Chapter 10: File-System Interface

Prof. Li-Pin Chang

National Chiao Tung University

Chapter 10: File-System Interface

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

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

File Concept

- A computer resource to write data to and read data from storage device
- A contiguous logical address space

- Types:
  - Regular files
  - Device files (device node)
  - Directory files
  - Links

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
  - Regular, directory, device, link (system functionality)
  - .c , .exe, .bat (user purpose)
- 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

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 Operations

Function	**description**
fopen()	create a new file or open a existing file
fclose()	closes a file
getc()	reads a character from a file
putc()	writes a character to a file
fscanf()	reads a set of data from a file
fprintf()	writes a set of data to a file
fread()	reads a number of bytes from a file
fwrite()	writes a number of bytes to a file
fseek()	set the position to desire point
link()	make a new name for a file
unlink()	decrement the reference count of a file (delete on ref=0)

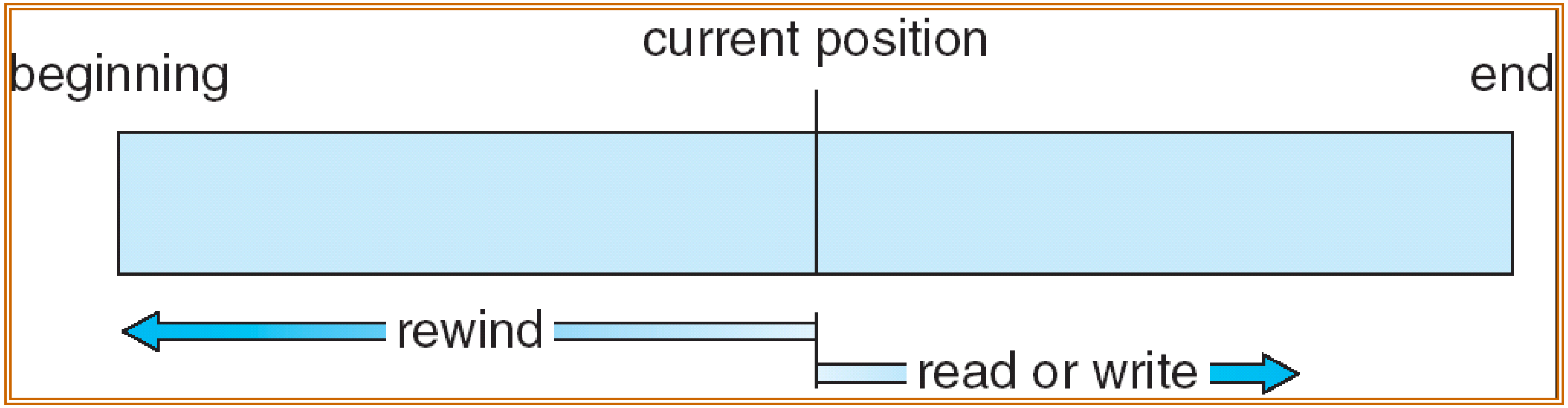
Why Opening Files

- Several data are needed to manage opened 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
    - (recall the removal of USB drive in XP)
  - Disk location of the file
  - Access rights: per-process access mode information
- All the above are called "metadata", i.e., data of data
- Caching metadata upon file opening for efficient operations
- Flushing modified to disk metadata upon file closing

fopen(): Binary or Text?

- fopen(“abc.txt”,”r+t”);
- fopen(“xyz.mp3”,”rb”);
- Text mode
  - Translate Ctrl-Z (1A) into EOF
  - Translation between \r\n and \n for different OSes
    - UNIX: \n (0A) Windows \r\n (0D 0A)
  - Possibility of filtering out the MSB (only 7 LSBs used)
- Binary mode
  - Raw input

