Chapter - FIVE

File System

Outline

- Introduction
- File system concepts and definition
- File attributes
- File access methods
- File operation, organization
- Directories
- File allocation
- File permission

Introduction

- Secondary storage is the *non-volatile repository for (both user and system)* data and programs.
- As (integral or separate) part of an operating system, the file system manages this information on secondary storage.
- Uses of secondary storage include:
  - storing various forms of programs (source, object, and executable) and
  - temporary storage of virtual memory pages (paging device or swap space).

Introduction…

- Generally there are three essential requirements for long term information storage:
  1. It must be possible to store a very large amount of information.
  2. The information must survive the termination of the process using it.
  3. Multiple processes must be able to access the information concurrently.
- The solution to all these problems is to store information on disks and other external media in units called **Files.**

File systems

- A file system provides a mapping between the logical and physical views of a file, through a set of services and an interface.
- Simply put, the file system hides all the device-specific aspects of file manipulation from users.
- The basic services of a file system include:
  - keeping track of files (knowing location),
  - I/O support, especially the transmission mechanism to and from main memory,
  - management of secondary storage,
  - sharing of I/O devices,
  - providing protection mechanisms for information held on the system.

File concept

- Files are managed by operating system.
- How they are structured, named, accessed, used, protected, and implemented are major topics in operating system.
- As a whole that part of the operating system dealing with files known as **file system.**
- A file is a named collection of related information, usually as a sequence of bytes, with two views:
  - *Logical (programmer's) view*, as the users see it.
  - *Physical (operating system) view*, as it actually resides on secondary storage.

File concept…

- What is the difference between a file and a data structure in memory? Basically,
  - files are intended to be non-volatile; hence in principle, they are long lasting,
  - files are intended to be moved around (i.e., copied from one place to another),
  - accessed by different programs and users, and so on.

File Attributes

- **Name** – only information kept in human-readable form
- **Type** – needed for systems that support different types
- **Location** – pointer to file location on device
- **Size** – current file size
- **Protection** – controls who can do reading, writing, executing
- **Time**, **date**, **and user identification** – data for protection, security, and usage monitoring
- Information about files are kept in the directory structure, which is maintained on the disk

File attributes

- Each file is associated with a collection of information, known as ***attributes:***
  - *NAME, owner, creator*
  - *type (e.g., source, data, binary)*
  - *location (e.g., I-node or disk address)*
  - *organization (e.g., sequential, indexed, random)*
  - *access permissions*
  - *time and date (creation, modification, and last accessed)*
  - *Size*
  - *variety of other (e.g., maintenance) information.*

File access methods

- The information stored in a file can be accessed in a variety of methods:
  - ***Sequential****: in order, one record after another.*
  - ***Direct*** *(random): in any order, skipping the previous records.*
  - ***Keyed****: in any order, but with particular value(s); e.g., hash table or* dictionary.
  - TLB lookup is one example of a keyed search.

File Operations

- Create
- Write
- Read
- file seek – reposition within file
- Delete
- Truncate
- Open(F_i) – search the directory structure on disk for entry F_i, and move the content of entry to memory
- Close (F_i) – move the content of entry F_i in memory to directory structure on disk

Addressing levels

- There are three basic mapping levels (abstractions) from a logical to physical view of a file (contents):
- **File relative**:
  - *<filename, offset>* form is used at the higher levels, where the file system is viewed as a collection of files.
- **Volume (partition) relative**:
  - device-independent part of a file system use
  - *<sector, offset>* (e.g., a partition is viewed as an array of sectors.)
- **Drive relative**:
  - at the lowest level, *<cylinder, head, sector>* (also known as *<track, platter, sector>*) is used.

File Types – Name, Extension

file type	usual extension	function
executable	exe, com, bin or none	read to run machine-language program
object	obj, o	compiled, machine language, not linked
source code	c, cc, java, pas, asm, a	source code in various languages
batch	bat, sh	commands to the command interpreter
text	txt, doc	textual data, documents
word processor	wp, tex, rrf, doc	various word-processor formats
library	lib, a, so, dll, mpeg, mov, rm	libraries of routines for programmers
print or view	arc, zip, tar	ASCII or binary file in a format for printing or viewing
archive	arc, zip, tar	related files grouped into one file, sometimes compressed, for archiving or storage
multimedia	mpeg, mov, rm	binary file containing audio or A/V information

File Organization

- One of the key elements of a file system is the way the files are organized.
- File organization is the "logical structuring" as well as the access method(s) of files.

- Common file organization schemes are:
  - Sequential
  - Indexed-sequential
  - Indexed
  - Direct (or hashed)

Access Methods

- **Sequential Access**

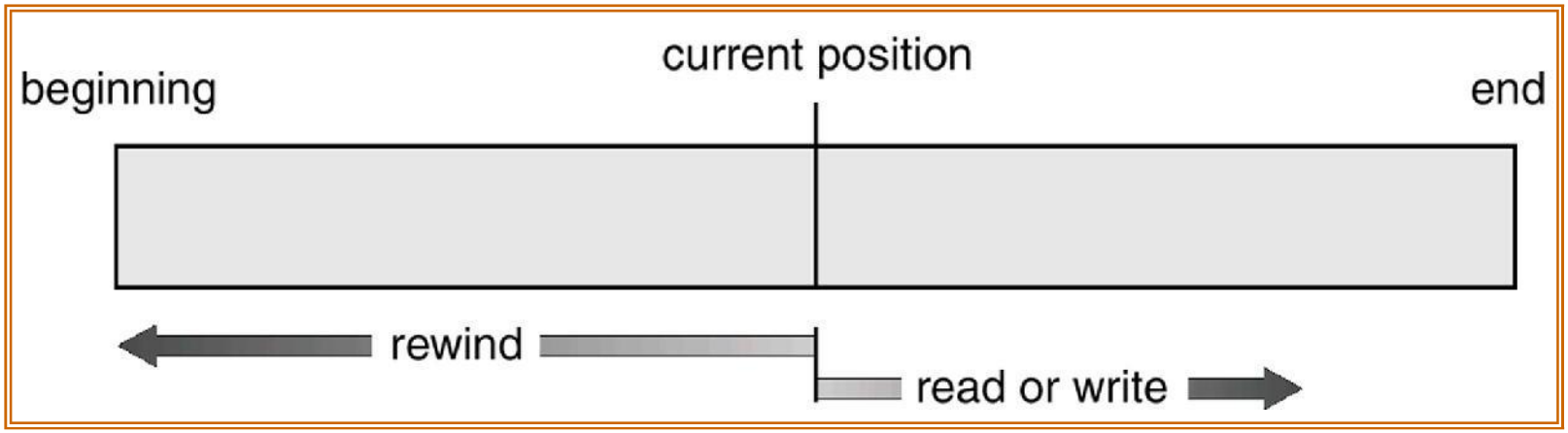
  read next
  write next
  reset
  no read after last write
  (rewrite)

