File-System Interface

Chapter 11

Adapted from the slides given by Silberschatz, Galvin, and Gagne
In "Operating System Concepts", 10th edition John Wiley and Sons, Inc 2018.

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Outline of this lecture

In this lecture, we will discuss the following:

- File Concept
- Access Methods
- Directory Structure
- Protection

File-System (FS) Structure

- File system consists of:
  - A collection of files – storing related data
  - Directory structure- provides information about all the files in the system.

- File system resides on secondary storage (disks).

File Concept

- A collection of data- normally is stored on a secondary storage device.
- File types refer to classifying the content of the file, such as:

- Types:
  - Data
    - numeric
    - character
    - binary
  - Program

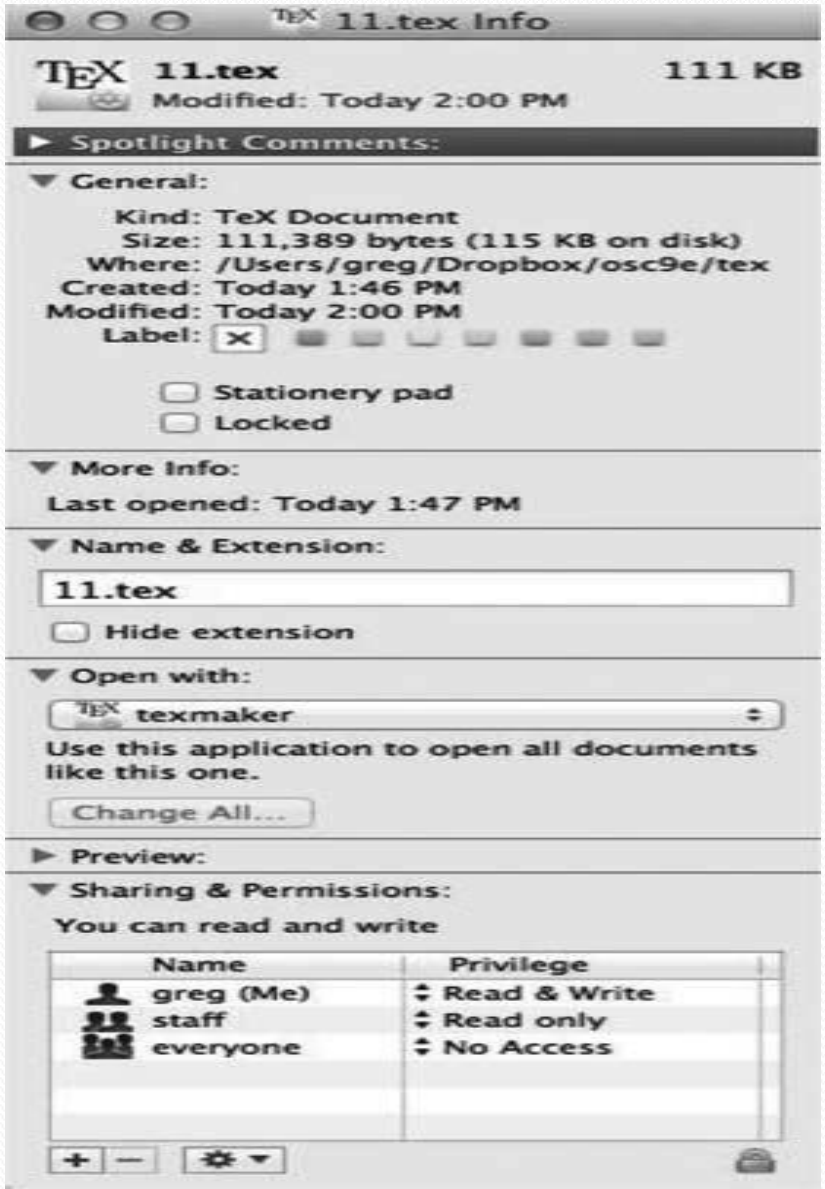
- Contents defined by file's creator
  - Many types
    - Consider **text file, source file, executable file**

File Attributes

A file has several attribute- vary from one O/S to another but consist of these:

- **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** – this information can be useful for protection, security, and usage monitoring.
- Information about files are kept in the directory structure, which is maintained on the disk.

File info Window on Mac OS X



File Operations

An OS must provide a number of operations associated with files so that users can safely store and retrieve data. Typical 6 basic operations are:

- *Create*- find space in the file system & entry for new file must be made in dir.
- *Write*- make system call specifying both the name of the file & inf to be written to it.
- *Read*- use system call specifying the file's name & where next block should be put.
- *Seek* -repositioning within file (searching the directory for the appropriate entry).
- *Delete*- search the directory for the named file, erase the directory entry.
- *Truncate*- erase the contents of file but keep its attributes.
- *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.

