0117401: Operating System
计算机原理与设计

Chapter 11: File system interface(文件系统接口)

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为了您和他人的工作学习，
请在课堂上关机或静音。

不要在课堂上接打电话。

提纲

File Concept

Access Methods（访问方式）

Directory Structure（目录结构）

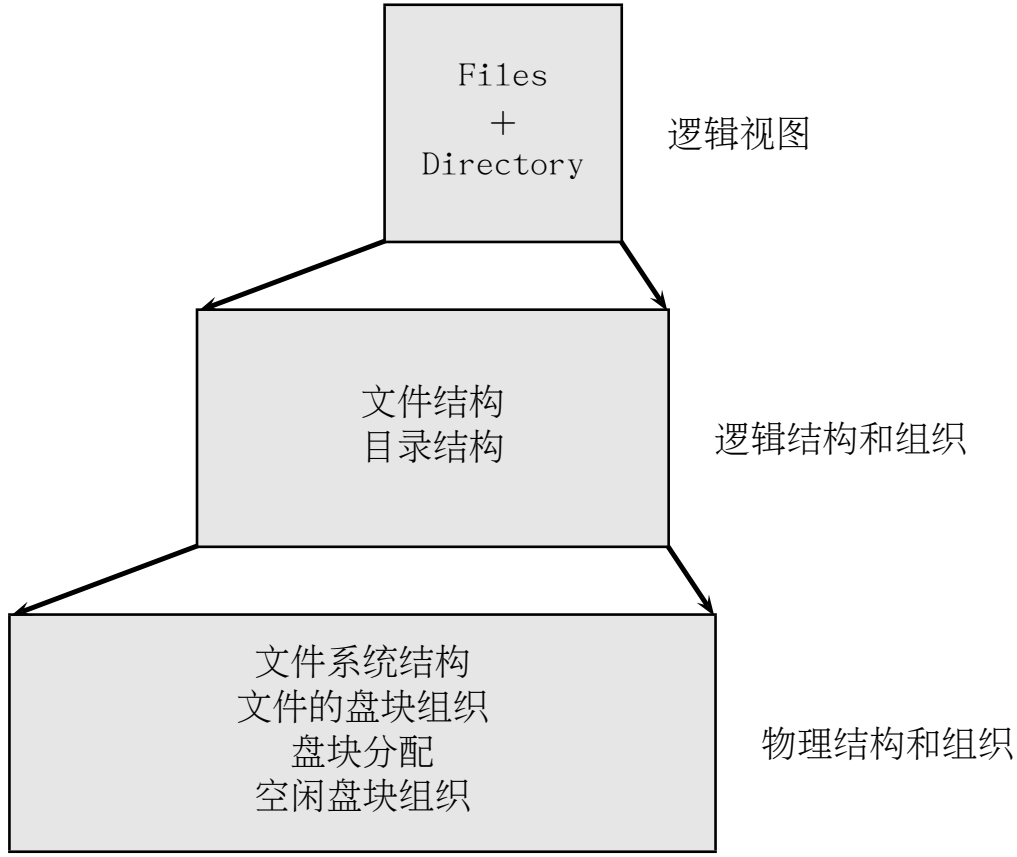
File System Mounting（文件系统挂载）

File sharing（文件共享）

Protection

小结和作业

File System


Files
+
Directory
逻辑视图
文件结构
目录结构
逻辑结构和组织
文件系统结构
文件的盘块组织
盘块分配
空闲盘块组织
物理结构和组织

Chapter Objectives

- To explain the function of file systems
- To describe the interfaces to file systems
- To discuss file-system design tradeoffs, including access methods, file sharing, file locking, and directory structures
- To explore file-system protection

Outline

File Concept

- OS provides a uniform logical view of infomation storage despite the various storage media (nonvolatile).
- A file is a logical storage unit.
  - A file is a named collection of related information that is recorded on secondary storage.
  - Types:
    - Data: numeric; character; binary
    - Program
  - In general, a file is a sequence of bits, bytes, lines, or records.
    - The meaning is defined by the file's creator and user.
  - A file has a certain defined structure, which depends on its type.
    - Example: text files, source files, object files, executable files
  - Contiguous logical address space

File Concept

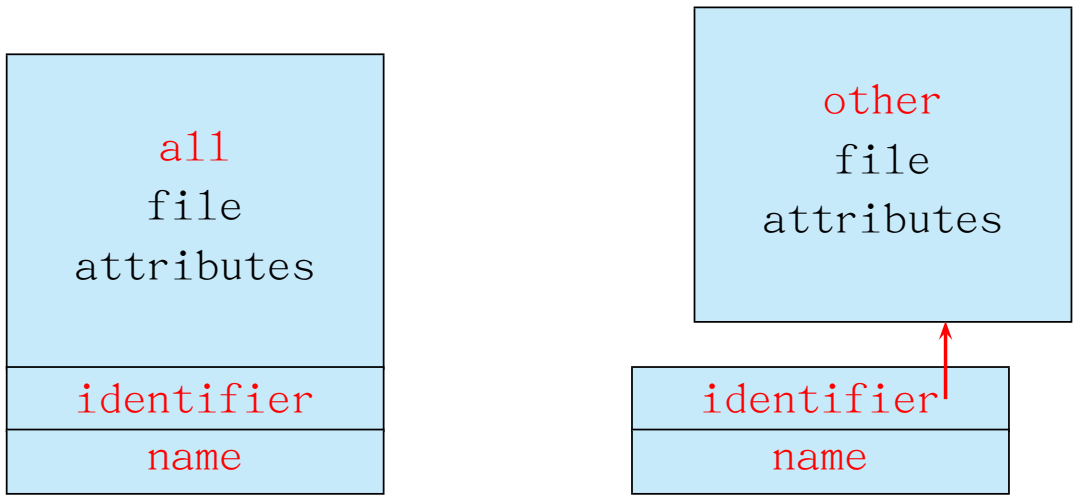
- File concept
  1. File attributes
  2. File operations
  3. File types
  4. File structures
  5. Internal file structure

1. File Attributes (文件属性)

- A file's attributes vary from one OS to another but typically consist of these:
  - **Name** — The only information kept in **human-readable** form
    - A name is usually a string of characters, such as "example.c"
    - Uppercase vs. lowercase: care or not care
  - **Identifier** — Unique tag, usually a number, identifies file within FS
    - The **non-human-readable** name for the file
  - **Type** — Needed for systems that support different types
  - **Location** — A pointer to **file location on device**
  - **Size** — Current file size; may also include MAX size
  - **Protection** — Access-control (访问控制) information: who can do reading, writing, executing
  - **Time, date, and user identification** — Data for protection, security, and usage monitoring

1. File Attributes (文件属性)

- Information about files are kept in the directory structure, which is also maintained on the secondary storage



directory structure 1 directory structure 2

- Typically, a directory entry only **consists of the file's name and its unique identifier.** The identifier in turn locates the other file attributes.

