



File System

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Files

```
❏ % ls -l
```

```
• d rwX--X--X 7 liuyh gcs 1024 Sep 22 17:25 public_html
```

File type

File access mode

of inodes

File user owner

File group owner

File size

File last modify time

File name

Outline

❑ File System Architecture

- Pathname
- File Tree
- Mounting
- File Types

❑ inode and file

- Link

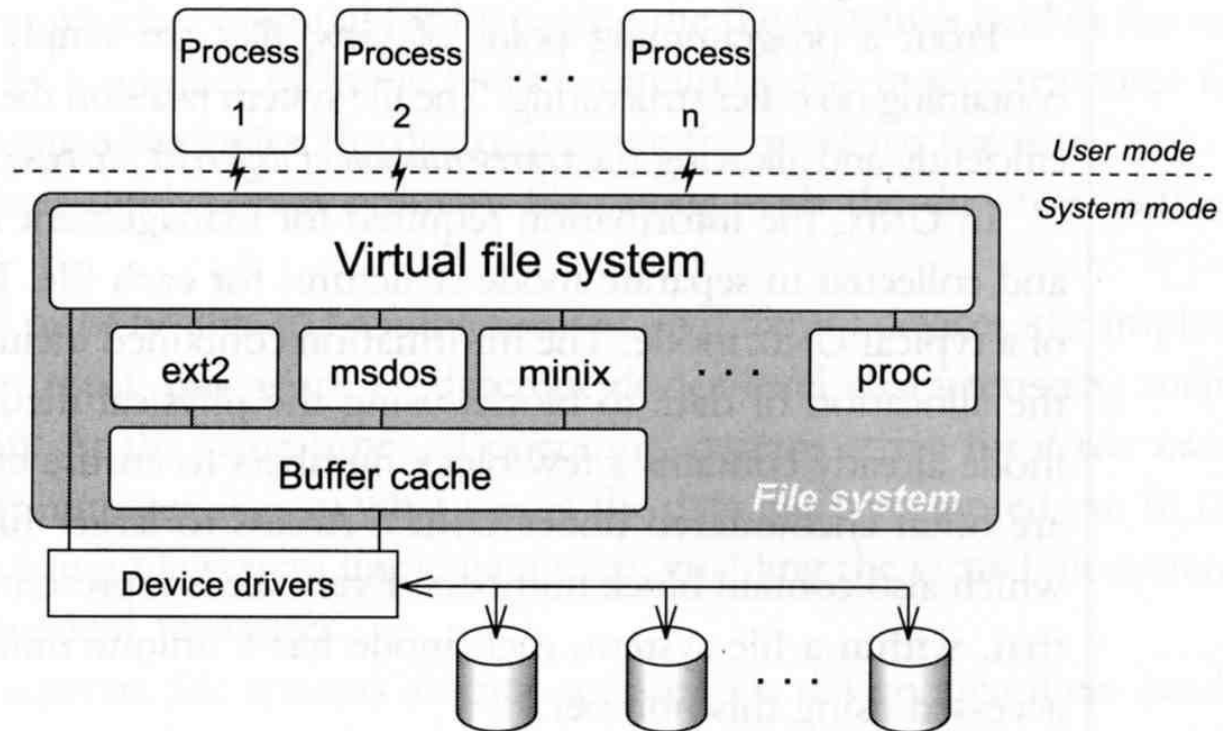
❑ File Access Mode

- Changing File Owner
- FreeBSD bonus flags

File System Architecture (1)

□ Application ↔ Kernel ↔ Hardware

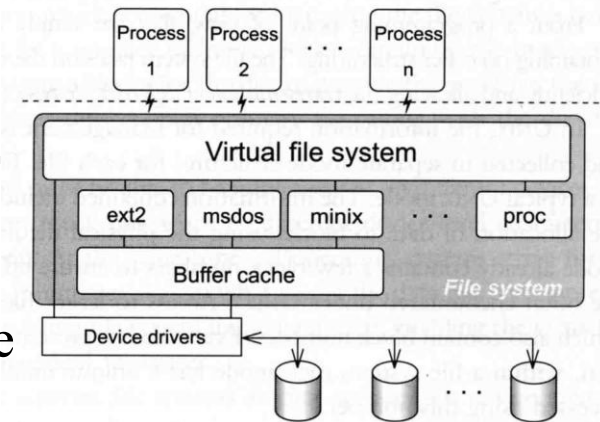
- Applications call system-calls to request service
- Kernel invokes corresponding drivers to fulfill this service



File System Architecture (2)