- **Direct Access**

  read *n*
  write *n*
  position to *n*
  read next
  write next
  rewrite *n*

n = relative block number

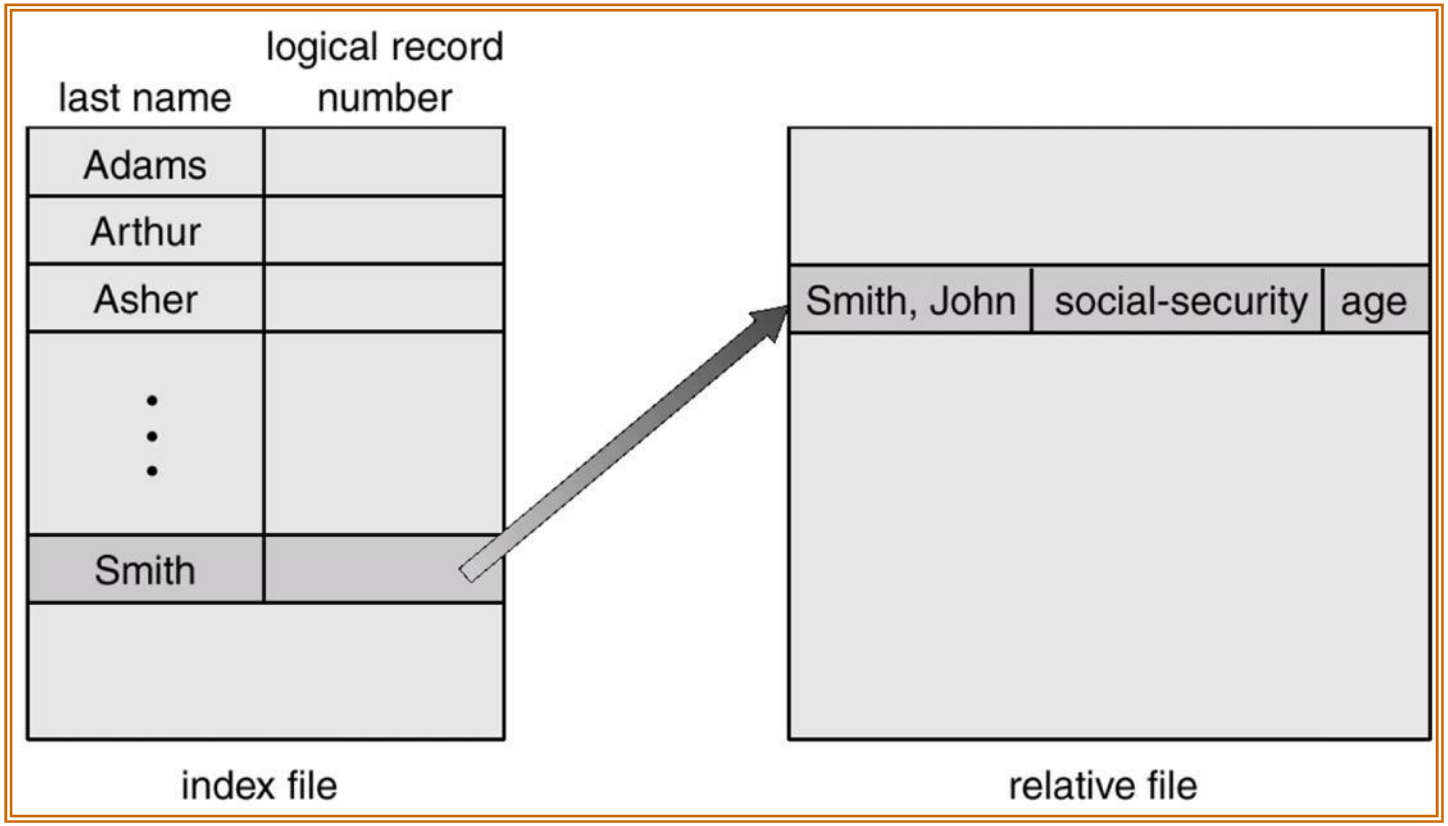
Sequential-access File



Simulation of Sequential Access on a Direct-access File

sequential access	implementation for direct access
reset	*cp* = 0;
read next	*read cp*; *cp* = *cp*+1;
write next	*write cp*; *cp* = *cp*+1;

Example of Index and Relative Files



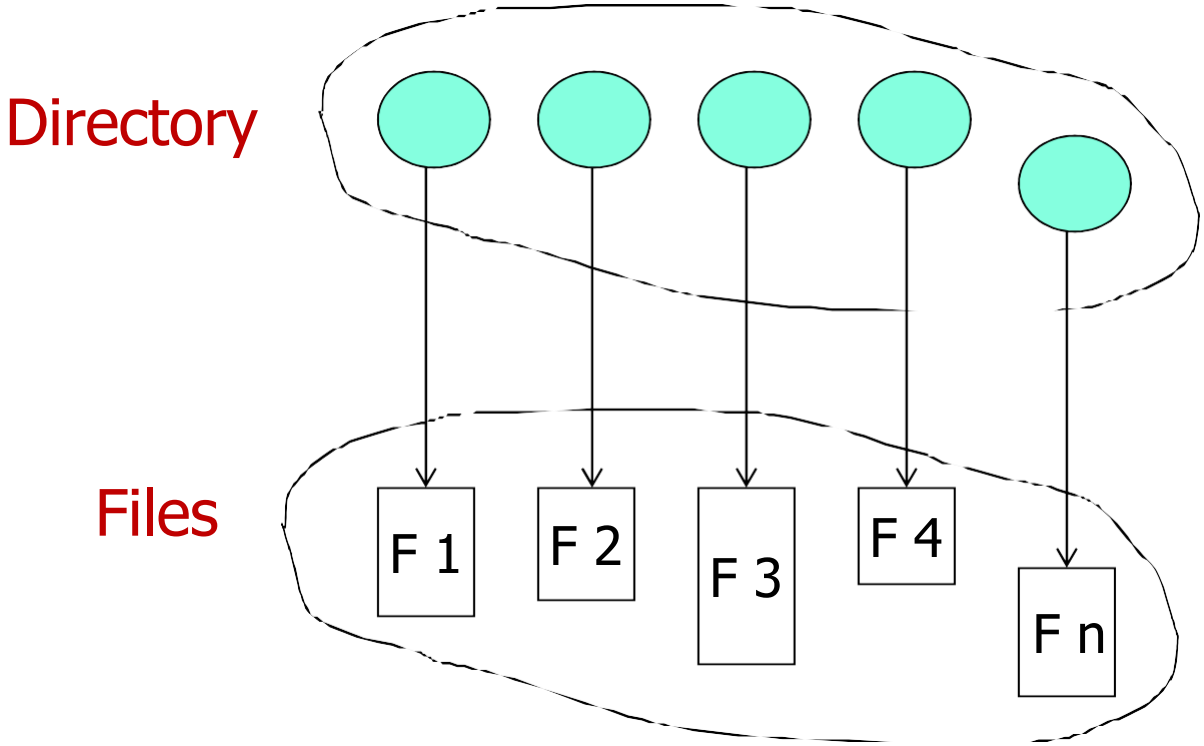
Directories

- A directory is a *symbol table*, which can be searched for information about the files.
- Also, it is the fundamental way of organizing files.
- Usually, a directory is itself a file.
- A typical *directory entry* contains information (attributes) about a file. Directory entries are added as files are created, and are removed when files are deleted.

- Common directory structures are:
  - **Single-level (flat):** shared by *all* users.
  - **Two-level:** one level for *each* user.
  - **Tree:** arbitrary (sub)-tree for *each* user.

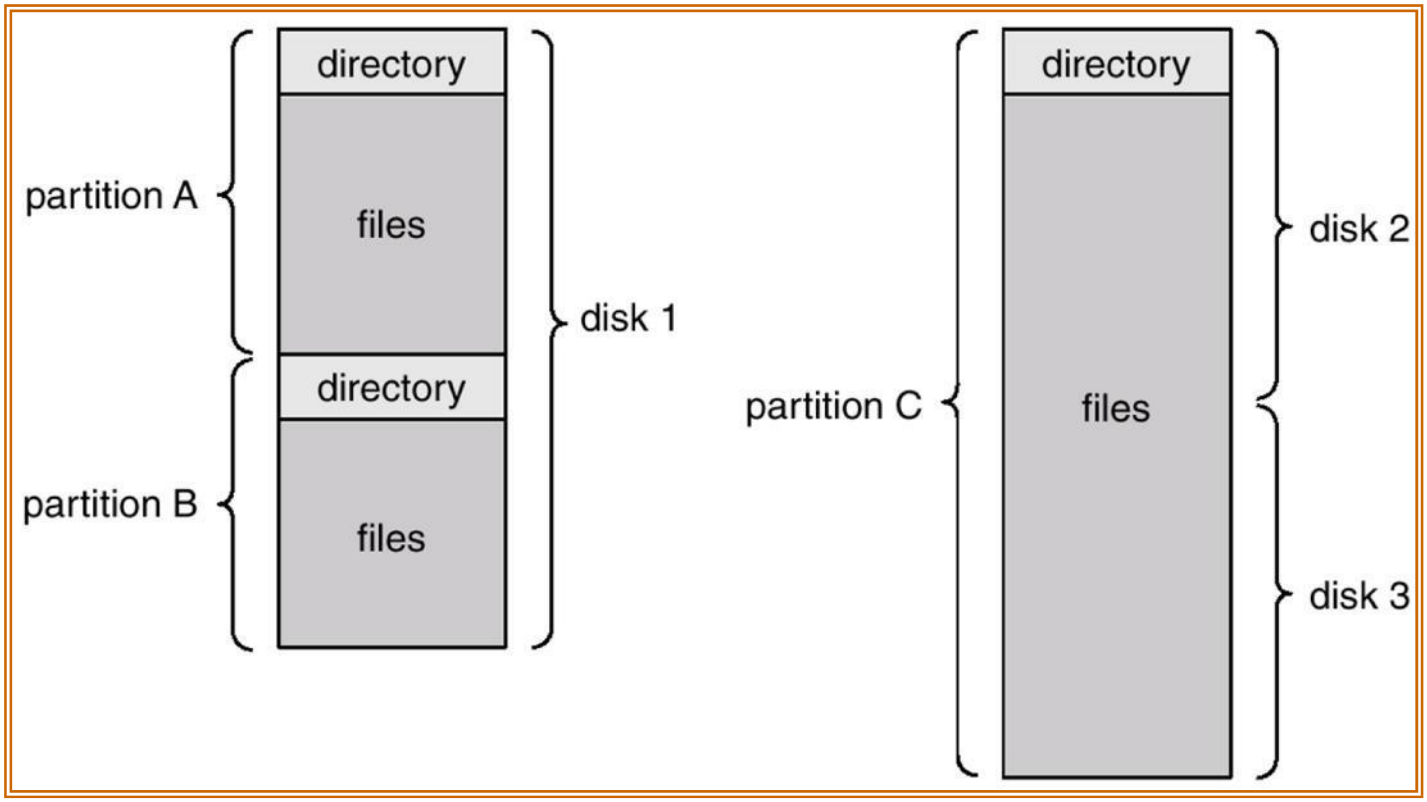
Directory Structure

- A collection of nodes containing information about all files



Both the directory structure and the files reside on disk

A Typical File-system Organization



Information in a Device Directory

- Name
- Type
- Address
- Current length
- Maximum length
- Date last accessed (for archival)
- Date last updated (for dump)
- Owner ID
- Protection information (discuss later)

