Operating Systems

16. Storage: File system interface

Hyunchan, Park

http://oslab.chonbuk.ac.kr

Division of Computer Science and Engineering

Chonbuk National University

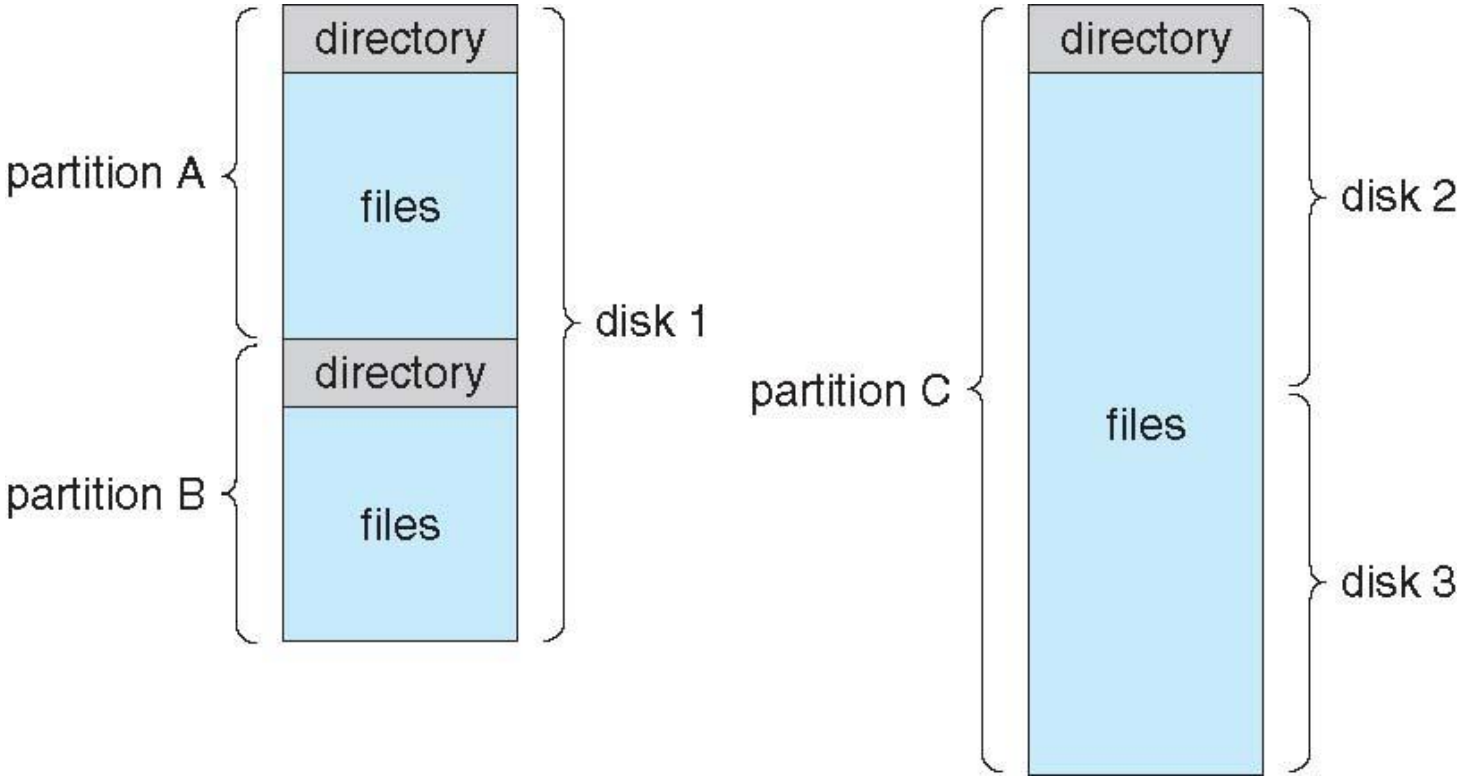
Contents

- Disk and File system
- File
  - Concept
  - Operations
  - Access Methods
- Directory
  - Disk Structure (cont'd)
  - Directory Structure
- Others
  - File-System Mounting
  - File Sharing
  - Protection

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
- Entity containing file system known as a **volume**
  - Logical concept: 1 or more partitions can be a single 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



