COMP 2021

Unix and Script Programming

Unix File, Security and Link

File? Device?

- In UNIX a file is a sequence of bytes of data that reside in semi permanent form on some stable medium.
- This file can contains anything you can represent as a stream of bytes.
  - A network interface, a disk drive, a keyboard, and a printer
- All input and output devices are treated as files in UNIX.
  - Described under file types and file system structure.

File Name and Extension

- File names are limited to 14 chars in system V and 255 chars in BSD.
  - To avoid any problem use only letters, numbers, period and underscore.

- Extensions (usually) have no meaning to UNIX, they are parts of files names, used by users to mark their files types.
  - common files extensions:

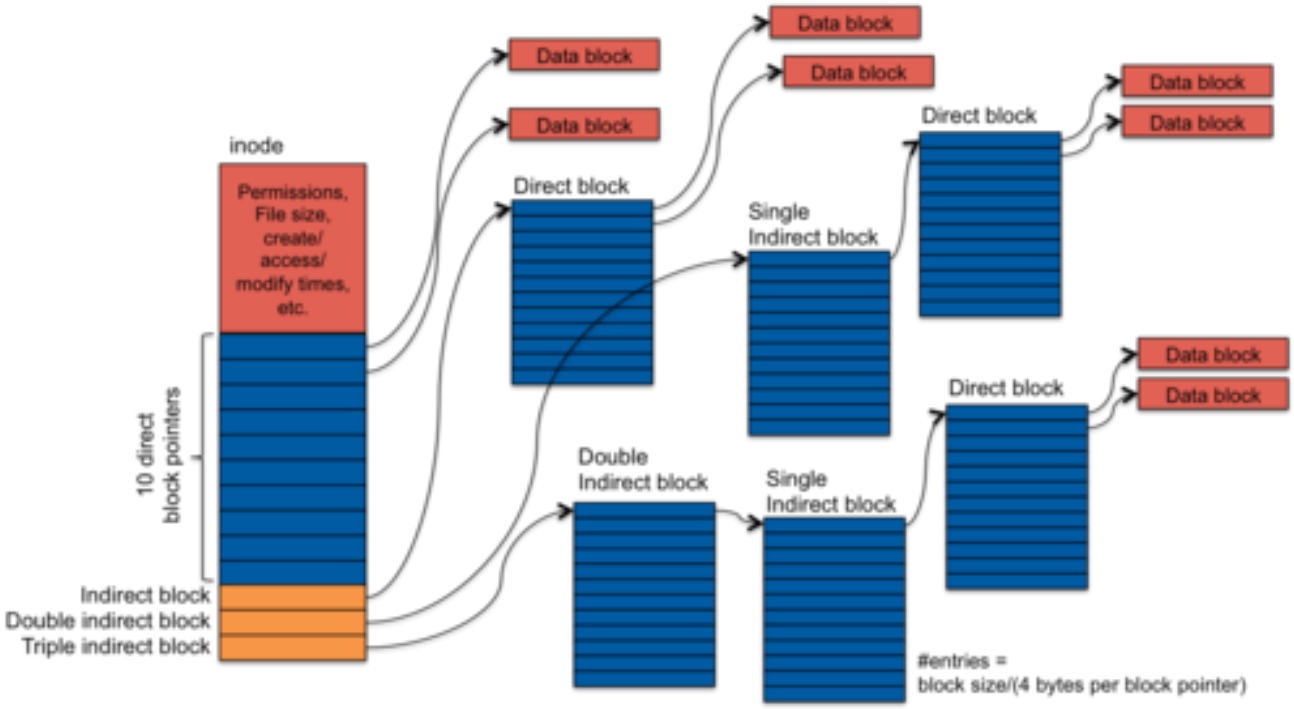
.c	c source code.
.C, .cc	c++ source code
.o	object file
.ps	PostScript format document
.gz	gzip compressed file
.tar	Tape archive, used by tar command
.dat	Data or other information
.pl	Perl Program
.bak	Backup cope of file
.asc	ASCII (text) file, often containing ANSI codes

Types of Files in Unix

- Simple/ordinary file
  - Store info and data on secondary storage device, typically a disk.
  - It can contain a source program, an executable program such as compilers, DB tools, pictures, audio, graphics, and so on.
  - Unix does not treat any kind of these files differently from others. For example a C++ file is no different to UNIX than an HTML file, however the files are treated differently by C++ compiler and WEB browser.