Open Files

- Most of the file operations involve **searching** the directory for the entry associated with the named file. To avoid searching, the OS keeps a table

- Several pieces of data are needed to **manage** open files:
  - **Open-file table**: contains info abt all open files
  - **File pointer:** pointer must track the last read/write location as a current file position pointer, per process that has the file open
  - **File-open count**: counter of number of times a file is open by many processes, when the open count reaches o, the file is no longer in use, and the file's entry is removed from the open file table
  - **Disk location of the file:** most file operations require the system to modify data within the file. The info needed to locate the file on a disk is kept in memory
  - **Access rights:** each process opens a file in an access mode. This info is stored on the per-process table so the OS can allow/deny I/O requests.

File Types – name, extension

file type	usual extension	function
executable	exe, com, bin or none	ready-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, rtf, doc	various word-processor formats
library	lib, a, so, dll	libraries of routines for programmers
print or view	ps, pdf, jpg	ASCII or binary file in a format for printing or viewing
archive	arc, zip, tar	related files grouped into one file, sometimes com-pressed, for archiving or storage
multimedia	mpeg, mov, rm, mp3, avi	binary file containing audio or A/V information

File Structure

- Files must conforms to a required structure understood by the OS. i.e. OS requires that the exe file have a specific structure, so that it can determine where in memory to load the file & what the location of the 1st instruction.
- None - sequence of words, bytes
- Simple record structure
  - Lines
  - Fixed length
  - Variable length
- Complex Structures
  - Formatted document
  - Relocatable load file
- Can simulate last two with first method by inserting appropriate control characters
- Who decides:
  - Operating system
  - Program

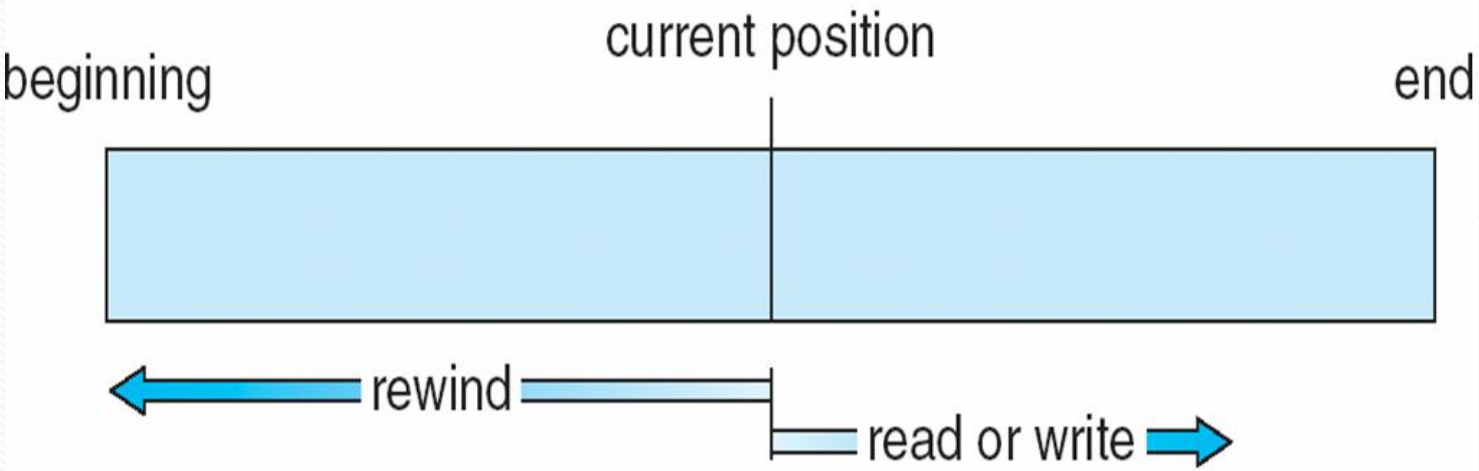
Access Methods

Information stored in files must be accessed & read into memory.
So how can this information be accessed?

- **Sequential Access**
  - information in the file is processed in order- 1 record after another
  - Most common, Editors & compilers access files in this fashion.

- **Direct Access / Relative Access**
  - File is made up of fixed-length logical records, allow programs to read/write records rapidly in no particular order.
  - file is viewed as a numbered sequence of records.
  - Records are organized in a manner that allows direct access to a particular record without having to read any of the preceding records.
  - Allows blocks to be read or written in any order- no restriction on the order of reading/writing for a direct-access file.
  - Useful for immediate access to large amounts of info (DB).