Operations Performed on Directory

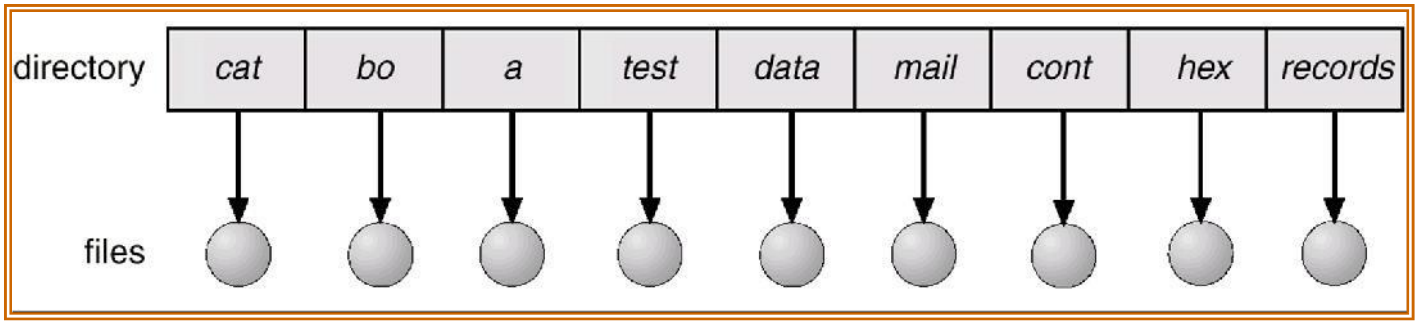
- Search for a file
- Create a file
- Delete a file
- List a directory
- Rename a file
- Traverse the file system

Organize the Directory (Logically) to Obtain

- Efficiency – locating a file quickly
- Naming – convenient to users
  - Two users can have same name for different files
  - The same file can have several different names
- Grouping – logical grouping of files by properties, (e.g., all Java programs, all games, …)

Single-Level Directory

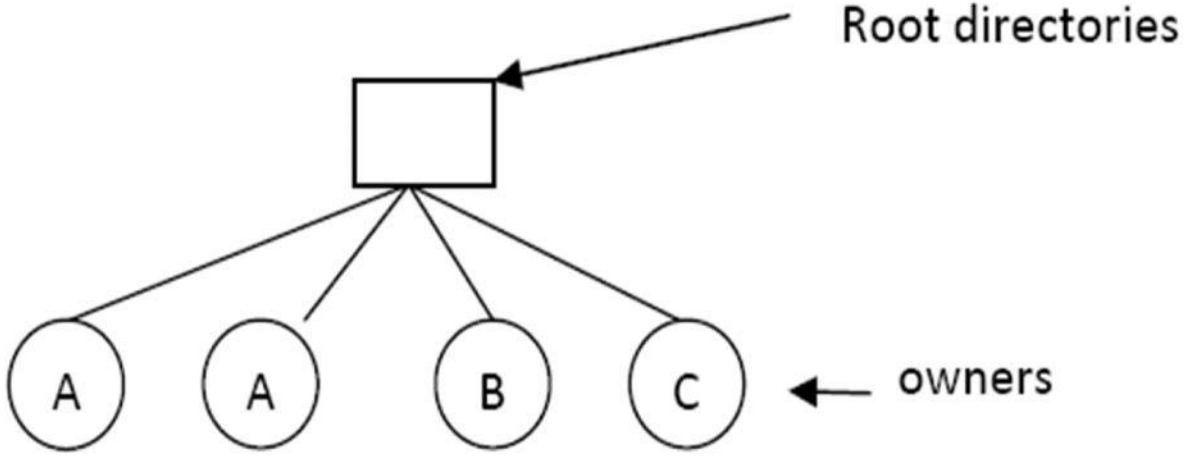
- A single directory for all users
- Shared by all users.
- One directory containing all the files (**root directory**).



Naming problem

Grouping problem

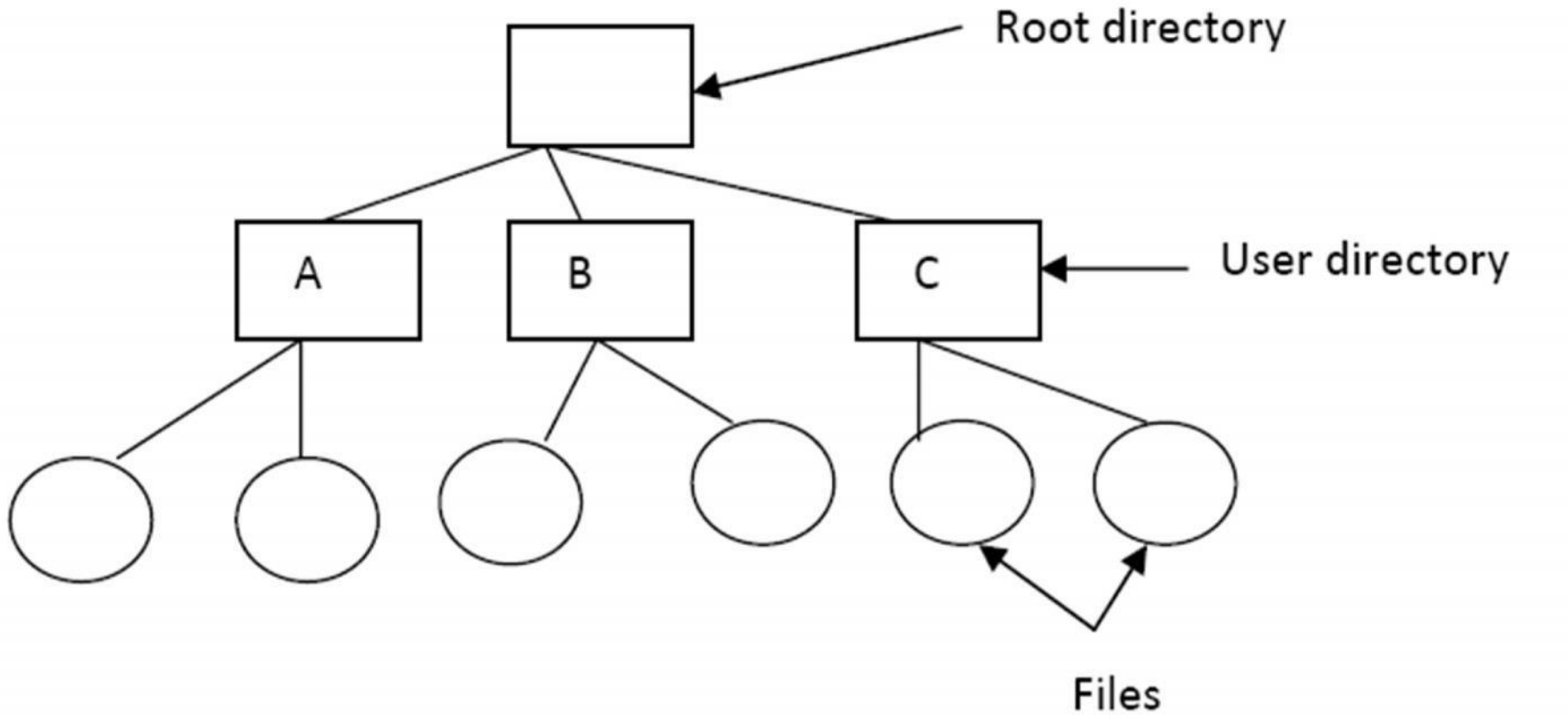
Example:



- Here the directory contains four files.
- Disadvantage:
  - Different users may accidentally use the same names for their files.
  - Example: User A creates file name mailbox. Latter user B creates file name mailbox. Then B's file will overwrite A's file.

