Operating System: Chap10 File System Interface

National Tsing Hua University

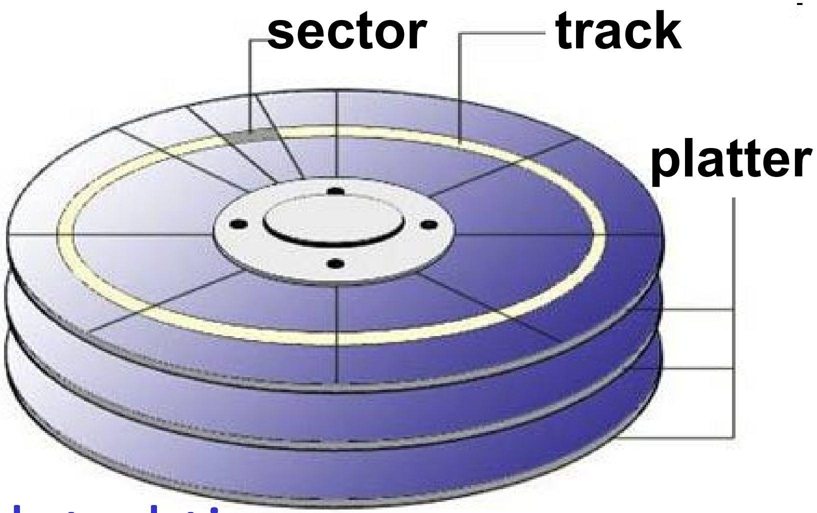
2024, Fall Semester

Overview

- File Concept
- Access Methods
- Directory Structure
- File System Mounting
- File Sharing
- Protection

File Concept

- **File (Data)**: a logical storage unit created by OS
  - v.s. physical storage unit in disk (**sector, track**)
- File attributes (Metadata)
  - Identifier: non-human-readable name
  - Name
  - Type
  - Location
  - Size
  - Protection
  - Last-access time, Last-updated time

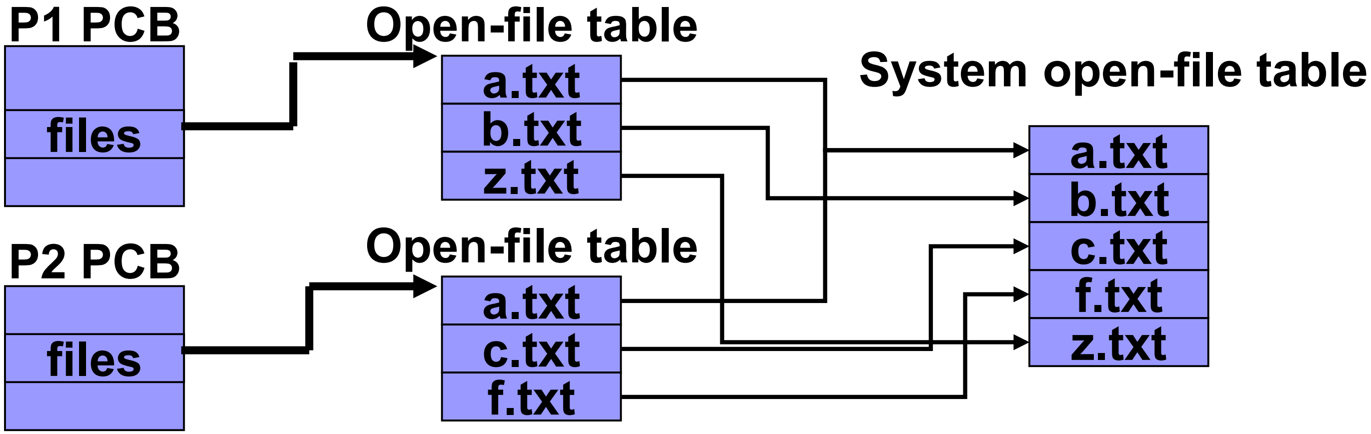


File Operations

- File operations include
  - Creating a file
  - Writing a file
  - Reading a file
  - Repositioning within a file (i.e. *file seek*)
  - Deleting a file
  - Truncating a file
  - Appending a file
- Process: open-file table
- OS: system-wide table

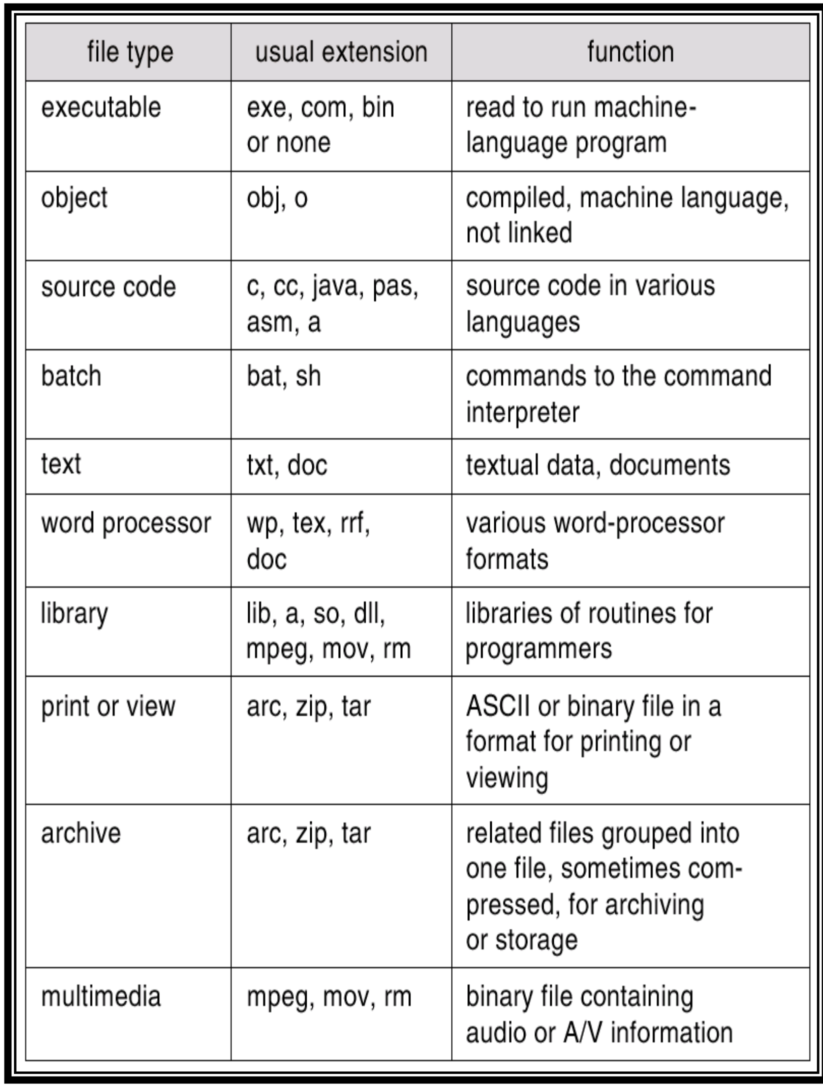
Open-File Tables

- **Per-process table**
  - Tracking all files opened by this process
  - Current **file pointer** for each opened file
  - Access rights and accounting information
- **System-wide table**
  - Each entry in the per-process table points to this table
  - **Process-independent** information such as disk location, access dates, file size
  - Open count



Open File Attributes

- Open-file attributes (metadata)
  - File pointer (per-process)
  - File open count (system table)
  - Disk location (system table)
  - Access rights (per-process)
- File types
  - .exe, .com, .obj, .cc, .mov, etc
  - Hint for OS to operate file in a reasonable way

