The Linux Filesystem Explained

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A **filesystem** is a method and data structure used by operating systems to manage how data is stored, organized and retrieved. Each operating system has a different filesystem with different logical rules and structures. Also, every external storage device has a filesystem included. Without this, data storage & data retrieval would be impossible.

File systems perform multiple functions. They are responsible for the following:

- User data management
- Space management
- Filenames
- Directories
- Metadata
- Access permission & restriction
- Data integrity

In this article, we will perform a general overview of the Linux directory tree starting from the root directory. We will then discuss the functions of each directory, their relation with the Linux Kernel and some important command line utilities for interacting with the filesystem. We will also perform some examples to help clarify if this is the first time we'll be interacting with a Linux system.

We will be using WSL2 (*Windows Subsystem for Linux*) with Ubuntu, although this article applies for every other installation method and distribution. We will use the Windows terminal and `bash` commands to illustrate examples.

We will not cover the installation process for each of the components mentioned. Links for that purpose can be found below:

- WSL2 installation
- Ubuntu installation on WSL2
- Windows terminal installation

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Table of Contents

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Overview

As stated earlier, a filesystem is a way for operating systems to interact with the data saved in hard drives. Each operating system family has its filesystem. Without going into much detail, we can mention the three main operating systems used today:

1. The Windows filesystem

The current Windows filesystem dates back to MS-DOS *(Microsoft Disk Operating System)*, the command-line-based operating system initially used to run the Windows operating system. MS-DOS used letters to assign drives, which, back then, represented physical floppy disks. Some years later, internal hard drives were made available, and Microsoft designated the letter `C` for its internal hard drive. Currently, all Windows program files are installed on `C:\Program Files`.

2. The Linux filesystem

Linux is a UNIX-like operating system. The UNIX structure was fundamentally different from MS-DOS when created, and upon evolving, Linux adopted most of its conventions, including the filesystem. Linux, unlike Windows, has a hierarchical file structure; it contains a root directory and subdirectories. Also, Linux treats most of its components as files.

Interestingly, not all Linux distributions manage their directory structure equally. For example, a given distribution may use `/media` for mounting external drives, while another may use `/run`. Still, detailed information regarding directory structures for a given distribution can be found on its respective documentation site. Ubuntu's filesystem structure can be found here.

3. The macOS filesystem

MacOS is more similar to Linux since it evolved from a similar UNIX-like operating system called BSD. It has the same hierarchical file structure, but the executables are not binary-compatible with Linux.

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Preparing our environment

1. A word of caution

A word of caution before we begin: Some of the directories we'll review, such as `/boot`, contain vital information for the Linux operating system to function correctly. We could easily break our system if we were to access them using `root` privileges and accidentally delete or modify their content.

An excellent option for avoiding messing up when tinkering around is to use a Virtual Machine; if we were to break anything, we could quickly restore the entire system from a snapshot or even do a fresh reinstall.

2. Choosing a distribution, an emulator and a shell

Given that we already have a Linux distribution installed, we can start by getting our hands on a terminal emulator and a shell. All distributions have at least one terminal emulator and one shell already installed. The most common shell is `bash`. As for terminal emulators, it depends on which family of distributions and which desktop manager we installed.

In our case, we'll be using Ubuntu running on Windows WSL2. We'll use the windows Terminal as our terminal emulator and `zsh` as our shell. The WSL2 setup process is out of the scope of this article but will be covered in the future.

We can confirm which shell is currently used by the system:

Code

```
ps -p $$
```

Output

```
PID TTY          TIME CMD
128 pts/0    00:00:02 zsh
```

The output tells us we're currently using the `zsh` shell, which has a process ID PID = 128 (*not to worry, we'll discuss processes more in-depth in the* `/proc` *section*).

Ubuntu is a distribution based on Debian, so the filesystem will be similar for the two. Also, we'll be able to use either the `apt` or the `dpkg` package managers for installing terminal utilities.

3. Installing two useful packages

Many of the packages we'll be using already come preinstalled on Ubuntu. For the remaining ones, we can use the two package managers mentioned, depending on our preference:

- `apt` : The native Ubuntu package manager.
- `dpkg` : The native Debian package manager.

For this example, we'll be using Ubuntu's `apt`.

We'll first install the `tree` package for visualizing our directory structure in a tree-like diagram.

We can confirm we don't yet have the `tree` package:

Code

```
tree
```

Output

```
Command 'tree' not found, but can be installed with:
sudo apt install tree
```

We can then install it:

Code

```
sudo apt install tree
```

The shell will prompt us for our `sudo` password since we're installing this package for all users, including root (*similar to Windows administrator permissions*).