Sequential-access File

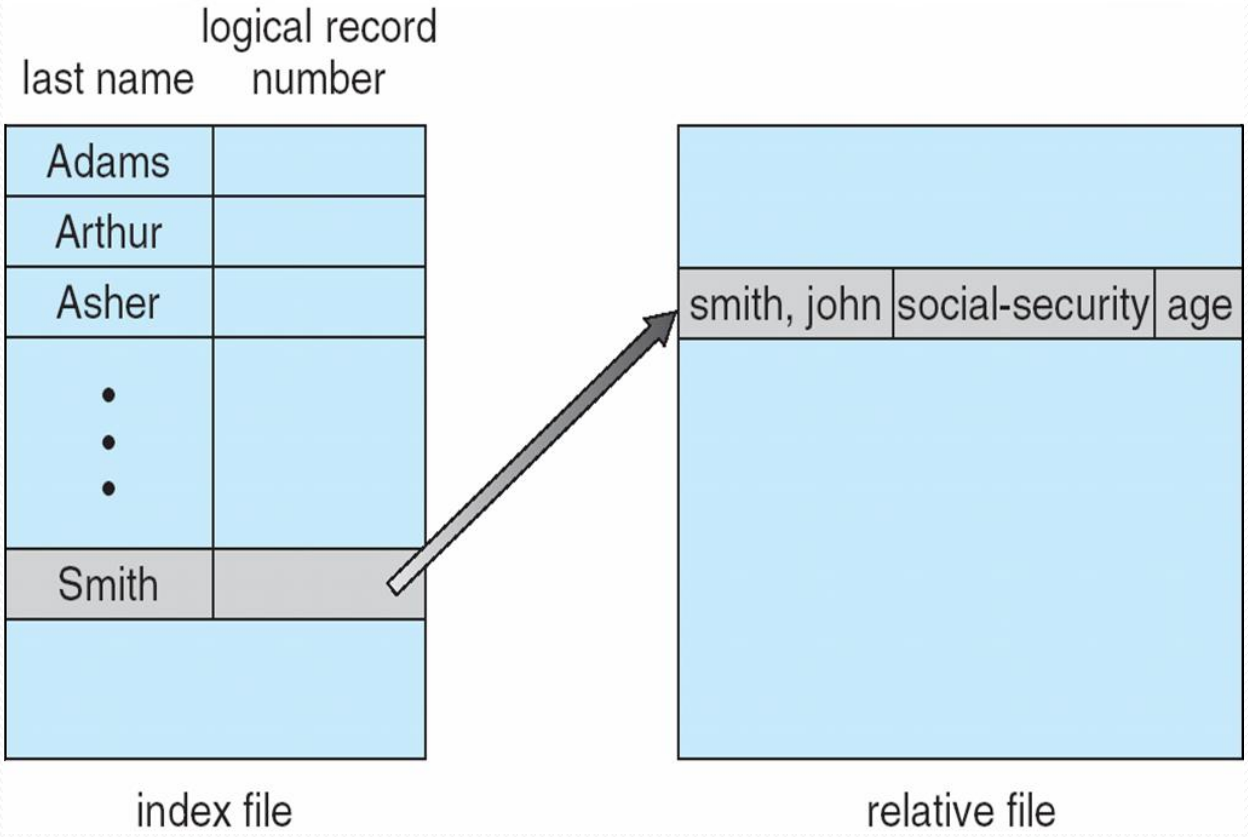


Other Access Methods

- Can be built on top of direct Access
- General involve creation of an index for the file
- ***Index file-*** stores an index into another file
- With large files, the index file become too large --------→ solution
- ***Primary, secondary index file-*** primary index file contains pointers to the secondary one, which points to the actual data items.

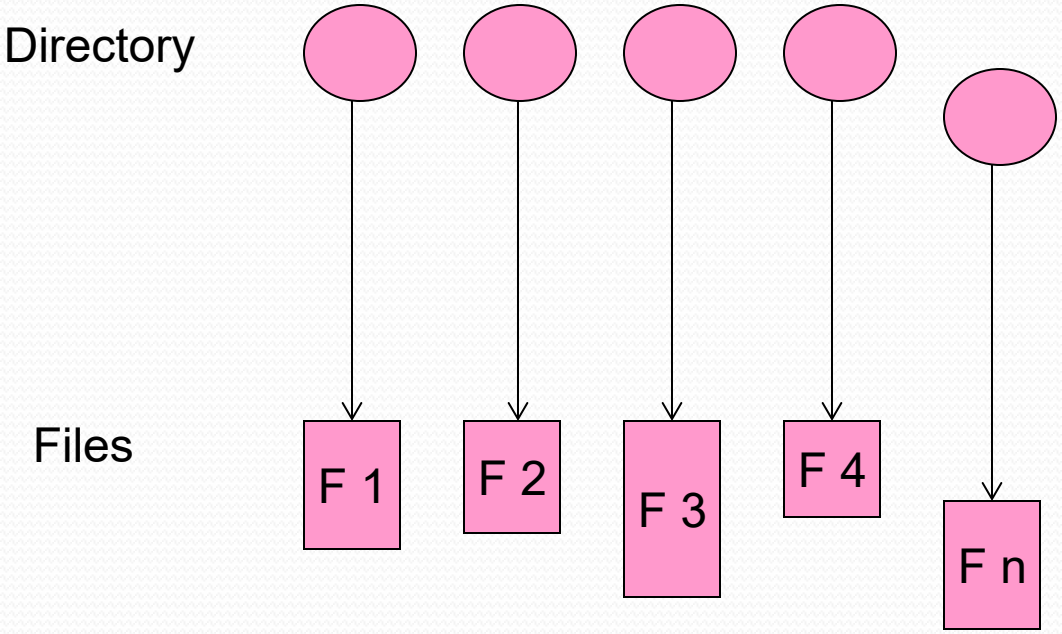
- IBM indexed sequential-access method (ISAM)
  - Small master index, points to disk blocks of secondary index
  - File kept sorted on a defined key
  - All done by the OS
- VMS operating system provides index and relative files as another example (see next slide)