2. File Operations (文件操作)

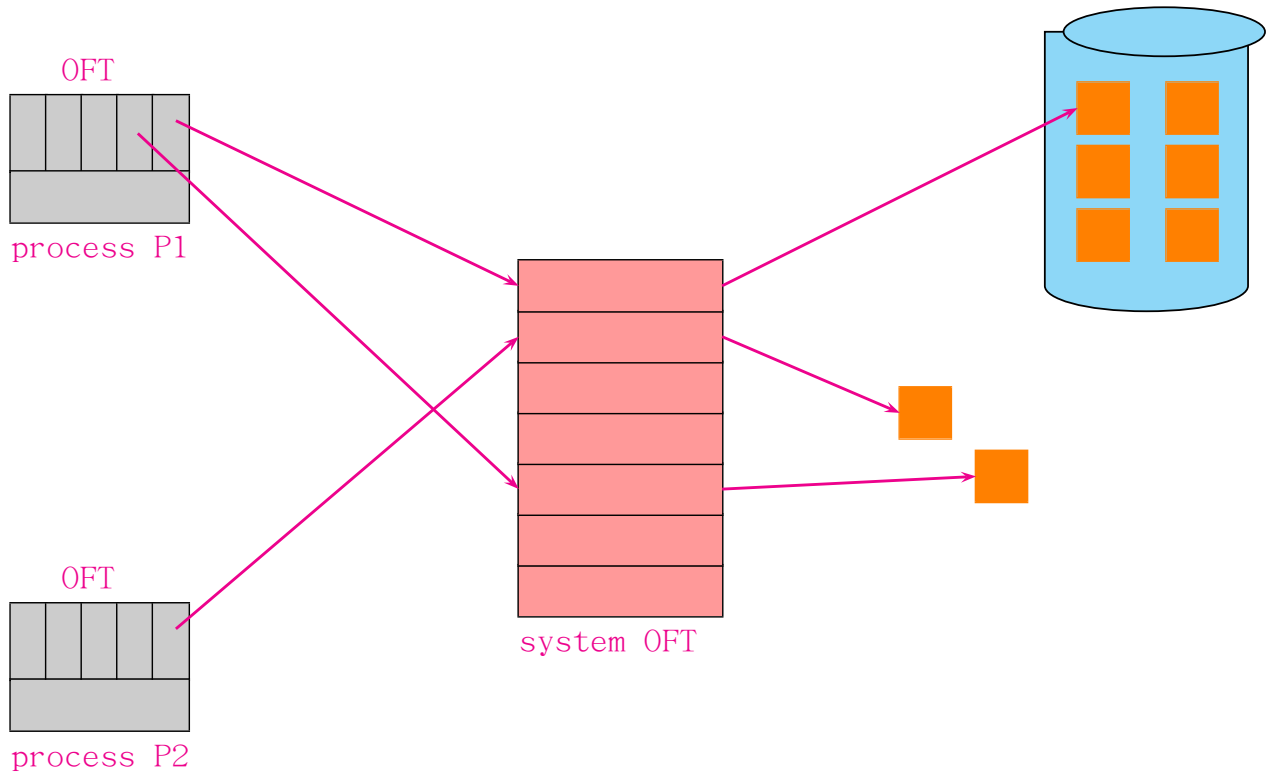
- File is an **abstract data type**. OS provides the 6 **basic** system calls
  1. **Create** : allocate space + create an directory entry
  2. **Write** : write pointer
  3. **Read** : read pointer
  4. **Reposition within file** : also known as **seek**
  5. **Delete** : release space + erase the directory entry
  6. **Truncate** : file len=0; release space; all other attributes remain unchanged

- others:
  - For **file** : append, rename
  - For file **attribute**: chown, chmod, ...
  - For **directory** & **directory entries**:
    - 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

2. File Operations (文件操作)

- **Open Files & Open-File Table**
  - **Open-file table**, OFT: a small table containing information about all open files
  - Several processes may open the same file at the same time

    ⇒2-levels: a **per-process table** & a **system-wide table** with process-independent information



2. File Operations (文件操作)

- **Open Files & Open-File Table**
  - Several pieces of data are needed to manage open files:
    - **File pointer**: pointer to last read/write location, process-dependent
    - **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**: the information needed to locate the file on disk, always is kept in memory
    - **Access rights**: per-process access mode information

2. File Operations (文件操作)

- **Open file locking**: Provided by some OSes and FSes
  - allow one process to lock a file and prevent other processes from gaining access to it
  - functionality is similar to reader-writer locks
  - OS- or FS-dependent

1. **Mandatory**: for example, Windows OSes, or
   - access is denied depending on locks held and requested;
   - OS ensures locking integrity
2. **Advisory**: for example, UNIX
   - processes can find status of locks and decide what to do
   - up to software developers

3. 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
work 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, someti compressed, for archiving/storage
multimedia	mpeg, mov, rm, mp3, avi	binary file containing audio or A/V information

4. File Structure

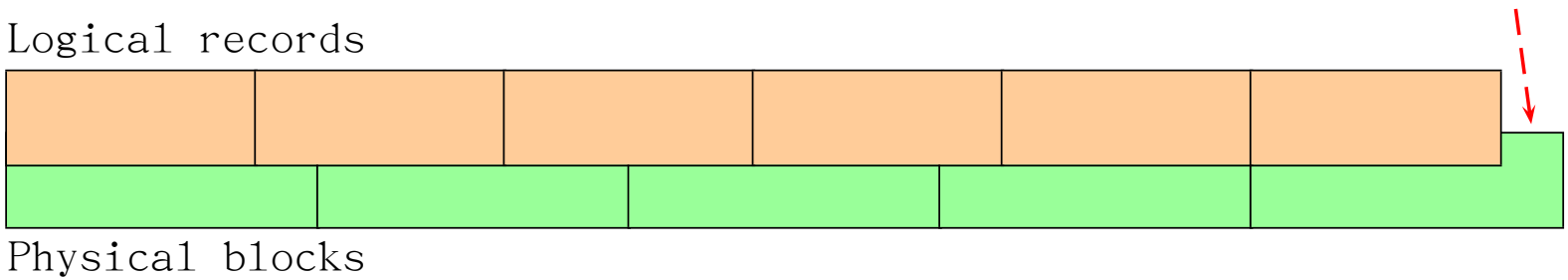
- Sometimes, file types can indicate the internal structure of file
- File structures(文件结构)(逻辑上)
  - None - sequence of words, bytes
  - Simple record structure
    - Lines
    - Fixed length;
    - Variable length
  - Complex Structures
    - Formatted document
    - Relocatable load file
- Can simulate last two with first method

4. File Structure

- System-supported file structures
  - Most modern OSes support a minimal number of file structures directly
    - Example: UNIX sees every file as a sequence of 8-bit bytes
  - Benefits:
    - Applications have more flexibility
    - Simplifies the OS

