What is File System Management

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Goals for Today
Overview

- User view of file systems
  - System calls
  - Structures, organisation, file types
- Implementation view of file systems
  - Disk and partition layout
  - File tables
  - Free space management ...

Different views of file system

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File Systems
Different Views

- A **user view** that defines a file system in terms of the **abstractions** that the operating system provides
  - How files are named, what operations allowed on them
  - What directories looks like
  - Interface issue
- An **implementation view** that defines the file system in terms of its **low level implementation**
  - How files and directories are stored
  - How disk space is managed
  - How to make everything work efficiently

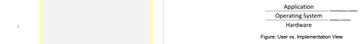

Figure: User vs. Implementation View

User view=> definition

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User View
Definition

- Important aspects of the **user view** include:
  - The **file abstraction** which hides away implementation details to the user (similar to processes and memory)
    - File **naming policies** (two-part file names, abstracts storage details)
    - User file **attributes** (metadata, e.g. size, protection, owner, protection, dates)
      - There are also **system attributes** for files (e.g. non-human readable file descriptors (similar to a PID), archive flag, temporary flag, etc.)
  - **Directory** structures and organisation
  - **System calls** to interact with the file system

Implementation view=>context of file system

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Implementation view of file system
Context

- Irrespectively of the type of file system, a number of **additional considerations** have to be addressed, including
  - Disk **partitions**, **partition tables**, **boot sectors**, etc.
  - Free **space management** (=> free memory)
  - System wide and per process **file tables** (=> process tables)
  - How file and directories **store** (to be introduced in the **next lecture**)
- **Low level formatting** writes sectors to the disk, **high level formatting** imposes a file system on top of this
  - File system manage **blocks** that can cover multiple **sectors**
  - The file is split up into a number of (not necessarily) contiguous blocks.

File types

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Files
Types

- Many OSs support several types of file.
- Both Windows and Unix (including OS X) have regular **files and directories:**
  - **Regular files** contain user data in **ASCII** or **binary** (well defined) **format**
    - A file is a named collection of data
    - ASCII files consist of lines of text, (can be displayed, can be edited by text editor)
    - Binary files have internal structure
  - **Directories** group files together (but are files on an implementation level)
    - They provide a mapping of the logical file onto the physical location

Directories

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Directories
Directory structure

- **Directories are special files** that **group files** together and of which the **structure is defined** by the **file system**
  - A bit is set to indicate that they are directories!
- Different directory structures have been used over the years
  - **Single level**: all files in the same directory (reborn in consumer electronics)
  - **Two or multiple level directories** (hierarchical): tree structures
    - Absolute path name: from the root of the file system
    - Relative path name: the current working directory is used as the starting point
  - **Directed acyclic graph (DAG)**: allows files to be shared (i.e. **links** to files or sub-directories) but **cycles are forbidden**

Implementation => How Disk is structured

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Hard Disk Structures
Partitions

- Disks are usually divided into **multiple partitions**
  - An independent file system may exist on each partition
- **Master boot record** located at start of the entire drive:
  - Used to boot the computer (BIOS reads and executes MBR)
  - Contains **partition table** at its end with active partition
  - One partition is listed as **active** containing a boot block to load the operating system

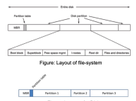

Figure: Layout of a Disk

Implementation => How free disk space is managed?

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Disk Space Management
Free Space Management

- Two methods are commonly used to keep track of free disk space: **bitmaps** and **linked lists**
  - Note that these approaches are very similar to the ones to keep track of free memory

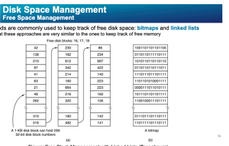

Figure: Free Block Management with Linked Lists (Tanenbaum)

Implementation => How files are managed?

