# File Management

Tanenbaum, Chapter 4

COMP3231
Operating Systems

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## Outline

- Files and directories from the programmer (and user) perspective
- Files and directories internals – the operating system perspective



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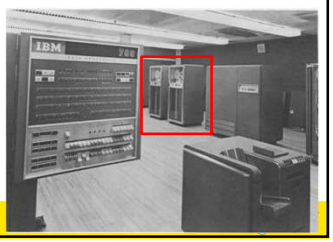
## A brief history of file systems

Early batch processing systems
–No OS
–I/O from/to punch cards
–Tapes and drums for external storage, but no FS
–Rudimentary library support for reading/writing tapes and drums

IBM 709 [1958]

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## A brief history of file systems

•The first file systems were single-level (everything in one directory)
•Files were stored in contiguous chunks
–Maximal file size must be known in advance
•Now you can edit a program and save it in a named file on the tape!

PDP-8 with DECTape [1965]



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## A brief history of file systems

•Time-sharing OSs
–Required full-fledged file systems
•MULTICS
–Multilevel directory structure (keep files that belong to different users separately)
–Access control lists
–Symbolic links

Honeywell 6180 running MULTICS [1976]

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## A brief history of file systems

•UNIX
–Based on ideas from MULTICS
–Simpler access control model
–Everything is a file!

PDP-7



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## Overview of the FS abstraction

| User's view | Under the hood |
|---|---|
| Uniform namespace | Heterogeneous collection of storage devices |
| Hierarchical structure | Flat address space (block numbers) |
| Arbitrarily-sized files | Fixed-size blocks |
| Symbolic file names | Numeric block addresses |
| Contiguous address space inside a file | Fragmentation |
| Access control | No access control |
| Tools for<br>• Formatting<br>• Defragmentation<br>• Backup<br>• Consistency checking | |





## File Names

- File system must provide a convenient naming scheme
  - Textual Names
  - May have restrictions
    - Only certain characters
      - E.g. no '/' characters
    - Limited length
    - Only certain format
      - E.g DOS, 8 + 3
  - Case (in)sensitive
  - Names may obey conventions (.c files for C files)
    - Interpreted by tools (e.g. UNIX)
    - Interpreted by operating system (e.g. Windows "con:")





## File Structure

- Sequence of Bytes
  - OS considers a file to be unstructured
  - Applications can impose their own structure
  - Used by UNIX, Windows, most modern OSes






## File Types

- Regular files
- Directories
- Device Files
  - –May be divided into
    - Character Devices – stream of bytes
    - Block Devices
- Some systems distinguish between regular file types
  - –ASCII text files, binary files





## File Access Types (Patterns)

- Sequential access
  - –read all bytes/records from the beginning
  - –cannot jump around, could rewind or back up
  - –convenient when medium was magnetic tape
- Random access
  - –bytes/records read in any order
  - –essential for data base systems
  - –read can be …
    - move file pointer (seek), then read or
      - –lseek(location,…);read(…)
    - each read specifies the file pointer
      - –read(location,…)





## File Attributes

| Attribute | Meaning |
|---|---|
| Protection | Who can access the file and in what way |
| Password | Password needed to access the file |
| Creator | ID of the person who created the file |
| Owner | Current owner |
| Read-only flag | 0 for read/write; 1 for read only |
| Hidden flag | 0 for normal; 1 for do not display in listings |
| System flag | 0 for normal files; 1 for system file |
| Archive flag | 0 for has been backed up; 1 for needs to be backed up |
| ASCII/binary flag | 0 for ASCII file; 1 for binary file |
| Random access flag | 0 for sequential access only; 1 for random access |
| Temporary flag | 0 for normal; 1 for delete file on process exit |
| Lock flags | 0 for unlocked; nonzero for locked |
| Record length | Number of bytes in a record |
| Key position | Offset of the key within each record |
| Key length | Number of bytes in the key field |
| Creation time | Date and time the file was created |
| Time of last access | Date and time the file was last accessed |
| Time of last change | Date and time the file has last changed |
| Current size | Number of bytes in the file |
| Maximum size | Number of bytes the file may grow to |

## Typical File Operations

- Create
- Delete
- Open
- Close
- Read
- Write
- Append
- Seek
- Get attributes
- Set Attributes
- Rename





## An Example Program Using File System Calls (1/2)

```
/* File copy program. Error checking and reporting is minimal. */

#include <sys/types.h>                  /* include necessary header files */
#include <fcntl.h>
#include <stdlib.h>
#include <unistd.h>

int main(int argc, char *argv[]);       /* ANSI prototype */

#define BUF_SIZE 4096                   /* use a buffer size of 4096 bytes */
#define OUTPUT_MODE 0700                /* protection bits for output file */

int main(int argc, char *argv[])
{
    int in_fd, out_fd, rd_count, wt_count;
    char buffer[BUF_SIZE];

    if (argc != 3) exit(1);             /* syntax error if argc is not 3 */
```