5. Internal file structure

- How to locate an offset within a file?
  - Logical file (record) (vary in length)
    $\rightarrow$ Physical block (fixed size)
- Solution: Packing — packing a number of logical records into physical blocks.
  - Pack & unpack: convert between logical records and physical blocks
  - Internal fragmentation will occur



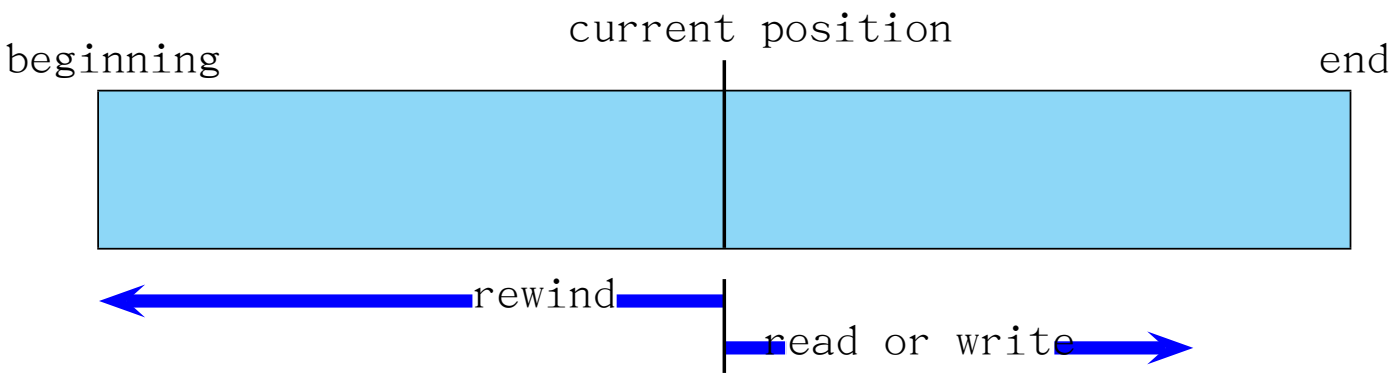
Outline

Access Methods（访问方式）

- Files store information. When it is used, this information must be accessed and read into computer memory
- On a logical perspective of users, access a file of records
  1. Sequential Access（顺序访问方式）
  2. Direct Access（直接访问方式）
  3. Indexed Access（索引访问方式）

1. Sequential Access (顺序访问方式)

- **Sequential Access (顺序访问方式)**: the simplest access method.
  Information in the file is processed **in order**, one **record after the other**.
  - This is a most common access mode.
    For example: editors, compilers
  - A **tape** model of file
- File **operations** & the effect on file **pointer**
  - **read/write next**
  - **reset**
  - **rewind/forward n**



2. Direct Access (直接访问方式)

- **Direct Access (直接访问方式)**
  Information in the file is processed in **no particular order**.
  - File is made up of a numbered sequence of **fixed-length logical records**
    - A **disk** model of a file, allow **random** access, immediate access
      For example: databases, or an ailine-reservation system
  - Can move quickly to any record location by supplying a **relative** record number (n)
    - **Read n & Write n**,
      File pointer $= L * n$, $0 \leq n \leq N$, where N is the last record number, L is the fixed length of each record.
    - $=$ **Position n & read/write next**, for example:

```
seek(20);          // move to rec. 20
seek(-1);          // move to rec. 19
read();
```

2. Direct Access（直接访问方式）

- 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;

- How can we get n?
  If the record is with variable length, then ?

3. Indexed Access (索引访问方式)

- To improves search time and reduce I/O
  1. **Make an index file** for the file, which contains pointers to various records
  2. **Search the index file first**,
  3. and then use the pointer to access the file directly and to find the desired record.

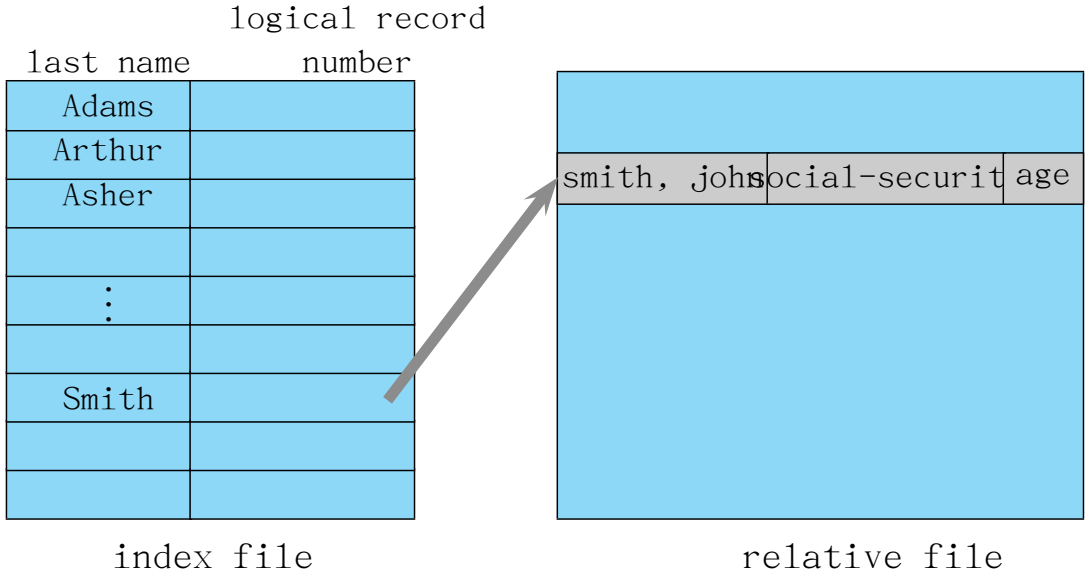


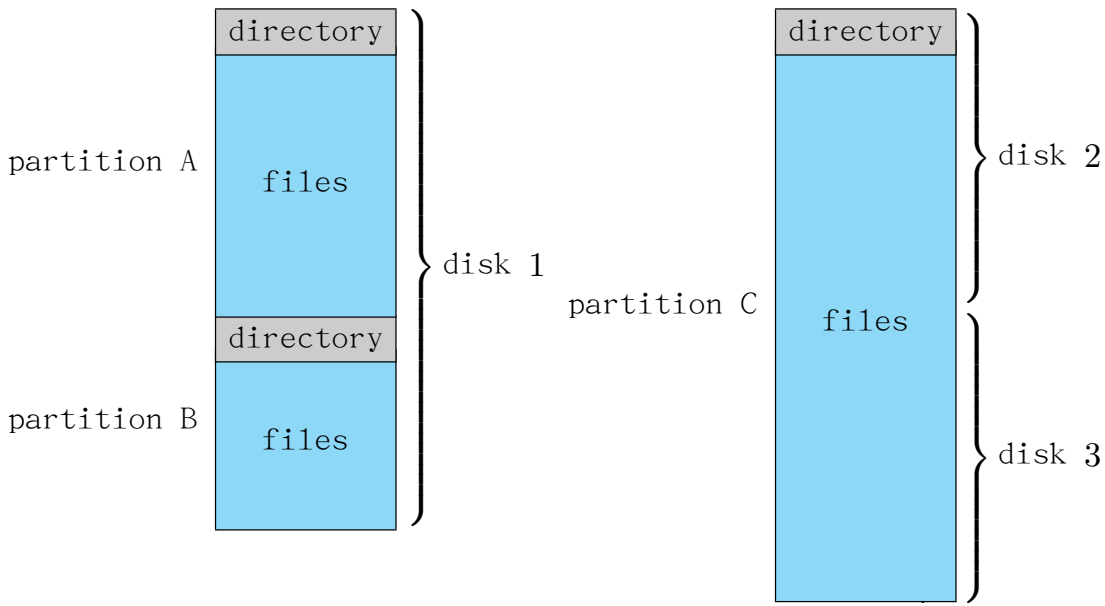
Figure: Example of index and relative files