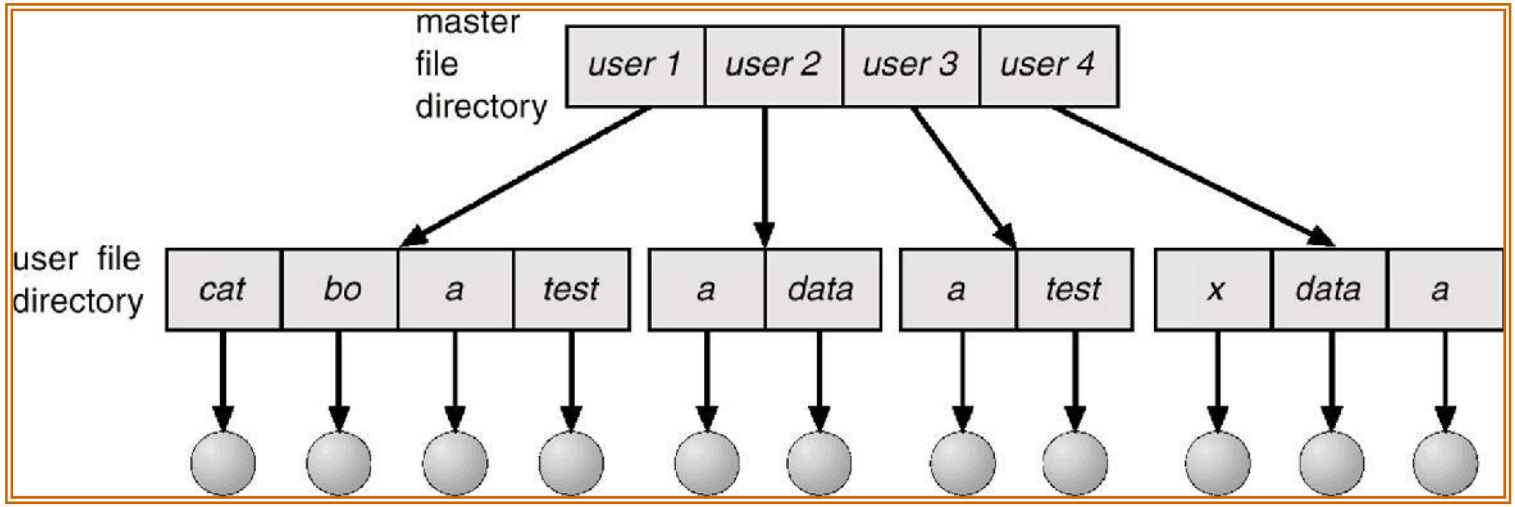
Two-level directory system

- To overcome the above problem, just give each user a private directory.
- One level for each user.



Two-Level Directory…

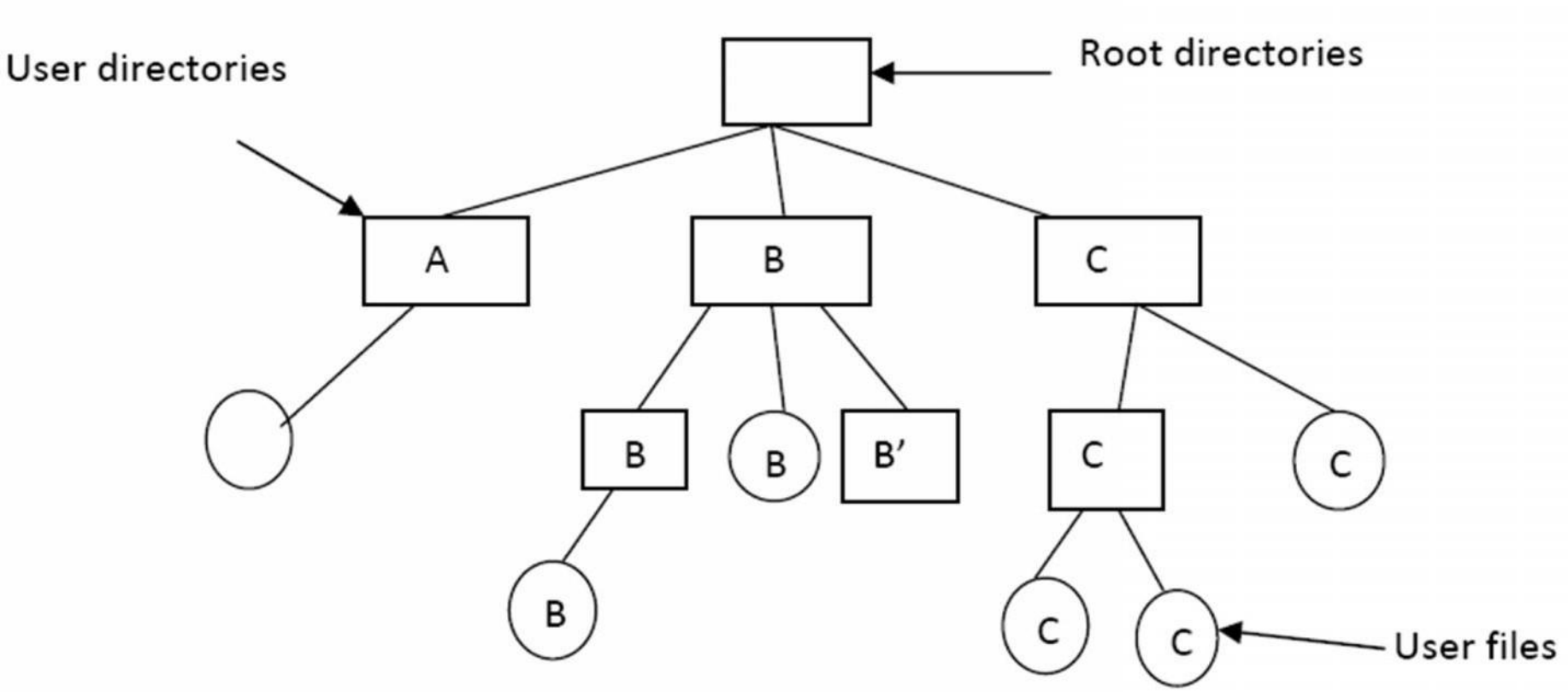
- Separate directory for each user



- Path name
- Can have the same file name for different user
- Efficient searching
- No grouping capability

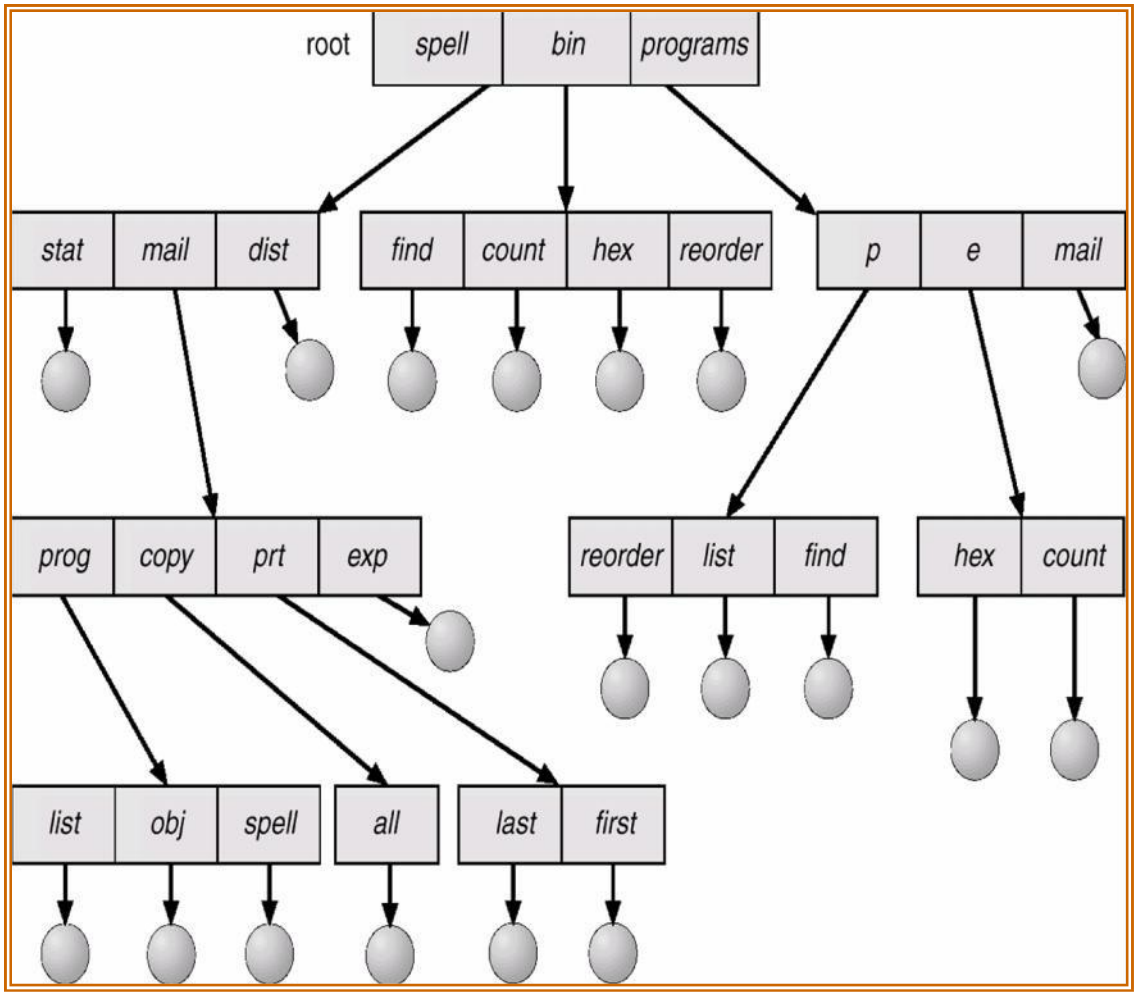
Tree (Hierarchical directory system)

- Arbitrary (sub)-tree for each user.
- It is used for large number of files.
- Each user can have as many directories as possible.