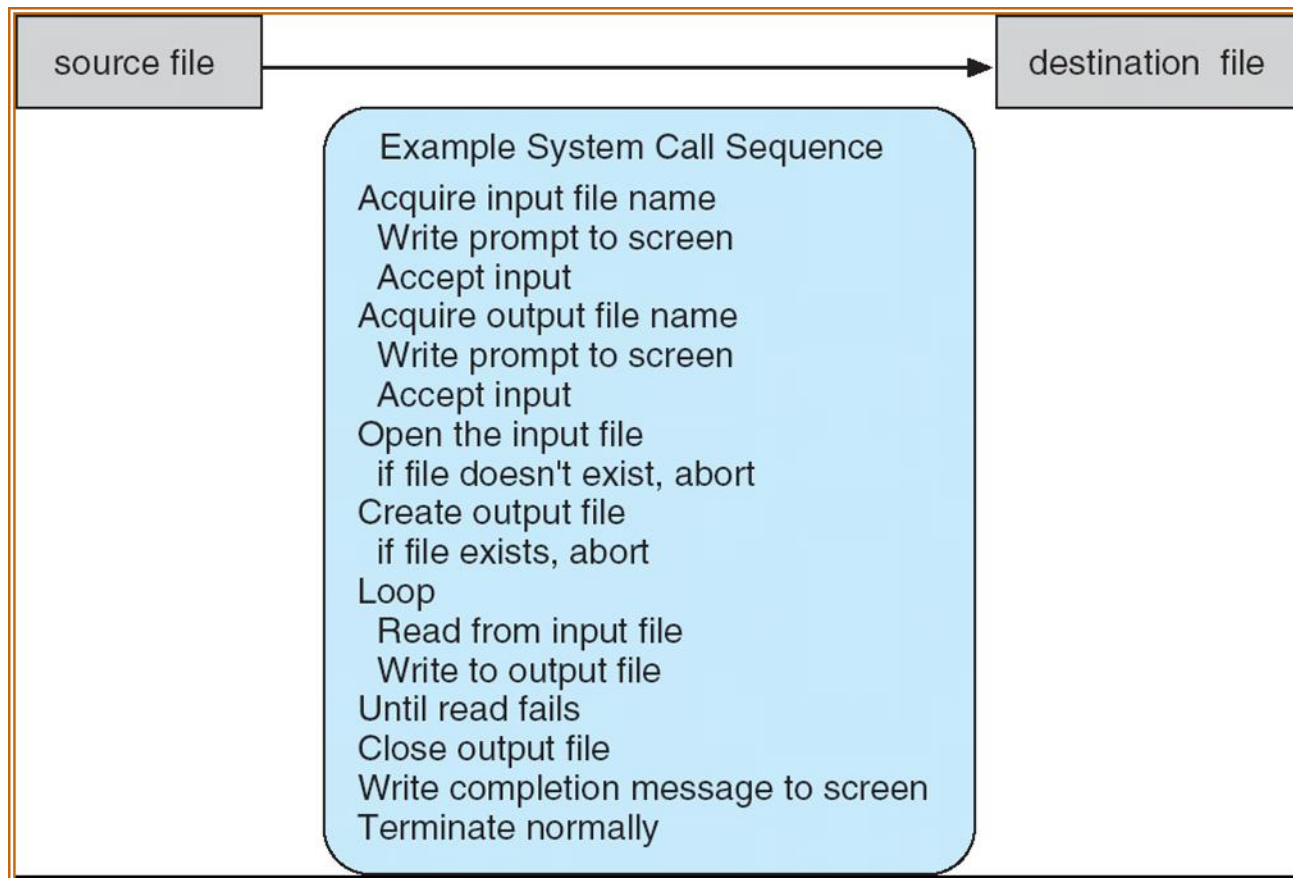
❑ The basic purpose of filesystem

- Represent and organize the system's storage
- Four main components:
 - Namespace
 - A way of naming things and arranging them in a hierarchy
 - Application Programming Interface (API)
 - A set of system calls for navigating and manipulating nodes
 - Security model
 - A scheme for protecting, hiding and sharing things
 - Implementation
 - Code that ties the logical model to an actual disk



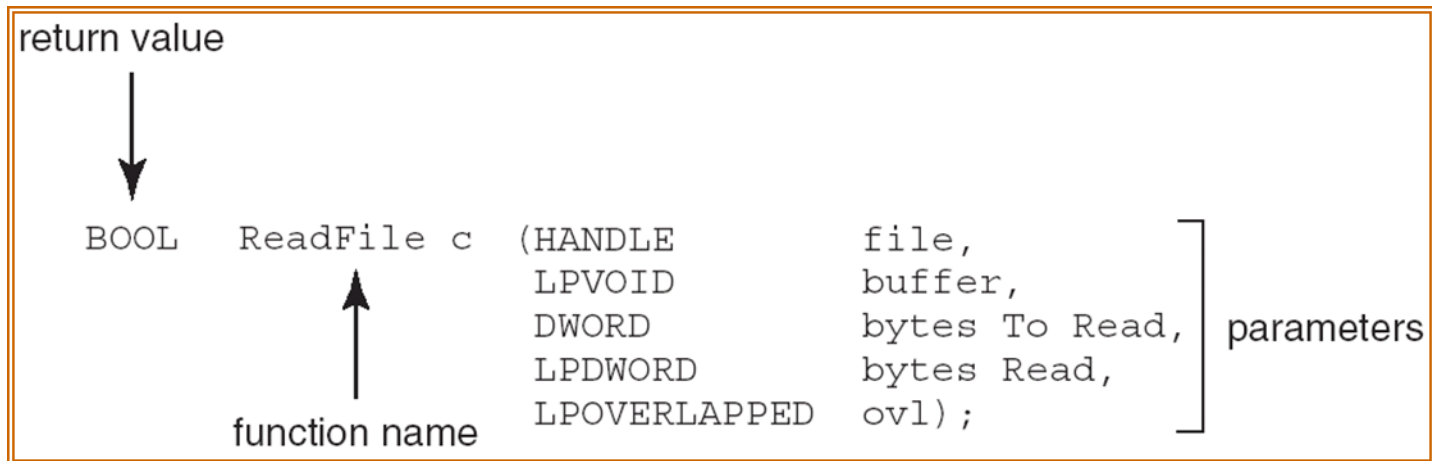
File System Architecture (2)

- ❑ System call sequence to copy the contents of one file to another file



File System Architecture (2)

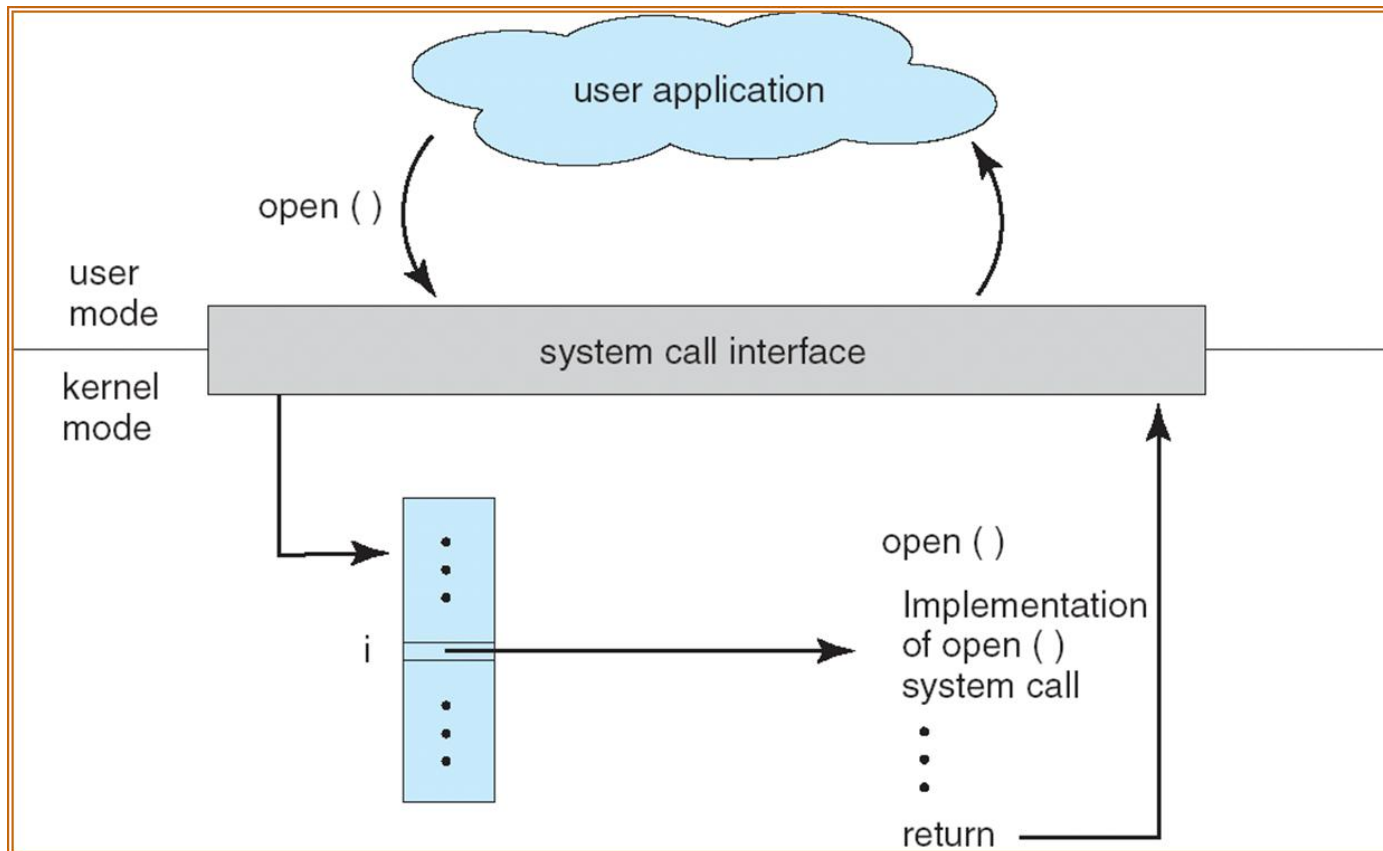
- ❑ Consider the ReadFile() function in the
- ❑ Win32 API—a function for reading from a file