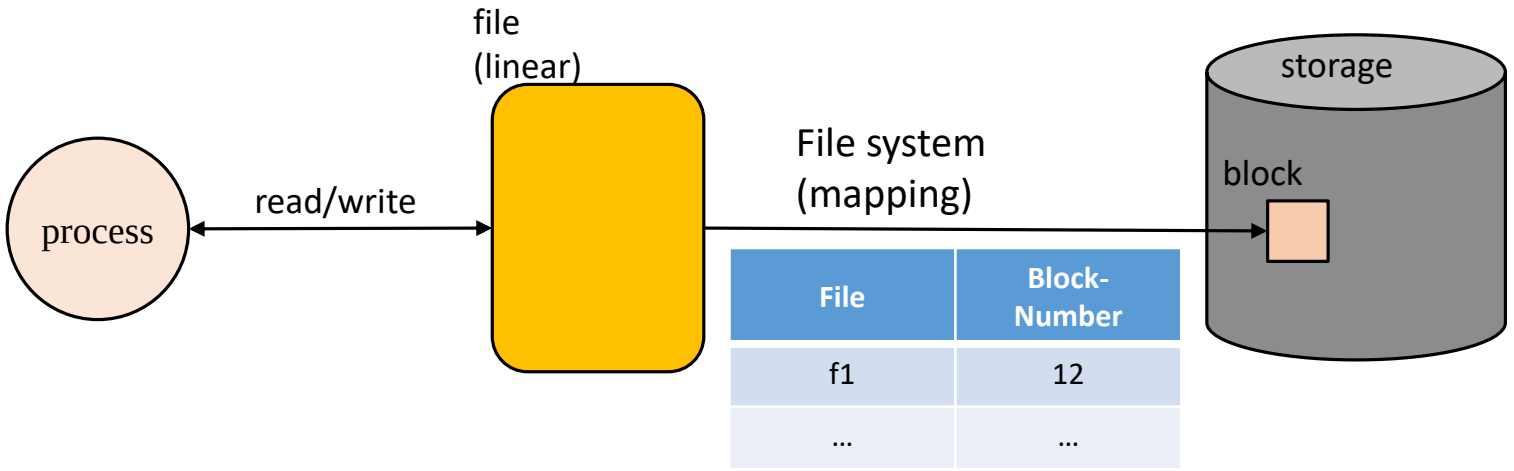
Types of File Systems

- 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 Concept

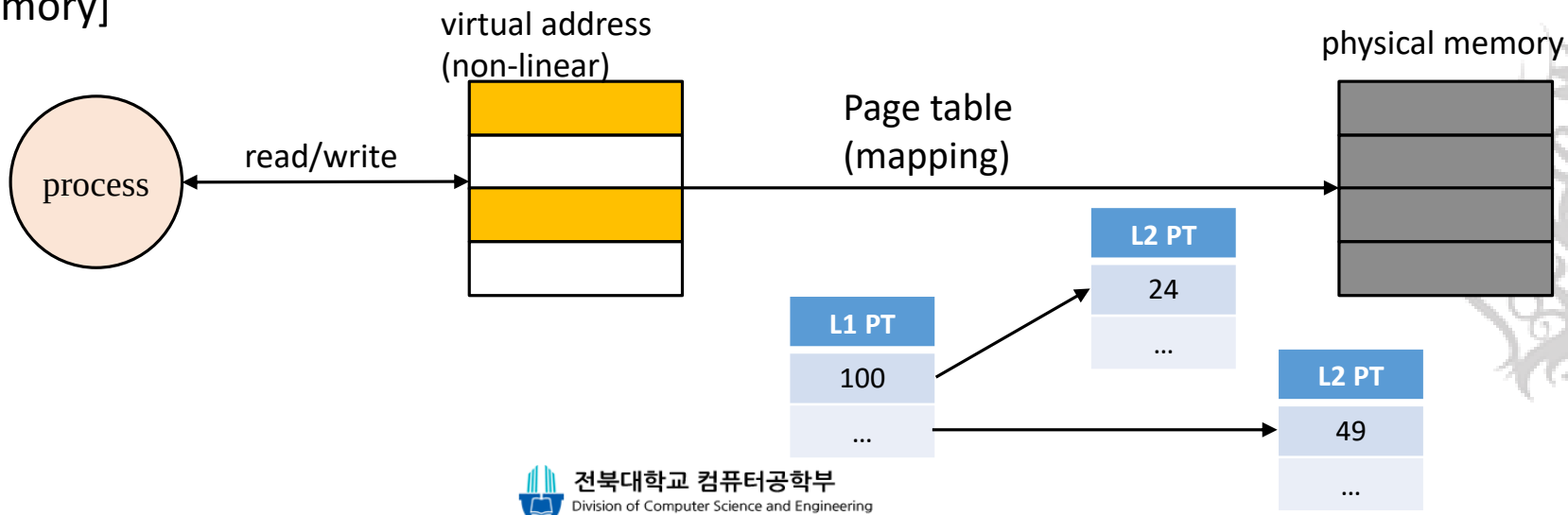
- Contiguous logical address space on storage device
  - Other definitions:
    - Named collection of bytes (or linear array of bytes)
    - Collection of data with some properties; name, size, owner, and etc.
- Types:
  - Data
    - numeric
    - character
    - binary
  - Program
- Contents defined by file's creator
  - Many types
    - Consider text file, source file, executable file

File-System vs. Virtual Memory



[file system]

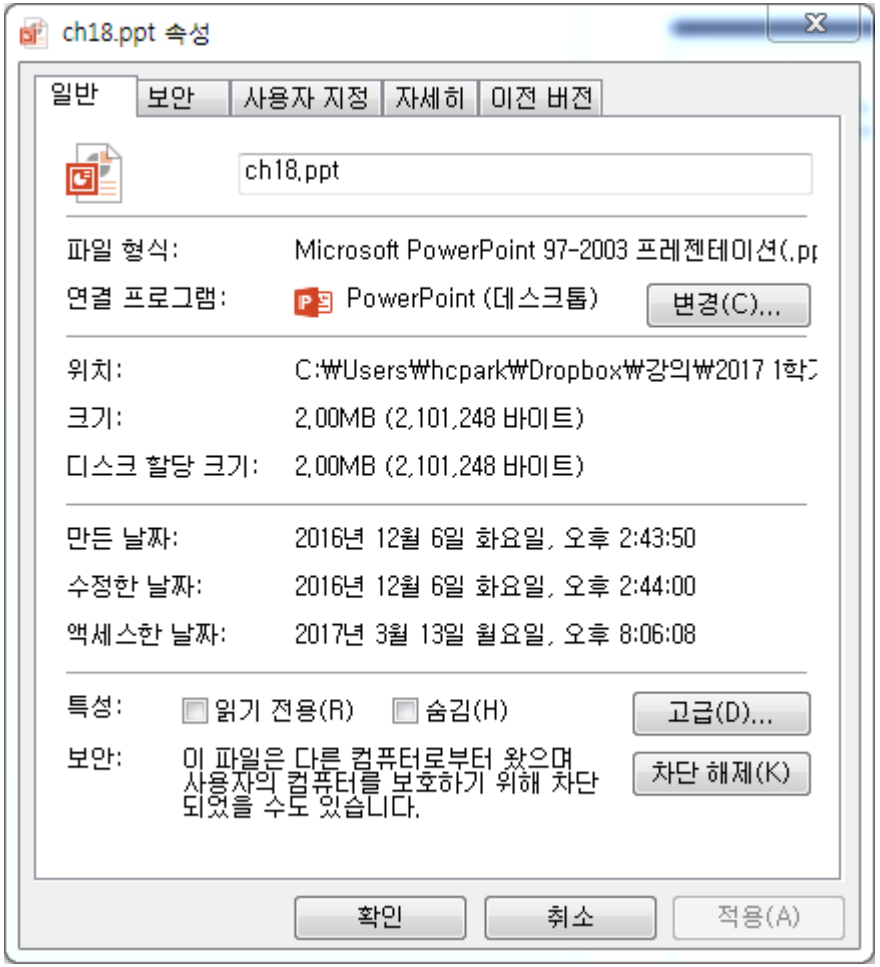
[virtual memory]