Types of Files in Unix (cont.)

- Directory files
  - Store (inode, filename) for each file or subdirectory it contains.



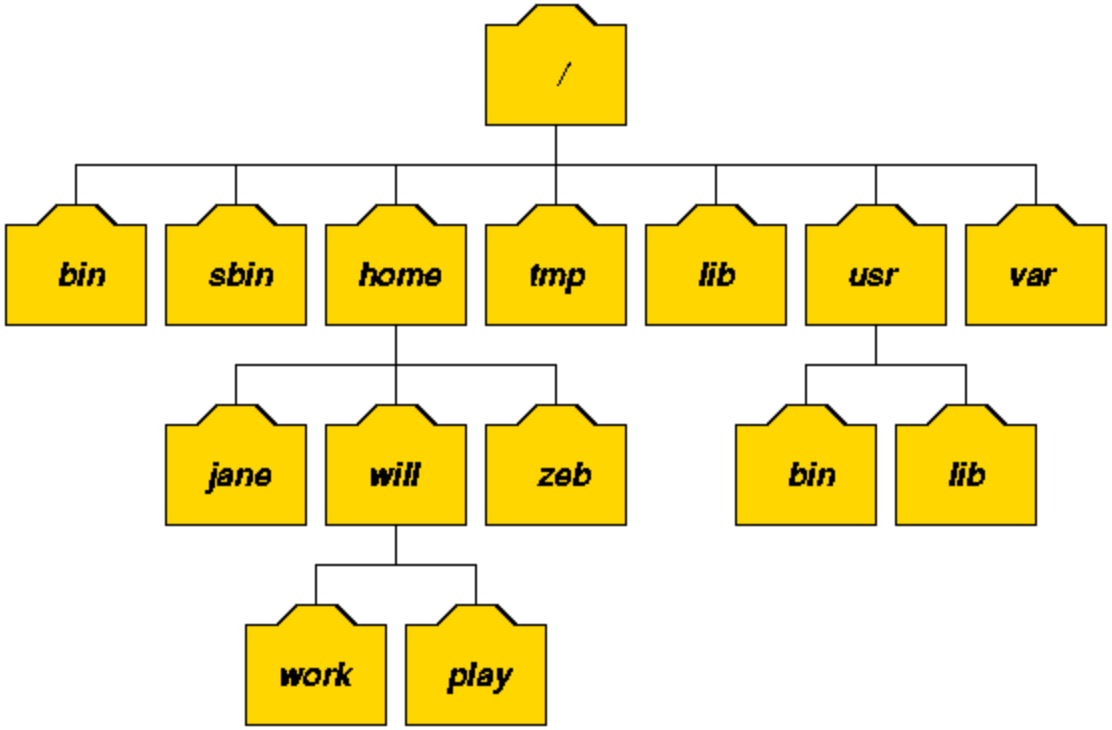
Types of Files in Unix (cont.)

- Link files
  - Point to the existing file, allowing you to rename an existing file and share it without duplicating its contents.
  - Establish connection between the file to be shared
  - `ln` command links the file to a directory.
- Special files (devices)
  - A mean of accessing hardware device, including the keyboard, hard disk, CD-ROM drive…etc.
  - Each hardware device is associated with at least one special file.
  - Usually reside in the `/dev` directory.

File System

- What is a file system?
  - A means of organizing information on the computer.
  - A file system is a logical view, not necessarily a physical view.
- What does the file system provide:
  - Ways to create, move, and remove files
  - Ways to order files
  - Security
- Examples of file systems:
  - DOS, Macintosh, CD-ROM, UNIX, NFS (networked file system)

Unix File System



- Hierarchical Organization
- Kinds of files:
  - Directory files (the branches in the tree)
  - Regular files (leaves in the tree)

Home and Working Directories

- Home directory
  - The directory you are in when you first login in
  - This is your space; you control security
  - Place to put your personalized .startup files
  - Your working directory after typing `cd` with no arguments
- Working directory
  - Can access files in your working directory by simply typing the filename
  - To access files in other directories, must use a pathname
  - `pwd` command prints the working directory
  - `cd` command changes the working directory
- Directory shortcuts
  - "." is the directory itself
  - ".." is the parent directory
  - In most shells "~" means your home directory
  - ~*user* means *user*'s home directory, so:

    ```
    $ more ~cindy/.secret
    ```

    looks at the file `.secret` in `/homes/cindy`, which is `cindy's` home directory.

