File Systems

Operating Systems

G53OPS: Operating Systems

Graham Kendall

File Systems

Operating Systems

Why Use Files?

- It allows data to be stored between processes
- It allows us to store large volumes of data
- Allows more than one process to access the data at the same time

File Systems

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Two Views of File System

- User View
- Implementators View

File Systems

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File Naming

- Different operating systems have different file naming conventions
- MS-DOS only allows an eight character filename (and a three character extension)
- This limitation also applies to Windows 3.1
- Windows 95 and Windows NT allow filenames up to 255 characters (although the full path name is only allowed to be a maximum of 260 characters)

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File Naming

- Restrictions as to the characters that can be used in filenames
- Some operating systems distinguish between upper and lower case characters
- To MS-DOS, the filename ABC, abc, and AbC all represent the same file. UNIX sees these as different files

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File Extensions

- Filename are made up of two parts (typically PC based OS’s) separated by a full stop
- The part of the filename up to the full stop is the actual filename
- The part following the full stop is often called a file extension
- In MS-DOS the extension is limited to three characters
- UNIX and Windows 95/NT allow longer extensions

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File Extensions

- Used to tell the operating system what type of data the file contains
- It associates the file with a certain application
- Using tools provided with the operating system the user is able to change the file associations
- UNIX allows a file to have more than one extension associated with it

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Common File Extensions

Extension	File Contents
BIN	Binary File
C	C Program File
CPP	C++ Program File
DLL	Dynamic Link Library
DOC	Microsoft Word file
EXE	Executable File
HLP	Help File
TXT	Text File
XLS	Microsoft Excel File

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File Attributes

- Each file has a set of attributes associated with it
- Typical attributes:

Attribute	Description
Archive Flag	Bit Field : has the file been archived?
Creation Date/Time	Date and Time file was created
Creator	User ID of the person creating the file
Hidden Flag	Bit Field : Is the file a hidden file?
Last Accessed Date/Time	Date and Time file was last accessed
Owner	The ID of the current owner
Password	Password required to access the file
Protection	Access rights to the file
Read-Only	Bit Field : Ids the file read only?
Size in Bytes	How large is the file
System Flag	Bit Field : Is the file a system file?
Temporary Flag	Bit Field : Should the file be deleted at end of the process?

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File Structure

- Store the file as a sequence of bytes. It is up to the program that accesses the file to interpret the byte sequence
  - Fixed length records
  - Variable length records
  - Indexed Files

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File Access

- Sequential Access
- Batch Updating Model
- Random Access

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Directories

- Allow like files to be grouped together
- Allow operations to be performed on a group of files which have something in common. For example, copy the files or set one of their attributes
- Allow files to have the same filename (as long as they are in different directories). This allows more flexibility in naming files
- Typical directory entry contains a number of entries; one per file

User View

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Directories

- All the data (filename, attributes and disc addresses) can be stored within the directory
- Alternatively, just the filename can be stored in the directory together with a pointer to a data structure which contains the other details
- Hierarchical Directory Structure
- Simulating a hierarchical directory structure?

User View

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Path Names

Absolute path names

- C:\COURSES\OPS\FILE SYSTEMS
- OR
- \COURSES\OPS\FILE SYSTEMS

Relative path names

- Related to Current Working Directory (CWD)
- If CWD is C:\COURSES then the relative path name for the above file would be
- OPS\FILE SYSTEMS

User View

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Working Directory

Finding out the CWD

- Under UNIX – PWD
- Under MS-DOS it is usual to change the command prompt so that the current working directory is displayed:
- PROMPT pg
- $p displays the current drive and working directory
- $g tells MS-DOS to display a '>'
- '.' and '..' – what do they represent?

User View

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Operations

- Copy
- Move
- Rename
- etc..