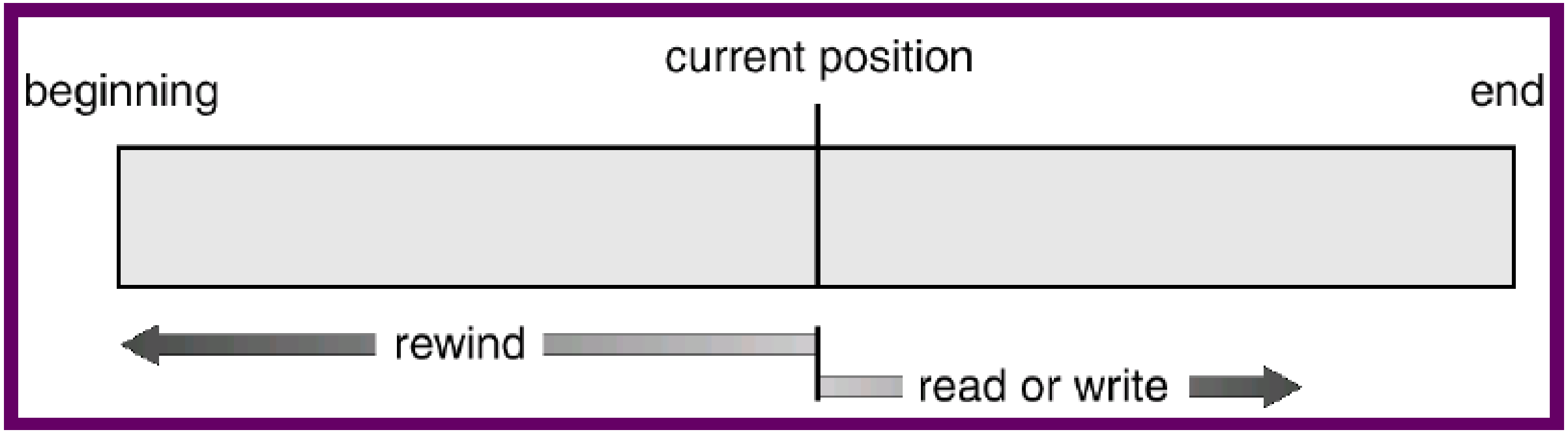


file type	usual extension	function
executable	exe, com, bin or none	read to run machine-language program
object	obj, o	compiled, machine language, not linked
source code	c, cc, java, pas, asm, a	source code in various languages
batch	bat, sh	commands to the command interpreter
text	txt, doc	textual data, 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

Access Method

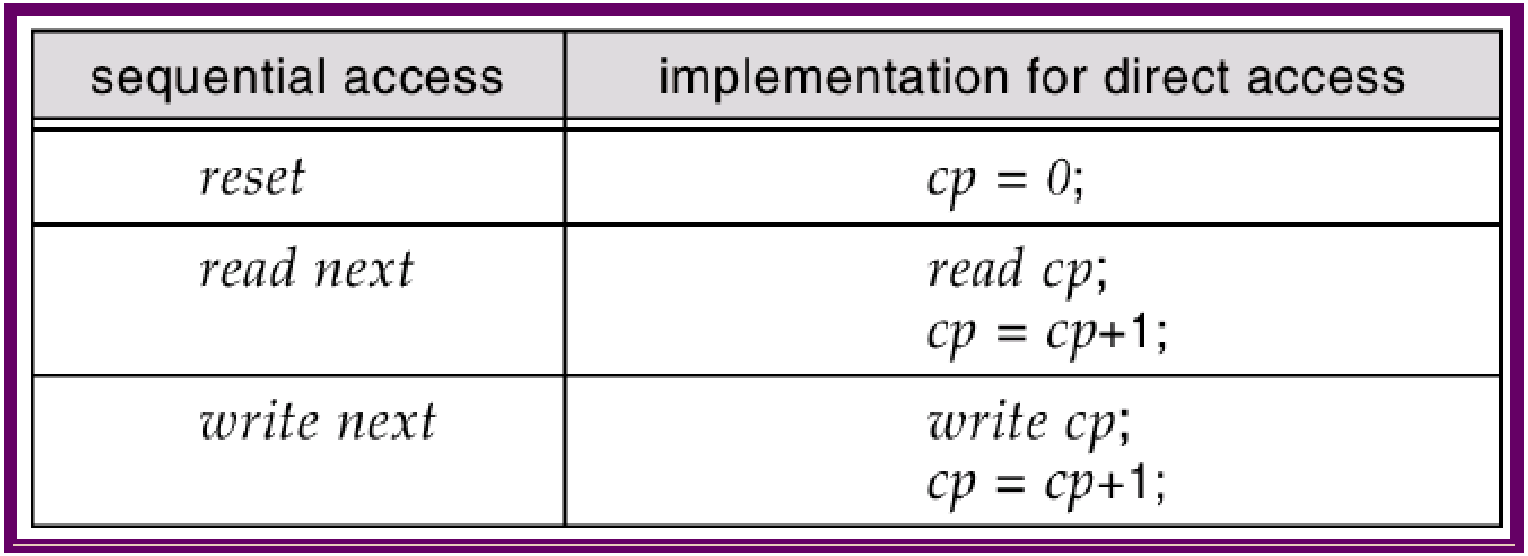
Access Methods

- Sequential access
  - Read/write next (block)
  - Reset: repositioning the file pointer to the beginning
  - Skip/rewind *n* records



Access Methods

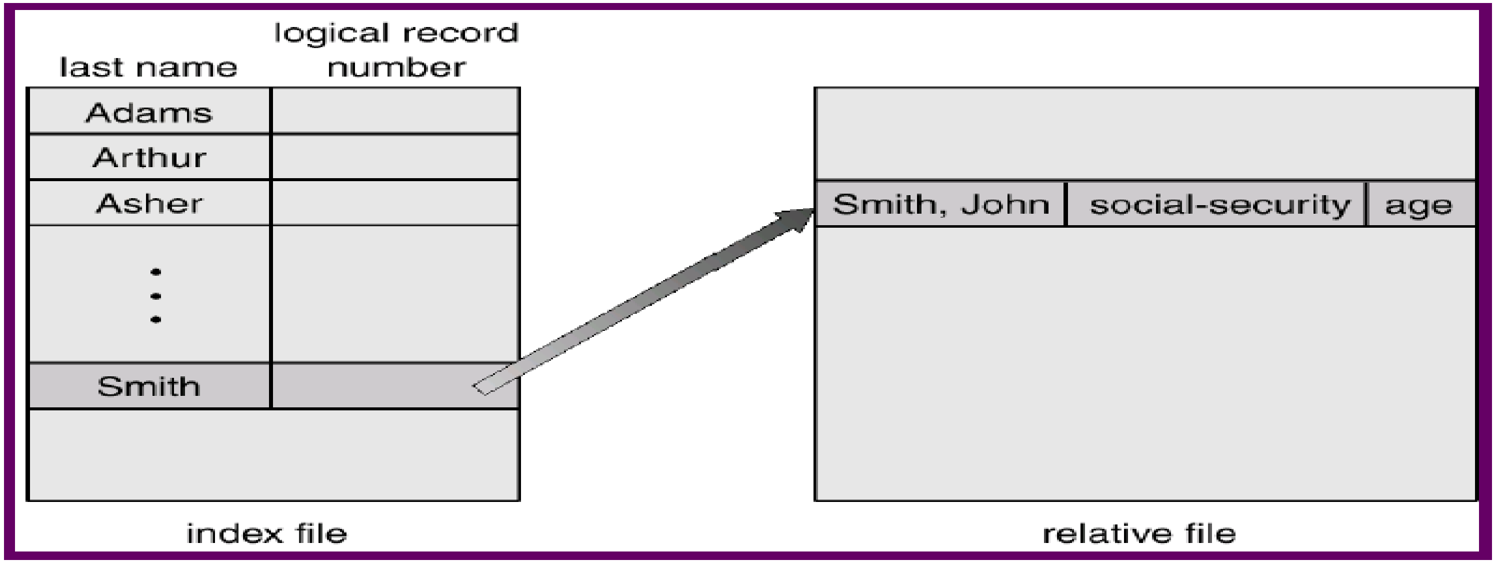
- Direct (relative) access
  - Access an element at an arbitrary position in a sequence
  - File operations include the block # as parameter
  - Often use **random access** to refer the access pattern from direct access



