CISC 3320
File System Interface

Hui Chen

Department of Computer & Information Science

CUNY Brooklyn College

Acknowledgement

- These slides are a revision of the slides provided by the authors of the textbook via the publisher of the textbook

Outline

- File System Interface
  - File Concept
  - Access Methods
  - Disk and Directory Structure
  - File-System Mounting
  - File Sharing
  - Protection

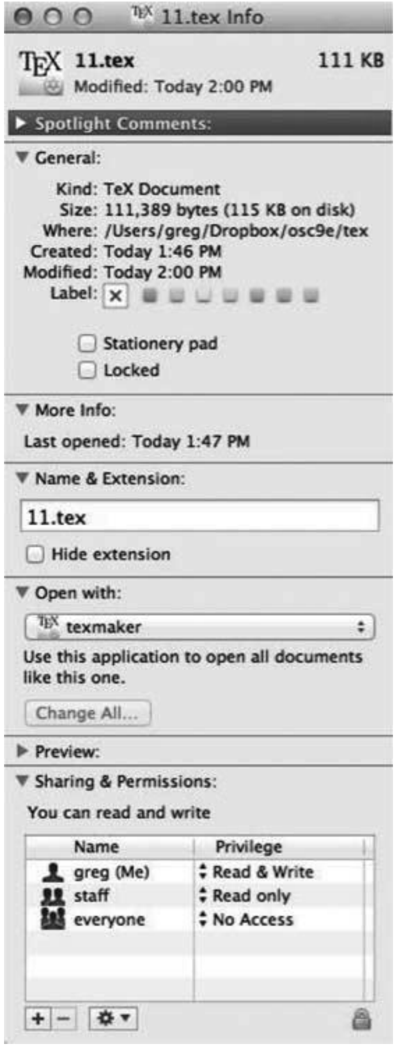
File Concept

- Contiguous logical address space
- Types:
  - Data
    - numeric
    - character
    - binary
  - Program
- Contents defined by file’s creator
  - Many types
    - Consider **text file, source file, executable file**

File Attributes

- **Name** – only information kept in human-readable form
- **Identifier** – unique tag (number) identifies file within file system
- **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
- Many variations, including extended file attributes such as file checksum
- Information kept in the directory structure

File Info/Properties: Examples



11.tex Info

11.tex 111 KB
Modified: Today 2:00 PM

▶ Spotlight Comments:

▼ General:

Kind: TeX Document
Size: 111,389 bytes (115 KB on disk)
Where: /Users/greg/Dropbox/osc9e/tex
Created: Today 1:46 PM
Modified: Today 2:00 PM
Label: ☒

□ Stationery pad
□ Locked

▼ More Info:

Last opened: Today 1:47 PM

▼ Name & Extension:

11.tex

□ Hide extension

▼ Open with:

texmaker

Use this application to open all documents like this one.

Change All...

▶ Preview:

▼ Sharing & Permissions:

You can read and write

Name	Privilege
greg (Me)	Read & Write
staff	Read only
everyone	No Access

File Operations

- File is an **abstract data type**
- **Create**
- **Write –** at **write pointer** location
- **Read –** at **read pointer** location
- **Reposition within file - seek**
- **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

Open Files

- Several pieces of data are needed to manage open files:
  - **Open-file table**: tracks open files
  - File pointer: pointer to last read/write location, per process that has the file open
  - **File-open count**: counter of number of times a file is open – to allow removal of data from open-file table when last processes closes it
  - Disk location of the file: cache of data access information
  - Access rights: per-process access mode information

Open File Locking

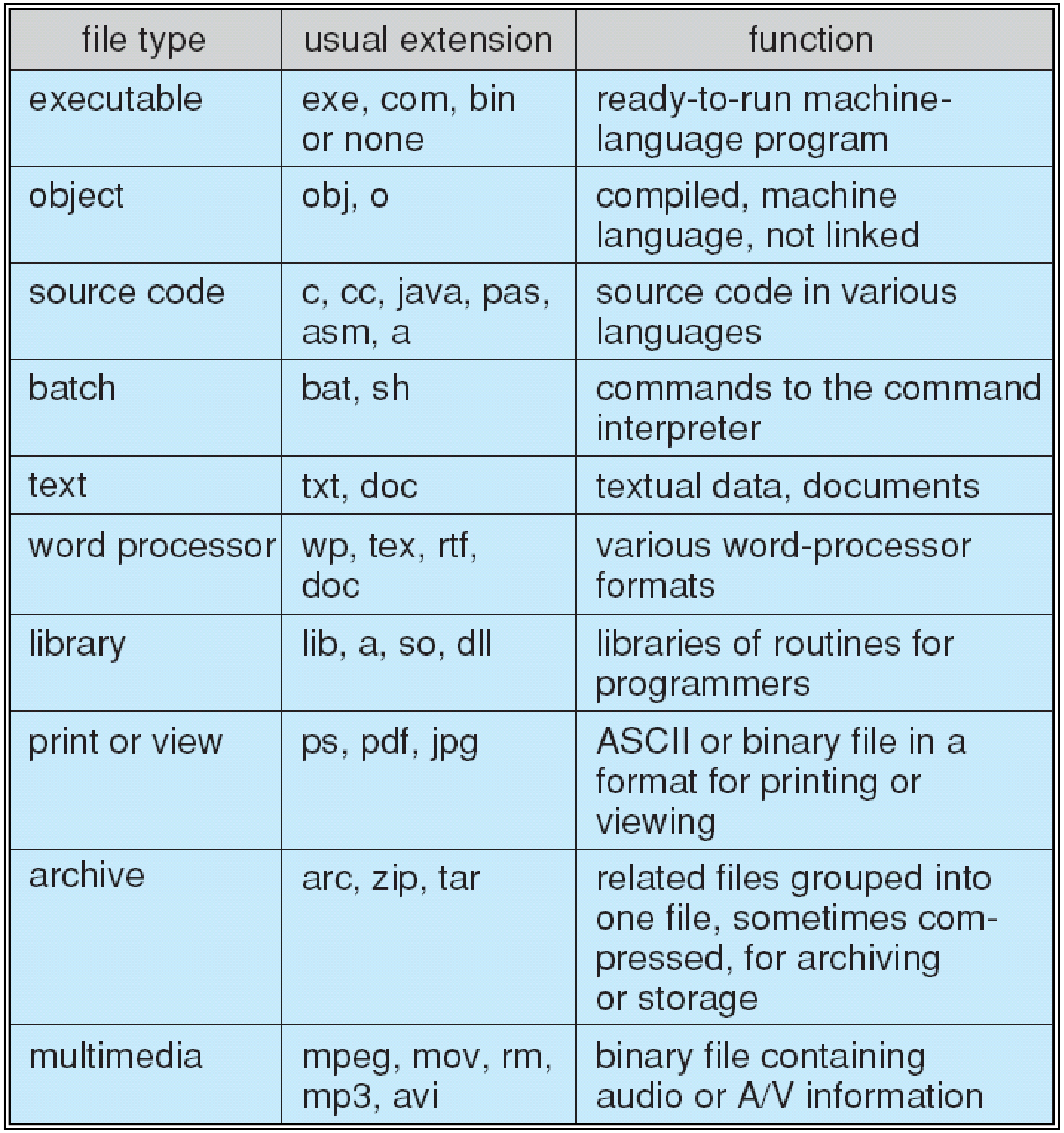
- Provided by some operating systems and file systems
  - Similar to reader-writer locks
  - **Shared lock** similar to reader lock – several processes can acquire concurrently
  - **Exclusive lock** similar to writer lock
- Mediates access to a file
- Mandatory or advisory:
  - **Mandatory** – access is denied depending on locks held and requested
  - **Advisory** – processes can find status of locks and decide what to do

Locking: Examples

- Java
  - java.nio.channels.FileChannel::lock
- Linux
  - flock

File Types

- Extensions are often used to differentiate types of files



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 compressed, for archiving or storage
multimedia	mpeg, mov, rm, mp3, avi	binary file containing audio or A/V information

