Rocky Linux Admin Guide (English version)

A book from the Documentation Team

Version : 2025/07/07

Rocky Documentation Team

Table of contents

1. Licence

RockyLinux offers Linux courseware for trainers or people wishing to learn how to administer a Linux system on their own.

RockyLinux materials are published under Creative Commons-BY-SA. This means you are free to share and transform the material, while respecting the author's rights.

BY : **Attribution**. You must cite the name of the original author.

SA : **Share Alike**.

- Creative Commons-BY-SA licence : https://creativecommons.org/licenses/by-sa/4.0/

The documents and their sources are freely downloadable from:

- https://docs.rockylinux.org
- https://github.com/rocky-linux/documentation

Our media sources are hosted at github.com. You'll find the source code repository where the version of this document was created.

From these sources, you can generate your own personalized training material using mkdocs. You will find instructions for generating your document here.

How can I contribute to the documentation project?

You'll find all the information you need to join us on our git project home page.

We wish you all a pleasant reading and hope you enjoy the content.

2. Learning Linux with Rocky

The Administrator's Guide is a collection of educational documents focused on System Administrators. They can be used by future System Administrators trying to get up to speed, by current System Administrators who would like a refresher, or by any Linux user who'd like to learn more about the Linux environment, commands, processes, and more. Like all documents of this type, it will evolve and update over time.

We start with Introduction to Linux, which outlines Linux, distributions, and the whole ecosystem around our operating system.

User Commands contains essential commands for getting up to speed with Linux. More experienced users should also consult the following chapter on Advanced Linux Commands.

The VI Text Editor deserves its own chapter. While Linux comes with many editors, VI is one of the most powerful. Other commands sometimes use identical syntax to VI (`sed` comes to mind). So, knowing something about VI, or at least demystifying its essential functions (how to open a file, save, quit or quit without saving), is very important. The user will become more comfortable with the other functions of VI as they use the editor. An alternative would be to use nano which comes installed by default in Rocky Linux. While not as versatile, it is simple to use, straightforward, and gets the job done.

We can then get into the deep functioning of Linux to discover how the system addresses:

- User Management
- File Systems
- Process Management

Backup and Restoration is essential info for the System Administrator. Linux comes with many software solutions to enhance backups (rsnapshot, lsyncd, etcetera.). It is valuable to know the essential components of the backup that exist within the operating system. We investigate two tools: `tar` and the less widespread `cpio` in this chapter.

System Startup is also an important read because management of the system during the boot process has evolved significantly in recent years since the arrival of the systemd.

Final chapters address Task Management, Implementing the Network, and Software Management including installation.

3. Introduction to the Linux Operating System

In this chapter, you will learn about GNU/Linux distributions.

Objectives: In this chapter, you will learn how to:

- ✓ Describe the features and possible architectures of an operating system.
- ✓ Recount the history of UNIX and GNU/Linux.
- ✓ Choose the right Linux distribution for your needs.
- ✓ Explain the philosophy of Free and Open-source Software.
- ✓ Discover the usefulness of the shell.

🏁 **generalities**, **linux**, **distributions**

Knowledge: ⭐
Complexity: ⭐

Reading time: 10 minutes

3.1 What is an operating system?

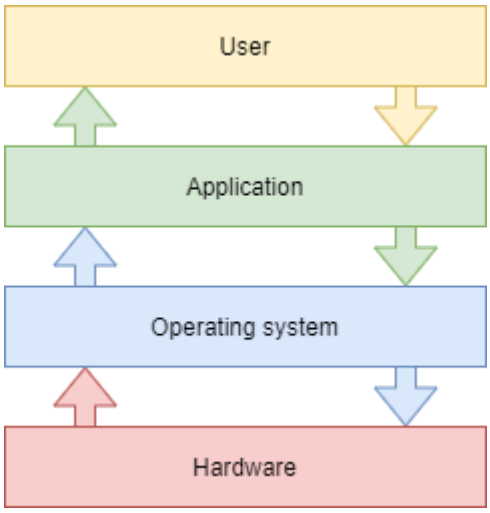
Linux, UNIX, BSD, Windows, and MacOS are all **operating systems**.

Abstract

An operating system is a **set of programs that manages the available resources of a computer**.

As part of this management of resources, the operating system has to:

- Manage the **physical** or **virtual** memory.
- The **physical memory** is made up of the RAM bars and the processor cache memory, which are used for program execution.
- The **virtual memory** is a location on the hard disk (the **swap** partition) that allows the unloading of the physical memory and the saving of the current state of the system during the electrical shutdown of the computer.
- Intercept **access to peripherals**. Software can rarely access hardware directly (except for graphics cards for specific needs).
- Provide applications with proper **task management**. The operating system is responsible for scheduling processes to occupy the processor
- **Protect files** from unauthorized access.
- **Collect information** about programs in use or in progress.



3.2 Generalities UNIX - GNU/Linux

3.2.1 History

UNIX

- **1964 — 1968**: MULTICS (MULTiplexed Information and Computing Service) is developed for MIT, Bell Labs (AT&T) and General Electric.

- **1969 — 1971**: After the withdrawal of Bell (1969) and then General Electric from the project, two developers, Ken Thompson and Dennis Ritchie (joined later by Brian Kernighan), judging MULTICS to be too complex, begin development of UNIX (UNiplexed Information and Computing Service). While it was created in Assembly language, the creators of UNIX eventually developed the B language and then the C language (1971) and completely rewrote UNIX. As it was developed in 1970, the reference (epoch) date for the start of time of UNIX/Linux systems is set at January 01, 1970.

C remains one of the most popular programming languages today. A low-level language close to the hardware, it allows the operating system to be adapted to any machine architecture having a C compiler.

UNIX is an open and evolving operating system that has played a major role in the history of computing. It forms the basis for many other systems, such as Linux, BSD, MacOS, etc.

UNIX remains relevant today (HP-UX, AIX, Solaris, etc.).

GNU Project

- **1984**: Richard Matthew Stallman launched the GNU (GNU's Not Unix) Project, which aims to establish a **free** and **open** Unix system, in which the more important tools are: gcc compiler, bash shell, Emacs editor and so on. GNU is a Unix-like operating system. The development of GNU, started in January 1984, is known as the GNU Project. Many of the programs in GNU are released under the auspices of the GNU Project; those we call GNU packages.
- **1990**: GNU's own kernel, the GNU Hurd, was started in 1990 (before Linux was started).

MINIX

- **1987**: Andrew S. Tanenbaum develops MINIX, a simplified UNIX, to teach operating systems in a simple way. Mr. Tanenbaum makes the source code of his operating system available.

Linux

- **1991**: A Finnish student, **Linus Torvalds**, creates an operating system that runs on his personal computer and names it Linux. He publishes his first version, called 0.02, on the Usenet discussion forum, and other developers help him improve his system. The term Linux is a play on words between the founder's first name, Linus, and UNIX.
- **1993**: The Debian distribution is created. Debian is a non-commercial, community-based distribution. Originally developed for use on servers, it is well-suited for this role; however it is a universal system, usable on a personal computer as well. Debian forms the basis for many other distributions, such as Mint or Ubuntu.
- **1994**: The commercial distribution Red Hat is created by the company Red Hat, which is today the leading distributor of the GNU/Linux operating system. Red Hat supports the community version Fedora and until recently the free distribution CentOS.
- **1997**: The KDE desktop environment is created. It is based on the Qt component library and the C++ development language.
- **1999**: The GNOME desktop environment is created. It is based on the GTK+ component library.
- **2002**: The Arch distribution is created. Its distinctive is that it offers rolling release (continuous update).
- **2004**: Ubuntu is created by the Canonical company (Mark Shuttleworth). It is based on Debian but includes free and proprietary software.
- **2021**: Rocky Linux is created, based on Red Hat distribution.

Info

Dispute over the name: although people are accustomed to calling the Linux operating system verbally, Linux is strictly a kernel. We must not forget the development and contribution of the GNU project to the open source cause, so! I prefer to call it the GNU/Linux operating system.

3.2.2 Market share

Despite its prevalence, Linux remains relatively unknown to the general public. Linux is hidden within **smartphones**, **televisions**, **internet boxes**, etc. Almost **70% of the websites** in the world are hosted on a Linux or UNIX server!

Linux equips about **3% of personal computers** but more than **82% of smartphones**. The **Android** operating system, for example, uses a Linux kernel.

Linux equips 100% of the top 500 supercomputers since 2018. A supercomputer is a computer designed to achieve the highest possible performance with the techniques known during its design, especially concerning computing speed.

3.2.3 Architectural design

- The **kernel** is the first software component.
- It is the heart of the Linux system.
- It manages the hardware resources of the system.
- The other software components must go through it to access the hardware.
- The **shell** is a utility that interprets user commands and ensures their execution.
- Main shells: Bourne shell, C shell, Korn shell, and Bourne-Again shell (bash).
- **Applications** are user programs including but not limited to:
- Internet browsers
- Word processors
- Spreadsheets

Multi-task

Linux belongs to the family of time-sharing operating systems. It divides processing time between several programs, transparently switching from one to another for the user. This implies:

- Simultaneous execution of several programs.
- Distribution of CPU time by the scheduler.
- Reduction of problems caused by a failed application.
- Reduced performance in the event of too many programs running.

Multi-user

MULTICS's purpose was to allow users to work from several terminals (screen and keyboard) on a single computer (which was very expensive at the time). Inspired by this operating system, Linux kept this ability to work with several users simultaneously and independently, each with its user account with memory space and access rights to files and software.

Multi-processor

Linux can work with multi-processor computers or with multi-core processors.

Multi-platform

Linux is written in a high-level language that can be adapted to different platforms during compilation. This allows it to run on:

- Home computers (PC and laptop)
- Servers (data and applications)
- Portable computers (smartphones and tablets)
- Embedded systems (car computers)
- Active network elements (routers and switches)
- Household appliances (TVs and refrigerators)

Open

Linux is based on recognized standards such as POSIX, TCP/IP, NFS, and Samba, which allow it to share data and services with other application systems.

3.2.4 The UNIX/Linux Philosophy

- Treat everything as a file.
- Value portability.
- Do one thing and do it well.
- KISS: Keep It Simple Stupid.
- "UNIX is a simple operating system, but you have to be a genius to understand the simplicity." (**Dennis Ritchie**)
- "Unix is user-friendly. It just isn't promiscuous about which users it's friendly with." (**Steven King**)

3.3 The GNU/Linux distributions

A Linux distribution is a **consistent set of software** assembled around the Linux kernel, ready to be installed along with the necessary components to manage itself (installation, removal, configuration). There are **associative** or **community** distributions (Debian, Rocky) and **commercial** distributions (Red Hat, Ubuntu).

Each distribution offers one or more **desktop environments**, and provides a set of pre-installed software and a library of additional software. Configuration options (kernel or services options for example) are specific to each distribution.

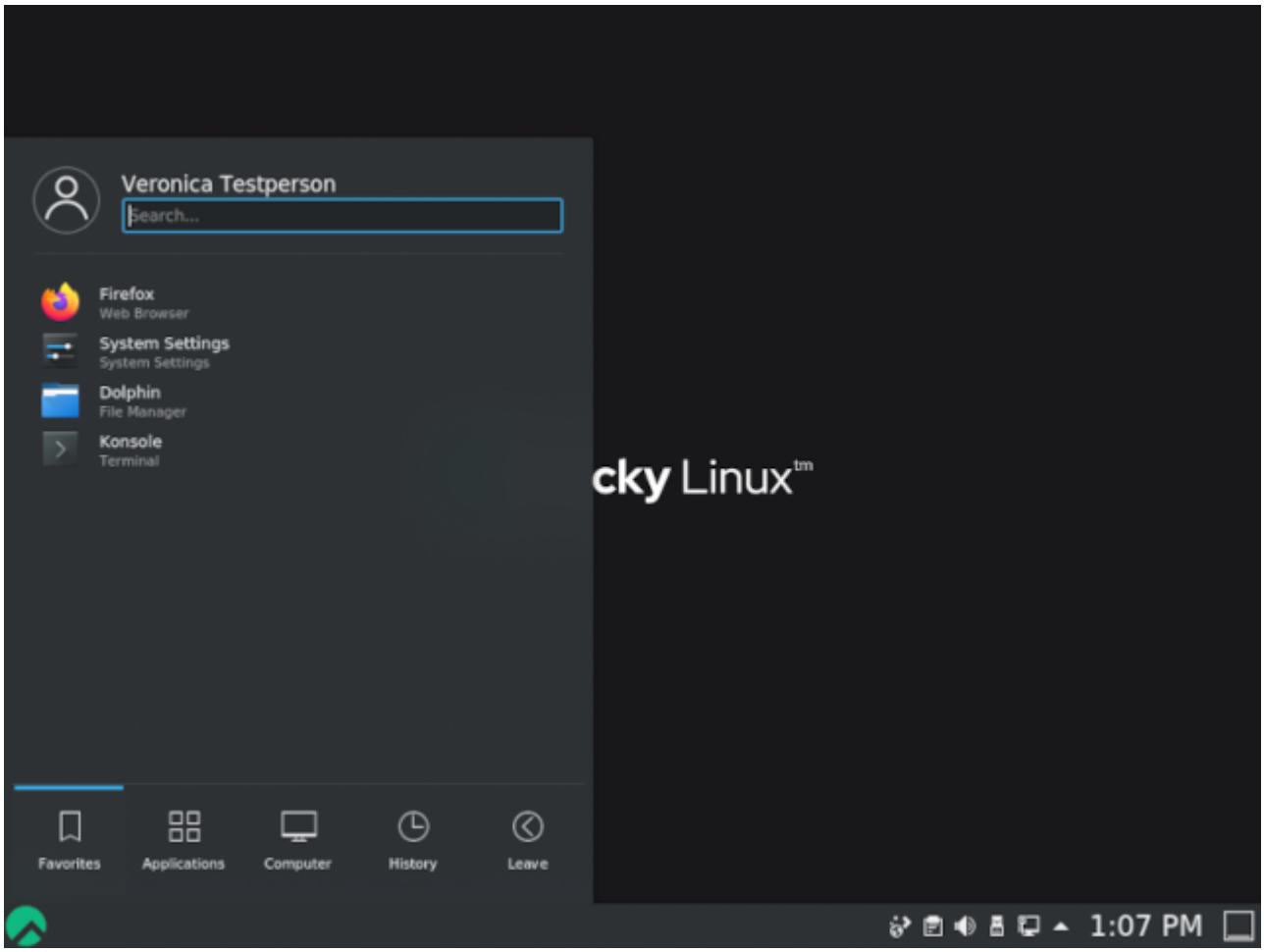
This principle allows distributions to be geared to **beginners** (Ubuntu, Linux Mint...) or fully customizable for **advanced users** (Gentoo, Arch); distributions can also be more adept with **servers** (Debian, Red Hat) or **workstations** (Fedora).

3.3.1 Desktop environments

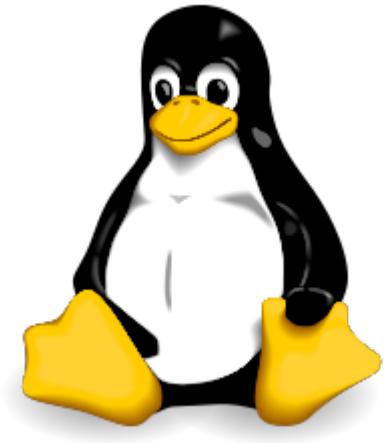
There are many graphic environments such as **GNOME**, **KDE**, **LXDE**, **XFCE**, etc. There is something for everyone, and their **ergonomics** hold their own against Microsoft or Apple systems.

So why is there so little enthusiasm for Linux, when this system is practically **virus free**? Could it be because so many editors (Adobe) and manufacturers (Nvidia) do not play the free game and do not provide a version of their software or **drivers** for GNU/Linux? Perhaps it's fear of change, or the difficulty of finding where to buy a Linux computer, or too few games distributed under Linux. That last excuse, at least, shouldn't be true for long, with the advent of the game engine Steam for Linux.

The **GNOME 3** desktop environment no longer uses the concept of desktop but that of GNOME Shell (not to be confused with the command line shell). It serves as a desktop, a dashboard, a notification area and a window selector. The GNOME desktop environment is based on the **GTK+** component library.



The **KDE** desktop environment is based on the **Qt** component library. It is traditionally recommended for users familiar with a Windows environment.



3.3.2 Free / Open Source

A Microsoft or Mac operating system user must purchase a license to use the system. This license has a cost, although it is usually transparent (the price of the license is included in the price of the computer).

The Free Software movement provides mostly free distributions in the **GNU/Linux** world.

Free does not mean free!

Open Source: the source code is available, so consulting and modifying it under certain conditions is possible.

A free software is necessarily open-source, but the opposite is not true since open-source software is distinct from the freedom offered by the GPL license.

GNU GPL (GNU General Public License)

The **GPL** guarantees the author of a software its intellectual property, but allows modification, redistribution or resale of software by third parties, provided that the source code is included with the software. The GPL is the license that came out of the **GNU** (GNU is Not UNIX) project, which was instrumental in creating Linux.

It implies:

- The freedom to run the program, for any purpose.
- The freedom to study how the program works and adapt it to your needs.
- The freedom to redistribute copies.
- The freedom to improve the program, and publish those improvements for the benefit of the whole community.

On the other hand, even products licensed under the GPL can have a cost. This is not for the product itself, but the **guarantee that a team of developers will continue to work on it to make it evolve and troubleshoot errors, or even provide support to users**.

3.4 Areas of use

A Linux distribution excels for:

- **Servers**: HTTP, email, groupware, file sharing, etc.
- **Security**: Gateway, firewall, router, proxy, etc.
- **Central computers**: Banks, insurance, industry, etc.
- **Embedded systems**: Routers, Internet boxes, SmartTVs, etc.

Linux is a suitable choice for hosting databases or websites, or as a mail server, DNS or firewall. In short, Linux can do just about anything, which explains the quantity of specific distributions.

3.5 Shell

3.5.1 Generalities

The **shell**, known as *command interface*, allows users to send commands to the operating system. It is less visible today since the implementation of graphical interfaces, but remains a privileged means on Linux systems which do not all have graphical interfaces and whose services do not always have a setting interface.

It offers a real programming language including classical structures (loops, alternatives) and common constituents (variables, passing of parameters, and sub-programs). It allows the creation of scripts to automate certain actions (backups, creation of users, system monitoring, etc.).

There are several types of shells available and configurable on a platform or according to the user's preference. A few examples include:

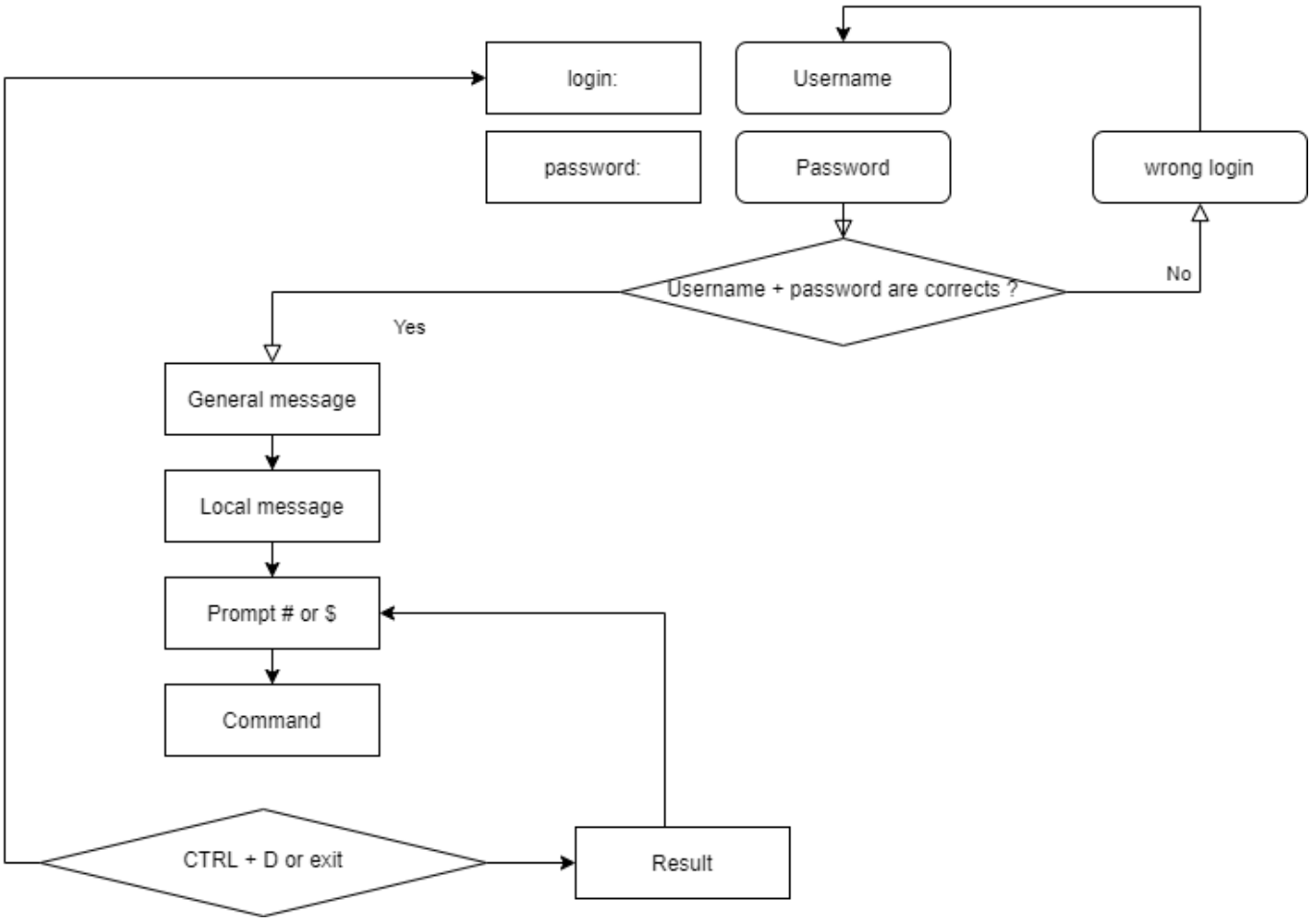
- sh, the POSIX standard shell
- csh, command-oriented shell in C
- bash, Bourne-Again Shell, Linux shell

3.5.2 Functionalities

- Command execution (checks the command given and executes it).

- Input/Output redirection (returns data to a file instead of writing it on the screen).
- Connection process (manages the user's connection).
- Interpreted programming language (allowing the creation of scripts).
- Environment variables (access to information specific to the system during operation).

3.5.3 Principle



3.6 Check your Knowledge

✔ An operating system is a set of programs for managing the available resources of a computer:

- True
- False

✔ The operating system is necessary to:

- Manage physical and virtual memory
- Allow direct access to peripherals
- Subcontract the management of tasks to the processor
- Collect information about the programs used or in use

✔ Among these personalities, which ones participated in the development of UNIX:

- Linus Torvalds
- Ken Thompson
- Lionel Richie
- Brian Kernighan
- Andrew Stuart Tanenbaum

✔ The original nationality of Linus Torvalds, creator of the Linux kernel, is:

- Swedish
- Finnish
- Norwegian
- Flemish
- French

✔ Which of the following distributions is the oldest:

Debian

Slackware

Red Hat

Arch

✔ Is the Linux kernel:

Multi-tasking

Multi-user

Multi-processor

Multi-core

Cross-platform

Open

✔ Is free software necessarily open-source?

True

False

✔ Is open-source software necessarily free?

True

False

✔ Which of the following is not a shell:

Jason

Jason-Bourne shell (jbsh)

Bourne-Again shell (bash)

C shell (csh)

Korn shell (ksh)

4. Commands for Linux Users

In this chapter you will learn Linux commands and how to use them.

Objectives: In this chapter, future Linux administrators will learn how to:

✓ **Move** within the system tree.
✓ **Create** a text file, **display** its contents and **modify** it.
✓ **Use** the most useful Linux commands.

🏁 **user commands**, **linux**

Knowledge: ⭐
Complexity: ⭐

Reading time: 40 minutes

4.1 Generalities

Current Linux systems have graphical utilities dedicated to the work of an administrator. However, it is important to be able to use the interface in command line mode for several reasons:

- The majority of system commands are common to all Linux distributions, which is not the case for graphical tools.
- It can happen that the system does not start correctly but that a backup command interpreter remains accessible.
- Remote administration is done on the command line with an SSH terminal.
- In order to preserve server resources, the graphical interface is either not installed or launched on demand.
- Administration is done by scripts.

Learning these commands allows the administrator to connect to a Linux terminal, to manage its resources and files, to identify the station, the terminal, and the connected users, etc.

4.1.1 The users

The user of a Linux system will be defined in the `/etc/passwd` file, by:

- A **login name**, more commonly called "login", containing no spaces.
- A numeric identifier: **UID** (User Identifier).
- A group identifier: **GID** (Group Identifier).
- A **command interpreter**, e.g., a shell, which can be different from one user to another.
- A **connection directory**, e.g., the **home directory**.

In other files the user will be defined by:

- A **password**, which is encrypted before being stored (`/etc/shadow`).
- A **command prompt**, or **prompt** login, which is symbolized by a
- `#` for administrators
- and a `$` for other users (`/etc/profile`).

Depending on the security policy implemented on the system, the password will require a certain number of characters and meet certain complexity requirements.

Among the existing command interpreters, the **Bourne-Again Shell** (`/bin/bash`) is the one most frequently used. It is assigned by default to new users. For various reasons, advanced Linux users can choose alternative shells such as the Korn Shell (`ksh`), the C Shell (`csh`), etc.

The user's login directory is by convention stored in the `/home` directory of the workstation. It will contain the user's personal data and the configuration files of his applications. By default, at login, the login directory is selected as the current directory.

A workstation-type installation (with graphical interface) starts this interface on terminal 1. Linux being multi-user, it is possible to connect several users several times, on different **physical terminals** (TTY) or **virtual terminals** (PTS). Virtual terminals are available within a graphical environment. A user switches from one physical terminal to another using ⎇ Alt + Fx from the command line or using ^ Ctrl + ⎇ Alt + Fx.

4.1.2 The shell

Once the user is connected to a console, the shell displays the **command prompt**. It then behaves like an infinite loop, repeating the same pattern with each statement entered:

- Displays the command prompt.
- Reads the command.
- Analyzes the syntax.
- Substitutes special characters.
- Executes the command.
- Displays the command prompt.
- Etc.

The key sequence ^ Ctrl + C is used to interrupt a running command.

The use of a command generally follows this sequence:

```
command [option(s)] [argument(s)]
```

The name of the command is often **lower case**.

A space separates each item.

Short options begin with a dash (`-l`), while **long options** begin with two dashes (`--list`). A double dash (`--`) indicates the end of the option list.

It is possible to group some short options together:

```
ls -l -i -a
```

is equivalent to:

```
ls -lia
```

There can be several arguments after an option:

```
ls -lia /etc /home /var
```

In the literature, the term "option" is equivalent to the term "parameter," which is more commonly used in programming. The optional side of an option or argument is symbolized by enclosing it in square brackets `[` and `]`. When more than one option is possible, a vertical bar called a "pipe" separates them `[a|e|i]`.

4.2 General commands

4.2.1 `apropos`, `whatis` and `man` commands

It is impossible for an administrator at any level to know all the commands and options in detail. A manual is usually available for all installed commands.

`apropos` command

The command `apropos` allows you to search by keyword within these manual pages:

Options	Description
`-s`, `--sections list` or `--section list`	Limited to manual sections.
`-a` or `--and`	Displays only the item matching all the provided keywords.

Example:

```
$ apropos clear
clear (1)            - clear the terminal screen
clear_console (1)    - clear the console
clearenv (3)         - clear the environment
clearerr (3)         - check and reset stream status
clearerr_unlocked (3) - nonlocking stdio functions
feclearexcept (3)    - floating-point rounding and exception handling
```

```
fwup_clear_status (3) - library to support management of system firmware
updates
klogctl (3)           - read and/or clear kernel message ring buffer; set
console_loglevel
sgt-samegame (6)      - block-clearing puzzle
syslog (2)            - read and/or clear kernel message ring buffer; set
console_loglevel
timerclear (3)        - timeval operations
XClearArea (3)        - clear area or window
XClearWindow (3)      - clear area or window
XSelectionClearEvent (3) - SelectionClear event structure
```

To find the command that will allow changing the password of an account:

```
$ apropos --exact password  -a change
chage (1)             - change user password expiry information
passwd (1)            - change user password
```

`whatis` command

The `whatis` command displays the description of the command passed as argument:

```
whatis clear
```

Example:

```
$ whatis clear
clear (1)             - clear the terminal screen
```

`man` command

Once found by `apropos` or `whatis`, the manual is read by `man` ("Man is your friend"). This set of manuals is divided into 8 sections, grouping information by topic, the default section being 1:

1. Executable programs or commands.
2. System calls (functions given by the kernel).
3. Library calls (functions given by the library).
4. Special files (usually found in /dev).
5. File Formats and conventions (configuration files such as etc/passwd).
6. Games (such as character-based applications).
7. Miscellaneous (e.g. man (7)).
8. System administration commands (usually only for root).
9. Kernel routines (non-standard).

Information about each section can be accessed by typing `man x intro`, where `x` is the section number.

The command:

```
man passwd
```

will tell the administrator about the passwd command, its options, etc. While a:

```
man 5 passwd
```

will inform him about the files related to the command.

Navigate through the manual with the arrows `↑ Up` and `↓ Down`. Exit the manual by pressing the `Q` key.

4.2.2 `shutdown` command

The `shutdown` command allows you to **electronically shut down** a Linux server, either immediately or after a certain period of time.

```
shutdown [-h] [-r] time [message]
```

Specify the shutdown time in the format `hh:mm` for a precise time, or `+mm` for a delay in minutes.

To force an immediate stop, use the word `now` in place of the time. In this case, the optional message is not sent to other users of the system.

Examples:

```
[root]# shutdown -h 0:30 "Server shutdown at 0:30"
[root]# shutdown -r +5
```

Options:

Options	Remarks
`-h`	Shuts down the system electronically.
`-r`	Restarts the system.

4.2.3 `history` command

The `history` command displays the history of commands that have been entered by the user.

The commands are stored in the `.bash_history` file in the user's login directory.

Example of a history command

```
$ history
147 man ls
148 man history
```

Options	Comments
`-w`	Writes the current history to the history file.
`-c`	Deletes the history of the current session (but not the contents of the `.bash_history` file).

- Manipulating history:

To manipulate the history, the following commands entered from the command prompt will:

Keys	Function
`!` + `!`	Recalls the last command placed.
`!` + `N`	Recalls the command by its number in the list.
`!` + `string`	Recalls the most recent command beginning with the string.
`↑ Up`	Navigates through your history working backward in time from the most recent command.
`↓ Down`	Navigates through your history working forward in time.

4.2.4 Auto-complete

Auto-completion is a great help.

- Completes commands, entered paths, or file names.
- Press the `Tab ⇥` key to complete the entry in the case of a single solution.
- In the case of multiple solutions, press `Tab ⇥` a second time to see options.

If double-pressing the `Tab ⇥` key presents no options, then there is no solution to the current completion.

4.3 Display and Identification

4.3.1 `clear` command

The `clear` command clears the contents of the terminal screen. More accurately, it shifts the display so that the command prompt is at the top of the screen on the first line.

On a physical terminal, the display will be permanently hidden, whereas in a graphical interface, a scrollbar will allow you to go back in the history of the virtual terminal.

> **Tip**
>
> ^ Ctrl + L will have the same effect as the `clear` command

4.3.2 `echo` command

The `echo` command is used to display a string of characters.

This command is most commonly used in administration scripts to inform the user during execution.

The `-n` option indicates no newline output string (by default, newline output string).

```
shell > echo -n "123";echo "456"
123456

shell > echo "123";echo "456"
123
456
```

For various reasons, the script developer may need to use special sequences (starting with a `\` character). In this case, the `-e` option will be stipulated, allowing interpretation of the sequences.

Among the frequently used sequences, we can mention:

Sequence	Result
`\a`	Sends a sonar beep
`\b`	Back
`\n`	Adds a line break
`\t`	Adds a horizontal tab
`\v`	Adds a vertical tab

4.3.3 `date` command

The `date` command displays the date and time. The command has the following syntax:

```
date [-d yyyyMMdd] [format]
```

Examples:

```
$ date
Mon May 24 16:46:53 CEST 2021
$ date -d 20210517 +%j
137
```

In this last example, the `-d` option displays a given date. The `+%j` option formats this date to show only the day of the year.