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

Index Access Methods

- Index: contains pointers to blocks of a file
- To find a record in a file:
  - search the index file → find the pointer
  - use the pointer to directly access the record
- With a large file → index could become too large



Review Slides (I)

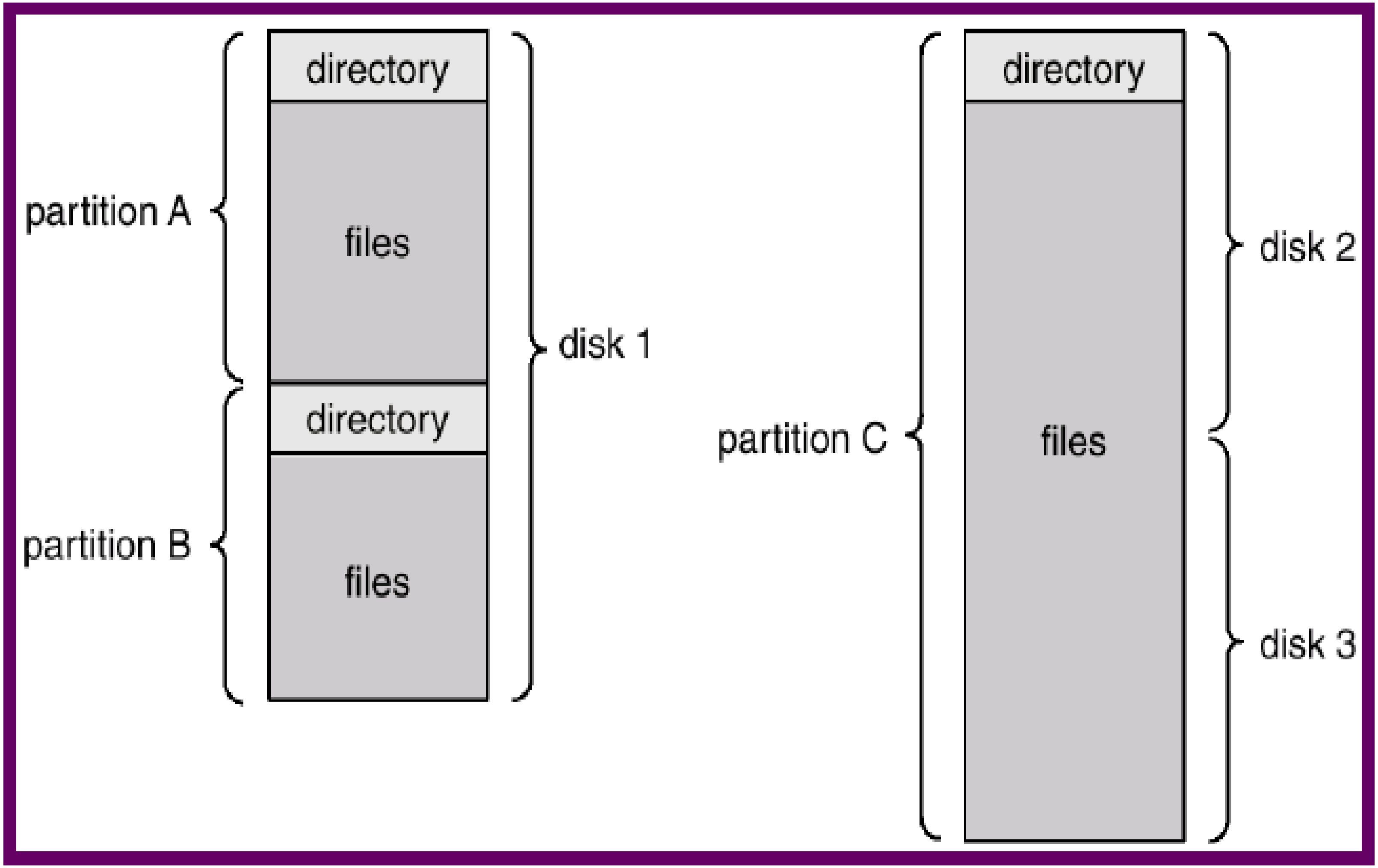
- File vs. Sector, Track
- Open-file (in-memory) attributes
  - Per-process, system-wide?
- File-access methods?
  - Sequential access
  - Direct access
  - Index access

Directory Structure

Partition, Volume & Directory

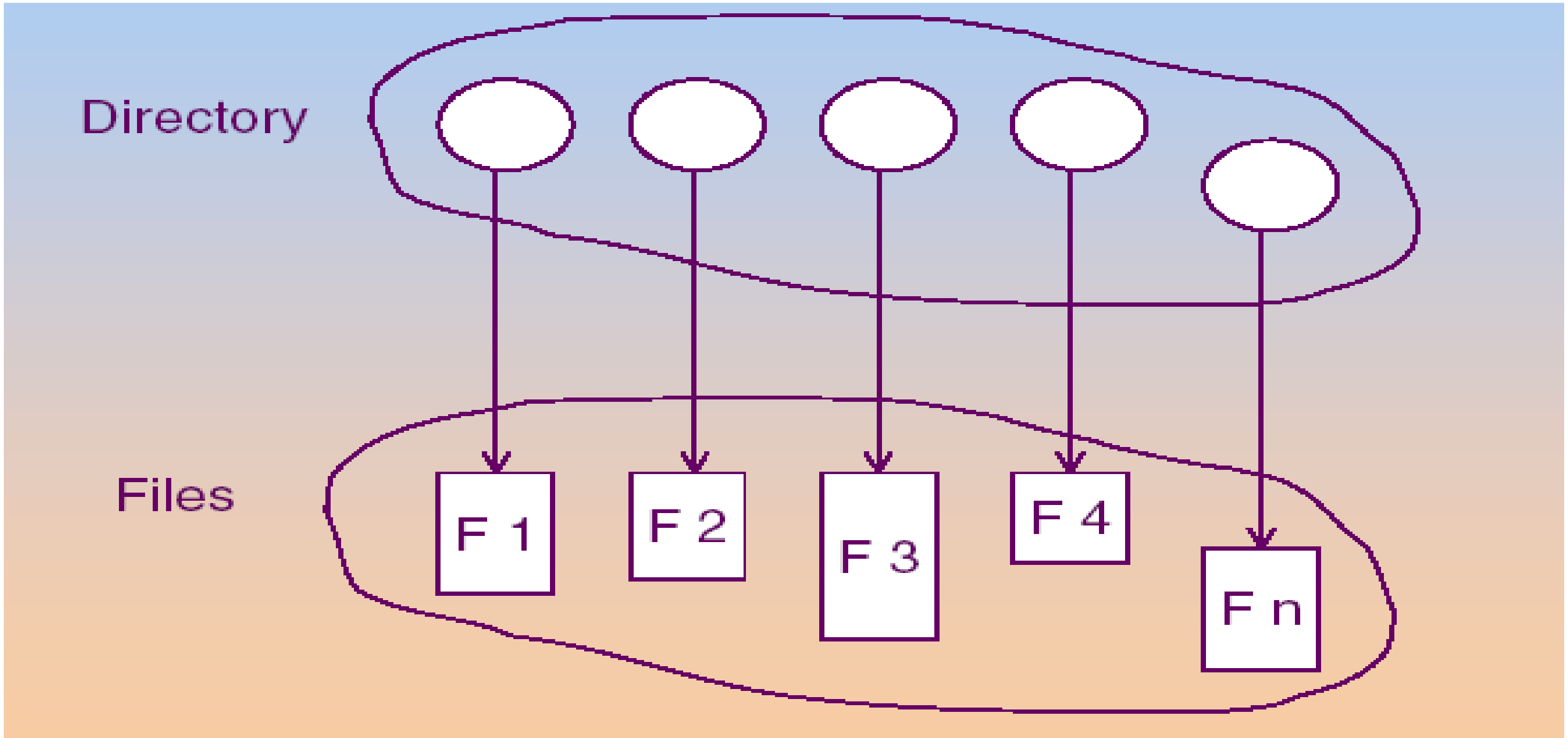
- A **partition** (formatted or raw)
  - raw partition (no file system): UNIX swap space, database
  - Formatted partition with **file system** is called **volume**
  - a partition can be a portion of a disk or group of multiple disks (distributed file system)
  - Some storage devices (e.g.: floppy disk) does not and cannot have partition
- **Directories** are used by file system to store the information about the files in the partition

