# Chap. 10) File System

경희대학교 컴퓨터공학과

이 승 룡

# Basic Concept

- Requirements for long-term information storage
  - ✓ It must be possible to store a very large amount of information
  - ✓ The information must survive the termination of the process using it
  - ✓ Multiple processes must be able to access the information concurrently

- File system
  - ✓ Implement an abstraction for secondary storage (files)
  - ✓ Organize files logically (directories)
  - ✓ Permit sharing of data between processes, people, and machines (sharing)
  - ✓ Protect data from unwanted access (protection)



# Files

- File
  - ✓ A named collection of related information that is recorded on secondary storage
    - persistent through power failures and system reboots
  - ✓ OS provides a uniform logical view of information storage via files

- File structures
  - ✓ Flat: byte sequence
  - ✓ Structured:
    - Lines
    - Fixed length records
    - Variable length records



# File Attributes

- Attributes or metadata

| Attribute | Meaning |
|---|---|
| Protection | Who can access the file and in what way |
| Password | Password needed to access the file |
| Creator | ID of the person who created the file |
| Owner | Current owner |
| Read-only flag | 0 for read/write; 1 for read only |
| Hidden flag | 0 for normal; 1 for do not display in listings |
| System flag | 0 for normal files; 1 for system file |
| Archive flag | 0 for has been backed up; 1 for needs to be backed up |
| ASCII/binary flag | 0 for ASCII file; 1 for binary file |
| Random access flag | 0 for sequential access only; 1 for random access |
| Temporary flag | 0 for normal; 1 for delete file on process exit |
| Lock flags | 0 for unlocked; nonzero for locked |
| Record length | Number of bytes in a record |
| Key position | Offset of the key within each record |
| Key length | Number of bytes in the key field |
| Creation time | Date and time the file was created |
| Time of last access | Date and time the file was last accessed |
| Time of last change | Date and time the file has last changed |
| Current size | Number of bytes in the file |
| Maximum size | Number of bytes the file may grow to |



# File Operations

- Unix operations

```
int creat (const char *pathname, mode_t mode);
int open (const char *pathname, int flags, mode_t mode);
int close (int fd);
ssize_t read (int fd, void *buf, size_t count);
ssize_t write (int fd, const void *buf, size_t count);
off_t lseek (int fd, off_t offset, int whence);
int stat (const char *pathname, struct stat *buf);
int chmod (const char *pathname, mode_t mode);
int chown (const char *pathname, uid_t owner, gid_t grp);
int flock (int fd, int operation);
int fcntl (int fd, int cmd, long arg);
```



# File Types

- Files may have types
  - ✓ Understood by file systems
    - device, directory, symbolic link, etc.
  - ✓ Understood by other parts of OS or runtime libraries
    - executable, dll, source code, object code, text, etc.
  - ✓ Understood by application programs
    - jpg, mpg, avi, mp3, etc.

- Encoding file types
  - ✓ Windows encodes type in name
    - .com, .exe, .bat, .dll, .jpg, .avi, .mp3, etc.
  - ✓ Unix encodes type in contents
    - magic numbers (e.g., 0xcafebabe for Java class files)
    - initial characters (e.g., #! for shell scripts)



# 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 |

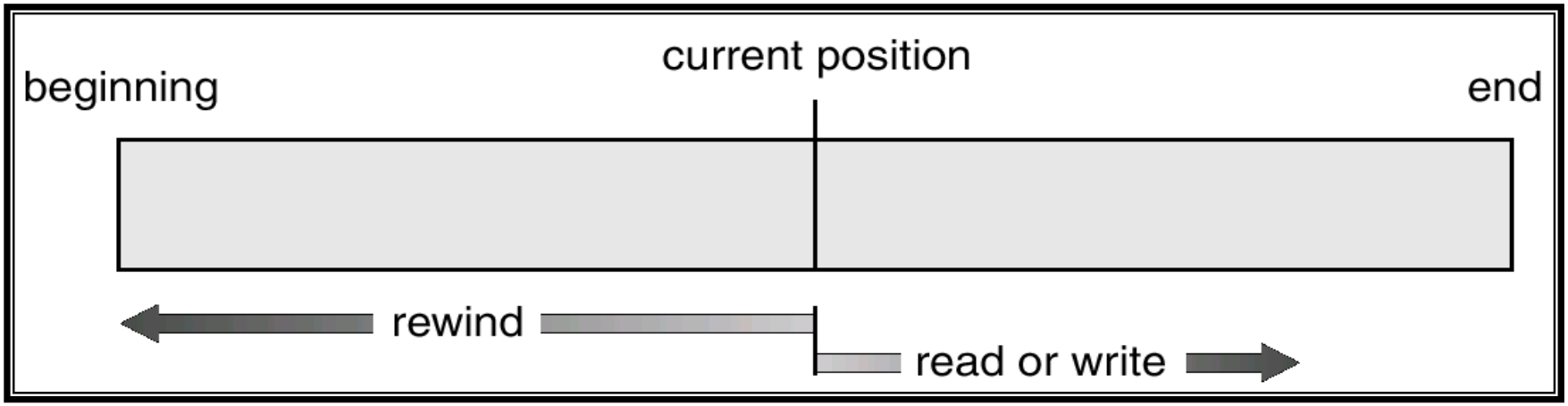
# File Access

- Some file systems provide different access methods that specify different ways for accessing data in a file.