> **Warning**
>
> The format of a date can change depending on the value of the language defined in the environment variable `$LANG`.

The date display can follow the following formats:

Option	Format
`+%A`	Locale's full weekday name (e.g., Sunday)
`+%B`	Locale's full month name (e.g., January)
`+%c`	Locale's date and time (e.g., Thu Mar 3 23:05:25 2005)
`+%d`	Day of month (e.g., 01)
`+%F`	Date in `YYYY-MM-DD` format
`+%G`	Year
`+%H`	Hour (00..23)
`+%j`	Day of the year (001..366)
`+%m`	Month number (01..12)
`+%M`	Minute (00..59)
`+%R`	Time in `hh:mm` format
`+%s`	Seconds since January 1, 1970
`+%S`	Second (00..60)
`+%T`	Time in `hh:mm:ss` format
`+%u`	Day of the week (`1` for Monday)
`+%V`	Week number (`+%V`)
`+%x`	Date in format `DD/MM/YYYY`

The `date` command also allows you to change the system date and time. In this case, the `-s` option will be used.

```
[root]# date -s "2021-05-24 10:19"
```

The format to be used following the `-s` option is this:

```
date -s "yyyy-MM-dd hh:mm[:ss]"
```

4.3.4 `id` , `who` and `whoami` commands

The `id` command is used to display information about users and groups. By default, no user parameter is added, and the information of the currently logged in user and group is displayed

```
$ id rockstar
uid=1000(rockstar) gid=1000(rockstar) groups=1000(rockstar),10(wheel)
```

The `-g`, `-G`, `-n` and `-u` options display the main group GID, subgroup GIDs, names instead of numeric identifiers, and the user's UID respectively.

The `whoami` command displays the login of the current user.

The `who` command alone displays the names of logged in users:

```
$ who
rockstar tty1   2021-05-24 10:30
root     pts/0  2021-05-24 10:31
```

Since Linux is multi-user, it is possible that multiple sessions are open on the same station, either physically or over the network. It is interesting to know which users are logged in, if only to communicate with them by sending messages.

- tty: represents a terminal.
- pts/: represents a virtual console in a graphical environment with the number after representing the instance of the virtual console (0, 1, 2...)

The `-r` option also displays the runlevel (see chapter "startup").

4.4 File Tree

In Linux, the file tree is an inverted tree, called a **single hierarchical tree**, whose root is the directory `/`.

The **current directory** is the directory where the user is located.

The **connection directory** is the working directory associated with the user. The login directories are, by default, stored in the `/home` directory.

When the user logs in, the current directory is the login directory.

An **absolute path** references a file from the root by traversing the entire tree to the file level:

- `/home/groupA/alice/file`

The **relative path** references that same file by traversing the entire tree from the current directory:

- `../alice/file`

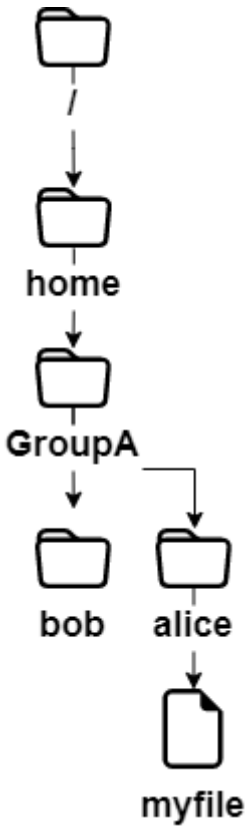
In the above example, the "`..`" refers to the parent directory of the current directory.

A directory, even if it is empty, will necessarily contain at least **two references**:

- `.`: reference to itself.
- `..`: reference to the parent directory of the current directory.

A relative path can thus start with `./` or `../`. When the relative path refers to a subdirectory or file in the current directory, then the `./` is often omitted. Mentioning the first `./` in the tree will only really be required to run an executable file.

Errors in paths can cause many problems: creating folders or files in the wrong places, unintentional deletions, etc. It is therefore strongly recommended to use auto-completion when entering paths.



In the above example, we are looking to give the location of the file `myfile` from the directory of bob.

- By an **absolute path**, the current directory does not matter. We start at the root, and work our way down to the directories `home`, `groupA`, `alice` and finally the file `myfile`: `/home/groupA/alice/myfile`.
- By a **relative path**, our starting point being the current directory `bob`, we go up one level through `..` (i.e., into the `groupA` directory), then down into the alice directory, and finally the `myfile` file: `../alice/myfile`.

4.4.1 `pwd` command

The `pwd` (Print Working Directory) command displays the absolute path of the current directory.

```
$ pwd
/home/rockstar
```

To use a relative path to reference a file or directory, or use the `cd` command to move to another directory, you must know its location in the file tree.

Depending on the type of shell and the different parameters of its configuration file, the terminal prompt (also known as the command prompt) will display the absolute or relative path of the current directory.

4.4.2 `cd` command

The `cd` (Change Directory) command allows you to change the current directory -- in other words, to move through the tree.

```
$ cd /tmp
$ pwd
/tmp
$ cd ../
$ pwd
/
$ cd
$ pwd
/home/rockstar
```

As you can see in the last example above, the command `cd` with no arguments moves the current directory to the `home directory`.

4.4.3 `ls` command

The `ls` command displays the contents of a directory.

```
ls [-a] [-i] [-l] [directory1] [directory2] […]
```

Example:

```
$ ls /home
.    ..    rockstar
```

The main options of the `ls` command are:

Option	Information
`-a`	Displays all files, even hidden ones. Hidden files in Linux are those beginning with `.`.
`-i`	Displays inode numbers.
`-l`	Use a long listing format, that is, each line displays long format information for a file or directory.

The `ls` command, however, has a lot of options (see `man`):

Option	Information
`-d`	Displays information about a directory instead of listing its contents.
`-g`	Like -l option, but do not list owner.
`-h`	Displays file sizes in the most appropriate format (byte, kilobyte, megabyte, gigabyte, ...). `h` stands for Human Readable. Needs to be used with -l option.
`-s`	Displays the allocated size of each file, in blocks. In the `ls` command, the default size of a single block is 1024-Byte. In the GNU/Linux operating system, "block" is the smallest unit of storage in the file system, and generally speaking, one block is equal to 4096-Byte. In the Windows operating system, taking the NTFS file system as an example, its smallest storage unit is called a "Cluster". The definition of the minimum storage unit name may vary depending on different file systems.
`-A`	Displays all files in the directory except `.` and `..`
`-R`	Displays the contents of subdirectories recursively.
`-F`	Displays the type of files. Prints a `/` for a directory, `*` for executables, `@` for a symbolic link, and nothing for a text file.
`-X`	Sorts files according to their extensions.

- Description of columns generated by running the `ls -lia` command:

```
$ ls -lia /home
78489 drwx------ 4 rockstar rockstar 4096 25 oct. 08:10 rockstar
```

Value	Information
`78489`	Inode Number.
`drwx------`	File type (`d`) and rights (`rwx------`).
`4`	Number of subdirectories (`.` and `..` included). For a file, it represents the number of hard links, and 1 represents itself.
`rockstar`	User ownership.
`rockstar`	Group ownership.
`4096`	For files, it shows the size of the file. For directories, it shows the fixed value of 4096 bytes occupied by the file naming. To calculate the total size of a directory, use `du -sh rockstar/`
`25 oct. 08:10`	Last modified date.
`rockstar`	The name of the file (or directory).

Note

Aliases are frequently positioned in common distributions.

This is the case of the alias `ll`:

```
alias ll='ls -l --color=auto'
```

The `ls` command has many options. Here are some advanced examples of uses:

- List the files in `/etc` in order of last modification:

```
$ ls -ltr /etc
total 1332
-rw-r--r--.  1 root root    662 29 may   2021 logrotate.conf
-rw-r--r--.  1 root root    272 17 may.   2021 mailcap
-rw-------.  1 root root    122 12 may.  2021 securetty
...
-rw-r--r--.  2 root root     85 18 may.  17:04 resolv.conf
-rw-r--r--.  1 root root     44 18 may.  17:04 adjtime
-rw-r--r--.  1 root root    283 18 may.  17:05 mtab
```

- List `/var` files larger than 1 megabyte but less than 1 gigabyte. The example here uses advanced `grep` commands with regular expressions. Novices don't have to struggle too much, there will be a special tutorial to introduce these regular expressions in the future.

```
$ ls -lhR /var/ | grep ^\- | grep -E "[1-9]*\.[0-9]*M"
...
-rw-r--r--. 1 apache apache 1.2M 10 may.  13:02 XB RiyazBdIt.ttf
-rw-r--r--. 1 apache apache 1.2M 10 may.  13:02 XB RiyazBd.ttf
-rw-r--r--. 1 apache apache 1.1M 10 may.  13:02 XB RiyazIt.ttf
...
```

Of course, we highly recommend that you use the `find` command.

```
find /var -size +1M -a -size -1024M  -a -type f  -exec ls -lh {} \;
```

- Show the rights on a folder:

To find out the rights to a folder, in our example `/etc`, the following command would **not** be appropriate:

```
$ ls -l /etc
total 1332
-rw-r--r--.  1 root root     44 18 nov.  17:04 adjtime
-rw-r--r--.  1 root root   1512 12 janv.  2010 aliases
-rw-r--r--.  1 root root  12288 17 nov.  17:41 aliases.db
drwxr-xr-x.  2 root root   4096 17 nov.  17:48 alternatives
...
```

The above command will display the contents of the folder (inside) by default. For the folder itself, you can use the `-d` option.

```
ls -ld /etc
drwxr-xr-x. 69 root root 4096 18 nov.  17:05 /etc
```

- Sort by file size, largest first:

```
ls -lhS
```

- time/date format with `-l`:

```
$ ls -l --time-style="+%Y-%m-%d %m-%d %H:%M" /
total 12378
dr-xr-xr-x. 2 root root 4096 2014-11-23 11-23 03:13 bin
dr-xr-xr-x. 5 root root 1024 2014-11-23 11-23 05:29 boot
```

- Add the *trailing slash* to the end of folders:

By default, the `ls` command does not display the last slash of a folder. In some cases, like for scripts for example, it is useful to display them:

```
$ ls -dF /etc
/etc/
```

- Hide some extensions:

```
ls /etc --hide=*.conf
```

4.4.4 `mkdir` command

The `mkdir` command creates a directory or directory tree.

```
mkdir [-p] directory [directory] [...]
```

Example:

```
mkdir /home/rockstar/work
```

The "rockstar" directory must exist to create the "work" directory.

Otherwise, the `-p` option should be used. The `-p` option creates the parent directories if they do not exist.

Danger

It is not recommended to use Linux command names as directory or file names.

4.4.5 `touch` command

The `touch` command changes the timestamp of a file or creates an empty file if the file does not exist.

```
touch [-t date] file
```

Example:

```
touch /home/rockstar/myfile
```

Option	Information
`-t date`	Changes the date of last modification of the file with the specified date.

Date format: `[AAAA]MMJJhhmm[ss]`

Tip

The `touch` command is primarily used to create an empty file, but it can be useful for incremental or differential backups for example. Indeed, the only effect of executing a `touch` on a file will be to force it to be saved during the next backup.

4.4.6 `rmdir` command

The `rmdir` command deletes an empty directory.

Example:

```
rmdir /home/rockstar/work
```

Option	Information
`-p`	Removes the parent directory or directories provided if they are empty.

Tip

To delete both a non-empty directory and its contents, use the `rm` command.

4.4.7 `rm` command

The `rm` command deletes a file or directory.

```
rm [-f] [-r] file [file] [...]
```

Danger

Any deletion of a file or directory is final.

Options	Information
`-f`	Do not ask whether to delete.
`-i`	Ask whether to delete.
`-r`	Delete a directory and recursively delete its subdirectories.

Note

The `rm` command itself does not ask for confirmation when deleting files. However, with a Red Hat/Rocky distribution, `rm` does ask for confirmation of deletion because the `rm` command is an `alias` of the `rm -i` command. Don't be surprised if on another distribution, like Debian for example, you don't get a confirmation request.

Deleting a folder with the `rm` command, whether the folder is empty or not, will require the `-r` option to be added.

The end of the options is signaled to the shell by a double dash `--`.

In the example:

```
$ >-hard-hard # To create an empty file called -hard-hard
hard-hard
[CTRL+C] To interrupt the creation of the file
$ rm -f -- -hard-hard
```

The hard-hard file name starts with a `-`. Without the use of the `--` the shell would have interpreted the `-d` in `-hard-hard` as an option.

4.4.8 `mv` command

The `mv` command moves and renames a file.

```
mv file [file ...] destination
```

Examples:

```
mv /home/rockstar/file1 /home/rockstar/file2

mv /home/rockstar/file1 /home/rockstar/file2 /tmp
```

Options	Information
`-f`	Don't ask for confirmation if overwriting the destination file.
`-i`	Request confirmation if overwriting destination file (default).

A few concrete cases will help you understand the difficulties that can arise:

```
mv /home/rockstar/file1 /home/rockstar/file2
```

Renames `file1` to `file2`. If `file2` already exists, replace the contents of the file with `file1`.

```
mv /home/rockstar/file1 /home/rockstar/file2 /tmp
```

Moves `file1` and `file2` into the `/tmp` directory.

```
mv file1 /repexist/file2
```

Moves `file1` into `repexist` and renames it `file2`.

```
mv file1 file2
```

`file1` is renamed to `file2`.

```
mv file1 /repexist
```

If the destination directory exists, `file1` is moved to `/repexist`.

```
mv file1 /wrongrep
```

If the destination directory does not exist, `file1` is renamed to `wrongrep` in the root directory.

4.4.9 `cp` command

The `cp` command copies a file.

```
cp file [file ...] destination
```

Example:

```
cp -r /home/rockstar /tmp
```

Options	Information
`-i`	Request confirmation if overwriting (default).
`-f`	Do not ask for confirmation if overwriting the destination file.
`-p`	Keeps the owner, permissions and timestamp of the copied file.
`-r`	Copies a directory with its files and subdirectories.
`-s`	Creates a symbolic link rather than copying.

```
cp file1 /repexist/file2
```

`file1` is copied to `/repexist` under the name `file2`.

```
cp file1 file2
```

`file1` is copied as `file2` to this directory.

```
cp file1 /repexist
```

If the destination directory exists, `file1` is copied to `/repexist`.

```
cp file1 /wrongrep
```

If the destination directory does not exist, `file1` is copied under the name `wrongrep` to the root directory.

4.5 Visualization

4.5.1 `file` command

The `file` command displays the type of a file.

```
file file1 [files]
```

Example:

```
$ file /etc/passwd /etc
/etc/passwd:    ASCII text
/etc:        directory
```

4.5.2 `more` command

The `more` command displays the contents of one or more files screen by screen.

```
more file1 [files]
```

Example:

```
$ more /etc/passwd
root:x:0:0:root:/root:/bin/bash
...
```

Using the `Enter ⏎` key, the move is line by line. Using the `Space` key, the move is page by page. `/text` allows you to search for the occurrence in the file.

4.5.3 `less` command

The `less` command displays the contents of one or more files. The `less` command is interactive and has its own commands for use.

```
less file1 [files]
```

The commands specific to `less` are:

Command	Action
h or H	Help.
↑ Up ↓ Down → Right ← Left	Move up, down a line, or to the right or left.
Enter ⏎	Move down one line.
Space	Move down one page.
⇞ Page Up and ⇟ Page Down	Move up or down one page.
g and G	Move to the first and last pages
/text	Search for text.
q or Q	Quit the `less` command.

4.5.4 `cat` command

The `cat` command concatenates the contents of multiple files and displays the result on the standard output.

```
cat file1 [files]
```

Example 1 - Displaying the contents of a file to the standard output:

```
cat /etc/passwd
```

Example 2 - Displaying the contents of multiple files to standard output:

```
cat /etc/passwd /etc/group
```

Example 3 - Combining the contents of multiple files into one file using output redirection:

```
cat /etc/passwd /etc/group > usersAndGroups.txt
```

Example 4 - Displaying the line numbering:

```
$ cat -n /etc/profile
     1    # /etc/profile: system-wide .profile file for the Bourne shell
(sh(1))
     2    # and Bourne compatible shells (bash(1), ksh(1), ash(1), ...).
     3
     4    if [ "`id -u`" -eq 0 ]; then
     5      PATH="/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin"
     6    else
…
```

Example 5 - Shows the numbering of non-empty lines:

```
$ cat -b /etc/profile
     1    # /etc/profile: system-wide .profile file for the Bourne shell
(sh(1))
     2    # and Bourne compatible shells (bash(1), ksh(1), ash(1), ...).

     3    if [ "`id -u`" -eq 0 ]; then
     4      PATH="/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin"
     5    else
…
```

4.5.5 `tac` command

The `tac` command does almost the opposite of the `cat` command. It displays the contents of a file starting from the end (which is particularly interesting for reading logs!).

Example: Display a log file by displaying the last line first:

```
[root]# tac /var/log/messages | less
```

4.5.6 `head` command

The `head` command displays the beginning of a file.

```
head [-n x] file
```

Option	Description
`-n x`	Display the first `x` lines of the file

By default (without the `-n` option), the `head` command will display the first 10 lines of the file.

4.5.7 `tail` command

The `tail` command displays the end of a file.

```
tail [-f] [-n x] file
```

Option	Description
`-n x`	Displays the last `x` lines of the file
`-f`	Displays changes to the file in real time

Example:

```
tail -n 3 /etc/passwd
sshd:x:74:74:Privilege-separeted sshd:/var/empty /sshd:/sbin/nologin
tcpdump::x:72:72::/:/sbin/nologin
user1:x:500:500:grp1:/home/user1:/bin/bash
```

With the `-f` option, the change information of the file will always be output unless the user exits the monitoring state with `^ Ctrl` + `C`. This option is very frequently used to track log files (the logs) in real time.

Without the `-n` option, the `tail` command displays the last 10 lines of the file.

4.5.8 `sort` command

The `sort` command sorts the lines of a file.

It allows you to order the result of a command or the content of a file in a given order, numerically, alphabetically, by size (KB, MB, GB) or in reverse order.

```
sort [-k] [-n] [-u] [-o file] [-t] file
```

Example:

```
$ sort -k 3,4 -t ":" -n /etc/passwd
root:x:0:0:root:/root:/bin/bash
adm:x:3:4:adm:/var/adm/:/sbin/nologin
```

Option	Description
`-k`	Specify the columns to be separated. You can specify multiple columns.
`-n`	Requests a numeric sort.
`-o file`	Saves the sort to the specified file.
`-t`	Specify a delimiter, which requires that the contents of the corresponding file must be regularly delimited column contents, otherwise they cannot be sorted properly.
`-r`	Reverse the order of the result. Used in conjunction with the `-n` option to sort in order from largest to smallest.
`-u`	Remove duplicates after sorting. Equivalent to `sort FILE | uniq` command.

The `sort` command sorts the file only on the screen. The file is not modified by the sorting. To save the sort, use the `-o` option or an output redirection `>`.

By default, the numbers are sorted according to their character. Thus, "110" will be before "20", which will itself be before "3". The `-n` option must be specified so that the numeric character blocks are sorted by their value.

The `sort` command reverses the order of the results, with the `-r` option:

```
$ sort -k 3 -t ":" -n -r /etc/passwd
nobody:x:65534:65534:Kernel Overflow User:/:/sbin/nologin
systemd-coredump:x:999:997:systemd Core Dumper:/:/sbin/nologin
polkitd:x:998:996:User for polkitd:/:/sbin/nologin
```

In this example, the `sort` command will sort the contents of the `/etc/passwd` file this time from largest uid (user identifier) to smallest.

Some advanced examples of using the `sort` command:

- Shuffling values

The `sort` command also allows you to shuffle values with the `-R` option:

```
sort -R /etc/passwd
```

• Sorting IP addresses

A system administrator is quickly confronted with the processing of IP addresses from the logs of his services such as SMTP, VSFTP or Apache. These addresses are typically extracted with the `cut` command.

Here is an example with the file `dns-client.txt`:

```
192.168.1.10
192.168.1.200
5.1.150.146
208.128.150.98
208.128.150.99
```

```
$ sort -nr dns-client.txt
208.128.150.99
208.128.150.98
192.168.1.200
192.168.1.10
5.1.150.146
```

• Sorting file by removing duplicates

The `sort` command knows how to remove the duplicates from the file output using `-u` as option.

Here is an example with the file `colours.txt`:

```
Red
Green
Blue
Red
Pink
```

```
$ sort -u colours.txt
Blue
Green
```

```
Pink
Red
```

- Sorting file by sizes

The `sort` command knows how to recognize file sizes, from commands like `ls` with the `-h` option.

Here is an example with the file `size.txt`:

```
1.7G
18M
69K
2.4M
1.2M
4.2G
6M
124M
12.4M
4G
```

```
$ sort -hr size.txt
4.2G
4G
1.7G
124M
18M
12.4M
6M
2.4M
1.2M
69K
```

4.5.9 `wc` command

The `wc` command counts the number of lines, words and/or bytes in a file.

```
wc [-l] [-m] [-w] file [files]
```

Option	Description
`-c`	Count the number of bytes.
`-m`	Count the number of characters.
`-l`	Counts the number of lines.
`-w`	Counts the number of words.

4.6 Search

4.6.1 `find` command

The `find` command searches for files or directories location.

```
find directory [-name name] [-type type] [-user login] [-date date]
```

Since there are so many options to the `find` command, it is best to refer to the `man`.

If the search directory is not specified, the `find` command will search from the current directory.

Option	Description
`-perm permissions`	Search for files by their permissions.
`-size size`	Search for files by size.

4.6.2 `-exec` option of the `find` command

It is possible to use the `-exec` option of the `find` command to execute a command on each result line:

```
find /tmp -name *.txt -exec rm -f {} \;
```

The previous command searches for all files in the `/tmp` directory named `*.txt` and deletes them.

Understand the `-exec` option

In the example above, the `find` command will construct a string representing the command to be executed.

If the `find` command finds three files named `log1.txt`, `log2.txt`, and `log3.txt`, then the `find` command will construct the string by replacing in the string `rm -f {} \;` the braces with one of the results of the search, and do this as many times as there are results.

This will give us:

```
rm -f /tmp/log1.txt ; rm -f /tmp/log2.txt ; rm -f /tmp/log3.txt ;
```

The `;` character is a special shell character that must be protected by a `\` to prevent it from being interpreted too early by the `find` command (and not in the `-exec`).

Tip

`$ find /tmp -name *.txt -delete` does the same thing.

4.6.3 `whereis` command

The `whereis` command searches for files related to a command.

```
whereis [-b] [-m] [-s] command
```

Example:

```
$ whereis -b ls
ls: /bin/ls
```

Option	Description
`-b`	Searches only the binary file.
`-m`	Searches only for man pages.
`-s`	Searches only for source files.

4.6.4 `grep` command

The `grep` command searches for a string in a file.

```
grep [-w] [-i] [-v] "string" file
```

Example:

```
$ grep -w "root:" /etc/passwd
root:x:0:0:root:/root:/bin/bash
```

Option	Description
`-i`	Ignores the case of the searched string.
`-v`	Excludes lines containing the string.
`-w`	Searches for the exact word.

The `grep` command returns the complete line containing the string you are looking for.

- The `^` special character is used to search for a string at the beginning of a line.
- The special character `$` searches for a string at the end of a line.

```
grep -w "^root" /etc/passwd
```

Note

This command is very powerful and it is highly recommended to consult its manual. It has many derivatives.

It is possible to search for a string in a file tree with the `-R` option.

```
grep -R "Virtual" /etc/httpd
```

4.6.5 Meta-characters (wildcards)

Meta-characters replace one or more characters (or even an absence of characters) during a search. These meta-characters are also known as wildcards.

They can be combined.

The `*` character replaces a string composed of any characters. The `*` character can also represent an absence of character.

```
$ find /home -name "test*"
/home/rockstar/test
/home/rockstar/test1
/home/rockstar/test11
```

```
/home/rockstar/tests
/home/rockstar/test362
```

Meta-characters allow more complex searches by replacing all or part of a word. Simply replace the unknowns with these special characters.

The character `?` replaces a single character, whatever it is.

```
$ find /home -name "test?"
/home/rockstar/test1
/home/rockstar/tests
```

The square brackets `[` and `]` are used to specify the values that a single character can take.

```
$ find /home -name "test[123]*"
/home/rockstar/test1
/home/rockstar/test11
/home/rockstar/test362
```

Note

Always surround words containing meta-characters with `"` to prevent them from being replaced by the names of files that meet the criteria.

Warning

Do not confuse shell meta-characters with regular expression meta-characters. The `grep` command uses regular expression meta-characters.

4.7 Redirects and pipes

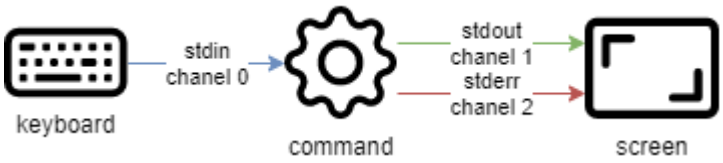
4.7.1 Standard input and output

On UNIX and Linux systems, there are three standard streams. They allow programs, via the `stdio.h` library, to input or output information.

These streams are called X channel or X file descriptor.

By default:

- the keyboard is the input device for channel 0, called **stdin** ;
- the screen is the output device for channels 1 and 2, called **stdout** and **stderr**.



stderr receives the error streams returned by a command. The other streams are directed to **stdout**.

These streams point to peripheral files, but since everything is a file in UNIX/Linux, I/O streams can easily be diverted to other files. This principle is the strength of the shell.

4.7.2 Input redirection

It is possible to redirect the input stream from another file with the character `<` or `<<`. The command will read the file instead of the keyboard:

```
ftp -in serverftp << ftp-commands.txt
```

Note

Only commands that require keyboard input will be able to handle input redirection.

Input redirection can also be used to simulate user interactivity. The command will read the input stream until it encounters the defined keyword after the input redirection.

This feature is used to script interactive commands:

```
$ ftp -in serverftp << END
user alice password
put file
bye
END
```

The keyword `END` can be replaced by any word.

```
$ ftp -in serverftp << STOP
user alice password
put file
bye
STOP
```

The shell exits the `ftp` command when it receives a line containing only the keyword.

> **Warning**
>
> The ending keyword, here `END` or `STOP`, must be the only word on the line and must be at the beginning of the line.

The standard input redirection is rarely used because most commands accept a filename as an argument.

The command `wc` could be used like this:

```
$ wc -l .bash_profile
27 .bash_profile # the number of lines is followed by the file name
$ wc -l < .bash_profile
27 # returns only the number of lines
```

4.7.3 Output redirection

Standard output can be redirected to other files using the `>` or `>>` characters.

The simple `>` redirection overwrites the contents of the output file:

```
date +%F > date_file
```

When the `>>` character is used, it indicates that the output result of the command is appended to the file content.

```
date +%F >> date_file
```

In both cases, the file is automatically created when it does not exist.

The standard error output can also be redirected to another file. This time it will be necessary to specify the channel number (which can be omitted for channels 0 and 1):

```
ls -R / 2> errors_file

ls -R / 2>> errors_file
```

4.7.4 Examples of redirection

Redirection of 2 outputs to 2 files:

```
ls -R / >> ok_file 2>> nok_file
```

Redirection of the 2 outputs to a single file:

```
ls -R / >> log_file 2>&1
```

Redirection of *stderr* to a "bottomless pit" (`/dev/null`):

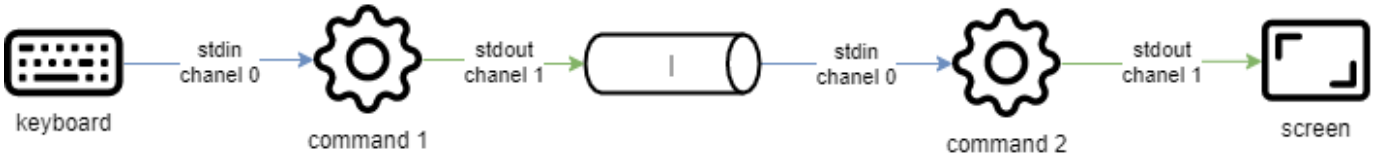
```
ls -R / 2>> /dev/null
```

When both output streams are redirected, no information is displayed on the screen. To use both the output redirection and to keep the display, you will have to use the command `tee` .

4.7.5 Pipes

A **pipe** is a mechanism allowing you to link the standard output of a first command to the standard input of a second command.

This communication is uni directional and is done with the `|` symbol. The pipe symbol `|` is obtained by pressing the ⇧ Shift + | simultaneously.



All data sent by the control on the left of the pipe through the standard output channel is sent to the standard input channel of the control on the right.

The commands particularly used after a pipe are filters.

• Examples:

Display only the beginning:

```
ls -lia / | head
```

Display only the end:

```
ls -lia / | tail
```

Sort the result:

```
ls -lia / | sort
```

Count the number of words / characters:

```
ls -lia / | wc
```

Search for a string in the result:

```
ls -lia / | grep fichier
```

4.8 Special Points

4.8.1 `tee` command

The `tee` command is used to redirect the standard output of a command to a file while maintaining the screen display.

It is combined with the `|` pipe to receive as input the output of the command to be redirected:

```
ls -lia / | tee fic

cat fic
```

The `-a` option adds to the file instead of overwriting it.

4.8.2 `alias` and `unalias` commands

Using **alias** is a way to ask the shell to remember a particular command with its options and give it a name.

For example:

```
ll
```

will replace the command:

```
ls -l
```

The `alias` command lists the aliases for the current session. Aliases are set by default on Linux distributions. Here, the aliases for a Rocky server:

```
$ alias
alias l.='ls -d .* --color=auto'
alias ll='ls -l --color=auto'
alias ls='ls --color=auto'
alias vi='vim'
alias which='alias | /usr/bin/which --tty-only --read-alias --show-dot --show-
tilde'
```

The aliases are only defined temporarily, for the time of the user session.

For permanent use, they must be created in the:

- `.bashrc` file in the user's login directory;
- `/etc/bashrc` file for all users.

> **Warning**
>
> Special care must be taken when using aliases which can be potentially dangerous! For example, an alias set up without the administrator's knowledge:
>
> ```
> alias cd='rm -Rf'
> ```

The `unalias` command allows you to delete aliases.

To delete a single alias:

```
unalias ll
```

To delete all aliases:

```
unalias -a
```

To disable an alias temporarily, the combination is `\<alias name>`.

For example if we do:

```
type ls
```

it might return the following:

```
ls is an alias to « ls -rt »
```

Now that this is known, we can see the results of using the alias or disabling it one time with the `\` by executing the following:

```
$ ls file*   # order by time
file3.txt  file2.txt  file1.txt
$ \ls file*  # order by name
file1.txt  file2.txt  file3.txt
```

4.8.3 Aliases and Useful Functions

- `grep` alias.

Colorize the result of the `grep` command: `alias grep='grep --color=auto'`

- `mcd` function

It is common to create a folder and then move around in it: `mcd() { mkdir -p "$1"; cd "$1"; }`

- `cls` function

Move to a folder and list its contents: `cls() { cd "$1"; ls; }`

- `backup` function

Create a backup copy of a file: `backup() { cp "$1"{,.bak}; }`

- `extract` function

Extract any type of archive:

```
extract () {
  if [ -f $1 ] ; then
    case $1 in
      *.tar.bz2) tar xjf $1 ;;
      *.tar.gz) tar xzf $1 ;;
      *.bz2) bunzip2 $1 ;;
      *.rar) unrar e $1 ;;
      *.gz) gunzip $1 ;;
      *.tar) tar xf $1 ;;
      *.tbz2) tar xjf $1 ;;
      *.tgz) tar xzf $1 ;;
      *.zip) unzip $1 ;;
      *.Z) uncompress $1 ;;
      *.7z) 7z x $1 ;;
      *)
        echo "'$1' cannot be extracted via extract()" ;;
    esac
  else
    echo "'$1' is not a valid file"
  fi
}
```

- If `alias cmount` returns the following: `alias cmount="mount | column -t"`

Then we can use `cmount` to show all of the system mounts in columns like this: `[root]# cmount`

which would return our mounted filesystem in the following format:

```
/dev/simfs  on  /                                   type  simfs
(rw,relatime,usrquota,grpquota)
proc        on  /proc                               type  proc
(rw,relatime)
sysfs       on  /sys                                type  sysfs
(rw,relatime)
none        on  /dev                                type  devtmpfs
(rw,relatime,mode=755)
none        on  /dev/pts                            type  devpts
(rw,relatime,mode=600,ptmxmode=000)
none        on  /dev/shm                            type  tmpfs
(rw,relatime)
none        on  /proc/sys/fs/binfmt_misc            type  binfmt_misc
(rw,relatime)
```

4.8.4 The character `;`

The `;` character strings the commands.