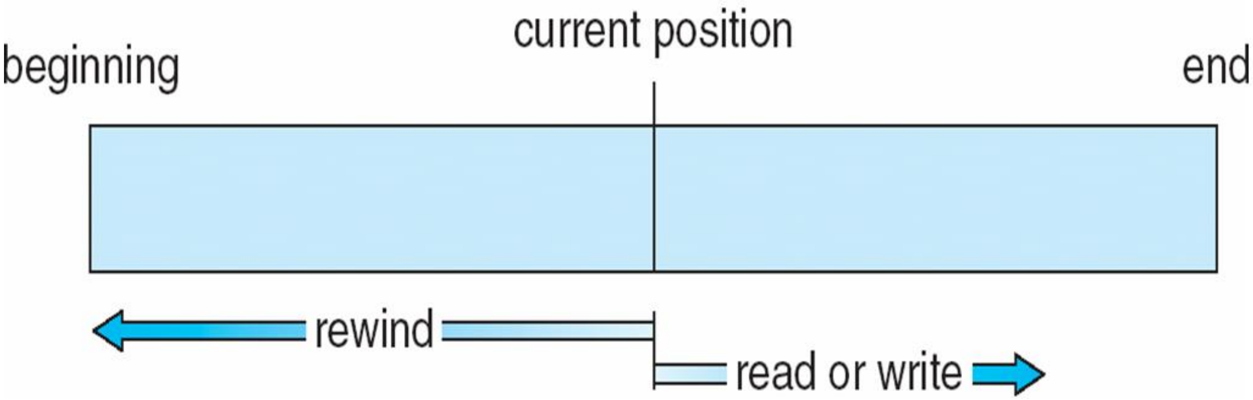
File Types: Example

- Unix
  - Using the utility “file”

File Structure

- 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

Sequential-Access File



Access Methods

- **Sequential Access**

```
read next
write next
reset
```

no read after last write
    (rewrite)

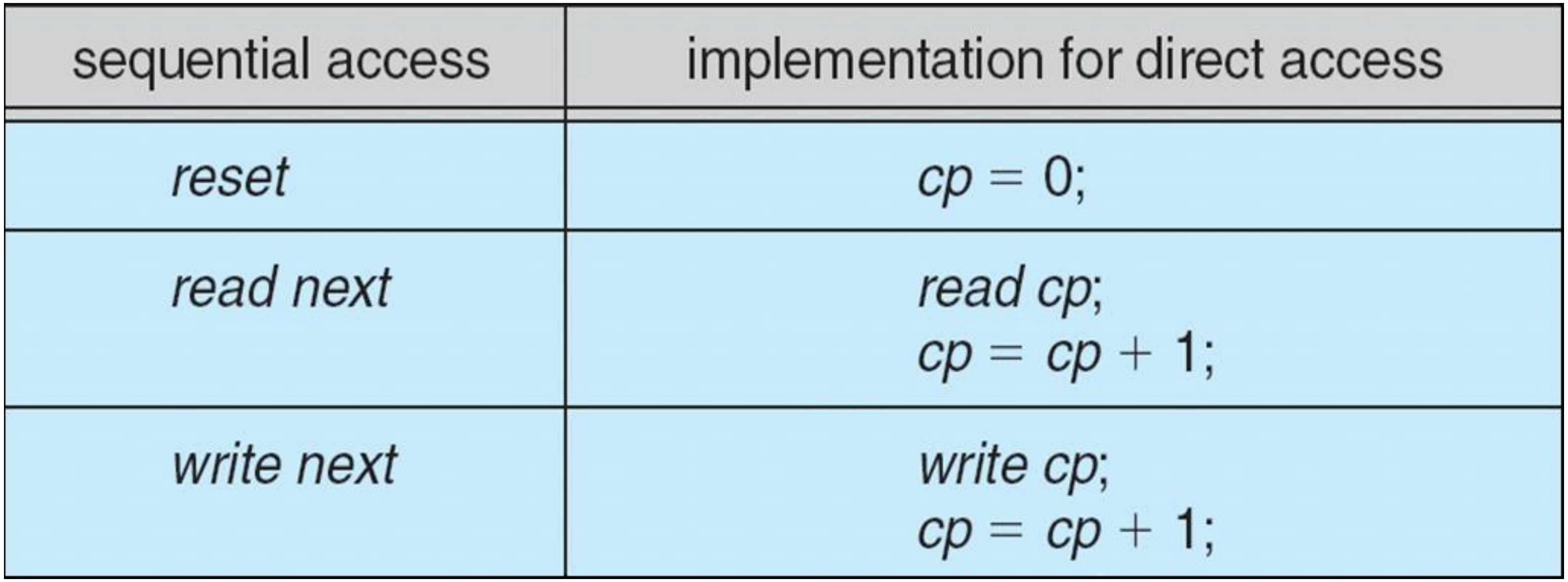
- **Direct Access –** file is fixed length logical records

```
read n
write n
position to n
        read next
        write next
rewrite n
```

n = relative block number

- Relative block numbers allow OS to decide where file should be placed

Simulation of Sequential Access on Direct-access File

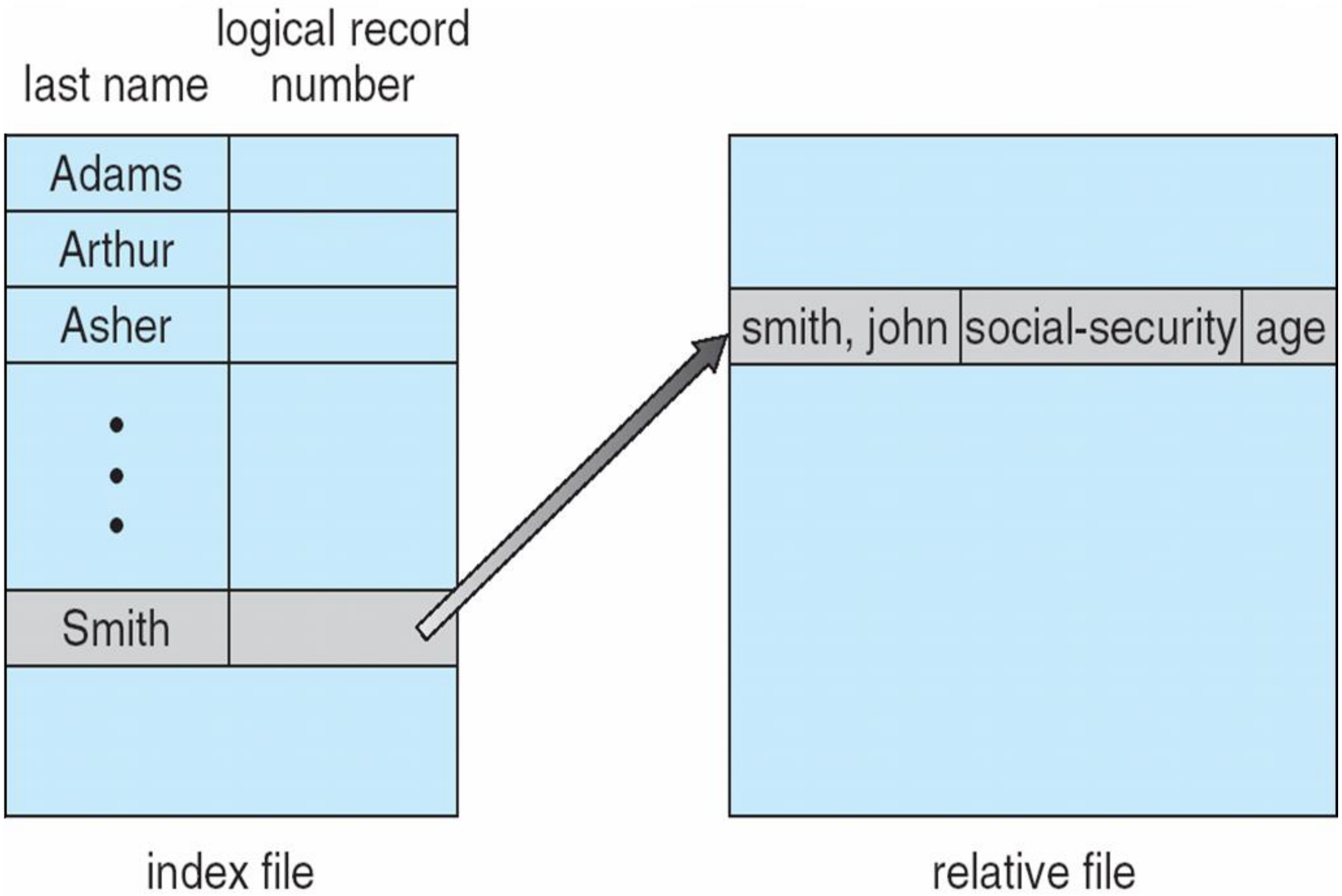


sequential access	implementation for direct access
reset	*cp* = 0;
read next	*read cp*; *cp* = *cp* + 1;
write next	*write cp*; *cp* = *cp* + 1;

