CS3281 / CS5281

Filesystems

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Overview

- A filesystem is an organized collection of files and directories
- The Linux kernel maintains a single hierarchical directory structure to organize all files in the system
  - Not like Windows where each drive (C, D, E, etc) has its own hierarchy
- Root directory is named /
  - Pronounced “slash”

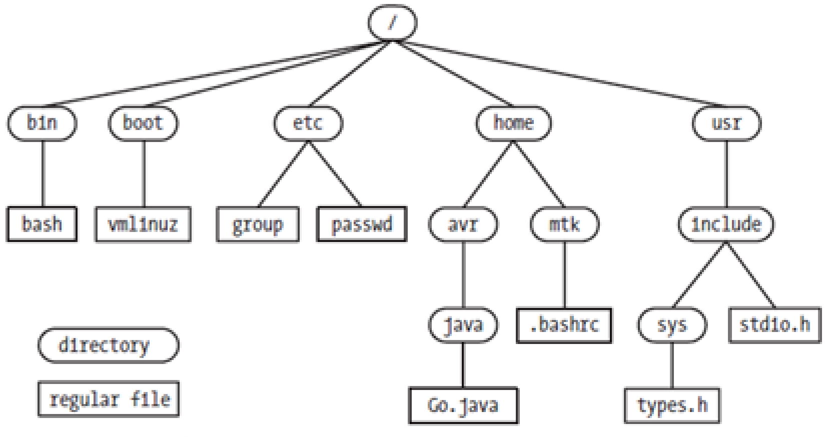
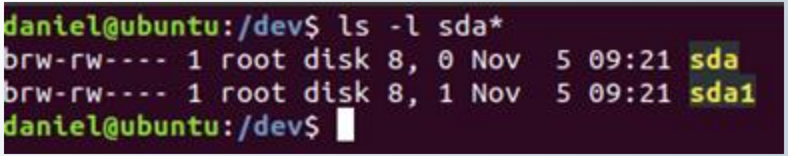


Figure 2-1: Subset of the Linux single directory hierarchy

*Figure from *The Linux Programming Interface* by Michael Kerrisk

File Types

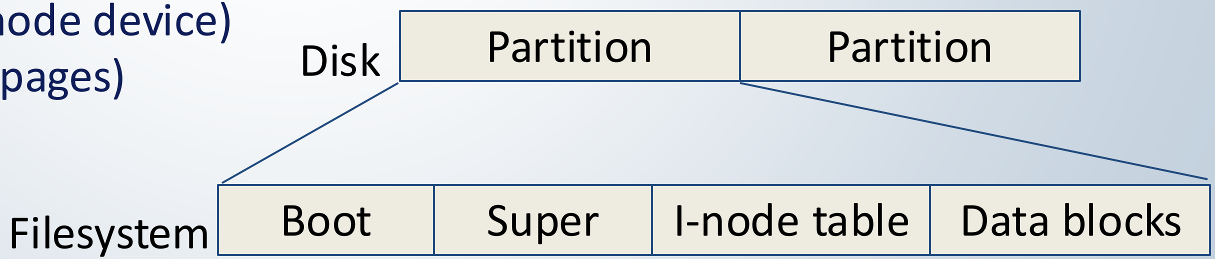
- Every file has a type
  - This is the character in the first column when you do ls -l
- Regular files: ordinary data files, like text files, executables, libraries
- Special files: files other than ordinary data files
  - Devices: represents a device (virtual or physical)
    - Block device (e.g., disk)
    - Character device (keyboard)
  - Named pipes (also called fifos)
  - Directories
  - Symbolic links
- Example on right: block device files



```
daniel@ubuntu:/dev$ ls -l sda*
brw-rw---- 1 root disk 8, 0 Nov  5 09:21 sda
brw-rw---- 1 root disk 8, 1 Nov  5 09:21 sda1
daniel@ubuntu:/dev$ 
```