The commands will all run sequentially in the order of input once the user presses `Enter ⏎`.

```
ls /; cd /home; ls -lia; cd /
```

4.9 Check your Knowledge

✔ What defines a user under Linux? (7 answers)

✔ What characterizes a long option for a command?

✔ Which commands allow you to search for help on a command?

`google`

`chuck --norris`

`info`

`apropos`

`whatis`

✔ Which command allows you to view a user's history?

✔ Which command allows you to search for text in a file?

`find`

`grep`

✔ Which command allows you to search for a file?

`find`

`grep`

✔ Which command redirects the error stream of a command to a new `errors.log` file?

`ls -R / 2> errors.log`

`ls -R / 2>> errors.log`

`ls -R / 2> errors.log 2>&1`

5. Advanced Commands for Linux users

Advanced commands provide greater customization and controls in more specialized situations once you become familiar with basic commands.

Objectives: In this chapter, future Linux administrators will learn:

✔ some useful commands not covered in the previous chapter.
✔ some advanced commands.

🏁 **user commands**, **Linux**

Knowledge: ⭐
Complexity: ⭐ ⭐ ⭐

Reading time: 20 minutes

5.1 `uniq` command

The `uniq` command is a very powerful command, used with the `sort` command, especially for log file analysis. It allows you to sort and display entries by removing duplicates.

To illustrate how the `uniq` command works, let us use a `firstnames.txt` file containing a list of first names:

```
antoine
xavier
steven
patrick
xavier
antoine
antoine
steven
```

> **Note**
>
> `uniq` requires the input file to be sorted before running because it only compares consecutive lines.

With no argument, the `uniq` command will not display identical lines that follow each other in the `firstnames.txt` file:

```
$ sort firstnames.txt | uniq
antoine
patrick
steven
xavier
```

To display only the rows that appear only once, use the `-u` option:

```
$ sort firstnames.txt | uniq -u
patrick
```

Conversely, to display only the lines that appear at least twice in the file, use the `-d` option:

```
$ sort firstnames.txt | uniq -d
antoine
steven
xavier
```

To simply delete lines that appear only once, use the `-D` option:

```
$ sort firstnames.txt | uniq -D
antoine
antoine
antoine
steven
steven
xavier
xavier
```

Finally, to count the number of occurrences of each line, use the `-c` option:

```
$ sort firstnames.txt | uniq -c
      3 antoine
      1 patrick
      2 steven
      2 xavier
```

```
$ sort firstnames.txt | uniq -cd
      3 antoine
      2 steven
      2 xavier
```

5.2 `xargs` commands

The `xargs` command allows the construction and execution of command lines from standard input.

The `xargs` command reads whitespace or linefeed delimited arguments from standard input, and executes the command (`/bin/echo` by default) one or more times using the initial arguments followed by the arguments read from standard input.

A first and simplest example would be the following:

```
$ xargs
use
of
xargs
<CTRL+D>
use of xargs
```

The `xargs` command waits for an input from the standard **stdin** input. Three lines are entered. The end of the user input is specified to `xargs` by the keystroke sequence `^ Ctrl` + `D`. `xargs` then executes the default command `echo` followed by the three arguments corresponding to the user input, namely:

```
$ echo "use" "of" "xargs"
use of xargs
```

It is possible to specify a command to be run by `xargs`.

In the following example, `xargs` will run the command `ls -ld` on the set of folders specified in the standard input:

```
$ xargs ls -ld
/home
/tmp
```

```
/root
<CTRL+D>
drwxr-xr-x. 9 root root 4096  5 avril 11:10 /home
dr-xr-x---. 2 root root 4096  5 avril 15:52 /root
drwxrwxrwt. 3 root root 4096  6 avril 10:25 /tmp
```

In practice, the `xargs` command executed the `ls -ld /home /tmp /root` command.

What happens if the command to be executed does not accept multiple arguments, such as with the `find` command?

```
$ xargs find /var/log -name
*.old
*.log
find: paths must precede expression: *.log
```

The `xargs` command attempted to execute the `find` command with multiple arguments behind the `-name` option, which caused `find` to generate an error:

```
$ find /var/log -name "*.old" "*.log"
find: paths must precede expression: *.log
```

In this case, the `xargs` command must be forced to execute the `find` command several times (once per line entered as standard input). The `-L` option followed by an **integer** allows you to specify the maximum number of entries to be processed with the command at one time:

```
$ xargs -L 1 find /var/log -name
*.old
/var/log/dmesg.old
*.log
/var/log/boot.log
/var/log/anaconda.yum.log
/var/log/anaconda.storage.log
/var/log/anaconda.log
/var/log/yum.log
/var/log/audit/audit.log
/var/log/anaconda.ifcfg.log
/var/log/dracut.log
/var/log/anaconda.program.log
<CTRL+D>
```

To specify both arguments on the same line, use the `-n 1` option:

```
$ xargs -n 1 find /var/log -name
*.old *.log
/var/log/dmesg.old
/var/log/boot.log
/var/log/anaconda.yum.log
/var/log/anaconda.storage.log
/var/log/anaconda.log
/var/log/yum.log
/var/log/audit/audit.log
/var/log/anaconda.ifcfg.log
/var/log/dracut.log
/var/log/anaconda.program.log
<CTRL+D>
```

Case study of a backup with a `tar` based on a search:

```
$ find /var/log/ -name "*.log" -mtime -1 | xargs tar cvfP /root/log.tar
$ tar tvfP /root/log.tar
-rw-r--r-- root/root      1720 2017-04-05 15:43 /var/log/boot.log
-rw-r--r-- root/root    499270 2017-04-06 11:01 /var/log/audit/audit.log
```

The special feature of the `xargs` command is that it places the input argument at the end of the called command. This works very well with the above example since the files passed in will form the list of files to be added to the archive.

Using the example of the `cp` command, to copy a list of files in a directory, this list of files will be added at the end of the command... but what the `cp` command expects at the end of the command is the destination. To do this, use the `-I` option to put the input arguments somewhere else than at the end of the line.

```
find /var/log -type f -name "*.log" | xargs -I % cp % /root/backup
```

The `-I` option allows you to specify a character (the `%` character in the above example) where the input files to `xargs` will be placed.

5.3 `yum-utils` package

The `yum-utils` package is a collection of utilities, built for `yum` by various authors, which make it easier and more powerful to use.

Note

While `yum` has been replaced by `dnf` in Rocky Linux 8, the package name has remained `yum-utils`, although it can be installed as `dnf-utils` as well. These are classic YUM utilities implemented as CLI shims on top of DNF to maintain backwards compatibility with `yum-3`.

Here are some examples of these utilities.

5.3.1 `repoquery` command

The `repoquery` command is used to query the packages in the repository.

Examples of use:

- Display the dependencies of a package (it can be a software package that has been installed or not installed), equivalent to `dnf deplist <package-name>`

```
repoquery --requires <package-name>
```

- Display the files provided by an installed package (does not work for packages that are not installed), equivalent to `rpm -ql <package-name>`

```
$ repoquery -l yum-utils
/etc/bash_completion.d
/etc/bash_completion.d/yum-utils.bash
/usr/bin/debuginfo-install
/usr/bin/find-repos-of-install
/usr/bin/needs-restarting
/usr/bin/package-cleanup
/usr/bin/repo-graph
/usr/bin/repo-rss
/usr/bin/repoclosure
/usr/bin/repodiff
/usr/bin/repomanage
/usr/bin/repoquery
/usr/bin/reposync
/usr/bin/repotrack
/usr/bin/show-changed-rco
/usr/bin/show-installed
/usr/bin/verifytree
/usr/bin/yum-builddep
/usr/bin/yum-config-manager
/usr/bin/yum-debug-dump
/usr/bin/yum-debug-restore
```

```
/usr/bin/yum-groups-manager
/usr/bin/yumdownloader
…
```

5.3.2 `yumdownloader` command

The `yumdownloader` command downloads RPM packages from the repositories. Equivalent to `dnf download --downloadonly --downloaddir ./  package-name`

> **Note**
>
> This command is very useful to quickly build a local repository of a few rpms!

Example: `yumdownloader` will download the *samba* rpm package and all its dependencies:

```
$ yumdownloader --destdir /var/tmp --resolve samba
or
$ dnf download --downloadonly --downloaddir /var/tmp  --resolve  samba
```

Options	Comments
`--destdir`	The downloaded packages will be stored in the specified folder.
`--resolve`	Also downloads the package dependencies.

5.4 `psmisc` packages

The `psmisc` package contains utilities for managing system processes:

- `pstree`: the `pstree` command displays the current processes on the system in a tree-like structure.
- `killall`: the `killall` command sends a kill signal to all processes identified by name.
- `fuser`: the `fuser` command identifies the `PID` of processes that use the specified files or file systems.

Examples:

```
$ pstree
systemd─┬─NetworkManager───2*[{NetworkManager}]
```

```
          ├─agetty
          ├─auditd───{auditd}
          ├─crond
          ├─dbus-daemon───{dbus-daemon}
          ├─firewalld───{firewalld}
          ├─lvmetad
          ├─master─┬─pickup
          │        └─qmgr
          ├─polkitd───5*[{polkitd}]
          ├─rsyslogd───2*[{rsyslogd}]
          ├─sshd───sshd───bash───pstree
          ├─systemd-journal
          ├─systemd-logind
          ├─systemd-udevd
          └─tuned───4*[{tuned}]
```

```
# killall httpd
```

Kill processes (option `-k`) that access the `/etc/httpd/conf/httpd.conf` file:

```
# fuser -k /etc/httpd/conf/httpd.conf
```

5.5 `watch` command

The `watch` command regularly executes a command and displays the result in the terminal in full screen.

The `-n` option allows you to specify the number of seconds between each execution of the command.

> **Note**
>
> To exit the `watch` command, you must type the keys: `^ Ctrl` + `C` to kill the process.

Examples:

- Display the end of the `/etc/passwd` file every 5 seconds:

```
watch -n 5 tail -n 3 /etc/passwd
```

Result:

```
Every 5.0s: tail -n 3 /etc/
passwd
rockstar.rockylinux.lan: Thu Jul  1 15:43:59 2021

sssd:x:996:993:User for sssd:/:/sbin/nologin
chrony:x:995:992::/var/lib/chrony:/sbin/nologin
sshd:x:74:74:Privilege-separated SSH:/var/empty/sshd:/sbin/nologin
```

- Monitoring the number of files in a folder:

```
watch -n 1 'ls -l | wc -l'
```

- Display a clock:

```
watch -t -n 1 date
```

5.6 `install` command

Contrary to what its name might suggest, the `install` command is not used to install new packages.

This command combines file copying (`cp`) and directory creation (`mkdir`), with rights management (`chmod`, `chown`) and other useful functionalities (like backups).

```
install source dest
install -t directory source [...]
install -d directory
```

Options:

Options	Remarks
`-b` or `--backup[=suffix]`	creates a backup of destination file
`-d`	treats arguments as directory names
`-D`	creates all leading components before copying SOURCE to DEST
`-g` and `-o`	sets ownership
`-m`	sets permissions
`-p`	preserves the timestamps of the sources files
`-t`	copies all source arguments to the directory

> **Note**
>
> There are options for managing the SELinux context (see the manual page).

Examples:

Create a directory with the `-d` option:

```
install -d ~/samples
```

Copy a file from a source location to a directory:

```
install src/sample.txt ~/samples/
```

These two orders could have been carried out with a single command:

```
$ install -v -D -t ~/samples/ src/sample.txt
install: creating directory '~/samples'
'src/sample.txt' -> '~/samples/sample.txt'
```

This command already saves time. Combine it with owner, owner group, and rights management to improve the time savings:

```
sudo install -v -o rocky -g users -m 644 -D -t ~/samples/ src/sample.txt
```

> **Note**
>
> `sudo` is required in this case to make property changes.

You can also create a backup of existing files thanks to the `-b` option:

```
$ install -v -b -D -t ~/samples/ src/sample.txt
'src/sample.txt' -> '~/samples/sample.txt' (archive: '~/samples/sample.txt~')
```

As you can see, the `install` command creates a backup file with a `~` tilde appended to the original file name.

The suffix can be specified thanks to the `-S` option:

```
$ install -v -b -S ".bak" -D -t ~/samples/ src/sample.txt
'src/sample.txt' -> '~/samples/sample.txt' (archive: '~/samples/
sample.txt.bak')
```

5.7 `tree` command

Expand the files or directories in the directory in a tree-like manner.

options	description
`-a`	All files are listed
`-h`	Prints the size in a more human-readable way
`-u`	Displays file owner or UID number
`-g`	Displays file group owner or GID number
`-p`	Print the protections for each file

For example:

```
$ tree -hugp /etc/yum.repos.d/
/etc/yum.repos.d/
├── [-rw-r--r-- root     root      1.6K]  epel-modular.repo
├── [-rw-r--r-- root     root      1.3K]  epel.repo
├── [-rw-r--r-- root     root      1.7K]  epel-testing-modular.repo
├── [-rw-r--r-- root     root      1.4K]  epel-testing.repo
├── [-rw-r--r-- root     root       710]  Rocky-AppStream.repo
├── [-rw-r--r-- root     root       695]  Rocky-BaseOS.repo
├── [-rw-r--r-- root     root      1.7K]  Rocky-Debuginfo.repo
├── [-rw-r--r-- root     root       360]  Rocky-Devel.repo
├── [-rw-r--r-- root     root       695]  Rocky-Extras.repo
├── [-rw-r--r-- root     root       731]  Rocky-HighAvailability.repo
├── [-rw-r--r-- root     root       680]  Rocky-Media.repo
├── [-rw-r--r-- root     root       680]  Rocky-NFV.repo
├── [-rw-r--r-- root     root       690]  Rocky-Plus.repo
├── [-rw-r--r-- root     root       715]  Rocky-PowerTools.repo
├── [-rw-r--r-- root     root       746]  Rocky-ResilientStorage.repo
├── [-rw-r--r-- root     root       681]  Rocky-RT.repo
└── [-rw-r--r-- root     root      2.3K]  Rocky-Sources.repo

0 directories, 17 files
```

5.8 `stat` command

The `stat` command displays the status of a file or file system.

```
$ stat /root/anaconda-ks.cfg
  File: /root/anaconda-ks.cfg
  Size: 1352            Blocks: 8          IO Block: 4096   regular file
Device: 10302h/66306d   Inode: 2757097     Links: 1
Access: (0755/-rwxr-xr-x)  Uid: (    0/    root)   Gid: (    0/    root)
Access: 2024-01-20 13:04:57.012033583 +0800
Modify: 2023-09-25 14:04:48.524760784 +0800
Change: 2024-01-24 16:37:34.315995221 +0800
 Birth: 2
```

- `File` - Displays the path location of the file.
- `Size` - Displays the file size in bytes. If this is a directory, it displays the fixed 4096 bytes occupied by the directory name.
- `Blocks` - Displays the number of allocated blocks. Attention, please! The size of each block in this command is 512 bytes. The default size of each block in `ls -ls` is 1024 bytes.
- `Device` - Device number in decimal or hexadecimal notation.
- `Inode` - Inode is a unique ID number the Linux kernel assigns to a file or directory.
- `Links` - Number of hard links. Hard links are sometimes referred to as physical links.
- `Access` - The last access time of files and directories, i.e. `atime` in GNU/Linux.
- `Modify` - The last modification time of files and directories, i.e. `mtime` in GNU/Linux.
- `Change` - The last time the property is changed, i.e. `ctime` in GNU/Linux.
- `Birth` - Birth time (Creation time). In some documents, it is abbreviated as `btime` or `crtime`. You need a file system and kernel version higher than a certain version to display the creation time.

For files:

atime - After accessing the file content using commands such as `cat`, `less`, `more`, and `head`, the `atime` of the file can be updated. Please pay attention! The `atime` of

the file is not updated in real-time, and for performance reasons, it needs to wait for a period of time before it can be displayed. **mtime** - Modifying the file content can update the `mtime` of the file (such as appending or overwriting the file content through redirection), because the file size is a property of the file, the `ctime` will also be updated simultaneously. **ctime** - Changing the owner, group, permissions, file size, and links (soft and hard links) of the file will update ctime.

For directories:

atime - After using the `cd` command to enter a new directory that has never been accessed before, you can update and fix the `atime` of that directory. **mtime** - Performing operations such as creating, deleting, and renaming files in this directory will update the `mtime` and `ctime` of the directory. **ctime** - When the permissions, owner, group, etc. of a directory change, the `ctime` of the directory will be updated.

Tip

- If you create a new file or directory, its `atime`, `mtime`, and `ctime` are exactly the same
- If the file content is modified, the `mtime` and `ctime` of the file will inevitably be updated.
- If a brand new file is created in the directory, the `atime`, `ctime`, and `mtime` of that directory will be updated simultaneously.
- If the `mtime` of a directory is updated, then the `ctime` of that directory must be updated.

6. VI Text Editor

In this chapter you will learn how to work with the VIsual editor.

Objectives: In this chapter, future Linux administrators will learn how to:

✔ Use the main commands of the VI editor;
✔ Modify a text with the VI editor.

🏁 **user commands**, **linux**

Knowledge: ⭐
Complexity: ⭐ ⭐

Reading time: 20 minutes

Visual (**VI**) is a popular text editor under Linux despite its limited ergonomics. It is indeed an editor entirely in text mode: each action is done with a key on the keyboard or dedicated commands.

Very powerful, it is above all very practical since it is on the whole minimal for basic applications. It is therefore accessible in case of system failure. Its *universality* (it is present on all Linux distributions and under Unix) makes it a *crucial* tool for the administrator.

Its functionalities are:

- Insert, delete, and modify text;
- Copy words, lines, or blocks of text;
- Search and replace characters.

6.1 `vi` command

The `vi` command opens the *VI* text editor.

```
vi [-c command] [file]
```

Example:

```
vi /home/rockstar/file
```

Option	Information
`-c command`	Execute VI by specifying a command at the opening

If the file exists at the location mentioned by the path, VI reads it and puts it in **commands** mode.

If the file does not exist, VI opens a blank file, displaying an empty page on the screen. When the file is saved, it will take the name specified with the command.

If the command `vi` is executed without specifying a file name, VI opens a blank file and displays an empty page on the screen. When the file is saved, VI will ask for a file name.

The `vim` editor takes the interface and functions of VI with many improvements.

```
vim [-c command] [file]
```

Among these improvements, the user has syntax highlighting, which is useful for editing shell scripts or configuration files.

During a session, VI uses a buffer file to record all the user's changes.

Note

The original file is not modified as long as the user has not saved his work.

At startup, VI is in *commands* mode.

Tip

A line of text is ended by pressing Enter ⏎ but if the screen is not wide enough, VI makes automatic line breaks, *wrap* configuration by default. These line breaks may not be desired, this is the *nowrap* configuration.

To exit VI from the Commands mode, press `:`, then type:

- `q` to exit without saving (*quit*);
- `w` to save your work (*write*);
- `wq` (*write quit*) or `x` (*eXit*) to save and exit.

In command mode, Click the `Z` key of uppercase status twice in a row to save and exit.

You must add *!* to the previous commands to force the exit without confirmation.

> **Warning**
>
> There is no periodic backup, so you must remember to save your work regularly.

6.2 Operating mode

In VI, there are 3 working modes:

- The *command* mode;
- The *insertion* mode;
- The *ex* mode.

The philosophy of VI is to alternate between the *command* mode and the *insertion* mode.

The third mode, *ex*, is a footer command mode from an old text editor.

6.2.1 The Command Mode

This is the default mode when VI starts up. To access it from any of the other modes, simply press the `⎋ Esc` key.

At this time, all keyboard typing is interpreted as commands and the corresponding actions are executed. These are essentially commands for editing text (copy, paste, undo, ...).

The commands are not displayed on the screen.

6.2.2 The Insert mode

This is the text modification mode. To access it from the *command* mode, you have to press special keys that will perform an action in addition to changing the mode.

The text is not entered directly into the file but into a buffer zone in the memory. The changes are only effective when the file is saved.

6.2.3 The Ex mode

This is the file modification mode. To access it, you must first switch to *command* mode, then enter the *ex* command frequently starting with the character `:`.

The command is validated by pressing the [Enter ⏎] key.

6.3 Moving the cursor

In *command* mode, there are several ways to move the cursor.

The mouse is not active in a text environment but is in a graphic environment, it is possible to move it character by character, but shortcuts exist to go faster.

VI remains in *command* mode after moving the cursor.

The cursor is placed under the desired character.

6.3.1 From a character

- Move one or `n` characters to the left:

[← Left], [n] [← Left], [h] or [n] [h]

- Move one or `n` characters to the right:

[→ Right], [n] [→ Right], [l] or [n] [l]

- Move one or `n` characters up:

[↑ Up], [n] [↑ Up], [k] or [n] [k]

- Move one or `n` characters down:

↓ Down, n ↓ Down, j or n j

- Move to the end of the line:

$ or ⤓ End

- Move to the beginning of the line:

0 or ⤒ Home

6.3.2 From the first character of a word

Words are made up of letters or numbers. Punctuation characters and apostrophes separate words.

If the cursor is in the middle of a word w moves to the next word, b moves to the beginning of the word.

If the line is finished, VI goes automatically to the next line.

- Move one or `n` words to the right:

w or n w

- Move one or `n` words to the left:

b or n b

6.3.3 From any location on a line

- Move to last line of text:

G

- Move to line `n`:

n G

- Move to the first line of the screen:

`H`

- Move to the middle line of the screen:

`M`

- Move to the last line of the screen:

`L`

- Move to the first line of the file content

`g` `g`

6.4 Inserting text

There are several ways to insert text in *command* mode.

VI switches to *insert* mode after entering one of these keys.

> **Note**
>
> VI switches to *insertion* mode. So you will have to press the `Esc` key to return to *command* mode.

6.4.1 In relation to a character

- Inserting text before a character:

`i` (*insert*)

- Inserting text after a character:

`a` (*append*)

6.4.2 In relation to a line

- Inserting text at the beginning of a line:

`I`

- Inserting text at the end of a line:

A

6.4.3 In relation to the text

- Inserting text before a line:

0

- Inserting text after a line:

o

6.5 Characters, words and lines

VI allows text editing by managing:

- characters,
- words,
- lines.

In each case it is possible to :

- delete,
- replace,
- copy,
- cut,
- paste.

These operations are done in *command* mode.

6.5.1 Characters

- Delete one or `n` characters:

x or n x

- Replace a character with another:

r + character

- Replace more than one character with others:

R + characters + ⎋ Esc

> **Note**
>
> The R command switches to *replace* mode, which is a kind of *insert* mode.

6.5.2 Words

- Delete (cut) one or `n` words:

d + w or n + d + w

- Copy one or `n` words:

y + w or n + y + w

- Paste a word once or `n` times after the cursor:

p or n + p

- Paste a word once or `n` times before the cursor:

P or n + P

- Replace one word:

C + W + word + ⎋ Esc

> **Tip**
>
> It is necessary to position the cursor under the first character of the word to cut (or copy) otherwise VI will cut (or copy) only the part of the word between the cursor and the end. To delete a word is to cut it. If it is not pasted afterwards, the buffer is emptied and the word is deleted.

6.5.3 Lines

- Delete (cut) one or `n` lines:

`d` + `d` or `n` + `d` + `d`

• Copy one or `n` lines:

`y` + `y` or `n` + `y` + `y`

• Paste what has been copied or deleted once or `n` times after the current line:

`p` or `n` + `p`

• Paste what has been copied or deleted once or `n` times before the current line:

`P` or `n` + `P`

• Delete (cut) from the beginning of the line to the cursor:

`d` + `0`

• Delete (cut) from the cursor to the end of the line:

`d` + `$`

• Copy from the beginning of the line to the cursor:

`y` + `0`

• Copy from the cursor to the end of the line:

`y` + `$`

• Delete (cut) the contents from the cursor line to the last line of the file:

`d` + `G`

• Delete (cut) the contents from the cursor line to the last line of the screen:

`d` + `L`

• Copy the content from the cursor line to the end of the file:

`y` + `G`

• Copy the content from the cursor line to the end of the screen

y + L

6.5.4 Cancel an action

- Undo the last action:

u

- Undo the actions on the current line:

U

6.5.5 Cancel cancellation

- Cancel a cancellation

^ Ctrl + R

6.6 EX commands

The *Ex* mode allows you to act on the file (saving, layout, options, ...). It is also in *Ex* mode where search and replace commands are entered. The commands are displayed at the bottom of the page and must be validated with the Enter ⏎ key.

To switch to *Ex* mode, from *command* mode, type :.

6.6.1 File line numbers

- Show/hide numbering:

`:set nu` or the longer `:set number`

`:set nonu` or the longer `:set nonumber`

6.6.2 Search for a string

- Search for a string from the cursor:

`/string`

- Search for a string before the cursor:

`?string`

- Find the next matching string:

`n`

- Find the previous matching string:

`N`

There are regular expressions to facilitate the search in VI.

- `[]` : Searches for a range of characters or a single character whose possible values are specified.

Example:

`/[Ww]ord` : search *word* or *Word*

`/[1-9]word` : search *1word*, *2word* ... `x` *word* where `x` is a number

- `^` : Search for lines that begin with characters.

Example:

`/^Word`

- `$` : Search for lines that end with characters.

Example:

`/Word$`

- `.` : Search for any single character except newline characters.

Example:

`/W.rd` : search *Word*, *Ward* ...

- `*` : The number of times the previous character matches, 0 times, or any number of times.

Example:

```
/W*d
```

Note: If you want to ignore case (temporary) when matching strings, Please type the `:set ic`.

6.6.3 Replace a string

From the 1st to the last line of the text, replace the searched string by the specified string:

```
:1,$ s/search/replace
```

Note: You can also use `:0,$s/search/replace` to specify starting at the absolute beginning of the file.

From line `n` to line `m`, replace the searched string with the specified string:

```
:n,m s/search/replace
```

By default, only the first occurrence found of each line is replaced. To force the replacement of each occurrence, you have to add `/g` at the end of the command:

```
:n,m s/search/replace/g
```

Browse an entire file to replace the searched string with the specified string:

```
:% s/search/replace
```

6.6.4 Deletes the specified row

- Delete a blank line

`:g/^$/d`

• Delete lines with line numbers n to m

`:n,md`

• Delete the line on which the string is located

`:g/string/d`

• Delete a line that does not contain a string

`:g!/string/d`

• Delete all lines that begin with #

`:g/^#/d`

The **g** here stands for **global**.

6.6.5 File operations

• Save the file:

`:w`

• Save under another name:

`:w file`

• Save from line `n` to line `m` in another file:

`:n,m w file`

• Reload the last record of the file:

`e!`

• Paste the content of another file after the cursor:

`:r file`

• Quit editing a file without saving:

`:q`

- Quit editing a file that has been modified during the session but not saved:

`:q!`

- Exit the file and save:

`:wq` or `:x`

6.7 Other functions

Executing VI by specifying the options to be loaded for the session is possible. To do this, you must use the `-c` option:

```
vi -c "set nu" /home/rockstar/file
```

It is also possible to enter the *Ex* commands in a file named `.exrc` in the user's login directory. The commands will be read and applied at each VI or VIM startup.

6.7.1 `vimtutor` command

There is a tutorial for learning how to use VI. It is accessible with the command `vimtutor`.

```
vimtutor
```

6.7.2 visualization mode

This mode is a sub-item of the command mode. You can complete it by typing v or V; the former's operation content is at the character level, and the latter's operation content is at the line level.

Info

You can use the arrow keys to mark the character or line content you want to operate on.

character level

- **Delete (cut)** - Type the v key to mark the character content you want to delete, and then type x to delete it
- **Copy** - Type the v key to mark the character content to copy, and then type the y key to copy it

line level

- **Delete (cut)** - Type the V key to mark the line to be deleted, and then type x to delete it
- **Copy** - Type the V key to mark the line to copy, and then type the y key to copy it

7. User Management

In this chapter you will learn how to manage users.

Objectives: In this chapter, future Linux administrators will learn how to:

✔ add, delete or modify a **group**;
✔ add, delete or modify a **user**;
✔ understand the files associated with users and groups and learn how to manage them;
✔ change the *owner* or the *group owner* of a file;
✔ *secure* user accounts;
✔ change identity.

🏁 **users**

Knowledge: ⭐ ⭐
Complexity: ⭐ ⭐

Reading time: 30 minutes

7.1 General

Each user must have a group called the user's **primary group**.

Several users can be part of the same group.

Groups other than the primary group are called the user's **supplementary groups**.

> **Note**
>
> Each user has a primary group and can be invited into one or more supplementary groups.

Groups and users are managed by their unique numerical identifiers `GID` and `UID`.

- `UID`: *User IDentifier*. Unique user ID.
- `GID`: *Group IDentifier*. Unique group identifier.

The kernel recognizes Both UID and GID, meaning that the Super Admin is not necessarily the **root** user, as long as the **uid=0** user is the Super Admin.

The files related to users/groups are:

- /etc/passwd
- /etc/shadow
- /etc/group
- /etc/gshadow
- /etc/skel/
- /etc/default/useradd
- /etc/login.defs

Danger

You should always use the administration commands instead of manually editing the files.

Note

Some commands in this chapter require administrator rights. By convention, we will specify the command `sudo` when commands are to be run with administrator rights. For the examples to work properly, please ensure your account has the right to use the `sudo` command.

7.2 Group management

Modified files, added lines:

- `/etc/group`
- `/etc/gshadow`

7.2.1 `groupadd` command

The `groupadd` command adds a group to the system.

```
groupadd [-f] [-g GID] group
```

Example:

```
sudo groupadd -g 1012 GroupeB
```

Option	Description
`-g GID`	Defines the `GID` of the group to create.
`-f`	The system chooses a `GID` if the one specified by the `-g` option already exists.
`-r`	Creates a system group with a `GID` between `SYS_GID_MIN` and `SYS_GID_MAX`. These two variables are defined in `/etc/login.defs`.

Group naming rules:

- No accents or special characters;
- Different from the name of an existing user or system files.

Note

Under **Debian**, the administrator should use, except in scripts intended to be portable to all Linux distributions, the `addgroup` and `delgroup` commands as specified in the `man`:

```
$ man addgroup
DESCRIPTION
adduser and addgroup add users and groups to the system according to command line options and configuration information
in /etc/adduser.conf. They are friendlier front ends to the low-level tools like useradd, groupadd and usermod programs,
by default, choosing Debian policy conformant UID and GID values, creating a home directory with skeletal configuration,
running a custom script, and other features.
```

7.2.2 Command `groupmod`

The `groupmod` command allows you to modify an existing group on the system.

```
groupmod [-g GID] [-n nom] group
```

Example:

```
sudo groupmod -g 1016 GroupP

sudo groupmod -n GroupC GroupB
```

Option	Description
`-g GID`	New `GID` of the group to modify.
`-n name`	New name.

It is possible to change the name of a group, its `GID`, or both simultaneously.

After modification, the files belonging to the group have an unknown `GID`. They must be reassigned to the new `GID`.

```
sudo find / -gid 1002 -exec chgrp 1016 {} \;
```

7.2.3 `groupdel` command

The `groupdel` command deletes an existing group on the system.

```
groupdel group
```

Example:

```
sudo groupdel GroupC
```

Tip

When deleting a group, two conditions can occur:

- If a user has a unique primary group and you issue the `groupdel` command on that group, you will be prompted that there is a specific user under the group and it cannot be deleted.
- If a user belongs to a supplementary group (not the primary group for the user) and that group is not the primary group for another user on the system, then the `groupdel` command will delete the group without any additional prompts.

Examples:

```
$ sudo useradd test
$ id test
uid=1000(test) gid=1000(test) group=1000(test)
$ sudo groupdel test
groupdel: cannot remove the primary group of user 'test'

$ sudo usermod -g users -G test test
$ id test
uid=1000(test) gid=100(users) group=100(users),1000(test)
$ sudo groupdel test
```

Tip

When you delete a user using the `userdel -r` command, the corresponding primary group is also deleted. The primary group name is usually the same as the username.