Other Access Methods: Index

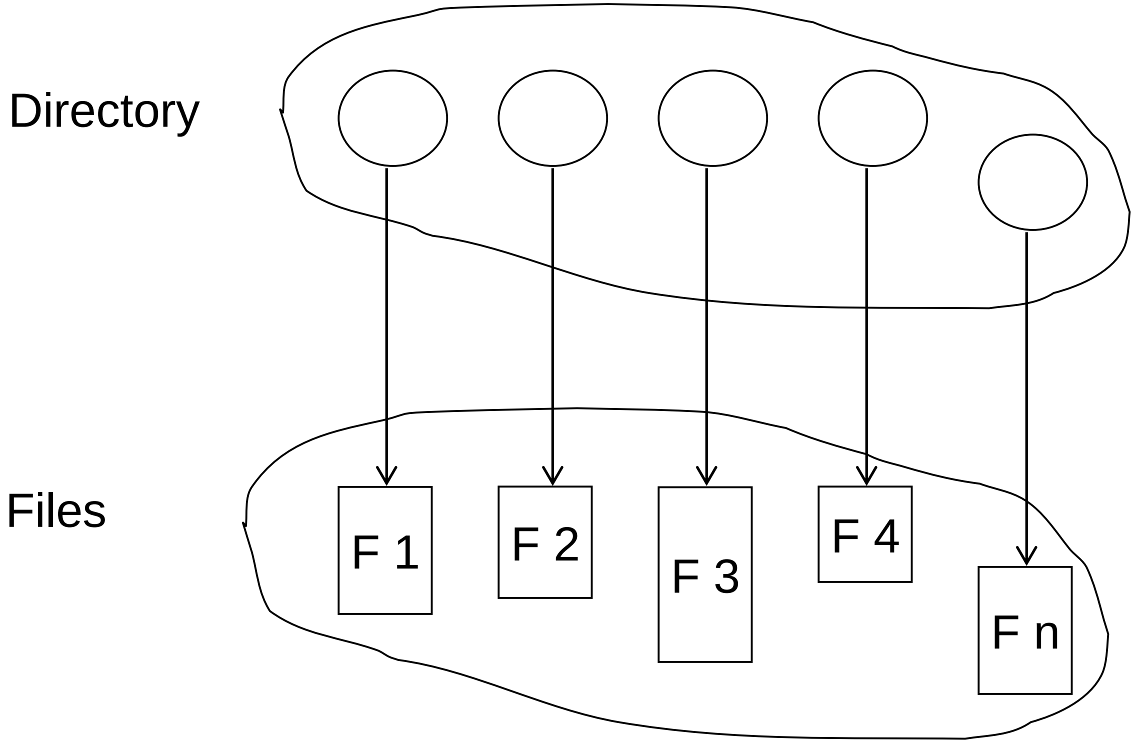
- Can be built on top of base methods
- General involve creation of an index for the file
- Keep index in memory for fast determination of location of data to be operated on (consider UPC code plus record of data about that item)
- If too large, index (in memory) of the index (on disk)
- IBM indexed 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

Questions?

- Files and directories?

Operations Performed on Directory

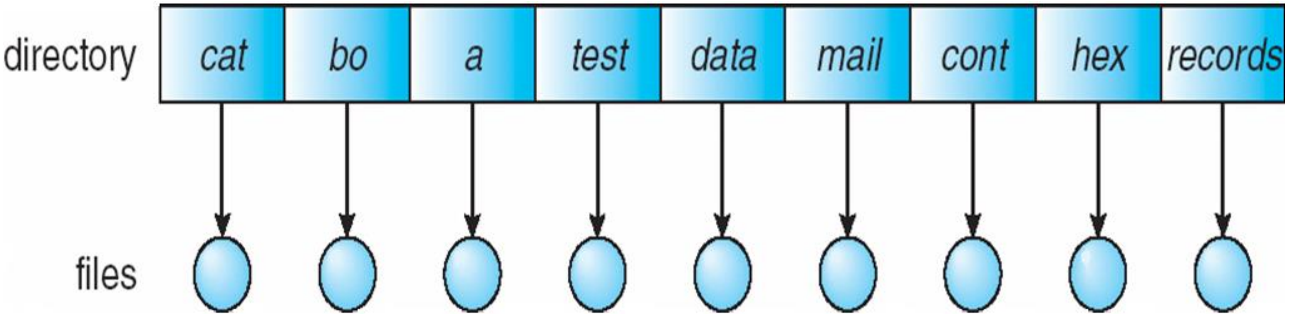
- Search for a file
- Create a file
- Delete a file
- List a directory
- Rename a file
- Traverse the file system

Directory Organization

- The directory is organized logically for
    - 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