File-System Organization



Directory vs. File

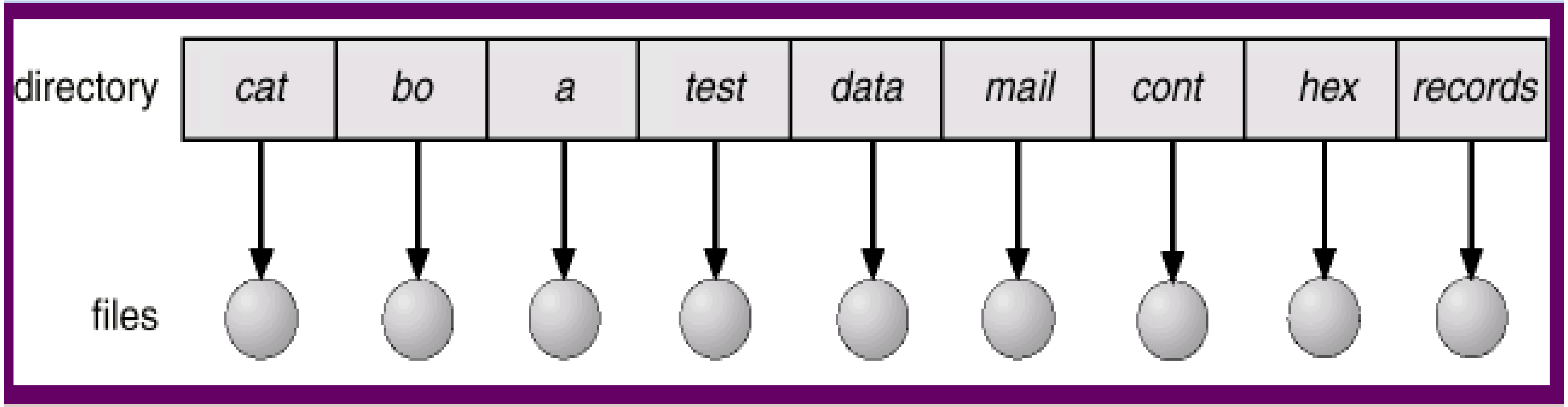
- **Directory**: A collection of nodes containing information about all files
  - Both the directory structure and the files reside on disk



Directory Operations

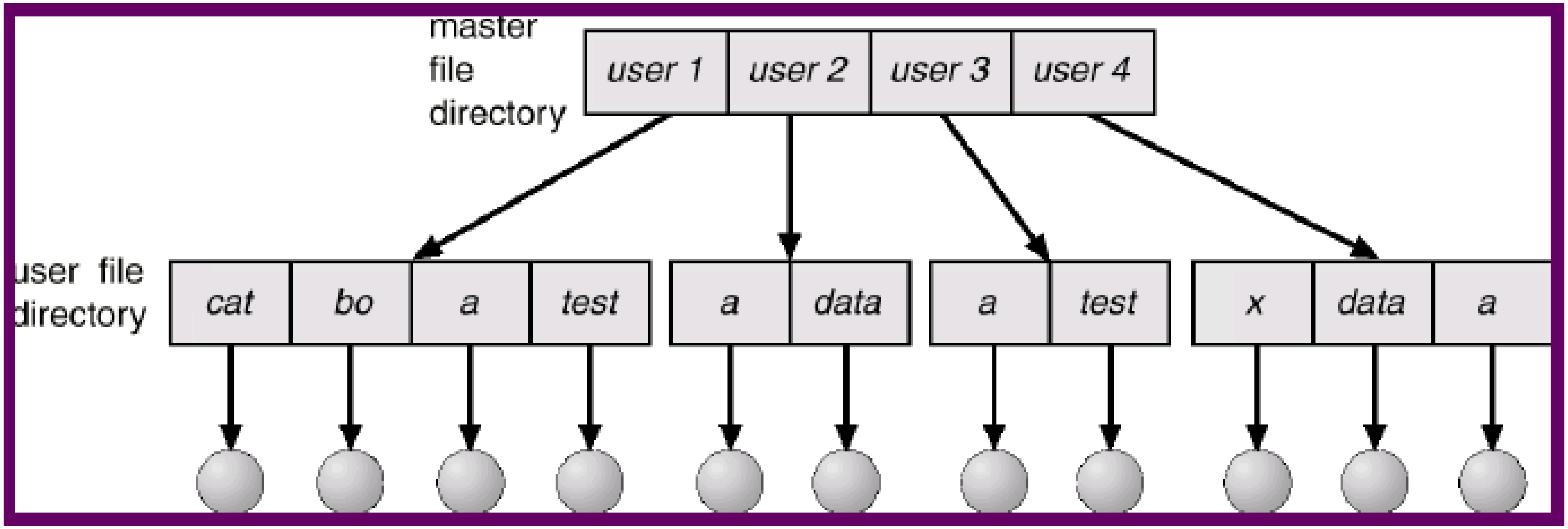
- Search for a file
- Create a file
- Delete a file
- List a directory
- Rename a file
- Traverse the file system

Single-Level Directory



- All files in one directory
  - Filename has to be **unique**
  - **Poor efficiency** in locating a file as number of files increases