Tip

Each group has a unique `GID`. Multiple users can use a group as a supplementary group. By convention, The GID of the super administrator is 0. The GIDS reserved for some services or processes is 201-999, called system groups or pseudo-user groups. The GID for users is usually greater than or equal to 1000. These are related to /etc/login.defs, which we will talk about later.

```
# Comment line ignored
shell > cat  /etc/login.defs
MAIL_DIR        /var/spool/mail
UMASK           022
HOME_MODE       0700
PASS_MAX_DAYS   99999
PASS_MIN_DAYS   0
PASS_MIN_LEN    5
PASS_WARN_AGE   7
UID_MIN                  1000
UID_MAX                 60000
SYS_UID_MIN               201
SYS_UID_MAX               999
GID_MIN                  1000
GID_MAX                 60000
SYS_GID_MIN               201
SYS_GID_MAX               999
CREATE_HOME     yes
USERGROUPS_ENAB yes
ENCRYPT_METHOD SHA512
```

Tip

Since a user is necessarily part of a group, it is best to create the groups before adding the users. Therefore, a group may not have any members.

7.2.4 `/etc/group` file

This file contains the group information (separated by `:`).

```
$ sudo tail -1 /etc/group
GroupP:x:516:patrick
  (1)  (2)(3)   (4)
```

- 1: Name of the group.
- 2: The group password is identified by `x`. The group password is stored in `/etc/gshadow`.
- 3: GID.
- 4: Supplementary users in the group (excluding the unique primary user).

Note

Each line in the `/etc/group` file corresponds to a group. The primary user info is stored in `/etc/passwd`.

7.2.5 `/etc/gshadow` file

This file contains the security information about the groups (separated by `:`).

```
$ sudo grep GroupA /etc/gshadow
GroupA:$6$2,9,v...SBn160:alain:rockstar
   (1)      (2)            (3)      (4)
```

- 1: Name of the group.
- 2: Encrypted password.
- 3: Name of the group administrator.
- 4: Supplementary users in the group (excluding the unique primary user).

Warning

The name of the group in **/etc/group** and **/etc/gshadow** must correspond one by one. That is, each line in the **/etc/group** file must have a corresponding line in the **/etc/gshadow** file.

An `!` in the password indicates it is locked. Thus, no user can use the password to access the group (since group members do not need it).

7.3 User management

7.3.1 Definition

A user is defined as follows in the `/etc/passwd` file:

- 1: Login name;
- 2: Password identification, `x` indicates that the user has a password, the encrypted password is stored in the second field of `/etc/shadow`;
- 3: UID;
- 4: GID of the primary group;
- 5: Comments;
- 6: Home directory;
- 7: Shell (`/bin/bash`, `/bin/nologin`, ...).

There are three types of users:

- **root(uid=0)**: the system administrator;
- **system users(uid is one of the 201~999)**: Used by the system to manage application access rights;
- **regular user(uid>=1000)**: Other account to log in to the system.

Modified files, added lines:

- `/etc/passwd`
- `/etc/shadow`

7.3.2 `useradd` command

The `useradd` command adds a user.

```
useradd [-u UID] [-g GID] [-d directory] [-s shell] login
```

Example:

```
sudo useradd -u 1000 -g 1013 -d /home/GroupC/carine carine
```

Option	Description
`-u UID`	`UID` of the user to create.
`-g GID`	`GID` of the primary group. The `GID` here can also be a `group name`.
`-G GID1, [GID2]...`	`GID` of the supplementary groups. The `GID` here can also be a `group name`. It is possible to specify many supplementary groups separated by commas.
`-d directory`	Creates the home directory.
`-s shell`	Specifies the user's shell.
`-c COMMENT`	Adds a comment.
`-U`	Adds the user to a group with the same name created simultaneously. If not specified, the creation of a group with the same name occurs when creating the user.
`-M`	Does not create the user's home directory.
`-r`	Creates a system account.

At creation, the account has no password and is locked.

The user must assign a password to unlock the account.

When invoking the `useradd` command without any options, the following default settings are set for the new user:

- A home directory with the same name as the username is created;
- A primary group with the same name as the username is created;
- A default shell that points to `/bin/bash` is assigned to the user;
- The user's UID and primary group GID values are automatically deduced. This is usually a unique value between 1000 and 60,000.

Note

The default settings and values are obtained from the following configuration files:

`/etc/login.defs` and `/etc/default/useradd`

```
$ sudo useradd test1

$ tail -n 1 /etc/passwd
test1:x:1000:1000::/home/test1:/bin/bash

$ tail -n 1 /etc/shadow
```

```
test1:!!:19253:0:99999:7:::

$ tail -n 1 /etc/group ; tail -n 1 /etc/gshadow
test1:x:1000:
test1:!::
```

Account naming rules:

- Lowercase letters, numbers, and underscores are allowed; other special characters such as asterisks, percent signs, and full-width symbols are not accepted.
- Although you can use an uppercase user name in RockyLinux, we do not recommend it;
- It is not recommended to start with numbers and underscores, although you may be allowed to do so;
- Different from the name of an existing group or system file;
- The user name can contain up to 32 characters.

Warning

The user must create the home directory, except for the last directory.

The last directory is created by the `useradd` command, which takes the opportunity to copy the files from `/etc/skel` into it.

A user can belong to several groups besides their primary group.

Example:

```
sudo useradd -u 1000 -g GroupA -G GroupP,GroupC albert
```

Note

Under **Debian**, you will have to specify the `-m` option to force the creation of the login directory or set the `CREATE_HOME` variable in the `/etc/login.defs` file. In all cases, the administrator should use the `adduser` and `deluser` commands as specified in the `man`, except in scripts intended to be portable to all Linux distributions:

```
$ man useradd
DESCRIPTION
    **useradd** is a low-level utility for adding users. On Debian, administrators should usually use **adduser(8)**
     instead.
```

Default value for user creation

Modification of the file `/etc/default/useradd`.

```
useradd -D [-b directory] [-g group] [-s shell]
```

Example:

```
sudo useradd -D -g 1000 -b /home -s /bin/bash
```

Option	Description
`-D`	Sets the default values for user creation.
`-b base_directory`	Defines the base directory for the user's home directory. If you do not specify this option, use the HOME variable in the /etc/default/useradd file or /home/
`-g group`	Sets the default group.
`-s shell`	Sets the default shell.
`-f`	Sets the number of days after the password expires before disabling the account.
`-e`	Sets the date for disabling the account.

7.3.3 `usermod` command

The `usermod` command allows to modify a user.

```
usermod [-u UID] [-g GID] [-d directory] [-m] login
```

Example:

```
sudo usermod -u 1044 carine
```

Options identical to the `useradd` command.

Option	Description
`-m`	Associated with the `-d` option. Moves the contents of the old login directory to the new one. If the old home directory does not exist, creation of a new home directory does not occur; Creation of the new home directory occurs when it does not exist.
`-l login`	Modifies the login name. After you modify the login name, you also need to modify the name of the home directory to match it.
`-e YYYY-MM-DD`	Modifies the account expiration date.
`-L`	Locks the account permanently. That is, it adds an `!` at the beginning of the `/etc/shadow` password field.
`-U`	Unlocks the account.
`-a`	Appends the user's supplementary groups, which must be used together with the `-G` option.
`-G`	Modifies the user's supplementary groups and overwrites previous supplementary groups.

Tip

To be modified, a user must be disconnected and have no running processes.

After changing the identifier, the files belonging to the user have an unknown `UID`. It must be reassigned to the new `UID`.

Where `1000` is the old `UID` and `1044` is the new one. Examples are as follows:

```
sudo find / -uid 1000 -exec chown 1044: {} \;
```

Locking and unlocking of user accounts. Examples are as follows:

```
$ usermod -L test1
$ grep test1 /etc/shadow
test1:!
$6$n.hxglA.X5r7X0ex$qCXeTx.kQVmqsPLeuvIQnNidnSHvFiD7bQTxU7PLUCmBOcPNd5meqX6AEKSQvC

$ usermod -U test1
```

The difference between the `-aG` option and the `-G` option can be explained by the following example:

```
$ sudo useradd test1
$ sudo passwd test1
$ sudo groupadd groupA ; sudo groupadd groupB ; sudo groupadd groupC ; sudo
groupadd groupD
$ id test1
```

```
uid=1000(test1) gid=1000(test1) groups=1000(test1)

$ sudo gpasswd -a test1 groupA
$ id test1
uid=1000(test1) gid=1000(test1) groups=1000(test1),1002(groupA)

$ sudo usermod -G groupB,groupC test1
$ id test1
uid=1000(test1) gid=1000(test1) groups=1000(test1),1003(groupB),1004(groupC)

$ sudo usermod -aG groupD test1
$ id test1
uid=1000(test1) gid=1000(test1) groups=1000(test1),1003(groupB),1004(groupC),
1005(groupD)
```

7.3.4 `userdel` command

The `userdel` command lets you delete a user's account.

```
sudo userdel -r carine
```

Option	Description
`-r`	Deletes the user's home directory and mail files located in the `/var/spool/mail/` directory

Tip

To be deleted, a user must be logged out and have no running processes.

The `userdel` command removes the corresponding lines in `/etc/passwd`, `/ etc/shadow`, `/etc/group`, `/etc/gshadow`. As mentioned above, `userdel -r` will also delete the corresponding primary group of the user.

7.3.5 `/etc/passwd` file

This file contains user information (separated by `:`).

```
$ sudo head -1 /etc/passwd
root:x:0:0:root:/root:/bin/bash
(1)(2)(3)(4)(5)  (6)    (7)
```

- 1: Login name;
- 2: Password identification, `x` indicates that the user has a password, the encrypted password is stored in the second field of `/etc/shadow`;
- 3: UID;
- 4: GID of the primary group;
- 5: Comments;
- 6: Home directory;
- 7: Shell (`/bin/bash`, `/bin/nologin`, ...).

7.3.6 `/etc/shadow` file

This file contains the users' security information (separated by `:`).

```
$ sudo tail -1 /etc/shadow
root:$6$...:15399:0:99999:7:::
 (1)    (2)  (3) (4) (5) (6)(7,8,9)
```

- 1: Login name.
- 2: Encrypted password. Uses the SHA512 encryption algorithm, defined by the `ENCRYPT_METHOD` of `/etc/login.defs`.
- 3: The time when the password was last changed, the timestamp format, in days. The so-called timestamp is based on January 1, 1970 as the standard time. Every time one day goes by, the timestamp is +1.
- 4: Minimum lifetime of the password. That is, the time interval between two password changes (related to the third field), in days. Defined by the `PASS_MIN_DAYS` of `/etc/login.defs`, the default is 0, that is, when you change the password for the second time, there is no restriction. However, if it is 5, it means that it is not allowed to change the password within 5 days, and only after 5 days.
- 5: Maximum lifetime of the password. That is, the validity period of the password (related to the third field). Defined by the `PASS_MAX_DAYS` of `/etc/login.defs`.
- 6: The number of warning days before the password expires (related to the fifth field). The default is 7 days, defined by the `PASS_WARN_AGE` of `/etc/login.defs`.
- 7: Number of days of grace after password expiration (related to the fifth field).
- 8: Account expiration time, the timestamp format, in days. **Note that an account expiration differs from a password expiration. In case of an account expiration, the user shall not be allowed to login. In case of a password expiration, the user is not allowed to login using her password.**
- 9: Reserved for future use.

Danger

For each line in the `/etc/passwd` file there must be a corresponding line in the `/etc/shadow` file.

For time stamp and date conversion, please refer to the following command format:

```
# The timestamp is converted to a date, "17718" indicates the timestamp to be
filled in.
$ date -d "1970-01-01 17718 days"
```

```
# The date is converted to a timestamp, "2018-07-06" indicates the date to be
filled in.
$ echo $(($(date --date="2018-07-06" +%s)/86400+1))
```

7.4 File owners

> **Danger**
>
> All files necessarily belong to one user and one group.

By default, the primary group of the user creating the file is the group that owns the file.

7.4.1 Modification commands

`chown` command

The `chown` command allows you to change the owners of a file.

```
chown [-R] [-v] login[:group] file
```

Examples:

```
sudo chown root myfile

sudo chown albert:GroupA myfile
```

Option	Description
`-R`	Recursively changes the owners of the directory and all files under the directory.
`-v`	Displays the changes.

To change only the owner user:

```
sudo chown albert file
```

To modify only the owner group:

```
sudo chown :GroupA file
```

Changing the user and owner group:

```
sudo chown albert:GroupA file
```

In the following example the group assigned will be the primary group of the specified user.

```
sudo chown albert: file
```

Change the owner and group of all files in a directory

```
sudo chown -R albert:GroupA /dir1
```

7.4.2 `chgrp` command

The `chgrp` command allows you to change the owner group of a file.

```
chgrp [-R] [-v] group file
```

Example:

```
sudo chgrp group1 file
```

Option	Description
`-R`	Recursively changes the groups of the directory and all files under the directory.
`-v`	Displays the changes.

Note

It is possible to apply to a file an owner and an owner group by taking as reference those of another file:

```
chown [options] --reference=RRFILE FILE
```

For example:

```
chown --reference=/etc/groups /etc/passwd
```

7.5 Guest management

7.5.1 `gpasswd` command

The command `gpasswd` allows to manage a group.

```
gpasswd [option] group
```

Examples:

```
$ sudo gpasswd -A alain GroupA
[alain]$ gpasswd -a patrick GroupA
```

Option	Description
`-a USER`	Adds the user to the group. For the added user, this group is a supplementary group.
`-A USER,...`	Sets the list of administrative users.
`-d USER`	Removes the user from the group.
`-M USER,...`	Sets the list of group members.

The command `gpasswd -M` acts as a modification, not an addition.

```
# gpasswd GroupeA
New Password:
Re-enter new password:
```

Note

In addition to using `gpasswd -a` to add users to a group, you can also use the `usermod -G` or `usermod -aG` mentioned earlier.

7.5.2 `id` command

The `id` command displays the group names of a user.

```
id USER
```

Example:

```
$ sudo id alain
uid=1000(alain) gid=1000(GroupA) groupes=1000(GroupA),1016(GroupP)
```

7.5.3 `newgrp` command

The `newgrp` command can select a group from the user's supplementary groups as the user's new **temporary** primary group. The `newgrp` command every time you switch a user's primary group, there will be a new **child shell** child process). Be careful! **child shell** and **sub shell** are different.

```
newgrp [secondarygroups]
```

Example:

```
$ sudo useradd test1
$ sudo passwd test1
$ sudo groupadd groupA ; sudo groupadd groupB
$ sudo usermod -G groupA,groupB test1
$ id test1
uid=1000(test1) gid=1000(test1) groups=1000(test1),1001(groupA),1002(groupB)
$ echo $SHLVL ; echo $BASH_SUBSHELL
1
0

$ su - test1
$ touch a.txt
$ ll
-rw-rw-r-- 1 test1 test1 0 10   7 14:02 a.txt
$ echo $SHLVL ; echo $BASH_SUBSHELL
1
0

# Generate a new child shell
$ newgrp groupA
$ touch b.txt
$ ll
-rw-rw-r-- 1 test1 test1  0 10   7 14:02 a.txt
-rw-r--r-- 1 test1 groupA 0 10   7 14:02 b.txt
$ echo $SHLVL ; echo $BASH_SUBSHELL
2
0

# You can exit the child shell using the `exit` command
$ exit
$ logout
$ whoami
root
```

7.6 Securing

7.6.1 `passwd` command

The `passwd` command manages a password.

```
passwd [-d] [-l] [-S] [-u] [login]
```

Examples:

```
sudo passwd -l albert

sudo passwd -n 60 -x 90 -w 80 -i 10 patrick
```

Option	Description
`-d`	Permanently removes the password. For root (uid=0) use only.
`-l`	Permanently locks the user account. For root (uid=0) use only.
`-S`	Displays the account status. For root (uid=0) use only.
`-u`	Permanently unlocks user account. For root (uid=0) use only.
`-e`	Permanently expires the password. For root (uid=0) use only.
`-n DAYS`	Defines the minimum password lifetime. Permanent change. For root (uid=0) use only.
`-x DAYS`	Defines the maximum password lifetime. Permanent change. For root (uid=0) use only.
`-w DAYS`	Defines the warning time before expiration. Permanent change. For root (uid=0) use only.
`-i DAYS`	Defines the delay before deactivation when the password expires. Permanent change. For root (uid=0) use only.

Use `password -l`, that is, add "!!" at the beginning of the password field of the user corresponding to `/etc/shadow`.

Example:

- Alain changes his password:

```
[alain]$ passwd
```

- root changes Alain's password

```
sudo passwd alain
```

> **Note**
>
> Users logged in to the system can use the `passwd` command to change their passwords (this process requires requesting the user's old password). The root(uid=0) user can change the password of any user.

Changing passwords requires compliance with prescribed security policies, which involves **PAM (Pluggable Authentication Modules)** knowledge.

When managing user accounts by shell script, setting a default password after creating the user may be useful.

This can be done by passing the password to the `passwd` command.

Example:

```
sudo echo "azerty,1" | passwd --stdin philippe
```

> **Warning**
>
> The password is entered in clear text, `passwd` encrypts it.

7.6.2 `chage` command

The `chage` command is to change user password expiry information.

```
chage [-d date] [-E date] [-I days] [-l] [-m days] [-M days] [-W days] [login]
```

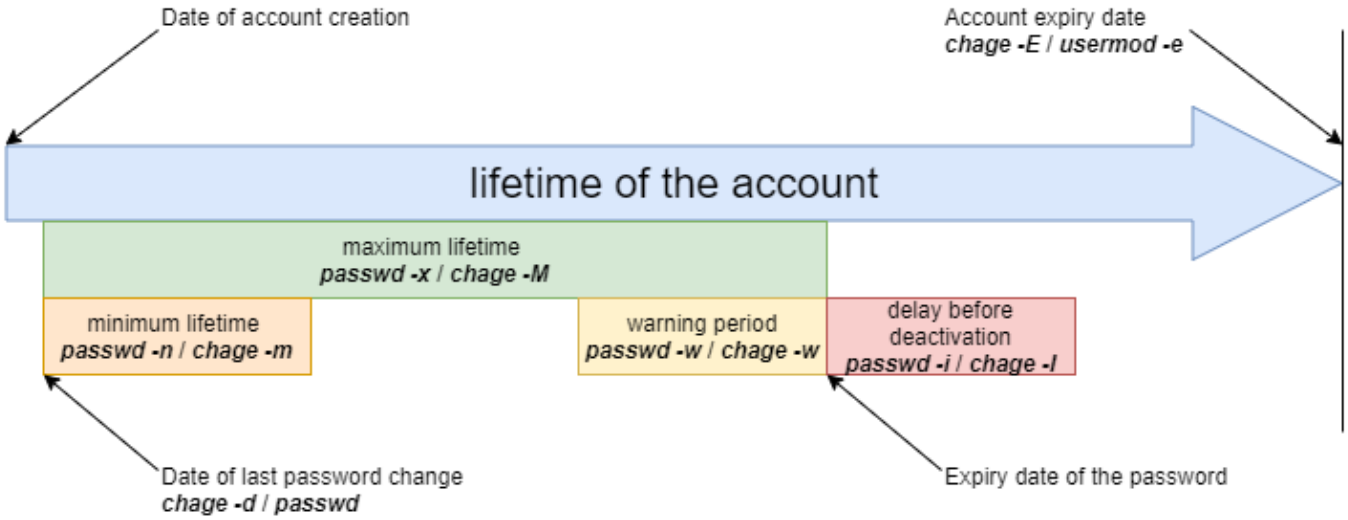
Example:

```
sudo chage -m 60 -M 90 -W 80 -I 10 alain
```

Option	Description
`-I DAYS`	Defines the days to delay before deactivation, password expired. Permanent change.
`-l`	Displays the policy details.
`-m DAYS`	Defines the minimum lifetime of the password. Permanent change.
`-M DAYS`	Defines the maximum lifetime of the password. Permanent change.
`-d LAST_DAY`	Defines the number of days since the password was last changed. You can use the days' timestamp style or the YYYY-MM-DD style. Permanent change.
`-E EXPIRE_DATE`	Defines the account expiration date. You can use the days' timestamp style or the YYYY-MM-DD style. Permanent change.
`-W WARN_DAYS`	Defines the number of days warning time before expiration. Permanent change.

Examples:

```
# The `chage` command also offers an interactive mode.
$ sudo chage philippe

# The `-d` option changes the password when logging in.
$ sudo chage -d 0 philippe
```



7.7 Advanced management

Configuration files:

- `/etc/default/useradd`
- `/etc/login.defs`
- `/etc/skel`

> **Note**
>
> Editing the `/etc/default/useradd` file is done with the `useradd` command.
>
> The other files are to be modified with a text editor.

7.7.1 `/etc/default/useradd` file

This file contains the default data settings.

> **Tip**

If the options are not specified when creating a user, the system uses the default values defined in `/etc/default/useradd`.

This file is modified by the command `useradd -D` (`useradd -D` entered without any other option displays the contents of the `/etc/default/useradd` file).

```
Shell > grep -v ^# /etc/default/useradd
GROUP=100
HOME=/home
INACTIVE=-1
EXPIRE=
SHELL=/bin/bash
```

```
SKEL=/etc/skel
CREATE_MAIL_SPOOL=yes
```

Parameters	Comment
`GROUP`	Defines the default primary group GID.
`HOME`	Defines the directory path of the upper level of the common user's home directory.
`INACTIVE`	Defines the number of days of grace after password expiration. Corresponds to the 7th field of the `/etc/shadow` file. `-1` value means that the grace period feature is turned off.
`EXPIRE`	Defines the account expiration date. Corresponds to the 8th field of the `/etc/shadow` file.
`SHELL`	Defines the command interpreter.
`SKEL`	Defines the skeleton directory of the login directory.
`CREATE_MAIL_SPOOL`	Defines the mailbox creation in `/var/spool/mail/`.

If you do not need a primary group with the same name when creating users, you can do this:

```
Shell > useradd -N test2
Shell > id test2
uid=1001(test2) gid=100(users) groups=100(users)
```

Note

GNU/Linux has two group mechanisms:

1. Public group, its primary group is GID=100
2. Private group, that is, when adding users, a group with the same name is created as its primary group. This group mechanism is commonly used by RHEL and related downstream distributions.

7.7.2 `/etc/login.defs` file

```
# Comment line ignored
shell > cat  /etc/login.defs
MAIL_DIR        /var/spool/mail
UMASK           022
HOME_MODE       0700
PASS_MAX_DAYS   99999
PASS_MIN_DAYS   0
PASS_MIN_LEN    5
PASS_WARN_AGE   7
UID_MIN                  1000
UID_MAX                 60000
SYS_UID_MIN               201
```

```
SYS_UID_MAX               999
GID_MIN                  1000
GID_MAX                 60000
SYS_GID_MIN               201
SYS_GID_MAX               999
CREATE_HOME     yes
USERGROUPS_ENAB yes
ENCRYPT_METHOD SHA512
```

`UMASK 022`: This means that the permission to create a file is 755 (rwxr-xr-x). However, for security, GNU/Linux does not have **x** permission for newly created files. This restriction applies to root(uid=0) and ordinary users(uid>=1000). For example:

```
Shell > touch a.txt
Shell > ll
-rw-r--r-- 1 root root     0 Oct  8 13:00 a.txt
```

`HOME_MODE 0700`: The permissions of an ordinary user's home directory. Does not work for root's home directory.

```
Shell > ll -d /root
dr-xr-x---. 10 root root 4096 Oct  8 13:12 /root

Shell > ls -ld /home/test1/
drwx------ 2 test1 test1 4096 Oct  8 13:10 /home/test1/
```

`USERGROUPS_ENAB yes`: "When you delete a user using the `userdel -r` command, the corresponding primary group is also deleted." Why? That's the reason.

7.7.3 `/etc/skel` directory

When a user is created, their home directory and environment files are created. You can think of the files in the `/etc/skel/` directory as the file templates you need to create users.

These files are automatically copied from the `/etc/skel` directory.

- `.bash_logout`
- `.bash_profile`
- `.bashrc`

All files and directories placed in this directory will be copied to the user tree when created.

7.8 Identity change

7.8.1 `su` command

The `su` command allows you to change the identity of the connected user.

```
su [-] [-c command] [login]
```

Examples:

```
$ sudo su - alain
[albert]$ su - root -c "passwd alain"
```

Option	Description
`-`	Loads the user's complete environment.
`-c` command	Executes the command under the user's identity.

If the login is not specified, it will be `root`.

Standard users will have to type the password for the new identity.

Tip

You can use the `exit` / `logout` command to exit users who have been switched. It should be noted that after switching users, there is no new `child shell` or `sub shell`, for example:

```
$ whoami
root
$ echo $SHLVL ; echo $BASH_SUBSHELL
1
0

$ su - test1
$ echo $SHLVL ; echo $BASH_SUBSHELL
1
0
```

Attention please! `su` and `su -` are different, as shown in the following example:

```
$ whoami
test1
$ su root
$ pwd
/home/test1

$ env
...
USER=test1
PWD=/home/test1
HOME=/root
MAIL=/var/spool/mail/test1
LOGNAME=test1
...
```

```
$ whoami
test1
$ su - root
$ pwd
/root

$ env
...
USER=root
PWD=/root
HOME=/root
MAIL=/var/spool/mail/root
LOGNAME=root
...
```

So, when you want to switch users, remember not to lose the `-`. Because the necessary environment variable files are not loaded, there may be problems running some programs.

8. File System

In this chapter, you will learn how to work with file systems.

Objectives: In this chapter, future Linux administrators will learn how to:

✓ manage partitions on disk;
✓ use LVM for a better use of disk resources;
✓ provide users with a filesystem and manage the access rights.

and also discover:

✓ how the tree structure is organized in Linux;
✓ the different types of files offered and how to work with them;

🏁 **hardware**, **disk**, **partition**, **lvm**, **linux**

Knowledge: ⭐ ⭐
Complexity: ⭐ ⭐

Reading time: 20 minutes

8.1 Partitioning

Partitioning will allow the installation of several operating systems because it is impossible for them to cohabit on the same logical drive. It also allows the separation of data logically (security, access optimization, etc.).

The partition table, stored in the first sector of the disk (MBR: *Master Boot Record*), records the division of the physical disk into partitioned volumes.

For **MBR** partition table types, the same physical disk can be divided into a maximum of 4 partitions:

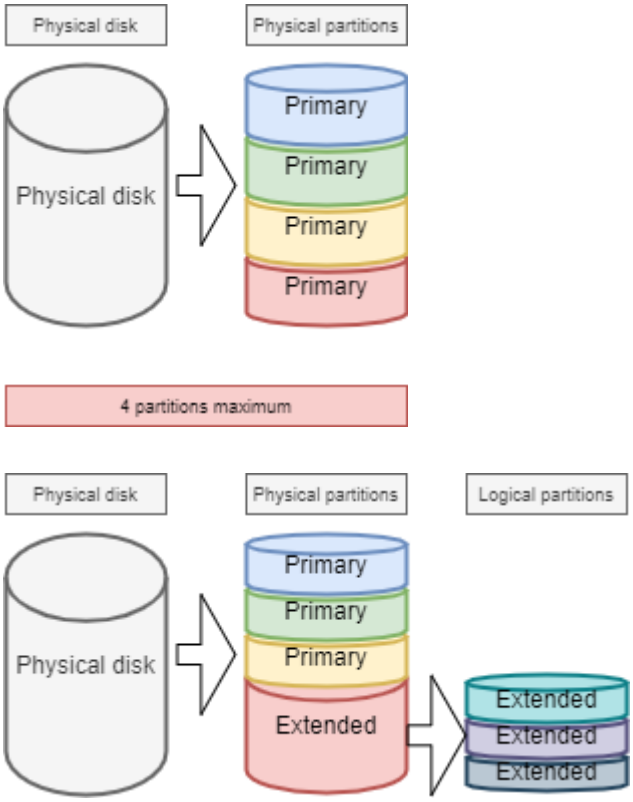
- *Primary partition* (or main partition)
- *Extended partition*

Warning

There can be only one extended partition per physical disk. That is, a physical disk can have in the MBR partition table up to:

1. Three primary partitions plus one extended partition
2. Four primary partitions

The extended partition cannot write data and format and can only contain logical partitions. The largest physical disk that the MBR partition table can recognize is **2TB**.



8.1.1 Naming conventions for device file names

In the world of GNU/Linux, everything is a file. For disks, they are recognized in the system as:

Hardware	Device file name
IDE hard disk	/dev/hd[a-d]
SCSI/SATA/USB hard disk	/dev/sd[a-z]
Optical drive	/dev/cdrom or /dev/sr0
Floppy disk	/dev/fd[0-7]
Printer (25 pins)	/dev/lp[0-2...]
Printer (USB)	/dev/usb/lp[0-15]
Mouse	/dev/mouse
Virtual hard disk	/dev/vd[a-z]

The Linux kernel contains drivers for most hardware devices.

What we call *devices* are the files stored without `/dev`, identifying the different hardware detected by the motherboard.

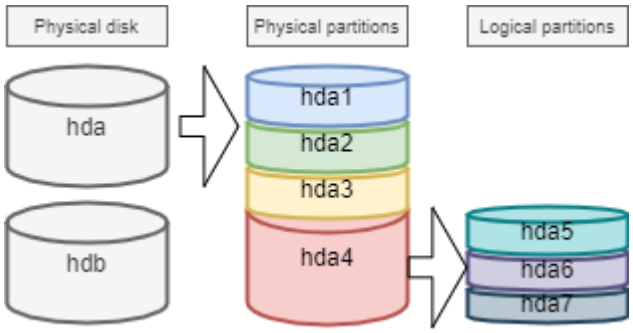
The service called udev is responsible for applying the naming conventions (rules) and applying them to the devices it detects.

For more information, please see here.

8.1.2 Device partition number

The number after the block device (storage device) indicates a partition. For MBR partition tables, the number 5 must be the first logical partition.

> **Warning**
>
> Attention please! The partition number we mentioned here mainly refers to the partition number of the block device (storage device).



There are at least two commands for partitioning a disk: `fdisk` and `cfdisk`. Both commands have an interactive menu. `cfdisk` is more reliable and better optimized, so it is best to use it.

The only reason to use `fdisk` is when you want to list all logical devices with the `-l` option. `fdisk` uses MBR partition tables, so it is not supported for **GPT** partition tables and cannot be processed for disks larger than **2TB**.

```
sudo fdisk -l
sudo fdisk -l /dev/sdc
sudo fdisk -l /dev/sdc2
```

8.1.3 `parted` command

The `parted` (*partition editor*) command can partition a disk without the drawbacks of `fdisk`.

The `parted` command can be used on the command line or interactively. It also has a recovery function capable of rewriting a deleted partition table.

```
parted [-l] [device]
```

Under the graphical interface, there is the very complete `gparted` tool: *G*nome *PAR*tition *ED*itor.

The `gparted -l` command lists all logical devices on a computer.

The `gparted` command, when run without any arguments, will show an interactive mode with its internal options:

- `help` or an incorrect command will display these options.
- `print all` in this mode will have the same result as `gparted -l` on the command line.
- `quit` to return to the prompt.

8.1.4 `cfdisk` command

The `cfdisk` command is used to manage partitions.

```
cfdisk device
```

Example:

```
$ sudo cfdisk /dev/sda
                                 Disk: /dev/sda
               Size: 16 GiB, 17179869184 bytes, 33554432 sectors
                       Label: dos, identifier: 0xcf173747
    Device        Boot       Start        End     Sectors    Size   Id Type
>>  /dev/sda1     *           2048    2099199     2097152      1G   83 Linux
    /dev/sda2              2099200   33554431    31455232     15G   8e Linux LVM
 lqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqk
 x Partition type: Linux (83)                                                x
 x     Attributes: 80                                                        x
 xFilesystem UUID: 54a1f5a7-b8fa-4747-a87c-2dd635914d60                      x
 x     Filesystem: xfs                                                       x
 x     Mountpoint: /boot (mounted)                                           x
 mqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqqj
     [Bootable]  [ Delete ]  [ Resize ]  [  Quit  ]  [  Type  ]  [  Help  ]
     [  Write ]  [  Dump  ]
```

The preparation, without *LVM*, of the physical media goes through five steps:

- Setting up the physical disk;
- Partitioning of the volumes (a division of the disk, possibility of installing several systems, ...);
- Creation of the file systems (allows the operating system to manage the files, the tree structure, the rights, ...);
- Mounting of file systems (registration of the file system in the tree structure);
- Manage user access.

8.2 Logical Volume Manager (LVM)

Logical **V**olume **M**anager (*LVM*)

The partition created by the **standard partition** cannot dynamically adjust the resources of the hard disk, once the partition is mounted, the capacity is completely fixed, this constraint is unacceptable on the server. Although the standard partition can be forcibly expanded or shrunk through certain technical means, it can easily cause data loss. LVM can solve this problem very well. LVM is available under Linux from kernel version 2.4, and its main features are:

- More flexible disk capacity;
- Online data movement;
- Disks in *stripe* mode;
- Mirrored volumes (recopy);
- Volume snapshots (*snapshot*).