Upon inputting it, we can see what `apt` will install for us:

Output

```
The following NEW packages will be installed:
  tree
0 upgraded, 1 newly installed, 0 to remove and 0 not upgraded.
```

We can also install the `htop` command line utility used for monitoring and managing active processes, similar to the Task manager application on Windows.

Code

```
sudo apt install htop
```

Now, we can begin exploring the Linux filesystem.

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root (/)

This is the root directory and is the uppermost directory in the Linux system containing all the files, device data and system information.

If we're executing our terminal emulator as a user different than `root`, the shell will start in `/home/ourusername`. This is the home directory for our user. We can confirm where we are by executing the following command:

Code

```
pwd
```

Output

```
/home/pabloagnck
```

Now that we know where we are, we can change directories to the `root` directory by executing one of the following:

Code

```
cd ../..

pwd
```

Code

```
cd /

pwd
```

The two periods `..` in the first prompt allow us to change the directory to the relative parent directory we are currently in. If we do that two times with a slash `/` in between, we can change directories two times, arriving at the `root` directory `/`.

Output

```
/
```

If we execute the `tree` command without any parameters, it will recursively go over every directory and file on `/` and list it. We don't want that. Instead, we can specify a recursion level which will list only the immediate directories.

Code

```
tree -L 1
```

Output

```
.
|-- bin -> usr/bin
|-- boot
|-- dev
|-- etc
|-- home
|-- lib -> usr/lib
|-- lost+found
|-- media
|-- mnt
|-- opt
|-- proc
|-- root
|-- run
|-- sbin -> usr/sbin
|-- snap
|-- srv
|-- sys
|-- tmp
|-- usr
`-- var
```

We can see that 21 directories were listed:

- The first directory `.` denotes the current directory `/`.
- The ones with the arrow symbol on the right `->` denote symbolic links, or `symlinks`. This means they are links pointing to another directory.

Each directory has an `owner` and a `group` assigned. If we recall, the file structure in Linux is hierarchical. It's based on a set of standards called the FHS *(File Hierarchy Standard)*; all directories immediately below `/` will have `root` as their owner. We can confirm this by using the *list* `ls` command with the *single column* output parameter `-l`:

Code

```
ls -l
```

Output

```
lrwxrwxrwx   1 root root       7 Oct 25 16:34 bin -> usr/bin
drwxr-xr-x   2 root root    4096 Apr 18  2022 boot
drwxr-xr-x  10 root root    3040 Jan 27 22:19 dev
drwxr-xr-x  79 root root    4096 Jan 27 22:19 etc
drwxr-xr-x   3 root root    4096 Dec 16 12:07 home
-rwxrwxrwx   1 root root 1939720 Dec 31  1969 init
lrwxrwxrwx   1 root root       7 Oct 25 16:34 lib -> usr/lib
lrwxrwxrwx   1 root root       9 Oct 25 16:34 lib32 -> usr/lib32
lrwxrwxrwx   1 root root       9 Oct 25 16:34 lib64 -> usr/lib64
lrwxrwxrwx   1 root root      10 Oct 25 16:34 libx32 -> usr/libx32
drwx------   2 root root   16384 Dec 16 12:06 lost+found
drwxr-xr-x   2 root root    4096 Oct 25 16:34 media
drwxr-xr-x   6 root root    4096 Dec 16 12:06 mnt
drwxr-xr-x   2 root root    4096 Oct 25 16:34 opt
dr-xr-xr-x 263 root root       0 Jan 27 22:19 proc
drwx------   4 root root    4096 Dec 16 23:31 root
drwxr-xr-x   7 root root     140 Jan 27 22:45 run
lrwxrwxrwx   1 root root       8 Oct 25 16:34 sbin -> usr/sbin
drwxr-xr-x   8 root root    4096 Oct 25 16:36 snap
drwxr-xr-x   2 root root    4096 Oct 25 16:34 srv
dr-xr-xr-x  11 root root       0 Jan 27 22:19 sys
drwxrwxrwt   3 root root    4096 Jan 27 22:19 tmp
drwxr-xr-x  14 root root    4096 Oct 25 16:34 usr
drwxr-xr-x  13 root root    4096 Oct 25 16:35 var
```

From left to right:

- The first column denotes if we're dealing with a file, folder, link or block, as well as the permissions:
  - The first character can be `-`, `d`, `l` or `b`, denoting files, directories, links or blocks.
  - The second, third and fourth characters denote permissions for the owner: `r` for read, `w` for write, `x` for execute. If we're missing a character on any given field, that specific permission is not granted.
  - The fourth, fifth and sixth characters denote the `group` permissions in the same format as above.
  - The last three characters denote permissions for anyone else in the same format as before.
- The third column denotes the `owner`.
- The fourth column denotes the `group`.
- The fifth column denotes the size in bytes.
- The sixth column denotes the last update date and time.
- The last column denotes the name of the file, directory or link.