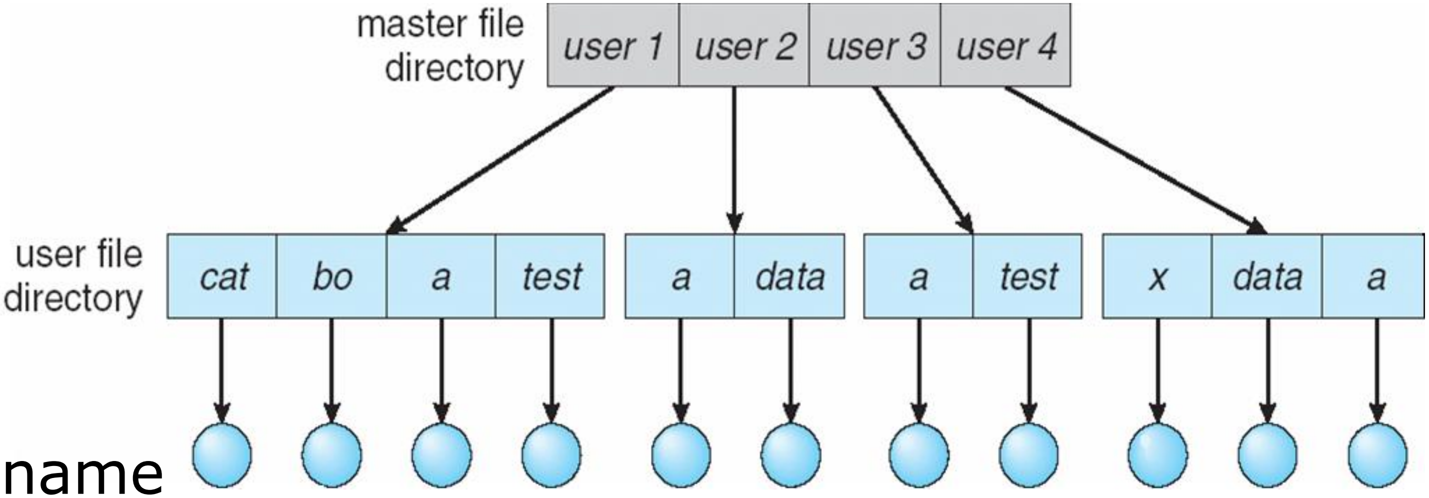
- A single directory for all users



- Naming problem
- Grouping problem

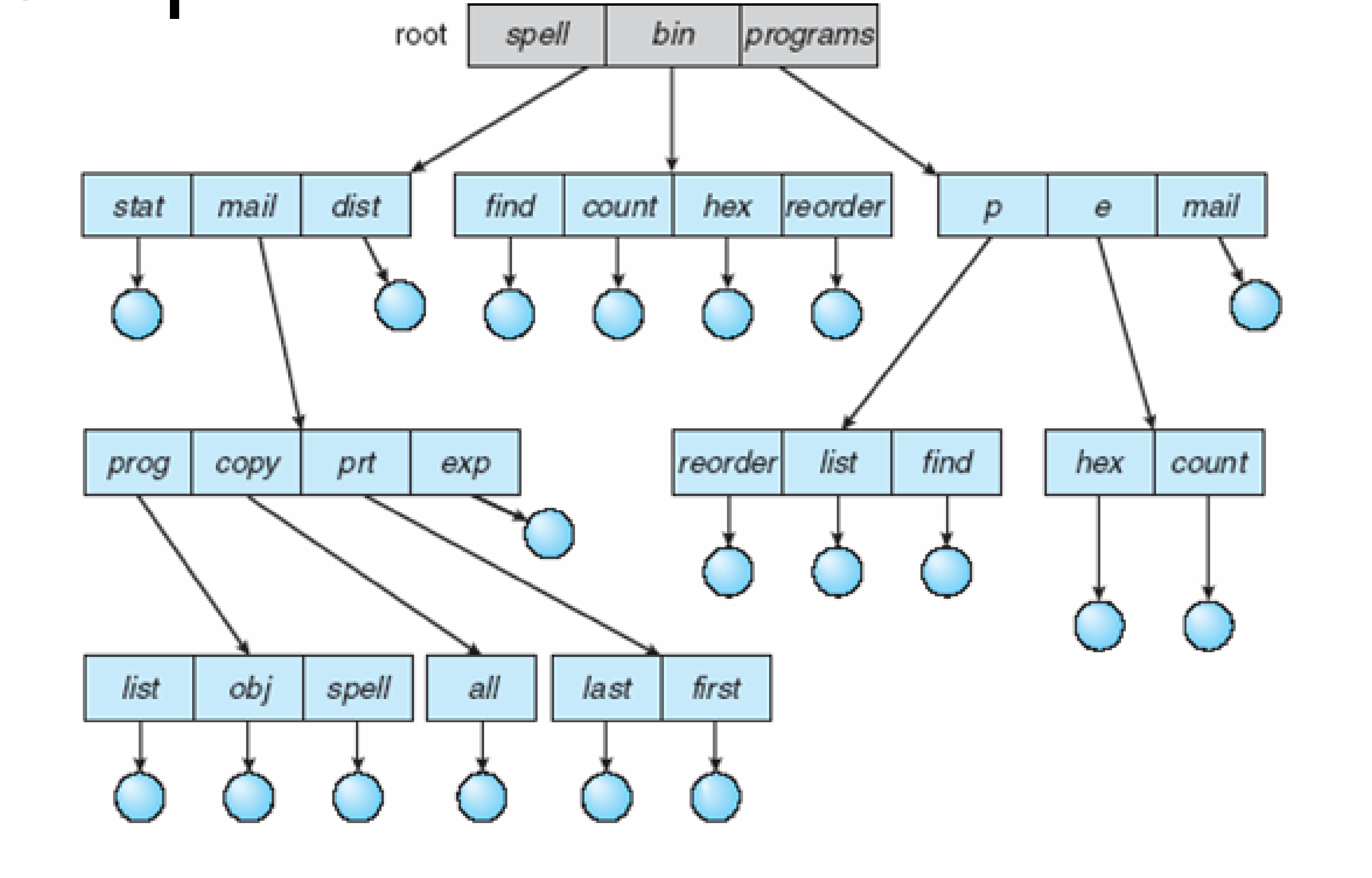
Two-Level Directory

- Separate directory for each user



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

Tree-Structured Directories: Example



Tree-Structured Directories

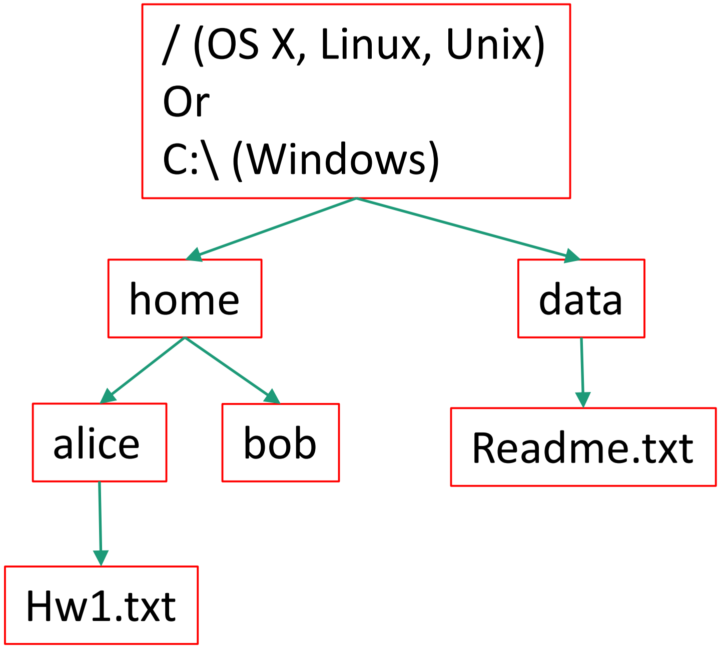
- Efficient searching
- Grouping Capability
- Current directory (working directory)
  - **`cd /spell/mail/prog`**
  - **`type list`**

Path Names

- A path name of a file (or directory) is a traversal of the file system tree or the directory tree to the file (or directory)
    - Any traversal is a valid path name
- Absolute path
- Relative path

Path Name: Examples

- File system tree traversal
  - Example: identify Hw1.txt
  - OS X
    - /home/alice/Hw1.txt
  - Windows
    - C:\home\alice\Hw1.txt
  - Delimiter
    - Windows: "\"
    - Unix-like: "/"



Relative and Absolute Path

- Absolute path
  - Contains the root element and the complete directory list required to locate the file
    - Example: /home/alice/Hw1.txt or C:\home\alice\Hw1.txt
- Relative path
  - Needs to be combined with another path in order to access a file.
  - Example
    - alice/Hw1.txt or alice\Hw1.txt, without knowing where alice is, a program cannot locate the file
  - "." is the path representing the current working directory
  - ".." is the path representing the parent of the current working directory

Working with Directories and Files: Examples

- Creating a new file is done in current directory
- Delete a file

```
rm <file-name>
```

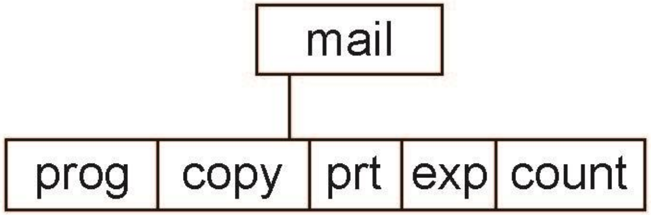
- Creating a new subdirectory is done in current directory

```
mkdir <dir-name>
```