Back to Filesystems

- A disk drive is divided into circles called tracks
  - Tracks are divided into sectors
    - Sectors are a series of physical blocks
      - Physical block: the smallest unit a disk can read or write
        - Usually 512 bytes (older disks) or 4096 bytes (newer disks)
- Each disk is divided into partitions
  - Each is a separate device under /dev
  - A partition holds either
    - *Filesystem* (on-disk structures)
    - Data area (raw-mode device)
    - Swap (for virtual pages)

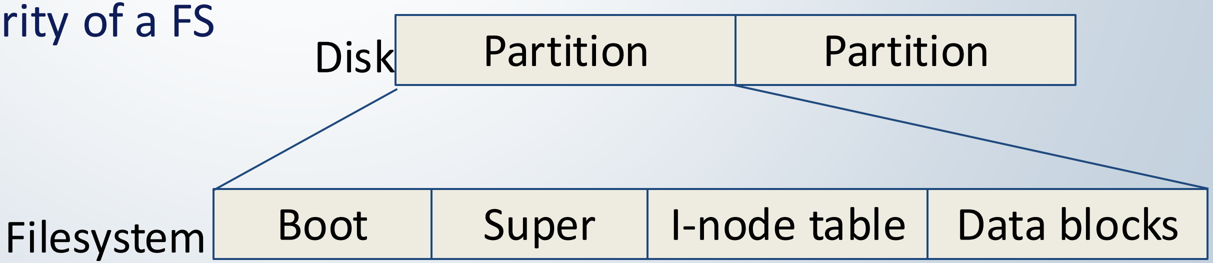


Disk: Partition | Partition

Filesystem: Boot | Super | I-node table | Data blocks

Filesystem Structure

- Boot block: always the first block in a filesystem (FS)
  - Not used by FS; contains info to boot the OS
  - Only one needed by OS
- Super block: contains parameter info about the filesystem
  - Size of the i-node table, size of logical blocks, size of the filesystem (in logical blocks)
- I-node table: contains one (unique) entry for every file in file system
  - Contains most of the “metadata” about individual file
- Data blocks: the (logical) blocks that contain the data for files and directories
  - This is the vast majority of a FS



Disk

Partition

Partition

Filesystem

Boot

Super

I-node table

Data blocks

I-Nodes

- Index nodes (i-nodes) contains the following metadata about a file
    - File type (for example, regular, char device, block device, directory, symbolic link)
    - Owner of the file
    - Group of the file
    - File access permissions for three categories: user (owner), group, other
    - Three timestamps:
        - Time of last access (ls -lu)
        - Time of last modification (default timestamp in ls -l)
        - Time of last status change (change to i-node info) (ls -lc)
    - Number of hard links (pathnames) to file
    - Size of the file (in bytes)
  - Number of blocks allocated to file
    - Pointers to the data blocks

Directories

- A directory is stored in a filesystem in a similar way as a regular file, but
  - It is marked as a directory in its i-node
  - It's a file with a special organization: it's a table consisting of filenames and i-node numbers
- Example is on the right
- Note: the i-node doesn't have a filename!
  - Implication: you can have multiple links to the same file!