Recap: UNIX File Utilities

- `ls` **l**ist directory contents
- `cd` **c**hange **d**irectory
- `pwd` **p**rint **w**orking **d**irectory
- `cat` display file
- `more` display one screen of file
- `rm` **rm**ove (delete) a file
- `rmdir` **rm**ove (delete) **dir**ectory
- `cp` **cp**y source file to target file
- `mv` rename or **mv**e a file

User and Group

- Unix was designed to allow multiple people to use the same machine at once
- Security and sharing are important issues to be dealt with
  - Access to files depends on the users account
  - All accounts are presided over by the Superuser, or "root" account
  - Each use has absolute control over any files he/she owns, which can only be superseded by root
  - Files can also be assigned to groups of users, allowing reading, modifications and/or execution to be restricted to a subset of users

File Ownership

- Each file is assigned to a single user and a single group (usually written user : group)
  - cindy's file belongs to `cindy : cs`, and roots files belong to `root : root`
- Needs root privilege to change file ownership – a regular user can't take ownership of their files to another user or a group they don't belong to

Class Exercises

Find out who you are (login name) and which groups do you belong to?

`whoami` `groups`

Discovering Permissions

- Use `ls -l` to tell about ownership and permissions of files
  - `ls – l` lists files and directories in the long format

Example

```
-rw------- 1 lixin cs  1355 Feb  1 21:32 2021StuList
```

Question: What permission is allowed?

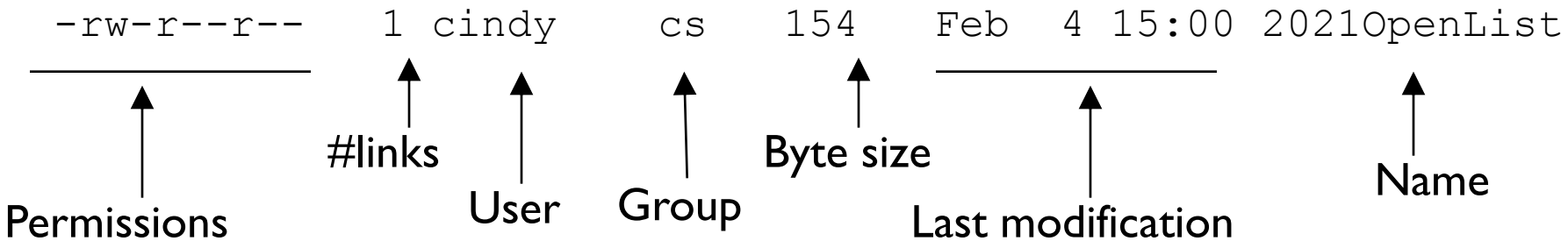
```
-rw-r--r-- 1 lixin cs  1355 Feb  1 21:32 2021OpenList
```

- Can use `ls -ld` to lists a directory's information

Security and Access Permissions

- There are three types of users:
  - The owner of the file (*user*)
  - The group of the file (*group*)
  - Anyone else (*other*)
- There are three types of permission (independent of each other):
  - Read permission
  - Write permission
  - Execute permission

Crack the Format



- There are four sets of items in the permissions:

  type **user** **group** **other**

  –rwxrwxrwx

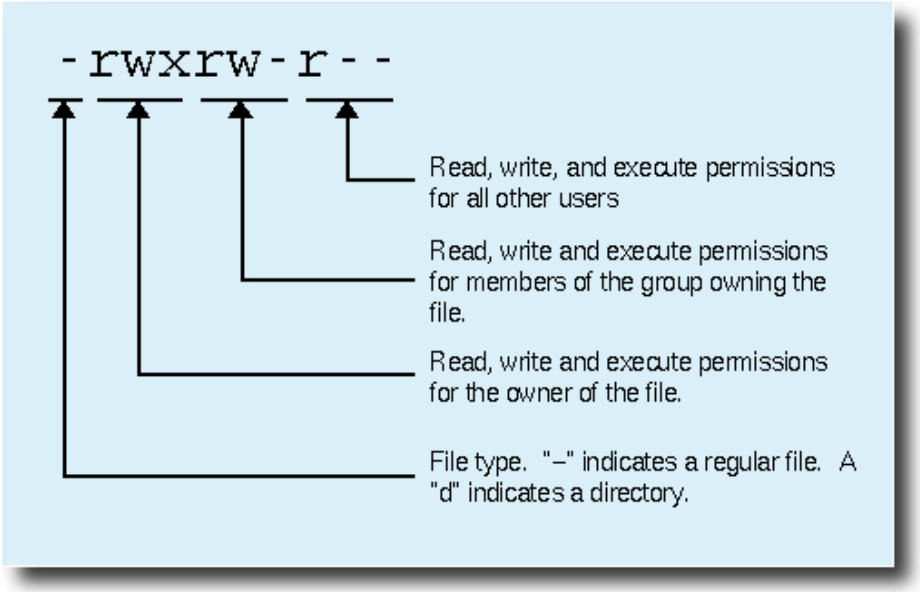
  - The type is:
    "–" regular files, "d" directories , "l" symbolic links.
  - The next nine characters indicate if the file is readable, writable, or executable for the file owner, the file group, or other users, respectively.

Changing Permissions

Change Mode

```
chmod [ugoa] [+-=] [rwx] [file/dir]
```

- Changes `file/directory` permissions
- Optionally, one of the characters: `u` (user/owner), `g` (group), `o` (other), or `a` (all).
- Optionally, one of the characters: `+` (add permission), `-` (remove permission), or `=` (set permission).
- Any combination of the characters `r` (read), `w` (write), or `x` (execute).



Permission Example

- To let everybody read or write the `file`

```
$ chmod a+rw file
$ ls -l file
-rw-rw-rw- 1       cindy   cs      154     Feb 4   15:00   file
```

- To allow user to execute `file`

```
$ chmod u+x file
$ ls -l file
-rwxrw-rw- 1       cindy   cs      154     Feb 4   15:00   file*
```

- To not let "other" to read or write file `file`

```
$ chmod o-rw file
$ ls -l file
-rwxrw---- 1       cindy   cs      154     Feb 4   15:00   file*
```

- To let "group" only read the file `file`

```
$ chmod g=r file
$ ls -l file
-rwxr----- 1       cindy   cs      154     Feb 4   15:00   file*
```

Permission Shortcut

- Think of r, w, and x as binary variables
  - 1 ON, 0 OFF

Binary	Symbolic	Allowed file accesses
111000000	rwx------	Owner can read, write, and execute
111111000	rwxrwx---	Owner and group can read, write, and execute
110100000	rw-r-----	Owner can read and write; group can read
110100100	rw-r--r--	Owner can read and write; all others can read
111101101	rwxr-xr-x	Owner can do everything, rest can read and execute
000000000	---------	Nobody has any access
000000111	------rwx	Only outsiders have access (strange, but legal)

Decimal Permission
`chmod 755:  rwxr-xr-x`
`chmod 600:  rw-------`
`chmod 777:  rwxrwxrwx`

Class Exercise

Setup your homepage at Department of Computer Science and Engineering

First of all, logon to any UNIX workstations, e.g. ras, make a directory "public_html" under your home, i.e. **"mkdir ~/public_html"**, put an index file, "index.html" under the "public_html" directory.

Make sure the permissions have been set appropriately, for instance:

- Your home directory has to be at least world-accessible, i.e. **"chmod 701 ~"**
- The same for "public_html" directory, i.e. **"chmod 701 ~/public_html"**
- The files under "public_html" directory should be world-readable, i.e.**"chmod 604 ~/public_html/*.html"**