- With **large files**, the index file itself may become too large to be kept in memory $\Rightarrow$ **Multi-level index table**

Outline

A Typical File-system Organization

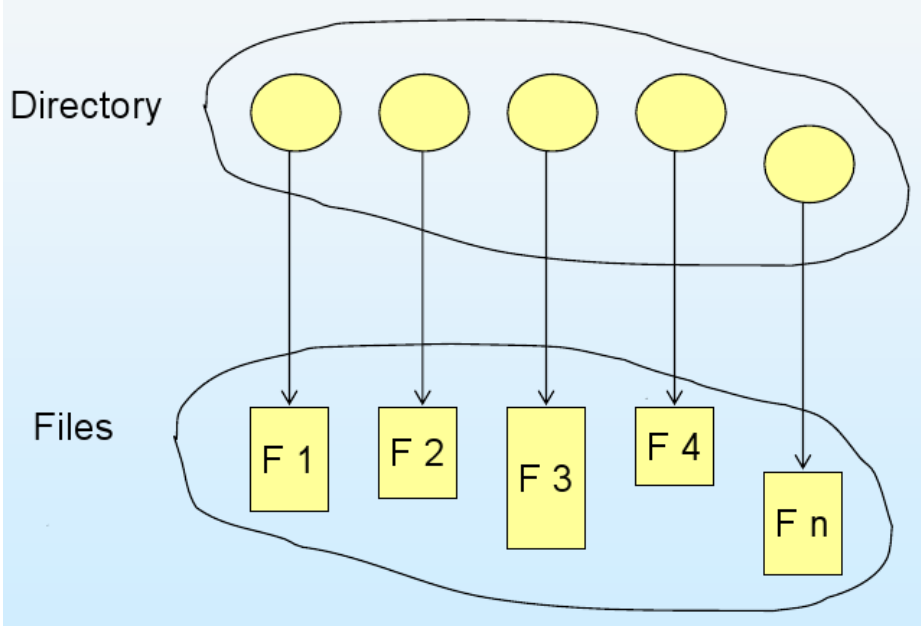
- **Partition** (mini-disks, volumes)
  1. One disk
  2. Part of a disk: provide separate logical spaces on one disk
  3. N disks: group several disks into a single logical space



- **Partition = files + directories**
  - **Directory**: holds file information (name, location, size, type, ...) for all files in that partition

Directory Overview

- **Directory**:
  A collection of nodes containing information about all files



- Directory + files: **all reside on disk**
- Backups of these two structures are kept on tapes

Directory Overview

- **Information in a directory entry**

- File attributes
  - Name
  - Type
  - Address
  - Current length
  - Maximum length
  - Date last accessed (for archival)
  - Date last updated (for dump)
  - Owner ID (who pays)
  - Protection information

In DOS

- **Directory entry = FCB** (file control block)
- 32 bytes each
- May cost many I/O operations to search for an entry

In UNIX

- **Inode**: Store most of file attributes
- **Directory entry** = file name + a pointer to the inode
- 16 bytes each

Directory Overview

- Operations performed on directory

Search for a file	$\Rightarrow$	Search in the table for an entry
Create a file	$\Rightarrow$	
Delete a file	$\Rightarrow$	Insert an entry
List a directory	$\Rightarrow$	Delete an entry
Rename a file		Modify an entry
Traverse the file system		...

Directory Overview

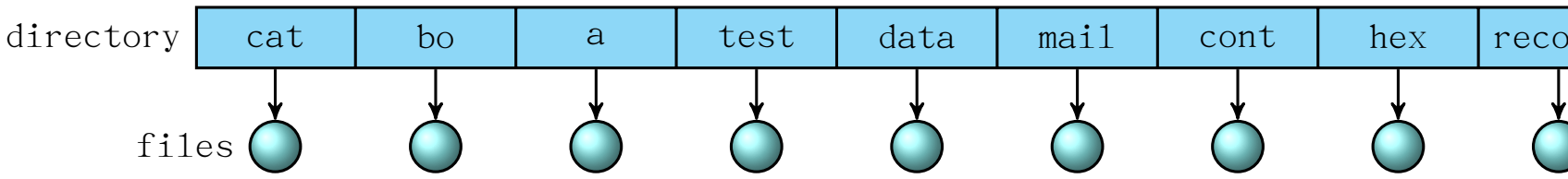
- Organize the directory (logically) to obtain
  1. **Efficiency** — locating a file quickly
  2. **Naming** — convenient to users
     - Two users can have same name for different files
     - The same file can have several different names
  3. **Grouping** — human convention
     - logical grouping of files by properties, (e.g., all Java programs, all games, ···)

Directory Structures (目录结构)

1. Single-level directory (单层目录)
2. Two-level directory (双层目录)
3. Tree-structured directory (树型结构目录)
4. Acyclic-graph directory (无环图目录)
5. General-graph directory (通用图目录)