We can read further documentation on the `ls` command by consulting its manual pages, using the `man` command:

Code

```
man ls
```

As we go over the directory structure, we will notice that, as opposed to Windows, the directory & system file names are intuitive; they're acronyms for actual names describing their purpose. This is also part of the UNIX philosophy and applies not just to the directory structure but to commands and file naming conventions.

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/bin

The `/bin` directory stands for **binary** and contains the most basic executables such as `ls`, `man` and `cat`. In modern distributions, it's usually linked to `/usr/bin`.

We can list the contents of the `/bin` directory. The output will be large since our Linux system has multiple executables already installed. We can truncate our output to the ten first entries by piping our `ls` output into the `head` command:

Code

```
cd /bin

ls | head -10
```

Output

```
2to3-2.7
NF
X11
[
aa-enabled
aa-exec
aa-features-abi
add-apt-repository
addpart
addr2line
```

We can also filter the `ls` output to look for a given executable, in this case, the actual `ls`:

Code

```
ls ls
```

Output

```
ls
```

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/boot

The `/boot` directory contains everything necessary for the operating system to boot. Here, we can find the following:

- The bootloader
- The initial ram system `initramfs`
- The Linux Kernel files

We need to be careful with this directory since deleting or modifying files could cause our system to stop working.

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/dev

The `/dev` directory stands for **devices** and contains file representations of all virtual and physical devices on our system. These include but are not exclusive to:

- External hard drives (`/sda`)
- Internal hard drives (`/sda`)
- RAM (`/ram`)
- USB device topologies (`/bus/devices`)
- Standard input and standard output (`/stdin`, `/stdout`)
- Other serial ports
- Every other peripheral we connect to our system

This can be confusing at first, but we must remember that for Linux, almost anything is represented by a file (*even directories*).

We can get all the RAM devices on `/dev`:

Code

```
cd /dev

ls -l ram*
```

Output

```
brw------- 1 root root 1,  0 Jan 28 14:02 ram0
brw------- 1 root root 1,  1 Jan 28 14:02 ram1
brw------- 1 root root 1, 10 Jan 28 14:02 ram10
brw------- 1 root root 1, 11 Jan 28 14:02 ram11
brw------- 1 root root 1, 12 Jan 28 14:02 ram12
brw------- 1 root root 1, 13 Jan 28 14:02 ram13
brw------- 1 root root 1, 14 Jan 28 14:02 ram14
brw------- 1 root root 1, 15 Jan 28 14:02 ram15
brw------- 1 root root 1,  2 Jan 28 14:02 ram2
brw------- 1 root root 1,  3 Jan 28 14:02 ram3
brw------- 1 root root 1,  4 Jan 28 14:02 ram4
brw------- 1 root root 1,  5 Jan 28 14:02 ram5
brw------- 1 root root 1,  6 Jan 28 14:02 ram6
brw------- 1 root root 1,  7 Jan 28 14:02 ram7
brw------- 1 root root 1,  8 Jan 28 14:02 ram8
brw------- 1 root root 1,  9 Jan 28 14:02 ram9
```

Most of these block files don't contain any information but can be written by programs.

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/etc

The `/etc` directory stands for **etcetera** and contains all system-wide configuration files. It also contains startup scripts. Applications installed for all users will have system-wide settings in this directory.

We can display the head of the `/etc` directory:

Code

```
ls | head -10
```

Output

```
PackageKit
X11
adduser.conf
alternatives
apache2
apparmor
apparmor.d
apport
apt
bash.bashrc
```

One important thing to remember is that this directory belongs to the `root` user. That means we cannot edit files inside the `/etc` directly within our user shell without using the super user do `sudo` command.

It is also not recommended to modify the settings of conventional executables here since they will most likely get overwritten with an update. That's what the `/home/.config` directory is for, which we'll visit shortly.

The `/etc` directory is also extremely important when managing users in our Linux system since here; we will find the `sudoers` configuration file in charge of managing user credentials and permissions.

If we were to add a new user to our system, we would have to login as `root` and include username, user password and permissions here (*not directly, but by using the* `visudo` *command, which in turn writers to the* `sudoers` *file*).