File Accessing Model

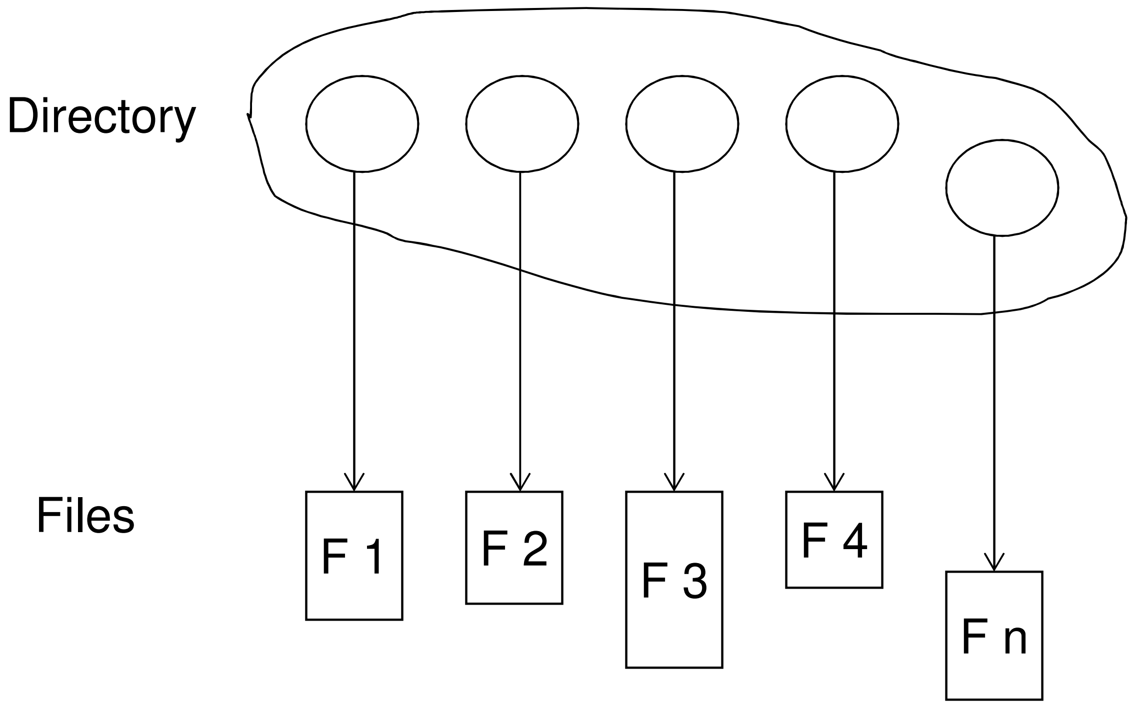


Device Node

- Commonly appear under the /dev directory
- Can be manually created using `mknode` command, with proper device major-minor #'s assigned
- Device drivers register themselves to the kernel using the device major-minor #'s
- open(), close(), read(), write() a device node will communicate with the device driver registered with the same major-minor #'s as that of the device node
- Example: `open() on /dev/sda` → #M8m0