Tree-Structured Directories…

- Efficient searching
- Grouping Capability
- Current directory (working directory)
  - cd /spell/mail/prog
  - type list



Tree-Structured Directories (Cont)

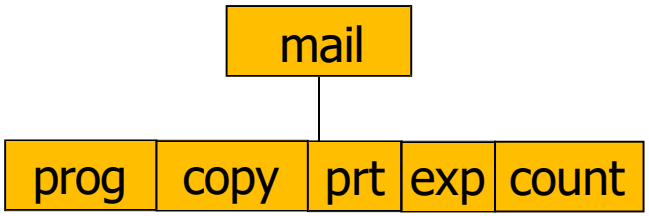
- **Absolute** or **relative** path name
- Creating a new file is done in current directory
- Delete a file

  rm <file-name>
- Creating a new subdirectory is done in current directory

  mkdir <dir-name>

Example: if in current directory /mail

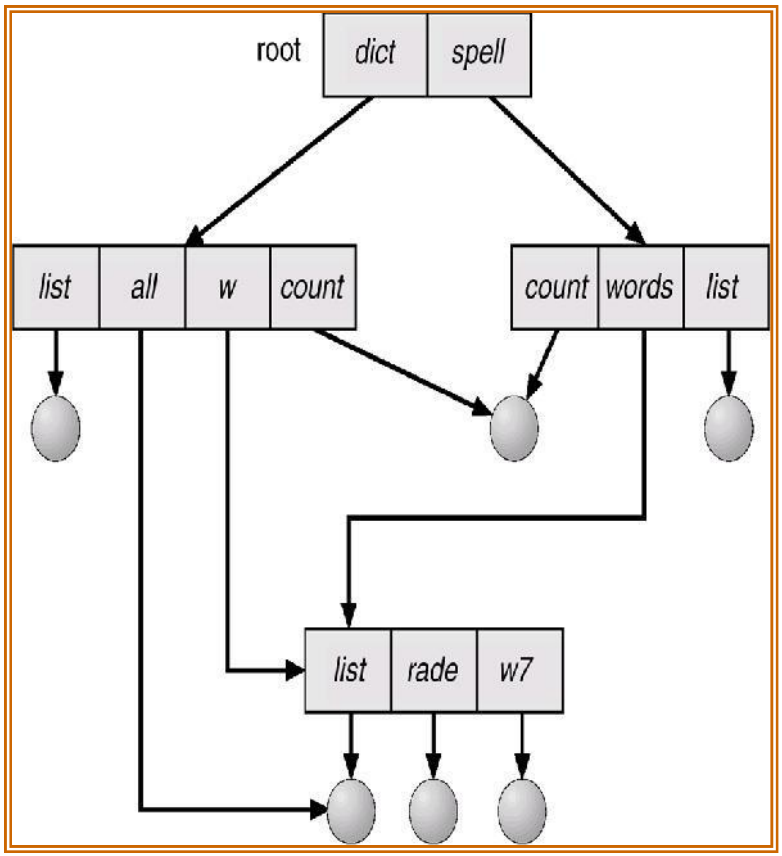
mkdir count



Deleting "mail" ⇒ deleting the entire subtree rooted by "mail"

Acyclic-Graph Directories

- Have shared subdirectories and files
- Two different names (aliasing)
- If *dict* deletes *list* ⇒ dangling pointer

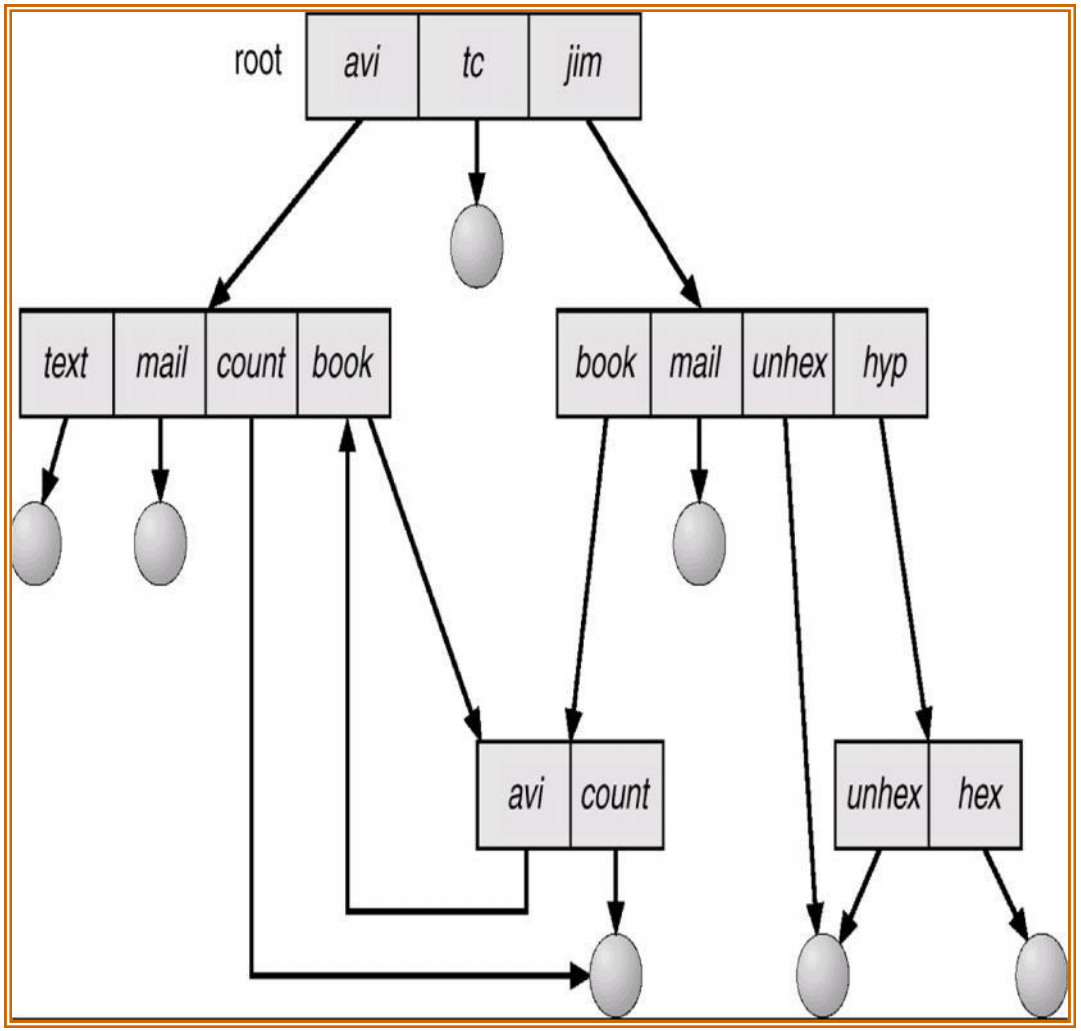


Solutions:

- Backpointers, so we can delete all pointers
  Variable size records a problem
- Backpointers using a daisy chain organization
- Entry-hold-count solution

General Graph Directory

- How do we guarantee no cycles?
  - Allow only links to file not subdirectories
  - Garbage collection
  - Every time a new link is added use a cycle detection algorithm to determine whether it is OK



Directory operation

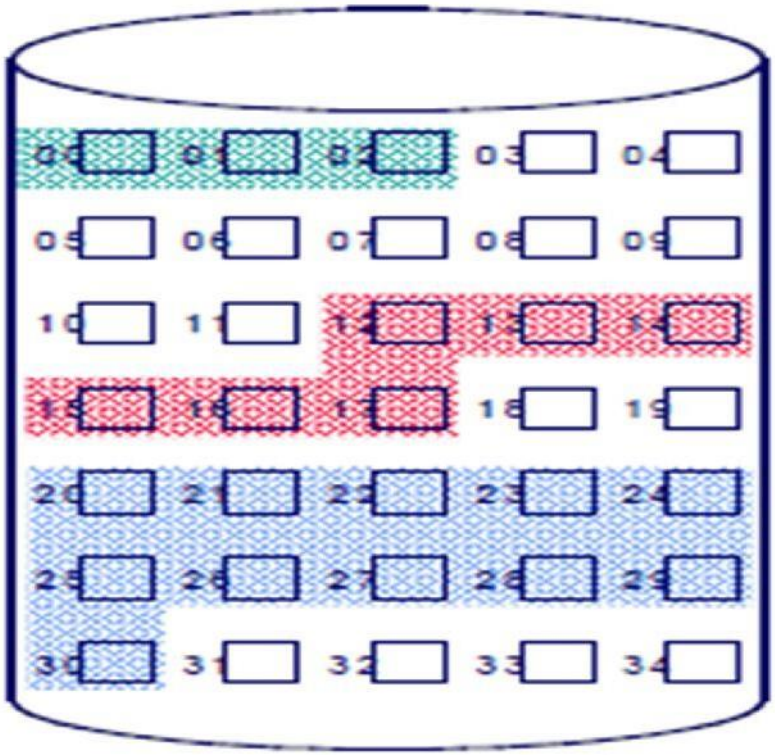
- **Create**- a directory is created.
- **Delete**- a directory is deleted.
- **Opendir**- directories can be read.
- **Closedir**- directory can be closed.
- **Readdir**- this call returns the next entry in an open directory.