We can take a look at our `sudoers` file to explore its contents:

Code

```
sudo cat sudoers
```

We will skip some lines and refer to the *User privilege specification* section:

Output

```
# User privilege specification
root    ALL=(ALL:ALL) ALL

# Members of the admin group may gain root privileges
%admin ALL=(ALL) ALL

# Allow members of group sudo to execute any command
%sudo   ALL=(ALL:ALL) ALL
```

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/home

The `/home` directory contains a collection of the non-root user's folders. When a user is created, a directory with its username is also generated on `/home`. The username folder is created with the username as the `owner` and the username group as the `group`. This makes this folder accessible by the user without needing `root` permissions.

We can list the contents of the `/home` directory:

Code

```
cd /home

tree -L 1
```

Output

```
.
`-- pabloagnck
```

Since we only have one non-root user set up, we are shown the current directory and the username folder.

If we go one level deeper, we can see the contents of the user's home folder:

Code

```
cd pabloagnck/

ls -la
```

Here we use the `ls` command along with the `la` parameters. As we have seen, the *list* parameter `l` lists the content in a columnar format, while the *all* parameter `a` lists all content, including hidden files and folders. This is important because usually, the user's home folder contains user-level configuration folders and files hidden by default (*prepended by a dot* `.`).

Output

```
drwxr-x--- 5 pabloagnck pabloagnck  4096 Jan 27 22:46 .
drwxr-xr-x 3 root       root        4096 Dec 16 12:07 ..
-rw------- 1 pabloagnck pabloagnck  1182 Dec 16 23:22 .bash_history
-rw-r--r-- 1 pabloagnck pabloagnck   220 Dec 16 12:07 .bash_logout
-rw-r--r-- 1 pabloagnck pabloagnck  3771 Dec 16 12:07 .bashrc
drwxr-xr-x 9 pabloagnck pabloagnck  4096 Jan 28 14:35 .cache
drwxr-xr-x 8 pabloagnck pabloagnck  4096 Dec 17 13:46 .config
drwxr-xr-x 5 pabloagnck pabloagnck  4096 Dec 16 23:33 .local
-rw-r--r-- 1 pabloagnck pabloagnck     0 Dec 16 12:07 .motd_shown
-rw-r--r-- 1 pabloagnck pabloagnck 91419 Dec 17 11:42 .p10k.zsh
-rw-r--r-- 1 pabloagnck pabloagnck   807 Dec 16 12:07 .profile
-rw------- 1 pabloagnck pabloagnck   184 Dec 16 23:36 .python_history
-rw-r--r-- 1 pabloagnck pabloagnck    10 Dec 16 23:39 .shell.pre-oh-my-zsh
-rw-r--r-- 1 pabloagnck pabloagnck     0 Jan 27 22:46 .sudo_as_admin_successful
-rw------- 1 pabloagnck pabloagnck  5579 Dec 17 13:44 .viminfo
-rw-r--r-- 1 pabloagnck pabloagnck   165 Dec 17 13:40 .wget-hsts
-rw-r--r-- 1 pabloagnck pabloagnck  1060 Dec 17 13:48 .zshenv
```

If we pay attention, we can notice three things:

- As usual, the first file we get is the current directory folder denoted by `.`, but we also get a second file, `..`. This is the parent directory file; in this case, since our parent directory is `/home`, its owner and group are `root`.
- We have several hidden files, each denoting a configuration file for a specific application.
- We also have several hidden folders, each denoting a configuration folder, the cache folder, or the libraries folder (*inside* `.local/`) containing user-wide libraries and application settings.

By default, our system includes all these files directly in `/home/pabloagnck`, but this can become a mess quickly, so the best practice is to try to have every configuration file live inside the `.config` directory *(we can not do this by simply dragging the files inside* `.config`*. Instead, we need to specify a separate variable which is out of* *the scope of this article)*. This directory is analogous to `/etc` for system-wide configuration. In fact, most applications usually include a user-level configuration file template and a system-wide one as well.

As we can see, we don't have any `Desktop`, `Documents`, or `Downloads` folders. This is because we're using WSL2, which does not need all these home directories.

One important thing to remember is that a typical user will not be able to see other users' content without superuser permission.

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/lib, /lib32, /lib64

The `/lib`, `/lib32` and `/lib64` stand for **libraries** and contain files that applications can use to perform various functions. They hold the shared libraries our system's executables will need. `/lib/systemd/system`, for example, hosts unit files used in Linux services, a crucial component in any Linux system.