Example: if in current directory **`/mail`**

```
mkdir count
```

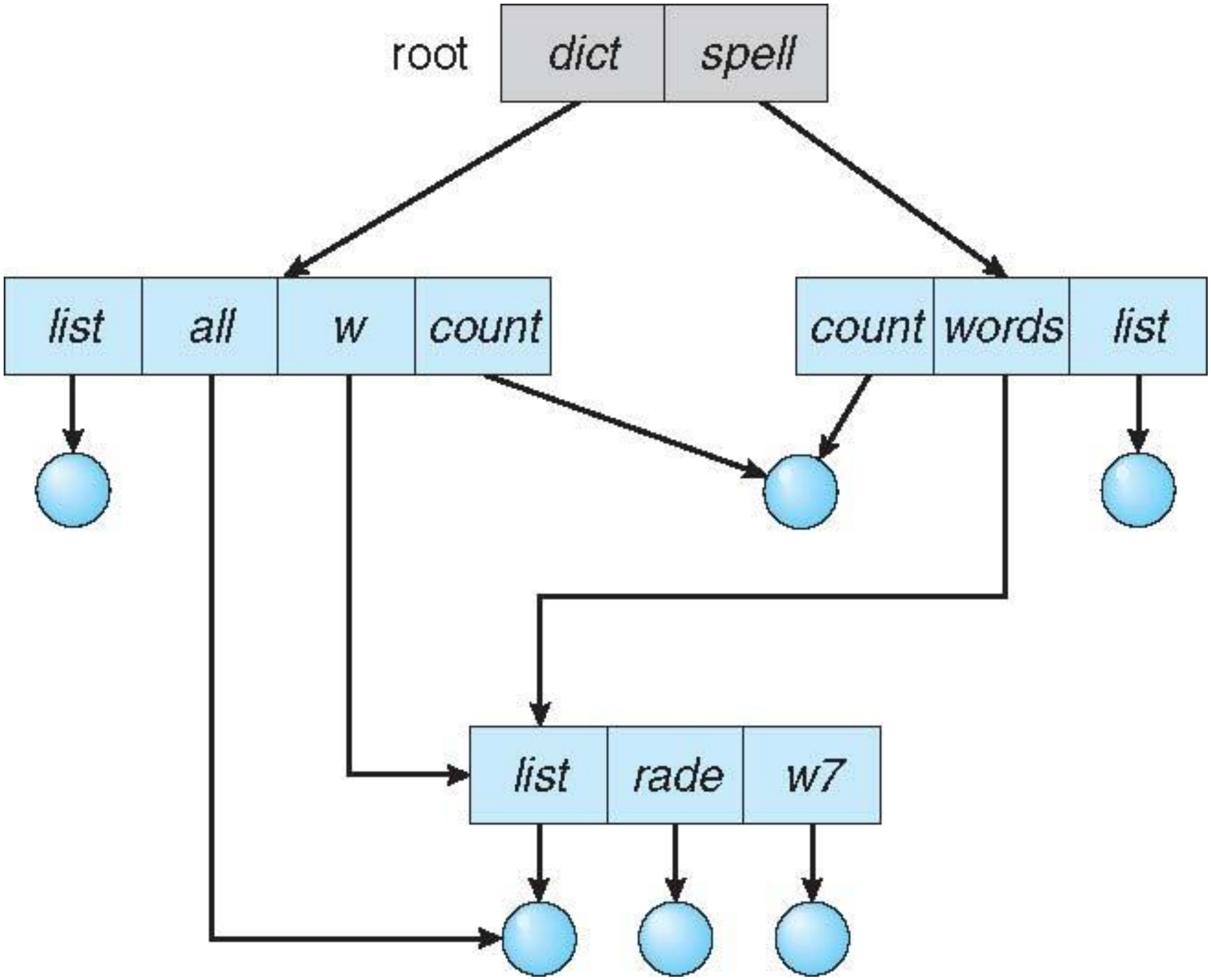
Working with Directories and Files: Examples



Deleting “mail” ⇒ deleting the entire subtree rooted by “mail”

Acyclic-Graph Directories

- Have shared subdirectories and files


root
dict
spell
list
all
w
count
count
words
list
list
rade
w7

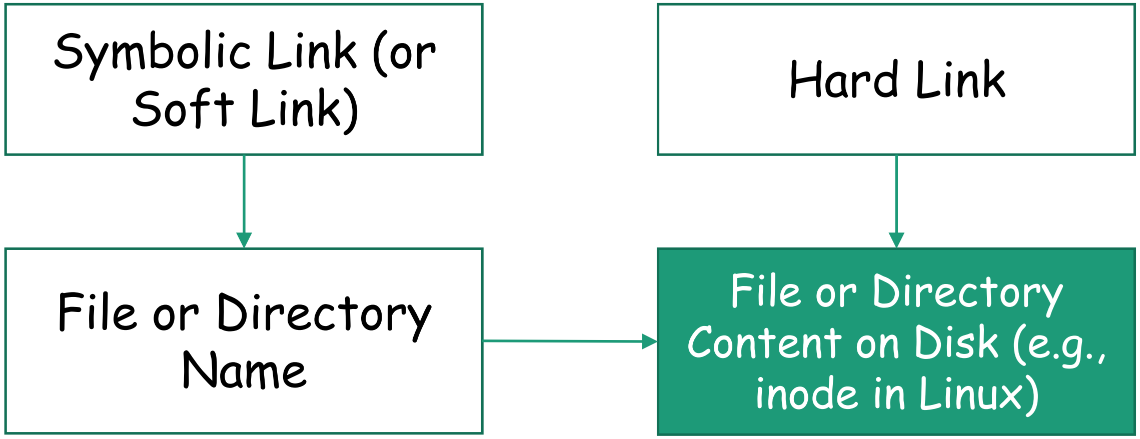
Aliasing and Links

- Two different names (aliasing)
- If deleteing ***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
- New directory entry type
  - **Link** – another name (pointer) to an existing file
  - **Resolve the link** – follow pointer to locate the file

Examples: Symbolic Link and Hard Link

- A file-system object (source) that points to another file system object (target).
  - Symbolic link (soft link): an “alias” to a file or directory name
  - Hard link: another name of a file or directory


Symbolic Link (or Soft Link)
Hard Link
File or Directory Name
File or Directory Content on Disk (e.g., inode in Linux)

