National University of Singapore

CS2106 Operating System

Second Half Summary Notes

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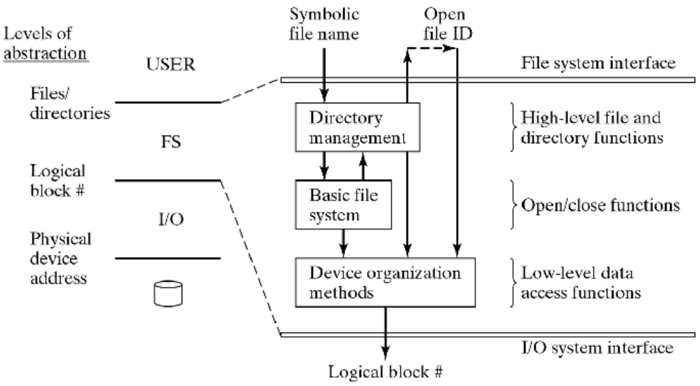
1 File System

Definition 1.1. File system

- Present logical (abstract) view of files and directories
  - Accessing a disk is very complicated: (2D or 3D structure, track/surface/sector, seek, rotation, ...)
  - Hide complexity of hardware devices
- Facilitate efficient use of storage devices: Optimise access e.g. to disk.
- Support sharing
  - Files persist even when owner/creator is not currently active (unlike main memory)
  - Key issue: Provide protection (control access)

Definition 1.2. Hierarchical View of File system



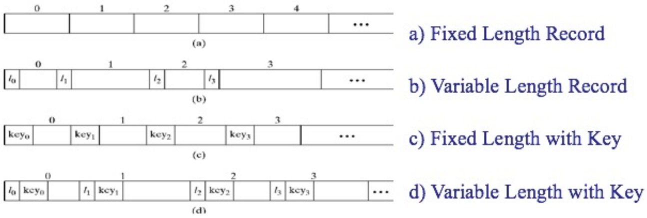
- **Directory management**: map logical name tounique Id, file descriptor
- **Basic file system**: open/close files
- **Physical device organization**: map file data to disk blocks

Definition 1.3. User-end view of File

- **File name and type**
  - Valid name: number or characters, lower or upper cases, illegal characters ...
  - Extension: tied to type of file, used by applications
  - File type is recorded in header
    - * Cannot be changed (even when extension changes)
    - * Basic types: text, object, load file, directory

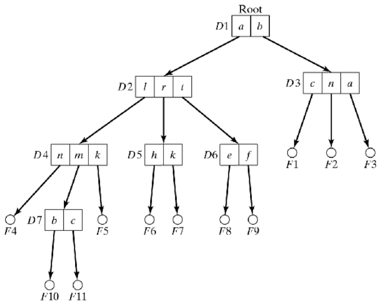
    - Application-specific types, e.g., .doc, .ps, .html

- **Logical file organization**
  - Most common: byte stream
  - Fixed-size or variable-size records
  - Addressed: **Implicitly** (sequential access to next record), or **Explicitly** by position (record#) or key

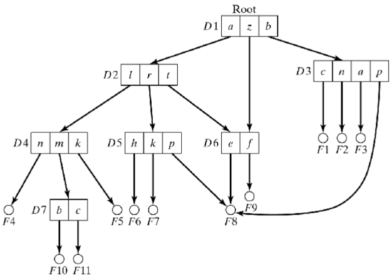


Definition 1.4. Directory Management

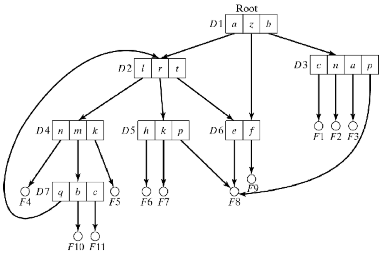
- **Main issues**:
  - **Shape** of the data structure
  - **What** info to keep about files
  - **Where** to keep the files in directory
  - **How** to organise entries for efficiency?
- **File directory data structure**:
  - **Tree-structured**
    - **Simple** search, insert, delete operations
    - Sharing is **asymmetric**



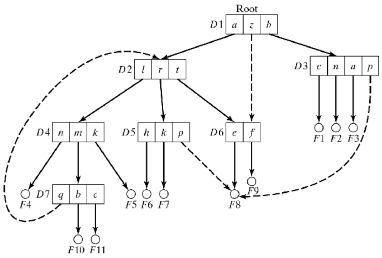
  - **DAG-structured**
    - **Symmetric** sharing
    - **Delete**: only last parent should remove files, so need **Reference count**