Typically, we will have two additional `/lib` directories apart from `/lib`:

- `/lib32` : Libraries for 32-bit programs
- `/lib64` : Libraries for 64-bit programs

As with the `/bin` directory, the `/lib` directories will be symbolically linked to their corresponding `/usr/lib` directory:

Code

```
cd /

ls -l lib*
```

Output

```
lrwxrwxrwx 1 root root  7 Oct 25 16:34 lib -> usr/lib
lrwxrwxrwx 1 root root  9 Oct 25 16:34 lib32 -> usr/lib32
lrwxrwxrwx 1 root root  9 Oct 25 16:34 lib64 -> usr/lib64
lrwxrwxrwx 1 root root 10 Oct 25 16:34 libx32 -> usr/libx32
```

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/lost+found

The `/lost+found` directory contains pieces of broken files after a system crash. It also includes programs that were already unlinked (*i.e. their name had been erased*) but still opened by some process when the system halted. Most distributions contain a predefined space in `/lost+found` for the filesystem check utility `fsck` to deposit unlinked files.

/media

The `/media` directory contains the files representing the mounted drives. If we were to attach an external hard drive to our operating system, `/media` would be one of the options where the system could mount it. Each distribution handles this differently, but it has become the standard for the system's automatic mounts.

In short, it serves as a mount point for system-mounted devices, but we can also use it to mount devices manually.

We can connect an external hard drive in our system to exemplify (*currently, WSL2 does not support flash drive mount, only external hard drives*).

For our case, since we're using WSL2, we'll mount our device to our subsystem first:

Code

```
# First, we invoke an elevated PowerShell instance
start-process PowerShell -verb runas

# Then we get the current Windows mount Point of our USB device
GET-CimInstance -query "SELECT * from Win32_DiskDrive"
```

Output

```
DeviceID           Caption                         Partitions
--------           -------                         ----------
\\.\PHYSICALDRIVE1 Microsoft Virtual Disk          1
\\.\PHYSICALDRIVE0 NVMe SAMSUNG MZVL21T0HCLR-00B00 5
\\.\PHYSICALDRIVE2 WD Elements 25A3 USB Device     1
```

We're looking for a WD External Hard Drive, so we mount the corresponding device to our subsystem:

Code

```
wsl --mount \\.\PHYSICALDRIVE2 --bare
```

We use the `--bare` flag since the `NTFS` filesystem is not natively supported by Linux.

Output

```
The operation completed successfully.
```

We can confirm that our device exists in our WSL2 subsystem:

Code

```
lsblk
```

Output

```
NAME    MAJ:MIN RM   SIZE RO TYPE MOUNTPOINTS
sdd       8:48   0   7.3T  0 disk
|-sdd1    8:49   0    16M  0 part
`-sdd2    8:50   0   7.3T  0 part
```

This tells us that our device exists as `sdd` and has two partitions available: `sdd1` and `sdd2`.

Since the filesystem for our external hard drive is `NTFS`, we will need two additional packages:

Code

```
sudo apt install ntfs-3g fuse3
```

We will then need to mount the device manually. When mounting devices in Linux, it's important to choose a directory we create; if we mount it directly at `/media`, the whole directory will become the mount point, and we don't want that. We instead want to isolate the mounted device by creating a folder as mount point:

Code

```
cd /media

sudo mkdir WD
```

We already know the device and partition names, thus can proceed as such:

Code

```
cd WD

sudo mount -t ntfs /dev/sdd2 .
```

The dot at the end of the statement tells the system to mount our device in the current directory `/media/WD`. We need to mount using `sudo` since `/media` is a `root` folder, and the `mount` command also requires superuser permissions.

We can confirm that our device was mounted correctly:

Code

```
df -aTh
```

Output

```
/dev/sdd2      fuseblk      7.3T   74G  7.3T   1% /media/WD
```

We can also list the contents of our mounted partition:

Code

```
ls -la
```

Output

```
drwxrwxrwx 1 root root    0 Jan 25 13:47 '$RECYCLE.BIN'
drwxrwxrwx 1 root root 4096 Jan 26 11:25  .
drwxr-xr-x 3 root root 4096 Jan 28 17:48  ..
drwxrwxrwx 1 root root    0 Jan 26 11:53 'System Volume Information'
drwxrwxrwx 1 root root    0 Jan 25 10:47 'Transfer to QNAP'
```

All folders have `root` as owner and group since we mounted using `sudo` permissions.

Finally, we must remember to unmount our device. If we're still on `/media/WD`, we need to change directories first:

Code

```
cd ..

sudo umount WD
```

If we want to remove this mount point, we can do so:

Code

```
sudo rm -r WD
```

We also have to unmount the device from PowerShell:

Code

```
wsl --unmount \\.\PHYSICALDRIVE2
```

Output

```
The operation completed successfully.
```

This was too much work for mounting an external drive to our Linux system because we're using a subsystem which has limitations. Still, if we're working on a Linux machine, this process is straightforward, specifically on user-friendly distributions such as Ubuntu, and can be further customized using configuration files.