- ❑ A description of the parameters passed to ReadFile()
 - HANDLE file—the file to be read
 - LPVOID buffer—a buffer where the data will be read into and written from
 - DWORD bytesToRead—the number of bytes to be read into the buffer
 - LPDWORD bytesRead—the number of bytes read during the last read
 - LPOVERLAPPED ovl—indicates if overlapped I/O is being used

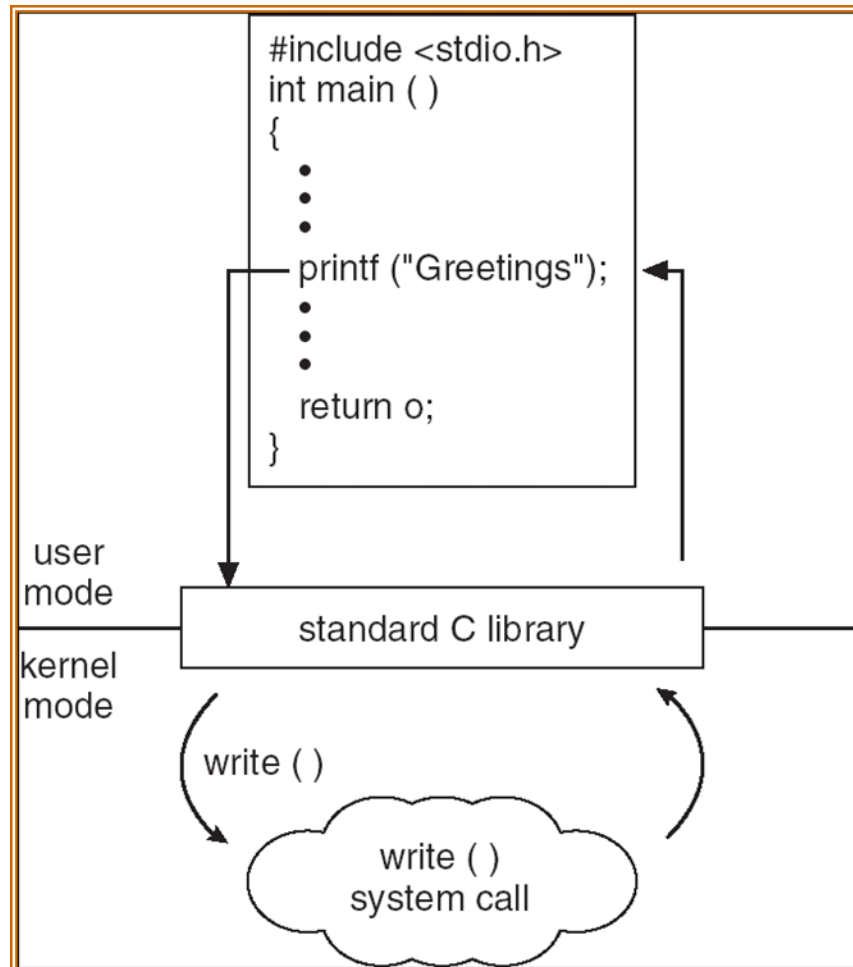
File System Architecture (2)

□ API – System Call – OS Relationship



File System Architecture (2)

- ❑ C program invoking printf() library call, which calls write() system call



File System Architecture (3)

❑ Objects in the filesystem:

- What you can find in a filesystem:
 - Files and directories
 - Hardware device files
 - Processes information
 - Interprocess communication channel (IPC)
 - Shared memory segments (SHM)
- We can use common filesystem interface to access such “object”
 - open 、 read 、 write 、 close 、 seek 、 ioctl,fcntl, ...

Pathname

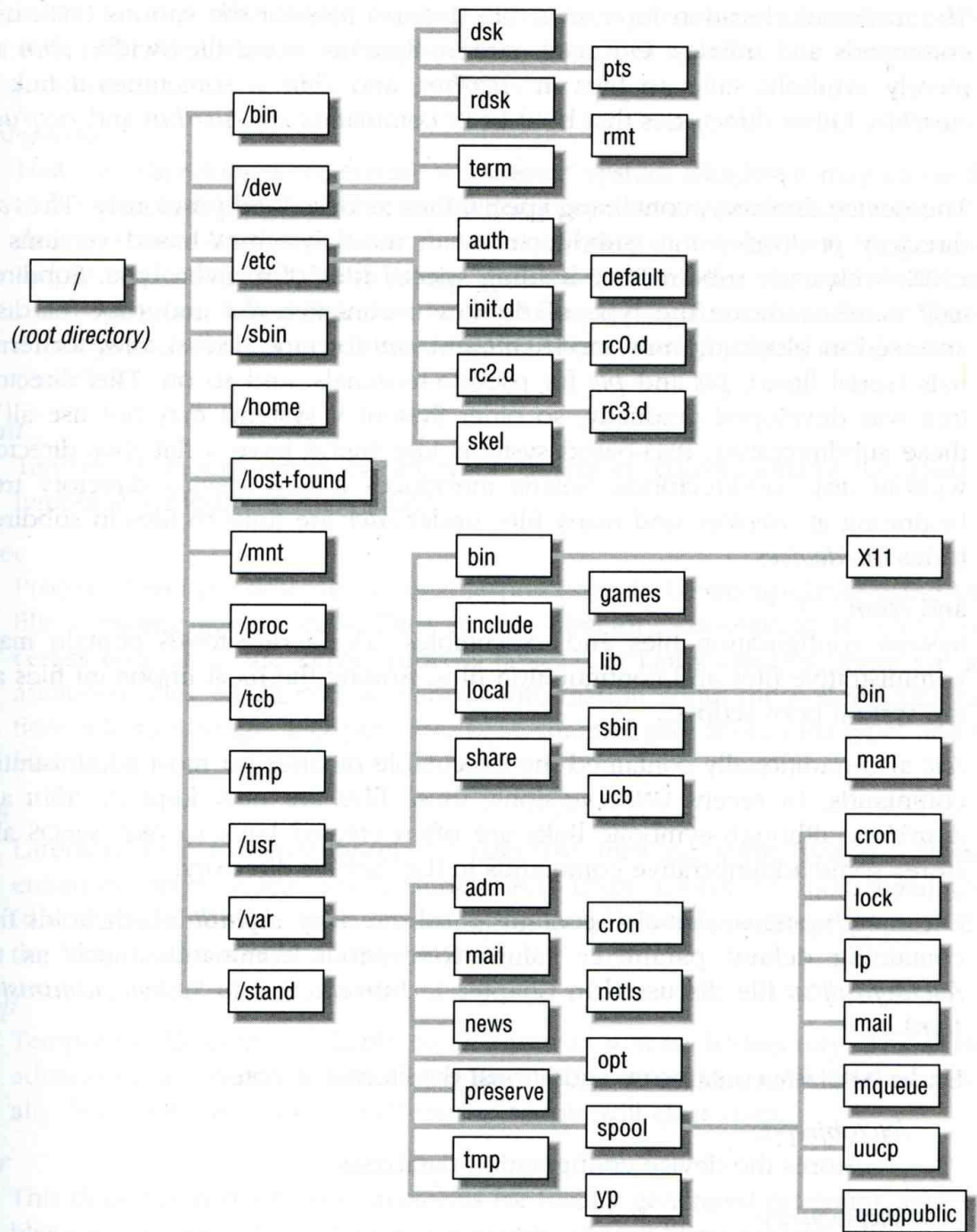
❑ Two kinds of path

- Absolute path → start from /
 - Ex. /u/dcs/97/9755806/test/hehe.c
- Relative path → start from your current directory
 - Ex. test/hehe.c