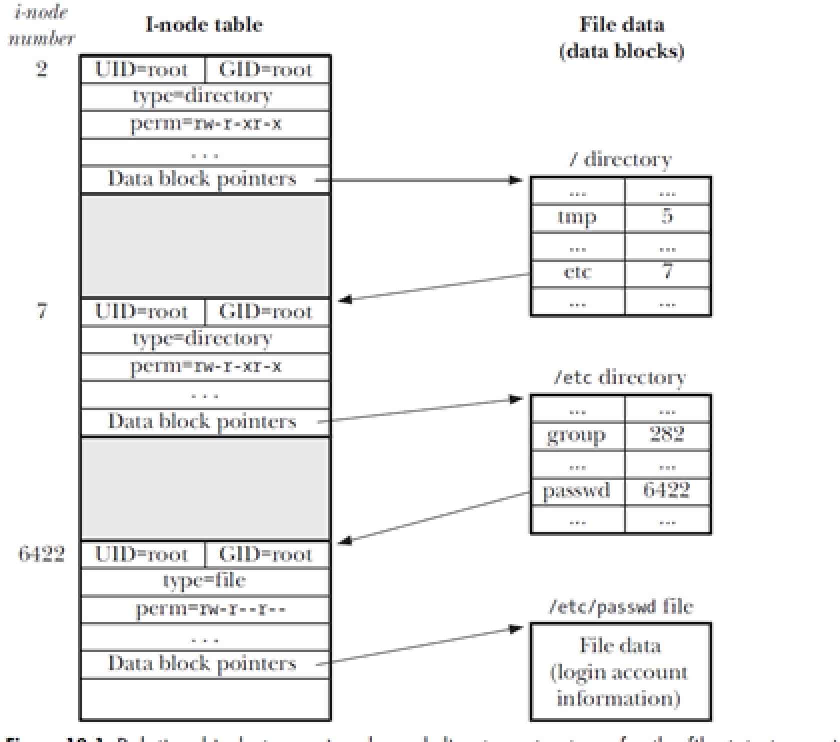


Figure 18-1: Relationship between i-node and directory structures for the file /etc/passwd

*Figure from *The Linux Programming Interface* by Michael Kerrisk

Data blocks

- How can files of very different sizes be supported?
  - One method: store pointers to the data blocks!
- Figure on the right shows how ext2 does this
  - Small files might fit entirely in direct pointers
- Bigger files use:
  - Indirect pointers
  - Double-indirect pointers
  - Triple-indirect pointers
- Advantages of pointers
  - Fixed-size i-node
    - But arbitrary size files
  - Store blocks non-contiguously

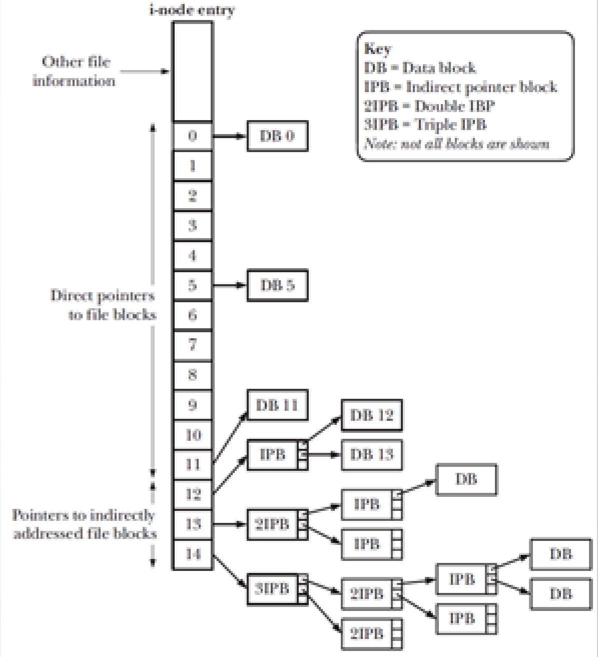
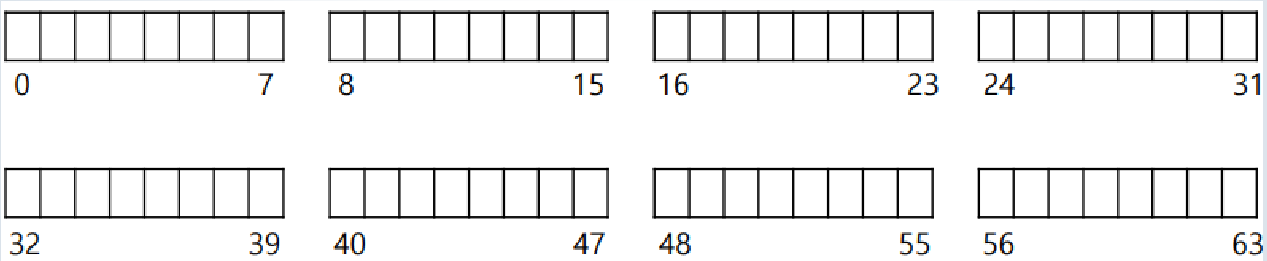