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/mnt

The `/mnt` directory stands for **mount** and was the original mounting point for external devices. Nowadays, most distributions use `/media` instead, although `/mnt` is still a temporary mount point.

WSL2 mounts devices on `/mnt` if Linux natively supports their filesystem.

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/opt

The `/opt` directory stands for **optional** and contains installed software from external sources. We can also use this directory to host the software we create.

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/proc

The `/proc` directory stands for **processes** and contains information about system processes. Every process executed will have a directory inside `/proc` and be assigned a unique `pid` (*process ID*). Continuing with the UNIX *"almost everything is treated as a file"* philosophy, processes are no exception.

This directory is extremely helpful when developing software in a Linux environment. We can see which processes are firing and obtain detailed information about their nature.

We can list the content of our `/proc` directory:

Code

```
cd /proc

ls -l
```

Output

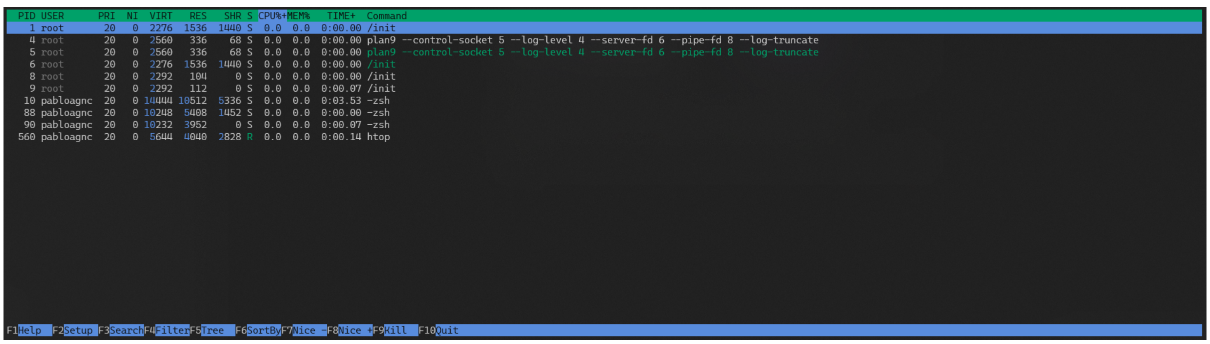
```
dr-xr-xr-x  9 root       root                    0 Jan 27 22:19 1
dr-xr-xr-x  9 pabloagnck pabloagnck              0 Jan 27 22:19 10
dr-xr-xr-x  9 pabloagnck pabloagnck              0 Jan 27 22:41 13
dr-xr-xr-x  9 root       root                    0 Jan 27 22:41 4
dr-xr-xr-x  9 pabloagnck pabloagnck              0 Jan 28 00:22 552
dr-xr-xr-x  9 root       root                    0 Jan 27 22:41 8
dr-xr-xr-x  9 pabloagnck pabloagnck              0 Jan 27 22:19 88
dr-xr-xr-x  9 root       root                    0 Jan 27 22:41 9
dr-xr-xr-x  9 pabloagnck pabloagnck              0 Jan 27 22:41 90
...
```

We can view & monitor the active processes by using the `htop` utility we installed earlier:

Code

```
htop
```

Output



We can see that the system is currently running ten processes. Looking at the first column, we can identify each process by its respective PID.

Processes 1 through 9 are being run by `root`, while the remaining ones are being run by our user.

To exit the `htop` utility, we use the `q` key. If we go back to `/proc` and look for process `88`, we can see a directory. We then `cd` into it and list its contents:

Code

```
cd /proc/88

ls -l
```

Output

```
total 0
-r--r--r--  1 pabloagnck pabloagnck 0 Jan 28 00:32 arch_status
dr-xr-xr-x  2 pabloagnck pabloagnck 0 Jan 28 00:32 attr
-r--------  1 pabloagnck pabloagnck 0 Jan 28 00:32 auxv
-r--r--r--  1 pabloagnck pabloagnck 0 Jan 28 00:32 cgroup
--w-------  1 pabloagnck pabloagnck 0 Jan 28 00:32 clear_refs
-r--r--r--  1 pabloagnck pabloagnck 0 Jan 27 22:41 cmdline
-rw-r--r--  1 pabloagnck pabloagnck 0 Jan 27 22:41 comm
-rw-r--r--  1 pabloagnck pabloagnck 0 Jan 28 00:32 coredump_filter
-r--r--r--  1 pabloagnck pabloagnck 0 Jan 28 00:32 cpuset
lrwxrwxrwx  1 pabloagnck pabloagnck 0 Jan 28 00:32 cwd -> /
-r--------  1 pabloagnck pabloagnck 0 Jan 28 00:32 environ
lrwxrwxrwx  1 pabloagnck pabloagnck 0 Jan 27 22:41 exe -> /usr/bin/zsh
```

As displayed, there is a link to the binary executable `/usr/bin/zsh` being run, which makes sense since we're using the `zsh` shell for this precise action.