- Sequential access
  - ✓ read bytes one at a time, in order
- Direct access
  - ✓ random access given block/byte number
- Record access
  - ✓ File is an array of fixed- or variable-length records, read/written sequentially or randomly by record #
- Index access
  - ✓ File system contains an index to a particular field of each record in a file, reads specify a value for that field and the system finds the records via the index (DBs)



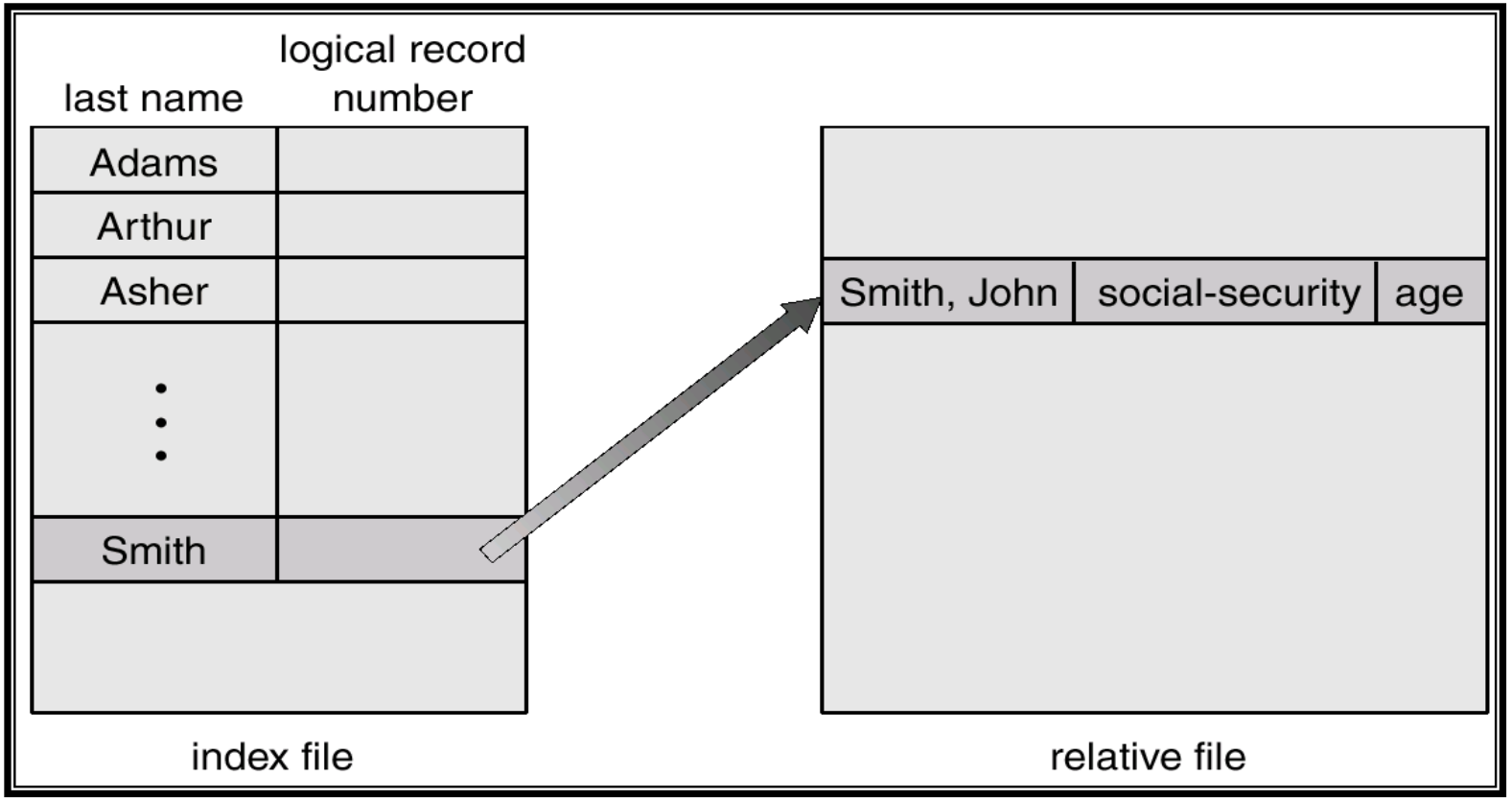
# Sequential-access File



# Simulation of Sequential Access on a Direct-access File

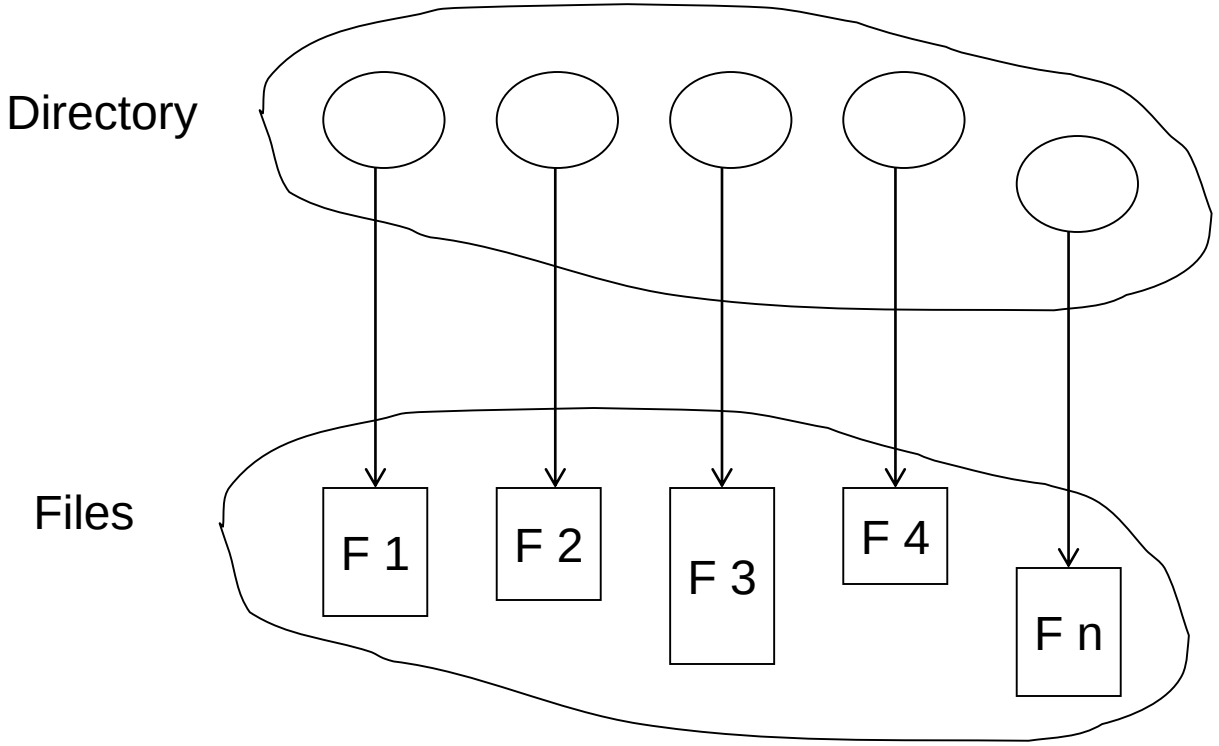
| sequential access | implementation for direct access |
|---|---|
| *reset* | *cp* = 0; |
| *read next* | *read cp*;<br>*cp* = *cp*+1; |
| *write next* | *write cp*;<br>*cp* = *cp*+1; |

# 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
Backups of these two structures are kept on tapes

## Directories

- ✓ For users, they provide a structured way to organize files
- ✓ For the file system, they provide a convenient naming interface that allows the implementation to separate logical file organization from physical file placement on the disk

## A hierarchical directory system

- ✓ Most file systems support multi-level directories