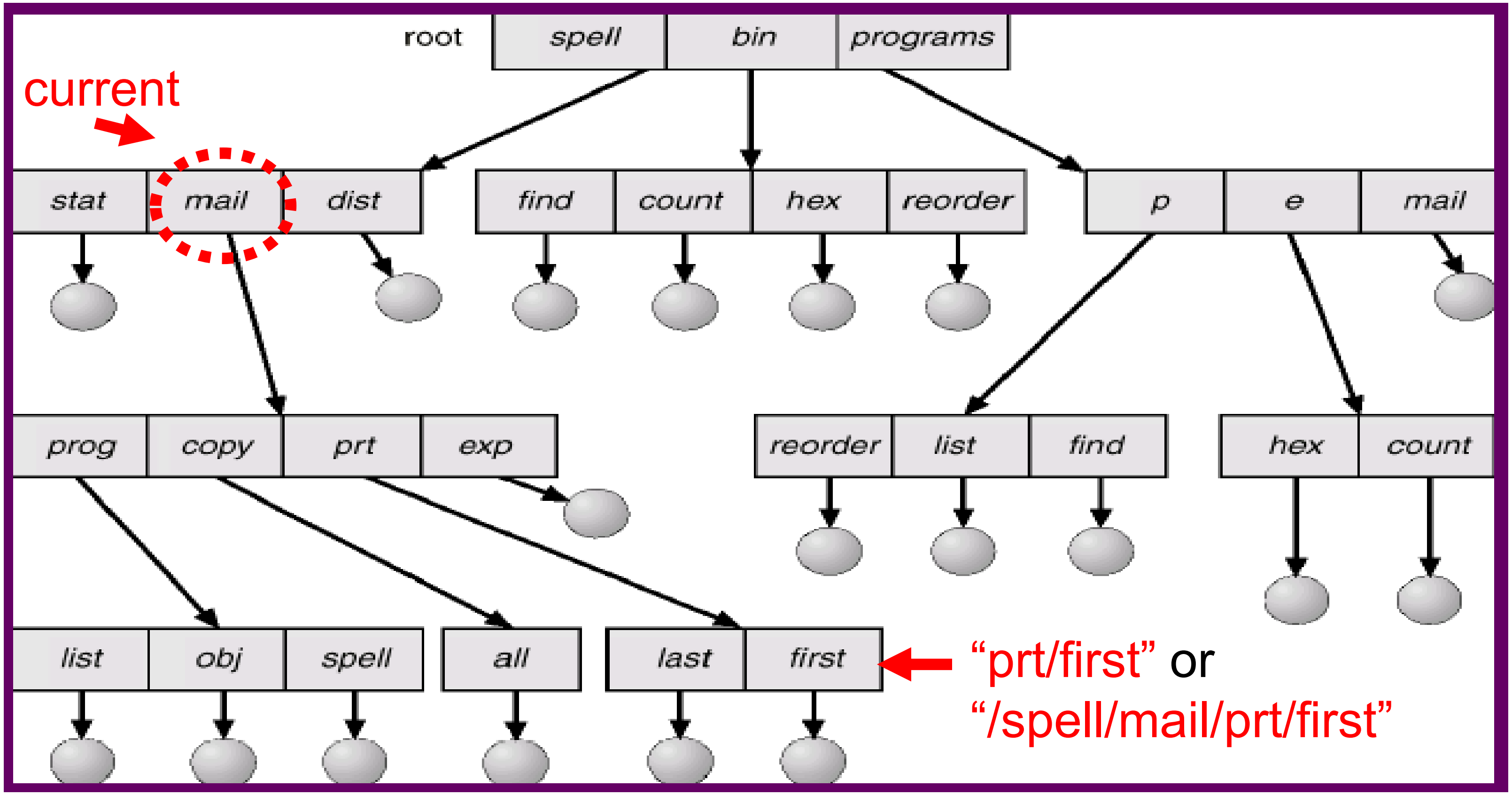
Two-Level Directory



- a separate dir for each user
- path = user name + file name
- single-level dir problems still exists per user

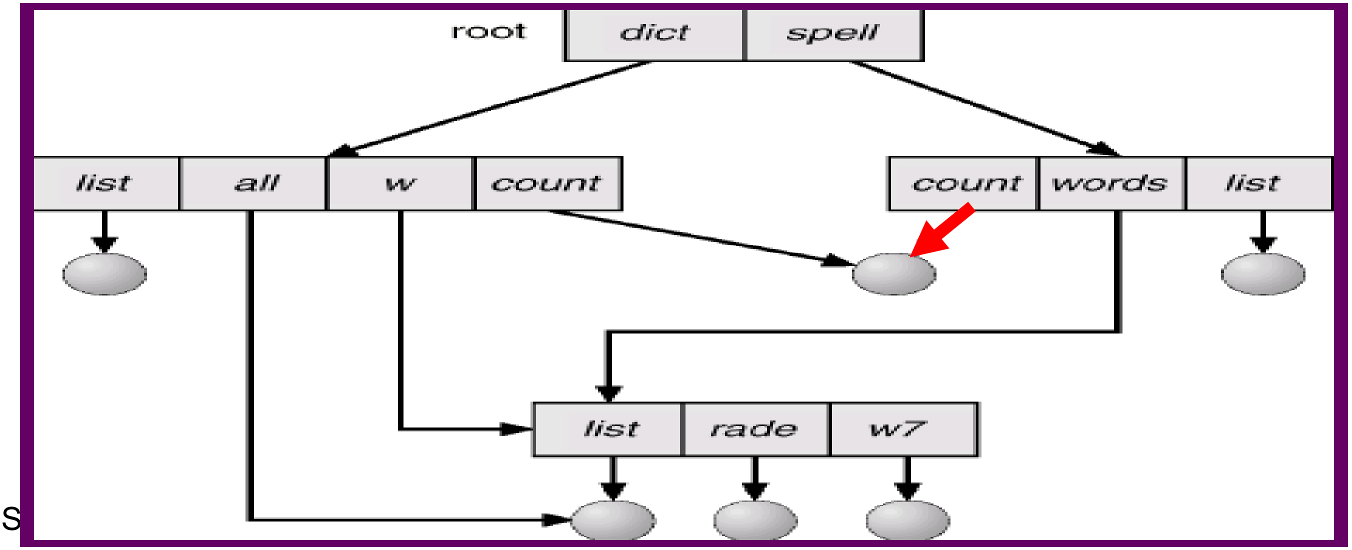
Tree-Structured Directory

- **Absolute path**: starting from the root
- **Relative path**: starting from a directory

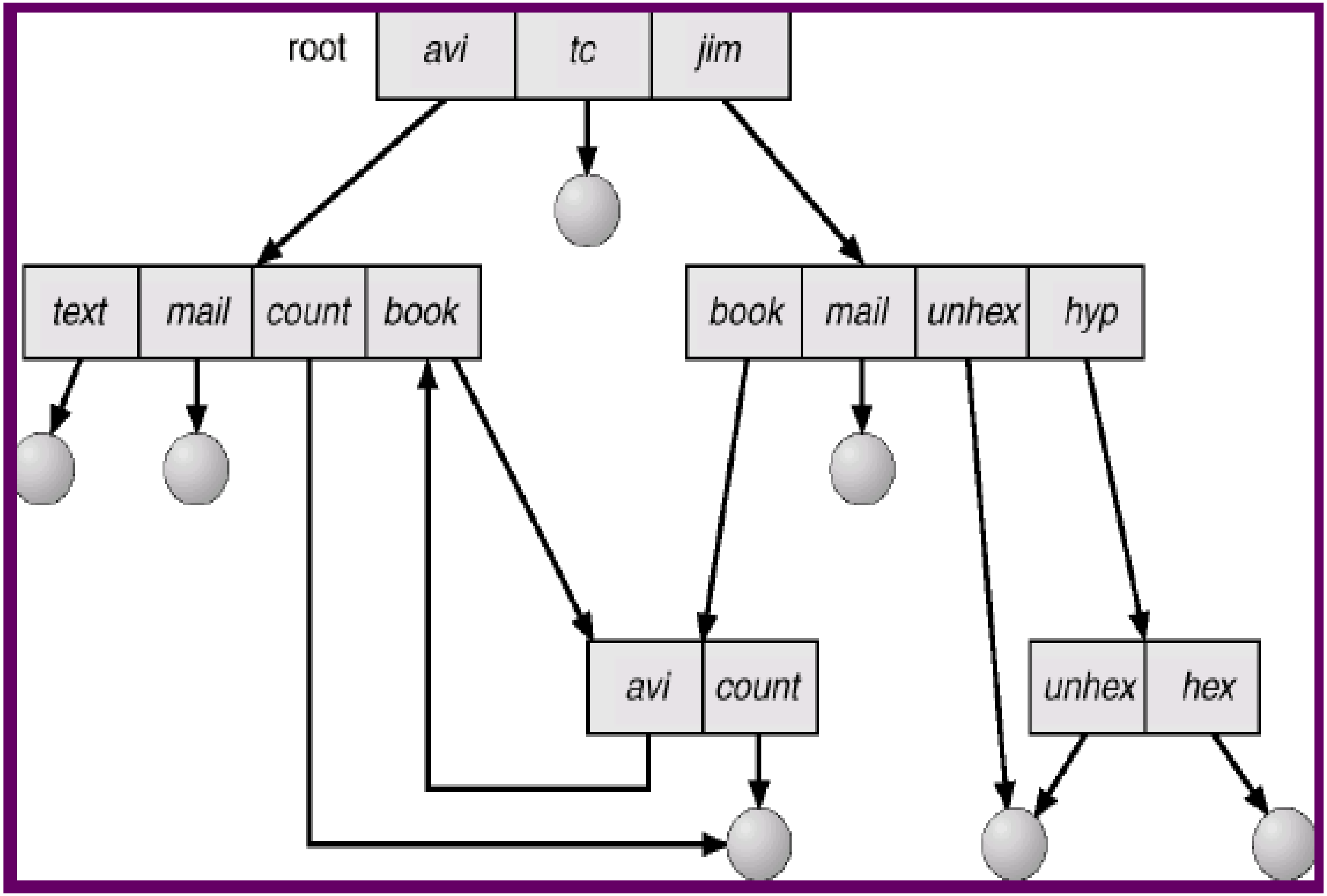


Acyclic-Graph Directory

- Use links to share files or directories
  - UNIX-like: ln /spell/count /dict/count
- A file can have multiple absolute paths
- When does a file actually get deleted?
  - deleting the link but not the file
  - deleting the file but leaves the link → dangling pointer
  - ☺ deleting the file when **reference counters** is 0