One important thing to know is that the first process is the `/init` process. This process refers to the initialization system and is in charge of creating the following processes. It is up from boot to shut down and will permanently be assigned a PID of `1` since it will always be the first process to start.

We can view the contents of any file by using the *concatenate* command `cat`:

Code

```
cat cmdline
```

Output

```
-zsh%
```

§

/root

The `/root` directory is the home directory for the `root` user. It contains `root` user configuration folders & files.

We cannot simply change directories into `/root` since we need `root` permissions. To be able to view the contents, we are going to change to the `root` shell by using the superuser command:

Code

```
sudo su
```

We need to be extremely careful since we are now in the `root` shell and can delete virtually anything without the system prompting us for a password.

We can now change directories to the root home directory:

Code

```
cd /root

ls -l
```

Output

In our case, we don't have anything since we have not configured anything `root` user-related.

To exit the `root` shell, we type `exit` and return to the user shell.

§

/run

The `/run` directory is somewhat new and has different uses depending on each distribution. It is a `tempfs` filesystem meaning it runs in ram and is deleted upon system shutdown. This is why some distributions use it to mount devices such as external hard drives.

It usually contains information regarding which users are currently logged in and active daemons running in our system, among others.

§

/sbin

The `/sbin` directory stands for **system binaries** and, similar to the `/bin` directory, contains executables that the system administrator would use. `/sbin` is often a link to `/usr/sbin`.

Differences between `/bin` and `/sbin` have a historical component as well as a functional one; historically, `/sbin` used to contain statically linked executables, thus having fewer library dependencies. Functionally, `/sbin` includes utilities typically only run by a sysadmin with `root` privileges and `/bin` contains everything else. On some systems, non-root users don't have `/sbin` in their path, so they must use the full path to run these tools.

We can find executables such as `adduser`, `addgroup`, `chgpasswd`, `chroot`, `fsck`, and other utilities typically used by a system administrator.

§

/snap

The `/snap` directory is specific to Linux distributions using the `systemd` init system since it contains all packages related to Snap, a software packaging and deployment system developed by Canonical. Snap packages are self-contained and run differently than conventional executables.

§

/srv

The `/srv` directory stands for **service** and contains files related to web or FTP servers. If we were running a server on our Linux system, it would serve as an access point for external users. It can be isolated from the rest of the directories by hosting it in a different partition, making file sharing and accessing by external users safe.

The `/srv` directory is usually empty and not commonly used for most distributions, although there are exceptions such as OpenSUSE, which uses it as the default for web servers.

§

/sys

The `/sys` directory stands for **system** and serves as a direct way to interact with the kernel. It contains information about devices, drivers and kernel features running on our system. As with `/run`, it resides on RAM and is deleted when we shut down the system. Its content structure is very similar to the `/proc` directory, although the first one is better organized.

We can compare the contents of both directories:

Code

```
cd /sys

tree -L 1
```

Output

```
.
|-- block
|-- bus
|-- class
|-- dev
|-- devices
|-- firmware
|-- fs
|-- kernel
`-- module
```

Code

```
cd /proc

tree -L 1
```

Output

```
.
|-- 1
|-- 1101
|-- 1102
|-- 1103
|-- 1106
|-- 1162
|-- 1164
|-- 1165
|-- 2070
|-- 2114
|-- 4
|-- acpi
|-- buddyinfo
|-- bus
|-- cgroups
|-- cmdline
|-- config.gz
|-- consoles
|-- cpuinfo
|-- crypto
|-- devices
|-- diskstats
|-- dma
|-- driver
|-- execdomains
|-- filesystems
|-- fs
|-- interrupts
|-- iomem
|-- ioports
|-- irq
|-- kallsyms
|-- kcore
|-- key-users
...
```

§

/tmp

The `/tmp` directory stands for **temporary** and contains files temporarily stored by applications. It also resides on RAM and is deleted upon system shutdown.

§

/usr

The `/usr` directory stands for **Unix System Resources** and contains all user binaries, libraries and documentation for the user applications, as opposed to the `/bin` directory used by the system and root user.