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 on Windows and Mac OS X



File Operations

- Create
- Write – at write pointer location
- Read – at read pointer location
- Reposition within file - seek
- Delete
- Truncate
- Open(Fi) – search the directory structure on disk for entry Fi, and move the content of entry to memory
- Close (Fi) – move the content of entry Fi 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

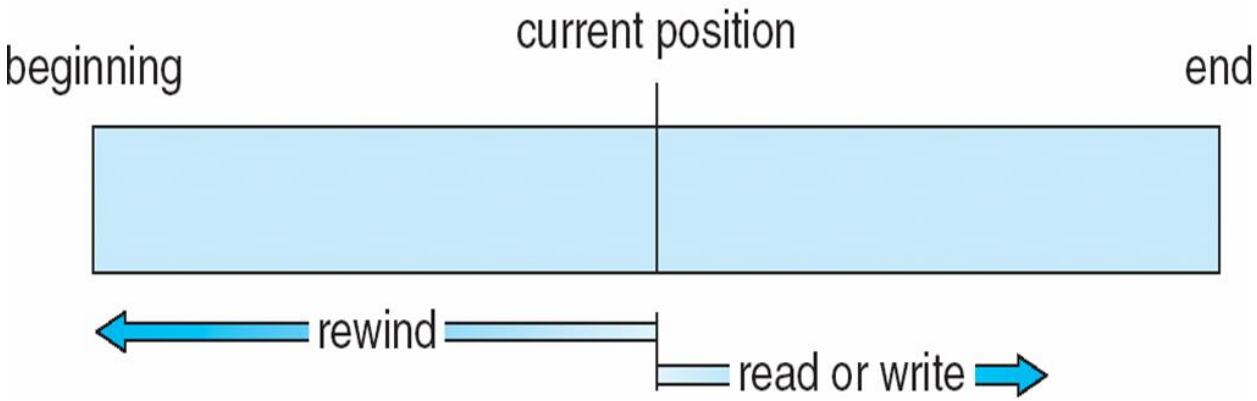
File Types – Name, Extension

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

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)