- ✓ Most file systems support the notion of a current directory (or working directory)
  - Relative names specified with respect to current directory
  - Absolute names start from the root of directory tree

# Directory Internals

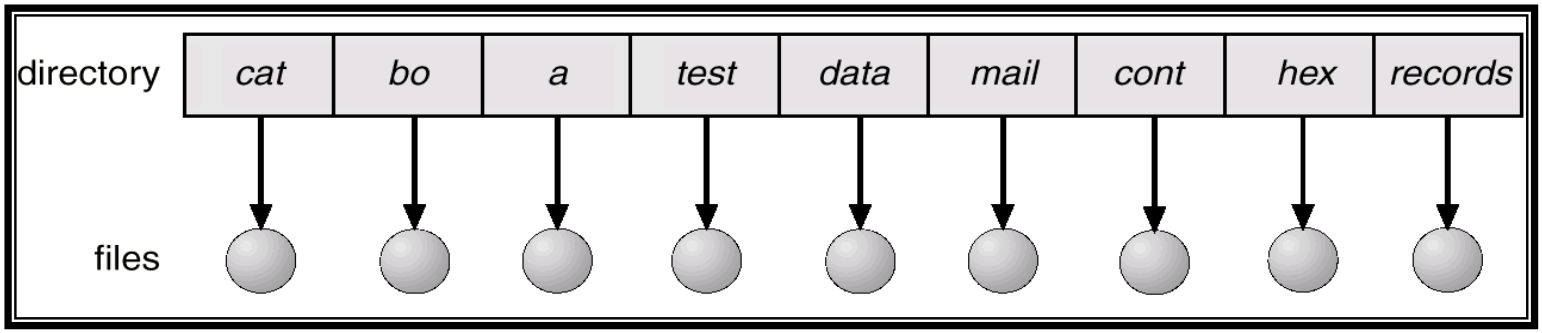
- A directory is …
  - ✓ typically just a file that happens to contain special metadata
    - Only need to manage one kind of secondary storage unit
  - ✓ directory = list of (file name, file attributes)
  - ✓ attributes include such things as:
    - size, protection, creation time, access time,
    - location on disk, etc.
  - ✓ usually unordered (effectively random)
    - Entries usually sorted by program that reads directory

# Directory Operations

- Unix operations
  - ✓ Directories implemented in files
    - Use file operations to manipulate directories
  - ✓ C runtime libraries provides a higher-level abstraction for reading directories
    - DIR *opendir (const char *name);
    - struct dirent *readdir (DIR *dir);
    - void seekdir (DIR *dir, off_t offset);
    - int closedir (DIR *dir);
  - ✓ Other directory-related system calls
    - int rename (const char *oldpath, const char *newpath);
    - int link (const char *oldpath, const char *newpath);
    - int unlink (const char *pathname);