1. Single-Level Directory (单层目录)

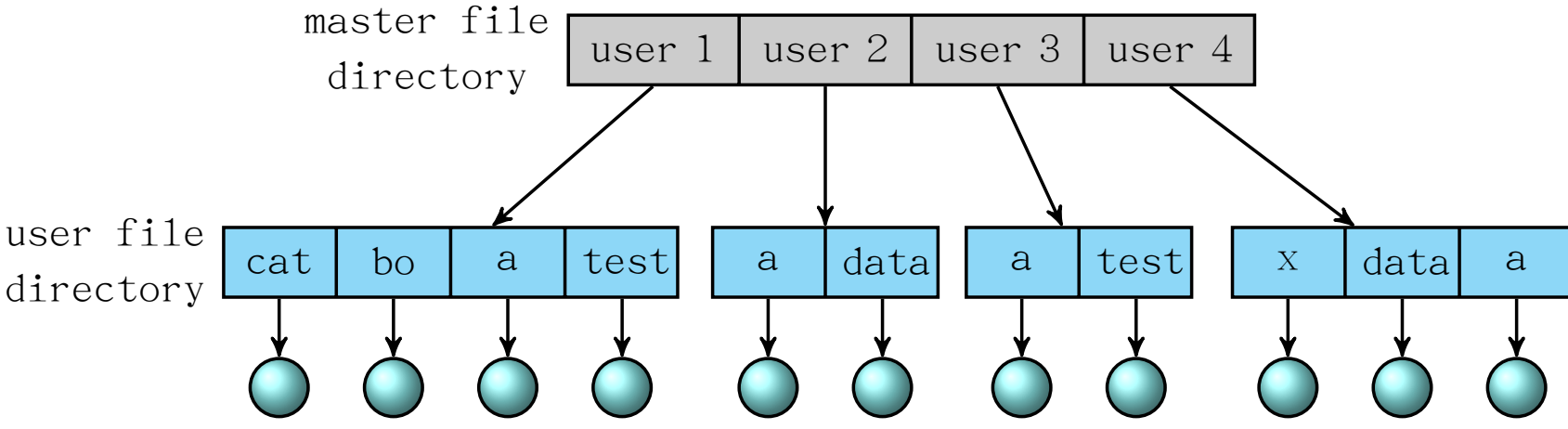
- A single directory for all users



- **Easy to support and understand.**
- But if there are large numbers of files and/or users ...
  - Very **low searching speed**, O(N)
  - **Naming problem**
    - Small naming space & Name collision
    - **MS-DOS: 11 bytes** for filename
    - **UNIX: 256 bytes**
  - **protection VS sharing**;
  - **grouping problem**

2. Two-Level Directory (双层目录)

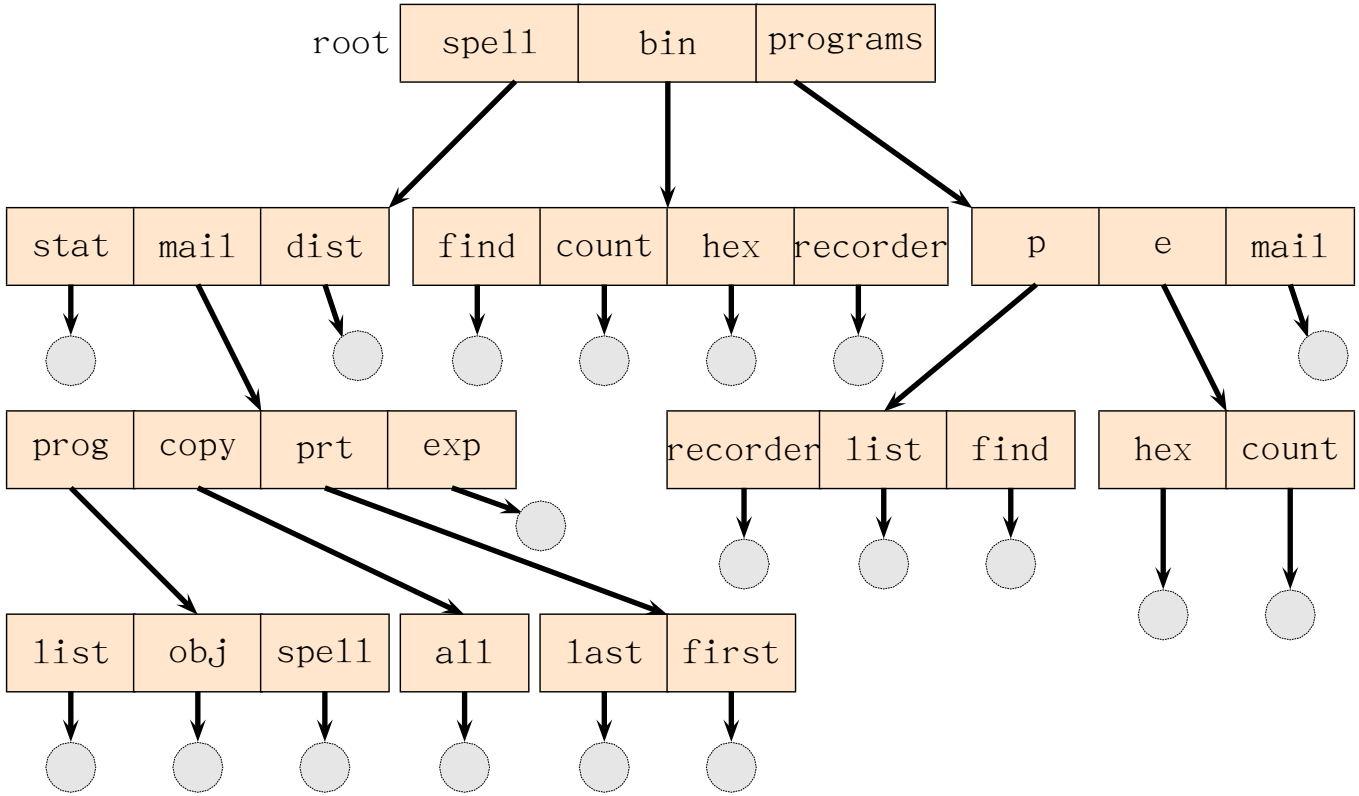
- **Two-Level Directory**: Separate directory for each user
  1. **User File Directory, UFD**
     - Each entry owns information for a user's file
  2. **Master file directory, MFD**
     - Each entry contains:
       (1) User name,
       (2) A pointer to his UFD



2. Two-Level Directory (双层目录)

- Can have the **same file name for different user**
- **Efficient searching**
- **No grouping capability**
- **Easy management**
  - Add/delete a user
- **Security VS. Sharing**
  - MFD, system administrator
  - UFD, isolated from other users
  - Directory tree (seen as an inverted tree) & path name
  - **How to share?** E.g. system-wide files (dara, program, ...)
    - copy for each user?
    - searching path
- **A UFD may be very large, then ...**

3. Tree-Structured Directories (树型结构目录)



- Root directory (根目录) & directory (目录) & subdirectory (子目录)

3. Tree-Structured Directories (树型结构目录)

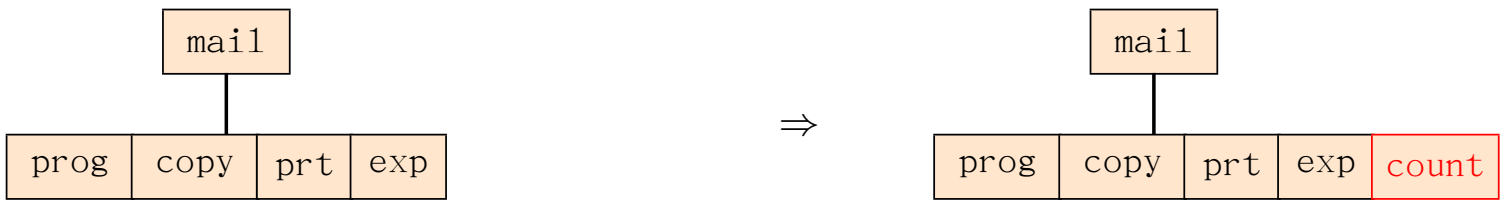
- **Regular file** VS. **subdirectory**
  - Treat a subdirectory like another file
  - Use a special bit in the directory entry to distinguish a file (0) from a subdirectory (1)
- **Current directory** (当前目录) (working/searching directory)
  - Creating a new file is done in current directory.
  - Initial current directory
- **Absolute** vs. **relative** path names (绝对/相对路径名)