❑ Constrains of pathname

- Single component: ≤ 255 characters
- Single absolute path: ≤ 1023 characters

File Tree



Layout of File Systems (1)

❑ hier(7)

pathname	Contents
/	The root directory of the file system
/bin & /sbin	User utilities & system programs fundamental to both single-user and multi-user environments
/usr	User utilities and applications
/usr/bin & /usr/sbin	Local executable
/lib	Shared and archive libraries
/libexec	Critical system utilities needed for binaries in /bin and /sbin
/mnt	Empty directory commonly used by system administrators as a temporary mount point
/tmp	Temporary files that are not guaranteed to persist across system reboots, also, there is /var/tmp
/usr/lib	Support libraries for standard UNIX programs
/usr/libexec	System daemons & system utilities (executed by other programs)
/usr/include	Libraries Header files
/usr/local	local executables, libraries, etc

Layout of File Systems (2)

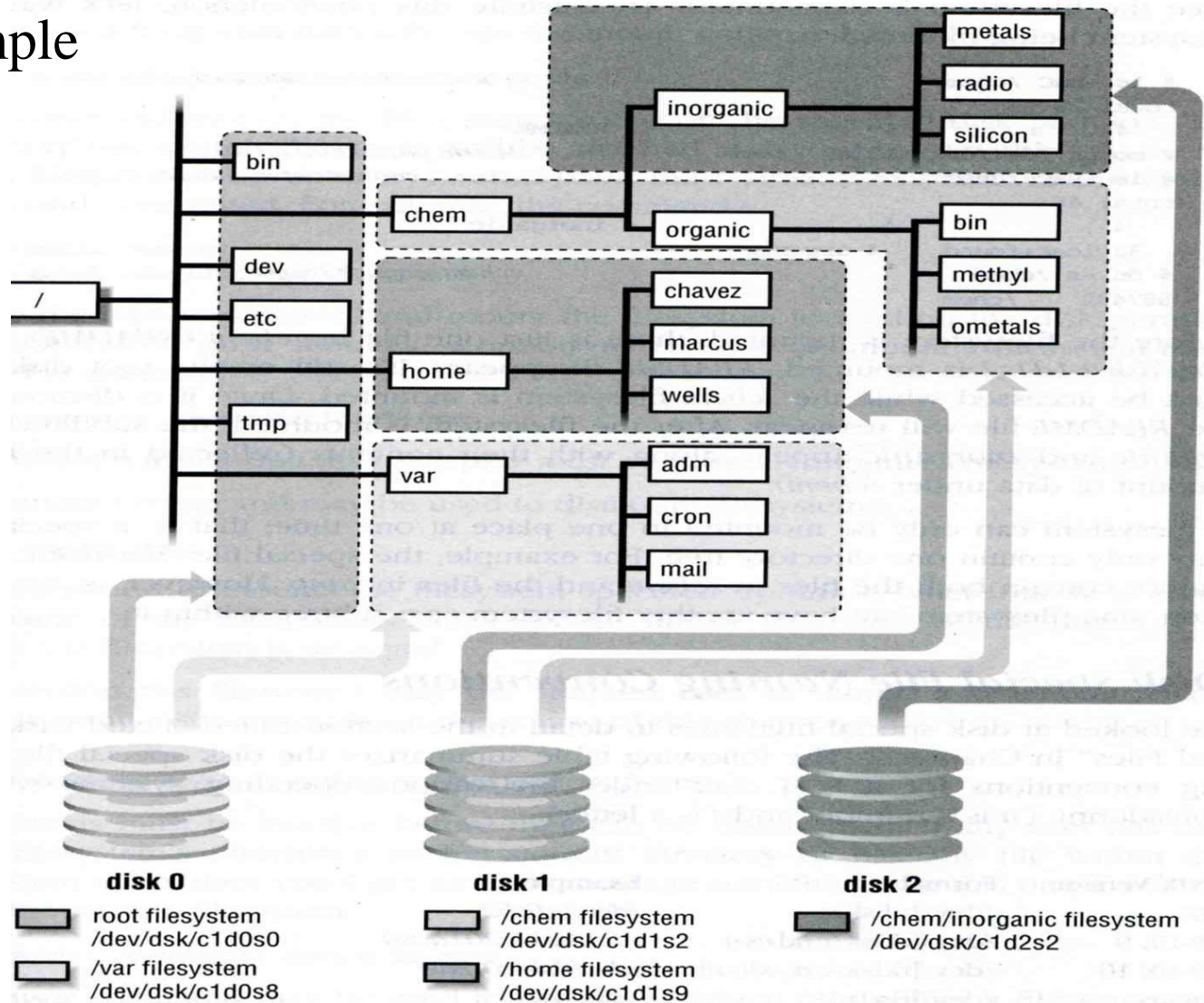
pathname	Contents
/usr/src	BSD, third-party, and/or local source files
/usr/obj	architecture-specific target tree produced by building the /usr/src tree
/etc	system configuration files and scripts
/usr/local/etc	/etc of /usr/local, mimics /etc
/dev	Device entries for disks, terminals, modems, etc
/proc	Images of all running process
/var	Multi-purpose log, temporary, transient, and spool files
/var/db	Database files
/var/db/pkg & /var/db/ports	Ports Collection management files. ports(7)
/var/log	Various system log files
/var/mail	user mailbox files
/var/spool	Spooling directories for printers, mails, etc

Mounting file system (1)

- ❑ mount(8)
- ❑ The filesystem is composed of chunks
 - Most are disk partitions
 - Network file servers
 - Memory disk emulators
 - Kernel components
 - Etc,...
- ❑ "mount" command
 - Map the mount point of the existing file tree to the root of the newly attached filesystem
 - % mount /dev/ad2s1e /home2
 - The previous contents of the mount point become inaccessible

Mounting file system (2)

Example



Mounting file system (3)

❑ fstab(5)

❑ Filesystem table – fstab

- Automatically mounted at boot time
- /etc/fstab
 - Filesystem in this file will be checked and mounted automatically at boot time

Ex.

#	Device	Mountpoint	FStype	Options	Dump	Pass#
	/dev/ad0s1a	/	ufs	rw	1	1
	/dev/ad0s1b	none	swap	sw	0	0
	/dev/ad0s1d	/home	ufs	rw	2	2
	/dev/acd0	/cdrom	cd9660	ro,noauto	0	0
	csduty:/bsdhome	/bsdhome	nfs	rw,noauto	0	0

Mounting file system (4)

❑ umount(8)

❑ Unmounting File System

- “umount” command
 - % umount { node | device }
 - Ex: umount /home, umount /dev/ad0s1e
- Busy filesystem
 - Someone’s current directory is there or there are opened files
 - Use “umount -f”
 - We can use “lsof” or “fstat” like utilities to figure out who makes it busy

Mounting file system (5)

❑ fstat

```
liuyh@NASA ~ $ fstat
```

USER	CMD	PID	FD MOUNT	INUM	MODE	SZ	DV	R/W
liuyh	fstat	94218	wd /	234933	drwxr-xr-x	16		r
root	screen	87838	4 /tmp	9947	prwx-----	0		r