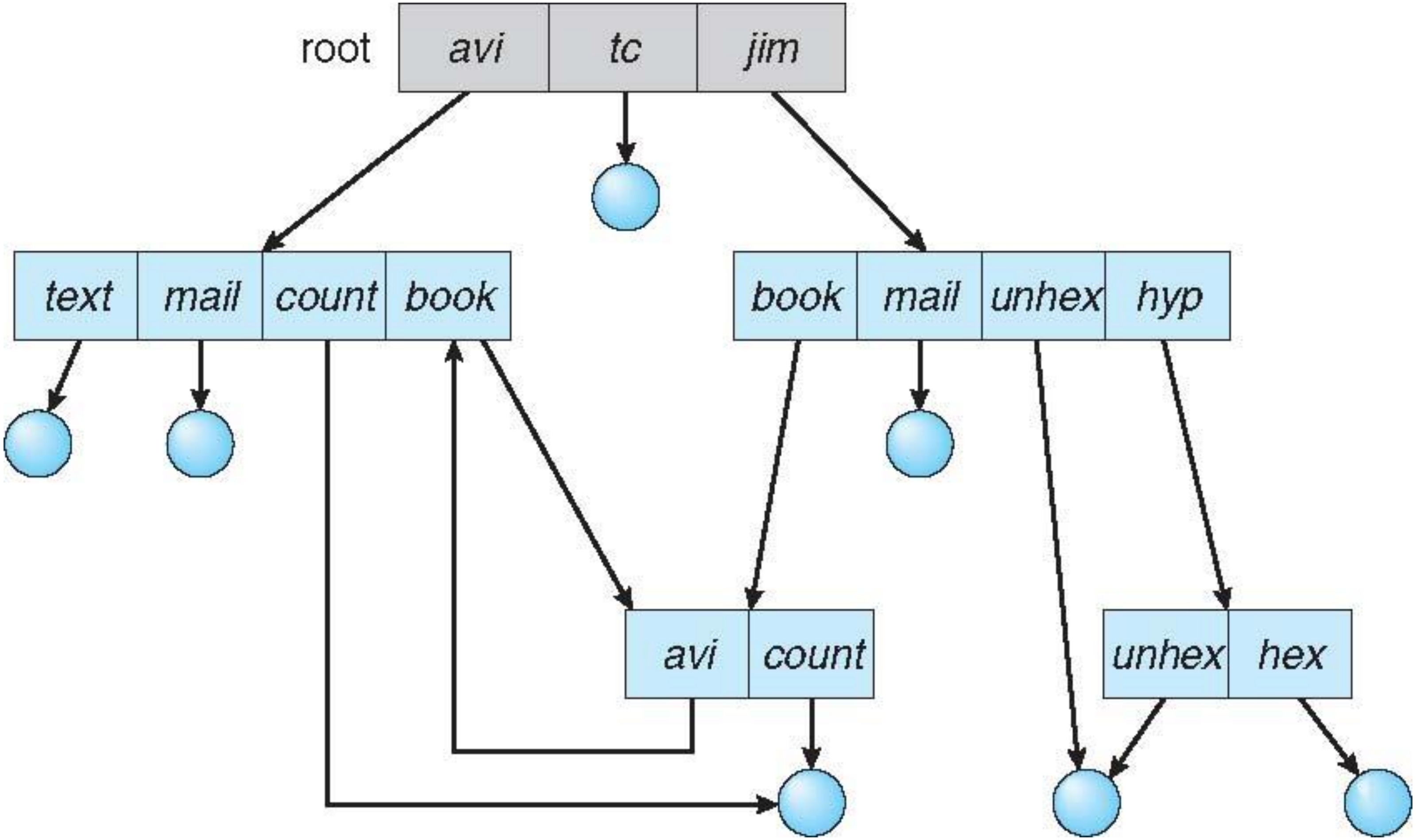
Unix-like OS: Example

- Unix-like (e.g., Linux, OS X): “#” leads a comment. do the following on the terminal,
  - echo “hello, world!” > hello.txt # create a file, the content is “hello, world!”
  - ln -s hello.txt hello_symlink.txt # create a soft link to hello.txt
  - ls -l hello_symlink.txt # list the file, what do we observe?
  - cat hello_symlink.txt # show the content using the symbolic link, what do we observe?
  - ln hello.txt hello_hardlink.txt # create a hard link
  - ln -l hello_hardlink.txt # observation?
  - cat hello_hardlink.txt # observation?
  - mv hello.txt hello2.txt # rename hello.txt
  - ls -l hello_symlink.txt # observation?
  - ln -l hello_hardlink.txt # observation?
  - cat hello_symlink.txt # observation?
  - cat hello_hardlink.txt # observation

Window: Example

- On Windows, it requires elevated privilege to create file symbolic link. Do not type the explanation in “()”.
  - echo “hello, world!” > hello.txt (create a file, the content is “hello, world!”)
  - mklink hello_symlink.txt hello.txt (create a soft link to hello.txt)
  - dir hello_symlink.txt (list the file, what do we observe?)
  - more hello_symlink.txt (show the content using the symbolic link, what do we observe?)
  - mklink /h hello_hardlink.txt hello.txt (create a hard link to hello.txt)
  - dir hello_hardlink.txt (observation?)
  - more hello_hardlink.txt (observation?)
  - move hello.txt hello2.txt (rename hello.txt)
  - dir hello_symlink.txt (observation?)
  - dir hello_hardlink.txt (observation?)
  - more hello_symlink.txt (observation?)
  - more hello_hardlink.txt (observation?)

General Graph Directories



Cycles

- 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

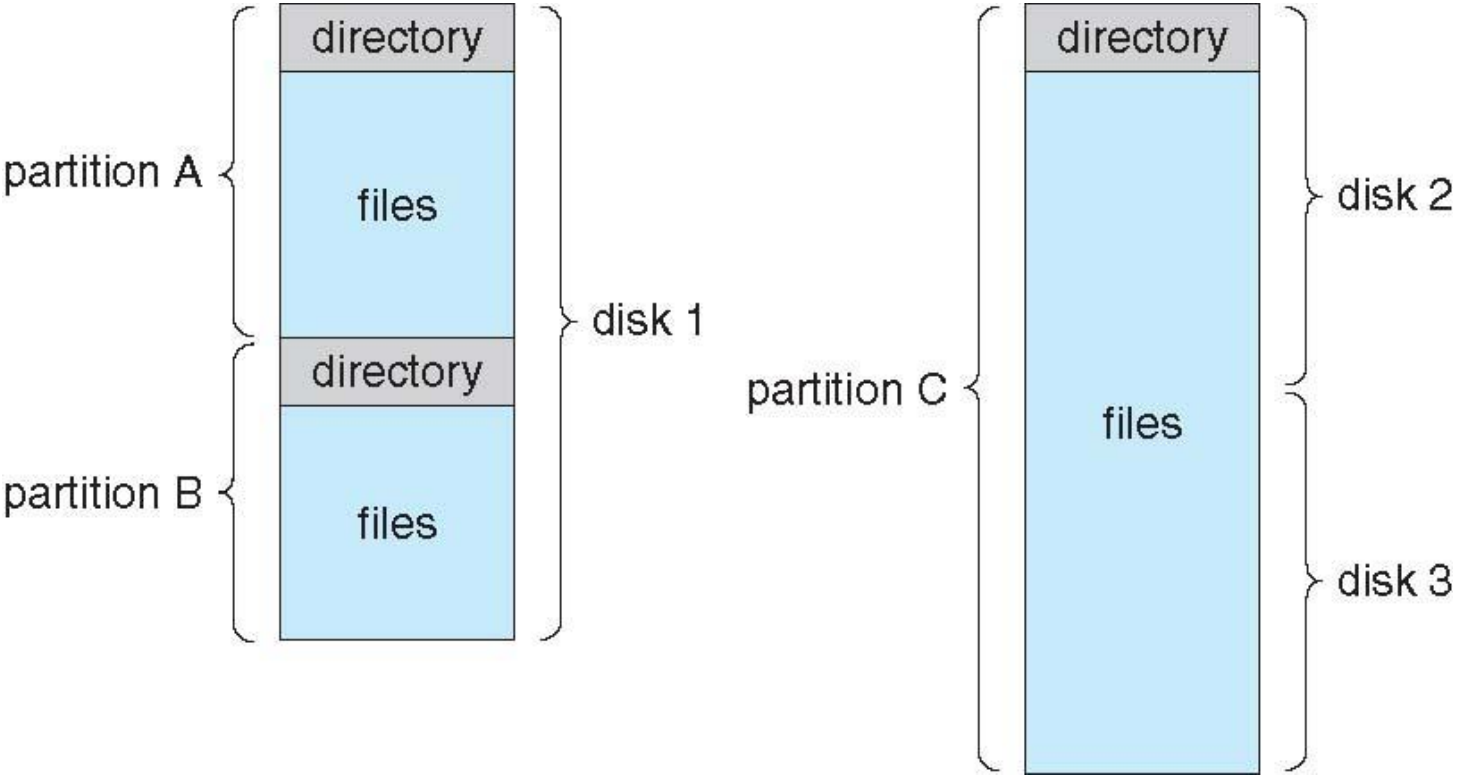
Questions?