Now, your homepage should be ready and can be accessed as:

http://www.cse.ust.hk/~<your name>

Directory Permissions

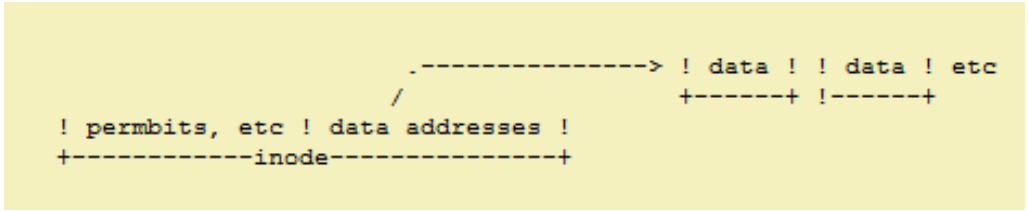
- Directory read permission means that you can see what files are in the directory.
- Directory write permission means that you can add/remove/rename files in the directory.
- Directory execute permission means that you can search the directory
  - You can use the directory name when accessing files inside it
  - you can do `ls` and `cp` on individual files in the directory.

Directory Permissions

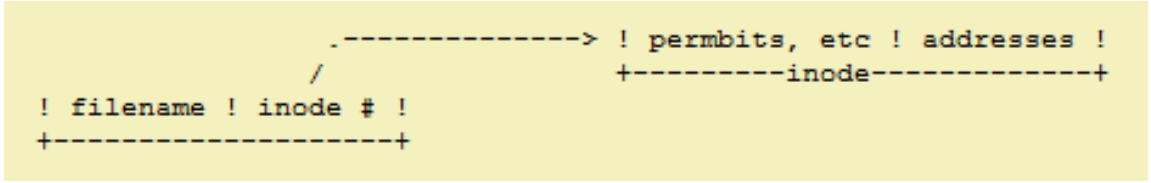
```
$ ls -ld secret*
drwxr-xr-x   2 cindy    cs           512 Feb  4 16:38 secret/
d---------   2 cindy    cs           512 Feb  4 16:39 secret1/
dr--r--r--   2 cindy    cs           512 Feb  4 16:39 secret2/
d--x--x--x   2 cindy    cs           512 Feb  4 16:38 secret3/


$ ls -l secret*
secret:
total 2
-rw-r--r--   1 cindy    cs          1054 Feb  4 16:38 letter1

secret1 unreadable

ls: secret2/letter1: Permission denied
secret2:
total 0

secret3 unreadable
```

More about Unix Files

- Unix files consist of two parts
  - Data part: associated with *inode* (owner, file permissions, size, data location, etc.)



  - Filename part: carries a name and an associated *inode* number



Links

- A *link* is a directory entry that points to blocks on disk.
  - In other words, every file on your system has at least one link
- In fact, in UNIX *all* filenames are just links to a file. Most files only have one link.

```
-rw------- 1 lixin cs 4 Feb 7 11:57 original1
-rw------- 1 lixin cs 4 Feb 7 11:57 original2
```

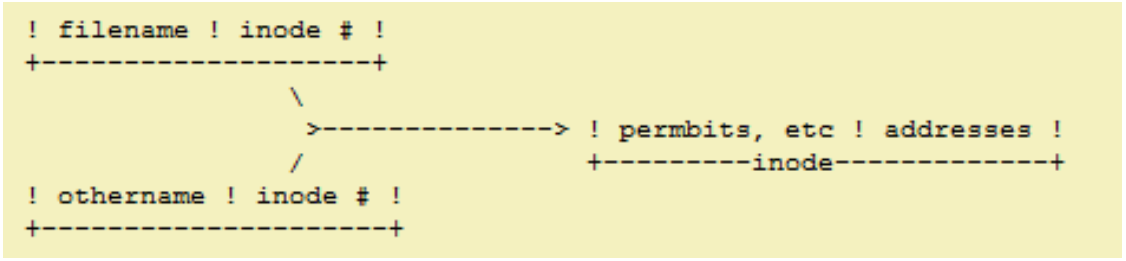
Number of links

- Additional links to a file allow the file to be shared.
- The `ln` command creates new links.

```
$ ln original1 original1-hard
$ ls -l
total 12
-rw------- 2 lixin cs 4 Feb 7 11:57 original1
-rw------- 2 lixin cs 4 Feb 7 11:57 original1-hard
-rw------- 1 lixin cs 4 Feb 7 11:57 original2
```