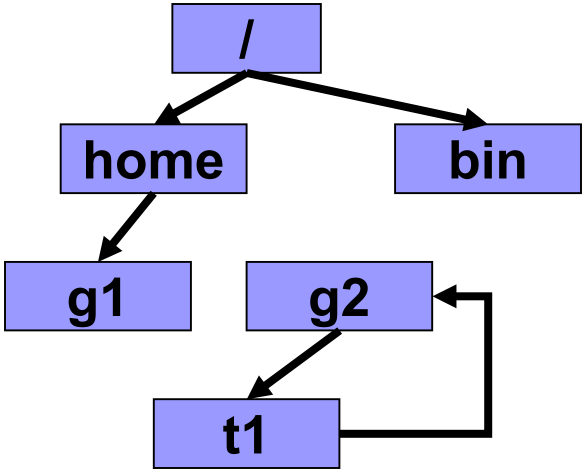


General-Graph Directory



General-Graph Directory

- May contain cycles
  - Reference count does not work any more
  - E.g. self-referencing file



- How can we deal with cycles?
  - **Garbage collection**
    - First pass traverses the entire graph and marks accessible files or directories
    - Second pass collect and free everything that is un-marked
    - ☹ Poor performance on millions of files …
  - Use cycle-detection algorithm when a link is created

Review Slides (II)

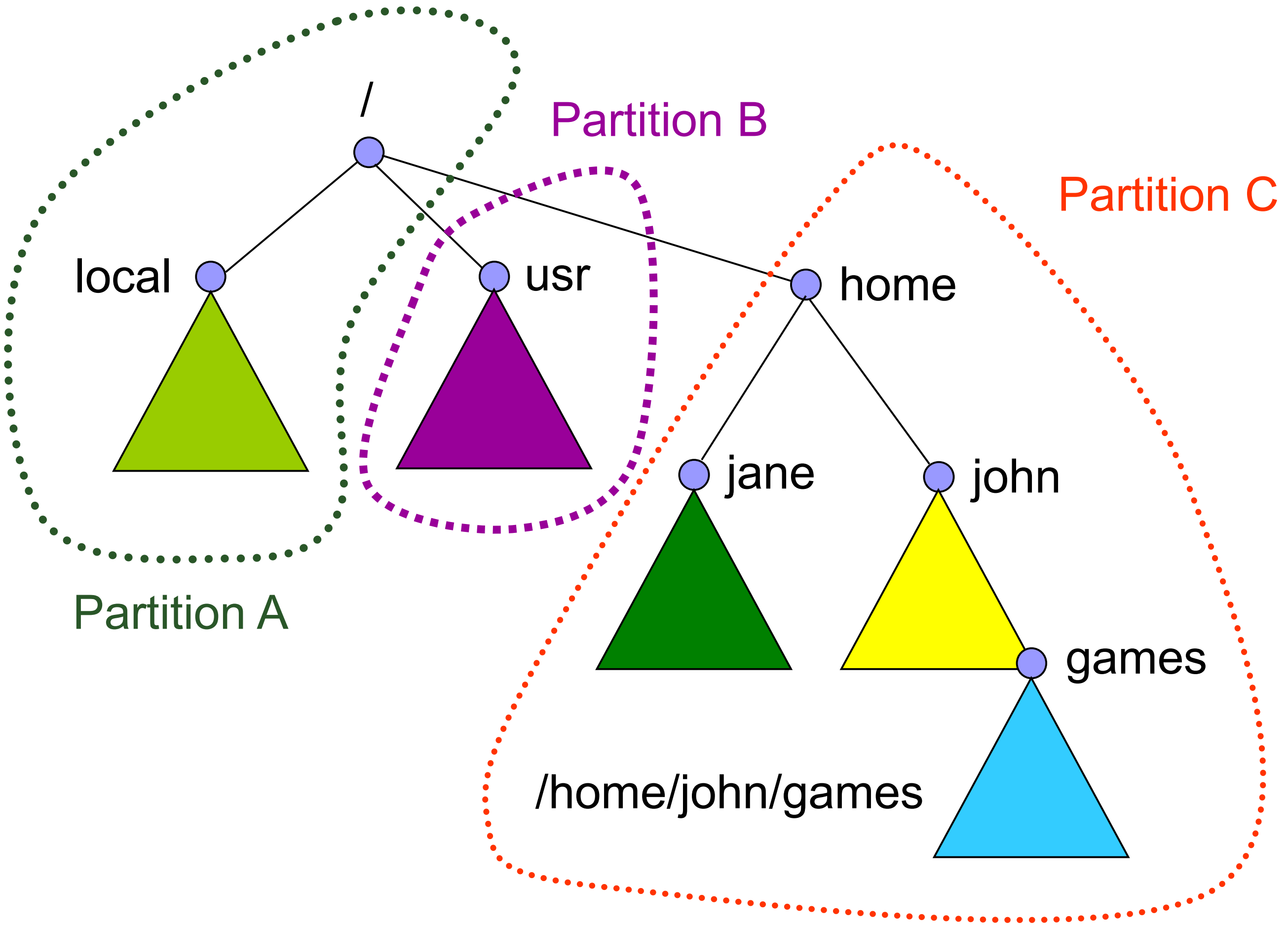
- Directory structure: pros & cons
  - One-level directory
  - Two-level directory
  - Tree-structured directory
  - Acyclic-graph directory
  - General-graph directory

File-System Mounting & File Sharing

File System Mounting

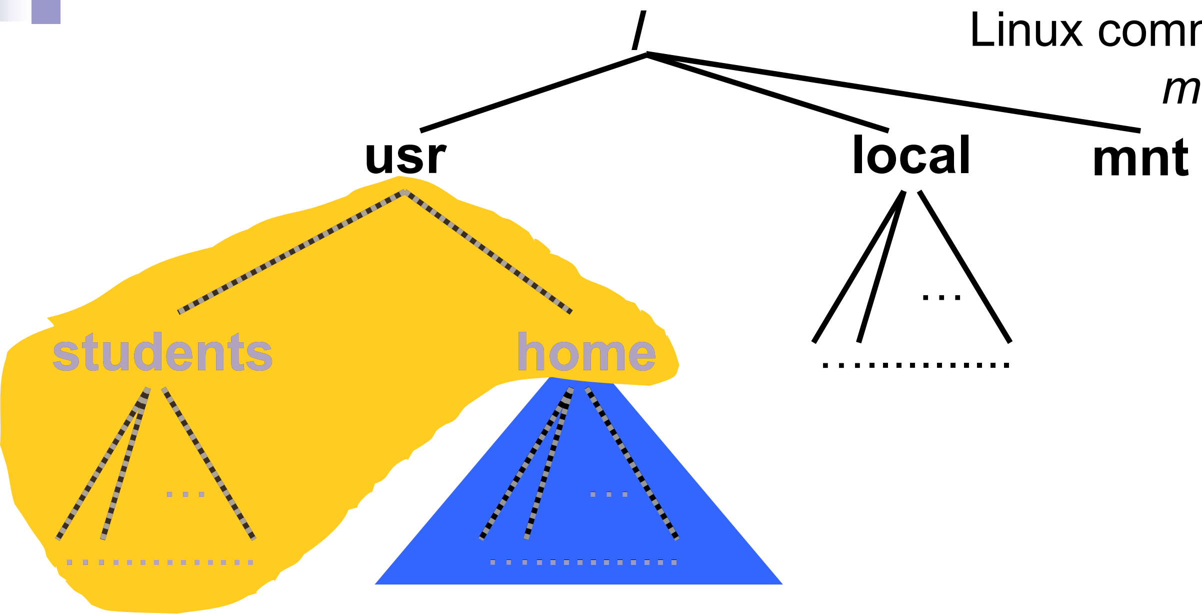
- A file system must be mounted before it can be accessed
- **Mount point**: the root path that a FS will be mounted to
- Mount timing:
  - boot time
  - automatically at run-time
  - manually at run-time