Access Methods

- Direct Access – file is fixed length logical records

  read n

  write n

  position to n

    read next

    write next

  rewrite n

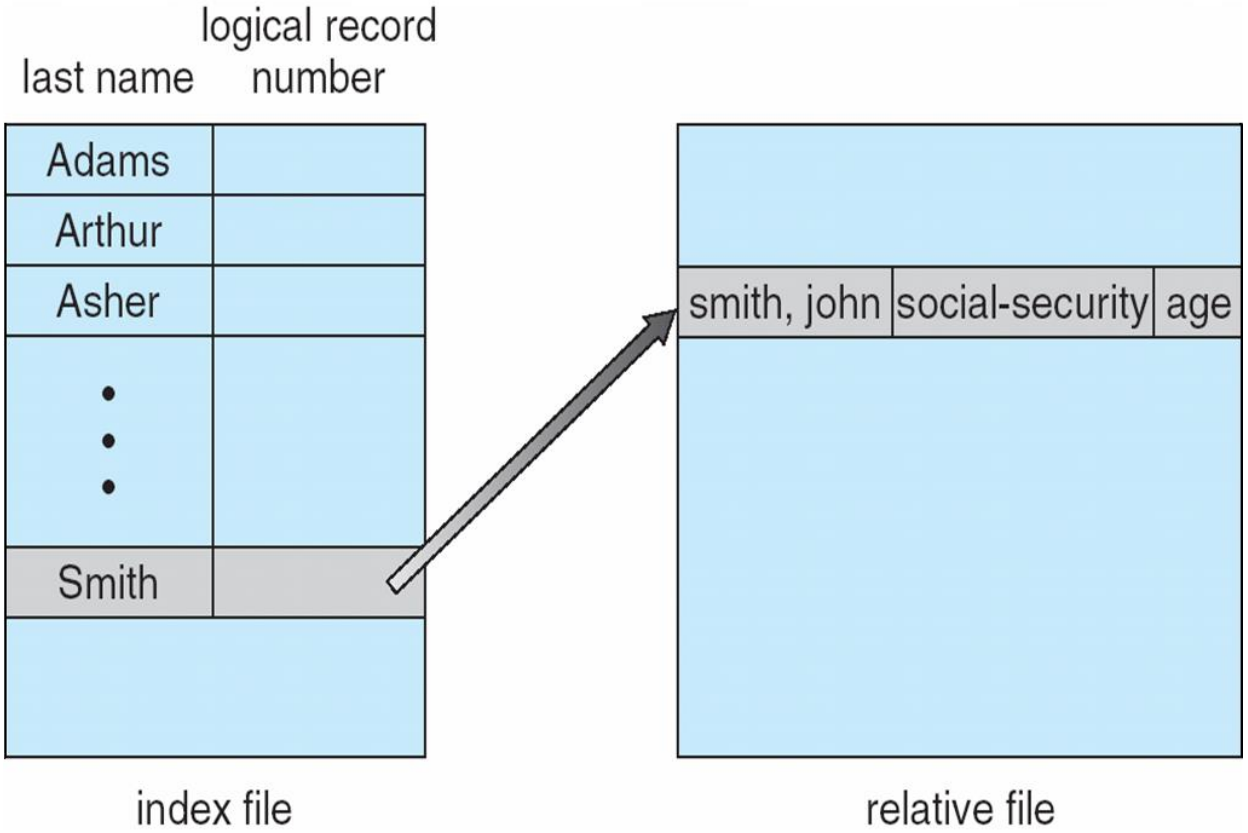
  n = relative block number

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

Other Access Methods

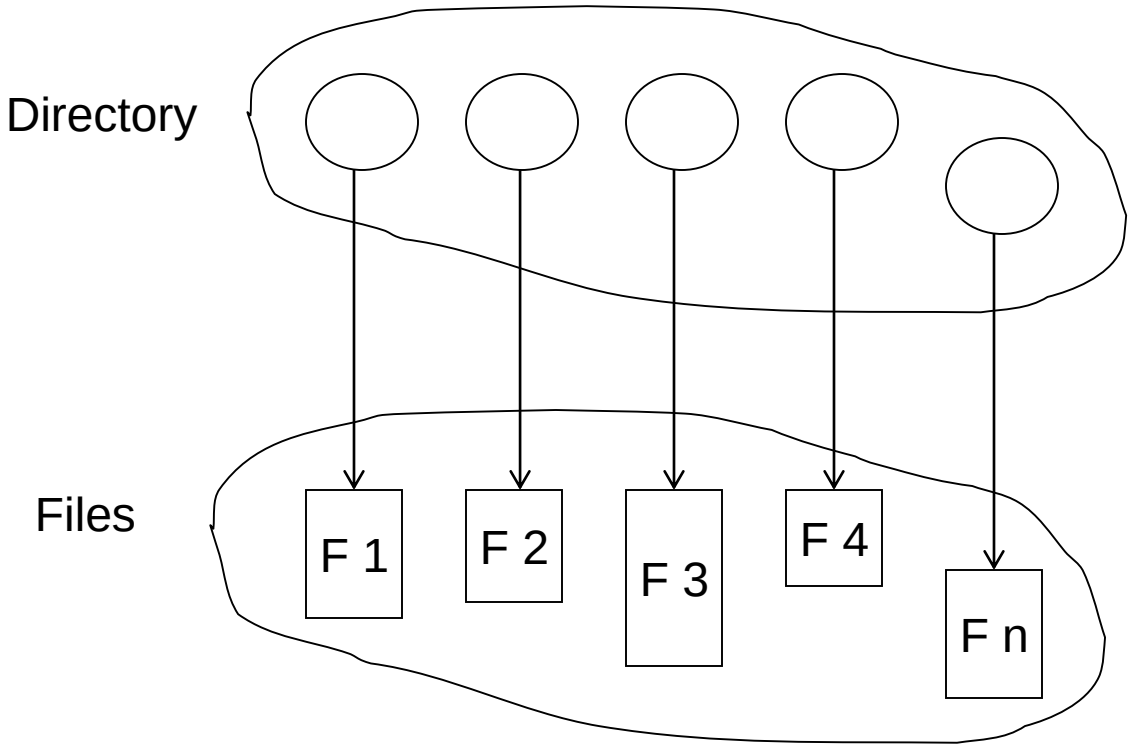
- Can be built on top of base methods
- General involve creation of an index for the file
- Keep index in memory for fast determination of location of data to be operated on (consider UPC code plus record of data about that item)
- If too large, index (in memory) of the index (on disk)
- IBM indexed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

Operations Performed on Directory

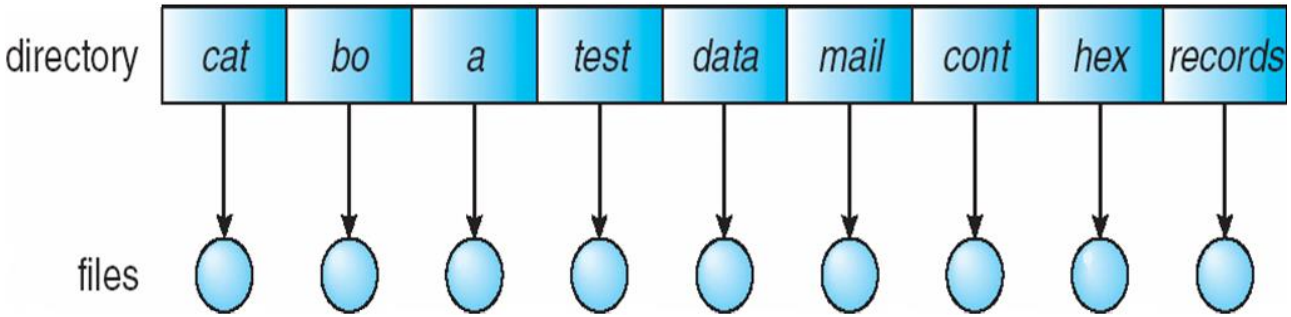
- Search for a file
- Create a file
- Delete a file
- List a directory
- Rename a file
- Traverse the file system