Directory

- A collection of nodes containing information about all files



Directory itself is a file, too

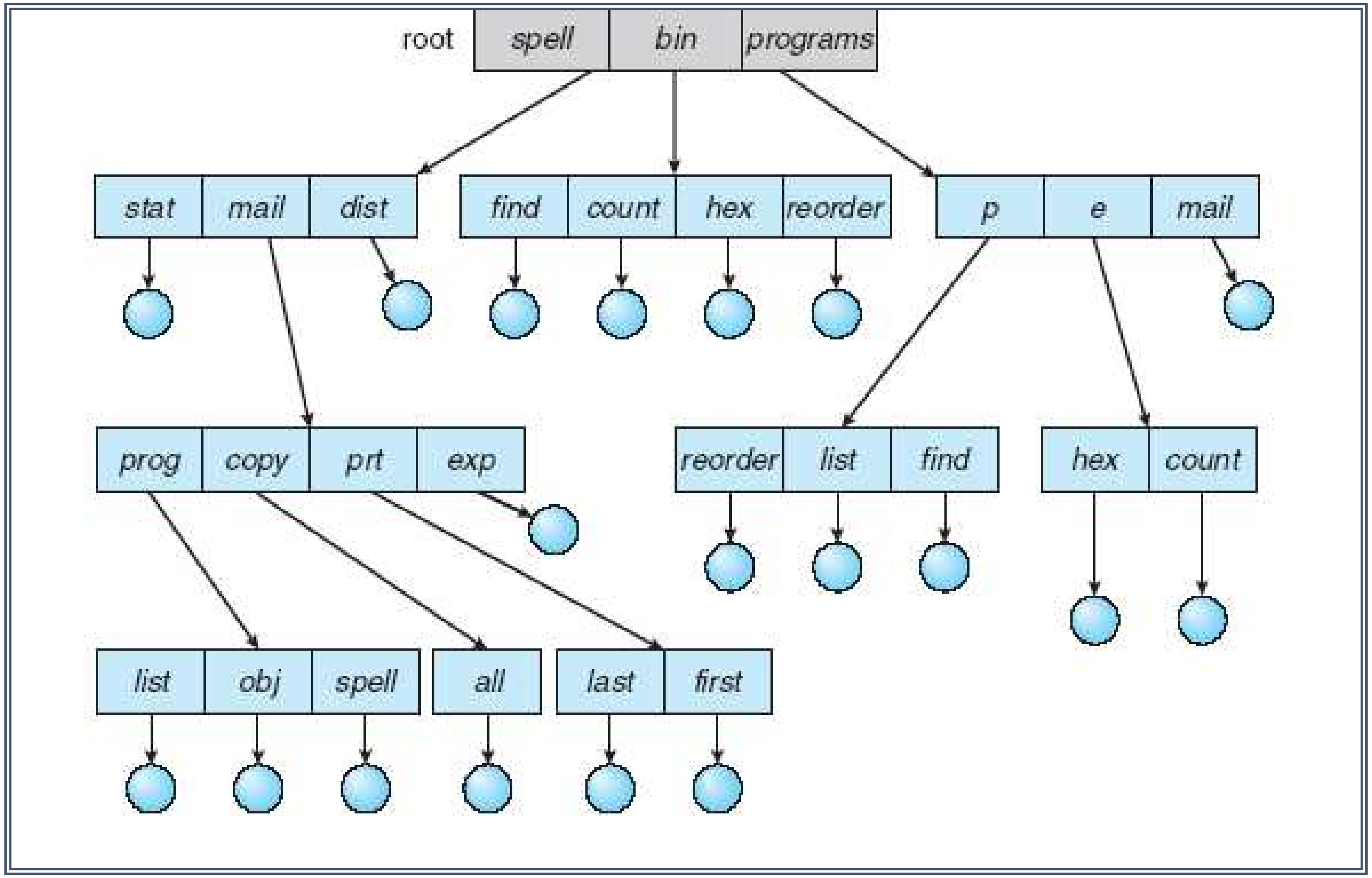
Directory Operations

- Search for a file
- Create a file
- Delete a file
  - If the deleted file is a directory?
    - Recursively delete all its files and sub-directories?
  - If the deleted file is a regular file?
- Directory enumeration (listing)
- Rename a file

Open and read a directory

```
DIR *opendir(const char *name);
struct dirent *readdir(DIR *dirp);

struct dirent {
        ino_t          d_ino;       /* Inode number */
        off_t          d_off;       /* Not an offset; see below */
        unsigned short d_reclen;    /* Length of this record */
        unsigned char  d_type;      /* Type of file; not supported
                                       by all filesystem types */
        char           d_name[256]; /* Null-terminated filename */
    };

// -----------------------------

#include <sys/types.h>
#include <dirent.h>

DIR *dir;
struct dirent *dirp;

dir = opendir("foo");
dirp = readdir(dir);
dirp = readdir(dir);
dirp = readdir(dir);
dirp = readdir(dir);
```

Tree-Structured Directories



Tree-Structured Directories (Cont)

- The *current working directory (CWD)* environment variable (per process)
  - cd /spell/mail/prog
  - type list
  - "." and ".."
- Absolute or relative path name
- Traverse the file system

```
char *getcwd(char *buf, size_t size);
int chdir(const char *path);
```

Tree-Structured Directories (Cont)