## An Example Program Using File System Calls (2/2)

```
    /* Open the input file and create the output file */
    in_fd = open(argv[1], O_RDONLY);    /* open the source file */
    if (in_fd < 0) exit(2);             /* if it cannot be opened, exit */
    out_fd = creat(argv[2], OUTPUT_MODE);  /* create the destination file */
    if (out_fd < 0) exit(3);            /* if it cannot be created, exit */

    /* Copy loop */
    while (TRUE) {
        rd_count = read(in_fd, buffer, BUF_SIZE); /* read a block of data */
        if (rd_count <= 0) break;       /* if end of file or error, exit loop */
        wt_count = write(out_fd, buffer, rd_count); /* write data */
        if (wt_count <= 0) exit(4);     /* wt_count <= 0 is an error */
    }

    /* Close the files */
    close(in_fd);
    close(out_fd);
    if (rd_count == 0)                  /* no error on last read */
        exit(0);
    else
        exit(5);                        /* error on last read */
}
```



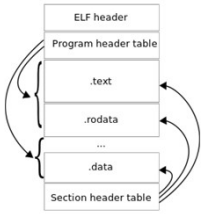


## File Organisation and Access
### Programmer's Perspective

- Given an operating system supporting unstructured files that are a *stream-of-bytes,*

  how can one organise the contents of the files?

E.g. Executable Linkable Format (ELF)








## File Organisation and Access
### Programmer's Perspective

- Some possible access patterns:
  - Read the whole file
  - Read individual records from a file
    - record = sequence of bytes containing the record
  - Read records preceding or following the current one
  - Retrieve a set of records
  - Write a whole file sequentially
  - Insert/delete/update records in a file

Programmers are free to structure the file to suit the application.





## Criteria for File Organization

Things to consider when designing file layout

- Rapid access
  - Needed when accessing a single record
  - Not needed for batch mode
    - read from start to finish
- Ease of update
  - File on CD-ROM will not be updated, so this is not a concern
- Economy of storage
  - Should be minimum redundancy in the data
  - Redundancy can be used to speed access such as an index

## File Directories

- Provide mapping between file names and the files themselves
- Contain information about files
  - –Attributes
  - –Location
  - –Ownership
- Directory itself is a file owned by the operating system



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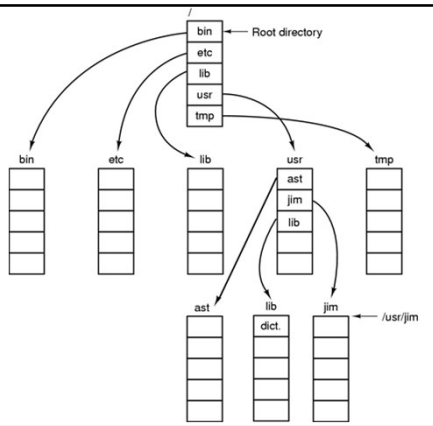




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## Hierarchical (Tree-Structured) Directory

- Files can be located by following a path from the root, or master, directory down various branches
  - –This is the *absolute* pathname for the file
- Can have several files with the same file name as long as they have unique path names



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## Current *Working Directory*

- Always specifying the absolute pathname for a file is tedious!
- Introduce the idea of a *working directory*
  - –Files are referenced relative to the working directory
- Example: cwd = /home/kevine

  .profile = /home/kevine/.profile



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## Relative and Absolute Pathnames

- Absolute pathname
  - –A path specified from the root of the file system to the file
- A *Relative* pathname
  - –A pathname specified from the cwd
- Note: '.' (dot) and '..' (dotdot) refer to current and parent directory

Example: cwd = /home/kevine

```
../../etc/passwd
/etc/passwd
../kevine/../.././etc/passwd
```

Are all the same file



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## Typical Directory Operations

- Create
- Delete
- Opendir
- Closedir
- Readdir
- Rename
- Link
- Unlink



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## Nice properties of UNIX naming

- Simple, regular format
  - –Names referring to different servers, objects, etc., have the same syntax.
    - Regular tools can be used where specialised tools would be otherwise be needed.
- Location independent
  - –Objects can be distributed or migrated, and continue with the same names.
    - Where is /home/kevine/.profile?
    - You only need to know the name!





## An example of a bad naming convention

- From, Rob Pike and Peter Weinberger, "The Hideous Name", Bell Labs TR

UCBVAX::SYS$DISK:[ROB.BIN]CAT_V.EXE;13





## File Sharing

- In multiuser system, allow files to be shared among users
- Two issues
  - –Access rights
  - –Management of simultaneous access





## Access Rights

- None
  - –User may not know of the existence of the file
  - –User is not allowed to read the directory that includes the file
- Knowledge
  - –User can only determine that the file exists and who its owner is





## Access Rights

- Execution
  - –The user can load and execute a program but cannot copy it
- Reading
  - –The user can read the file for any purpose, including copying and execution
- Appending
  - –The user can add data to the file but cannot modify or delete any of the file's contents





## Access Rights

- Updating
  - –The user can modify, delete, and add to the file's data. This includes creating the file, rewriting it, and removing all or part of the data
- Changing protection
  - –User can change access rights granted to other users
- Deletion
  - –User can delete the file

## Access Rights

- Owners
  - Has all rights previously listed
  - May grant rights to others using the following classes of users
    - Specific user
    - User groups
    - All for public files





## Simultaneous Access

- Most OSes provide mechanisms for users to manage concurrent access to files
  - Example: flock(), lockf(), system calls
- Typically
  - User may lock entire file when it is to be updated
  - User may lock the individual records (i.e. ranges) during the update
- Mutual exclusion and deadlock are issues for shared access