  /spell/words/rade

  ../spell/words/rade

3. Tree-Structured Directories (树型结构目录)

- Operations
  - Change current directory: cd /spell/mail/prog
  - Delete a file: rm <file-name>
  - List a dictory: ls
  - create a new directory: mkdir <dir-name>
    - Example: if in current directory /mail
      mkdir count



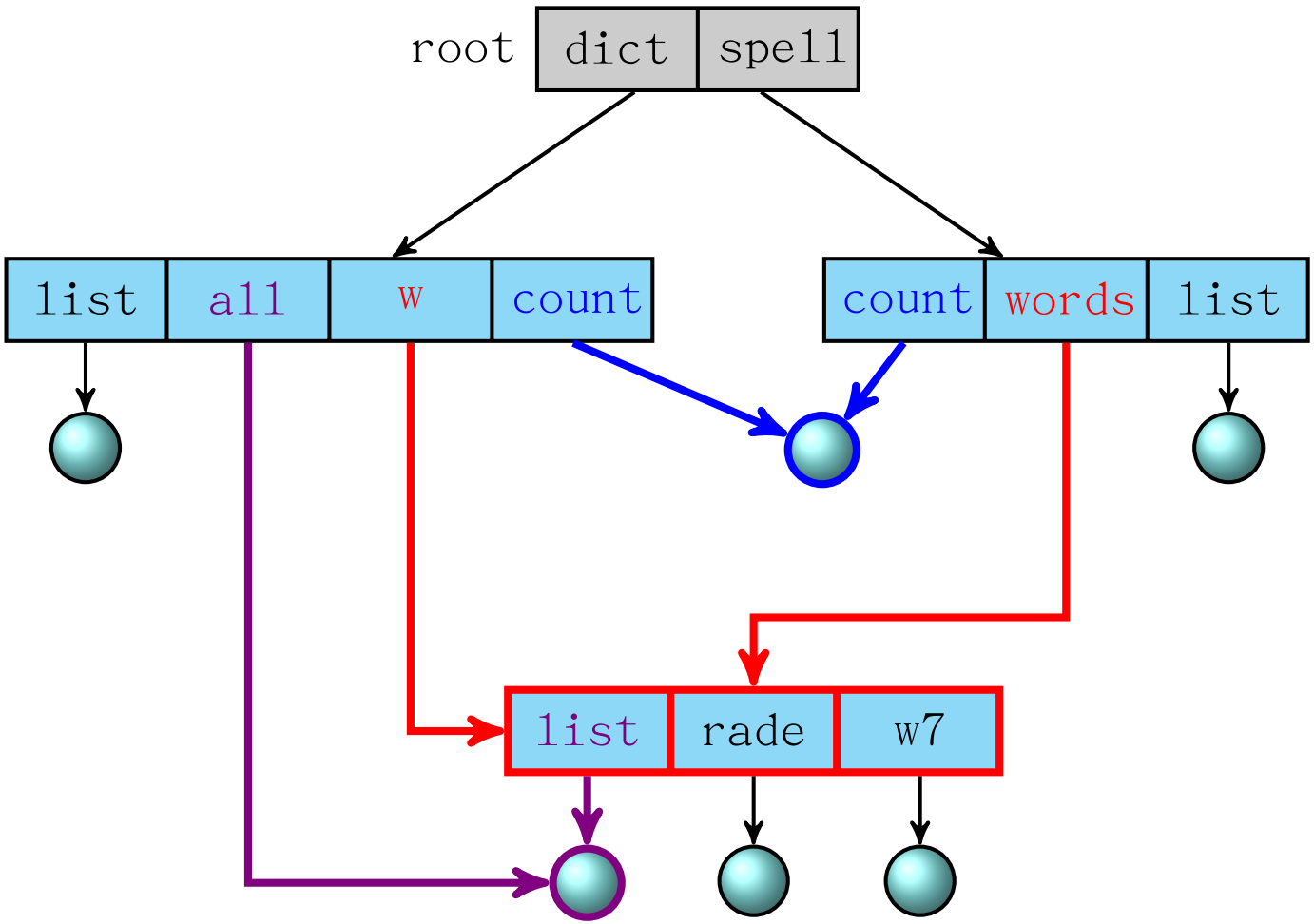
  - Delete a directory
    - MS-DOS (only empty directory) VS. UNIX (optional)
  - ...

3. Tree-Structured Directories (树型结构目录)

- Efficient searching
- Grouping Capability
- The tree structure
  prohibits the sharing of files and directories.

4. Acyclic-Graph Directories (无环图目录)

- **Acyclic-Graph Directories**
  - Have **shared** subdirectories and files, with no cycles
  - The same file or directory may be in two different directories, having two different names (**aliasing**)