# Single-Level Directory

- A single directory for all users

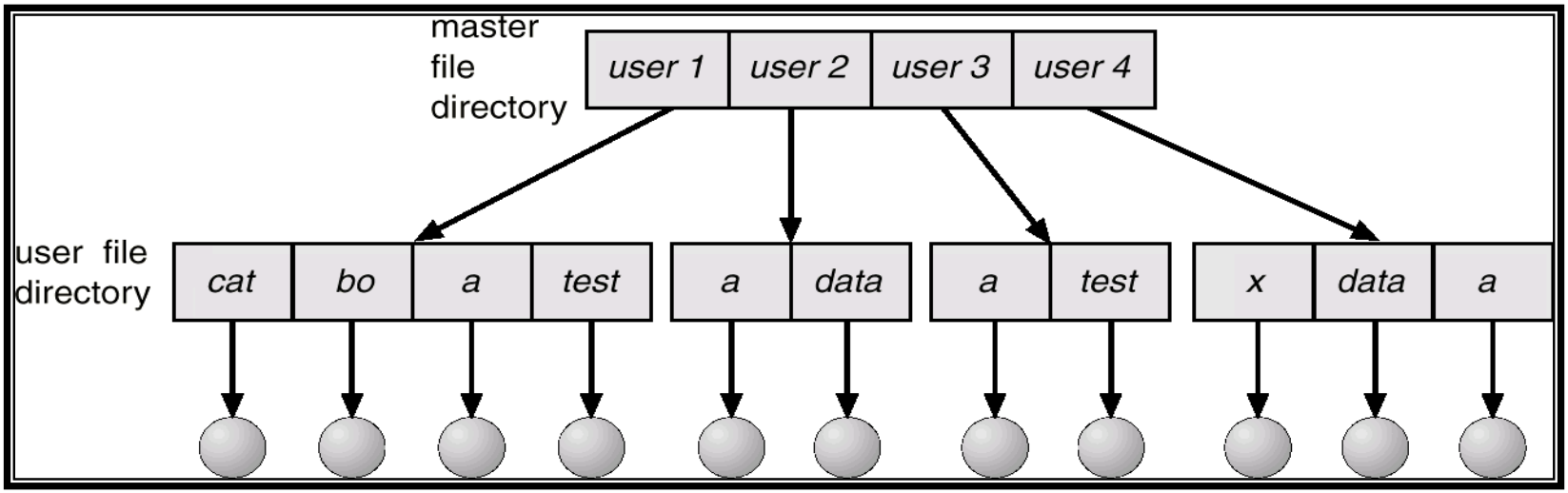



Naming problem

Grouping problem

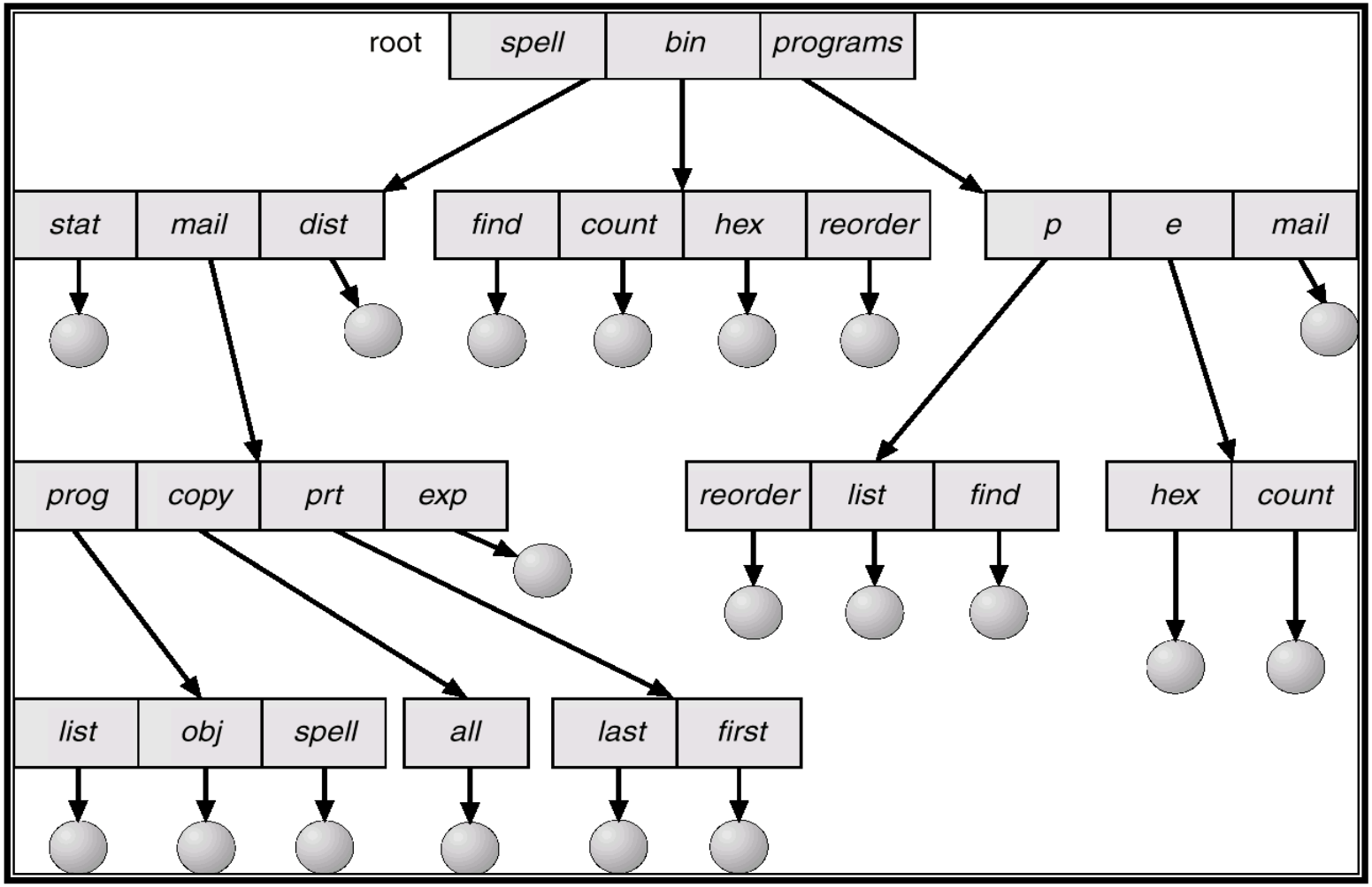