The principle of LVM is very simple:

- a logical abstraction layer is added between the physical disk (or disk partition) and the file system
- merge multiple disks (or disk partition) into Volume Group(**VG**)
- perform underlying disk management operations on them through something called Logical Volume(**LV**).

The physical media: The storage medium of the LVM can be the entire hard disk, disk partition, or RAID array. The device must be converted, or initialized, to an LVM Physical Volume(**PV**), before further operations can be performed.

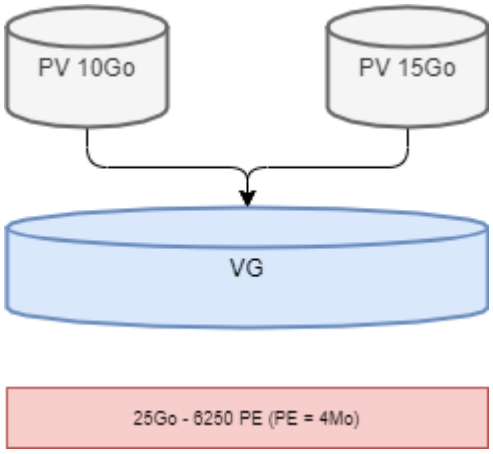
PV(Physical Volume) is the basic storage logic block of LVM. You can create a physical volume by using a disk partition or the disk itself.

VG(Volume Group): Similar to physical disks in a standard partition, a VG consists of one or more PV.

LV(Logical Volume): Similar to hard disk partitions in standard partitions, LV is built on top of VG. You can set up a file system on LV.

PE: The smallest unit of storage that can be allocated in a Physical Volume, default to **4MB**. You can specify an additional size.

LE: The smallest unit of storage that can be allocated in a Logical Volume. In the same VG, PE, and LE are the same and correspond one to one.



The disadvantage is that if one of the physical volumes becomes out of order, then all the logical volumes that use this physical volume are lost. You will have to use LVM on raid disks.

Note

LVM is only managed by the operating system. Therefore the *BIOS* needs at least one partition without LVM to boot.

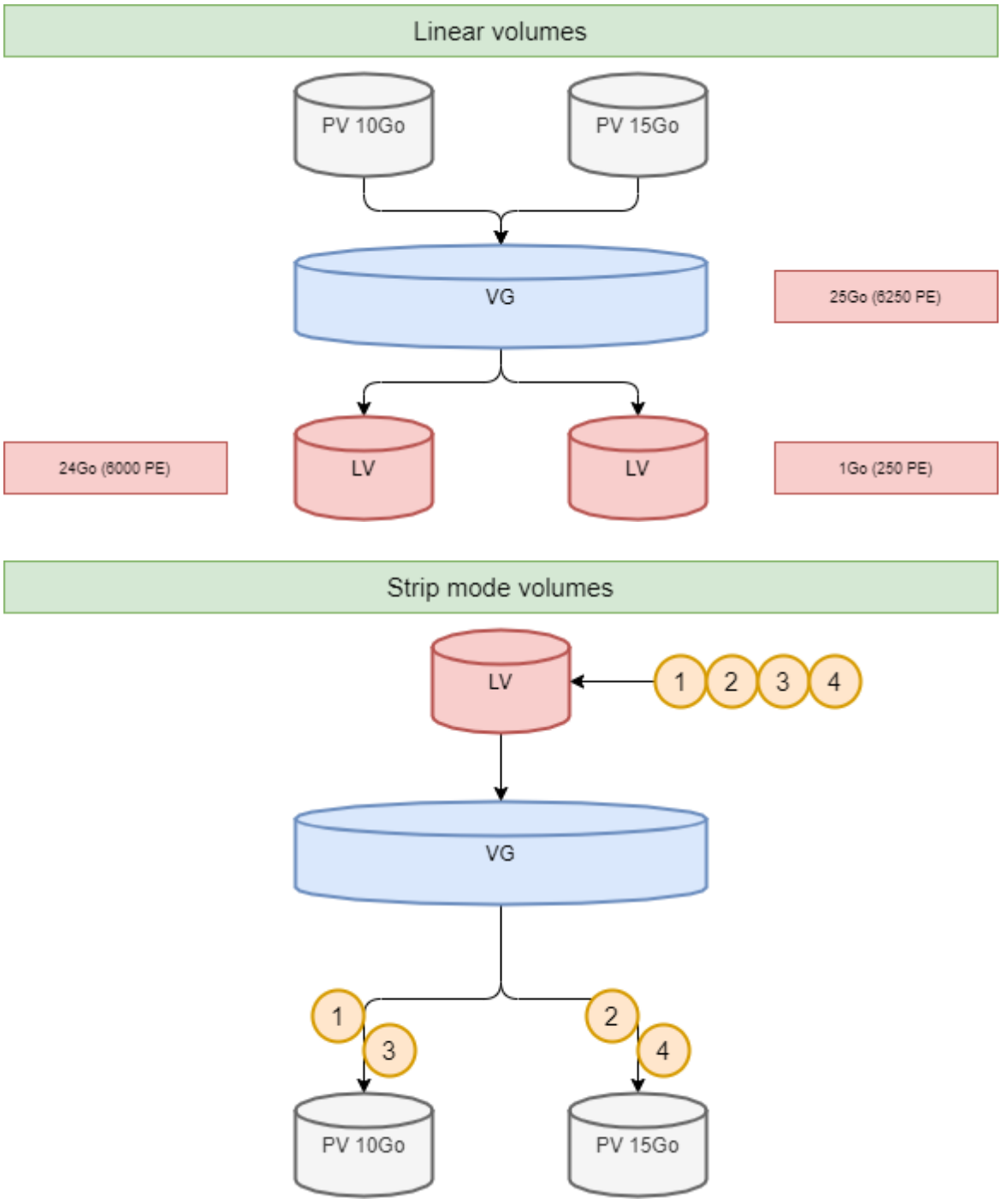
Info

In the physical disk, the smallest storage unit is the **sector**, in the file system, the smallest storage unit of GNU/Linux is the **block**, which is called **cluster** in the Windows operating system. In RAID, the smallest storage unit is **chunk**.

8.2.1 The Writing Mechanism of LVM

There are several storage mechanisms when storing data to **LV**, two of which are:

- Linear volumes;
- Volumes in *stripe* mode;
- Mirrored volumes.



8.2.2 LVM commands for volume management

The main relevant commands are as follows:

Item	PV	VG	LV
scan	pvscan	vgscan	lvscan
create	pvcreate	vgcreate	lvcreate
display	pvdisplay	vgdisplay	lvdisplay
remove	pvremove	vgremove	lvremove
extend		vgextend	lvextend
reduce		vgreduce	lvreduce
summary information	pvs	vgs	lvs

`pvcreate` command

The `pvcreate` command is used to create physical volumes. It turns Linux partitions (or disks) into physical volumes.

```
pvcreate [-options] partition
```

Example:

```
[root]# pvcreate /dev/hdb1
pvcreate -- physical volume « /dev/hdb1 » successfully created
```

You can also use a whole disk (which facilitates disk size increases in virtual environments for example).

```
[root]# pvcreate /dev/hdb
pvcreate -- physical volume « /dev/hdb » successfully created

# It can also be written in other ways, such as
[root]# pvcreate /dev/sd{b,c,d}1
[root]# pvcreate /dev/sd[b-d]1
```

Option	Description
`-f`	Forces the creation of the volume (disk already transformed into physical volume). Use with extreme caution.

`vgcreate` command

The `vgcreate` command creates volume groups. It groups one or more physical volumes into a volume group.

```
vgcreate  <VG_name>  <PV_name...>  [option]
```

Example:

```
[root]# vgcreate volume1 /dev/hdb1
…
vgcreate – volume group « volume1 » successfully created and activated

[root]# vgcreate vg01 /dev/sd{b,c,d}1
[root]# vgcreate vg02 /dev/sd[b-d]1
```

`lvcreate` command

The `lvcreate` command creates logical volumes. The file system is then created on these logical volumes.

```
lvcreate -L size [-n name] VG_name
```

Example:

```
[root]# lvcreate –L 600M –n VolLog1 volume1
lvcreate -- logical volume « /dev/volume1/VolLog1 » successfully created
```

Option	Description
`-L size`	Sets the logical volume size in K, M, or G.
`-n name`	Sets the LV name. A special file was created in `/dev/name_volume` with this name.
`-l number`	Sets the percentage of the capacity of the hard disk to use. You can also use the number of PE. One PE equals 4MB.

Info

After you create a logical volume with the `lvcreate` command, the naming rule of the operating system is - `/dev/VG_name/LV_name`, this file type is a soft link (otherwise known as a symbolic link). The link file points to files like `/dev/dm-0` and `/dev/dm-1`.

8.2.3 LVM commands to view volume information

`pvdisplay` command

The `pvdisplay` command allows you to view information about the physical volumes.

```
pvdisplay /dev/PV_name
```

Example:

```
[root]# pvdisplay /dev/PV_name
```

`vgdisplay` command

The `vgdisplay` command allows you to view information about volume groups.

```
vgdisplay VG_name
```

Example:

```
[root]# vgdisplay volume1
```

`lvdisplay` command

The `lvdisplay` command allows you to view information about the logical volumes.

```
lvdisplay /dev/VG_name/LV_name
```

Example:

```
[root]# lvdisplay /dev/volume1/VolLog1
```

8.2.4 Preparation of the physical media

The preparation with LVM of the physical support is broken down into the following:

- Setting up the physical disk
- Partitioning of the volumes
- **LVM physical volume**
- **LVM volume groups**
- **LVM logical volumes**
- Creating file systems
- Mounting file systems
- Manage user access

8.3 Structure of a file system

A *file system* **FS** is in charge of the following actions:

- Securing access and modification rights to files;
- Manipulating files: create, read, modify, and delete;
- Locating files on the disk;
- Managing partition space.

The Linux operating system is able to use different file systems (ext2, ext3, ext4, FAT16, FAT32, NTFS, HFS, BtrFS, JFS, XFS, ...).

8.3.1 `mkfs` command

The `mkfs` (make file system) command allows you to create a Linux file system.

```
mkfs [-t fstype] filesys
```

Example:

```
[root]# mkfs -t ext4 /dev/sda1
```

Option	Description
`-t`	Indicates the type of file system to use.

Warning

Without a file system it is not possible to use the disk space.

Each file system has an identical structure on each partition. The system initializes a **Boot Sector** and a **Super block**, and then the administrator initializes an **Inode table** and a **Data block**.

Note

The only exception is the **swap** partition.

8.3.2 Boot sector

The boot sector is the first sector of bootable storage media, that is, 0 cylinder, 0 track, 1 sector(1 sector equals 512 bytes). It consists of three parts:

1. MBR(master boot record): 446 bytes.
2. DPT(disk partition table): 64 bytes.
3. BRID(boot record ID): 2 bytes.

Item	Description
MBR	Stores the "boot loader"(or "GRUB"); loads the kernel, passes parameters; provides a menu interface at boot time; transfers to another loader, such as when multiple operating systems are installed.
DPT	Records the partition status of the entire disk.
BRID	Determines whether the device is usable to boot.

8.3.3 Super block

The size of the **Super block** table is defined at creation. It is present on each partition and contains the elements necessary for its utilization.

It describes the File System:

- Name of the Logical Volume;
- Name of the File System;
- Type of the File System;
- File System Status;
- Size of the File System;
- Number of free blocks;
- Pointer to the beginning of the list of free blocks;
- Size of the inode list;
- Number and list of free inodes.

After the system is initialized, a copy is loaded into the central memory. This copy is updated as soon as modified, and the system saves it periodically (command `sync`).

When the system stops, it copies this table in memory to its block.

8.3.4 Table of inodes

The size of the **inode table** is defined at its creation and is stored on the partition. It consists of records, called inodes, corresponding to the files created. Each record contains the addresses of the data blocks making up the file.

> **Note**
>
> An inode number is unique within a file system.

After the system is initialized, a copy is loaded into the central memory. This copy is updated as soon as it is modified, and the system saves it periodically (command `sync`).

When the system stops, it copies this table in memory to its block.

A file is managed by its inode number.

Note

The size of the inode table determines the maximum number of files the FS can contain.

Information present in the *inode table* :

- Inode number;
- File type and access permissions;
- Owner identification number;
- Identification number of the owner group;
- Number of links on this file;
- Size of the file in bytes;
- Date the file was last accessed;
- Date the file was last modified;
- Date of the last modification of the inode (= creation);
- Table of several pointers (block table) to the logical blocks containing the file pieces.

8.3.5 Data block

Its size corresponds to the rest of the partition's available space. This area contains the catalogs corresponding to each directory and the data blocks corresponding to the file's contents.

To guarantee the consistency of the file system, an image of the superblock and the inode table is loaded into memory (RAM) when the operating system is loaded so that all I/O operations are done through these system tables. When the user creates or modifies files, this memory image is updated first. The operating system must, therefore, regularly update the superblock of the logical disk (`sync` command).

These tables are written to the hard disk when the system is shut down.

Attention

In the event of a sudden stop, the file system may lose its consistency and cause data loss.

8.3.6 Repairing the file system

It is possible to check the consistency of a file system with the `fsck` command.

In case of errors, solutions are proposed to repair the inconsistencies. After repair, files that remain without entries in the inode table are attached to the logical drive's `/lost+found` folder.

`fsck` command

The `fsck` command is a console-mode integrity check and repair tool for Linux file systems.

```
fsck [-sACVRTNP] [ -t fstype ] filesys
```

Example:

```
[root]# fsck /dev/sda1
```

To check the root partition, it is possible to create a `forcefsck` file and reboot or run `shutdown` with the `-F` option.

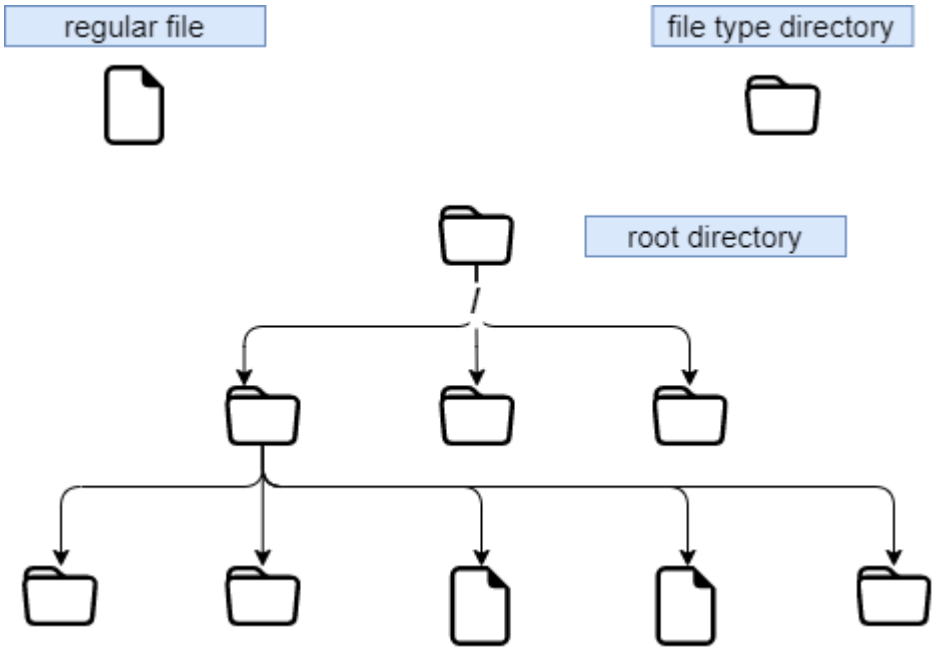
```
[root]# touch /forcefsck
[root]# reboot
or
[root]# shutdown –r -F now
```

Warning

The partition to be checked must be unmounted.

8.4 Organization of a file system

By definition, a File System is a tree structure of directories built from a root directory (a logical device can only contain one file system).



Note

In Linux, everything is a file.

Text document, directory, binary, partition, network resource, screen, keyboard, Unix kernel, user program, ...

Linux meets the **FHS** (*Filesystems Hierarchy Standard*) (see `man hier`), which defines the folders' names and roles.

Directory	Functionality	Complete word
`/`	Contains special directories	
`/boot`	Files related to system startup	
`/sbin`	Commands necessary for system startup and repair	*system binaries*
`/bin`	Executables of basic system commands	*binaries*
`/usr/bin`	System administration commands	
`/lib`	Shared libraries and kernel modules	*libraries*
`/usr`	Saves data resources related to UNIX	*UNIX System Resources*
`/mnt`	Temporary mount point directory	*mount*
`/media`	For mounting removable media	
`/misc`	To mount the shared directory of the NFS service.	
`/root`	Administrator's login directory	
`/home`	The upper-level directory of a common user's home directory	
`/tmp`	The directory containing temporary files	*temporary*
`/dev`	Special device files	*device*
`/etc`	Configuration and script files	*editable text configuration*
`/opt`	Specific to installed applications	*optional*
`/proc`	This is a mount point for the proc filesystem, which provides information about running processes and the kernel	*processes*
`/var`	This directory contains files which may change in size, such as spool and log files	*variables*
`/sys`	Virtual file system, similar to /proc	
`/run`	That is /var/run	
`/srv`	Service Data Directory	*service*

- To mount or unmount at the tree level, you must not be under its mount point.
- Mounting on a non-empty directory does not delete the content. It is only hidden.
- Only the administrator can perform mounts.
- Mount points automatically mounted at boot time must be entered in `/etc/fstab`.

8.4.1 `/etc/fstab` file

The `/etc/fstab` file is read at system startup and contains the mounts to be performed. Each file system to be mounted is described on a single line, the fields being separated by spaces or tabs.

> **Note**
>
> Lines are read sequentially (`fsck` , `mount` , `umount`).

```
/dev/mapper/VolGroup-lv_root   /         ext4    defaults        1   1
UUID=46….92                    /boot     ext4    defaults        1   2
/dev/mapper/VolGroup-lv_swap   swap      swap    defaults        0   0
tmpfs                          /dev/shm  tmpfs   defaults        0   0
devpts                         /dev/pts  devpts  gid=5,mode=620  0   0
sysfs                          /sys      sysfs   defaults        0   0
proc                           /proc     proc    defaults        0   0
  1                              2         3       4             5   6
```

Column	Description
1	File system device (`/dev/sda1` , UUID=..., ...)
2	Mount point name, **absolute path** (except **swap**)
3	Filesystem type (ext4, swap, ...)
4	Special options for mounting (`defaults` , `ro` , ...)
5	Enable or disable backup management (0:not backed up, 1:backed up). The `dump` command is used for backup here. This outdated feature was initially designed to back up old file systems on tape.
6	Check order when checking the FS with the `fsck` command (0:no check, 1:priority, 2:not priority)

The `mount -a` command allows you to mount automatically based on the contents of the configuration file `/etc/fstab` . The mounted information is then written to `/etc/mtab` .

Warning

Only the mount points listed in `/etc/fstab` will be mounted on reboot. Generally speaking, we do not recommend writing USB flash disks and removable hard drives to the `/etc/fstab` file because when the external device is unplugged and rebooted, the system will prompt that the device cannot be found, resulting in a failure to boot. So what am I supposed to do? Temporary mount, for example:

```
Shell > mkdir /mnt/usb
Shell > mount -t  vfat  /dev/sdb1  /mnt/usb

# Read the information of the USB flash disk
Shell > cd /mnt/usb/

# When not needed, execute the following command to pull out the USB flash disk
Shell > umount /mnt/usb
```

Info

It is possible to make a copy of the `/etc/mtab` file or to copy its contents to `/etc/fstab`. If you want to view the UUID of the device partition number, type the following command: `lsblk -o name,uuid`. UUID is the abbreviation of `Universally Unique Identifier`.

8.4.2 Mount management commands

`mount` command

The `mount` command allows you to mount and view the logical drives in the tree.

```
mount [-option] [device] [directory]
```

Example:

```
[root]# mount /dev/sda7 /home
```

Option	Description
`-n`	Sets mount without writing to `/etc/mtab`.
`-t`	Indicates the type of file system to use.
`-a`	Mounts all filesystems mentioned in `/etc/fstab`.
`-r`	Mounts the file system read-only (equivalent to `-o ro`).
`-w`	Mounts the file system read/write, by default (equivalent `-o rw`).
`-o opts`	The opts argument is a comma-separated list (`remount`, `ro`, ...).

Note

The `mount` command alone displays all mounted file systems. If the mount parameter is `-o defaults`, it is equivalent to `-o rw,suid,dev,exec,auto,nouser,async` and these parameters are independent of the file system. If you need to browse special mount options related to the file system, please read the "Mount options FS-TYPE" section in `man 8 mount` (FS-TYPE is replaced with the corresponding file system, such as ntfs, vfat, ufs, etc.)

`umount` command

The `umount` command is used to unmount logical drives.

```
umount [-option] [device] [directory]
```

Example:

```
[root]# umount /home
[root]# umount /dev/sda7
```

Option	Description
`-n`	Sets mounting removal without writing to `/etc/mtab`.
`-r`	Remounts as read-only if `umount` fails.
`-f`	Forces mounting removal.
`-a`	Removes mounts of all filesystems mentioned in `/etc/fstab`.

Note

When disassembling, you must not stay below the mounting point. Otherwise, the following error message is displayed: `device is busy`.

8.5 File naming convention

As in any system, it is important to respect the file naming rules to navigate the tree structure and file management.

- Files are coded on 255 characters;
- All ASCII characters can be used;
- Uppercase and lowercase letters are differentiated;
- Most files do not have a concept for file extension. In the GNU/Linux world, most file extensions are not required, except for a few (for example, .jpg, .mp4, .gif, etc.).

Groups of words separated by spaces must be enclosed in quotation marks:

```
[root]# mkdir "working dir"
```

Note

While nothing is technically wrong with creating a file or directory with a space, it is generally a "best practice" to avoid this and replace any space with an underscore.

Note

The **.** at the beginning of the file name only hides it from a simple `ls`.

Examples of file extension agreements:

- `.c` : source file in C language;
- `.h` : C and Fortran header file;
- `.o` : object file in C language;
- `.tar` : data file archived with the `tar` utility;
- `.cpio` : data file archived with the `cpio` utility;
- `.gz` : data file compressed with the `gzip` utility;
- `.tgz` : data file archived with the `tar` utility and compressed with the `gzip` utility;
- `.html` : web page.

8.5.1 Details of a file name

```
[root]# ls -liah /usr/bin/passwd
266037 -rwsr-xr-x 1 root root 59K mars  22  2019 /usr/bin/passwd
1      2    3     4  5    6    7       8              9
```

Part	Description
1	Inode number
2	File type (1st character of the block of 10), "-" means this is an ordinary file.
3	Access rights (last 9 characters of the block of 10)
4	If this is a directory, this number represents how many subdirectories there are in that directory, including hidden ones. If this is a file, it indicates the number of hard links. When the number 1 is, there is only one hard link.
5	Name of the owner
6	Name of the group
7	Size (byte, kilo, mega)
8	Date of last update
9	Name of the file

In the GNU/Linux world, there are seven file types:

File types	Description
-	Represents an ordinary file. Including plain text files (ASCII); binary files (binary); data format files (data); various compressed files.
d	Represents a directory file.
b	Represents a block device file. It includes hard drives, USB drives, and so on.
c	Represents a character device file. Interface device of serial port, such as mouse, keyboard, etc.
s	Represents a socket file. It is a file specially used for network communication.
p	Represents a pipe file. It is a special file type. The main purpose is to solve the errors caused by multiple programs accessing a file simultaneously. FIFO is the abbreviation of first-in-first-out.
l	Represents soft link files, also called symbolic link files, are similar to shortcuts in Windows. Hard link file, also known as physical link file.

Supplementary description of the directory

Each directory has two hidden files: **.** and **..**. You need to use `ls -al` to view, for example:

```
# . Indicates that in the current directory, for example, you need to execute a
script in a directory, usually:
Shell > ./scripts

# .. represents the directory one level above the current directory, for
example:
Shell > cd /etc/
Shell > cd ..
Shell > pwd
/

# For an empty directory, its fourth part must be greater than or equal to 2.
Because there are "." and ".."
Shell > mkdir /tmp/t1
Shell > ls -ldi /tmp/t1
1179657 drwxr-xr-x 2 root root 4096 Nov 14 18:41 /tmp/t1
```

Special files

To communicate with peripherals (hard disks, printers, etc.), Linux uses interface files called special files (*device file* or *special file*). These files allow the peripherals to identify themselves.

These files are special because they do not contain data but specify the access mode to communicate with the device.

They are defined in two modes:

- **block** mode;
- **character** mode.

```
# Block device file
Shell > ls -l /dev/sda
brw-------   1   root  root  8, 0 jan 1 1970 /dev/sda

# Character device file
Shell > ls -l /dev/tty0
crw-------   1   root  root  8, 0 jan 1 1970 /dev/tty0
```

Communication files

These are the pipe (*pipes*) and the *socket* files.

- **Pipe files** pass information between processes by FIFO (*First In, First Out*). One process writes transient information to a *pipe* file, and another reads it. After reading, the information is no longer accessible.
- **Socket files** allow bidirectional inter-process communication (on local or remote systems). They use an *inode* of the file system.

Link files

These files allow the possibility of giving several logical names to the same physical file, creating a new access point to the file.

There are two types of link files:

- Soft link files, also called symbolic link files;
- Hard link files, also called physical link files.

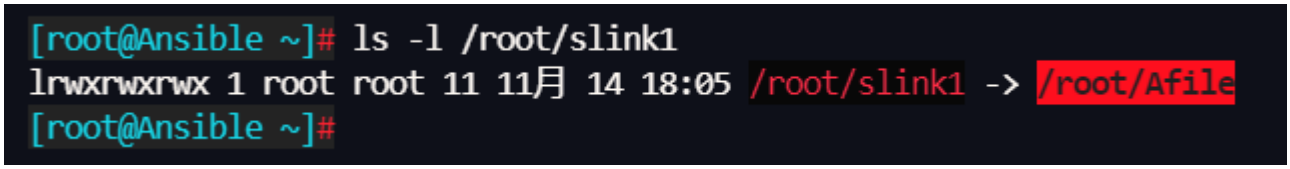
Their main features are:

Link types	Description
Soft link file	This file is similar to a shortcut for Windows. It has permission of 0777 and points to the original file. When the original file is deleted, you can use `ls -l` to view the output information of the soft link file. In the output information, the file name of the soft link appears in red, and the pointed original file appears in red with a flashing prompt.
Hard link file	This file represents different mappings occupying the same *inode* number. They can be updated synchronously (including file content, modification time, owner, group affiliation, access time, etc.). Hard-linked files cannot span partitions and file systems and cannot be used in directories.

Specific examples are as follows:

```
# Permissions and the original file to which they point
Shell > ls -l /etc/rc.locol
lrwxrwxrwx 1 root root 13 Oct 25 15:41 /etc/rc.local -> rc.d/rc.local

# When deleting the original file. "-s" represents the soft link option
Shell > touch /root/Afile
```

```
Shell > ln -s /root/Afile /root/slink1
Shell > rm -rf /root/Afile
```




```
Shell > cd /home/paul/
Shell > ls –li letter
666 –rwxr--r-- 1 root root … letter

# The ln command does not add any options, indicating a hard link
Shell > ln /home/paul/letter /home/jack/read

# The essence of hard links is the file mapping of the same inode number in
different directories.
Shell > ls –li /home/*/*
666 –rwxr--r-- 2 root root … letter
666 –rwxr--r-- 2 root root … read

# If you use a hard link to a directory, you will be prompted:
Shell > ln  /etc/  /root/etc_hardlink
ln: /etc: hard link not allowed for directory
```

8.6 File attributes

Linux is a multi-user operating system where the control of access to files is essential.

These controls are functions of:

- file access permissions ;
- users (*ugo Users Groups Others*).

8.6.1 Basic permissions of files and directories

The description of **file permissions** is as follows:

File permissions	Description
r	Read. Allows reading a file (`cat`, `less`, ...) and copying a file (`cp`, ...).
w	Write. Allows modification of the file content (`cat`, `>>`, `vim`, ...).
x	Execute. Considers the file as an e**X**ecutable (binary or script).
-	No right

The description of **directory permissions** is as follows:

Directory permissions	Description
r	Read. Allows reading the contents of a directory (`ls -R`).
w	Write. Allows you to create, and delete files/directories in this directory, such as commands `mkdir`, `rmdir`, `rm`, `touch`, and so on.
x	Execute. Allows entry into directory (`cd`).
-	No right

Info

For a directory's permissions, `r` and `x` usually appear at the same time. Moving or renaming a file depends on whether the directory where it is located has `w` permission, and so does deleting a file.

8.6.2 User type corresponding to basic permission

User type	Description
u	Owner
g	Owner group
o	Others users

Info

In some commands, you can use *a* (*all*) to represent *ugo*. For example: `chmod a+x FileName` is equivalent to `chmod u+x,g+x,o+x FileName` or `chmod ugo+x FileName`.

8.6.3 Attribute management

The display of rights is done with the command `ls -l`. It is the last 9 characters of the block of 10. More precisely 3 times 3 characters.

```
[root]# ls -l /tmp/myfile
-rwxrw-r-x  1  root  sys  ... /tmp/myfile
  1  2  3       4     5
```

Part	Description
1	Owner (**u**ser) permissions, here `rwx`
2	Owner group permissions (**g**roup), here `rw-`
3	Other users' permissions (**o**thers), here `r-x`
4	File owner
5	Group owner of the file

By default, the *owner* of a file is the one who created it. The *group* of the file is the group of the owner who created the file. The *others* are those not concerned by the previous cases.

The attributes are changed with the `chmod` command.

Only the administrator and the owner of a file can change the rights of a file.

`chmod` command

The `chmod` command allows you to change the access permissions to a file.

```
chmod [option] mode file
```

Option	Observation
`-R`	Recursively change the permissions of the directory and all files under the directory.

Warning

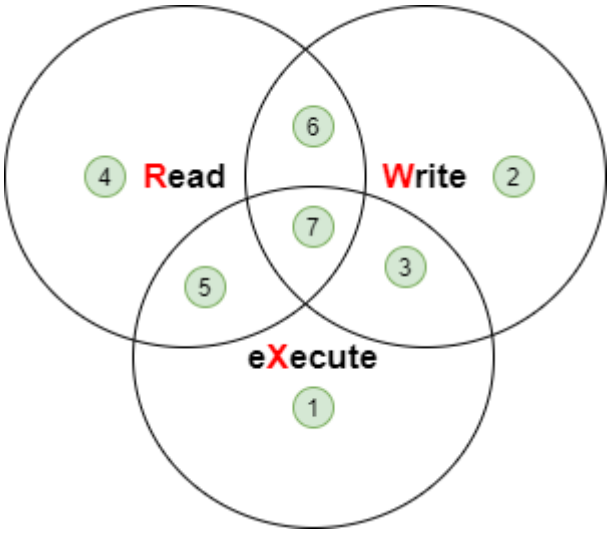
The rights of files and directories are not dissociated. For some operations, it will be necessary to know the rights of the directory containing the file. A write-protected file can be deleted by another user as long as the rights of the directory containing it allow this user to perform this operation.

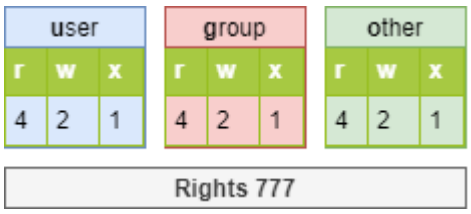
The mode indication can be an octal representation (e.g. `744`) or a symbolic representation ([`ugoa`] [`+=-`] [`rwxst`]).

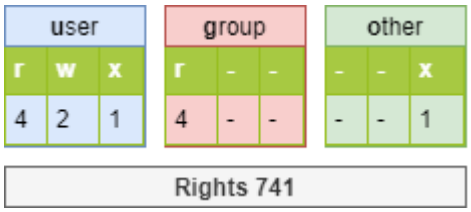
OCTAL OR NUMBER REPRESENTATION

Number	Description
4	r
2	w
1	x
0	-

Add the three numbers together to get one user type permission. E.g. **755=rwxr-xr-x**.







