- 1. a) 1) 4 inode blocks. 1 for the file c, and 3 for the directdories /, a, b
 - 2) 3 directory blocks one for root /, one for a, the other for b
 - 3) 1 single indirect block as far as we know. The file definitely has more than 12 blocks (# of data blocks pointed by direct pounters), but less than 1036 (# of data blocks pointed by direct pointers and single indirect pointers). We are reading block 1034.
 - 4) 1 data block for file c
 - b) All of the above

Notes

• Inode



- Is short form of index node
- Describes a file system object such as file or data
- Contains all information about a file/directory, including
 - * File Type,
 - * Size
 - * Number of blocks allocated to it
 - * Protection information
 - * Time information (e.g time created, time modified)
 - * Location of data blocks residing on disk

References

- 1) Wikipedia, Inode, link
- 2) Machanick, Philip. (2016). Teaching Operating Systems: Just Enough Abstraction. 642. 10.1007/978-3-319-47680-3_10., link

c) Size, the location of data blocks that reside on disk

Notes

- I wonder what information about blocks inode has. Is it total number of blocks both inode and data, or just data?
- I struggled a bit on this one. I should find an easier way to remember which information inode has

d) Rough Work

• Creash Scenarios

- When only new data block is written to disk
 - * This is fine in system's point of view
 - * No inode points to it (it doesn't contain any information about file)
 - * No bitmap points to it
 - * Is as if write never occured
- When only the updated inode is written to disk
 - * There is no bitmap that's pointing to it
 - * There is new inode where existing inode is
 - * The data block Db hasn't been created
 - * Reading data where Db is will return garbage data
 - * there is a term for this. Is called **File-System inconsistency**
- When only inode bitmap is written to disk
 - * inode block pointed by bitmap is assumed to be allocated
 - * But there is no desired inode where it's pointing
 - * This is another example of File-System-Inconsistency
 - * If left as is, then space cannot be used for future use (inode leak)
- When only data bitmap is written to disk
 - * data block pointed by bitmap is assumed to be allocated
 - * But there is no desired inode where it's pointing
 - * This is another example of File-System-Inconsistency
 - * If left as is, then space cannot be used for future use (data leak)

Notes

- I wonder how system call for reading file/directory works in UNIX. Does it check for bitmap?
- I wonder how system call for deleting file/directory works in UNIX
- I wonder how system call for creatubg file/directory works in UNIX

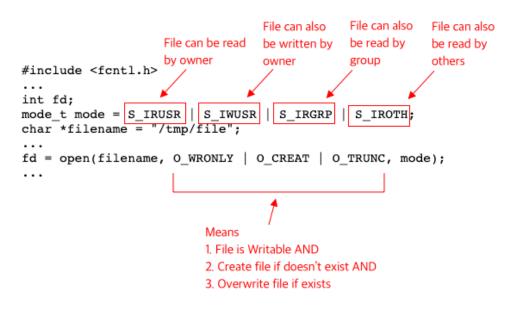
• File API

open (create/access file)

- * Is a system call
- * Does three things on creation
 - 1) make structure (inode) that racks all relevant information about file
 - 2) link human readible name to the file, and put that link to a directory
 - 3) increment **reference count** in inode
- * Syntax:

```
int fd = open("foo". O_CREAT|O_WRONLY|O_TRUNC, S_IRUSR|S_IWUSR)
```

- · O_CREAT Creates file "foo" if does not exist
- · O_WRONLY Open file for writing only (default)
- · O_TRUNC Overwrites existing file Need example/Clarification
- · Can have multiple flags
- * Returns file descriptor or fd for short
 - · Is an integer
 - · Is used to access a file
 - · Is private per process
 - · Can be used to read() and write() files



- (read) (read file)
 - * Is a system call
 - * Syntax:

```
ssize_t read (int fd, void *buf, size_t count)
```