Directory Organization

- The directory is organized logically 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

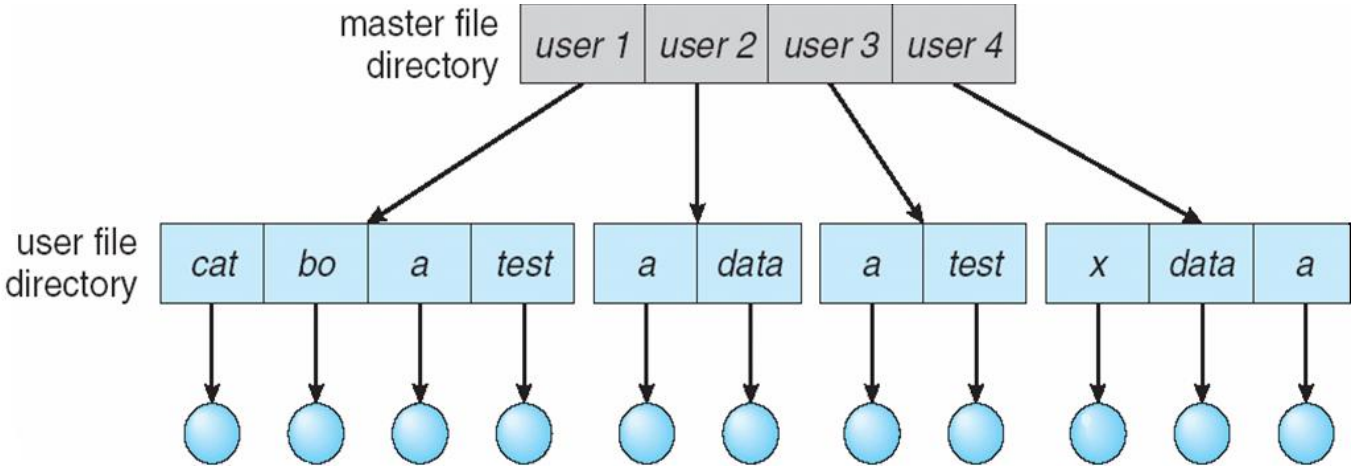
- A single directory for all users



- Naming problem
- Grouping problem

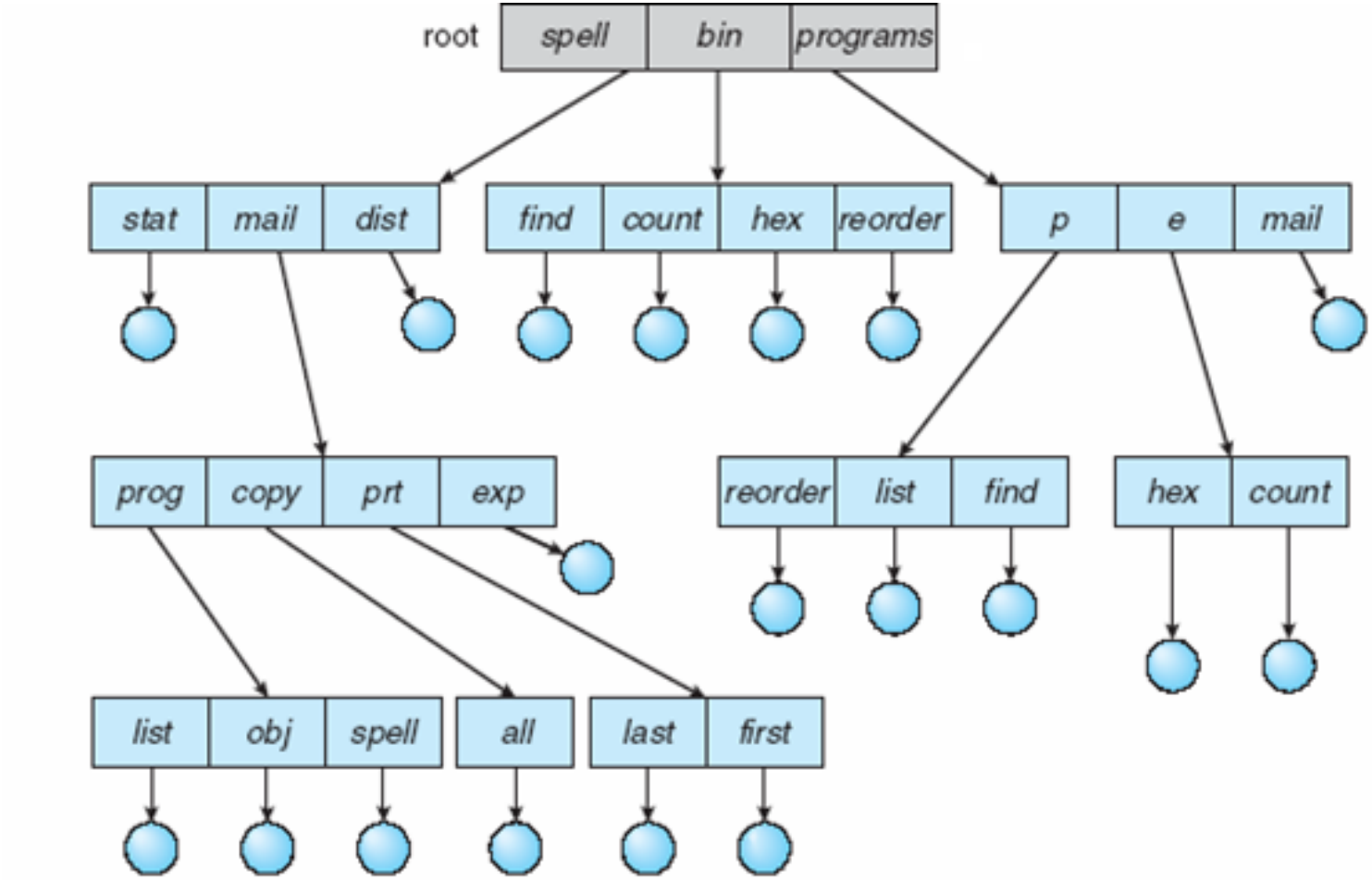
Two-Level Directory

- Separate directory for each user



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

Tree-Structured Directories

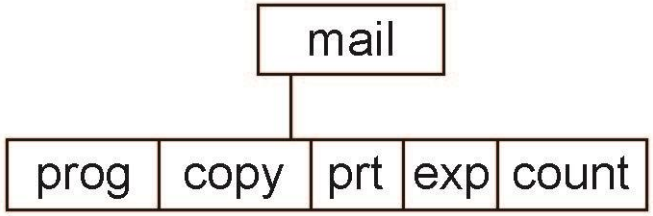