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

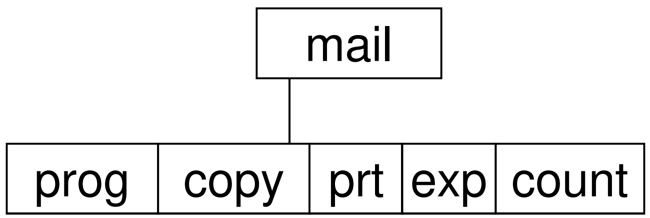
rm <file-name>

- Creating a new subdirectory is done in current directory

mkdir <dir-name>

Example: if in current directory /mail

mkdir count

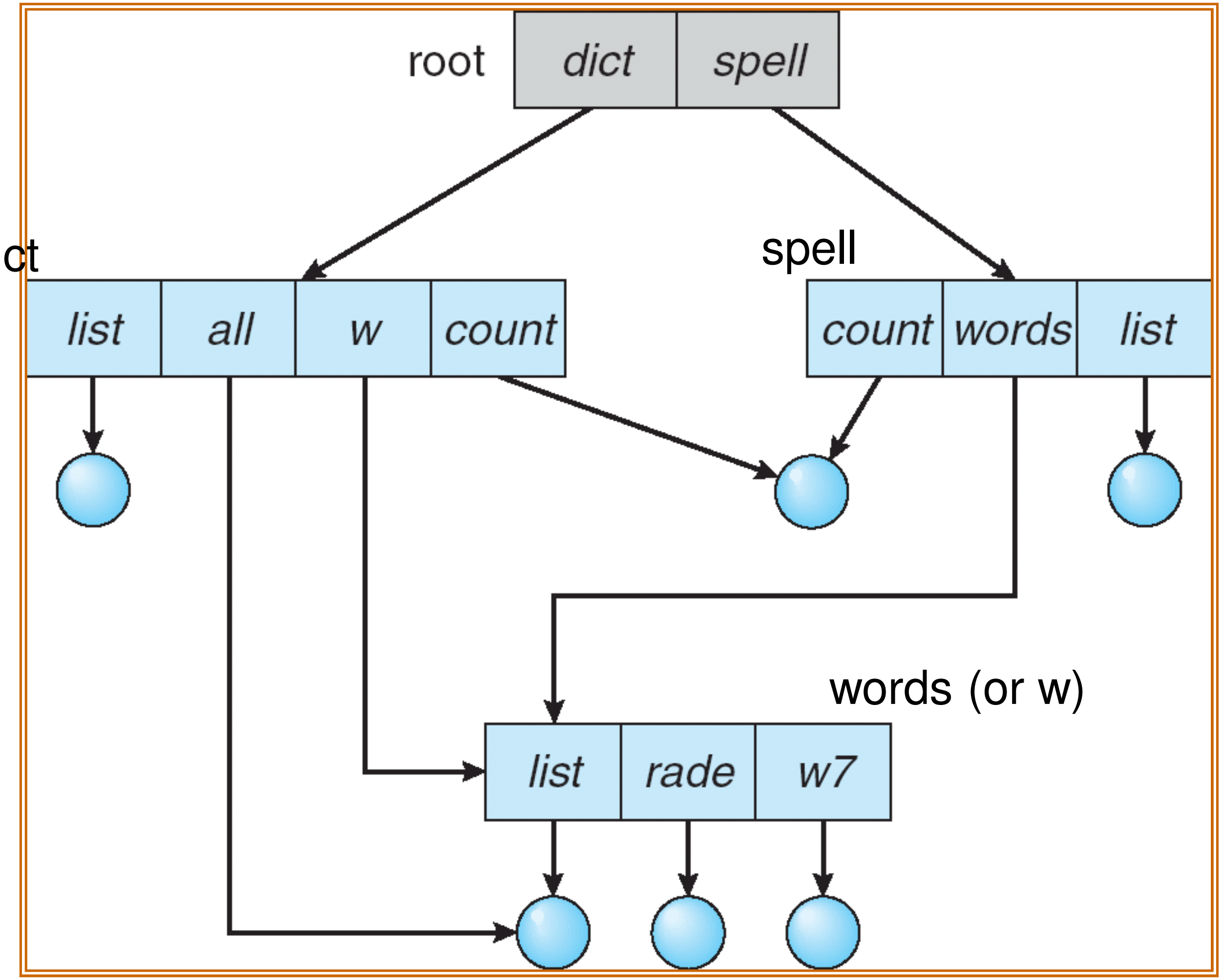


Deleting "mail" ⇒ deleting the entire subtree rooted by "mail"
rm -r or del /s

File Aliasing (Link)

- A file may have two different names (alias)
- Link: a new type of directory entry
  - Another name of (pointer to) an existing file
  - Resolve the link – follow pointer to locate the file

Acyclic-Graph Directories



Softlinks

- Softlinks (symbolic link)
  - String substitution
  - Independent of file system

- Usage
  - UNIX: ln -s [target] [link]
  - Windows (NTFS): junction.exe [link] [target]

Hardlinks

- Hardlinks
  - A link file points to the disk location of the target file
  - File-system-dependent
  - unlink() to delete files

- Usage
  - UNIX: ln [target] [link]
  - Windows (NTFS): fsutil hardlink create [link] [target]