- · fd file descriptor (from open ())
- · buf container for the read data
- · count number of bytes to read
- * Returns number of bytes read, if successful
- * Returns 0 if is at, or past the end of file

Example

```
char buf[4096];
int fd = open("/a/b/c", 0); // open in read-only mode
lseek(fd, 1034*4096, 0); // seek to position (1034*4096) from start of file
read(fd, buf, 4096); // read 4k of data from file
```

```
Return
                                               Current
System Calls
                                               Offset
                                      Code
fd = open("file", O_RDONLY);
                                                                     read continues
                                         100
read(fd, buffer, 100);
                                                   100
                                                                      for each call
read(fd, buffer, 100);
read(fd, buffer, 100);
                                         100
                                                   200
                                                   300
                                         100
read(fd, buffer, 100);
                                          0
                                                   300
                                           0
close(fd);
                                                                     if at end
```

- write (write file)
 - * Is a system call
 - * Writes data out of a buffer
 - * Syntax:

```
ssize_t write (int fd, const void * buf, size_t nbytes)
```

- · fd file descriptor
- · buf A pointer to a buffer to write to file
- · nbytes number of bytes to write. If smaller than buffer, the output is truncated

```
#include <unistd.h>
#include <fcntl.h>

int main(void)
{
    int filedesc = open("testfile.txt", O_WRONLY | O_APPEND);

    if (filedesc < 0) {
        return -1;
    }

    if (write(filedesc, "This will be output to testfile.txt\n", 36) != 36) {
        write(2, "There was an error writing to testfile.txt\n", 43);
        return -1;
    }

    return 0;
}</pre>
```

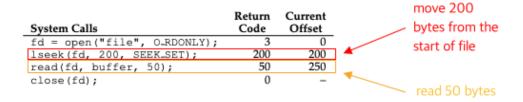
- lseek
 - * Reads or write to a specific offset within a file
 - * Syntax:

```
off_t lseek (int fd, off_t offset, int whence)
```

- · fd file descriptor
- · offset the offset of pointer within file (in bytes)
- · whence the method of offset

```
SEEK_SET - offset from the start of file (absolute)
SEEK_CUR - offset from current location + offset bytes (relative)
SEEK_END - offset from the end of file
```

- * Returns offset amount (in bytes) from the beginning of file
- * Returns -1 if error



- rename (update file name)
 - * Is a system call
 - * Changes the name of file
 - * Is atomic (after crash, it will be either old or new, but not in-between)
 - * Syntax: int rename (const char *old, const char *new)
 - · old name of old file

- · new name of new file
- * Returns 0 if successful
- * Returns -1 if error

Example

- stat (get file info)
 - * displays metadata of a certain file stored in **inode**
 - * Syntax: int stat(const char *path, struct stat *buf)
 - · path file descriptor of file that's being inquired
 - · buf A stat structure where data about the file will be stored (see below)

```
struct stat {
 dev_t
           st_dev;
                        // ID of device containing file
                        // inode number
  ino_t
            st_ino;
                        // protection
// number of hard links
 mode_t
            st_mode;
 nlink_t
           st_nlink;
                        // user ID of owner
  uid_t
            st_uid;
                        // group ID of owner
// device ID (if special file)
  gid_t
            st_gid;
  dev_t
            st_rdev;
           st_size;
                        // total size, in bytes
 blksize_t st_blksize; // blocksize for filesystem I/O
 blkcnt_t st_blocks; // number of blocks allocated
 time_t
           st_atime;
                       // time of last access
            st_mtime;
                        // time of last modification
 time_t
 time_t
            st_ctime;
                        // time of last status change
};
```