File System Mounting Example



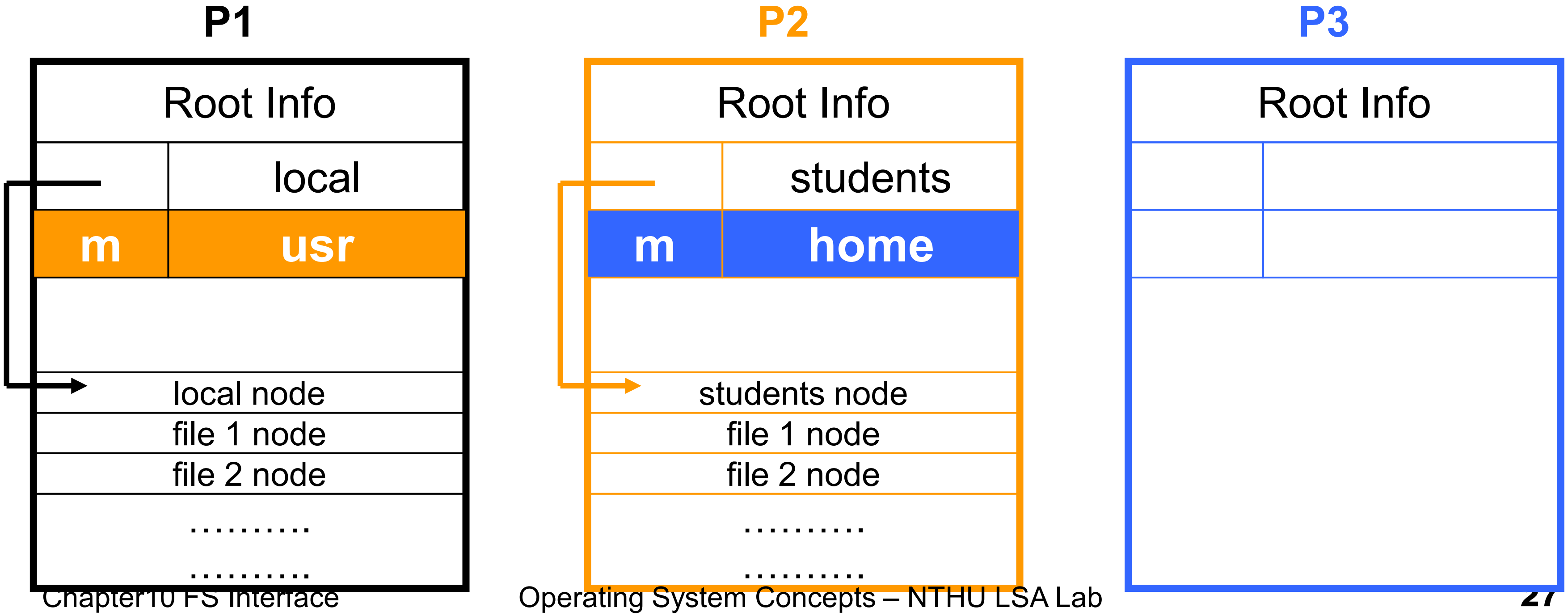
Linux command: **mount -t** *type device dir*