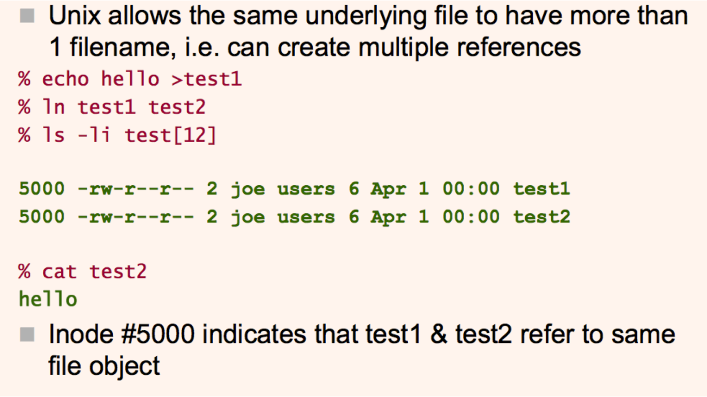
  - **DAG-structured with cycles**
    - Search is difficult with infinite loops
    - Deletion needs **garbage collection** (reference count not enough)



- **Symbolic links (shortcuts)**
  - **Compromise** to allow sharing but avoid cycles.
  - For **read/write**: symbolic link is the same as actual link.
  - For **deletion**: only symbolic link is deleted.



Definition 1.5. UNIX Hard Links



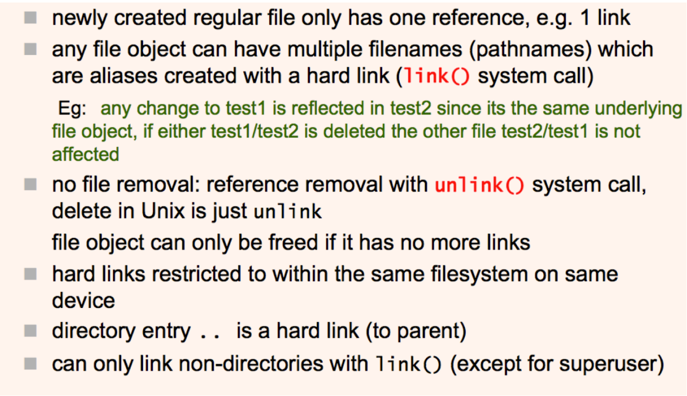
- Unix allows the same underlying file to have more than 1 filename, i.e. can create multiple references

```
% echo hello >test1
% ln test1 test2
% ls -li test[12]

5000 -rw-r--r-- 2 joe users 6 Apr 1 00:00 test1
5000 -rw-r--r-- 2 joe users 6 Apr 1 00:00 test2

% cat test2
hello
```

- Inode #5000 indicates that test1 & test2 refer to same file object

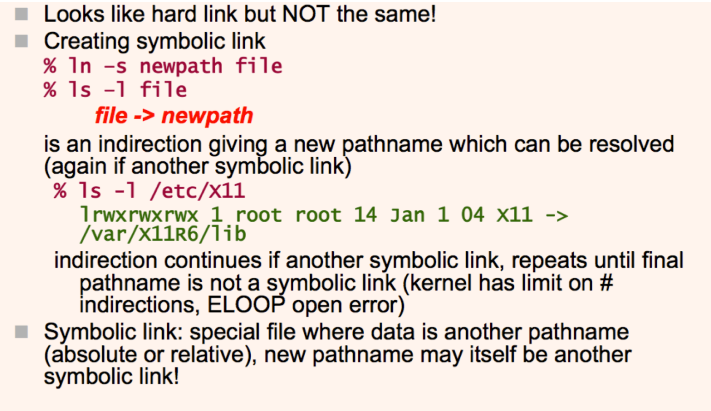


- newly created regular file only has one reference, e.g. 1 link
- any file object can have multiple filenames (pathnames) which are aliases created with a hard link (`link()` system call)

  Eg: any change to test1 is reflected in test2 since its the same underlying file object, if either test1/test2 is deleted the other file test2/test1 is not affected
- no file removal: reference removal with `unlink()` system call, delete in Unix is just `unlink`

  file object can only be freed if it has no more links
- hard links restricted to within the same filesystem on same device
- directory entry `..` is a hard link (to parent)
- can only link non-directories with `link()` (except for superuser)