Figure 39.5: The stat structure.

```
#include <unistd.h>
#include <stdio.h>
#include <sys/stat.h>
#include <sys/types.h>
int main(int argc, char **argv)
{
    if(argc != 2)
        return 1;
    struct stat fileStat;
    if(stat(argv[1],&fileStat) < 0)
        return 1;
    printf("Information for %s\n",argv[1]);
                   ----\n");
    printf("File Size: \t\t%d bytes\n",fileStat.st_size);
    printf("Number of Links: \t%d\n",fileStat.st_nlink);
    printf("File inode: \t\t%d\n",fileStat.st_ino);
    printf("File Permissions: \t");
    printf( (S_ISDIR(fileStat.st_mode)) ? "d" : "-");
    printf( (fileStat.st_mode & S_IRUSR) ? "r" : "-");
    printf( (fileStat.st_mode & S_IWUSR) ? "w" :
    printf( (fileStat.st_mode & S_IXUSR) ? "x" : "-");
printf( (fileStat.st_mode & S_IRGRP) ? "r" : "-");
    printf( (fileStat.st_mode & S_IWGRP) ? "w" : "-");
    printf( (fileStat.st_mode & S_IXGRP) ? "x" : "-");
    printf( (fileStat.st_mode & S_IROTH) ? "r" : "-");
    printf( (fileStat.st_mode & S_IWOTH) ? "w" : "-");
    printf( (fileStat.st_mode & S_IXOTH) ? "x" :
    printf("\n\n");
    printf("The file %s a symbolic link\n", (S_ISLNK(fileStat.st_mode)) ? "is" : "is not");
    return 0;
}
```

The result of above is:

- unlink (removing file)
 - Is a system call
 - Removes a file (including symbolic link) from the system
 - Syntax: int unlink(const char *pathname)
 - * pathname path to file
 - Returns 0 if successful
 - Returns -1 if error

```
#include <unistd.h>
                     char *path = "/modules/pass1";
                     int
                            status;
                     status = unlink(path);
• mkdir (creating directory)
   - Is a system call
   - Syntax: int mkdir(const char *path, mode_t mode)
     * path - path of directory (including name)
     * mode - permission group
   - Returns 0 if successful
   - Returns -1 if error
   - directories can never be written directly
     * directory is in format called File System Metadata
     * directory can only be updated directly
   - creates two directories on creation . (current) and ... (parent)
  Example
   #include <sys/types.h>
   #include <sys/stat.h>
   int status;
   status = mkdir("/home/cnd/mod1", S_IRWXU | S_IRWXG | S_IROTH | S_IXOTH);
• opendir, readdir, closedir (reading directory)
   - Are system calls
   - Are under <dirent.h> library
   - Requires struct dirent data structure
              struct dirent {
                              d_name[256]; // filename
                char
                             d_ino;  // inode number
d_off;  // offset to the next dirent
                ino_t
                                         // length of this record
                unsigned short d_reclen;
                                         // type of file
                unsigned char d_type;
              };
   - Syntax (opendir): DIR *opendir(const char *dirname)
```

```
* dirname - directory path
```

- * Returns a pointer to the directory stream
- * The stream is positioned at the first entry in the directory.

```
- Syntax (readdir): struct dirent *readdir(DIR *dirp);
```

- * dirp directory stream
- * Returns a pointer to a direct structure representing the next directory entry in the directory stream
- * Returns NULL on reaching the end of the directory stream

```
- Syntax (closedir): int closedir(DIR *dirp));
```

- * dirp directory stream
- * Returns 0 if successful
- * Returns -1 otherwise

Example

- rmdir (Deleting Directories)
 - Removes a directory whose name is given by path
 - Is performed only when directory is empty
 - Is included in <unistd.h> library
 - Fails if is symbolic link
 - Syntax: int rmdir(const char *path)
 - * path path of directory
 - Returns 0 if successful
 - Returns -1 if error

```
#include <unistd.h>
int status;
...
status = rmdir("/home/cnd/mod1");
```

- unlink
 - Is called **unlink** because it decrements **reference count** in inode
 - deletes file completely when reference count within the inode number is 0

References

- 1) codewiki, stat, link
- 2) The Open Group Base Specification, unlink, link