Example of Index and Relative Files



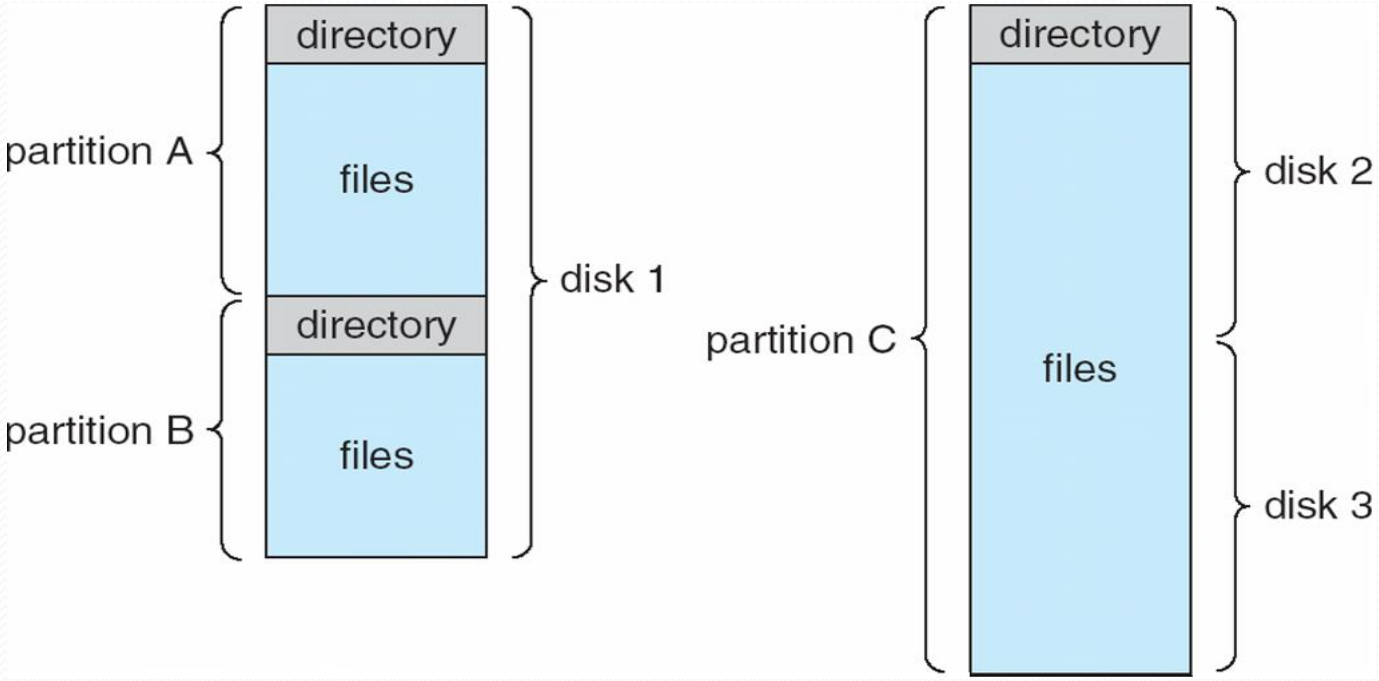
Directory Structure

- A collection of nodes containing information about all files.



- Both the directory structure and the files reside on disk.

A Typical File-system Organization



- Disks are split into 1 or more partitions, each treated as a separate storage device.
- Each partition contains info about files within it.
- Directory records info. i.e. name, location, size & type for all file on the partition.