Implementators View

File Systems

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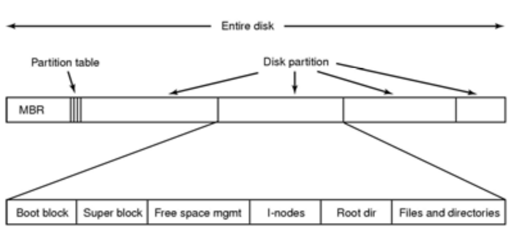
Possible File System Layout



Implementators View

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Implementation (Contigous)

Contiguous Allocation

- Allocate *n* contiguous blocks to a file. If a file was 100K in size and the block was 1K then 100 contiguous blocks would be required

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Implementators View

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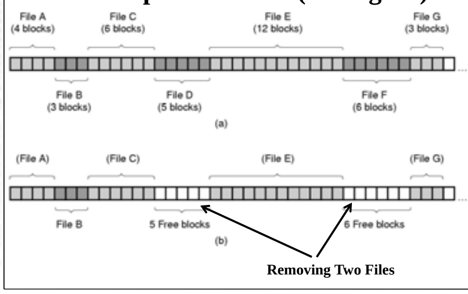
Implementation (Contigous)



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Implementators View

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Implementation (Contiguous)

Advantages
- It is simple to implement as keeping track of the blocks allocated to a file is reduced to storing the first block that the file occupies and its length
- The performance of such an implementation is good as the file can be read as a contiguous file. The read write heads have to move very little, if at all. You will never find a filing system that performs as well

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Implementators View

File Systems

Implementation (Contiguous)

Disadvantages
- Leads to fragmentation
- We need to keep a list of unused blocks (doable, but expensive)
- The operating system does not know, in advance, how much space a file can occupy
- Need to run defragmentation process periodically, but it is expensive

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Implementators View

File Systems

Implementation (Contiguous)

Question
- Can you think of a scenario where a contiguous file allocation scheme could be used?

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Implementators View

File Systems

Implementation (Contiguous)

Question
- Can you think of a scenario where a contiguous file allocation scheme could be used?

- Write once media (CDs, DVDs etc.)

Operating Systems

Implementators View

File Systems

Implementation (Linked List)

- Blocks of a file represented using linked lists
- All that needs to be held is the address of the first block that the file occupies
- Each block contains data and a pointer to the next block

Implementators View

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Implementation (Linked List)

- Blocks of a file represented using linked lists
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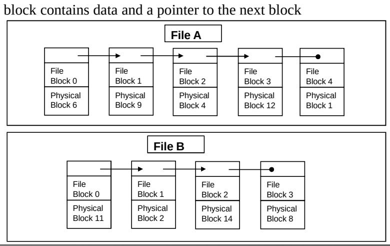

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Implementation (Linked List)

Advantages

- Every block can be used, unlike a scheme that insists that every file is contiguous
- No space is lost due to external fragmentation (although there is internal fragmentation within the file)
- The directory entry only has to store the first block number. The rest of the file can be found from there
- The size of the file does not have to be known beforehand (unlike a contiguous file allocation scheme)
- When more space is required for a file any block can be allocated (e.g. the first block on the free block list)
- Reading a file sequentially is straightforward, although may require more disc accesses than a contiguous allocation

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Implementation (Linked List)

Disadvantages

- Random access is very slow. It needs many disc reads to access a random point in the file (*n*-1 accesses are required to get to block *n*)
- Space is lost within each block due to the pointer. This does not allow the number of bytes to be a power of two. This is not fatal, but does have an impact on performance
- Reliability could be a problem. It only needs one corrupt block pointer and the whole system might become corrupted (e.g. writing over a block that belongs to another file)

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Implementation (Linked List: Using a Table in Memory)

- Store the pointers in an index (often called a File Allocation Table (FAT))
- Does not waste space in the block
- Random access is possible as index is in memory
- Therefore, eliminates the two main disadvantages of using linked lists

Implementators View

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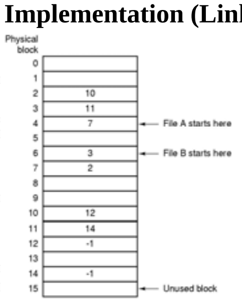
Implementation (Linked List: Using an Index)



Disadvantages?