Info

Sometimes you will see `chmod 4755`. The number 4 here refers to the special permission **set uid**. Special permissions will not be expanded here for the moment, just as a basic understanding.

```
[root]# ls -l /tmp/fil*
-rwxrwx--- 1 root root … /tmp/file1
-rwx--x--- 1 root root … /tmp/file2
-rwx--xr-- 1 root root … /tmp/file3

[root]# chmod 741 /tmp/file1
[root]# chmod -R 744 /tmp/file2
[root]# ls -l /tmp/fic*
-rwxr----x 1 root root … /tmp/file1
-rwxr--r-- 1 root root … /tmp/file2
```

SYMBOLIC REPRESENTATION

This method can be considered as a "literal" association between a user type, an operator, and rights.

Who?	
User	u
Group	g
Other	o
All	a

Operation	
add	+
remove	-
replace	=

Rights	
Read	r
Write	w
eXecute	x

```
[root]# chmod -R u+rwx,g+wx,o-r /tmp/file1
[root]# chmod g=x,o-r /tmp/file2
[root]# chmod -R o=r /tmp/file3
```

8.7 Default rights and mask

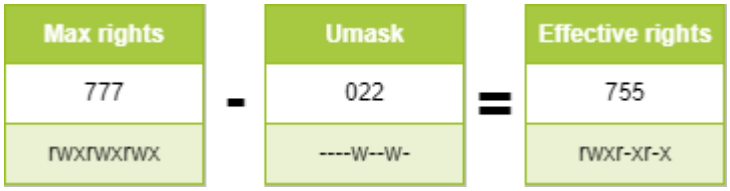
When a file or directory is created, it already has permissions.

- For a directory: `rwxr-xr-x` or *755*.
- For a file: `rw-r-r-` or *644*.

This behavior is defined by the **default mask**.

The principle is to remove the value defined by the mask at maximum rights without the execution right.

For a directory:



For a file, the execution rights are removed:

Info

The `/etc/login.defs` file defines the default UMASK, with a value of **022**. This means the permission to create a file is 755 (rwxr-xr-x). However, for the sake of security, GNU/Linux does not have **x** permission for newly created files. This restriction applies to root(uid=0) and ordinary users(uid>=1000).

```
# root user
Shell > touch a.txt
Shell > ll
-rw-r--r-- 1 root root     0 Oct  8 13:00 a.txt
```

8.7.1 `umask` command

The `umask` command allows you to display and modify the mask.

```
umask [option] [mode]
```

Example:

```
$ umask 033
$ umask
0033
$ umask -S
u=rwx,g=r,o=r
$ touch umask_033
$ ls -la  umask_033
-rw-r--r-- 1 rockstar rockstar 0 nov.   4 16:44 umask_033
```

```
$ umask 025
$ umask -S
u=rwx,g=rx,o=w
$ touch umask_025
$ ls -la  umask_025
-rw-r---w- 1 rockstar rockstar 0 nov.   4 16:44 umask_025
```

Option	Description
`-S`	Symbolic display of file rights.

Warning

`umask` does not affect existing files. `umask -S` displays the file rights (without the execute right) of the files that will be created. So, it is not the display of the mask used to subtract the maximum value.

Note

In the above example, using commands to modify masks applies only to the currently connected session.

Info

The `umask` command belongs to bash's built-in commands, so when you use `man umask`, all built-in commands will be displayed. If you only want to view the help of `umask`, you must use the `help umask` command.

To keep the value, you have to modify the following profile files

For all users:

- `/etc/profile`
- `/etc/bashrc`

For a particular user:

- `~/.bashrc`

When the above file is written, it actually overrides the **UMASK** parameter of `/etc/login.defs`. If you want to improve the security of the operating system, you can set umask to **027** or **077**.

9. Process Management

In this chapter, you will learn how to work with processes.

Objectives: In this chapter, future Linux administrators will learn how to:

✓ Recognize the `PID` and `PPID` of a process;
✓ View and search for processes;
✓ Manage processes.

🏁 **process**, **linux**

Knowledge: ⭐ ⭐
Complexity: ⭐

Reading time: 20 minutes

9.1 Generalities

An operating system consists of processes. These processes are executed in a specific order and are related. There are two categories of processes, those focused on the user environment and those focused on the hardware environment.

When a program runs, the system will create a process by placing the program data and code in memory and creating a **runtime stack**. A process is an instance of a program with an associated processor environment (ordinal counter, registers, etc...) and memory environment.

Each process has:

- a *PID*: ***P**rocess **ID**entifier*, a unique process identifier
- a *PPID*: ***P**arent **P**rocess **ID**entifier*, unique identifier of parent process

By successive filiations, the `init` process is the father of all processes.

- A parent process always creates a process
- A parent process can have multiple child processes

There is a parent/child relationship between processes. A child process results from the parent calling the *fork()* primitive and duplicating its code to create a child. The *PID* of the child is returned to the parent process so that it can talk to it. Each child has its parent's identifier, the *PPID*.

The *PID* number represents the process at the time of execution. When the process finishes, the number is available again for another process. Running the same command several times will produce a different *PID* each time.

> **Note**
>
> Processes are not to be confused with *threads*. Each process has its memory context (resources and address space), while *threads* from the same process share this context.

9.2 Viewing processes

The `ps` command displays the status of running processes.

```
ps [-e] [-f] [-u login]
```

Example:

```
# ps -fu root
```

Option	Description
`-e`	Displays all processes.
`-f`	Displays full format list.
`-u` login	Displays the user's processes.

Some additional options:

Option	Description
`-g`	Displays the processes in the group.
`-t tty`	Displays the processes running from the terminal.
`-p PID`	Displays the process information.
`-H`	Displays the information in a tree structure.
`-l`	Displays in long format.
`--sort COL`	Sort the result according to a column.
`--headers`	Displays the header on each terminal page.
`--format "%a %b %c"`	Customize the output display format.

Without an option specified, the `ps` command only displays processes running from the current terminal.

The result is displayed in the following columns:

```
# ps -ef
UID  PID PPID C STIME  TTY TIME      CMD
root 1   0    0 Jan01  ?   00:00/03  /sbin/init
```

Column	Description
`UID`	Owner user.
`PID`	Process identifier.
`PPID`	Parent process identifier.
`C`	Priority of the process.
`STIME`	Date and time of execution.
`TTY`	Execution terminal.
`TIME`	Processing duration.
`CMD`	Command executed.

The behavior of the control can be fully customized:

```
# ps -e --format "%P %p %c %n" --sort ppid --headers
 PPID   PID COMMAND          NI
    0     1 systemd           0
    0     2 kthreadd          0
    1   516 systemd-journal   0
    1   538 systemd-udevd     0
```

```
      1   598 lvmetad           0
      1   643 auditd           -4
      1   668 rtkit-daemon      1
      1   670 sssd              0
```

9.3 Types of processes

The user process:

- is started from a terminal associated with a user
- accesses resources via requests or daemons

The system process (*daemon*):

- is started by the system
- is not associated with any terminal and is owned by a system user (often `root`)
- is loaded at boot time, resides in memory, and is waiting for a call
- is usually identified by the letter `d` associated with the process name

System processes are therefore called daemons (***D*isk And Execution** MON**itor*).

9.4 Permissions and rights

The user's credentials are passed to the created process when a command is executed.

By default, the process's actual `UID` and `GID` (of the process) are identical to the **actual** `UID` and `GID` (the `UID` and `GID` of the user who executed the command).

When a `SUID` (and/or `SGID`) is set on a command, the actual `UID` (and/or `GID`) becomes that of the owner (and/or owner group) of the command and no longer that of the user or user group that issued the command. Effective and real **UIDs** are therefore **different**.

Each time a file is accessed, the system checks the rights of the process according to its effective identifiers.

9.5 Process management

A process cannot be run indefinitely, as this would be to the detriment of other running processes and would prevent multitasking.

Therefore, the total processing time available is divided into small ranges, and each process (with a priority) accesses the processor sequentially. The process will take several states during its life among the states:

- ready: waiting for the availability of the process
- in execution: accesses the processor
- suspended: waiting for an I/O (input/output)
- stopped: waiting for a signal from another process
- zombie: request for destruction
- dead: the parent process ends the child process

The end-of-process sequencing is as follows:

1. Closing of the open files
2. Release of the used memory
3. Sending a signal to the parent and child processes

When a parent process dies, their children are said to be orphans. They are then adopted by the `init` process, which will destroy them.

9.5.1 The priority of a process

GNU/Linux belongs to the family of time-sharing operating systems. Processors work in a time-sharing manner, and each process takes up some processor time. Processes are classified by priority:

- Real-time process: the process with priority of **0-99** is scheduled by real-time scheduling algorithm.
- Ordinary processes: processes with dynamic priorities of **100-139** are scheduled using a fully fair scheduling algorithm.
- Nice value: a parameter used to adjust the priority of an ordinary process. The range is **-20-19**.

The default priority of a process is **0**.

9.5.2 Modes of operation

Processes can run in two ways:

- **synchronous**: the user loses access to the shell during command execution. The command prompt reappears at the end of the process execution.
- **asynchronous**: the process is processed in the background. The command prompt is displayed again immediately.

The constraints of the asynchronous mode:

- the command or script must not wait for keyboard input
- the command or script must not return any result on the screen
- quitting the shell ends the process

9.6 Process management controls

9.6.1 `kill` command

The `kill` command sends a stop signal to a process.

```
kill [-signal] PID
```

Example:

```
kill -9 1664
```

Code	Signal	Description
`2`	*SIGINT*	Immediate termination of the process
`9`	*SIGKILL*	Interrupts the process (`^ Ctrl` + `d`)
`15`	*SIGTERM*	Clean termination of the process
`18`	*SIGCONT*	Resumes the process. Processes that use the SIGSTOP signal can use it to continue running
`19`	*SIGSTOP*	Suspends the process (Stops process). The effect of this signal is equivalent to `^ Ctrl` + `z`

Signals are the means of communication between processes. The `kill` command sends a signal to a process.

Tip

The complete list of signals taken into account by the `kill` command is available by typing the command:

```
$ man 7 signal
```

9.6.2 `nohup` command

`nohup` allows the launching of a process independently of a connection.

```
nohup command
```

Example:

```
nohup myprogram.sh 0</dev/null &
```

`nohup` ignores the `SIGHUP` signal sent when a user logs out.

Note

`nohup` handles standard output and error but not standard input, hence the redirection of this input to `/dev/null`.

9.6.3 [Ctrl] + [z]

The synchronous process is temporarily suspended by pressing the `^ Ctrl` + `z` keys simultaneously. Access to the prompt is restored after displaying the number of the process that has just been suspended.

9.6.4 `&` instruction

The `&` statement executes the command asynchronously (the command is then called *job*) and displays the number of *job*. Access to the prompt is then returned.

Example:

```
$ time ls -lR / > list.ls 2> /dev/null &
[1] 15430
$
```

The *job* number is obtained during background processing and is displayed in square brackets, followed by the `PID` number.

9.6.5 `fg` and `bg` commands

The `fg` command puts the process in the foreground:

```
$ time ls -lR / > list.ls 2>/dev/null &
$ fg 1
time ls -lR / > list.ls 2/dev/null
```

while the command `bg` places it in the background:

```
[CTRL]+[Z]
^Z
[1]+ Stopped
$ bg 1
[1] 15430
$
```

Whether it was put in the background when it was created with the `&` argument or later with the `^ Ctrl` + `z` keys, a process can be brought back to the foreground with the `fg` command and its job number.

9.6.6 `jobs` command

The `jobs` command displays the list of processes running in the background and specifies their job number.

Example:

```
$ jobs
[1]- Running    sleep 1000
[2]+ Running    find / > arbo.txt
```

The columns represent:

1. job number
2. the order that the processes run:
3. a `+` : The process selected by default for the `fg` and `bg` commands when no job number is specified
4. a `-` : This process is the next process to take the `+`
5. *Running* (running process) or *Stopped* (suspended process)
6. the command

9.6.7 `nice` and `renice` commands

The command `nice` allows the execution of a command by specifying its priority.

```
nice priority command
```

Usage example:

```
nice --adjustment=-5 find / -name "file"

nice -n -5 find / -name "file"

nice --5 find / -name "file"

nice -n 5 find / -name "file"

nice find / -name "file"
```

Unlike `root`, a standard user can only reduce the priority of a process and only values between 0 and 19 will be accepted.

As shown in the example above, the first three commands indicate setting the Nice value to "-5", while the second command is our recommended usage. The fourth command indicates setting the Nice value to "5". For the fifth command, not typing any options means that the Nice value is set to "10".

Tip

"Nice" is the abbreviation for "niceness".

Directly typing the `nice` command will return the Nice value of the current shell.

You can lift the Nice value limit for each user or group by modifying the `/etc/security/limits.conf` file.

The `renice` command allows you to change the priority of a running process.

```
renice priority [-g GID] [-p PID] [-u UID]
```

Example:

```
renice -n 15 -p 1664
```

Option	Description
`-g`	`GID` of the process owner group.
`-p`	`PID` of the process.
`-u`	`UID` of the process owner.

The `renice` command acts on existing processes. Therefore, it is possible to change the priority of a specific process and several processes belonging to a user or a group.

Tip

The `pidof` command, coupled with the `xargs` command (see the Advanced Commands course), allows a new priority to be applied in a single command:

```
$ pidof sleep | xargs renice -n 20
```

To adapt to different distributions, you should try to use command forms such as `nice -n 5` or `renice -n 6` as much as possible.

9.6.8 `top` command

The `top` command displays the processes and their resource consumption.

```
$ top
PID  USER PR NI ... %CPU %MEM  TIME+    COMMAND
2514 root 20 0       15    5.5 0:01.14   top
```

Column	Description
`PID`	Process identifier.
`USER`	Owner user.
`PR`	Process priority.
`NI`	Nice value.
`%CPU`	Processor load.
`%MEM`	Memory load.
`TIME+`	Processor usage time.
`COMMAND`	Command executed.

The `top` command allows control of the processes in real-time and in interactive mode.

9.6.9 `pgrep` and `pkill` commands

The `pgrep` command searches the running processes for a process name and displays the *PID* matching the selection criteria on the standard output.

The `pkill` command will send each process the specified signal (by default *SIGTERM*).

```
pgrep process
pkill [option] [-signal] process
```

Examples:

- Get the process number from `sshd`:

```
pgrep -u root sshd
```

- Kill all `tomcat` processes:

```
pkill tomcat
```

> **Note**
>
> Before you kill a process, it's best to know exactly what it is for; otherwise, it can lead to system crashes or other unpredictable problems.

In addition to sending signals to the relevant processes, the `pkill` command can also end the user's connection session according to the terminal number, such as:

```
pkill -t pts/1
```

9.6.10 `killall` command

This command's function is roughly the same as that of the `pkill` command. The usage is — `killall [option] [ -s SIGNAL | -SIGNAL ] NAME`. The default signal is *SIGTERM*.

Options	Description
`-l`	lists all known signal names
`-i`	asks for confirmation before killing
`-I`	case insensitive process name match

Example:

```
killall tomcat
```

9.6.11 `pstree` command

This command displays the progress in a tree style, and its usage is - `pstree [option]`.

Option	Description
`-p`	Displays the PID of the process
`-n`	sorts output by PID
`-h`	highlights the current process and its ancestors
`-u`	shows uid transitions

```
$ pstree -pnhu
systemd(1)─┬─systemd-journal(595)
           ├─systemd-udevd(625)
           ├─auditd(671)───{auditd}(672)
           ├─dbus-daemon(714,dbus)
           ├─NetworkManager(715)─┬─{NetworkManager}(756)
           │                     └─{NetworkManager}(757)
           ├─systemd-logind(721)
           ├─chronyd(737,chrony)
           ├─sshd(758)───sshd(1398)───sshd(1410)───bash(1411)───pstree(1500)
           ├─tuned(759)─┬─{tuned}(1376)
           │            ├─{tuned}(1381)
           │            ├─{tuned}(1382)
           │            └─{tuned}(1384)
           ├─agetty(763)
           ├─crond(768)
           ├─polkitd(1375,polkitd)─┬─{polkitd}(1387)
           │                       ├─{polkitd}(1388)
           │                       ├─{polkitd}(1389)
           │                       ├─{polkitd}(1390)
           │                       └─{polkitd}(1392)
           └─systemd(1401)───(sd-pam)(1404)
```

9.6.12 Orphan process and zombie process

orphan process: When a parent process dies, their children are said to be orphans. The init process adopts these special state processes, and status collection is completed until they are destroyed. Conceptually speaking, the orphanage process does not pose any harm.

zombie process: After a child process completes its work and is terminated, its parent process needs to call the signal processing function wait() or waitpid() to obtain the termination status of the child process. If the parent process does not do so, although the child process has already exited, it still retains some exit status information in the system process table. Because the parent process cannot obtain the status information of the child process, these processes will continue to occupy resources in the process table. We refer to processes in this state as zombies.

Hazard:

- They are occupying system resources and causing a decrease in machine performance.
- Unable to generate new child processes.

How can we check for any zombie processes in the current system?

```
ps -lef | awk '{print $2}' | grep Z
```

These characters may appear in this column:

- **D** - uninterruptible sleep (usually IO)
- **I** - Idle kernel thread
- **R** - running or runnable (on run queue)
- **S** - interruptible sleep (waiting for an event to complete)
- **T** - stopped by job control signal
- **t** - stopped by debugger during the tracing
- **W** - paging (not valid since the 2.6.xx kernel)
- **X** - dead (should never be seen)
- **Z** - defunct ("zombie") process, terminated but not reaped by its parent

10. Backup and Restore

In this chapter, you will learn how to back up and restore your data using Linux.

Objectives: In this chapter, future Linux administrators will learn how to:

✔ use the `tar` and `cpio` command to make a backup;
✔ check their backups and restore data;
✔ compress or decompress their backups.

🏁 **backup**, **restore**, **compression**

Knowledge: ⭐ ⭐ ⭐
Complexity: ⭐ ⭐

Reading time: 40 minutes

> **Note**
>
> Throughout this chapter, the command structures use "device" to specify both a target location for backup and the source location when restoring. The device can be either external media or a local file. You should get a feel for this as the chapter unfolds, but you can always refer back to this note for clarification if you need to.

The backup will answer the need to conserve and restore data effectively.

The backup allows you to protect yourself from the following:

- **Destruction**: voluntary or involuntary. Human or technical. Virus, ...
- **Deletion**: voluntary or involuntary. Human or technical. Virus, ...
- **Integrity**: data becomes unusable.

No system is infallible, and no human is infallible, so to avoid losing data, it must be backed up to restore it after a problem.

The backup media should be kept in another room (or building) than the server so that a disaster does not destroy the server and the backups.

In addition, the administrator must regularly check that the media are still readable.

10.1 Generalities

There are two principles: the **backup** and the **archive**.

- The archive destroys the information source after the operation.
- The backup preserves the source of information after the operation.

These operations consist of saving information in a file, on a peripheral, or a supported media (tapes, disks, and so on).

10.1.1 The process

Backups require a lot of discipline and rigor from the system administrator. System administrators need to consider the following issues before performing backup operations:

- What is the appropriate medium?
- What should be backed up?
- How many copies?
- How long will the backup take?
- Method?
- How often?
- Automatic or manual?
- Where to store it?
- How long will it be kept?
- Is there a cost issue to consider?

In addition to these issues, system administrators should also consider factors such as performance, data importance, bandwidth consumption, and maintenance complexity based on actual situations.

10.1.2 Backup methods

- **Full backup**: Refers to a one-time copy of all files, folders, or data in the hard disk or database.
- **Incremental backup**: Refers to the backup of the data updated after the last Full backup or Incremental backup.
- **Differential backup**: Refers to the backup of the changed files after the Full backup.
- **Selective backup (Partial backup)**: Refers to backing up a part of the system.
- **Cold backup**: Refers to the backup when the system is in a shutdown or maintenance state. The backed-up data is precisely the same as the data in the system during this period.
- **Hot backup**: Refers to the backup when the system is operating normally. As the data in the system is updated at any time, the backed-up data has a certain lag relative to the system's real data.
- **Remote backup**: Refers to backing up data in another geographic location to avoid data loss and service interruption caused by fire, natural disasters, theft, and more.

10.1.3 Frequency of backups

- **Periodic**: Backup within a specific period before a major system update (usually during off-peak hours)
- **cycle**: Backup in units of days, weeks, months, etc

> **Tip**
>
> Before a system change, it can be useful to make a backup. However, there is no point in backing up data every day that only changes every month.

10.1.4 Recover methods

Depending on the utilities available, performing several types of recovery will be possible.

In some relational database management systems, the corresponding operations of "recover" (sometimes "recovery" is used in the documentation) and "restore" are different. For further information, consult the official documentation. This basic document will not go into too much detail regarding this part of RDBMS.

- **Full recover**: Data recovery based on Full backup or "Full backup + Incremental backup" or "Full backup + Differential backup".
- **Selective recover**: Data recovery based on Selective backup (Partial backup).

We do not recommend directly deleting directories or files in the currently active operating system before performing a recovery operation (unless you know what will happen after deletion). If you don't know what will happen, you can perform a 'snapshot' operation on the current operating system.

Tip

For security reasons, storing the restored directory or file in the /tmp directory before performing the recovery operation is recommended to avoid situations where old files (old directory) overwrite new files (new directory).

10.1.5 The tools and related technologies

There are many utilities to make backups.

- **editor tools**;
- **graphical tools**;
- **command line tools**: `tar`, `cpio`, `pax`, `dd`, `dump`, ...

The commands we will use here are `tar` and `cpio`. If you want to learn about the `dump` tool, please refer to this document.

- `tar`:
- easy to use;
- allows adding files to an existing backup.
- `cpio`:
- retains owners;
- retains groups, dates and rights;
- skips damaged files;
- can be used for the entire file system.

> **Note**
>
> These commands save in a proprietary and standardized format.

Replication: A backup technology that copies a set of data from one data source to another or multiple data sources, mainly divided into **Synchronous Replication** and **Asynchronous Replication**. This is an advanced backup part for novice system administrators, so this basic document will not elaborate on these contents.

10.1.6 Naming convention

Using a naming convention allows one to quickly target a backup file's contents and thus avoid hazardous restorations.

- name of the directory;
- utility used;
- options used;
- date.

> **Tip**
>
> The name of the backup must be explicit.

> **Note**
>
> In the Linux world, most files do not have the extension concept except for a few exceptions in GUI environments (such as .jpg, .mp4, .gif). In other words, most file extensions are not required. The reason for artificially adding suffixes is to facilitate recognition by human users. If the systems administrator sees a `.tar.gz` or `.tgz` file extension, for instance, then he knows how to deal with the file.

10.1.7 Properties of the backup file

A single backup file can include the following properties:

- file name (including manually added suffixes);
- backup the atime, ctime, mtime, btime (crtime) of the file itself;
- file size of the backup file itself;
- the properties or characteristics of files or directories in the backup file will be partially preserved. For example, mtime for files or directories will be retained, but `inode` number will not be retained.

10.1.8 Storage methods

There are two different storage methods:

- Internal: Store backup files on the current working disk.
- External: Store backup files on external devices. External devices can be USB drives, CDs, disks, servers, or NAS, and more.

10.2 Tape ArchiveR - `tar`

The `tar` command allows saving on several successive media (multi-volume options).

It is possible to extract all or part of a backup.

`tar` implicitly backs up in relative mode even if the path of the information to be backed up is mentioned in absolute mode. However, backups and restores in absolute mode are possible. If you want to see a separate example of the usage of `tar`, please refer to this document.

10.2.1 Restoration guidelines

The right questions to ask are:

- what: partial or complete;
- where: the place where the data will be restored;
- how: absolute or relative.

> **Warning**
>
> Before a restoration, it is important to consider and determine the most appropriate method to avoid mistakes.

Restorations are usually performed after a problem has occurred that needs to be resolved quickly. A poor restoration can, in some cases, make the situation worse.

10.2.2 Backing up with `tar`

The default utility for creating backups on UNIX systems is the `tar` command. These backups can be compressed by `bzip2`, `xz`, `lzip`, `lzma`, `lzop`, `gzip`, `compress` or `zstd`.

`tar` allows you to extract a single file or a directory from a backup, view its contents, or validate its integrity.

Estimate the size of a backup

The following command estimates the size in bytes of a possible *tar* file:

```
$ tar cf - /directory/to/backup/ | wc -c
20480
$ tar czf - /directory/to/backup/ | wc -c
508
$ tar cjf - /directory/to/backup/ | wc -c
428
```

> **Warning**
>
> Beware, the presence of "-" in the command line disturbs `zsh`. Switch to `bash`!

Naming convention for a `tar` backup

Here is an example of a naming convention for a `tar` backup, knowing that the date will be added to the name.

keys	Files	Suffix	Functionality
`cvf`	`home`	`home.tar`	`/home` in relative mode, uncompressed form
`cvfP`	`/etc`	`etc.A.tar`	`/etc` in absolute mode, no compression
`cvfz`	`usr`	`usr.tar.gz`	`/usr` in relative mode, *gzip* compression
`cvfj`	`usr`	`usr.tar.bz2`	`/usr` in relative mode, *bzip2* compression
`cvfPz`	`/home`	`home.A.tar.gz`	`/home` in absolute mode, *gzip* compression
`cvfPj`	`/home`	`home.A.tar.bz2`	`/home` in absolute mode, *bzip2* compression
…			

Create a backup

CREATE A BACKUP IN RELATIVE MODE

Creating a non-compressed backup in relative mode is done with the `cvf` keys:

```
tar c[vf] [device] [file(s)]
```

Example:

```
[root]# tar cvf /backups/home.133.tar /home/
```

Key	Description
`c`	Creates a backup.
`v`	Displays the name of the processed files.
`f`	Allows you to specify the name of the backup (medium).

Tip

The hyphen (`-`) in front of the `tar` keys is optional!

CREATE A BACKUP IN ABSOLUTE MODE

Creating a non-compressed backup explicitly in absolute mode is done with the `cvfP` keys:

```
tar c[vf]P [device] [file(s)]
```

Example:

```
[root]# tar cvfP /backups/home.133.P.tar /home/
```

Key	Description
`P`	Creates a backup in absolute mode.

Warning

With the `P` key, the path of the files to be backed up must be entered as **absolute**. If the two conditions (`P` key and **absolute** path) are not indicated, the backup is in relative mode.

CREATING A COMPRESSED BACKUP WITH `gzip`

Creating a compressed backup with `gzip` is done with the `cvfz` keys:

```
tar cvzf backup.tar.gz dirname/
```

Key	Description
`z`	Compresses the backup in *gzip*.

Note

The `.tgz` extension is equivalent to `.tar.gz` .

Note

Keeping the `cvf` (`tvf` or `xvf`) keys unchanged for all backup operations and simply adding the compression key to the end of the keys makes the command easier to understand (such as: `cvfz` or `cvfj` , and others).

CREATING A COMPRESSED BACKUP WITH `bzip2`

Creating a compressed backup with `bzip2` is done with the keys `cvfj`:

```
tar cvfj backup.tar.bz2 dirname/
```

Key	Description
`j`	Compresses the backup in *bzip2*.

Note

The `.tbz` and `.tb2` extensions are equivalent to `.tar.bz2` extensions.

COMPARISON OF COMPRESSION EFFICIENCY

Compression, and consequently decompression, will impact resource consumption (time and CPU usage).

Here is a ranking of the compression of a set of text files from least to most efficient:

- compress (`.tar.Z`)
- gzip (`.tar.gz`)
- bzip2 (`.tar.bz2`)
- lzip (`.tar.lz`)
- xz (`.tar.xz`)

Add a file or directory to an existing backup

It is possible to add one or more items to an existing backup.

```
tar {r|A}[key(s)] [device] [file(s)]
```

To add `/etc/passwd` to the backup `/backups/home.133.tar`:

```
[root]# tar rvf /backups/home.133.tar /etc/passwd
```

Adding a directory is similar. Here add `dirtoadd` to `backup_name.tar`:

```
tar rvf backup_name.tar dirtoadd
```

Key	Description
`r`	Appends the files or directories to the end of the archive.
`A`	Appends all files in one archive to the end of another archive.

Note

It is not possible to add files or folders to a compressed backup.

```
$ tar rvfz backup.tgz filetoadd
tar: Cannot update compressed archives
Try `tar --help' or `tar --usage' for more information.
```

Note

If the backup was performed in relative mode, add files in relative mode. If the backup was done in absolute mode, add files in absolute mode.

Mixing modes can cause problems when restoring.

List the contents of a backup

Viewing the contents of a backup without extracting it is possible.

```
tar t[key(s)] [device]
```

Key	Description
`t`	Displays the content of a backup (compressed or not).

Examples:

```
tar tvf backup.tar
tar tvfz backup.tar.gz
tar tvfj backup.tar.bz2
```

When the number of files in the backup increases, you can use pipe characters (`|`) and some commands (`less`, `more`, `most`, and others) to achieve the effect of paging viewing:

```
tar tvf backup.tar | less
```

Tip

To list or retrieve the contents of a backup, it is not necessary to mention the compression algorithm used when the backup was created. That is, a `tar tvf` is equivalent to `tar tvfj`, to read the contents. The compression type or algorithm **must** only be selected when creating a compressed backup.

Tip

You should always check and view the backup file's contents before performing a restore operation.

Check the integrity of a backup

The integrity of a backup can be tested with the `W` key at the time of its creation:

```
tar cvfW file_name.tar dir/
```

The integrity of a backup can be tested with the key `d` after its creation:

```
tar vfd file_name.tar dir/
```

Tip

By adding a second `v` to the previous key, you will get the list of archived files as well as the differences between the archived files and those present in the file system.

```
$ tar vvfd  /tmp/quodlibet.tar .quodlibet/
drwxr-x--- rockstar/rockstar     0 2021-05-21 00:11 .quodlibet/
-rw-r--r-- rockstar/rockstar     0 2021-05-19 00:59 .quodlibet/queue
[…]
-rw------- rockstar/rockstar  3323 2021-05-21 00:11 .quodlibet/config
.quodlibet/config: Mod time differs
.quodlibet/config: Size differs
[…]
```

The `W` key is also used to compare the content of an archive against the filesystem:

```
$ tar tvfW file_name.tar
Verify 1/file1
1/file1: Mod time differs
1/file1: Size differs
Verify 1/file2
Verify 1/file3
```

You cannot verify the compressed archive with the `W` key. Instead, you must use the `d` key.

```
tar dfz file_name.tgz
tar dfj file_name.tar.bz2
```

Extract (*untar*) a backup

Extract (*untar*) a `*.tar` backup is done with the `xvf` keys:

Extract the `etc/exports` file from the `/savings/etc.133.tar` backup into the `etc` directory of the current directory:

```
tar xvf /backups/etc.133.tar etc/exports
```

Extract all files from the compressed backup `/backups/home.133.tar.bz2` into the current directory:

```
[root]# tar xvfj /backups/home.133.tar.bz2
```

Extract all files from the backup `/backups/etc.133.P.tar` to their original directory:

```
tar xvfP /backups/etc.133.P.tar
```

> **Warning**
>
> For security reasons, you should use caution when extracting backup files saved in absolute mode.
>
> Once again, before performing extraction operations, you should always check the contents of the backup files (particularly those saved in absolute mode).

Key	Description
`x`	Extracts files from backups (whether compressed or not)

Extracting a *tar-gzipped* (`*.tar.gz`) backup is done with the `xvfz` keys:

```
tar xvfz backup.tar.gz
```

Extracting a *tar-bzipped* (`*.tar.bz2`) backup is done with the `xvfj` keys:

```
tar xvfj backup.tar.bz2
```

Tip

To extract or list the contents of a backup, it is not necessary to mention the compression algorithm used to create the backup. That is, a `tar xvf` is equivalent to `tar xvfj`, to extract the contents, and a `tar tvf` is equivalent to `tar tvfj`, to list.

Warning

To restore the files in their original directory (key `P` of a `tar xvf`), you must have generated the backup with the absolute path. That is, with the `P` key of a `tar cvf`.

EXTRACT ONLY A FILE FROM A *TAR* BACKUP

To extract a specific file from a *tar* backup, specify the name of that file at the end of the `tar xvf` command.

```
tar xvf backup.tar /path/to/file
```

The previous command extracts only the `/path/to/file` file from the `backup.tar` backup. This file will be restored to the `/path/to/` directory created, or already present, in the active directory.

```
tar xvfz backup.tar.gz /path/to/file
tar xvfj backup.tar.bz2 /path/to/file
```

EXTRACT A FOLDER FROM A BACKUP *TAR*

To extract only one directory (including its subdirectories and files) from a backup, specify the directory name at the end of the `tar xvf` command.

```
tar xvf backup.tar /path/to/dir/
```

To extract multiple directories, specify each of the names one after the other:

```
tar xvf backup.tar /path/to/dir1/ /path/to/dir2/
tar xvfz backup.tar.gz /path/to/dir1/ /path/to/dir2/
tar xvfj backup.tar.bz2 /path/to/dir1/ /path/to/dir2/
```

EXTRACT A GROUP OF FILES FROM A *TAR* BACKUP USING WILDCARD

Specify a wildcard to extract the files matching the specified selection pattern.