File allocation

- The file system allocates disk space, when a file is created.
- With many files residing on the same disk, the main problem is how to allocate space for them.
- File allocation scheme has impact on the efficient use of disk space and file access time.
- Common file allocation techniques are:
  - Contiguous
  - Chained (linked)
  - Indexed
- All these techniques allocate disk space on a per block (smallest addressable disk units) basis.

Contiguous allocation

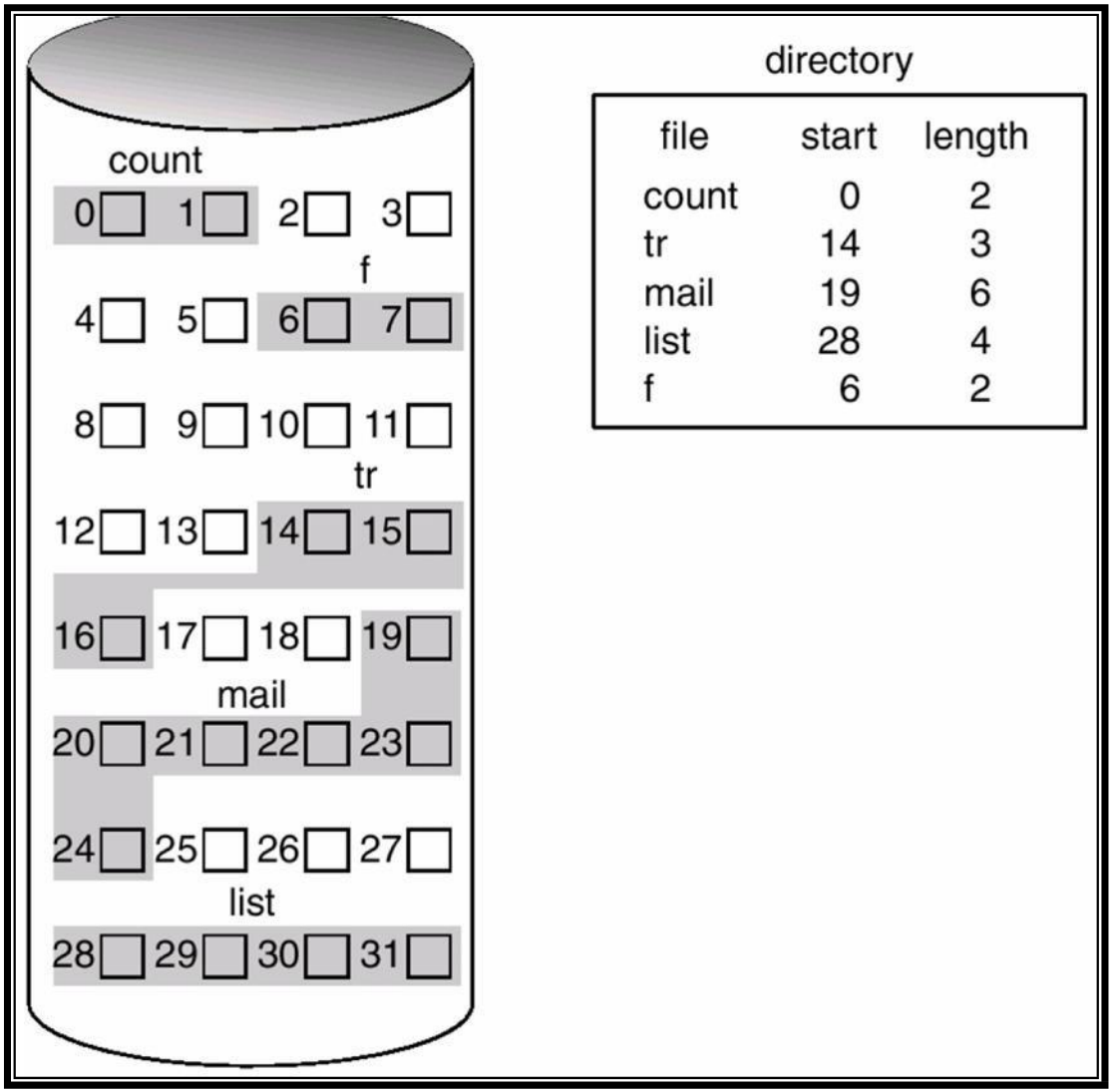
- Allocate disk space like paged, segmented memory.
- Keep a free list of unused disk space.
- Advantages
  - Easy access, both sequential and random
  - Simple
  - Few seeks
- Disadvantages
  - External fragmentation
  - May not known the file size in advance



Directory

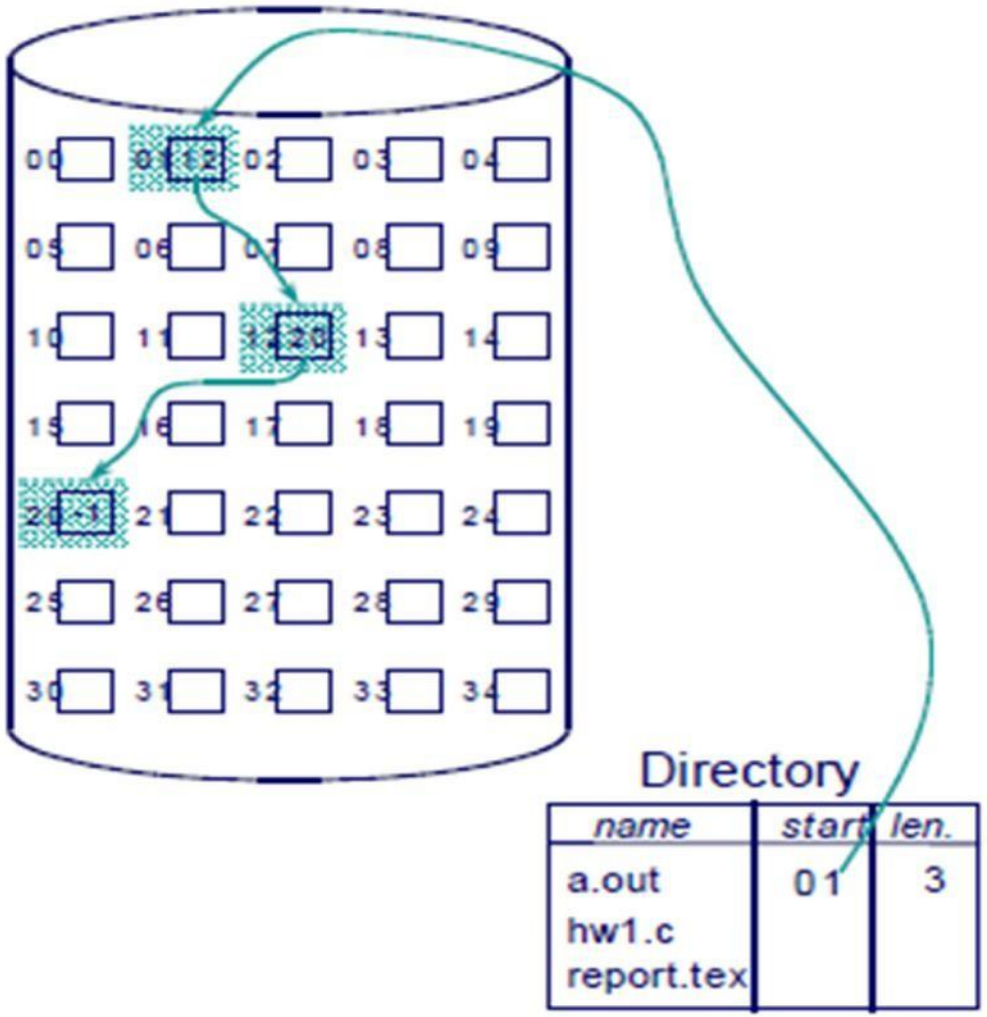
name	start	len.
a.out	00	3
hw1.c	12	6
report.tex	20	11