Operations Performed on Directory

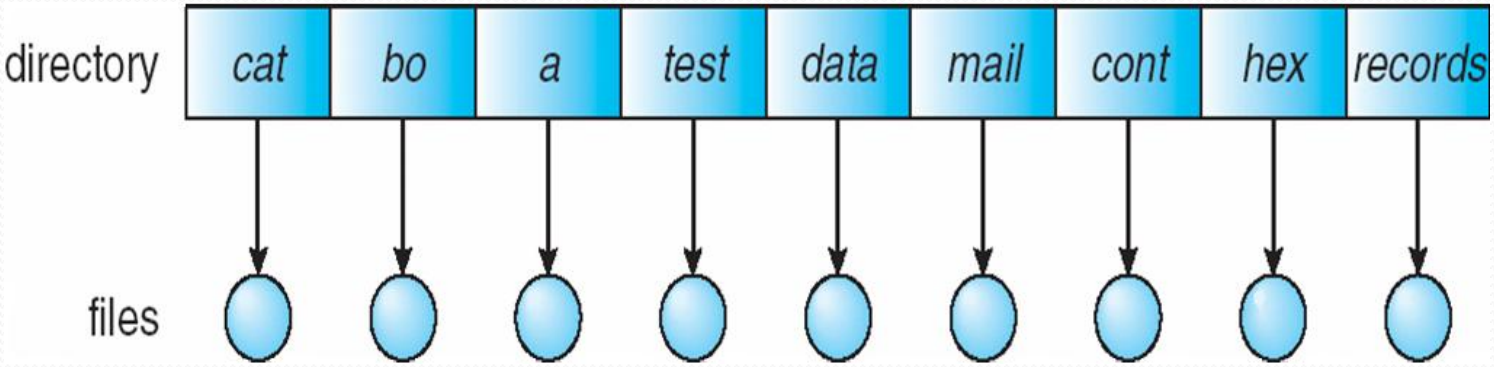
- *Search for a file*- be able to search a directory structure to find particular file
- *Create a file*- new files need to be created & added to the directory.
- *Delete a file*- be able to remove a file from the directory.
- *List a directory*- be able to list the files in a directory.
- *Rename a file*- be able to change the name of a file when the contents or use of the file changes.
- *Traverse the file system*- be able to access every directory & every file within a directory structure.

Directory Organization

- 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

- All files are in the same directory- easy to support & understand.

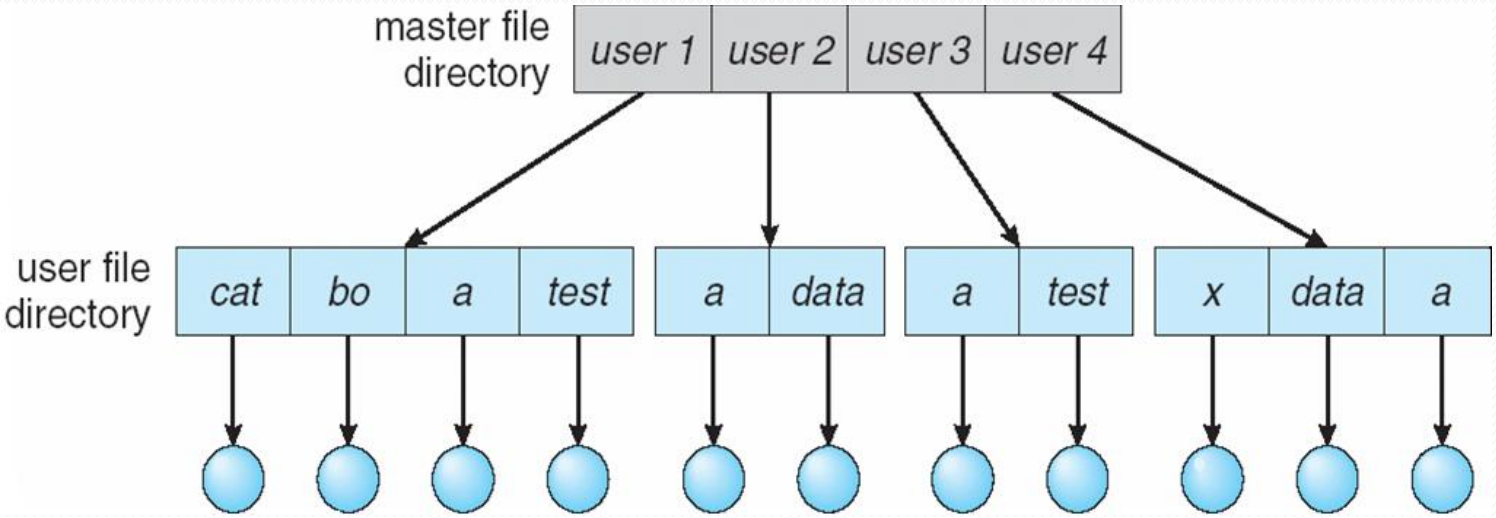


Limitations:

- *Naming problem*- all files need to have a unique names, as they are in the same directory.
- *Grouping problem*-

Two-Level Directory

- Separate directory for each user.
- Each user has her own *user file directory* (UFD).
- *Master file directory* (MFD) is searched when a user logs in.