4. Acyclic-Graph Directories (无环图目录)

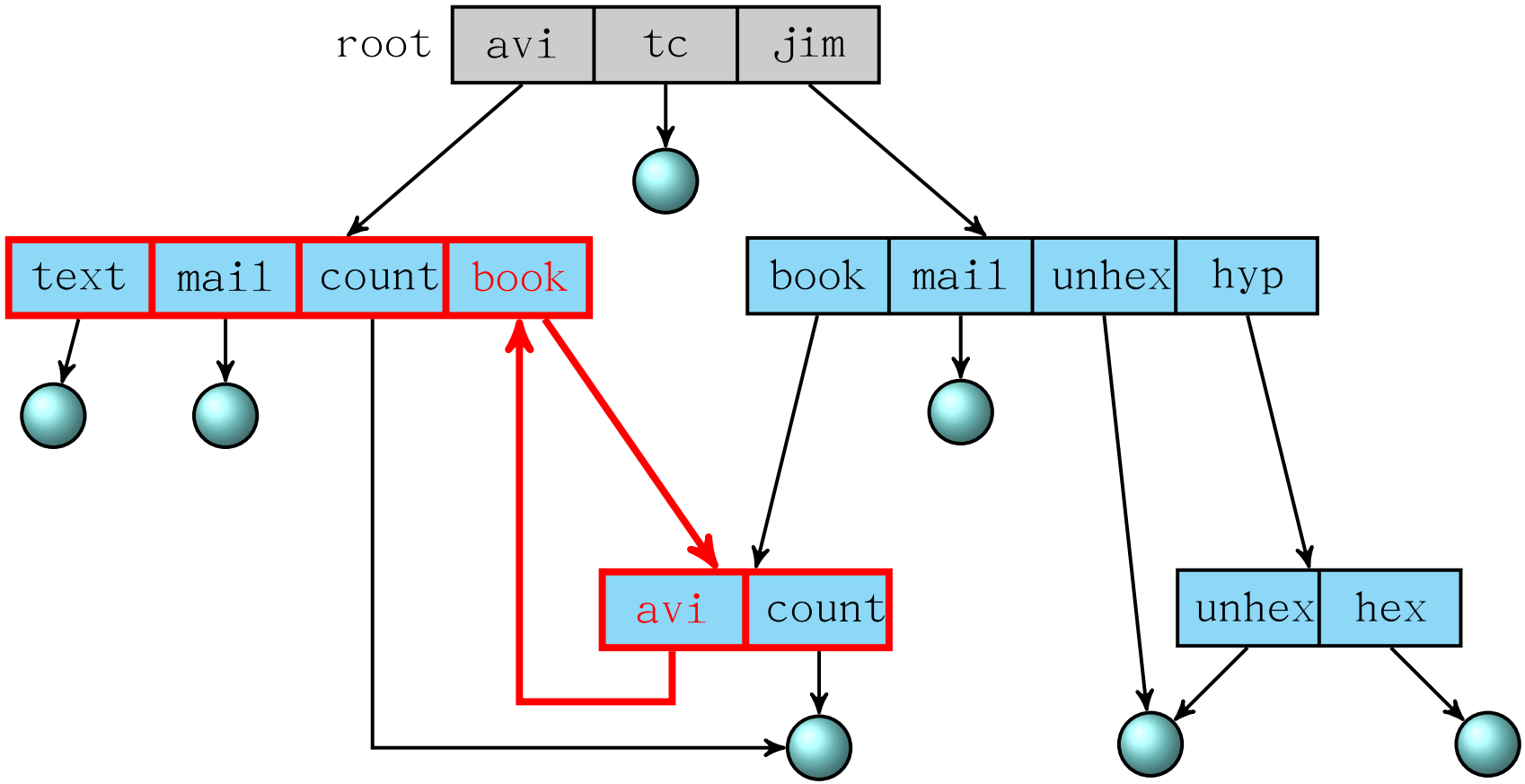
- Implementation
  1. Symbolic links (符号链接)
     - A special new directory entry (link)
     - The content of such file is the path name of the real file/directory
     - How to traverse a directory contains symbolic links?
  2. Duplicates directory entries
     - Hard to maintain consistency

4. Acyclic-Graph Directories (无环图目录)

- **Traversing** problem
  - Different names, actual only one file
  - traverse more than once
- **Deleting** problem
  - If direct deletes list $\Rightarrow$ dangling pointer
  - or preserve the file until all reference to it are deleted
  - **Solutions**:
    - File-reference list
    - Reference count: **hard link** (硬链接) in UNIX
- **How to ensure there are no cycles?**

5. General Graph Directory (通用图目录)

- If we allow cycles existed in directory



5. General Graph Directory (通用图目录)

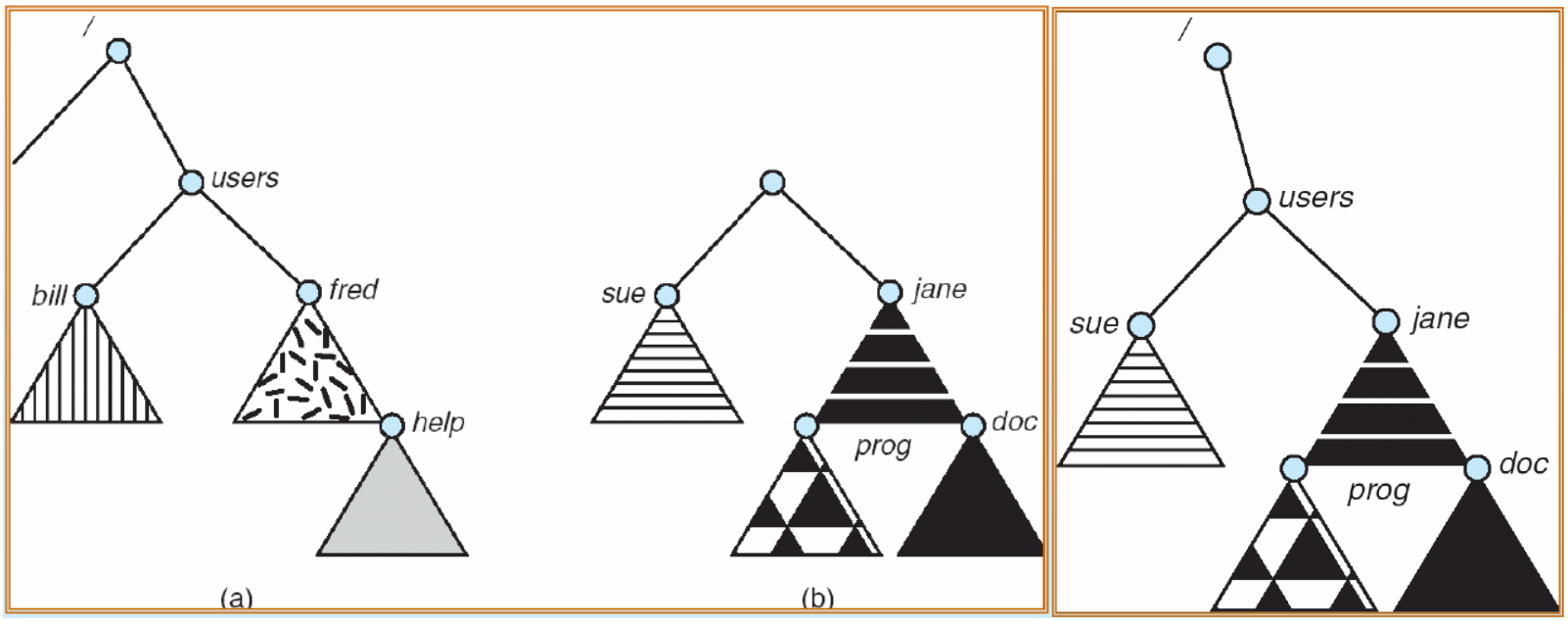
- The traversing problem and deleting problem still exists, even more complicatedly
  - Infinite loop
    - limit the access number of a directory while for a search
  - Garbage & garbage collection
- How do we guarantee no cycles?
  - Allow only links to file not subdirectories
  - Every time a new link is added use a cycle detection algorithm to determine whether it is OK

Outline

File System Mounting (文件系统挂载)

File System Mounting（文件系统挂载）

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



(a) Existing. (b) Unmounted Partition (c) if using /users as Mount Point

Outline

File sharing (文件共享)

File sharing (文件共享)

- 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

File sharing (文件共享)

1. Multiple Users share files
   - Multiple users⇒the issues of file sharing, file naming, file protection become preeminent
   - The system must control the sharing
     - allow by default, OR
     - require a user to specifically grant access to the file
   - More file and directory attributes are needed
     - Owner:User IDs identify users, allowing permissions and protections to be per-user
     - Group:Group IDs allow users to be in groups, permitting group access rights