Contiguous Allocation of Disk Space



Chained (linked) allocation

- Space allocation is similar to page frame allocation.
- Mark allocated blocks as in-use.
- *Advantages*:
  - no external fragmentation
  - files can grow easily
- *Disadvantages*
  - Lots of seeking
  - Random access difficult
- Example
  - MSDOS (FAT) file system

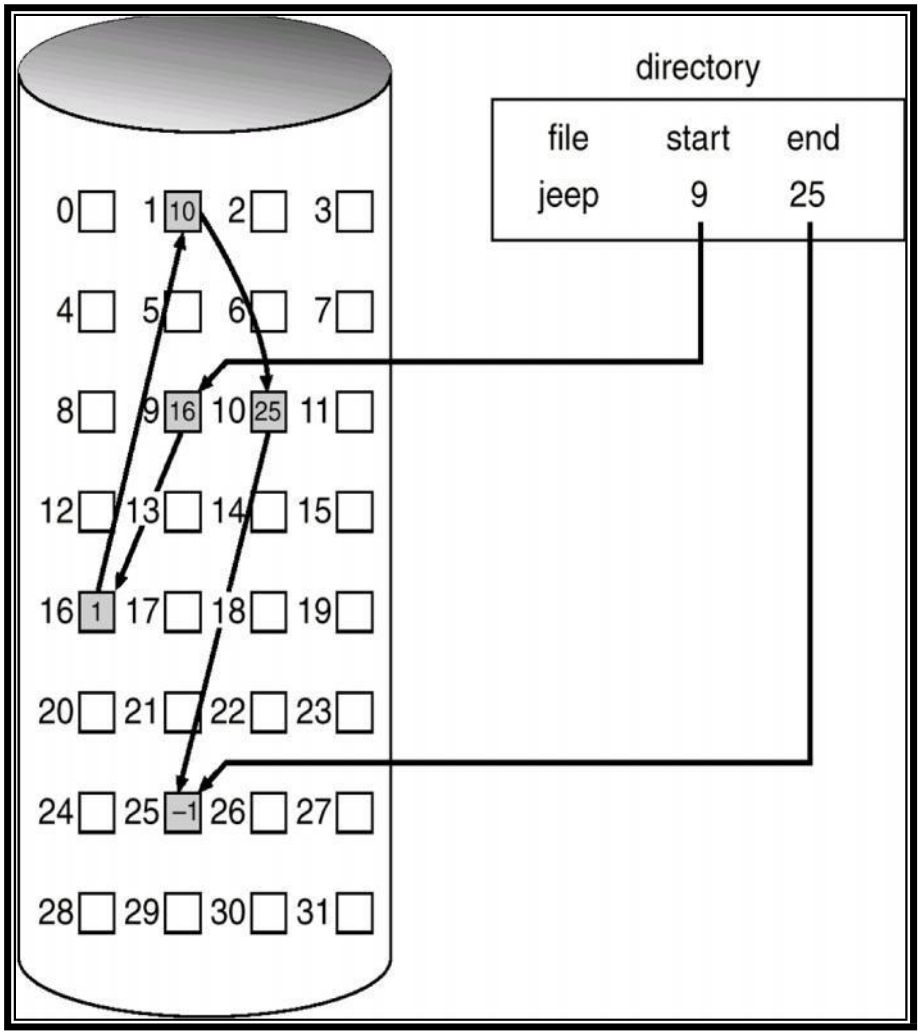


Linked Allocation…

- Each file is a linked list of disk blocks:
- blocks may be scattered anywhere on the disk.

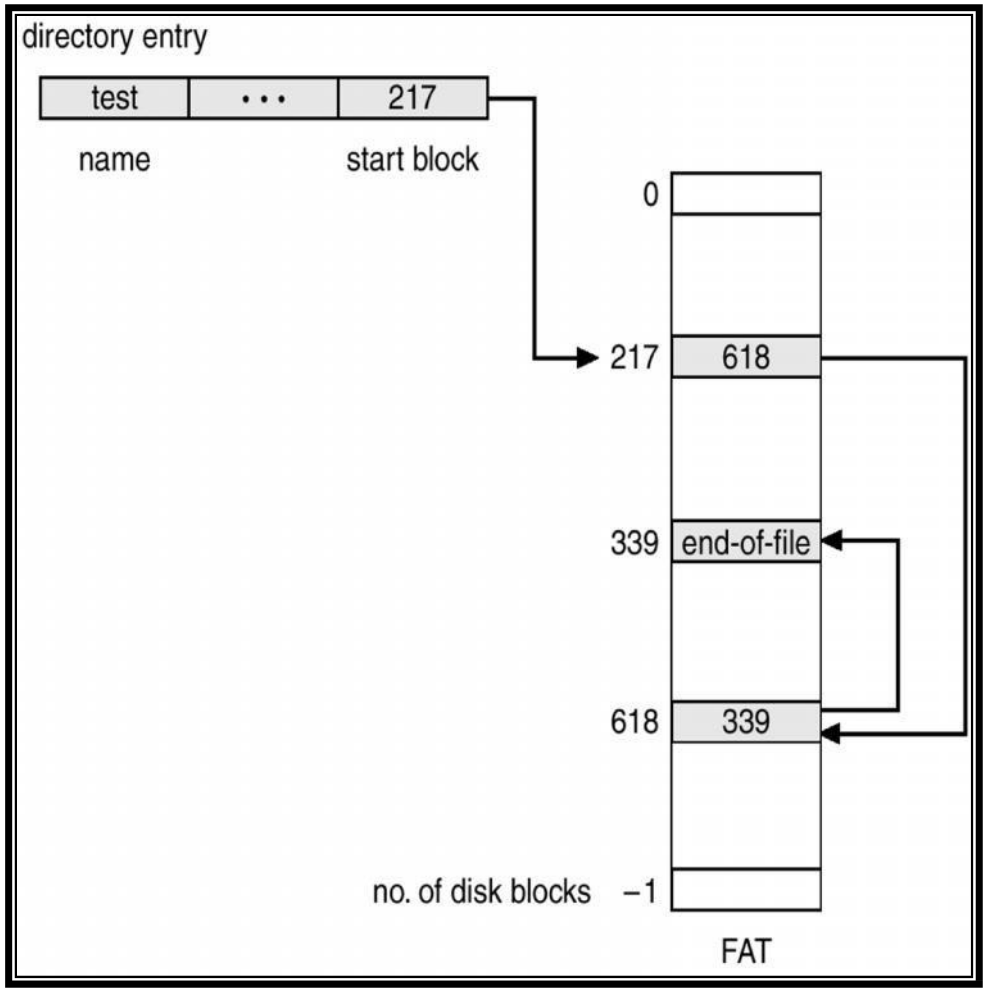
block =

pointer



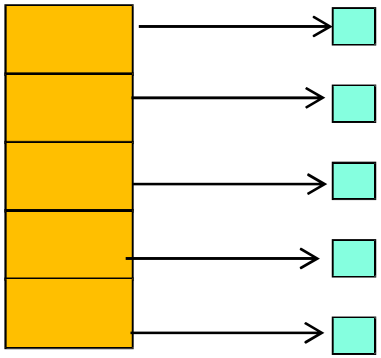
File-Allocation Table

- File-allocation table (FAT) – disk-space allocation used by MS-DOS and OS/2.



Indexed Allocation

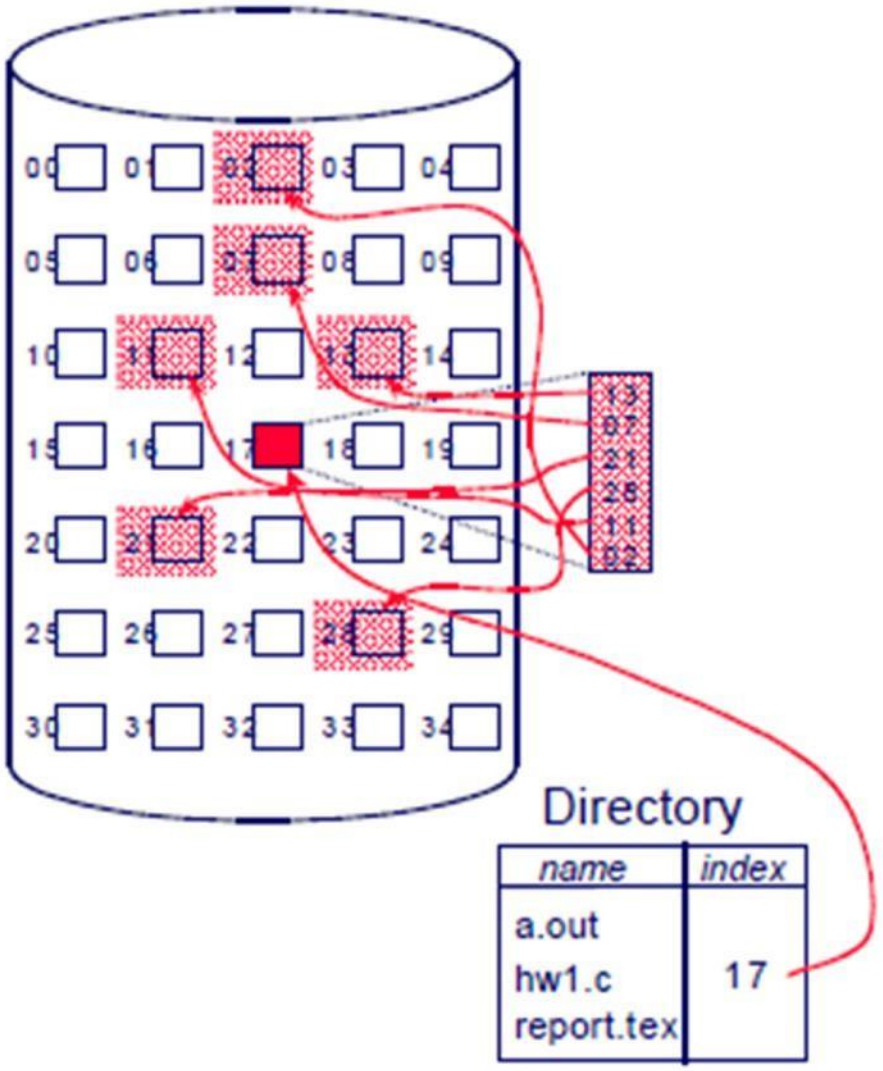
- Brings all pointers together into the *index block.*
- Logical view.