Problems with Aliasing

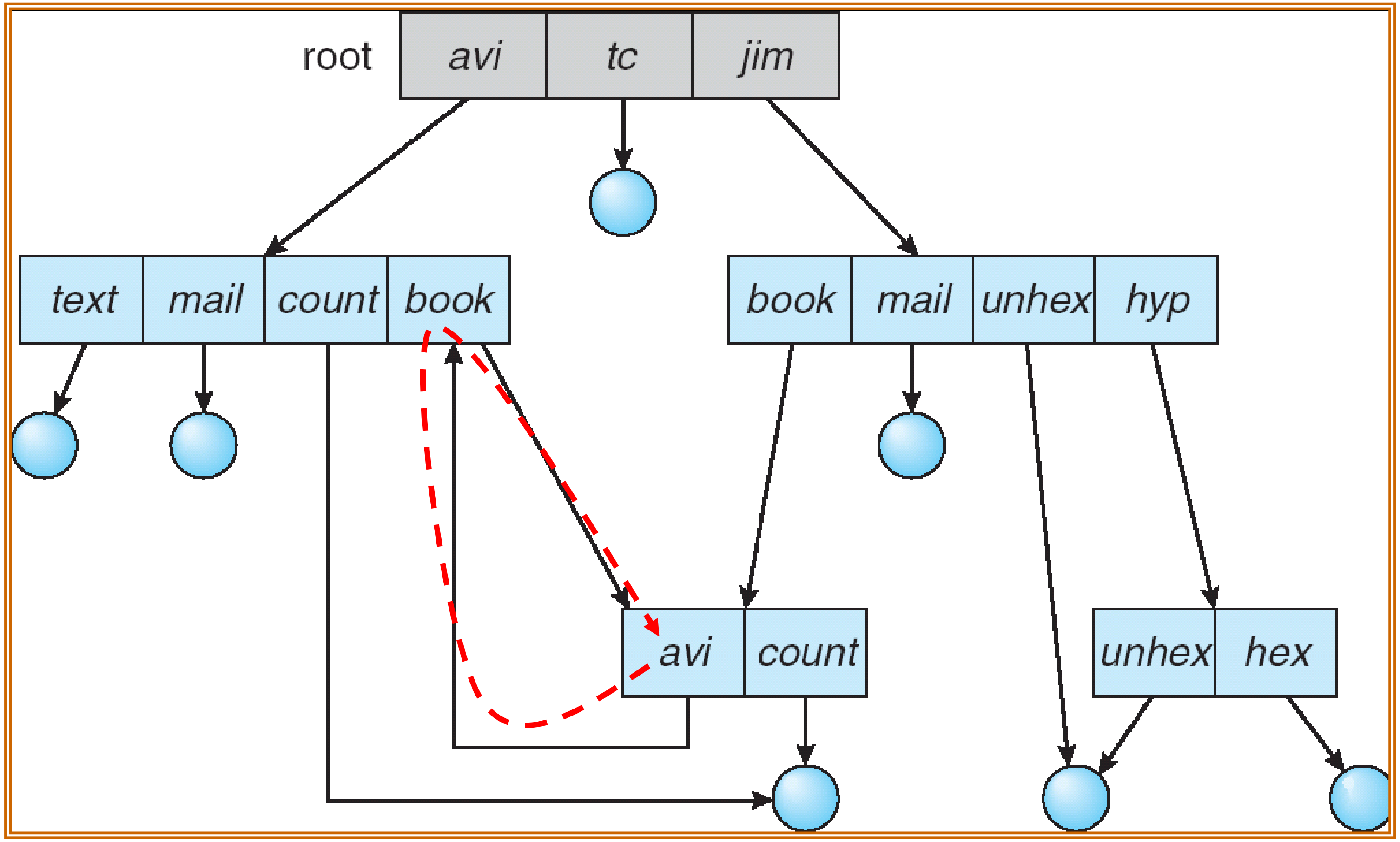
- Backup– Duplication problem
  - May duplicate files during backup
  - “cp -a” to preserve hard links

Problems with Aliasing

- Loop – Endless file path
- Loops caused by hard links
  - Hard links to directories are forbidden in recent UNIX implementations
  - Every time a new link is added use a cycle detection algorithm to determine whether it is OK (less practical)
- Loops caused by soft links
  - Soft links to directories are still possible
  - Linux: Keep a time-to-live counter (e.g., 40)
  - Windows: Limiting the pathname length (~ 260 chars)