File sharing (文件共享)

2. Remote File Systems

- Uses **networking** to allow file system access between systems
  - 2.1 Manually via programs like **FTP**
  - 2.2 Automatically, seamlessly using distributed file systems
  - 2.3 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
  - Example:
    NFS is standard UNIX client-server file sharing protocol
    CIFS is standard Windows protocol
  - Standard OS 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

File sharing (文件共享)

3. Failure Modes

- 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 include all information in each request, allowing easy recovery but less security

File sharing (文件共享)

4. Consistency Semantics

- Consistency semantics specify how multiple users are to access a shared file simultaneously
  - Similar to 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

Outline

Protection

- **Reliability (可靠性)**
  - Guarding against **physical damage**
  - File systems can be damaged by
    - Hardware problems, power surges or failures, head crashed, dirt, temperature extremes, or Vandalism
  - Generally provided by duplicate copies of files (disk→tape, ...)
- **Protection (保护，安全性)**
  - Guarding against **improper access**

Protection in multi-user system

- The need to protect files is a direct result of the ability to access files (of other users).
  1. **Complete protection** with prohibiting access
  2. **Free access** with no protection
  3. **Controlled access**. √
- **Controlled access**: limiting the types of file access that can be made
  - Types of access: **Read**/**Write**/**Execute**/Append/Delete/List
  - **Higher-level functions** may also be controlled: rename/copy/edit/...
- File owner/creator should be able to control:
  - what can be done? by whom?
- Many protection mechanisms have been proposed.

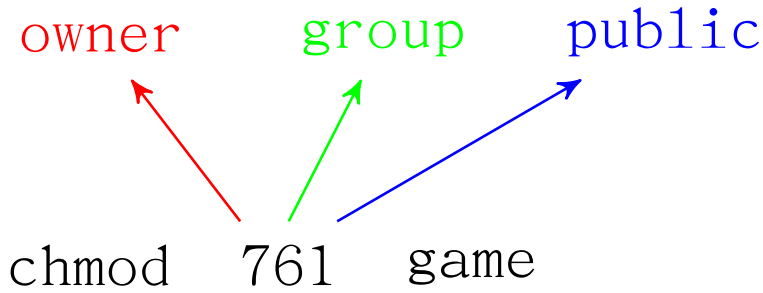
Access control (访问控制)

- **The most common approach** to the protection problem: ID-dependent access
  - Make access dependent on the ID of the user
- **The most general scheme** to implement ID-dependent access: Access control list (访问控制列表, ACL)
  - Associate with each file and directory an access list.
    - Access list specifies for each listed (allowed) user name and the types of (allowed) access allowed.
    - Stored in each directory entry
  - **Length problem**
    Solution: Three classes of users

			R	W	X
a) owner access	7	⇒	1	1	1
b) group access	6	⇒	1	1	0
c) public access	1	⇒	0	0	1

Access control (访问控制)

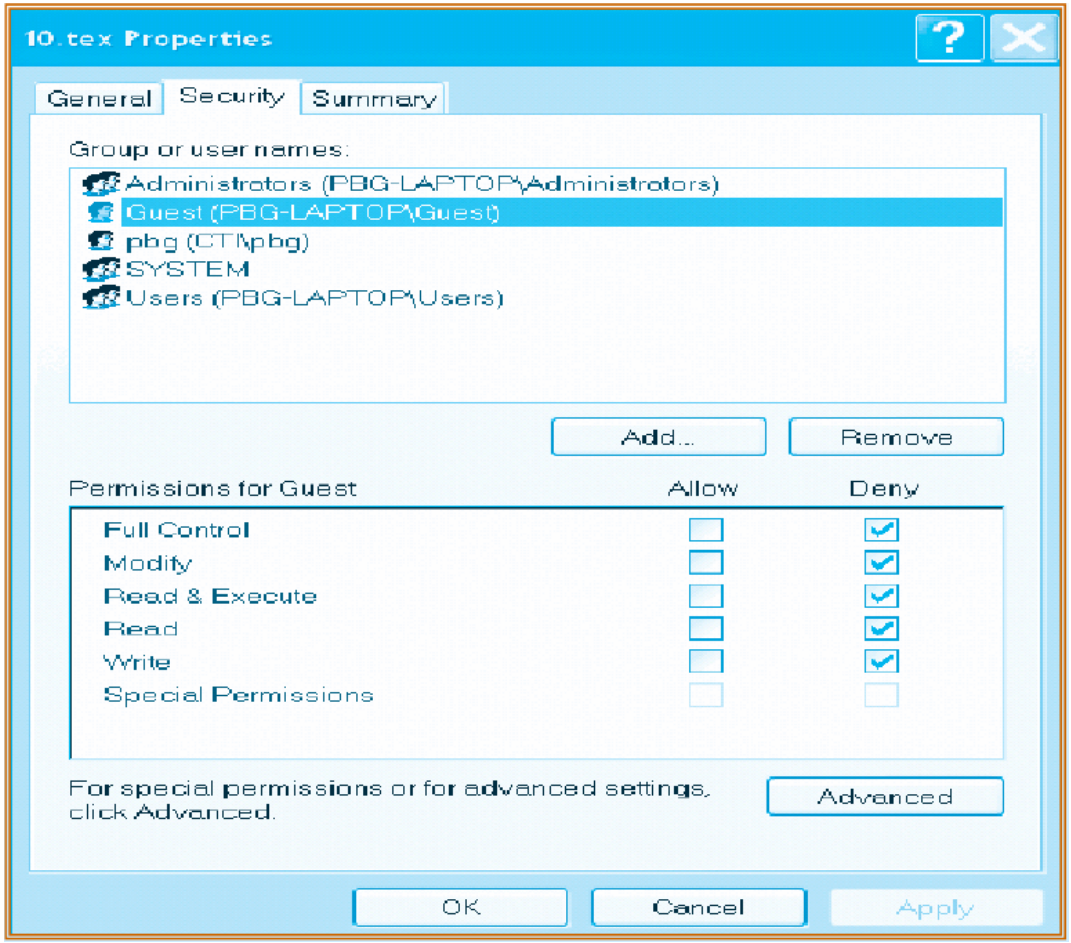
- About group:
  - Ask manager to create a group (unique name), say G, and add some users to the group.
  - For a particular file (say game) or subdirectory, define an appropriate access.



  - Attach a group to a file

    chgrp G game

Windows XP Access-control List Management



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/

Outline

小结

File Concept

Access Methods（访问方式）

Directory Structure（目录结构）

File System Mounting（文件系统挂载）

File sharing（文件共享）

Protection

小结和作业

作业

1. 名词解释：符号链接（symbolic links）和硬链接（hardlinks）
2. 说明Linux中创建符号链接和硬链接的命令。
   请你新创建一个文件，然后为这个文件建立1个硬链接。
   请问该文件最终有几个硬链接。

谢谢！