Tree-Structured Directories (Cont.)

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

Tree-Structured Directories (Cont)

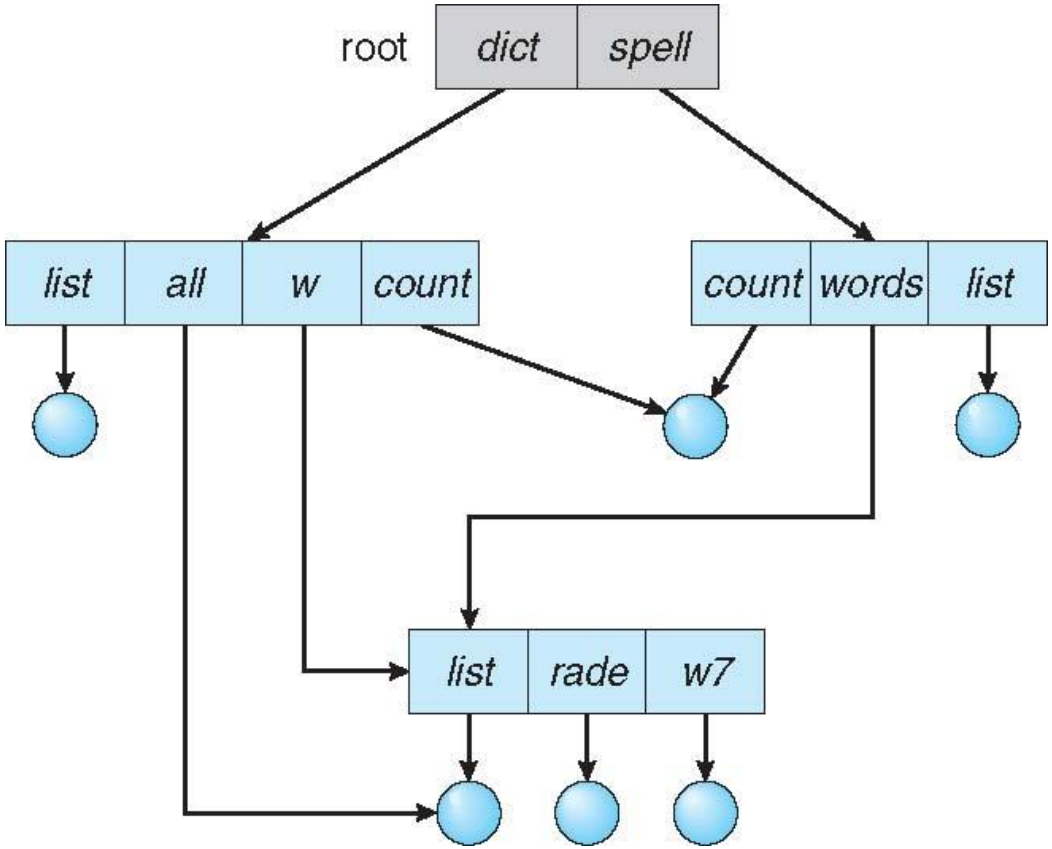
- Absolute or relative path name
- Creating a new file is done in current directory
- Delete a file
- rm <file-name>
- Creating a new subdirectory is done in current directory
  - mkdir <dir-name>
  - Example: if in current directory /mail
  - mkdir count