mount –t ext2 /dev/sda0 /mnt/hdd



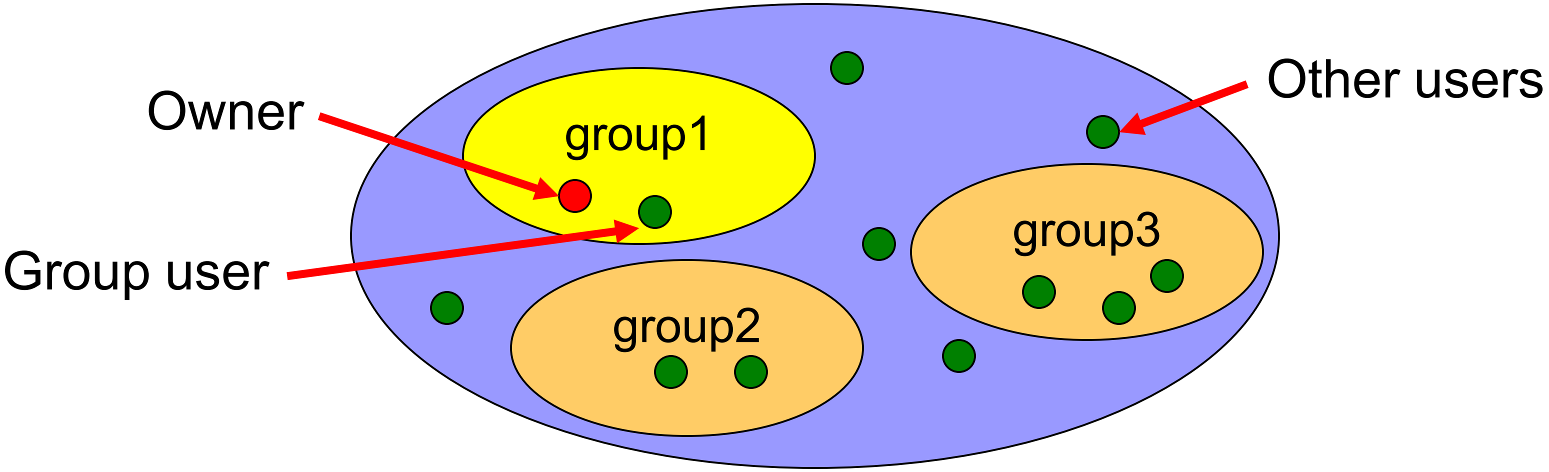
Mount Table

P2	/usr	ext2
P3	/usr/home	ntfs



File Sharing on Multiple Users

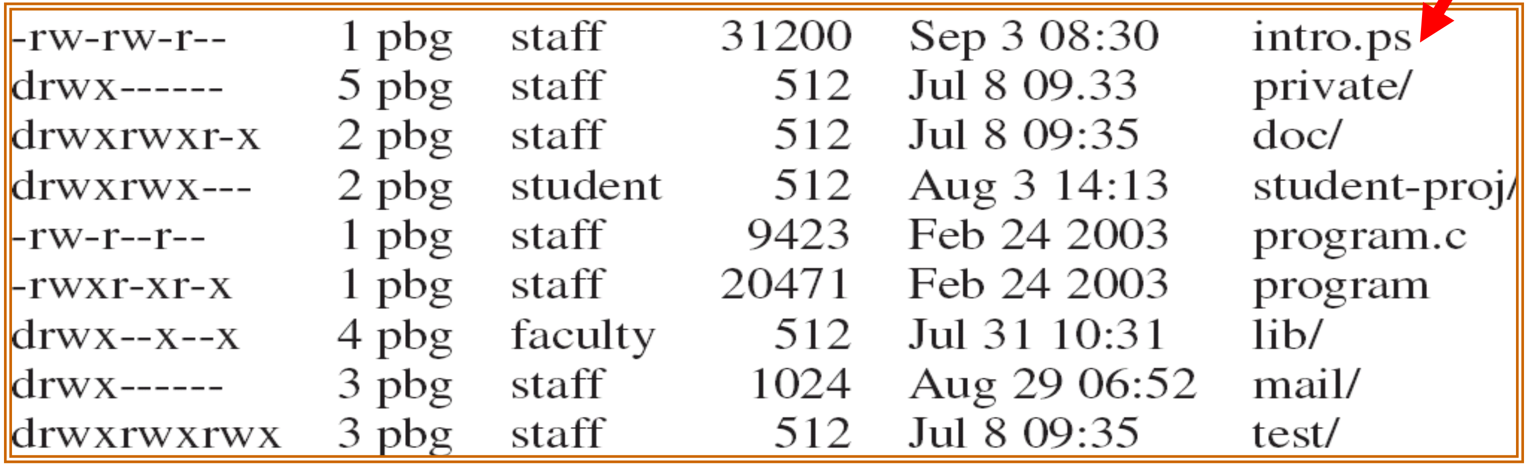
- Each user: (userID, groupID)
  - ID is associated with every ops/process/thread the user issues
- Each file has 3 sets of attributes
  - **owner, group, others**
- Owner attributes describe the privileges for the owner of the file
  - same for group/others attributes
  - group/others attributes are set by owner or root



Access-Control List

- We can create an **access-control list** (ACL) for each user
  - check requested file access against ACL
  - problem: unlimited # of users
- 3 classes of users ➔ 3 ACL (**RWX**) for each file
  - owner (e.g. 7 = RWX = 111)
  - group (e.g. 6 = RWX = 110)
  - public (others) (e.g. 4 = RWX = 100)

chmod 664 intro.ps



```
-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/
```

File Protection

- File owner/creator should be able to control
  - what can be done
  - by whom
  - → Access control list (ACL)
- Files should be kept from
  - physical damage (reliability): i.e. **RAID**
  - improper access (protection): i.e. password

Review Slides (III)

- File system mounting point, timing?
- Access-control list? How does it function?

Reading Material & HW

- Chap 10
- Problems
  - 10.1: Consider a file system where a file can be deleted and its disk space reclaimed while links to that file still exist. What problems may occur if a new file is created in the same storage area or with the same absolute path name? How can these problems be avoided?
  - 10.4: Provide examples of applications that typically access files according to “sequential” and “random”.
  - 10.6: If the operating system knew that a certain application was going to access file data in a sequential manner, how could it exploit this information to improve performance?

Consistency Semantics

- When files are shared, ops from different users to the same file must be **synchronized**
- UNIX semantics
  - write is visible to all other users opening the same file
  - Open-file option: share the same file pointer
- Session semantics (AFS file system)
  - write is not visible to all other users
  - once a file is closed, changes are visible for sessions starting later ➔ current sessions do not see changes
- Immutable-Shared-Files semantics
  - once a file is declared shared, it cannot be modified

File Sharing on Remote File Systems

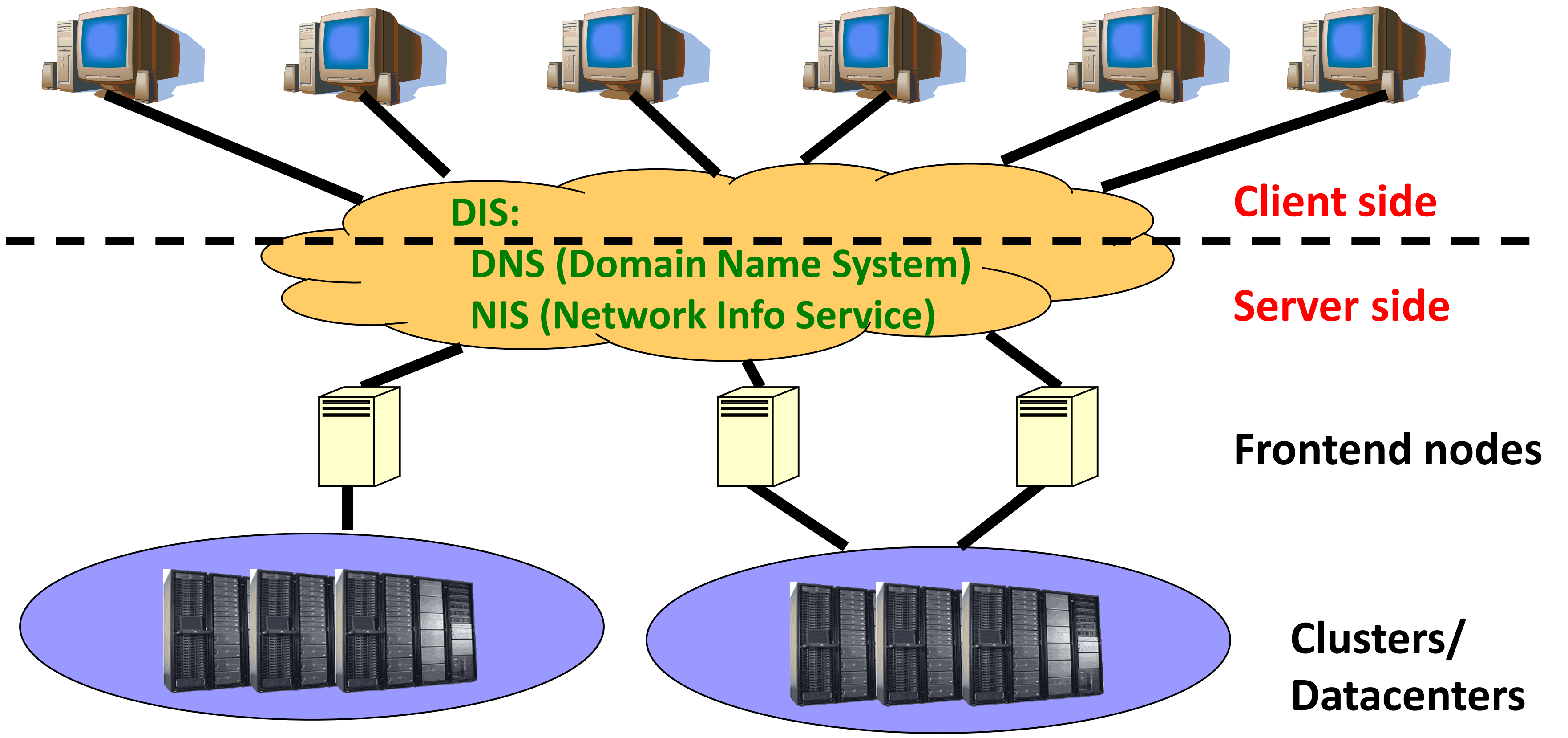
- Uses networking to allow file system access between systems
  - Manually via programs like **FTP**
  - Semi automatically via the **world wide web**
  - Automatically, seamlessly using **distributed file systems**

Client-server model

- Allows clients to mount remote file systems from servers
  - **Sever**: the machine that owns the files and serves multiple clients
  - **Client**: the machine that accesses remote files
  - Standard OS file calls are translated into remote calls
  - Client and user-on-client identification is insecure or complicated
- Example:
  - **NFS (network file sysytem)** for UNIX
  - **CIFS (common interface file system)** for Windows

Distributed Information Systems

- Distributed naming services
  - Provide **unified access** to the info for **remote computing**



Failure Modes

- Failures:
  - HW: disk, network cable, switch, server, etc.
  - SW: corruption or inconsistency of file, directory structure, etc.
- We need to recover:
  - Data: files, directory contents
  - **Metadata**: data and system management info.
- **Stateful** vs. **Stateless** communication protocol:
  - Stateless: treats each request as an independent transaction that is unrelated to any previous request (HTTP)
  - Stateful: info. maintained on both client and server is required