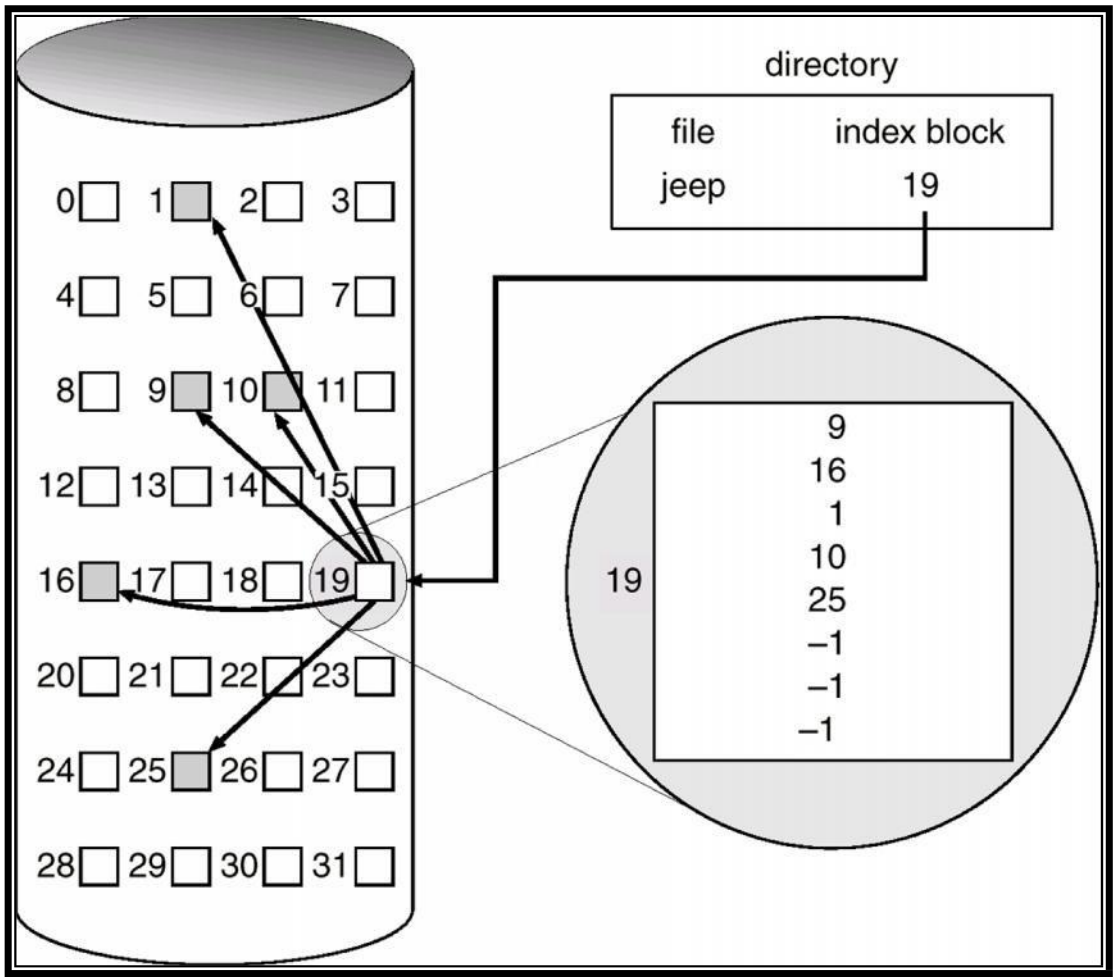
index table

Indexed allocation…

- Allocate an array of pointers during file creation.
- Fill the array as new disk blocks are assigned.
- *Advantages*
  - Small internal fragmentation
  - Easy sequential and direct access
- *Disadvantages*
  - Lots of seeks if the file is big
  - Maximum file size is limited to the size of the block
- Example
  - Unix file system



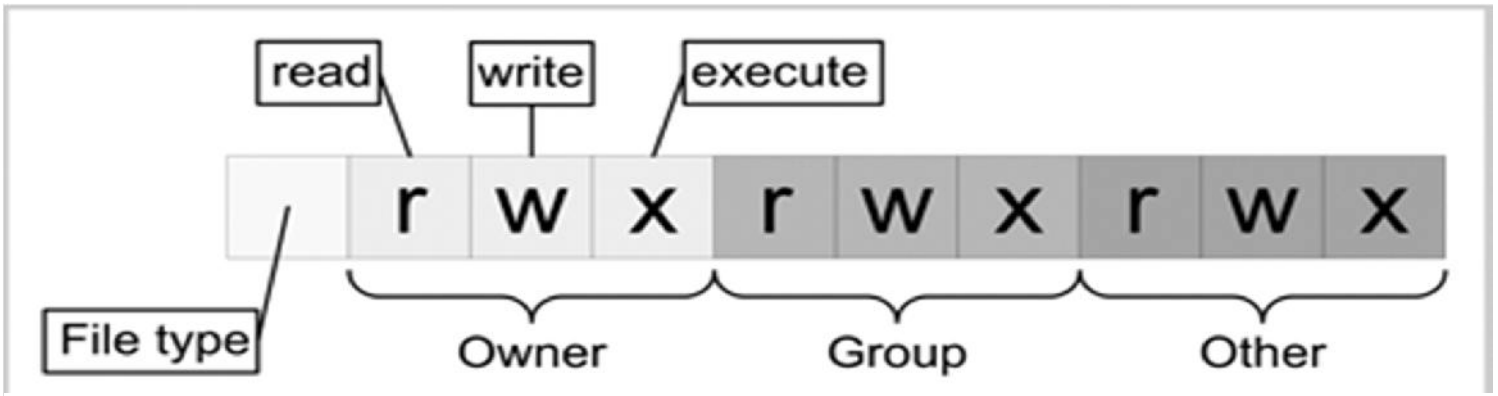
Example of Indexed Allocation



File Permissions

- Read, write, and execute privileges
- In Windows:
  - Change permission on the Security tab on a file's Properties dialog box
  - Allow indicates grant;
  - Deny indicates revoke
- In UNIX/Linux
  - Three permission settings:
    - owner; group to which owner belongs; all other users
  - Each setting consist of rwx
    - r for reading, w for writing, and x for executing
  - CHMOD command used to change file permissions

File Permissions



- One can easily view the permissions for a file by invoking a long format listing using the command **ls -l**.
- For instance, if the user Abe creates an executable file named test, the output of the command **ls -l** test would look like this:

rwxrwxr-x Abe student Sep 26 12:25 test.l

Access Permissions

- This listing indicates that the file is readable, writable, and executable by the user who owns the file (user Abe)
- as well as the group owning the file (which is a group named student).
- The file is also readable and executable, but not writable by other users.

rwxrwxr-x Abe student Sep 26 12:25 test.l

Access Permission of File/Directory

- The ownership of the file or directory can be changed using the command
  - **`chown <owner> <file/directory name>`**
- The group of the file or directory can be changed using the command
  - **`chgrp <group> <file/directory name>`**
- The permissions of the file can be changed using chmod command
  - **`chmod -R ### <filename or directory>`**
- -R is optional and when used with directories will traverse all the sub-directories of the target directory changing ALL the permissions to ###.

Access Permission of File/Directory

The #'s can be:

0 = Nothing
1 = Execute
2 = Write
3 = Execute & Write (2 + 1)
4 = Read
5 = Execute & Read (4 + 1)
6 = Read & Write (4 + 2)
7 = Execute & Read & Write (4 + 2 + 1)