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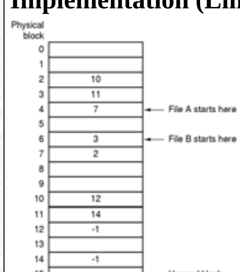
Implementation (Linked List: Using an Index)



- Main disadvantage is that the entire table must be in memory all the time
- For a (small) disc of 20GB, with a 1K block size, that requires 20 million entries. At 3 bytes per entry that is 60MB in main memory

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Implementation (I-Nodes)

- All the attributes for the file is stored in an i-node entry, which is loaded into memory when the file is opened
- The i-node also contains a number of direct pointers to disc blocks. Typically there are twelve direct pointers
- Only keep the i-node in memory if the file is open.
- If each i-node has *n* bytes and a maximum of *k* files can be open then the i-nodes take a maximum of *nk* bytes, regardless of disc size

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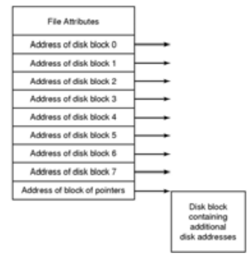
Operating Systems

Implementation (i-Nodes)



Implementators View

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Implementation (UNIX i-Nodes)

- UNIX V7 File System (PDP-11)
- A UNIX directory contains one entry for each file in that directory
- Each entry is very simple (name (14 bytes)/i-node number (2 bytes))

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File Systems

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Implementation (UNIX i-Nodes)

- UNIX V7 File System (PDP-11)
- In addition there are three additional indirect pointers. These pointers point to further data structures which eventually lead to a disc block address
- The first of these pointers is a single level of indirection, the next pointer is a double indirect pointer and the third pointer is a triple indirect pointer

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File Systems

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Implementation (UNIX i-Nodes)

Attributes

- File size
- Three times (creation, last accessed, last modified)
- Owner
- Group
- Protection information
- Number of directory entries pointing to that i-node (to cater for links)

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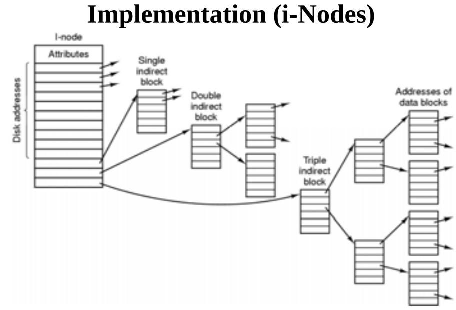
Implementation (i-Nodes)



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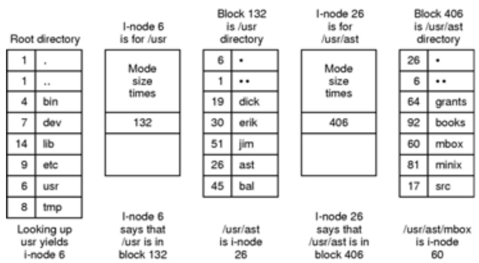
Implementation (i-Nodes)



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Implementation (MS-DOS vs i-node)

- Under MS-DOS a directory entry is 32 bytes long. It is split as follows

8 (bytes)	3 (bytes)	1 (byte)	10 (bytes)	2 (bytes)	2 (bytes)	2 (bytes)	4 (bytes)
Filename	Extension	Attributes	Reserved	Time	Date	First Block	Size

- Under UNIX we only need to store the file name and i-node number (as all the attributes are stored in the i-node)

2 (bytes)	14 (bytes)
i-node #	Filename

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Case Study

- Chapter 10 of the course textbook (ed. 2) is a case study of Unix and Linux

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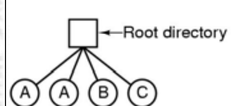
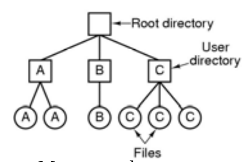
Directories