- Directory and directory structures
- Single and Multilevel Directories
- Tree Structured Directories
- Acyclic-Graph Directories
- General Graph Directories

Disk Structure

- Disk can be subdivided into **partitions**
- Disks or partitions can be **RAID** protected against failure
- Disk or partition can be used **raw** – without a file system, or **formatted** with a file system
- Partitions also known as minidisks, slices
- Entity containing file system known as a **volume**
- Each volume containing file system also tracks that file system's info in **device directory** or **volume table of contents**
- As well as **general-purpose file systems** there are many **special-purpose file systems**, frequently all within the same operating system or computer

A Typical File-system Organization



Types of File Systems

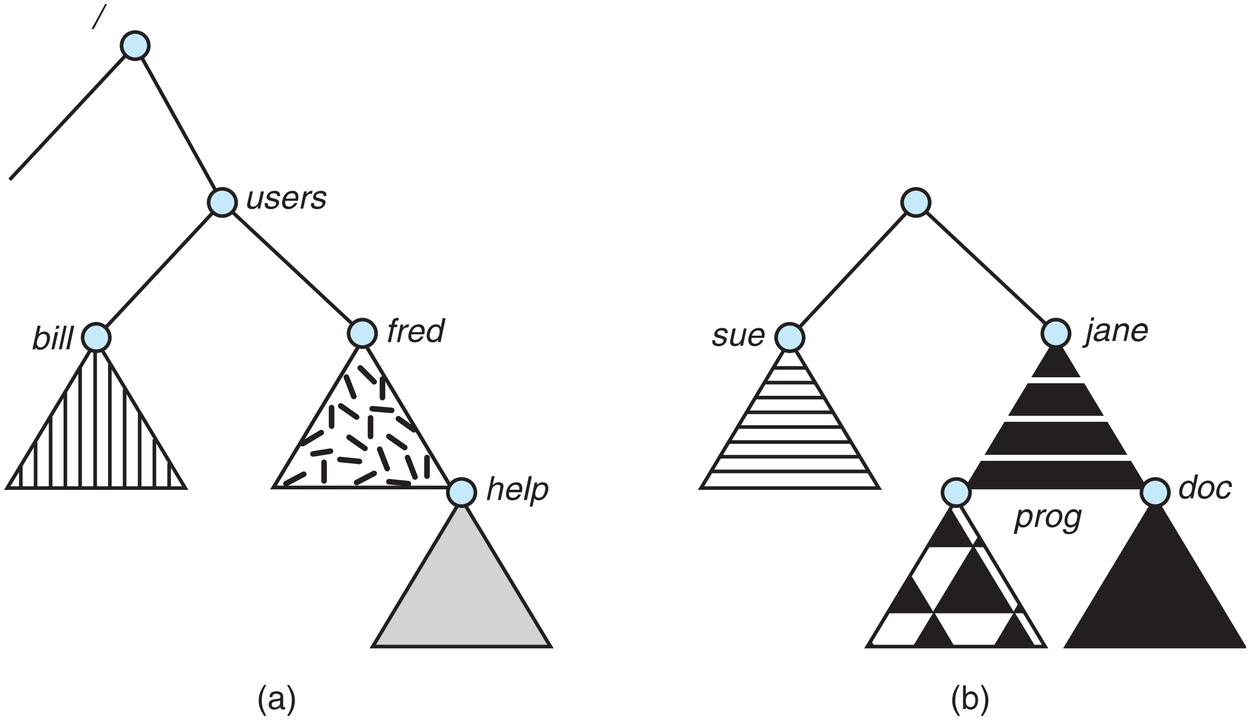
- We mostly talk of general-purpose file systems
- But systems frequently have may file systems, some general- and some special- purpose
- Consider Solaris has
    - tmpfs – memory-based volatile FS for fast, temporary I/O
    - objfs – interface into kernel memory to get kernel symbols for debugging
    - ctfs – contract file system for managing daemons
    - lofs – loopback file system allows one FS to be accessed in place of another
    - procfs – kernel interface to process structures
    - ufs, zfs – general purpose file systems

File System Mounting

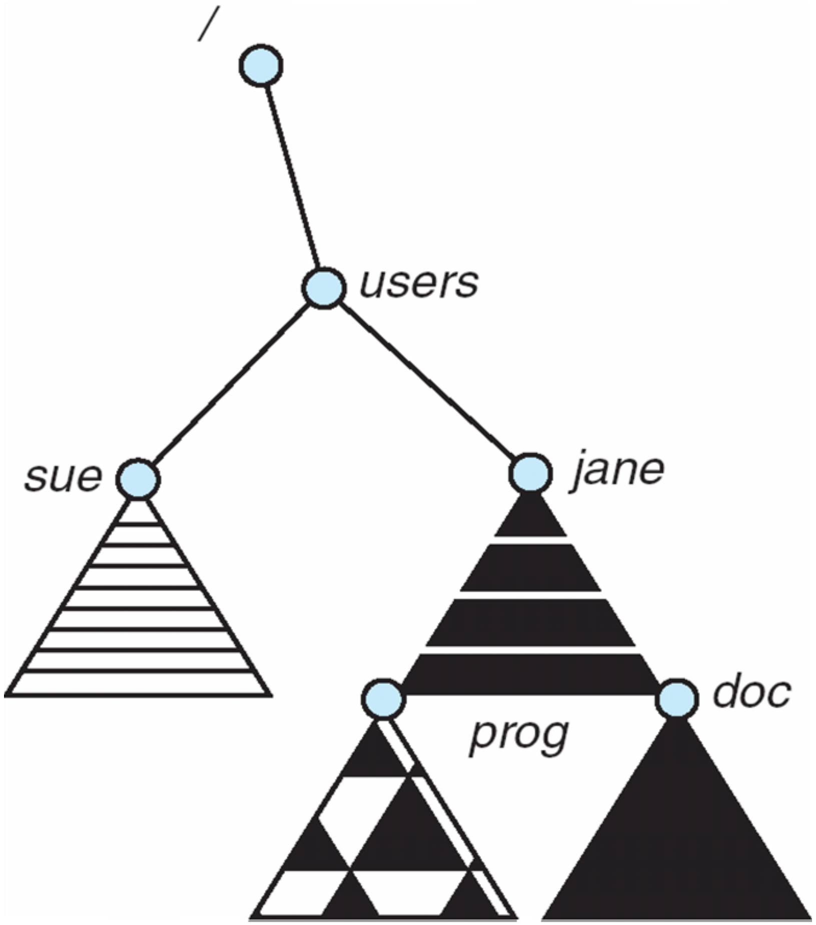
- A file system must be **mounted** before it can be accessed

Example: Mounting File Systems

- A unmounted file system is mounted at a **mount point**



Mount Point



Questions

- File systems
- File system mounting

File Sharing

- Sharing of files on multi-user systems is desirable
- Sharing may be done through a **protection** scheme
- On distributed systems, files may be shared across a network
- Network File System (NFS) is a common distributed file-sharing method
- If multi-user system
  - **User IDs** identify users, allowing permissions and protections to be per-user
    Group IDs allow users to be in groups, permitting group access rights
  - Owner of a file / directory
  - Group of a file / directory

Remote File Systems

- Uses networking to allow file system access between systems
  - Manually via programs like FTP
  - Automatically, seamlessly using **distributed file systems**
  - Semi automatically via the **world wide web**
- **Client-server** model allows clients to mount remote file systems from servers
  - Server can serve multiple clients
  - Client and user-on-client identification is insecure or complicated
  - **NFS** is standard UNIX client-server file sharing protocol
  - **CIFS** is standard Windows protocol
  - Standard operating system file calls are translated into remote calls
- Distributed Information Systems **(distributed naming services)** such as LDAP, DNS, NIS, Active Directory implement unified access to information needed for remote computing

Failure Modes

- All file systems have failure modes
  - For example corruption of directory structures or other non-user data, called **metadata**
- Remote file systems add new failure modes, due to network failure, server failure
- Recovery from failure can involve **state information** about status of each remote request
- **Stateless** protocols such as NFS v3 include all information in each request, allowing easy recovery but less security

Consistency

- Specify how multiple users are to access a shared file simultaneously
  - Similar to Ch 5 process synchronization algorithms
    - Tend to be less complex due to disk I/O and network latency (for remote file systems
  - Andrew File System (AFS) implemented complex remote file sharing semantics
  - Unix file system (UFS) implements:
    - Writes to an open file visible immediately to other users of the same open file
    - Sharing file pointer to allow multiple users to read and write concurrently
  - AFS has session semantics
    - Writes only visible to sessions starting after the file is closed