- Can have the same file name for different user
- Isolates one user from another- problem when users want to cooperate on some tasks & to access one another's files.
- Efficient searching
- No grouping capability

Tree-Structured Directories

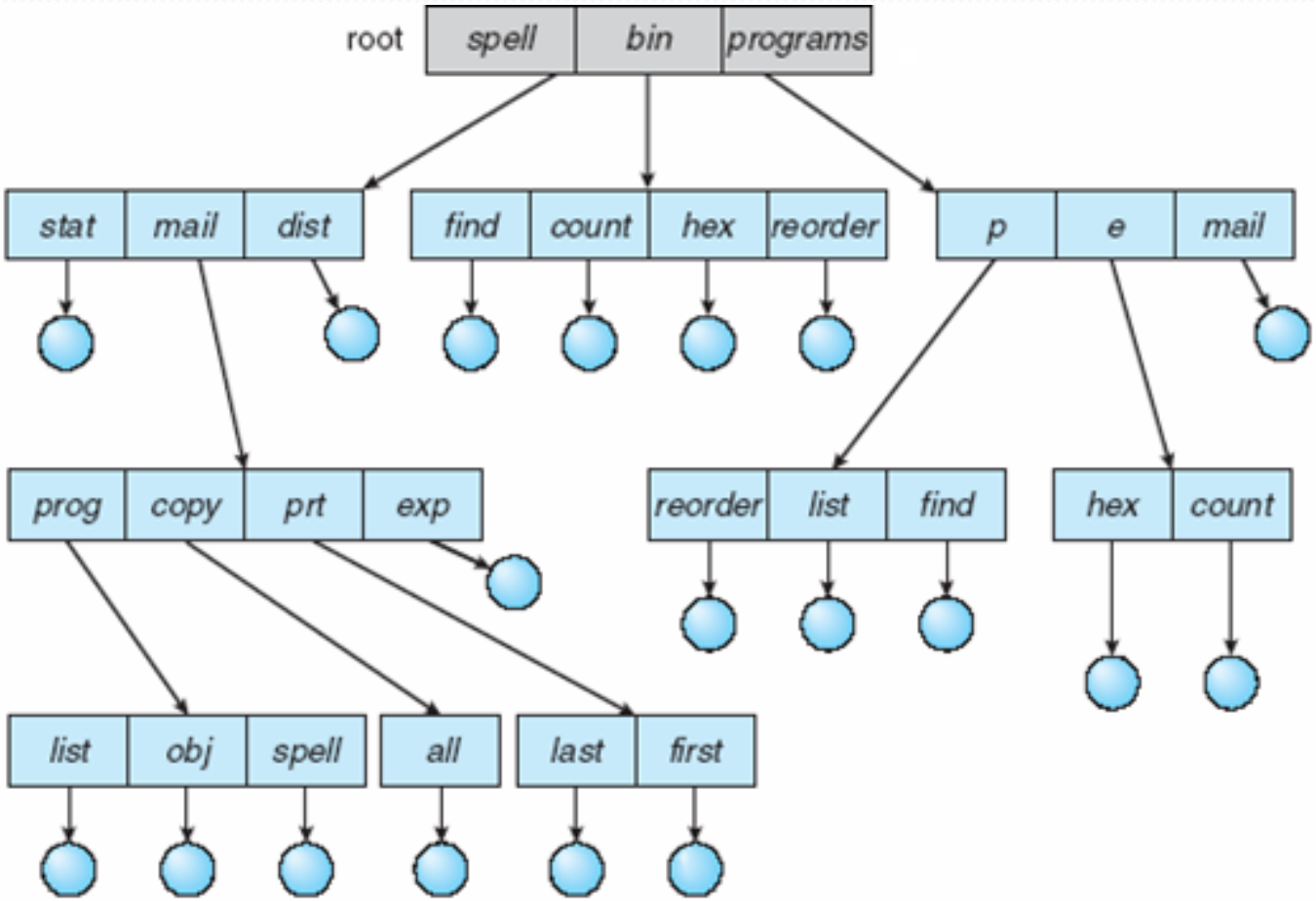
- A tree has a *root directory*, & every file in the system has a unique *path name*.
- *path name*- root ---→subdirectories ----→specified file.
- Efficient searching
- Grouping Capability: Each directory contains a set of files or Subdirectories.
- ***Current directory***- contains most the files that are of current interest to the user.
- ***Absolute path name:*** begins at the root --→ a path down--→ specified file.
- ***Relative path name:*** defines path from the current directory.
- Deletion of a directory
  - If empty- can be deleted.
  - If not empty- some systems, will not delete a directory. e.g: MS-DOS.

    - other systems, remove the entire dir structure. e.g. UNIX

      rm <file-name>

      - But, if the command is issued in error-→ large no of files & directories will need to be restored.