# Two-Level Directory

- Separate directory for each user



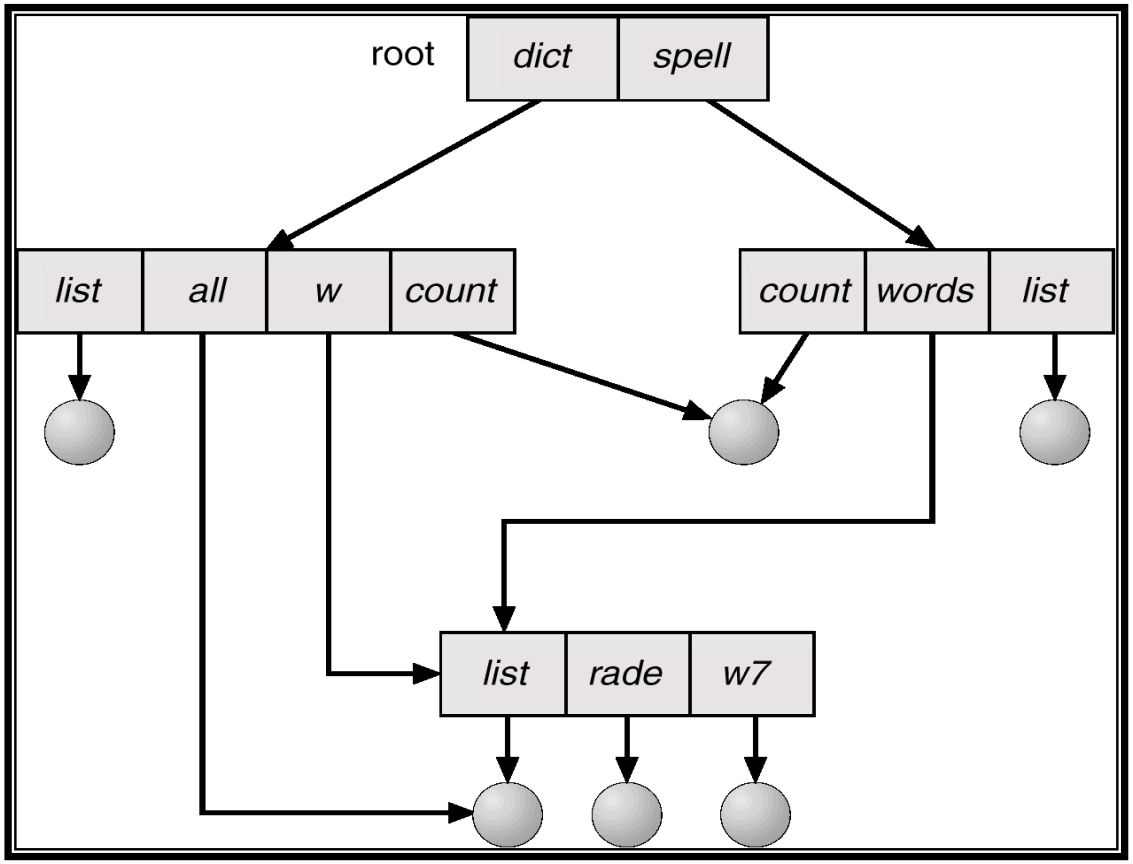

- Path name
- Can have the same file name for different user
- Efficient searching
- No grouping capability