Hard Link

- More than one filename can reference the same inode number; these files are said to be 'hard linked' together




```
$ ls -li
total 12
1744963559 -rw------- 2 lixin cs 4 Feb 7 11:57 original1
1744963559 -rw------- 2 lixin cs 4 Feb 7 11:57 original1-hard
1765251893 -rw------- 1 lixin cs 4 Feb 7 11:57 original2
```

inode number

`ln` command

- `ln` make links between files

The `ln` command
• `ln [option] TARGET LINK_NAME` Create a link to TARGET with the name LINK_NAME
• `ln [option] TARGET DIRECTORY` Create a link to TARGET in DIRECTORY

- `ln` creates hard link by default
- The last argument is the link destination, and can be:
  - A pathname of a new regular file

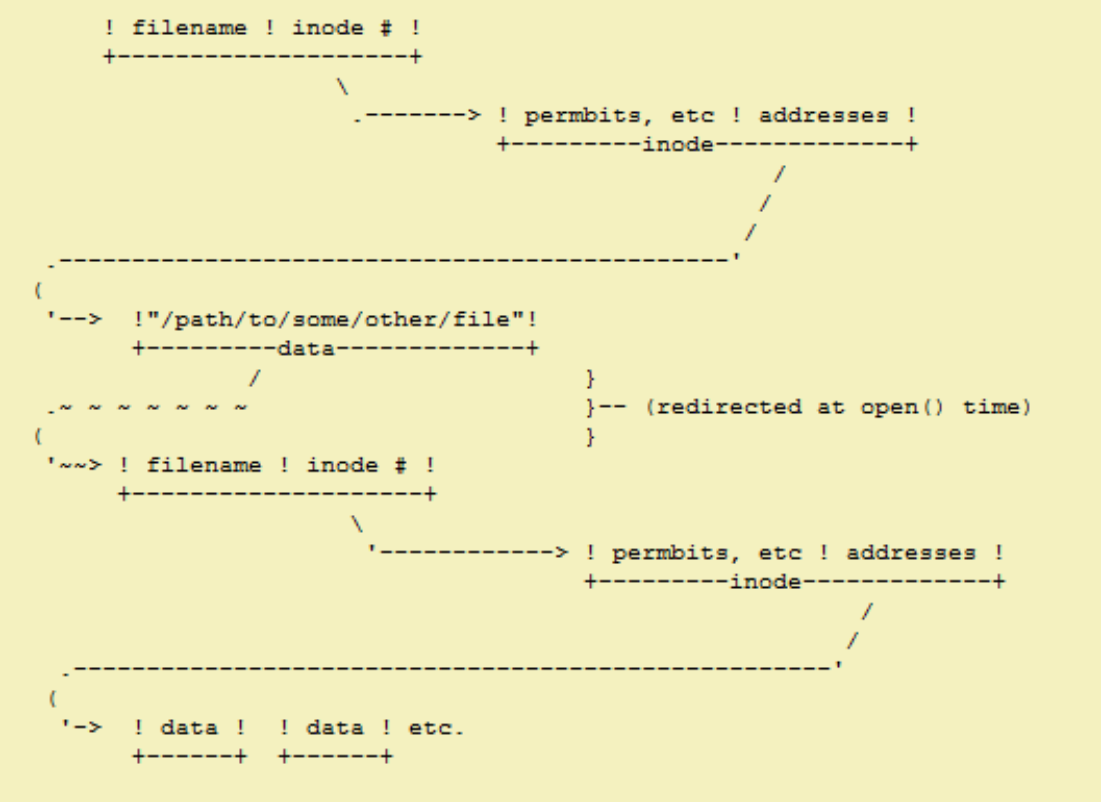
    ```
    $ ln original1 original1-hard
    ```

  - A pathname of an existing directory (a link with the same basename as the original file is created in the directory)

    ```
    $ ln original1 subdir
    ```

Soft Link

- There's a special file type whose data part carries a path to another file
  (a file that contains the name of another file)
- OS recognizes the data as a path, and redirects opens/reads/writes
- This special file is called a 'soft link', or a 'symbolic link' (aka a 'symlink')



Soft Link (cont.)