Figure 14-2: Structure of file blocks for a file in an *ext2* file system

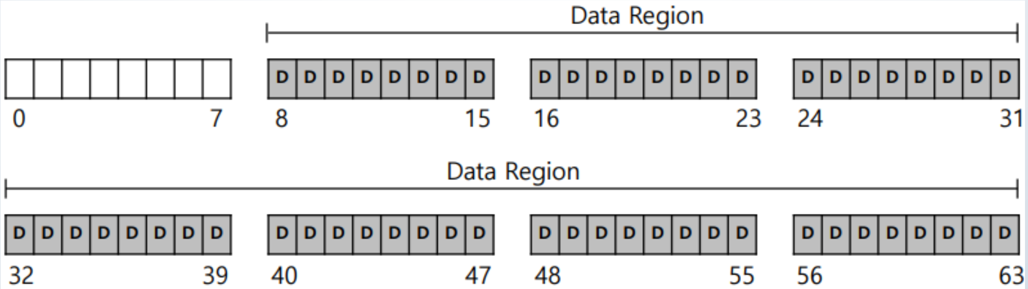
*Figure from *The Linux Programming Interface* by Michael Kerrisk

Very Simple File System (VSFS) Data Structures

- Divide disk into blocks
- Use one block size (4KB)
- Blocks are addressed from 0 to *N*-1 (N is the number of blocks)

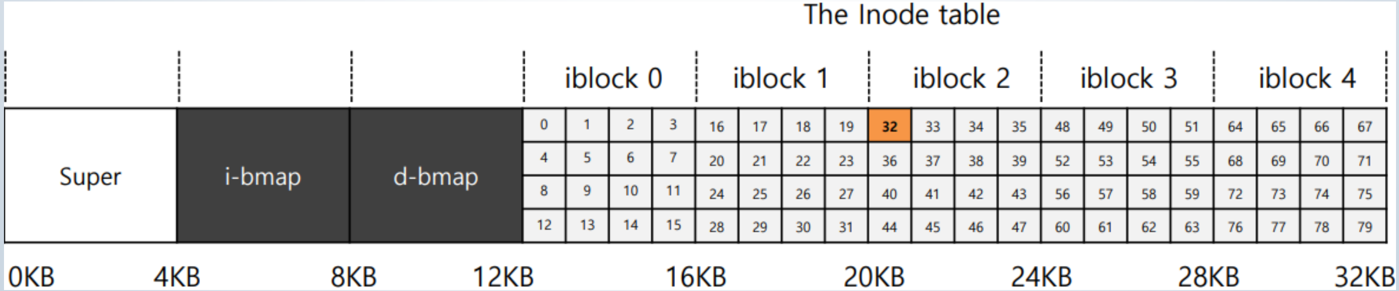


- Store user data in *data region* (e.g., files and directories)



The I-Node

- Index node (inode): array of nodes is indexed
- Each inode is identified by an i-number
  - Used for indexing an array of inodes
- Find the byte address for the inode with i-number 32
  - Compute the offset into the inode table: 32 * sizeof(inode) = 32 * 256 = 8192 (8KB)
  - Add the offset to start address of inode table: 12KB + 8KB = 20KB
- inodes are fetched using *sectors* (a block consists of sectors)
  - 512-byte sectors
  - Sector number: (20 * 1024)/512 = 40



The Inode table

			iblock 0				iblock 1				iblock 2				iblock 3				iblock 4			
Super	i-bmap	d-bmap	0	1	2	3	16	17	18	19	**32**	33	34	35	48	49	50	51	64	65	66	67
			4	5	6	7	20	21	22	23	36	37	38	39	52	53	54	55	68	69	70	71
			8	9	10	11	24	25	26	27	40	41	42	43	56	57	58	59	72	73	74	75
			12	13	14	15	28	29	30	31	44	45	46	47	60	61	62	63	76	77	78	79