# Tree-Structured Directories

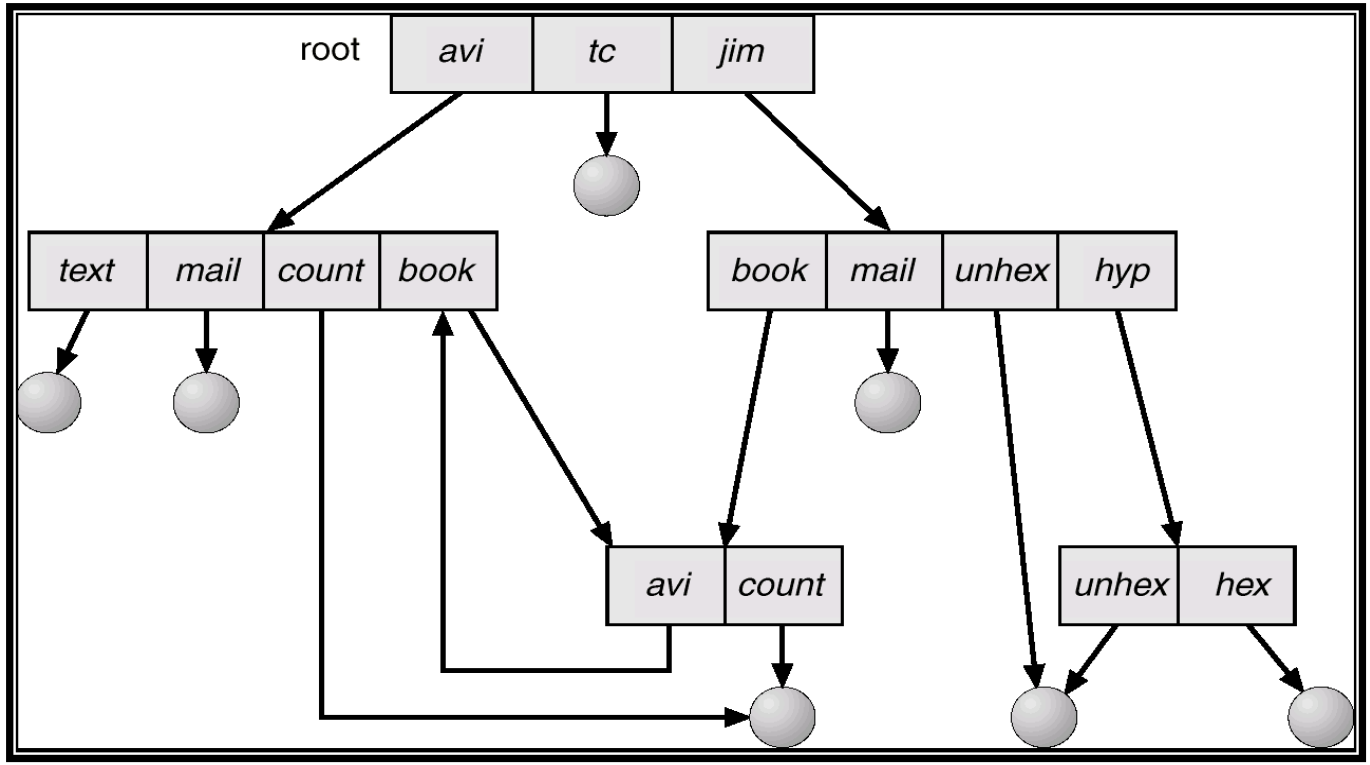


# Acyclic-Graph Directories

- Have shared subdirectories and files



# General Graph Directory



# General Graph Directory (Cont'd)

- 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

# Pathname Translation

- open("/a/b/c", …)
  - ✓ Open directory "/" (well known, can always find)
  - ✓ Search the directory for "a", get location of "a"
  - ✓ Open directory "a", search for "b", get location of "b"
  - ✓ Open directory "b", search for "c", get location of "c"
  - ✓ Open file "c"
  - ✓ (Of course, permissions are checked at each step)

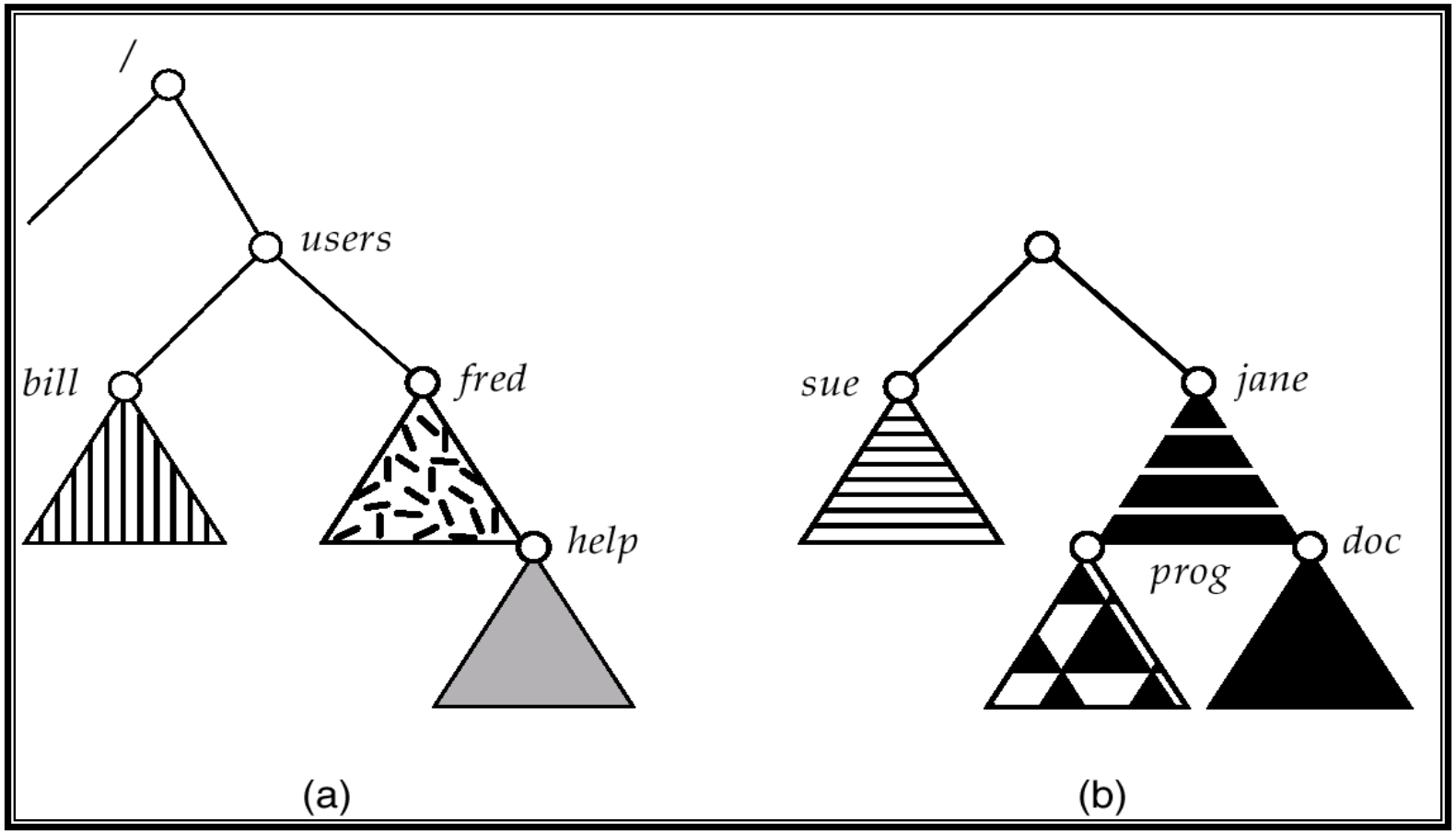
- System spends a lot of time walking down directory paths
  - ✓ This is why open is separate from read/write
  - ✓ OS will cache prefix lookups to enhance performance
    - /a/b, /a/bb, /a/bbb, etc. all share the "/a" prefix