Loop in directories

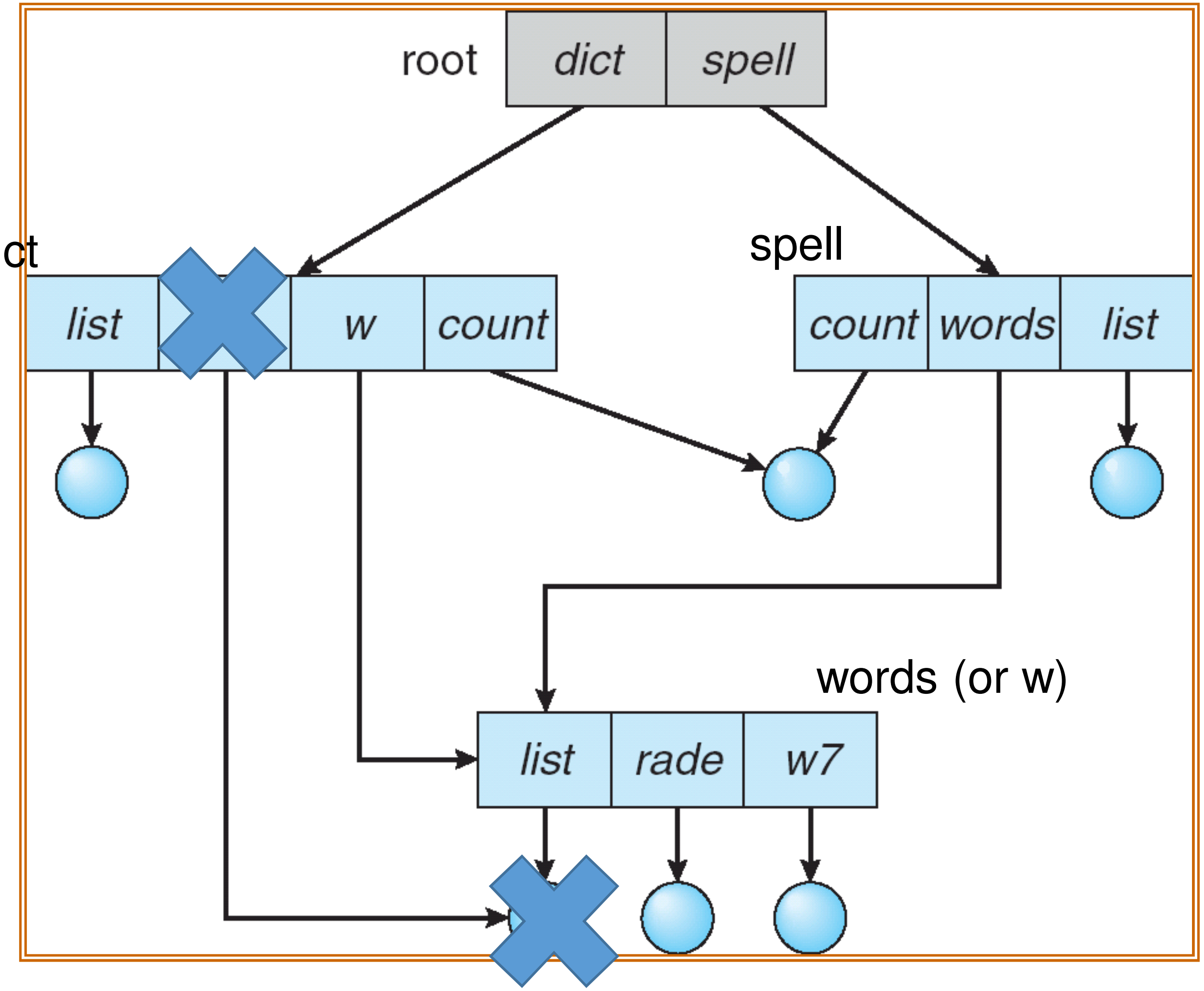
Modern UNIX systems do not allow
to create link to directories!



Problems with Aliasing

- Deletion– Dangling pointer problem
  - If dict deletes “all”
- Solutions:
  - Backpointers, so we can delete all pointers
  - Entry-hold-count solution