- **Single Level Directory Structure vs Two Level Directory Structure**



- Simple
- Problems with multiple filenames
- Still has its uses



- More complex
- More flexible
- Assumes a user structure

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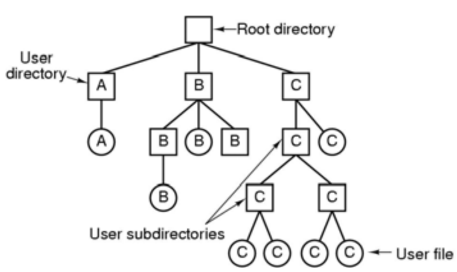
Directories



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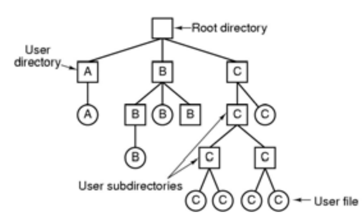
Directories



- Should we allow users to access other user’s files?
- Probably yes, but now we have to include security
- Also enables to have common resources (e.g. executables)

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Disk Space Management

- Whatever block size we choose then every file must occupy this amount of space as a minimum
- If we choose a large allocation unit, such as a cylinder then even a 1K file will occupy a cylinder
- Choosing a small allocation size (of say 1K) means that files will occupy many blocks which results in more time accessing the file as more blocks have to be located and accessed
- There is a compromise between a block size, fast access and wasted space. The usual compromise is to use a block size of 512 bytes, 1K bytes or 2K bytes

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Disk Space Management

- Some of the free blocks (which are no longer be free!) hold disc block numbers that are free
- The blocks that contain the free block numbers are linked together so we end up with a linked list of free blocks

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Disk Space Management

- We can calculate the maximum number of blocks we need to hold a complete free list (i.e. an empty disc) using the following reasoning:
  - Assume that we need a 16-bit number to store a block number (that is block numbers can be in the range 0 to 65535)
  - Assume that we are using a 1K block size
  - A block can hold 512 block addresses. That is, 1024*8 [number of bits in a block] / 16 [bits needed for a block address]
  - Assume that one of the addresses is used as a pointer to the next block that contains list of free blocks
  - For a 20Mb disc we need, at most, 41 blocks to hold all the free block numbers. That is, 20*1024 [maximum number of blocks] / 511 [number of disc addresses in a block]

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Disk Space Management

- A bit map is used to keep track of the free blocks
- That is, there is a bit for each block on the disc
- If the bit is 1 then the block is free. If the bit is zero, the block is in use
- To put it another way, a disc with *n* blocks requires a bit map with *n* entries
- The directory entry may also contain the attributes of the file (i-node) or may contain a pointer to a data structure

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Disk Space Management

- Consider a 20Mb disc with 1K blocks, then we can calculate the number of blocks needed to hold the disc map.
- A 20Mb disc has 20,480 (20 * 1024) blocks
- We need 20,480 bits for the map, or 2,560 (20,480 / 8) bytes
- A block can store 1024 bytes so we need 2.5 blocks (2560 / 1024) blocks to hold a complete bit map of the disc. This would obviously be rounded up to 3

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Disk Space Management

- Generally, bit maps requires a lesser number of blocks than a linked list
- Only when the disc is nearly full does the linked list implementation need fewer blocks

File Systems

Disk Space Management

Advantage of Linked List Over Bit Map

- When only a small amount of memory can be given over to keeping track of free blocks
- Assume, the operating system can only allow one block to be held in memory and that the disc is nearly full
- Using a bit map scheme, there is a good chance that the free block list will indicate that every block is being used
- This means a disc access must be done in order to get the next part of the bit map
- With a linked list scheme, once a block containing pointers of free blocks has been brought into memory then we will be able to allocate 511 blocks before doing another disc access