# File System Mounting

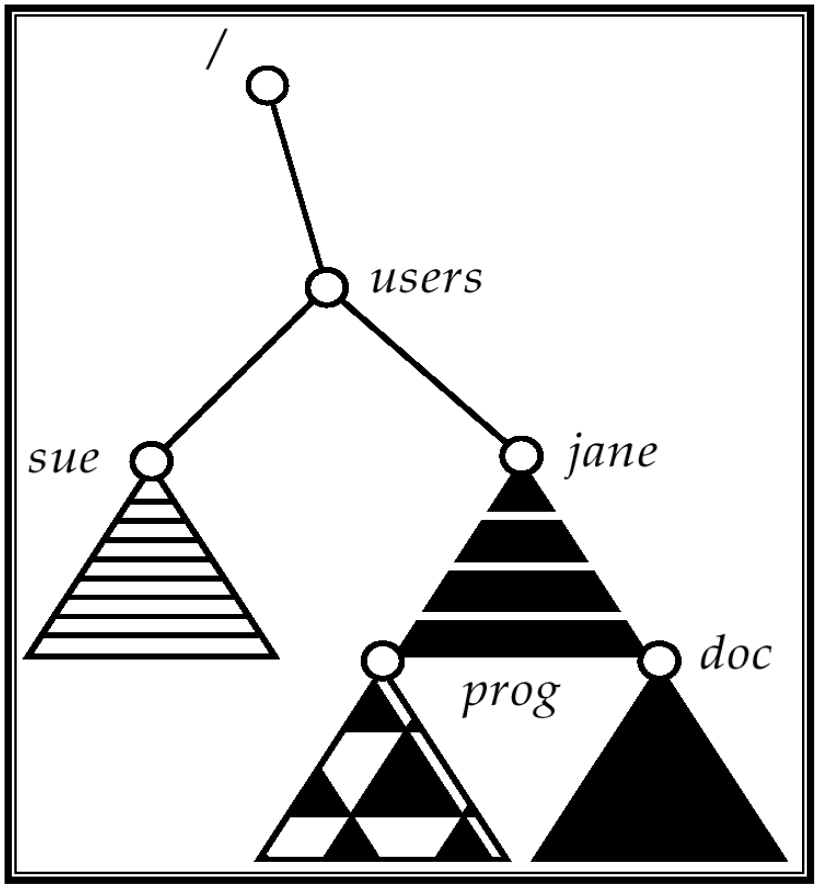
- A file system must be **mounted** before it can be accessed
- A unmounted file system (i.e. Fig. 11-11(b)) is mounted at a **mount point**
- *Example*
  - ✓ Windows: to drive letters (e.g., C:\, D:\, …)
  - ✓ Unix: to an existing empty directory (= mount point)