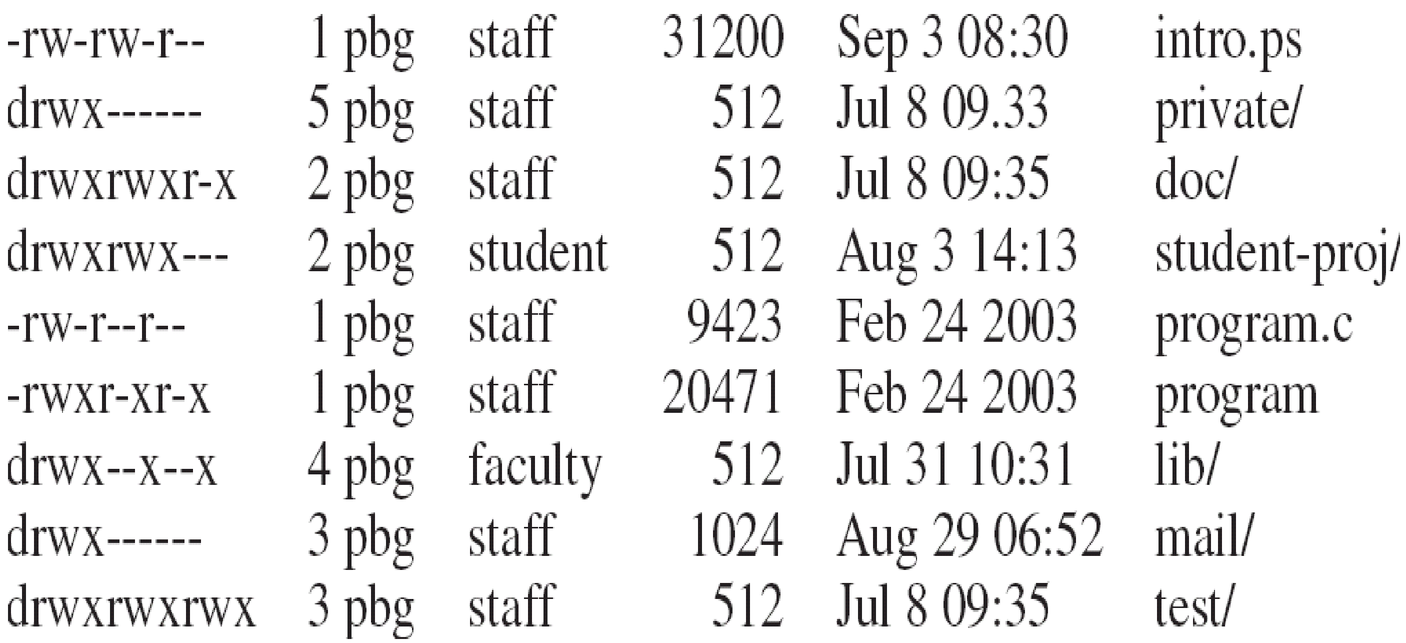
Questions?

- File sharing and remote file systems

Protection

- File owner/creator should be able to control:
  - what can be done
  - by whom
- Types of access
  - **Read**
  - **Write**
  - **Execute**
  - **Append**
  - **Delete**
  - **List**

A Sample UNIX Directory Listing



```
-rw-rw-r--    1 pbg   staff      31200   Sep 3 08:30    intro.ps
drwx------    5 pbg   staff        512   Jul 8 09.33    private/
drwxrwxr-x    2 pbg   staff        512   Jul 8 09:35    doc/
drwxrwx---    2 pbg   student      512   Aug 3 14:13    student-proj/
-rw-r--r--    1 pbg   staff       9423   Feb 24 2003    program.c
-rwxr-xr-x    1 pbg   staff      20471   Feb 24 2003    program
drwx--x--x    4 pbg   faculty      512   Jul 31 10:31   lib/
drwx------    3 pbg   staff       1024   Aug 29 06:52   mail/
drwxrwxrwx    3 pbg   staff        512   Jul 8 09:35    test/
```

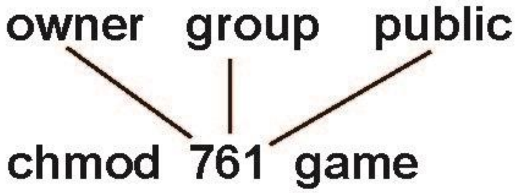
Access Lists

- Mode of access: read, write, execute
- Three classes of users on Unix / Linux

			RWX
a) **owner access**	7	⇒	1 1 1
			RWX
b) **group access**	6	⇒	1 1 0
			RWX
c) **public access**	1	⇒	0 0 1

Access Groups

- Ask manager to create a group (unique name), say G, and add some users to the group.
- For a particular file (say *game*) or subdirectory, define an appropriate access.



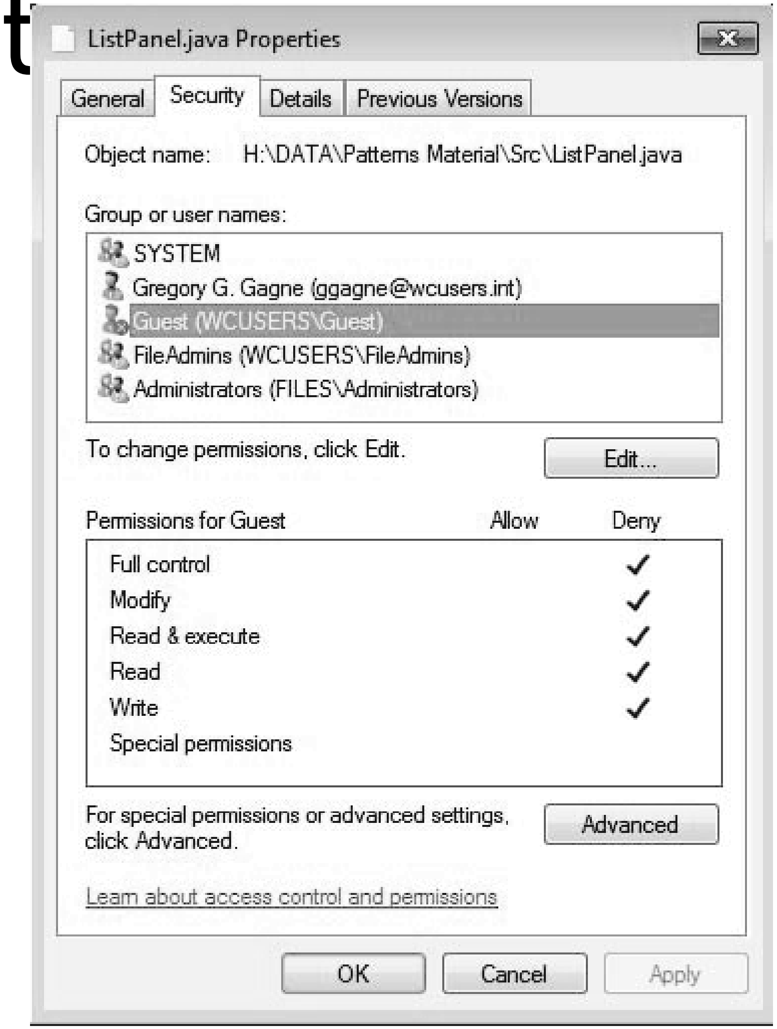
owner group public

```
chmod 761 game
```

Attach a group to a file

```
chgrp     G     game
```

Windows Access-Control List Management



Object name: H:\DATA\Patterns Material\Src\ListPanel.java

Group or user names:

- SYSTEM
- Gregory G. Gagne (ggagne@wcusers.int)
- Guest (WCUSERS\Guest)
- FileAdmins (WCUSERS\FileAdmins)
- Administrators (FILES\Administrators)

To change permissions, click Edit.

Permissions for Guest	Allow	Deny
Full control		✓
Modify		✓
Read & execute		✓
Read		✓
Write		✓
Special permissions		

For special permissions or advanced settings, click Advanced.

Learn about access control and permissions

]

Questions?

- Protection
- Access list and groups
- Access control list