Tree-Structured Directories (Example)

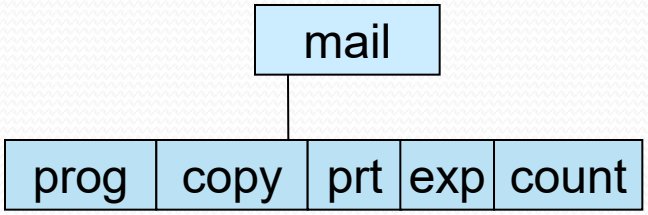


Tree-Structured Directories (Cont.)

- Creating a new file is done in current directory.
- Creating a new subdirectory is done in current directory.

  Ex: if in current directory /spell/mail

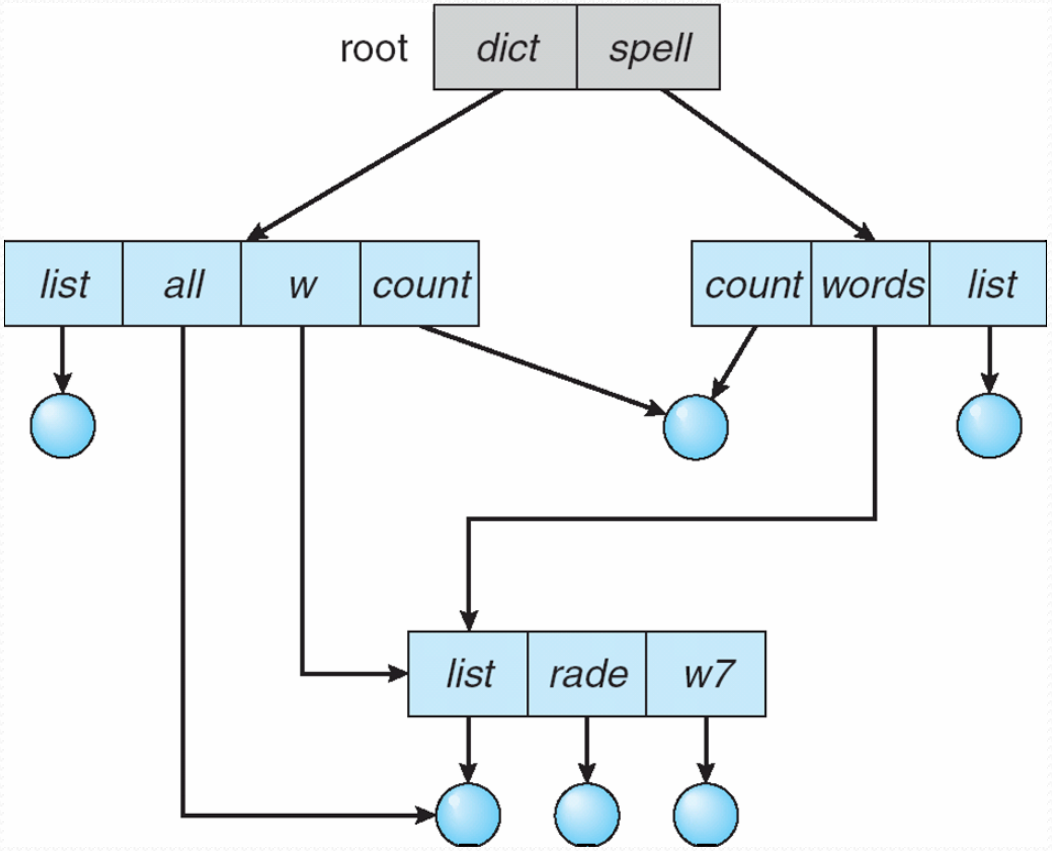
  mkdir count



- Deleting "mail" $\Rightarrow$ deleting the entire subtree rooted by "mail"

Acyclic-Graph Directories

- Allows directories to share subdirectories and files- any changes made by one user are immediately available to the other.