❑ lsof (/usr/ports/sysutils/lsof) – list open files

```
liuyh@NASA ~ $ lsof
```

COMMAND	PID	USER	FD	TYPE	SIZE/OFF	NODE	NAME
screen	87838	root	cwd	VDIR	7	522069	/usr/ports/sysutils/screen
screen	87838	root	rtd	VDIR	26	3	/
screen	87838	root	txt	VREG	337968	424757	/usr/local/bin/screen
screen	87838	root	txt	VREG	245976	679260	/libexec/ld-elf.so.1
screen	87838	root	txt	VREG	314504	678109	/lib/libncurses.so.8
screen	87838	root	txt	VREG	64952	678438	/lib/libutil.so.8
screen	87838	root	txt	VREG	33536	677963	/lib/libcrypt.so.5
screen	87838	root	txt	VREG	1255568	677294	/lib/libc.so.7

File Types (1)

□ File types

Symbol	File types
-	Regular file
b	Block device file
c	Character device file
d	Directory
l	Symbolic link
s	UNIX domain socket
p	Named pipe

□ file command

- determine file type
 - % file .tcshrc → .tcshrc: ASCII text
 - % file /bin → /bin: directory
 - % file /bin/sh → /bin/sh: ELF 32-bit LSB executable, Intel 80386, version 1 (FreeBSD), dynamically linked (uses shared libs), stripped
- /usr/ports/sysutils/file

File Types (2)

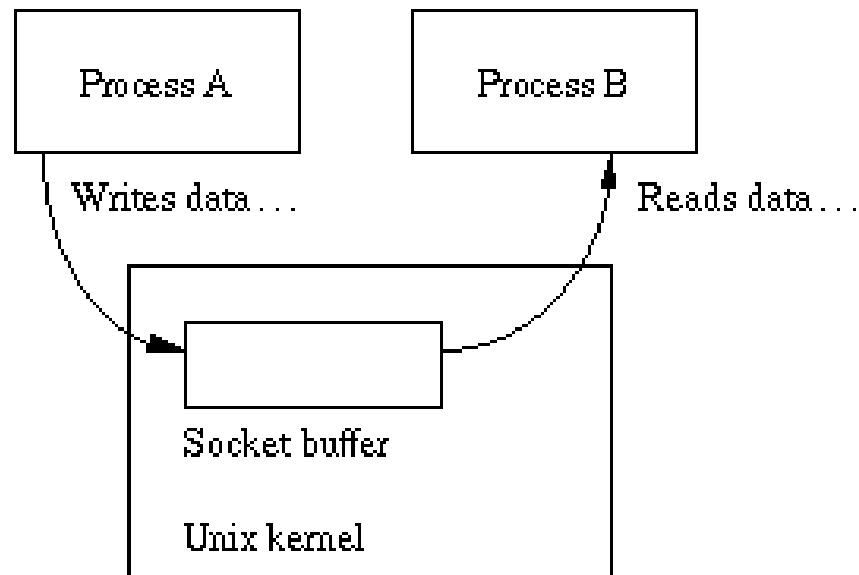
❑ Directory

- . and ..
- mkdir / rmdir

File Types (3)

❑ UNIX domain socket

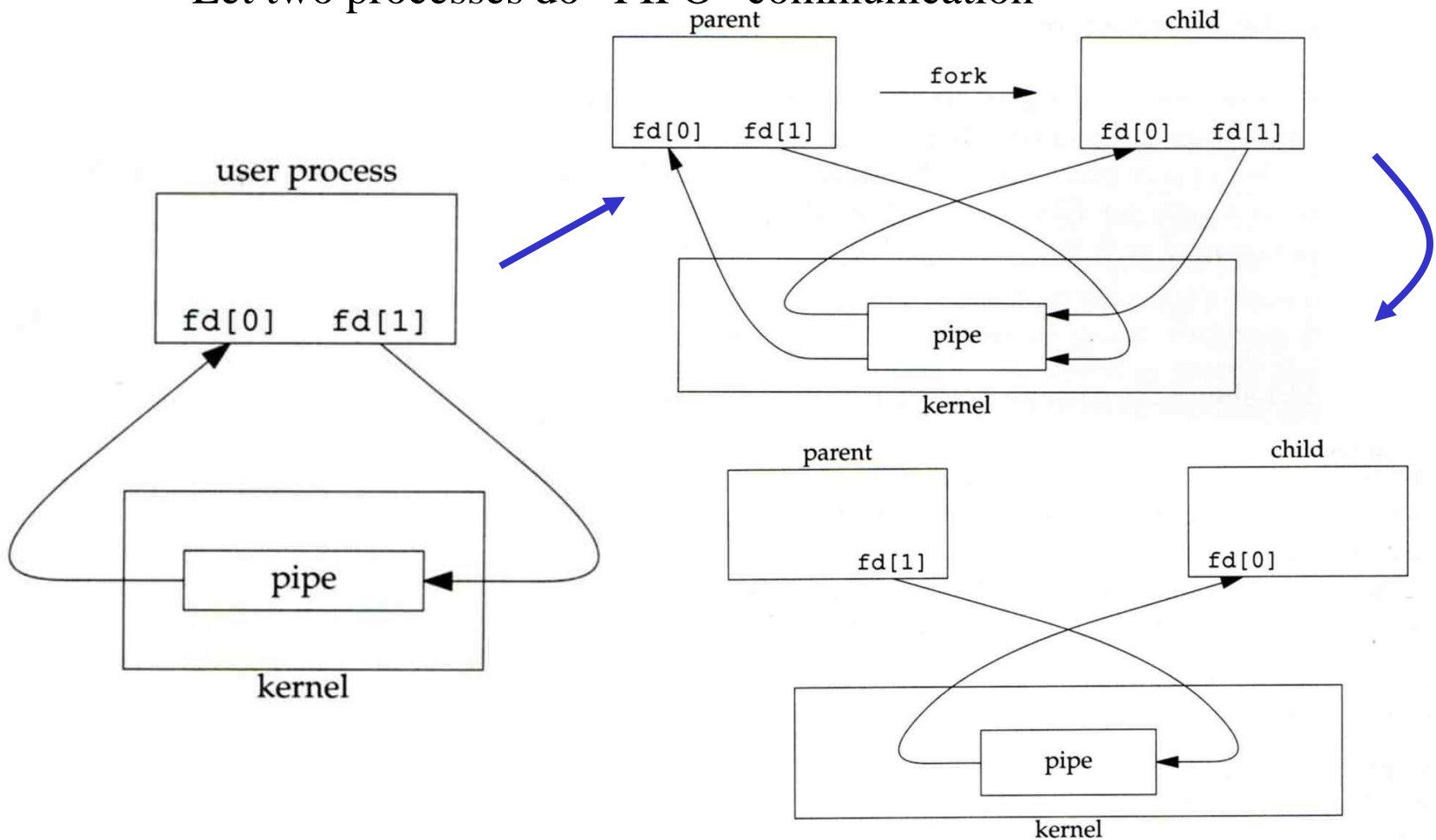
- Created by `socket()`
- Local to a particular host
- Be referenced through a filesystem object rather than a network port



File Types (4)

Named Pipes

- Let two processes do "FIFO" communication



File Types (5)

❑ Named Pipe

- `$ mkfifo [-m mode] fifo_name ...`

```
$ mkfifo pipe
```

```
$ du >> pipe
```

```
(another process)
```

```
$ sort -n pipe
```


File Types (6)