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File managed by OS
Implementation

- Apart from the free disk space tables, there is a number of key data structures stored in memory:
  - An in-memory **mount table**
  - An in-memory **directory cache** of recently accessed directory information
  - A **system-wide open file table**, containing a copy of the FCB for every currently open file in the system, including location on disk, file size, and "open count"
  - **(if processes that use the file)**
    - File control blocks (FCBs) are kernel data structures, i.e. they are protected and only accessible in kernel mode!
  - A **per-process open file table**, containing a pointer to the system open file table

File/ Directory Implementation => How files and directories are stored? (next lecture)

Implementation = > How shared files are managed? (next lecture)

File system calls

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System Calls
Types

- System calls enable a **user application** to **ask the operating system** to carry out an **action** on its behalf (in kernel mode)
- There are two different categories of **system calls**:
  - **File manipulation**: open(), close(), read(), write(), delete(), ...
  - **Directory manipulation**: create(), delete(), readdir(), rename(), link(), unlink(), list(), update()

Directory structure

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Directories
Directory structure

Figure: Single-level directory and DAG Directory Implementation (Tanenbaum)

Directories
DAG and Graph Complications

- The use of **DAGs** results in significant complications in the implementation
- Files have **multiple absolute file names**
- **Deleting files** becomes a lot more complicated (i.e. links may no longer point to a file)
- A **garbage collection scheme** may be required to remove files that are no longer accessible from the file system tree

Directories system calls

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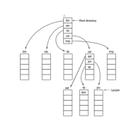
Directories
System Calls



- Similar to files, **directories** are manipulated using **system calls**
  - create/delete: a new directory is created/deleted
  - opendir, closedir: add/free directory to/from internal tables
  - Others: rename, link, unlink, list, update
  - cp ../lib/dictionary . => means copy the file /usr/lib/dictionary to its own directory using the command

Partition layout

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Partition Layouts
A Unix Partition

Figure: Layout of a unix Partition

- The layout of a partition differs depending on the file system
  - The partition **boot block**:
    - Contains code to boot the operating system
    - Every partition has boot block – even if it does not contain OS
  - **Super block** contains the partition's (file system's) key parameters, e.g., partition size, number of blocks, I-node table size
    - Read into main memory when computer is booted
  - **Free space management** contains, e.g., a bitmap or linked list that indicates the free blocks
  - **I-nodes** contains information on files, commonly maintained in I-nodes
  - **Root directory:** contains the top of the file-system tree
  - **Data**: files and directories

Bitmap vs. Linked list

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Disk Space Management
Free Space Management

- **Bitmaps** represent each block by a single bit in a map
  - The **size of the bitmap** grows with the size of the disk but is **constant** for a given disk
  - Bitmaps take **comparably less space than linked lists**
    - 1 bit per block **vs.** 1 pointer (32-bit/64-bit) per block
- **Linked Lists:**
  - Free blocks are used to hold the **numbers of the free blocks** (hence, they are no longer free)
    - Since the free list shrinks when the disk becomes full, this is not wasted space
  - **Blocks are linked together**, i.e., multiple blocks list the free blocks
  - The size of the list **grows with the size of the disk** and **shrinks with the size of the blocks (not constant)**
  - Linked lists can be modified by **keeping track of the number of consecutive free blocks** for each entry

Example

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Disk Space Management
Free Space Management: bitmap vs. linked list

- Bitmaps:
  - Require extra space. E.g. If block size = 2^{13} bytes and disk size = 2^{30} bytes (1 GB) => bitmap size: $2^{30-13} = 2^{17}$ (32KB)
  - Proportional to number of block
  - Keeping it in main memory is possible only for small disks.
- Linked lists:
  - No waste of disk space
  - We only need to keep in memory one block of pointers (load a new block when need)
  - If block size = 2^{13} (4K) bytes, 32-bit disk block number and disk size = 2^{30} bytes
    - block number $2^{30}/2^{13} = 2^{17}$
    - linked-list block number = $2^{13}/2^{2}$
    - linked-list size = 2^{5} * 4KB = 1024KB

File table management

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File managed by OS
File tables

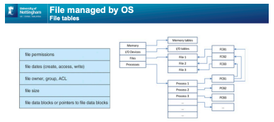

Figure: File control block (FCB) and File table

File table usage

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File Tables
Illustration

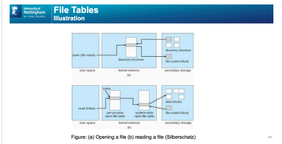

Figure: (a) Opening a file (b) reading a file (Silberschatz)