Filesystems

Requirements

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- close a file when we are done

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- create a new file
- delete a file
- open a file to access it
- read data from a file
- write data to a file
- close a file when we are done
- rename a file

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- create a new file
- delete a file
- open a file to access it
- read data from a file
- write data to a file
- close a file when we are done
- (rename a file)

That last one is actually a directory operation as we shall see in a moment

Filesystems

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And directories

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- delete a directory
- scan a directory for a filename or directory name
- add a file to a directory
- remove a file from a directory
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The last three are intertwined

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- efficient use of disk space

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- speed of access
- speed of update
- scalability to large numbers of files
- efficient use of disk space
- reliability
- protection/security
- simple backup and recovery

Filesystems

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Other filesystems are similar in their principles, though modern filesystems are immensely tweaked and tuned

They vary in their choice of datastructures and algorithms to implement the hierarchy for efficiency or other reasons

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Early files had structure, namely *records*

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A record is a fixed-size block of data, say 80 bytes

Records could only be read or written as a whole: this meant implementation on the hardware of the time was easy

Filesystems

Records

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Modern filesystems are *byte oriented* and you can access them however you please

Filesystems

Inodes

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The inode is a fixed size structure (stored on disk) that contains all the information about a file, its *metadata*

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- Reference count. The number of names this file has
- Pointers to areas on the disk where the actual data lives

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`foo.c`	23
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Originally just a table, these days clever datastructures are used to manage the large numbers of names we use

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Inodes

This is how a file can have many names: multiple directory entries referring to the same inode

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In some sense, the inode number is the true name of the file

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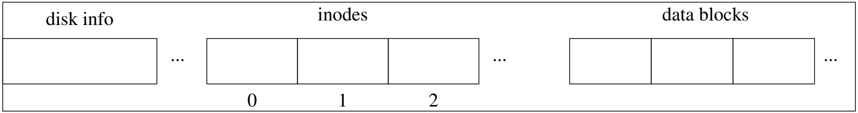
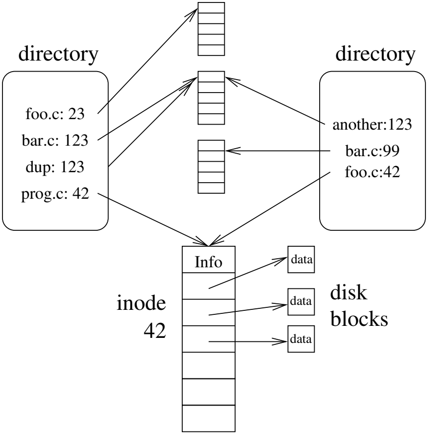


Disk blocks

Filesystems

Inodes



Filesystems

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- If the count reaches 0, the OS can free the inode and the disk blocks it refers to

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So it is possible for a program to create a new file (inc); open it (inc); delete it (dec); and still be able to read and write to it

The file will only disappear when the program ends (dec)

No other process can see this file: there is no name in any directory

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This can lead to wastage, e.g., a 1025 byte file might need two blocks, but uses just over half of the space. Though there are lot of tricks in real filesystems to avoid the worst of this

Filesystems

Inodes

Exercise Being of a fixed size an inode will only have room for a fixed number of block pointers. This will limit the size of a file. Read about *indirect blocks*

Exercise Read about *soft links* (similar to a Windows *shortcut*) that allows an inode to refer to a name (not a file, but a name of a file), and about the problems they solve

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Inodes

When a program opens a file, the OS must find where on disk the file lives

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This must be done for every file opened

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This must be done for every file opened

Caching can be used to great effect here: the kernel keeps copies of the inodes and directories in memory, rather than re-reading them every time

There's a great deal we haven't covered here!

Exercise Have a look at a modern filesystem

Exercise Solid state disks (SSDs) are common these days. What differences do they bring to the way filesystems should be implemented?

Filesystems

Other filesystems you might like to look at

- btrfs
- ext4
- FAT, VFAT
- FUSE
- GFS (Global File System)
- Google File System
- HFS+
- ISO 9660
- JFFS2
- Lustre
- NFS
- NTFS
- OCFS2
- procfs
- Reiser
- ReFS (Resilient File System)
- UnionFS
- ZFS

Also see “List of file systems” on Wikipedia