❑ Symbolic Link

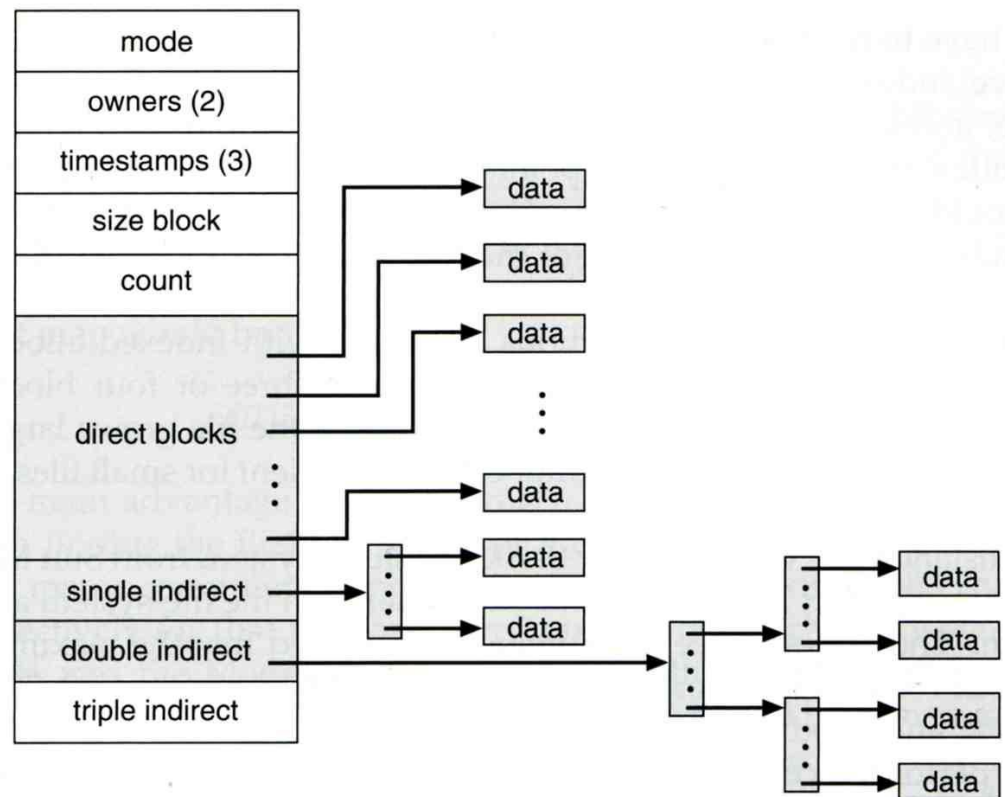
- A file which points to another pathname
- `% ln -s ori-file soft-file`
- Like “short-cut” in Windows

inode and file (1)

□ inode

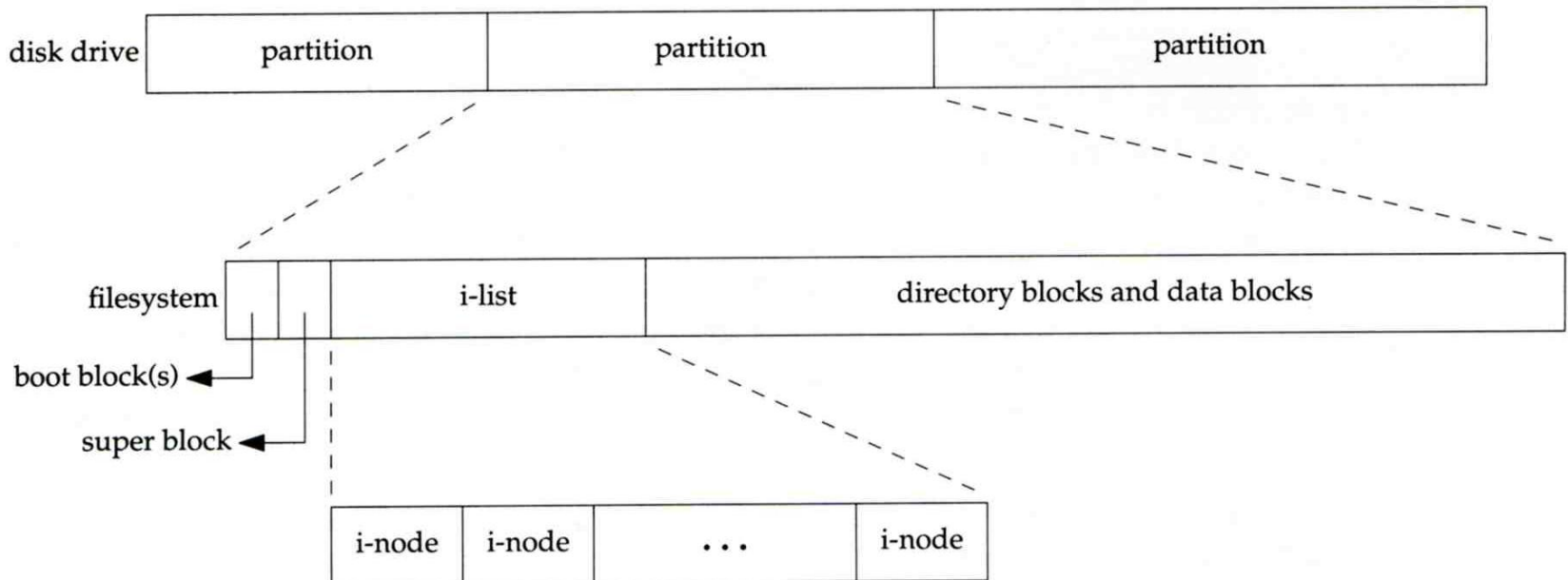
- A structure that records information of a file
 - You can use “ls -i” to see each file’s inode number

```
liuyh@NASA ~ $ ls -i
19255327 public_html
```



