent directory that hosts the new directory.

DIRECTORY RELATED FUNCTIONS

Opendir:

DIR* opendir (const char* path_name);

- **This opens the file for read-only**

Readdir:

Dirent* readdir(DIR* dir_fdesc);

- **The dir_fdesc value is the DIR* returnvalue from an opendir call.**

DIRECTORY RELATED FUNCTIONS

Closedir :

int closedir (DIR* dir_fdesc);

- **It terminates the connection between the dir_fdesc handler and a directory file.**

Rewinddir :

void rewinddir (DIR* dir_fdesc);

- **Used to reset the file pointer associated with a dir_fdesc.**

DIRECTORY RELATED FUNCTIONS

rmdir API:

int rmdir (const char* path_name);

- **Used to remove the directory files. Users may also use the unlink API to remove directories provided they have super user privileges.**

- **These API's require that the directories to be removed must be empty, in that they contain no files other than "." and ".." links.**

Device file APIs

- **Device files are used to interface physical devices (ex: console, modem) with application programs.**
- **Device files may be character-based or block-based**
- **The only differences between device files and regular files are the ways in which device files are created and the fact that lseek is not applicable for character device files.**

Device file APIs

To create:

int mknod(const char* path_name, mode_t mode, int device_id);

- **The mode argument specifies the access permission of the file**
- **The device_id contains the major and minor device numbers.**
- **The lowest byte of a device_id is set to minor device number and the next byte is set to the major device number.**

MAJOR AND MINOR NUMBERS

- **When a process reads from or writes to a device file, the file's major device number is used to locate and invoke a device driver function that does the actual data transmission.**

- **The minor device number is an argument being passed to a device driver function when it is invoked. The minor device number specifies the parameters to be used for a particular device type.**

Device file APIs

- **A device file may be removed via the unlink API.**
- **If O_NOCTTY flag is set in the open call, the kernel will not set the character device file opened as the controlling terminal in the absence of one.**
- **The O_NONBLOCK flag specifies that the open call and any subsequent read or write calls to a device file should be non blocking to the process.**

FIFO File APIs

- **These are special device files used for inter process communication.**
- **These are also known as named pipes.**
- **Data written to a FIFO file are stored in a fixed-size buffer and retrieved in a first-in-first-out order.**
- **To create:**

```
int mkfifo( const char* path_name, mode_t  mode);
```

How is synchronization provided?

- **When a process opens a FIFO file for read-only, the kernel will block the process until there is another process that opens the same file for write.**

- **If a process opens a FIFO for write, it will be blocked until another process opens the FIFO for read.**
- **This provides a method for process synchronization**

FIFO File APIs

- **If a process writes to a FIFO that is full, the process will be blocked until another process has read data from the FIFO to make room for new data in the FIFO.**
- **If a process attempts to read data from a FIFO that is empty, the process will be blocked until another process writes data to the FIFO.**
- **If a process does not desire to be blocked by a FIFO file, it can specify the O_NONBLOCK flag in the *open* call to the FIFO file.**

FIFO File APIs

- **UNIX System V defines the O_NDELAY flag which is similar to the O_NONBLOCK flag. In case of O_NDELAY flag the read and write functions will return a zero value when they are supposed to block a process.**

- **If a process writes to a FIFO file that has no other process attached to it for read, the kernel will send a SIGPIPE signal to the process to notify it of the illegal operation.**

FIFO File APIs

- **If Two processes are to communicate via a FIFO file, it is important that the writer process closes its file descriptor when it is done, so that the reader process can see the end-of-file condition.**
- **Pipe API**

Another method to create FIFO files for inter process communications

```
int pipe (int fds[2]);
```

- **Uses of the fds argument are:**
- **fds[0] is a file descriptor to read data from the FIFO file.**
- **fds[1] is a file descriptor to write data to a FIFO file.**
- **The child processes inherit the FIFO file descriptors from the parent, and they can communicate among themselves and the parent via the FIFO file.**

Symbolic Link File APIs

- **These were developed to overcome several shortcomings of hard links:**
- **Symbolic links can link from across file systems**
- **Symbolic links can link directory files**
- **Symbolic links always reference the latest version of the file to which they link**
- **Hard links can be broken by removal of one or more links. But symbolic link will not be broken.**

Symbolic Link File APIs

To create :

```
int symlink (const char* org_link, const  char* sym_link);

int readlink (const char* sym_link, char* buf,
                                        int size);
int lstat (const char* sym_link, struct stat*
                                        statv);
```

Symbolic Link File APIs

- **To QUERY the path name to which a symbolic link refers, users must use the readlink API. The arguments are:**
- **sym_link is the path name of the symbolic link**
- **buf is a character array buffer that holds the return path name referenced by the link**
- **size specifies the maximum capacity of the buf argument**