For example, to extract all files with the extension `.conf`:

```
tar xvf backup.tar --wildcards '*.conf'
```

keys:

- **--wildcards *.conf** corresponds to files with the extension `.conf`.

> **Expanded Knowledge**
>
> Although wildcard characters and regular expressions usually have the same symbol or style, the objects they match are completely different, so people often confuse them.
>
> **wildcard (wildcard character)**: used to match file or directory names. **regular expression**: used to match the content of a file.
>
> You can see an introduction with extra detail in this document.

10.3 *CoPy Input Output* - `cpio`

The `cpio` command allows saving on several successive media without specifying any options.

It is possible to extract all or part of a backup.

Unlike the `tar` command, there is no option to backup and compress simultaneously. So, it is done in two steps: backup and compression.

`cpio` has three operating modes, each corresponding to a different function:

1. **copy-out mode** - Creates a backup (archive). Enable this mode through the `-o` or `--create` options. In this mode, you must generate a list of files with a specific command (`find` , `ls` , or `cat`) and pass it to cpio.
2. `find` : browses a tree, recursive or not;
3. `ls` : lists a directory, recursive or not;
4. `cat` : reads a file containing the trees or files to be saved.

> **Note**
>
> `ls` cannot be used with `-l` (details) or `-R` (recursive).
>
> It requires a simple list of names.

5. **copy-in mode** – extracts files from an archive. You can enable this mode through the `-i` option.
6. **copy-pass mode** – copies files from one directory to another. You can enable this mode through the `-p` or `--pass-through` options.

Like the `tar` command, users must consider how the file list is saved (**absolute path** or **relative path**) when creating an archive.

Secondary function:

1. `-t` - Prints a table of input contents.
2. `-A` - Appends to an existing archive. It only works in copy-in mode.

> **Note**
>
> Some options of `cpio` need to be combined with the correct operating mode to work correctly. See `man 1 cpio`

10.3.1 copy-out mode

Syntax of the `cpio` command:

```
[files command |] cpio {-o| --create} [-options] [< file-list] [> device]
```

Example:

With a redirection of the output of `cpio`:

```
find /etc | cpio -ov > /backups/etc.cpio
```

Using the name of a backup media:

```
find /etc | cpio -ovF /backups/etc.cpio
```

The result of the `find` command is sent as input to the `cpio` command via a *pipe* (character `|`, ⇧ Left Shift + \).

Here, the `find /etc` command returns a list of files corresponding to the contents of the `/etc` directory (recursively) to the `cpio` command, which performs the backup.

Do not forget the `>` sign when saving or the `F save_name_cpio`.

Options	Description
`-o`	Creates a backup through *cp-out* mode.
`-v`	Displays the name of the processed files.
`-F`	Backup to specific media, which can replace standard input ("<") and standard output (">") in the `cpio` command

Backup to a media:

```
find /etc | cpio -ov > /dev/rmt0
```

The media can be of several types:

- tape drive: `/dev/rmt0`;
- a partition: `/dev/sda5`, `/dev/hda5`, etc.

Relative and absolute paths of the file list

```
cd /
find etc | cpio -o > /backups/etc.cpio
```

```
find /etc | cpio -o > /backups/etc.A.cpio
```

> **Warning**
>
> If the path specified in the `find` command is **absolute**, the backup will be performed in **absolute**.
>
> If the path indicated in the `find` command is **relative**, the backup will be done in **relative**.

Append files to existing backups

```
[files command |] cpio {-o| --create} -A [-options] [< fic-list] {F| > device}
```

Example:

```
find /etc/shadow | cpio -o -AF SystemFiles.A.cpio
```

Adding files is only possible on direct access media.

Option	Description
`-A`	Appends one or more files to an existing backup.
`-F`	Designates the backup to be modified.

Compressing a backup

- Save **then** compress

```
$ find /etc | cpio  –o > etc.A.cpio
$ gzip /backups/etc.A.cpio
$ ls /backups/etc.A.cpio*
/backups/etc.A.cpio.gz
```

- Save **and** compress

```
find /etc | cpio –o | gzip > /backups/etc.A.cpio.gz
```

Unlike the `tar` command, there is no option to save and compress simultaneously. So, it is done in two steps: saving and compressing.

The syntax of the first method is easier to understand and remember because it is done in two steps.

For the first method, the backup file is automatically renamed by the `gzip` utility, which adds `.gz` to the end of the file name. Similarly, the `bzip2` utility automatically adds `.bz2`.

10.3.2 Read the contents of a backup

Syntax of the `cpio` command to read the contents of a *cpio* backup:

```
cpio -t [-options] [< fic-list]
```

Example:

```
cpio -tv < /backups/etc.152.cpio | less
```

Options	Description
`-t`	Reads a backup.
`-v`	Displays file attributes.

After making a backup, you need to read its contents to ensure there are no errors.

In the same way, before performing a restore, you must read the contents of the backup that will be used.

10.3.3 copy-in mode

Syntax of the `cpio` command to restore a backup:

```
cpio {-i| --extract} [-E file] [-options] [< device]
```

Example:

```
cpio -iv < /backups/etc.152.cpio | less
```

Options	Description
`-i`	Restores a complete backup.
`-E file`	Restores only the files whose name is contained in file.
`--make-directories` or `-d`	Rebuilds the missing tree structure.
`-u`	Replaces all files even if they exist.
`--no-absolute-filenames`	Allows to restore a backup made in absolute mode in a relative way.

Warning

By default, at the time of restoration, files on the disk whose last modification date is more recent or equal to the date of the backup are not restored (to avoid overwriting recent information with older information).

On the other hand, the `u` option allows you to restore older versions of the files.

Examples:

- Absolute restoration of an absolute backup

```
cpio –ivF home.A.cpio
```

- Absolute restoration on an existing tree structure

The `u` option allows you to overwrite existing files at the location where the restore takes place.

```
cpio –iuvF home.A.cpio
```

- Restore an absolute backup in relative mode

The long option `no-absolute-filenames` allows a restoration in relative mode. Indeed, the `/` at the beginning of the path will be removed.

```
cpio --no-absolute-filenames -divuF home.A.cpio
```

> **Tip**
>
> The creation of directories is perhaps necessary, hence the use of the `d` option

- Restore a relative backup

```
cpio –iv < etc.cpio
```

- Absolute restoration of a file or directory

Restoring a particular file or directory requires the creation of a list file that must then be deleted.

```
echo "/etc/passwd" > tmp
cpio –iuE tmp -F etc.A.cpio
rm -f tmp
```

10.4 Compression - decompression utilities

Using compression at the time of a backup can have a number of drawbacks:

- Lengthens the backup time as well as the restore time.
- It makes it impossible to add files to the backup.

> **Note**
>
> It is, therefore, better to make a backup and compress it than to compress it during the backup.

10.4.1 Compressing with `gzip`

The `gzip` command compresses data.

Syntax of the `gzip` command:

```
gzip [options] [file ...]
```

Example:

```
$ gzip usr.tar
$ ls
usr.tar.gz
```

The file receives the extension `.gz`.

It keeps the same rights and the same last access and modification dates.

10.4.2 Compressing with `bzip2`

The `bzip2` command also compresses data.

Syntax of the `bzip2` command:

```
bzip2 [options] [file ...]
```

Example:

```
$ bzip2 usr.cpio
$ ls
usr.cpio.bz2
```

The file name is given the extension `.bz2`.

Compression by `bzip2` is better than compression by `gzip`, but executing it takes longer.

10.4.3 Decompressing with `gunzip`

The `gunzip` command decompresses compressed data.

Syntax of the `gunzip` command:

```
gunzip [options] [file ...]
```

Example:

```
$ gunzip usr.tar.gz
$ ls
usr.tar
```

The file name is truncated by `gunzip` and the extension `.gz` is removed.

`gunzip` also decompresses files with the following extensions:

- `.z`;
- `-z`;
- `_z`;
- `-gz`;

10.4.4 Decompressing with `bunzip2`

The `bunzip2` command decompresses compressed data.

Syntax of the `bzip2` command:

```
bzip2 [options] [file ...]
```

Example:

```
$ bunzip2 usr.cpio.bz2
$ ls
usr.cpio
```

The file name is truncated by `bunzip2`, and the extension `.bz2` is removed.

`bunzip2` also decompresses the file with the following extensions:

- `-bz`;
- `.tbz2`;
- `tbz`.

11. System Startup

In this chapter, you will learn how the system starts.

Objectives: In this chapter, future Linux administrators will learn:

✔ The different stages of the booting process;
✔ How Rocky Linux supports this boot by using GRUB2 and `systemd`;
✔ How to protect GRUB2 from an attack;
✔ How to manage the services;
✔ How to access logs from `journald`.

🏁 **users** .

Knowledge: ⭐ ⭐
Complexity: ⭐ ⭐ ⭐

Reading time: 20 minutes

11.1 The boot process

It is essential to understand the boot process of Linux to solve problems that might occur.

The boot process includes:

11.1.1 The BIOS startup

The **BIOS** (Basic Input/Output System) performs the **POST** (power on self-test) to detect, test, and initialize the system hardware components.

It then loads the **MBR** (Master Boot Record).

11.1.2 The Master boot record (MBR)

The Master Boot Record is the first 512 bytes of the boot disk. The MBR discovers the boot device, loads the bootloader **GRUB2** into memory, and transfers control to it.

The next 64 bytes contain the partition table of the disk.

11.1.3 The GRUB2 bootloader

The Rocky 8 distribution's default bootloader is **GRUB2** (GRand Unified Bootloader). GRUB2 replaces the old GRUB bootloader (also called GRUB legacy).

You can locate the GRUB2 configuration file under `/boot/grub2/grub.cfg`, but you should not edit this file directly.

You can find the GRUB2 menu configuration settings under `/etc/default/grub`. The `grub2-mkconfig` command uses these to generate the `grub.cfg` file.

```
# cat /etc/default/grub
GRUB_TIMEOUT=5
GRUB_DEFAULT=saved
GRUB_DISABLE_SUBMENU=true
GRUB_TERMINAL_OUTPUT="console"
GRUB_CMDLINE_LINUX="rd.lvm.lv=rhel/swap crashkernel=auto rd.lvm.lv=rhel/root
rhgb quiet net.ifnames=0"
GRUB_DISABLE_RECOVERY="true"
```

If you change one or more of these parameters, you must run the `grub2-mkconfig` command to regenerate the `/boot/grub2/grub.cfg` file.

```
[root] # grub2-mkconfig –o /boot/grub2/grub.cfg
```

- GRUB2 looks for the compressed kernel image (the `vmlinuz` file) in the `/boot` directory.
- GRUB2 loads the kernel image into memory and extracts the contents of the `initramfs` image file into a temporary folder in memory using the `tmpfs` file system.

11.1.4 The kernel

The kernel starts the `systemd` process with PID 1.

```
root           1      0  0 02:10 ?        00:00:02 /usr/lib/systemd/systemd --
switched-root --system --deserialize 23
```

11.1.5 `systemd`

`systemd` is the parent of all system processes. It reads the target of the `/etc/systemd/system/default.target` link (e.g., `/usr/lib/systemd/system/multi-user.target`) to determine the default target of the system. The file defines the services to start.

`systemd` then places the system in the target-defined state by performing the following initialization tasks:

1. Set the machine name
2. Initialize the network
3. Initialize SELinux
4. Display the welcome banner
5. Initialize the hardware based on the arguments given to the kernel at boot time
6. Mount the file systems, including virtual file systems like /proc
7. Clean up directories in /var
8. Start the virtual memory (swap)

11.2 Protecting the GRUB2 bootloader

Why protect the bootloader with a password?

1. Prevent *Single* user mode access - If an attacker can boot into single user mode, he becomes the root user.
2. Prevent access to GRUB console - If an attacker manages to use the GRUB console, he can change its configuration or collect information about the system by using the `cat` command.
3. Prevent access to insecure operating systems. If the system has dual boot, an attacker can select an operating system like DOS at boot time that ignores access controls and file permissions.

To password-protect the GRUB2 bootloader:

1. Log in to the operating system as root user and execute the `grub2-mkpasswd-pbkdf2` command. The output of this command is as follows:

```
Enter password:
Reenter password:
PBKDF2 hash of your password is
grub.pbkdf2.sha512.10000.D0182EDB28164C19454FA94421D1ECD6309F076F1135A2E5BFE91A50
88BD9EC87687FE14794BE7194F67EA39A8565E868A41C639572F6156900C81C08C1E8413.40F6981C
22F1F81B32E45EC915F2AB6E2635D9A62C0BA67105A9B900D9F365860E84F1B92B2EF3AA0F83CECC6
8E13BA9F4174922877910F026DED961F6592BB7
```

   You need to enter your password in the interaction. The ciphertext of the password is the long string "grub.pbkdf2.sha512...".

2. Paste the password ciphertext in the last line of the **/etc/grub.d/00_header** file. The pasted format is as follows:

```
cat <<EOF
set superusers='frank'
password_obkdf2 frank
grub.pbkdf2.sha512.10000.D0182EDB28164C19454FA94421D1ECD6309F076F1135A2E5BFE91A50
88BD9EC87687FE14794BE7194F67EA39A8565E868A41C639572F6156900C81C08C1E8413.40F6981C
22F1F81B32E45EC915F2AB6E2635D9A62C0BA67105A9B900D9F365860E84F1B92B2EF3AA0F83CECC6
8E13BA9F4174922877910F026DED961F6592BB7
EOF
```

   You can replace the 'frank' user with any custom user.

   You can also set a plaintext password, for example:

```
cat <<EOF
set superusers='frank'
password frank rockylinux8.x
EOF
```

3. The final step is to run the command `grub2-mkconfig -o /boot/grub2/grub.cfg` to update GRUB2's settings.

4. Restart the operating system to verify GRUB2's encryption. Select the first boot menu item, type the `e` key, and then enter the corresponding user and password.

```
Enter username:
frank
Enter password:
```

After successful verification, enter ^ Ctrl + x to start the operating system.

Sometimes, you may see in some documents that the `grub2-set-password` (`grub2-setpassword`) command is used to protect the GRUB2 bootloader:

command	Core functions	Configuration file modification method	automaticity
`grub2-set-password`	Sets password and update configuration	Auto Completion	high
`grub2-mkpasswd-pbkdf2`	Only generates encrypted hash values	Requires manual editing	low

Log in to the operating system as the root user and execute the `gurb2-set-password` command as follows:

```
[root] # grub2-set-password
Enter password:
Confirm password:

[root] # cat /boot/grub2/user.cfg
GRUB2_PASSWORD=grub.pbkdf2.sha512.10000.32E5BAF2C2723B0024C1541F444B8A3656E0A04429

[root] # grub2-mkconfig -o /boot/grub2/grub.cfg

[root] # reboot
```

After executing the `grub2-set-password` command, the **/boot/grub2/user.cfg** file will be automatically generated.

Select the first boot menu item and type the e key, and then enter the corresponding user and password:

```
Enter username:
root
Enter password:
```

11.3 Systemd

Systemd is a service manager for the Linux operating systems.

The development of `systemd` was to:

- remain compatible with older SysV initialization scripts,
- provide many features, such as parallel start of system services at system startup, on-demand activation of daemons, support for snapshots, or management of dependencies between services.

> **Note**
>
> `systemd` is the default initialization system since RedHat/CentOS 7.

`systemd` introduces the concept of unit files, also known as `systemd` units.

Type	File extension	Functionality
Service unit	`.service`	System service
Target unit	`.target`	A group of systemd units
Mount unit	`.automount`	An automatic mount point for file system

> **Note**
>
> There are many types of units: Device unit, Mount unit, Path unit, Scope unit, Slice unit, Snapshot unit, Socket unit, Swap unit, and Timer unit.

- `systemd` supports system state snapshots and restore.
- You can configure mount points as `systemd` targets.
- At startup, `systemd` creates listening sockets for all system services that support this type of activation and passes these sockets to these services as soon as they start. This makes it possible to restart a service without losing a single message sent to it by the network during its unavailability. The corresponding socket remains accessible while all messages queue up.
- System services that use D-BUS for inter-process communications can start on-demand the first time the client uses them.
- `systemd` stops or restarts only running services. Previous versions (before RHEL7) attempted to stop services directly without checking their current status.
- System services do not inherit any context (like HOME and PATH environment variables). Each service operates in its execution context.

All service unit operations are subject to a 5-minute default timeout to prevent a malfunctioning service from freezing the system.

Due to space limitations, this document will not provide a detailed introduction to `systemd`. If you have an interest in exploring `systemd` further, there is a very detailed introduction in this document.

11.3.1 Managing system services

Service units end with the `.service` file extension and have a similar purpose to init scripts. The use of `systemctl` command is to `display`, `start`, `stop`, or `restart` a system service. Except for very few cases, the `systemctl` single line command can

operate on one or more units in most cases (not limited to the unit type of ".service"). You can view it through the help system.

systemctl	Description
systemctl start *name*.service ...	Start one or more services
systemctl stop *name*.service ...	Stop one or more services
systemctl restart *name*.service ...	Restart one or more services
systemctl reload *name*.service ...	Reload one or more services
systemctl status *name*.service ...	Check one or more services status
systemctl try-restart *name*.service ...	Restart one or more services (If they are running)
systemctl list-units --type service --all	Displays the status of all services

The `systemctl` command is also used for the `enable` or `disable` of a system service and displaying associated services:

systemctl	Description
systemctl enable *name*.service ...	Activates one or more services
systemctl disable *name*.service ...	Disables one or more services
systemctl list-unit-files --type service	Lists all services and checks if they are running
systemctl list-dependencies --after	Lists the services that start before the specified unit
systemctl list-dependencies --before	Lists the services that start after the specified unit

Examples:

```
systemctl stop nfs-server.service
# or
systemctl stop nfs-server
```

To list all units currently loaded:

```
systemctl list-units --type service
```

To check the activation status of all units, you can list them with:

```
systemctl list-unit-files --type service
```

```
systemctl enable httpd.service
systemctl disable bluetooth.service
```

11.3.2 Example of a .service file for the postfix service

```
postfix.service Unit File
What follows is the content of the /usr/lib/systemd/system/postfix.service
unit file as currently provided by the postfix package:

[Unit]
Description=Postfix Mail Transport Agent
After=syslog.target network.target
Conflicts=sendmail.service exim.service

[Service]
Type=forking
PIDFile=/var/spool/postfix/pid/master.pid
EnvironmentFile=-/etc/sysconfig/network
ExecStartPre=-/usr/libexec/postfix/aliasesdb
ExecStartPre=-/usr/libexec/postfix/chroot-update
ExecStart=/usr/sbin/postfix start
ExecReload=/usr/sbin/postfix reload
ExecStop=/usr/sbin/postfix stop

[Install]
WantedBy=multi-user.target
```

11.3.3 Using system targets

`systemd` targets replace the concept of run levels on SysV or Upstart.

The representation of `systemd` targets is by target units. Target units end with the `.target` file extension, and their sole purpose is to group other `systemd` units into a chain of dependencies.

For example, the `graphical.target` unit that starts a graphical session starts system services such as the **GNOME display manager** (`gdm.service`) or the **accounts service** (`accounts-daemon.service`) and also activates the `multi-user.target` unit. If you need to view the dependencies of a certain "target", run the `systemctl list-dependencies` command. (For example, `systemctl list-dependencies multi-user.target`).

`sysinit.target` and `basic.target` are checkpoints during the startup process. Although one of the design goals of `systemd` is to start system services in parallel, it is necessary to start the "targets" of certain services and features before starting other services and "targets". Any error in `sysinit.target` or `basic target` will cause the initialization of `systemd` to fail. At this time, your terminal may have entered "emergency mode" (`emergency.target`).

Target Units	Description
poweroff.target	Shuts down the system and turns it off
rescue.target	Activates a rescue shell
multi-user.target	Activates a multi-user system without a graphical interface
graphical.target	Activates a multi-user system with a graphical interface
reboot.target	Shuts down and restarts the system

The default target

To determine the default target used by default:

```
systemctl get-default
```

This command searches for the target of the symbolic link located at `/etc/systemd/system/default.target` and displays the result.

```
$ systemctl get-default
graphical.target
```

The `systemctl` command can also provide a list of available targets:

```
systemctl list-units --type target
UNIT                   LOAD   ACTIVE SUB    DESCRIPTION
basic.target           loaded active active Basic System
bluetooth.target       loaded active active Bluetooth
cryptsetup.target      loaded active active Encrypted Volumes
getty.target           loaded active active Login Prompts
graphical.target       loaded active active Graphical Interface
local-fs-pre.target    loaded active active Local File Systems (Pre)
local-fs.target        loaded active active Local File Systems
multi-user.target      loaded active active Multi-User System
network-online.target  loaded active active Network is Online
network.target         loaded active active Network
```

```
nss-user-lookup.target loaded active active User and Group Name Lookups
paths.target           loaded active active Paths
remote-fs.target       loaded active active Remote File Systems
slices.target          loaded active active Slices
sockets.target         loaded active active Sockets
sound.target           loaded active active Sound Card
swap.target            loaded active active Swap
sysinit.target         loaded active active System Initialization
timers.target          loaded active active Timers
```

To configure the system to use a different default target:

```
systemctl set-default name.target
```

Example:

```
# systemctl set-default multi-user.target
rm '/etc/systemd/system/default.target'
ln -s '/usr/lib/systemd/system/multi-user.target' '/etc/systemd/system/
default.target'
```

To switch to a different target unit in the current session:

```
systemctl isolate name.target
```

The **Rescue mode** provides a simple environment for repairing your system in cases where a normal boot process is impossible.

In `rescue mode`, the system attempts to mount all local file systems and start several important system services but does not enable a network interface or allow other users to connect to the system simultaneously.

On Rocky 8, the `rescue mode` is equivalent to the old `single user mode` and requires the root password.

To change the current target and enter `rescue mode` in the current session:

```
systemctl rescue
```

Emergency mode provides the most minimalist environment possible and allows the system to be repaired even in situations where it is unable to enter rescue

mode. In emergency mode, the operating system mounts the root file system with the read-only option. It will not attempt to mount any other local file system, will not activate any network interface, and will start some essential services.

To change the current target and enter emergency mode in the current session:

```
systemctl emergency
```

Shutdown, suspension, and hibernation

The `systemctl` command replaces many power management commands used in previous versions:

Old command	New command	Description
`halt`	`systemctl halt`	Shuts down the system.
`poweroff`	`systemctl poweroff`	Turns off the system.
`reboot`	`systemctl reboot`	Restarts the system.
`pm-suspend`	`systemctl suspend`	Suspends the system.
`pm-hibernate`	`systemctl hibernate`	Hibernates the system.
`pm-suspend-hybrid`	`systemctl hybrid-sleep`	Hibernates and suspends the system.

11.3.4 The `journald` process

You can manage log files with the `journald` daemon, a component of `systemd 'in addition to ' rsyslogd`.

The `journald` daemon is responsible for capturing the following types of log messages:

- Syslog messages
- Kernel log messages
- Initramfs and system startup logs
- Standard output (stdout) and standard error output (stderr) information of all services

After capture, `journald` will index these logs and provide them to users through structured storage mechanism This mechanism stores logs in binary format,

supports tracking events in chronological order, and provides flexible filtering, searching and output capabilities in multiple formats (such as text/JSON). Note that `journald` does not enable log persistence by default, which means this component only retain and record all logs since startup. After the operating system restarts, the deletion of historical logs occurs. By default, all temporarily saved log files are in the **/run/log/journal/** directory.

11.3.5 `journalctl` command

The `journalctl` command is used to parse log files saved in binary, such as viewing log files, filtering logs, and controlling output entries.

```
journalctl
```

If you do not enter the command with any other options, the output log content is similar to the `/var/log/messages` file, but `journalctl` provides the following improvements:

- shows the priority of entries is visually marked
- shows the conversion of timestamps to the local time zone of your system
- all logged data is displayed, including rotating logs
- shows the marking of the beginning of a start with a special line

Using continuous display

With continuous display, log messages are displayed in real time.

```
journalctl -f
```

This command returns a list of the ten most recent log lines. The `journalctl` utility then continues to run and waits for new changes to occur before displaying them immediately.

Filtering messages

It is possible to use different filtering methods to extract information that fits different needs. Log messages are often used to track erroneous behavior on the system. To view entries with a selected or higher priority:

```
journalctl -p priority
```

You must replace priority with one of the following keywords (or a number):

- debug (7),
- info (6),
- notice (5),
- warning (4),
- err (3),
- crit (2),
- alert (1),
- emerg (0).

If you want to know more about the content of logs, there are more comprehensive introductions and descriptions in this document.

12. Task Management

In this chapter, you will learn how to manage scheduled tasks.

Objectives: In this chapter, future Linux administrators will learn how to:

✓ Linux deals with the task scheduling;
✓ restrict the use of `cron` to certain users;
✓ schedule tasks.

🏁 **crontab**, **crond**, **scheduling**, **linux**

Knowledge: ⭐⭐
Complexity: ⭐⭐

Reading time: 15 minutes

12.1 Generalities

The scheduling of tasks is managed with the `cron` utility. It allows the periodic execution of tasks.

It is reserved for administrators to perform system tasks, but can also be used by normal users for tasks or scripts that they have access to. To access the `cron` utility, we use: `crontab`.

The `cron` service is used for:

- Repetitive administration operations;
- Backups;
- Monitoring of system activity;
- Program execution.

`crontab` is short for **cron table**, but can be thought of as a task scheduling table.

Warning

To set up a schedule, the system must have the correct time set.

12.2 How the service works

A `crond` daemon present runs the `cron` service in memory.

To check its status:

```
[root] # systemctl status crond
```

Tip

If the `crond` daemon is not running, you will have to initialize it manually and/or automatically at startup. Indeed, even if tasks are scheduled, they will not be launched.

Initialization of the `crond` daemon in the manual:

```
[root]# systemctl {status|start|restart|stop} crond
```

Initialization of the `crond` daemon at startup:

```
[root]# systemctl enable crond
```

12.3 Security

To implement a schedule, a user must have permission to use the `cron` service.

This permission varies according to the information contained in the files below:

- `/etc/cron.allow`
- `/etc/cron.deny`

Warning

If neither file is present, all users can use `cron`.

12.3.1 The `cron.allow` and `cron.deny` Files

File `/etc/cron.allow`

Only users contained in this file are allowed to use `cron`.

If it exists and is empty, no users can use `cron`.

> **Warning**
>
> If `cron.allow` is present, `cron.deny` is **ignored**.

File `/etc/cron.deny`

Users in this file are not allowed to use `cron`.

If it is empty, all users can use `cron`.

By default, `/etc/cron.deny` exists and is empty and `/etc/cron.allow` does not exist. When two files exist at the same time, the system only uses the `cron.allow` content as the judgment basis and completely ignores the existence of `cron.deny` files.

12.3.2 Allowing a user

Only **user1** will be able to use `cron`.

```
[root]# vi /etc/cron.allow
user1
```

12.3.3 Prohibit a user

Only **user2** will not be able to use `cron`. Note that the `/etc/cron.allow` file cannot exist.

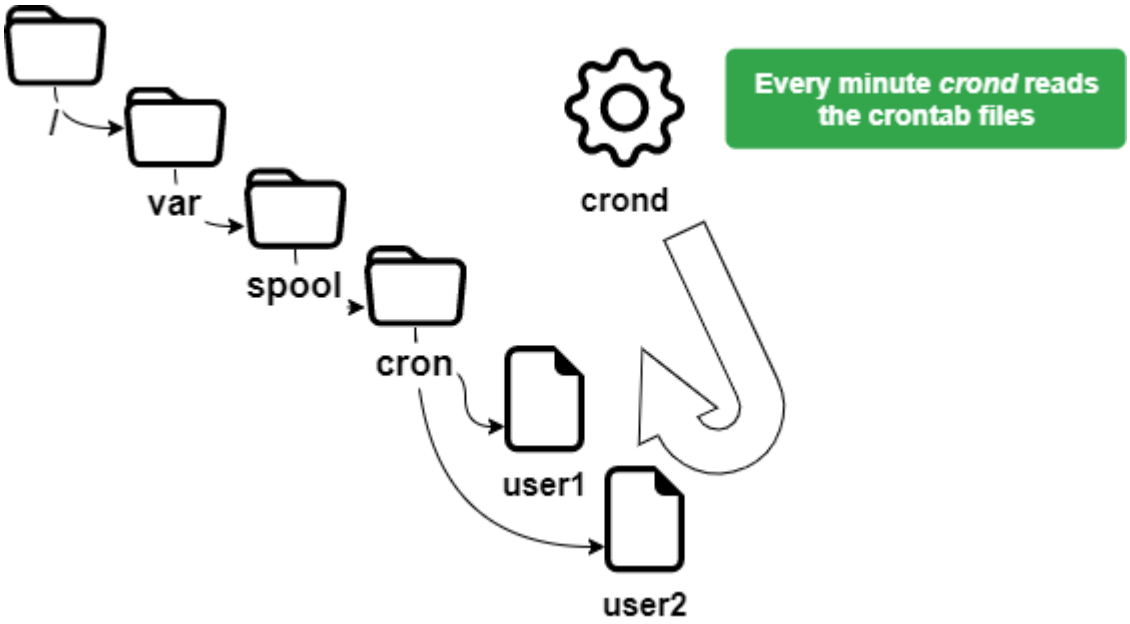
```
[root]# vi /etc/cron.deny
user2
```

If the same user exists in `/etc/cron.deny` and `/etc/cron.allow` at the same time, the user can use cron normally.

12.4 Scheduling tasks

When a user schedules a task, there is a file created with their name under `/var/spool/cron/`.

This file contains all the information the `crond` needs to know regarding tasks created by this user, including the commands or programs to run, and the schedule for running them (hour, minute, day, etc.). Note that the minimum time unit that `crond` can recognize is 1 minute. There are similar scheduling tasks in RDBMS (such as MySQL), where time-based scheduling tasks are referred to as the "Event Scheduler" (whose recognizable time unit is 1 second), and event-based scheduling tasks are referred to as "Triggers".



12.4.1 The `crontab` command

The `crontab` command is used to manage the schedule file.

```
crontab [-u user] [-e | -l | -r]
```

Example:

```
[root]# crontab -u user1 -e
```

Option	Description
`-e`	Edits the schedule file with vi
`-l`	Displays the contents of the schedule file
`-u <user>`	Specify a single user to operate
`-r`	Deletes the schedule file

Warning

`crontab` without options deletes the old schedule file and waits for the user to enter new lines. You have to press `ctrl` + `d` to exit this editing mode.

Only the `root` can use the `-u <user>` option to manage another user's schedule file.

The example above allows the root to schedule a task for user1.

12.4.2 Uses of `crontab`

The uses of `crontab` are many and include:

- Modifications to the `crontab` files taken into account immediately;
- No need to restart.

On the other hand, the following points must be taken into account:

- The program must be autonomous;
- Provide redirections (stdin, stdout, stderr);
- It is not relevant to run commands that use input/output requests on a terminal.

Note

It is important to understand that the purpose of scheduling is to perform tasks automatically, without the need for external intervention.

12.5 The `crontab` file

The `crontab` file is structured according to the following rules.

- Each line of this file corresponds to a schedule;
- Each line has six fields, 5 for the time and 1 for the order;
- A space or a tab separates each field;
- Each line ends with a carriage return;
- A `#` at the beginning of the line comments it.

```
[root]# crontab -e
10 4 1 * * /root/scripts/backup.sh
1  2 3 4 5       6
```

Field	Description	Detail
1	Minute(s)	From 0 to 59
2	Hour(s)	From 0 to 23
3	Day(s) of the month	From 1 to 31
4	Month of the year	From 1 to 12
5	Day(s) of the week	From 0 to 7 (0=7=sunday)
6	Task to execute	Full command or script

Warning

The tasks to be executed must use absolute paths, and if possible, use redirects.

To simplify the notation for the definition of time, it is advisable to use special symbols.