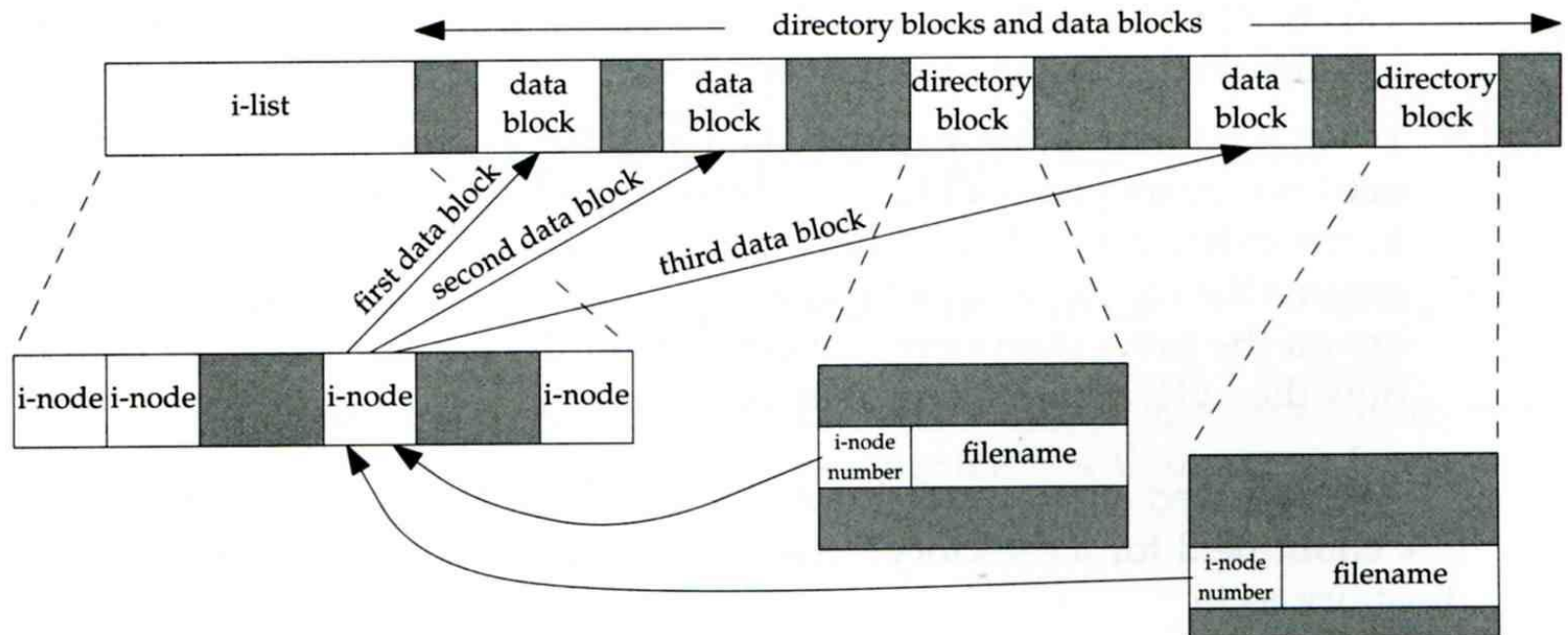
inode and file (2)

- Filesystem
 - Boot blocks
 - Super block
 - Inode list
 - Data block



inode and file (3)

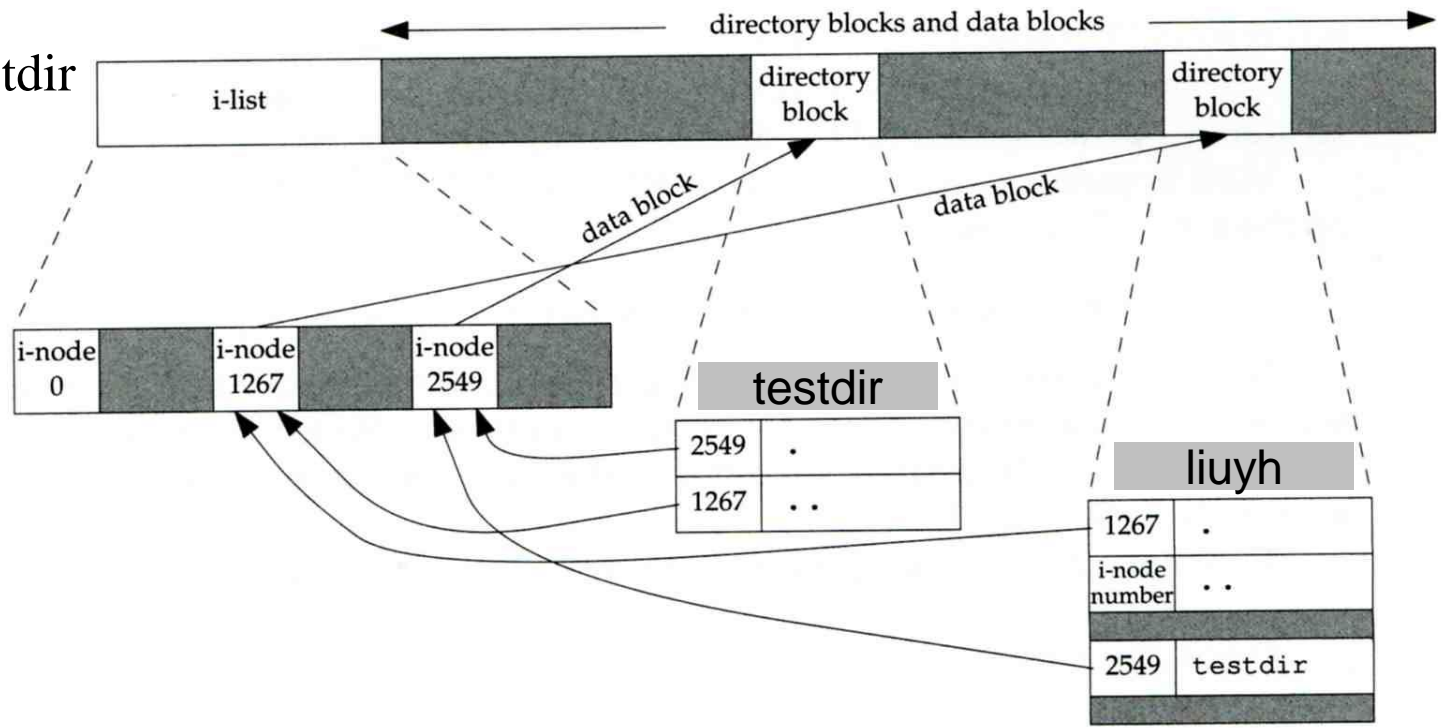
- More detail of inode and data block



inode and file (4)

□ Example

- .
- ..
- testdir



/home/liuyh/testdir

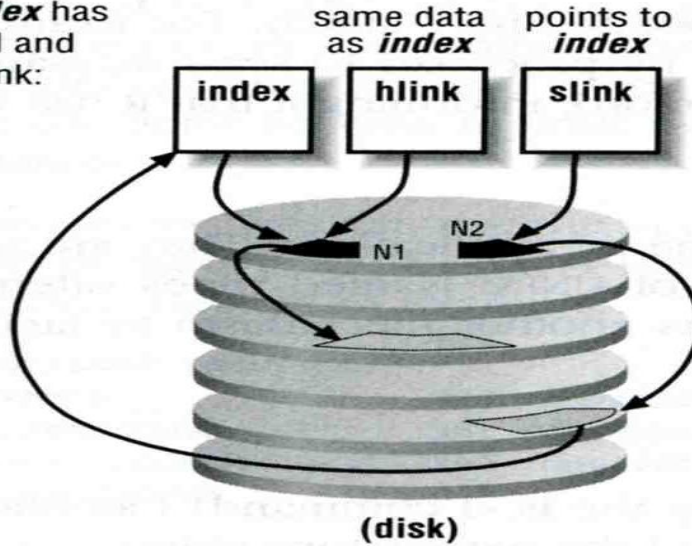
Hard Link V.S. Symbolic Link (1)

□ Link

- Hard link
 - associate two or more filenames with the same inode
 - Must in the same partition
 - % ln ori-file hard-file
- Soft (symbolic) link
 - A file which points to another pathname
 - % ln -s ori-file soft-file

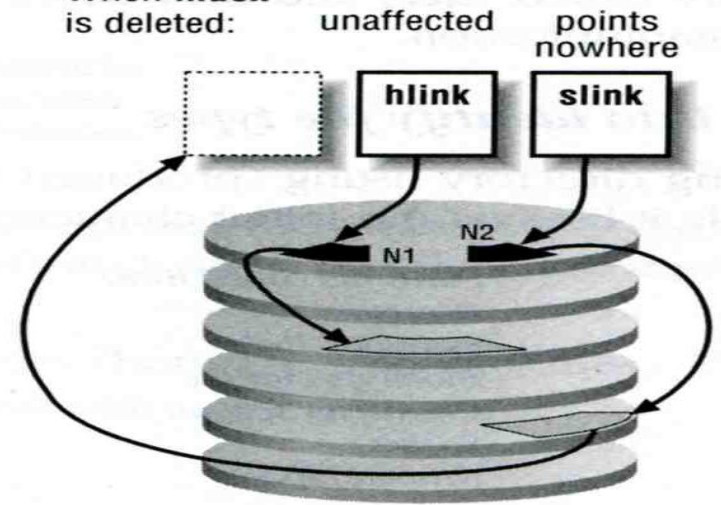
Hard Link V.S. Symbolic Link (2)