- A soft link is a pointer to a pathname, not a pointer to the file itself.
  - `ln -s TARGET LINK_NAME` creates a soft link.
  - The symbolic link has a different *inode*.

```
$ ln -s original2 original2-soft
$ ls -li
total 12
1744963559 -rw------- 2 lixin cs 4 Feb 7 11:57 original1
1744963559 -rw------- 2 lixin cs 4 Feb 7 11:57 original1-hard
1765251893 -rw------- 1 lixin cs 4 Feb 7 11:57 original2
1770683694 lrwxrwxrwx 1 lixin cs 9 Feb 7 12:55 original2-soft -
  > original2
```

Hard vs. Soft Links

```
csl2wk09:lixin:182> touch original1; touch original2
csl2wk09:lixin:183> echo "cat" >> original1
csl2wk09:lixin:184> echo "dog" >> original2
csl2wk09:lixin:185> cat original1; cat original2
cat
dog
csl2wk09:lixin:186> ln original1 original1-hard
csl2wk09:lixin:187> ln -s original2 original2-soft
csl2wk09:lixin:188> ls -li
total 12
1744963559 -rw------- 2 lixin cs 4 Feb 17 13:09 original1
1744963559 -rw------- 2 lixin cs 4 Feb 17 13:09 original1-hard
1765251893 -rw------- 1 lixin cs 4 Feb 17 13:09 original2
1747919295 lrwxrwxrwx 1 lixin cs 9 Feb 17 13:10 original2-soft -> original2
csl2wk09:lixin:189> cat original1-hard
cat
csl2wk09:lixin:190> cat original2-soft
dog
csl2wk09:lixin:191> chmod g+rw original1-hard
csl2wk09:lixin:192> ls -li
total 12
1744963559 -rw-rw---- 2 lixin cs 4 Feb 17 13:09 original1
1744963559 -rw-rw---- 2 lixin cs 4 Feb 17 13:09 original1-hard
1765251893 -rw------- 1 lixin cs 4 Feb 17 13:09 original2
1747919295 lrwxrwxrwx 1 lixin cs 9 Feb 17 13:10 original2-soft -> original2
csl2wk09:lixin:193> rm original1
csl2wk09:lixin:194> cat original1-hard
cat
csl2wk09:lixin:195> rm original2
csl2wk09:lixin:197> cat original2-soft
cat: original2-soft: No such file or directory
csl2wk09:lixin:198>
```

When you `rm` a file the actual system call is `unlink`.

It removes the directory entry.

Hard vs. Soft Links (Cont.)

- The most important difference between hard and soft links occur when a link is *removed*.
- When deleting files, the data part isn't disposed of until all the filename parts have been deleted.
  - *inode* keeps how many filenames point to this file
  - Count is decremented by 1 each time one of those filenames is deleted
  - When the count makes it to zero, the *inode* and its associated data are deleted.

Hard vs. Soft Links (Cont.)

- You can't make a hard link to a directory, but you can make a symbolic link to a directory.

```
$ mkdir subdir
$ cd subdir
$ touch original3
$ cd ..
$ ln subdir subdir-hard
ln: `subdir': hard link not allowed for directory
$ ln -s subdir subdir-soft
$ cd subdir-soft
$ ls
original3
```

- You can also make symbolic links across file systems.

```
$ ln /usr/include/stdio.h stdio.h
ln: creating hard link `stdio.h' to `/usr/include/stdio.h': Invalid
   cross-device link
$ ln -s /usr/include/stdio.h stdio.h
$ ls -li
317906316 lrwxrwxrwx 1 lixin cs 20 Feb 17 14:10 stdio.h ->
   /usr/include/stdio.h
```

  - There is no way to tell how many symbolic links there are to a file
  - The permission is not correctly reflected using `-l` option for soft links, use `-L` instead

Brain Storming

- A soft link can span file systems or reference directories, which a hard link can't do.
- A hard link can reference deleted files, but why you would want this behavior?
- A soft link seems more desirable in all circumstances. Why do we still have hard link?

Some possible motivations:

- Disk Efficiency: never have a file twice on your system (and thus save disk space)?
- Better information organization?
- Incremental backups (e.g. with rsync): you put a daily back-up in separate directories, so that every directory contains a full back-up of that date, but each back-up only takes up as much space as is needed for the differences with the previous back-up. Then when you don't need an old back-up anymore, you can safely remove its directory completely, without harming the back-ups of a later date.