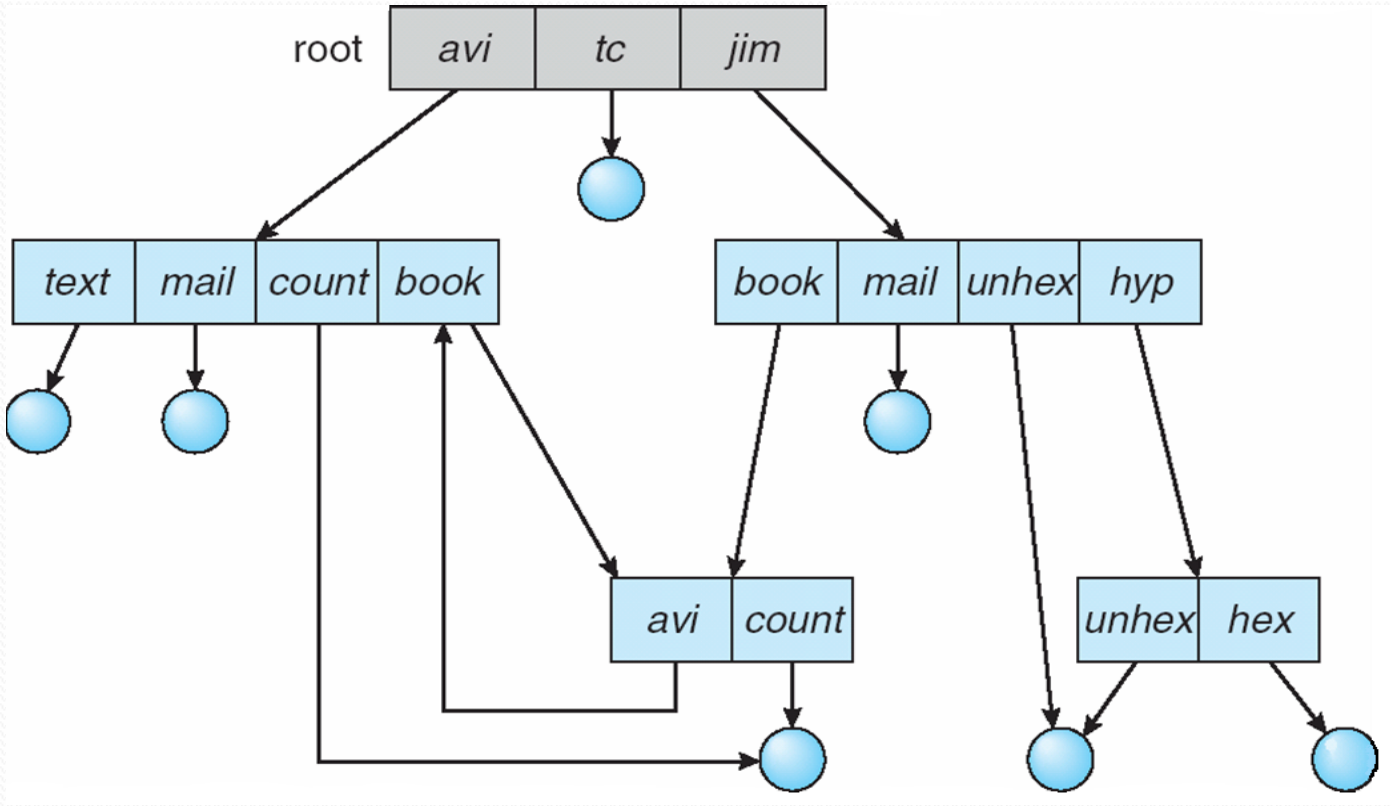
Acyclic-Graph Directories (Cont.)

- There are several ways to implement shared files and directories:
  - ***Link-*** pointer to another file or subdirectory (maybe implemented as relative/absolute path name).
  - **Resolve the link** – using path name to locate the real file
  - ***Duplicate File Information*** - Duplicating all information about the shared files in both sharing directories.

- **Aliasing problem** - A file can have multiple file absolute path names

- **Deletion Problem**: dangling pointers- remove the file whenever anyone deletes it
  - **Solution**
    - Delete only the link.
    - Preserve file until all references to it are deleted- when the file-reference list is empty, the file is deleted.

General Graph Directory



- If we start with a two-level dir & allow users to create subdirectories, what would result?
- By adding links to an existing tree structure dir, the tree structure is destroyed--→simple graph structure.

General Graph Directory (Cont.)

- When a file can be deleted?
- A value of 0 in the reference count→ no reference → delete in acyclic graph
- When cycles exist, reference count may not be 0 even when it is no longer possible to reference to a file/directory, due to self-referencing/ cycle in the directory
  - Allow only links to file not subdirectories.
  - Garbage collection to determine when the last reference has been deleted & the disk space can be reallocated.
  - Every time a new link is added use a cycle detection algorithm to determine whether it is OK. Will the new link complete a cycle or not?

Protection

- Protection is needed so that users do not accidentally/deliberately destroy someone else's information.
- Information is private & should not be read by other users.
- OS must provide means to protect the info in the file system.

- Many types of operations could be controlled:
  - Read
  - Write
  - Execute
  - Append
  - Delete
  - List

Access Lists and Groups

- Different users may need different types of access to a file or directory: read, write, execute
- Access-control list (ACL) to be associated with each file & directory specifying: username & type of access allowed for each user.
  - **problems:**
    - *Length*- must list all users with read access to allow read a file.
    - *List construction* could be a boring task- list of users in the system not known in advance.
    - *Variable size directory entry*- complicated space management.

- A more general scheme with three classes of users
  Example: UNIX

		RWX
a) owner access	⇒	1 1 1
b) groups access	⇒	RWX 1 1 0
c) universe access	⇒	RWX 0 0 1

- Other protection approaches: Associate a password with each file or dir.

Windows 7 Access-Control List Management