Definition 1.6. Symbolic Links



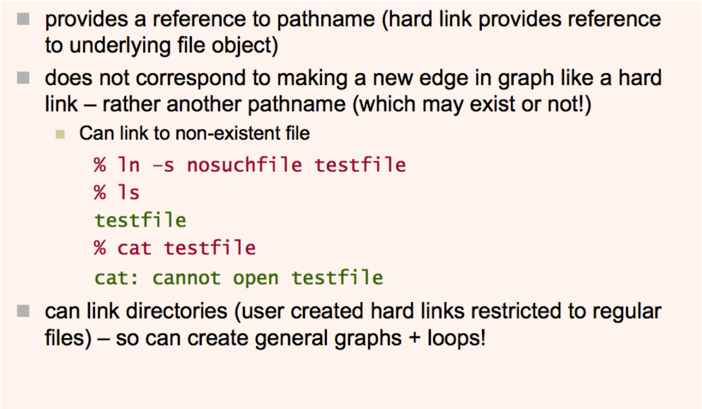
- Looks like hard link but NOT the same!
- Creating symbolic link

```
% ln -s newpath file
% ls -l file
      file -> newpath
```

is an indirection giving a new pathname which can be resolved (again if another symbolic link)

```
% ls -l /etc/X11
   lrwxrwxrwx 1 root root 14 Jan 1 04 X11 ->
   /var/X11R6/lib
```

indirection continues if another symbolic link, repeats until final pathname is not a symbolic link (kernel has limit on # indirections, ELOOP open error)
- Symbolic link: special file where data is another pathname (absolute or relative), new pathname may itself be another symbolic link!



- provides a reference to pathname (hard link provides reference to underlying file object)
- does not correspond to making a new edge in graph like a hard link – rather another pathname (which may exist or not!)
  - Can link to non-existent file

```
% ln -s nosuchfile testfile
% ls
testfile
% cat testfile
cat: cannot open testfile
```

- can link directories (user created hard links restricted to regular files) – so can create general graphs + loops!

Remark. Windows Shortcuts

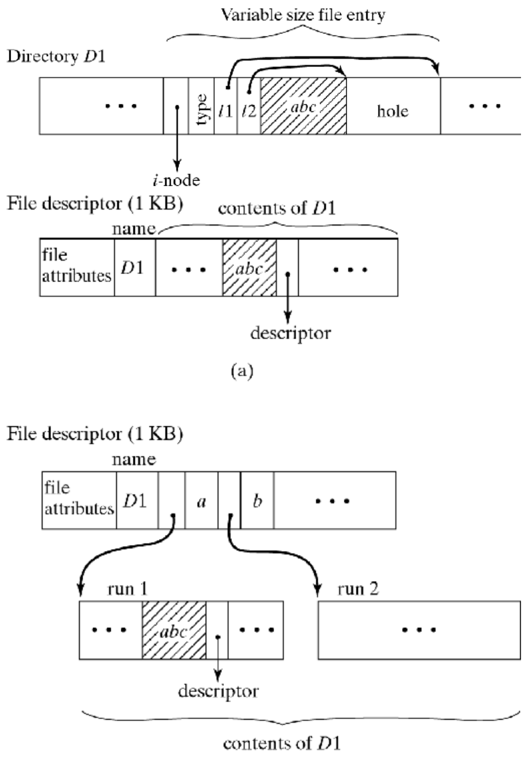
- Similar to symbolic links but does not re-expand further
- Only understood by GUI shell! Created also from GUI shell
- Win NTFS has hard links, symbolic links using junction mechanism (not normally used)

Remark. File Directories - Path name

- Concatenated local names with delimiter (. or / or \ )
- **Absolute** path name: start with root (/)
- **Relative** path name: start with current directory (.)
- Notation to move upward in hierarchy (..)

Method 1.1. Implementation of Directories

- **What information to keep in each entry**
  - **All** descriptive information, directory can become very large, searches are difficult / slow.
  - Only symbolic **name and pointer** to descriptor
    - ∗ Needs an extra disk access to descriptor
    - ∗ Variable name length
- **How to organise entries within directory**
  - **Fixed-size** entries: use array of slots
  - **Variable-size** entries: use linked list
  - **Size of directory**: fixed or expanding



(a)

(b)

red sftext tttext

Penghao is the best LaTeX writer.

```
def func():
    print("Penghao is cool!")
```

℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘℘

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1. 123
2. 123
3. 123

	M1	M2	M3	M4	M5
M1	0	108	180	228	396
M2		0	72	168	288
M3			0	48	144
M4				0	128
M5					0

Algorithm 1 title

```
123
```

References

[1] Albert Einstein. *Zur Elektrodynamik bewegter Körper.* (German) [*On the electrodynamics of moving bodies* `www.google.com.sg`]. Annalen der Physik, 322(10):891921, 1905.