The file *index* has both a hard and symbolic link:

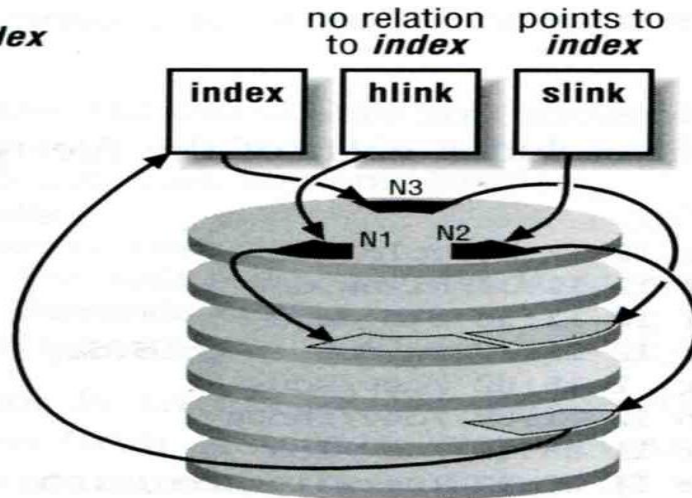


```
% touch index
% ln index hlink
% ln -s index slink
```

When *index* is deleted:



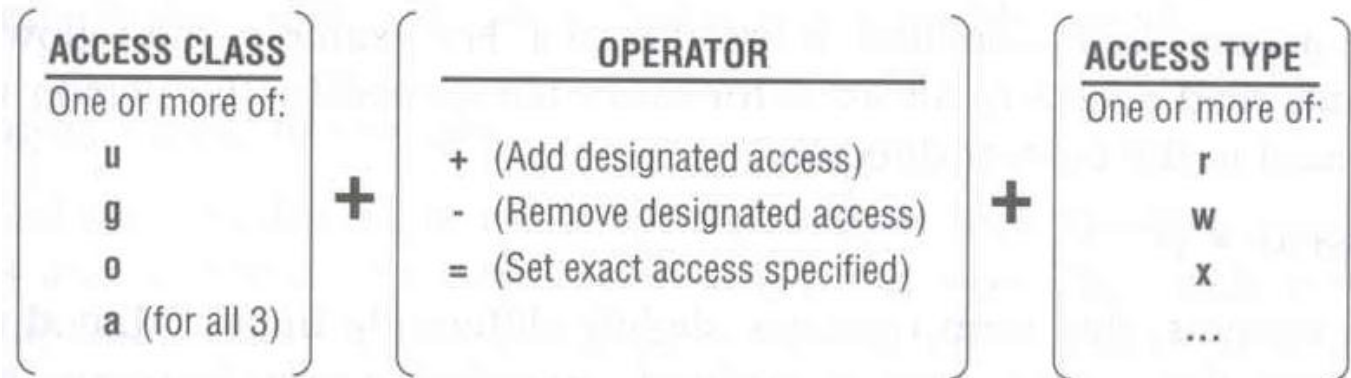
If a new *index* is created:



- Inode
- Data Block

File Access Mode (1)

- ❑ rwX r-X r-X
 - User, group, other privileges
- ❑ `chmod` command
 - `chmod(1)`, "MODES" section
 - % **chmod** *access-string* *file*
 - % **chmod u+x test.sh**
 - % **chmod go-w .tcshrc**
 - % **chmod u+w,g-w hehe haha**
 - % **chmod -R 755 public_html/**



File Access Mode (2)

❑ setuid, setgid, sticky bit

- setuid, setgid on file
 - The effective uid/gid of resulting process will be set to the UID/GID of the file
 - setuid
 - passwd, chsh, crontab
 - setgid
 - top, fstat, write
- setgid on directory
 - Cause newly created files within the directory to be the same group as directory
- sticky on directory (/tmp)
 - Do not allow to delete or rename a file unless you are
 - The owner of the file
 - The owner of the directory
 - root

File Access Mode (3)

□ Decimal argument of chmod

- setuid: 4000
- setgid: 2000
- sticky : 1000

Mode	Attribute	Mode	Attribute
755	- rwx r-x r-x	644	- rw- r-- r--
4755	- rws r-x r-x	600	- rw- --- ---
2755	- rwx r-s r-x	400	- r-- r-- r--
2775	d rwx rws r-x	1777	d rwx rwx rwt
755	d rwx r-x r-x	4555	- r-s r-x r-x
750	d rwx r-x ---	711	- rwx --x --x
700	d rwx --- ---	711	d rwx --x --x

File Access Mode (4)

❑ Assign default permissions: umask

- Shell built-in command
- Inference the default permissions given to the files newly created.
- The newly created file permission:
 - Use full permission bit (file: 666, dir: 777) xor umask value.
- Example:

umask	New File	New Dir
022	- rw- r-- r--	d rwx r-x r-x
033	- rw- r-- r--	d rwx r-- r--
066	- rw- --- ---	d rwx --x --x
000	- rw- rw- rw-	d rwx rwx rwx
477	- r-- --- ---	d r-x --- ---
777	- --- --- ---	d --- --- ---

File Protection

Command	Minimum Access Needed	
	On file itself	On directory file is in
<code>cd /home/test</code>		x
<code>ls /home/test/*.c</code>		r
<code>ls -s /home/test/*.c</code>		rx
<code>cat runme</code>	r	x
<code>cat >> runme</code>	w	x
<code>run-binary</code>	x	x
<code>run-script</code>	rx	x
<code>rm runme</code>		wx

Changing File Owner

❑ Changing File Owner

- Commands:
 - `chown` -- change user owner
 - `chgrp` -- change group owner

❑ Change the file ownership and group ownership

- `% chown -R liuyh /home/liuyh`
- `% chgrp -R cs /home/liuyh`
- `% chown -R liuyh:dcs /home/liuyh`
- `% chown -R :dcs /home/liuyh`

FreeBSD bonus flags

❑ chflags command

chflags(1)

- | | | |
|-----------|-------------------------|--------------|
| • schg | system immutable flag | (root only) |
| • sunlnk | system undeletable flag | (root only) |
| • sappnd | system append-only flag | (root only) |
| • uappend | user append-only flag | (root, user) |
| • uunlnk | user undeletable flag | (root, user) |
| • ... | | |

❑ ls -ol

```
liuyh@NASA ~ $ ls -ol /libexec/
total 1034
-r-xr-xr-x  1 root  wheel  schg 238472 Sep 21 12:50 ld-elf.so.1*
-r-xr-xr-x  1 root  wheel  -    238512 Jul 24 17:15 ld-elf.so.1.old
-r-xr-xr-x  1 root  wheel  schg 212204 Sep 21 12:51 ld-elf32.so.1
-r-xr-xr-x  1 root  wheel  -    212248 Jul 24 17:17 ld-elf32.so.1.old
```