Acyclic-Graph Directories



Problems with Aliasing

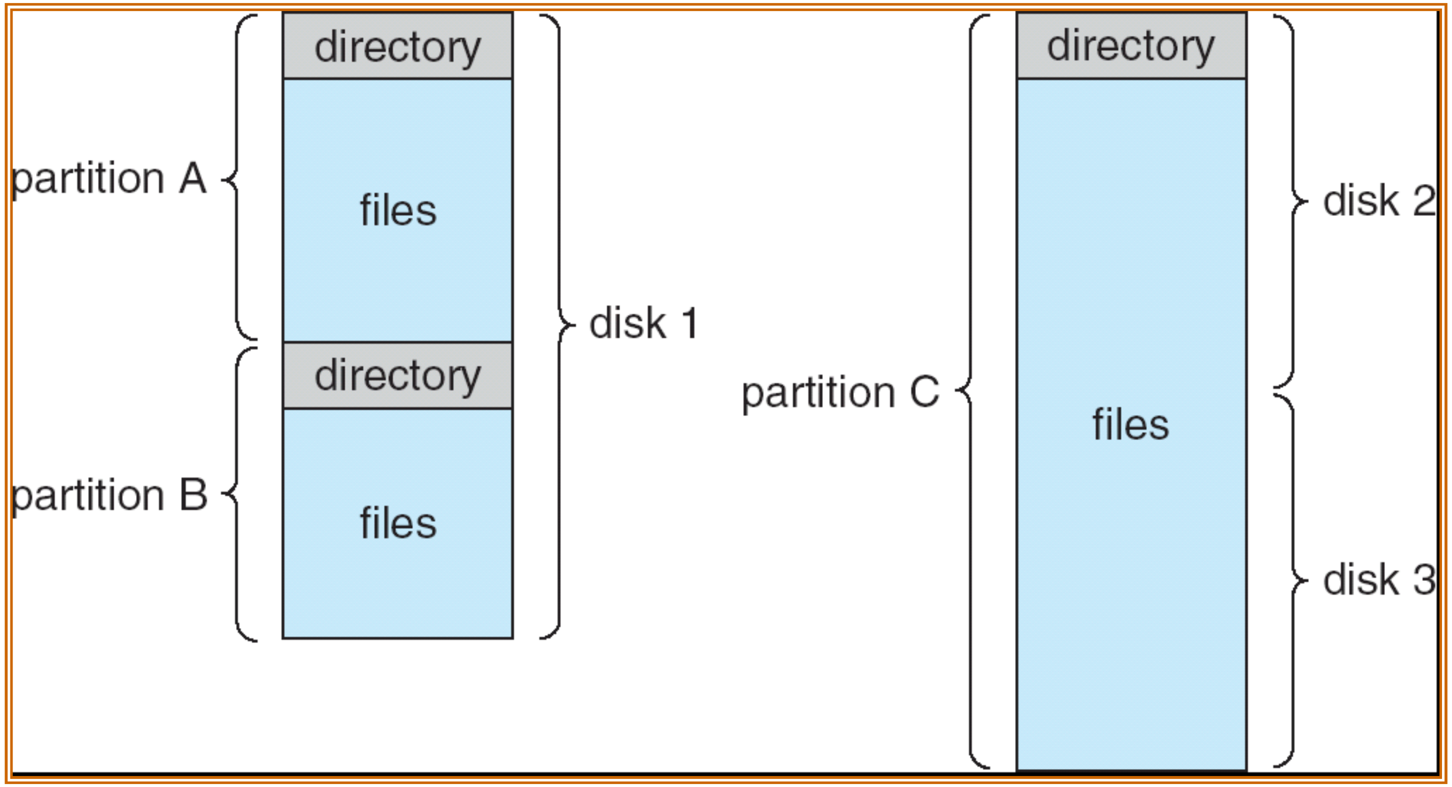
- Dangling pointers
- Softlink (symbolic link)
  - Simply leave the symbolic link dangling
  - /bin/ls → /sbin/ls
- Hardlink
  - link is established inside the file system
  - Keep a reference count
  - Creating hardlink to the file: +count
  - Removing a hardlink to the file: -count
  - When count==0: remove the file

Soft link vs. Hard link: Revisit

- Softlink
  - Can span over different file systems
  - Dangling pointer problem

- Hardlink
  - No Dangling pointer problem
  - Can not span over different file systems
  - There is no way to tell which file is the “original one”