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

Acyclic-Graph Directories

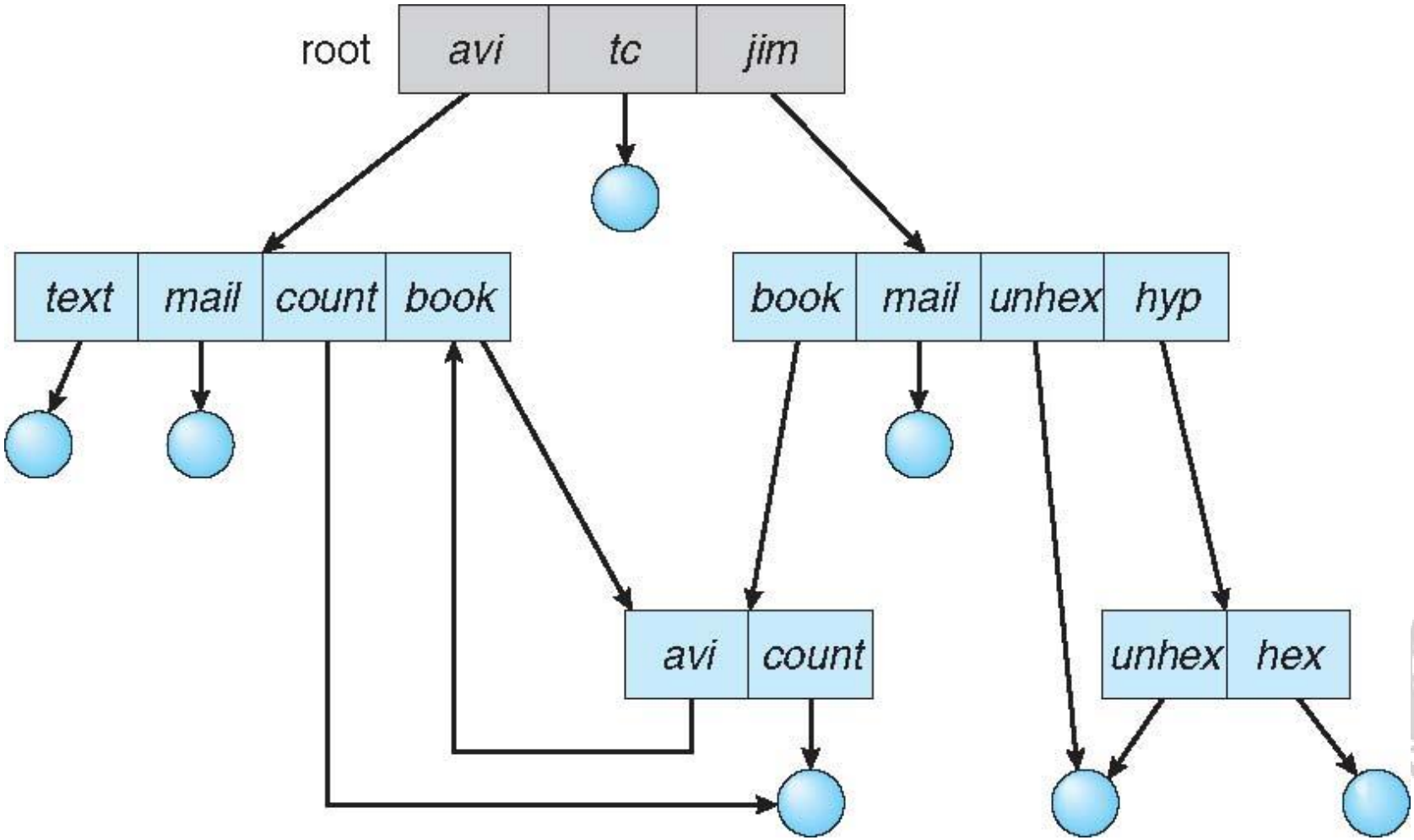
- Have shared subdirectories and files



Acyclic-Graph Directories (Cont.)

- New directory entry type
  - Link – another name (pointer) to an existing file
  - Resolve the link – follow pointer to locate the file
- Enables two different names (aliasing)
- If *dict* deletes *count* $\Rightarrow$ dangling pointer problem
  - Dangling pointer: a pointer without allocated disk blocks
  - Entry-hold-count solution
    - Counting the references for the file
    - When it changed to 0, actually delete the file

General Graph Directory



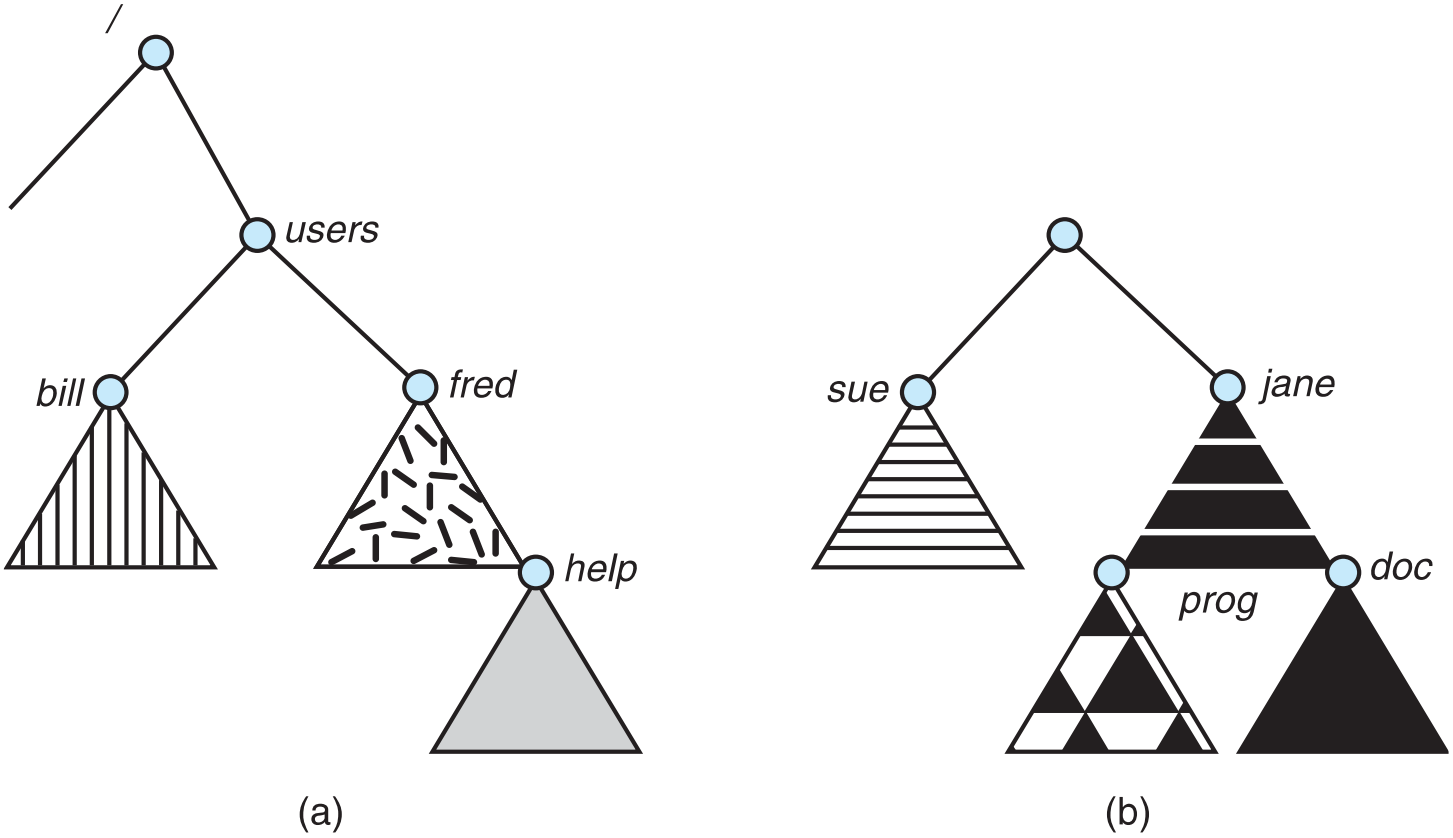
General Graph Directory (Cont.)