# (a) Existing (b) Unmounted Partition



# Mount Point

- Only when *users* directory is empty



# File Sharing

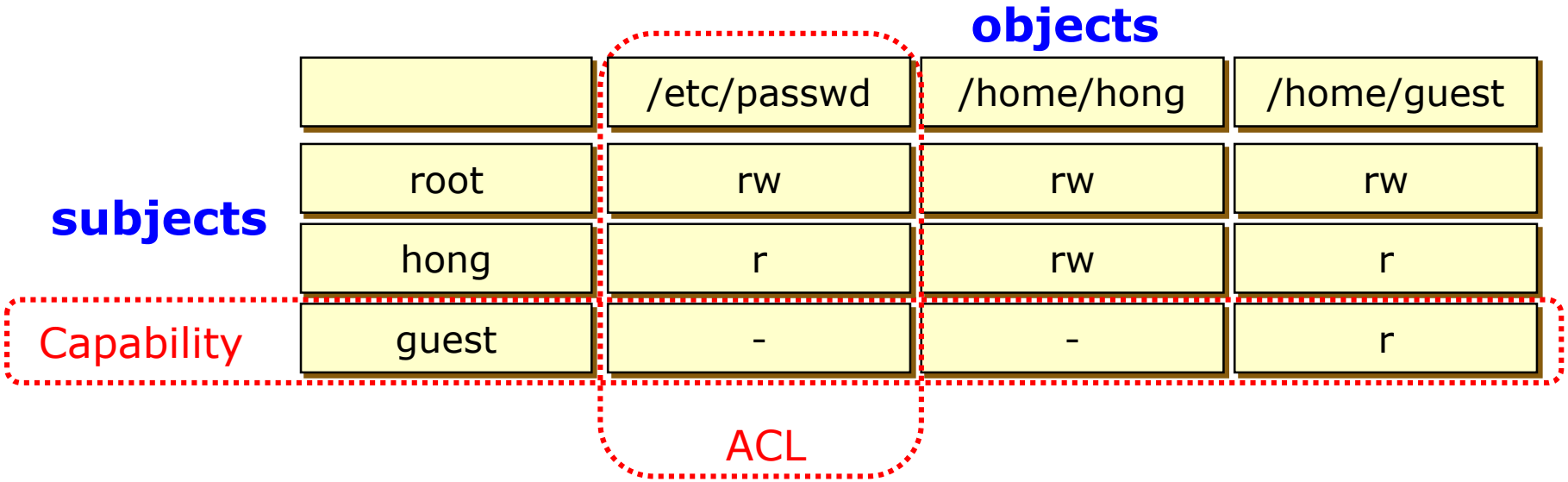
- Sharing of files on multi-user systems is desirable
- Sharing may be done through a *protection* scheme
- On distributed systems, files may be shared across a network
- Network File System (NFS) is a common distributed file-sharing method

# Protection

- File owner/creator should be able to control:
  - ✓ what can be done
  - ✓ by whom

- Types of access
  - ✓ Read
  - ✓ Write
  - ✓ Execute
  - ✓ Append
  - ✓ Delete
  - ✓ List

- Representing protection
  - ✓ Access control lists (ACLs)
    - For each object, keep list of subjects and their allowed actions
  - ✓ Capabilities
    - For each subject, keep list of objects and their allowed actions



# Protection (Cont'd)

- ACLs vs. Capabilities
  - ✓ Two approaches differ only in how the table is represented
  - ✓ Capabilities are easy to transfer
    - They are like keys; can hand them off
    - They make sharing easy
  - ✓ In practice, ACLs are easier to manage
    - Object-centric, easy to grant and revoke
    - To revoke capabilities, need to keep track of all subjects that have the capability – hard to do, given that subjects can hand off capabilities
  - ✓ ACLs grow large when object is heavily shared
    - Can simplify by using "groups"
    - Additional benefit: change group membership affects all objects that have this group in its ACL

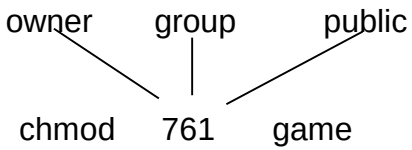


# Access Lists and Groups

- Mode of access: read, write, execute
- Three classes of users

| | RWX | | |
|---|---|---|---|
| a) **owner access** | 7 | ⇒ | 1 1 1 |
| | RWX | | |
| b) **group access** | 6 | ⇒ | 1 1 0 |
| | RWX | | |
| c) **public access** | 1 | ⇒ | 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 XP Access Control List Management

# File Locking

- Advisory lock on a whole file
  - ✓ int flock (int fd, int operation)
    - LOCK_SH(shared), LOCK_EX(exclusive), LOCK_UN(unlock)
- POSIX record lock
  - ✓ discretionary lock: can lock portions of a file
  - ✓ If a process dies, its locks are automatically removed
  - ✓ int fcntl (int fd, int cmd, struct flock *lock);
    - cmd: F_GETLK, F_SETLK, F_SETLKW
    - struct flock { type, whence, start, len, pid };
- System V mandatory lock
  - ✓ A file is marked as a candidate by setting the setgid bit and removing the group execute bit
  - ✓ Must mount the file system to permit mandatory file locks
  - ✓ Use the existing flock()/fcntl() to apply locks
  - ✓ Every read() and write() is checked for locking



# Summary

- File
  - ✓ A named collection of related information that is recorded on secondary storage
- Directory
  - ✓ A set or list of files
  - ✓ Provides a structured way to organize files
  - ✓ Folder in MS-Windows
- File protection
  - ✓ Access control list (ACL)
    - For each object, keep list of subjects and their allowed actions
    - Unix and MS-Windows take this approach
  - ✓ Capabilities
    - For each subject, keep list of objects and their allowed actions



# Summary (Cont'd)

- File system
  - ✓ Implement an abstraction for secondary storage (files)
  - ✓ Organize files logically (directories)
  - ✓ Permit sharing of data between processes, people, and machines (sharing)
  - ✓ Protect data from unwanted access (protection)
  - ✓ Examples
    - FAT32, NTFS, ext2, ext3, …
  - ✓ User's view: Chap. 10
  - ✓ Implementer's view: Chap. 11