A Typical File-system Organization



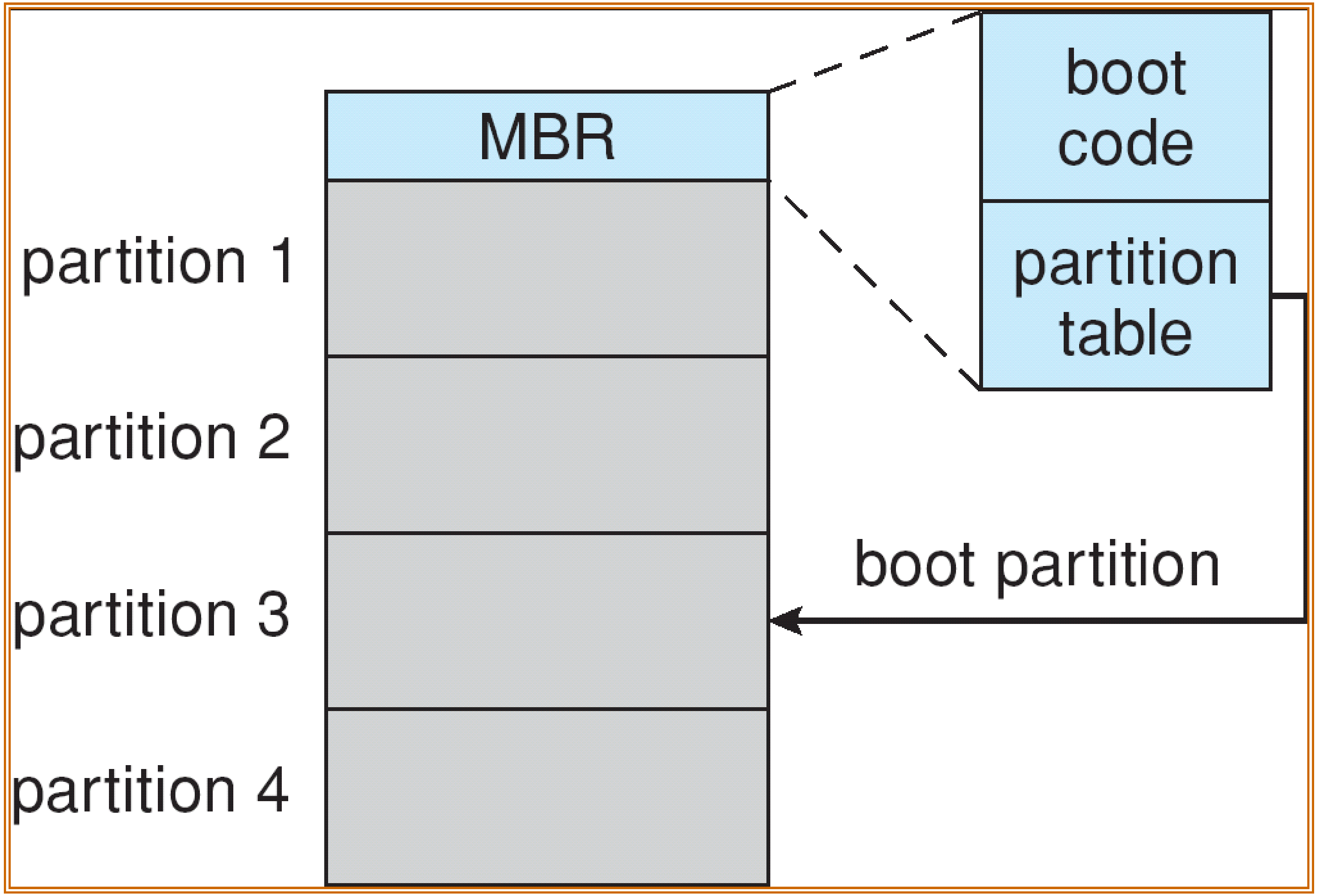
JBOD

Need a logical volume manager

A disk = a (physical) disk volume

A logical disk volume may span over many disks

Booting from Disk in Windows 2000



System Booting

- Boot block initializes system.
  - 1st bootstrap loader is stored in ROM (BIOS)
  - BIOS loads 2nd bootstrap loader from MBR
  - MBR loads OS loader

Disk Formatting

- To use a disk to hold files, the operating system still needs to record its own data structures on the disk.
  - Logical formatting, high-level formatting or "making a file system".
  - Writing file system metadata
- Low-level formatting, or physical formatting — Dividing a disk into sectors that the disk controller can read and write.
  - Remapping bad tracks to spare tracks
  - Zoned-bit encoding

File System Mounting

- A file system must be mounted before it can be accessed
- A unmounted file system is mounted at a mount point
- Mounting a file system
  - `mount -t ext4 /users /dev/hda1`
  - Specify the file system type
  - Find the file-system superblock in the partition
  - Specify the mounting point of the file-system naming space

Protection

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

- Types of access
  - Read
  - Write
  - Execute
  - Append (regards to disk space)
  - Delete
  - List

FTP

File Sharing – Multiple Users

- User IDs identify users, allowing permissions and protections to be per-user
- Group IDs allow users to be in groups, permitting group access rights

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

owner group public

chmod 761 game

A directory with the permission "x" = the directory can be entered

UNIX File Permission Management Utilities

- adduser: create a user
- mkgrp: create a group
- addgrp: add a user to a group
- chown: change the owner of a file
- chgrp: change the group of a file
- chmod: change file permissions

- Users are managed by /etc/password
- Groups are managed by /etc/group

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/

[Permission] [hard link count][Owner] [group] [filesize] [date] [filename]

- Regular file: link count >=1, file is deleted when link count =0
- A directory: link count is 2+n
  - 1 from its own directory entry + 1 from "." of itself
  - n from ".." of all its sub-directories

Windows XP Access-control List Management

End of Chapter 10