- Searching with General Graph Directory
  - Book and avi, book and avi, and the book……

- How do we guarantee no cycles? (for acyclic graph directory)
  - Allow only links to file not subdirectories
  - Garbage collection
    - For a disk? Very expensive operation
  - Every time a new link is added use a cycle detection algorithm to determine whether it is OK

File System Mounting

- A file system must be mounted before it can be accessed
- A unmounted file system is mounted at a mount point



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

File Sharing – 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

File Sharing – 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

File Sharing – Consistency Semantics

- 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

Protection

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

Access Lists and Groups

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

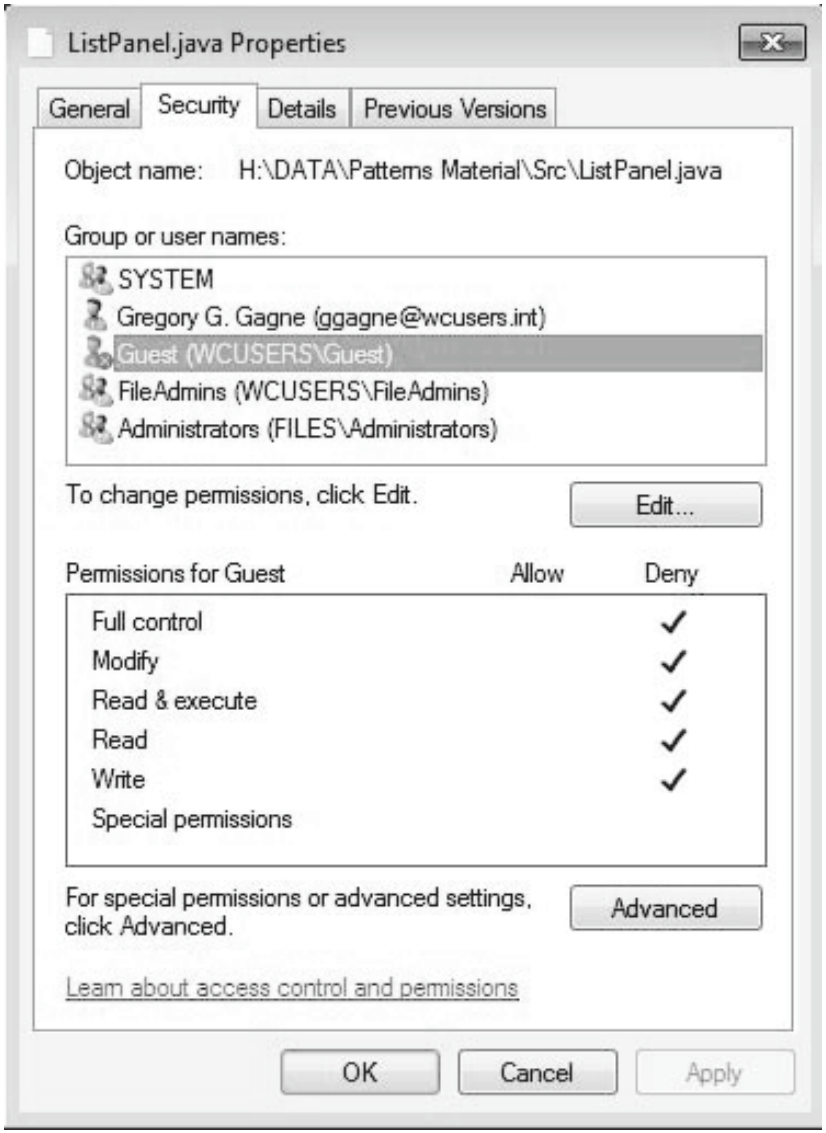
			RWX
a) **owner access**	7	⇒	1 1 1
b) **group access**	6	⇒	RWX 1 1 0
c) **public access**	1	⇒	RWX 0 0 1

- 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.

Attach a group to a file

```
chgrp      G      game
```

Windows 7 Access-Control List Management



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/