As we discussed, directories such as `/usr/bin`, `/usr/lib` and `/usr/sbin` are linked to `/bin`, `/lib` and `/sbin`, respectively. This is done for compatibility purposes.

We can take a look at its contents by executing the `tree` command:

Code

```
cd /usr

tree
```

Output

```
.
|-- bin
|-- games
|-- include
|-- lib
|-- lib32
|-- lib64
|-- libexec
|-- libx32
|-- local
|-- sbin
|-- share
`-- src
```

We can see we have 12 folders:

- The `bin` folder contains all user executables.
- The `games` folder contains installed user games.
- The `include` folder includes the header files for C compilers such as `stdio.h` and `stdlib.h`.
- The `lib`, `lib32` and `lib64` folders contain libraries required by the applications installed on `/usr/bin` or `/usr/sbin`
- The `libexec` folder contains system daemons and system utilities executed by other programs.
- The `libx32` folder contains software using the x86-64 instruction set but with 32-bit pointer size.
- The `local` folder contains user applications installed by source code.
- The `sbin` folder contains system binaries.
- The `share` folder contains larger user applications.
- The `src` folder contains source code applications, such as the Kernel source and headers.

The `/usr` directory is used differently depending on our distribution. It is also used differently between developers; one developer might adhere to the FHS standards, while another might choose a different folder to install his application.

§

/var

The `/var` directory stands for **variable** and contains directories and files expected to grow in size. A good example would be the `/var/log` folder, which includes system and user logs. Also, some web servers, such as Apache place can place their files here.

We can display the contents in the `/var` directory:

Code

```
cd /var

tree
```

Output

```
.
|-- backups
|-- cache
|-- crash
|-- lib
|-- local
|-- lock -> /run/lock
|-- log
|-- mail
|-- opt
|-- run -> /run
|-- snap
|-- spool
`-- tmp
```

We can view the contents of our `apt` package manager log files:

Code

```
cd /var/log/apt

ls -l
```

Output

```
total 112
drwxr-xr-x 2 root root    4096 Jan 28 17:50 .
drwxrwxr-x 7 root syslog  4096 Dec 16 12:07 ..
-rw-r--r-- 1 root root   20324 Jan 28 17:50 eipp.log.xz
-rw-r--r-- 1 root root   26247 Jan 28 17:50 history.log
-rw-r----- 1 root adm    50511 Jan 28 17:50 term.log
```

If we want to see the command history, we can concatenate `history.log`:

Code

```
cat history.log
```

Output

```
...
Start-Date: 2023-01-27  22:47:18
Commandline: apt install tree
Requested-By: pabloagnck (1000)
Install: tree:amd64 (2.0.2-1)
End-Date: 2023-01-27  22:47:19

Start-Date: 2023-01-28  17:50:29
Commandline: apt install fdisk
Requested-By: pabloagnck (1000)
Install: fdisk:amd64 (2.37.2-4ubuntu3), libfdisk1:amd64 (2.37.2-4ubuntu3, automatic)
End-Date: 2023-01-28  17:50:30
```

The command history for `apt` is displayed in ascending order.

We can also filter by specific date by piping our concatenation into a `grep -A` command:

Code

```
cat history.log | grep -A 10 '2023-01-28'
```

The `-A n` flag displays `n` lines posterior to our date match.

Output

```
Start-Date: 2023-01-28  17:50:29
Commandline: apt install fdisk
Requested-By: pabloagnck (1000)
Install: fdisk:amd64 (2.37.2-4ubuntu3), libfdisk1:amd64 (2.37.2-4ubuntu3, automatic)
End-Date: 2023-01-28  17:50:30
```

As we can see, this directory is extremely useful for any system administrator since it shows, in detail, each user's history log, among many other things.

§

Conclusions

We've reviewed the entire Linux filesystem and the functions each directory serves. At first, it might seem intimidating and confusing, but the reality is that the Linux filesystem is more optimal than other filesystems, such as Windows's.

Getting familiarized with the Linux folder structure is vital if we are to learn more advanced subjects. When getting more involved in the Linux ecosystem, we'll inevitably spend a fair amount of time on these directories.

Lastly, this was just an overview, but if we'd like to get more intimate with the Linux filesystem, we can always consult the official documentation. The Linux community is vast, active and heavily involved. We can use forums as an alternative way to learn or stick with using `man`, the masterfully crafted utility providing manual pages for virtually any package out there.

§

References

- Ubuntu, Official Ubuntu Documentation
- Ubuntu, LinuxFilesystemTreeOverview
- Filesystem Hierarchy Standard
- Microsoft, Mount a Linux disk in WSL2

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