Special symbol	Description
`*`	Indicates all the time values of the field
`-`	Indicates a continuous time range
`,`	Indicates the discontinuous time range
`/`	Indicateds time interval

Examples:

Script executed on April 15 at 10:25 am:

```
25 10 15 04 * /root/scripts/script > /log/…
```

Run the task once a day at 11 am and once a day at 4 pm:

```
00 11,16 * * * /root/scripts/script > /log/…
```

The task runs once an hour from 11 am to 4 pm every day:

```
00 11-16 * * * /root/scripts/script > /log/…
```

Run every 10 minutes during working hours on weekdays:

```
*/10 8-17 * * 1-5 /root/scripts/script > /log/…
```

For the root user, `crontab` also has some special time settings:

Setting	Description
@reboot	Runs a command on system reboot
@hourly	Runs a command every hour
@daily	Runs daily just after midnight
@weekly	Runs command every Sunday just after midnight
@monthly	Runs command on the first day of the month just after midnight
@annually	Runs January 1st just after midnight

12.5.1 Task execution process

A user, rockstar, wants to edit his `crontab` file:

1. The `crond` daemon checks to see if the user is allowed (`/etc/cron.allow` and `/etc/cron.deny`).
2. If the user is allowed, they access their `crontab` file (`/var/spool/cron/rockstar`).

The `crond` daemon:

- Reads - Reads the scheduled task files of all users every minute.
- Runs - Runs tasks according to the schedule.
- Writes - Writes the corresponding events and messages to the (`/var/log/cron`) file.

13. Implementing the Network

In this chapter you will learn how to work with and manage the network.

Objectives: In this chapter you will learn how to:

- ✓ Configure a workstation to use DHCP;
- ✓ Configure a workstation to use a static configuration;
- ✓ Configure a workstation to use a gateway;
- ✓ Configure a workstation to use DNS servers;
- ✓ Troubleshoot the network of a workstation.

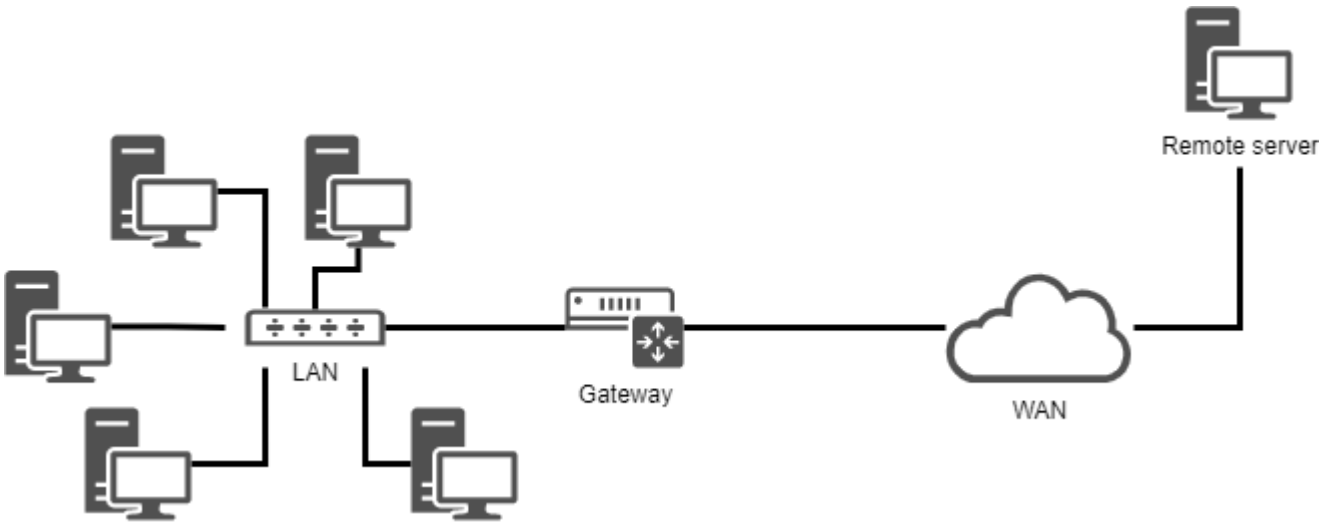
🏁 **network**, **linux**, **ip**

Knowledge: ★★
Complexity: ★★

Reading time: 30 minutes

13.1 Generalities

To illustrate this chapter, we will use the following architecture.



It will allow us to consider:

- integration in a LAN (local area network);
- the configuration of a gateway to reach a remote server;
- the configuration of a DNS server and the implementation of name resolution.

The minimum parameters to be defined for the machine are:

- the name of the machine;
- the IP address;
- the subnet mask.

Example:

- `pc-rocky`;
- `192.168.1.10`;
- `255.255.255.0`.

The notation called CIDR is more and more frequent: 192.168.1.10/24

IP addresses are used for the proper routing of messages (packets). They are divided into two parts:

- the fixed part, identifying the network;
- the identifier of the host in the network.

The subnet mask is a set of **4 bytes** intended to isolate:

- the network address (**NetID** or **SubnetID**) by performing a bitwise logical AND between the IP address and the mask;
- the host address (**HostID**) by performing a bitwise logical AND between the IP address and the complement of the mask.

There are also specific addresses within a network, which must be identified. The first address of a range as well as the last one have a particular role:

- The first address of a range is the **network address**. It is used to identify networks and to route information from one network to another.
- The last address of a range is the **broadcast address**. It is used to broadcast information to all the machines on the network.

13.1.1 MAC address / IP address

A **MAC address** is a physical identifier written in the factory onto the device. This is sometimes referred to as the hardware address. It consists of 6 bytes often given in hexadecimal form (for example 5E:FF:56:A2:AF:15). It is composed of: 3 bytes of the manufacturer identifier and 3 bytes of the serial number.

> **Warning**
>
> This last statement is nowadays a little less true with virtualization. There are also software solutions for changing the MAC address.

An Internet Protocol (**IP**) address is an identification number permanently or temporarily assigned to each device connected to a computer network using the Internet Protocol. One part defines the network address (NetID or SubnetID as the case may be), the other part defines the address of the host in the network (HostID). The relative size of each part varies according to the network (sub)mask.

An IPv4 address defines an address on 4 bytes. The number of available addresses being close to saturation a new standard was created, the IPv6 defined on 16 bytes.

IPv6 is often represented by 8 groups of 2 bytes separated by a colon. Insignificant zeros can be omitted, one or more groups of 4 consecutive zeros can be replaced by a double colon.

Subnet masks have from 0 to 128 bits. (for example 21ac:0000:0000:0611:21e0:00ba:321b:54da/64 or 21ac::611:21e0:00ba:321b:54da/64)

In a web address or URL (Uniform Resource Locator), an ip address can be followed by a colon and the port address (which indicates the application to which

the data is destined). Also to avoid confusion in a URL, the IPv6 address is written in square brackets [ ], colon, port address.

IP and MAC addresses must be unique on a network!

13.1.2 DNS Domain

Client machines can be part of a DNS (**Domain Name System**, e.g., `mydomain.lan`) domain.

The fully qualified machine name (**FQDN**) becomes `pc-rocky.mydomain.lan`.

A set of computers can be grouped into a logical, name-resolving, set called a DNS domain. A DNS domain is not, of course, limited to a single physical network.

In order for a computer to be part of a DNS domain, it must be given a DNS suffix (here `mydomain.lan`) as well as servers that it can query.

13.1.3 Reminder of the OSI model

Memory aid

To remember the order of the layers of the OSI model, remember the following sentence: **Please Do Not Touch Steven's Pet Alligator**.

Layer	Protocols
7 - Application	POP, IMAP, SMTP, SSH, SNMP, HTTP, FTP, ...
6 - Presentation	ASCII, MIME, ...
5 - Session	TLS, SSL, NetBIOS, ...
4 - Transport	TLS, SSL, TCP, UDP, ...
3 - Network	IPv4, IPv6, ARP, ...
2 - Data Link	Ethernet, WiFi, Token Ring, ...
1 - Physical	Cables, optical fibers, radio waves, ...

Layer 1 (Physical) supports transmission over a communication channel (Wifi, Optical fiber, RJ cable, etc.). Unit: the bit.

Layer 2 (Data Link) supports network topology (token-ring, star, bus, etc.), data splitting and transmission errors. Unit: the frame.

Layer 3 (Network) supports end-to-end data transmission (IP routing = Gateway). Unit: the packet.

Layer 4 (Transport) supports service type (connected or unconnected) encryption and flow control. Unit: the segment or the datagram.

Layer 5 (Session) supports the communication between two computers.

Layer 6 (Presentation) represents the area that is independent of data at the application layer. Essentially this layer translates from network format to the application format, or from the application format to the network format.

Layer 7 (Application) represents the contact with the user. It provides the services offered by the network: http, dns, ftp, imap, pop, smtp, etc.

13.2 The naming of interfaces

lo is the "**loopback**" interface which allows TCP/IP programs to communicate with each other without leaving the local machine. This enables testing if the **network module of the system is working properly** and also allows pinging the localhost. All packets that enter through localhost leave through localhost. The packets received are the packets sent.

The Linux kernel assigns interface names with a specific prefix depending on the type. Traditionally, all **Ethernet** interfaces, for example, began with **eth**. The prefix was followed by a number, the first being 0 (eth0, eth1, eth2...). The wifi interfaces were given a wlan prefix.

On Rocky8 Linux distributions, systemd will name interfaces with the new following policy where "X" represents a number:

- `enoX` : on-board devices
- `ensX` : PCI Express hotplug slot
- `enpXsX` : physical/geographical location of the connector of the hardware
- ...

13.3 Using the `ip` command

Forget the old `ifconfig` command! Think `ip`!

> **Note**
>
> Comment for administrators of older Linux systems:
>
> The historical network management command is `ifconfig`. This command has been replaced by the `ip` command, which is already well known to network administrators.
>
> The `ip` command is the only command to manage **IP address, ARP, routing, etc.**.
>
> The `ifconfig` command is no longer installed by default in Rocky8.
>
> It is important to get into good habits now.

13.4 The hostname

The `hostname` command displays or sets the host name of the system

```
hostname [-f] [hostname]
```

Option	Description
`-f`	Displays the FQDN
`-i`	Displays the system's IP address information

> **Tip**
>
> This command is used by various network programs to identify the machine.

To assign a host name, it is possible to use the `hostname` command, but the changes will not be retained at the next boot. The command with no arguments displays the host name.

To set the host name, the file `/etc/sysconfig/network` must be modified:

```
NETWORKING=yes
HOSTNAME=pc-rocky.mondomaine.lan
```

The RedHat boot script also consults the `/etc/hosts` file to resolve the host name of the system.

When the system boots, Linux evaluates the `HOSTNAME` value in the `/etc/sysconfig/network` file.

It then uses the `/etc/hosts` file to evaluate the main IP address of the server and its host name. It deduces the DNS domain name.

It is therefore essential to fill in these two files before any configuration of network services.

> **Tip**
>
> To know if this configuration is well done, the commands `hostname` and `hostname -f` must answer with the expected values.

13.5 /etc/hosts file

The `/etc/hosts` file is a static host name mapping table, which follows the following format:

```
@IP <hostname>  [alias]  [# comment]
```

Example of `/etc/hosts` file:

```
127.0.0.1       localhost localhost.localdomain
::1             localhost localhost.localdomain
192.168.1.10    rockstar.rockylinux.lan rockstar
```

The `/etc/hosts` file is still used by the system, especially at boot time when the system FQDN is determined.

> **Tip**
>
> RedHat recommends that at least one line containing the system name be filled in.

If the **DNS** service (**D**omain **N**ame **S**ervice) is not in place, you must fill in all the names in the hosts file for each of your machines.

The `/etc/hosts` file contains one line per entry, with the IP address, the FQDN, then the host name (in that order) and a series of aliases (alias1 alias2 ...). The alias is an option.

13.6 `/etc/nsswitch.conf` file

The **NSS** (**N**ame **S**ervice **S**witch) allows configuration files (e.g., `/etc/passwd`, `/etc/group`, `/etc/hosts`) to be substituted for one or more centralized databases.

The `/etc/nsswitch.conf` file is used to configure the name service databases.

```
passwd: files
shadow: files
group: files

hosts: files dns
```

In this case, Linux will first look for a host name match (`hosts:` line) in the `/etc/hosts` file (`files` value) before querying DNS (`dns` value)! This behavior can simply be changed by editing the `/etc/nsswitch.conf` file.

Of course, it is possible to imagine querying an LDAP, MySQL or other server by configuring the name service to respond to system requests for hosts, users, groups, etc.

The resolution of the name service can be tested with the `getent` command that we will see later in this course.

13.7 `/etc/resolv.conf` file

The `/etc/resolv.conf` file contains the DNS name resolution configuration.

```
#Generated by NetworkManager
domain mondomaine.lan
search mondomaine.lan
nameserver 192.168.1.254
```

Tip

This file is historical. It is no longer filled in directly!

Newer generations of distributions have generally integrated the `NetworkManager` service. This service allows you to manage the configuration more efficiently, either in graphical or console mode.

It allows for the addition of DNS servers from the configuration file of a network interface. It then dynamically populates the `/etc/resolv.conf` file which should never be edited directly, otherwise the configuration changes will be lost the next time the network service is started.

13.8 `ip` command

The `ip` command from the `iproute2` package allows you to configure an interface and its routing table.

Display interfaces:

```
[root]# ip link
```

Display interfaces information:

```
[root]# ip addr show
```

Display the information of an interface:

```
[root]# ip addr show eth0
```

Display the ARP table:

```
[root]# ip neigh
```

All historical network management commands have been grouped under the `ip` command, which is well known to network administrators.

13.9 DHCP configuration

The **DHCP** protocol (**D**ynamic **H**ost **C**ontrol **P**rotocol) allows you to obtain a complete IP configuration via the network. This is the default configuration mode of

a network interface under Rocky Linux, which explains why a system connected to the network of an Internet router can function without additional configuration.

The configuration of interfaces under Rocky Linux is done in the `/etc/sysconfig/network-scripts/` folder.

For each Ethernet interface, a `ifcfg-ethX` file allows for the configuration of the associated interface.

```
DEVICE=eth0
ONBOOT=yes
BOOTPROTO=dhcp
HWADDR=00:0c:29:96:32:e3
```

- Interface name: (must be in the file name)

```
DEVICE=eth0
```

- Automatically start the interface:

```
ONBOOT=yes
```

- Make a DHCP request when the interface starts up:

```
BOOTPROTO=dhcp
```

- Specify the MAC address (optional but useful when there are several interfaces):

```
HWADDR=00:0c:29:96:32:e3
```

Tip

If NetworkManager is installed, the changes are taken into account automatically. If not, you have to restart the network service.

- Restart the network service:

```
[root]# systemctl restart NetworkManager
```

13.10 Static configuration

The static configuration requires at least:

```
DEVICE=eth0
ONBOOT=yes
BOOTPROTO=none
IPADDR=192.168.1.10
NETMASK=255.255.255.0
```

- Here we are replacing "dhcp" with "none" which equals static configuration:

```
BOOTPROTO=none
```

- IP Address:

```
IPADDR=192.168.1.10
```

- Subnet mask:

```
NETMASK=255.255.255.0
```

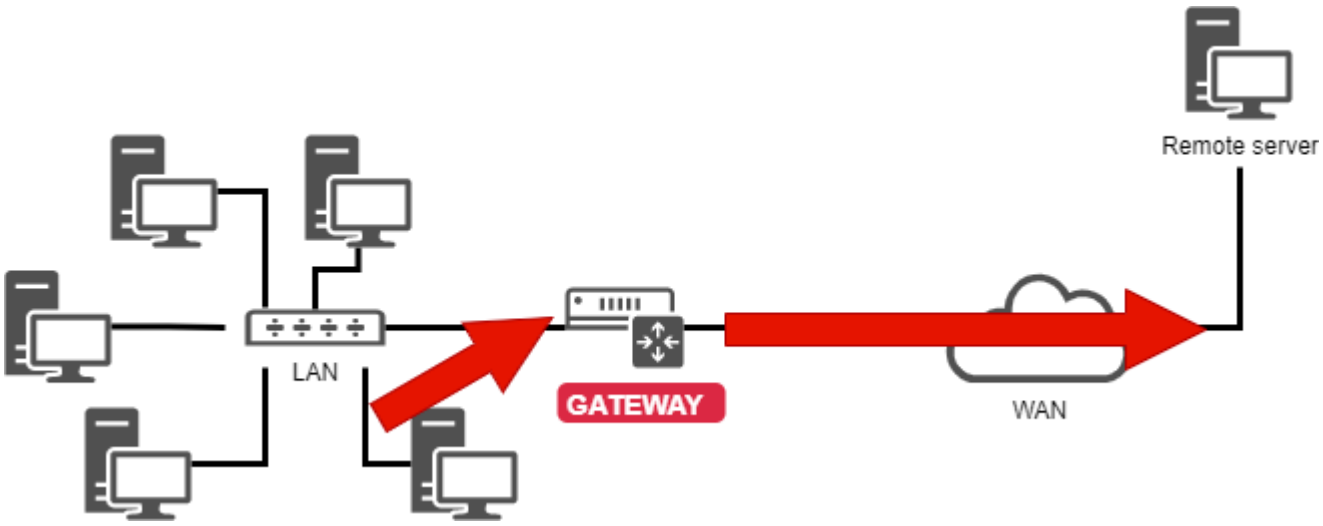
- The mask can be specified with a prefix:

```
PREFIX=24
```

Warning

You must use NETMASK OR PREFIX - Not both!

13.11 Routing




```
DEVICE=eth0
ONBOOT=yes
BOOTPROTO=none
HWADDR=00:0c:29:96:32:e3
IPADDR=192.168.1.10
NETMASK=255.255.255.0
GATEWAY=192.168.1.254
```

The `ip route` command:

```
[root]# ip route show
192.168.1.0/24 dev eth0 […] src 192.168.1.10 metric 1
default via 192.168.1.254 dev eth0 proto static
```

It is a good idea to know how to read a routing table, especially in an environment with multiple network interfaces.

- In the example shown, the `192.168.1.0/24` network is reachable directly from the `eth0` device, so there is a metric at `1` (does not traverse a router).
- All other networks than the previous one will be reachable, again from the `eth0` device, but this time the packets will be addressed to a `192.168.1.254` gateway. The routing protocol is a static protocol (although it is possible to add a route to a dynamically assigned address in Linux).

13.12 Name resolution

A system needs to resolve:

- FQDNs into IP addresses

```
www.free.fr = 212.27.48.10
```

- IP addresses into names

```
212.27.48.10 = www.free.fr
```

- or to obtain information about an area:

```
MX de free.fr = 10 mx1.free.fr + 20 mx2.free.fr
```

```
DEVICE=eth0
ONBOOT=yes
BOOTPROTO=none
HWADDR=00:0c:29:96:32:e3
IPADDR=192.168.1.10
NETMASK=255.255.255.0
GATEWAY=192.168.1.254
DNS1=172.16.1.2
DNS2=172.16.1.3
DOMAIN=rockylinux.lan
```

In this case, to reach the DNS, you have to go through the gateway.

```
#Generated by NetworkManager
domain mondomaine.lan
search mondomaine.lan
nameserver 172.16.1.2
nameserver 172.16.1.3
```

The file has been updated by NetworkManager.

13.13 Troubleshooting

The `ping` command sends datagrams to another machine and waits for a response.

It is the basic command for testing the network because it checks the connectivity between your network interface and another.

Syntax of the `ping` command:

```
ping [-c numerical] destination
```

The `-c` (count) option allows you to stop the command after the countdown in seconds.

Example:

```
[root]# ping –c 4 localhost
```

> **Tip**
>
> Validate connectivity from near to far

1. Validate the TCP/IP software layer

```
[root]# ping localhost
```

   "Pinging" the inner loop does not detect a hardware failure on the network interface. It simply determines whether the IP software configuration is correct.

2. Validate the network card

```
[root]# ping 192.168.1.10
```

   To determine the functionality of the network card, we must ping its IP address. If the network cable is not connected to the network card, it should be in a "down" state.

   If the ping does not work, first check the network cable to your network switch and reassemble the interface (see the `if up` command), then check the interface itself.

3. Validate the connectivity of the gateway

```
[root]# ping 192.168.1.254
```

4. Validate the connectivity of a remote server

```
[root]# ping 172.16.1.2
```

5. Validate the DNS service

```
[root]# ping www.free.fr
```

13.13.1 `dig` command

The `dig` command is used to query the DNS server.

The `dig` command syntax:

```
dig [-t type] [+short] [name]
```

Examples:

```
[root]# dig +short rockylinux.org
76.223.126.88
[root]# dig -t MX +short
rockylinux.org                                                  ✔
5 alt1.aspmx.l.google.com.
...
```

The `dig` command is used to query DNS servers. It is verbose by default, but the `+short` option can change this behavior.

It is also possible to specify a DNS **record type** to resolve, such as an MX **type** to get information about the mail exchangers for a domain.

13.13.2 `getent` command

The `getent` (get entry) command gets an NSSwitch entry (`hosts` + `dns`)

Syntax of the `getent` command:

```
getent hosts name
```

Example:

```
[root]# getent hosts rockylinux.org
  76.223.126.88 rockylinux.org
```

Querying only a DNS server may return an erroneous result that does not consider the contents of a `hosts` file, although this should be rare nowadays.

To take the `/etc/hosts` file into account, the NSSwitch name service must be queried, which will take care of any DNS resolution.

13.13.3 `ipcalc` command

The `ipcalc` (**ip calculation**) command calculates the address of a network or broadcast from an IP address and a mask.

Syntax of the `ipcalc` command:

```
ipcalc  [options] IP <netmask>
```

Example:

```
[root]# ipcalc –b 172.16.66.203 255.255.240.0
BROADCAST=172.16.79.255
```

Tip

This command is interesting, followed by a redirection to fill in the configuration files of your interfaces automatically:

```
[root]# ipcalc –b 172.16.66.203 255.255.240.0 >> /etc/sysconfig/network-scripts/ifcfg-eth0
```

Option	Description
`-b`	Displays the broadcast address.
`-n`	Displays the network address and mask.

`ipcalc` is a simple way to calculate a host's IP information. The various options indicate what information `ipcalc` should display on the standard output. You can specify multiple options. You must specify an IP address on which to operate. Most operations also require a network mask or CIDR prefix.

Option short	Option long	Description
`-b`	`--broadcast`	Displays the broadcast address of the given IP address and the network mask.
`-h`	`--hostname`	Displays the hostname of the IP address given via DNS.
`-n`	`--netmask`	Calculates the network mask for the given IP address. Assumes that the IP address is part of a complete class A, B, or C network. Many networks do not use default network masks, in which case an incorrect value will be returned.
`-p`	`--prefix`	Indicates the prefix of the mask/IP address.
`-n`	`--network`	Indicates the network address of the given IP address and mask.
`-s`	`--silent`	Does not display any error messages.

13.13.4 `ss` command

The `ss` (**socket statistics**) command displays the listening ports on the network.

Syntax of the `ss` command:

```
ss [-tuna]
```

Example:

```
[root]# ss –tuna
tcp   LISTEN   0   128   *:22   *:*
```

The commands `ss` and `netstat` (to follow) will be very important for the rest of your Linux life.

When implementing network services, it is common to check with one of these two commands that the service is listening on the expected ports.

13.13.5 `netstat` command

> **Warning**
>
> The `netstat` command is now deprecated and is no longer installed by default on Rocky Linux. You may still find some Linux versions that have it installed, but it is best to move on to using `ss` for everything that you would have used `netstat` for.

The `netstat` command (**network statistics**) displays the listening ports on the network.

Syntax of the `netstat` command:

```
netstat -tapn
```

Example:

```
[root]# netstat –tapn
tcp  0  0  0.0.0.0:22  0.0.0.0:*  LISTEN 2161/sshd
```

13.13.6 IP or MAC address conflicts

A misconfiguration can cause multiple interfaces to use the same IP address. This can happen when a network has multiple DHCP servers, or the same IP address is manually assigned numerous times.

When the network is malfunctioning, and when an IP address conflict could be the cause, it is possible to use the `arp-scan` software (requires the EPEL repository):

```
dnf install arp-scan
```

Example:

```
$ arp-scan -I eth0 -l

172.16.1.104  00:01:02:03:04:05       3COM CORPORATION
172.16.1.107  00:0c:29:1b:eb:97       VMware, Inc.
172.16.1.250  00:26:ab:b1:b7:f6       (Unknown)
172.16.1.252  00:50:56:a9:6a:ed       VMWare, Inc.
172.16.1.253  00:50:56:b6:78:ec       VMWare, Inc.
172.16.1.253  00:50:56:b6:78:ec       VMWare, Inc. (DUP: 2)
172.16.1.253  00:50:56:b6:78:ec       VMWare, Inc. (DUP: 3)
172.16.1.253  00:50:56:b6:78:ec       VMWare, Inc. (DUP: 4)
172.16.1.232  88:51:fb:5e:fa:b3       (Unknown) (DUP: 2)
```

Tip

As the above example shows, MAC address conflicts are possible! Virtualization technologies and the copying of virtual machines cause these problems.

13.14 Hot configuration

The `ip` command can hot add an IP address to an interface.

```
ip addr add @IP dev DEVICE
```

Example:

```
[root]# ip addr add 192.168.2.10 dev eth1
```

The `ip` command allows for the activation or deactivation of an interface:

```
ip link set DEVICE up
ip link set DEVICE down
```

Example:

```
[root]# ip link set eth1 up
[root]# ip link set eth1 down
```

The `ip` command adds a route:

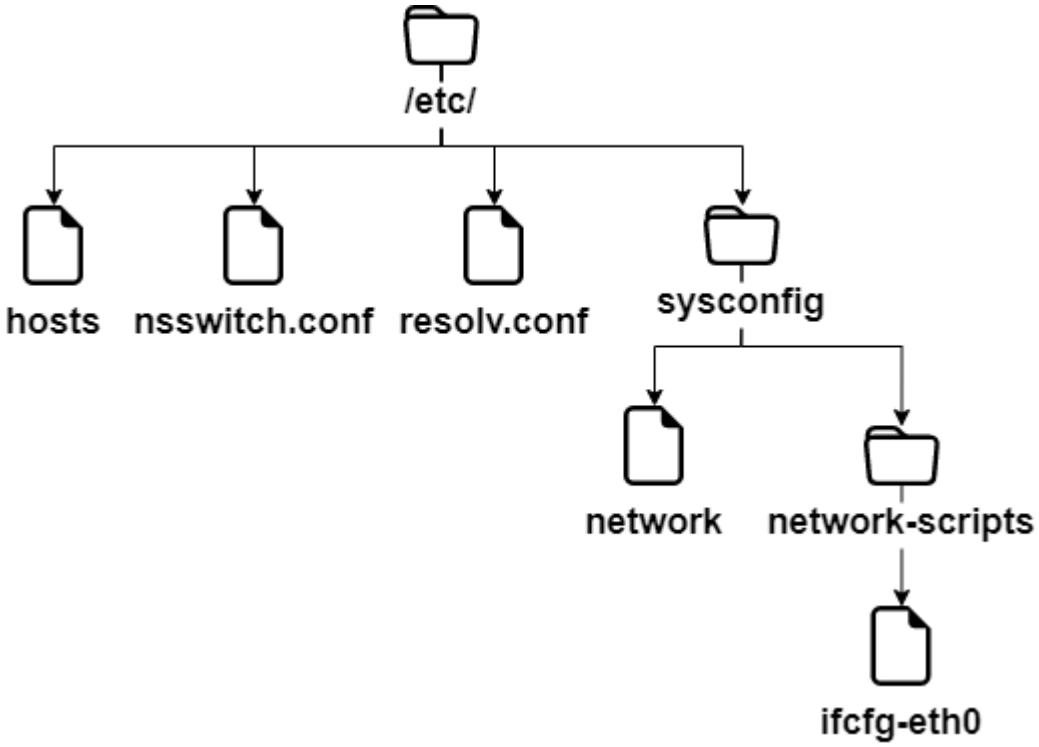
```
ip route add [default|netaddr] via @IP [dev device]
```

Example:

```
[root]# ip route add default via 192.168.1.254
[root]# ip route add 192.168.100.0/24 via 192.168.2.254 dev eth1
```

13.15 In summary

The files used in this chapter are:

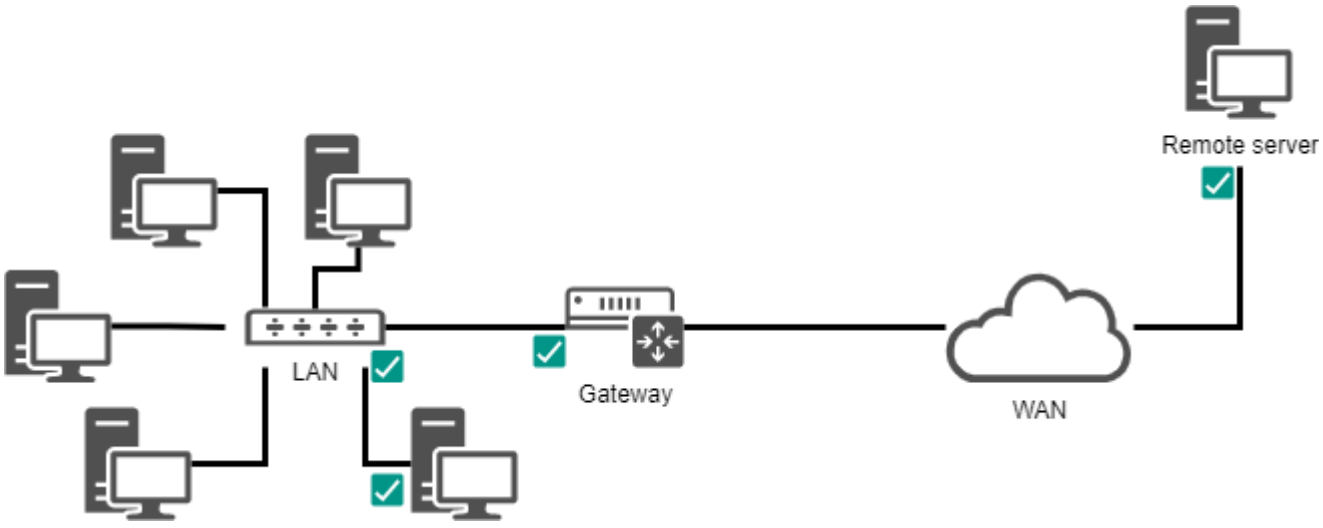


A complete interface configuration could be this (file `/etc/sysconfig/network-scripts/ifcfg-eth0`):

```
DEVICE=eth0
ONBOOT=yes
BOOTPROTO=none
HWADDR=00:0c:29:96:32:e3
IPADDR=192.168.1.10
NETMASK=255.255.255.0
GATEWAY=192.168.1.254
DNS1=172.16.1.1
DNS2=172.16.1.2
DOMAIN=rockylinux.lan
```

The troubleshooting method should go from closest to farthest:

1. ping localhost (software test)
2. ping IP-address (hardware test)
3. ping gateway (connectivity test)
4. ping remote server (routing test)
5. DNS query (dig or ping)



14. Software Management

14.1 Generalities

On a Linux system, it is possible to install software in two ways:

- Using an installation package;
- Compiling from source files.

> **Note**
>
> Installing from source is not covered here. As a rule, you should use the package method unless the software you want is not available via the package manager. The reason for this is that dependencies are generally managed by the package system, whereas with source, you need to manage the dependencies manually.

The package: This is a single file containing all the data needed to install the program. It can be executed directly on the system from a software repository.

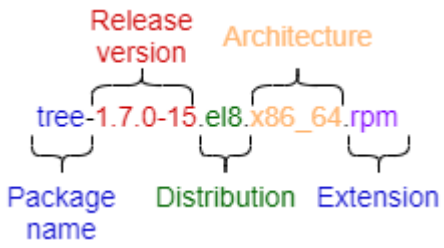
The source files: Some software is not provided in packages ready to be installed, but via an archive containing the source files. It is up to the administrator to prepare these files and compile them to install the program.

14.2 RPM: RedHat Package Manager

RPM (RedHat Package Manager) is a software management system. It is possible to install, uninstall, update or check software contained in packages.

RPM is the format used by all RedHat based distributions (RockyLinux, Fedora, CentOS, SuSe, Mandriva, ...). Its equivalent in the Debian world is DPKG (Debian Package).

The name of an RPM package follows a specific nomenclature:



14.2.1 `rpm` command

The rpm command allows you to install a package.

```
rpm [-i][-U] package.rpm [-e] package
```

Example (for a package named 'package'):

```
rpm -ivh package.rpm
```

Option	Description
`-i package.rpm`	Installs the package.
`-U package.rpm`	Updates an already installed package.
`-e package.rpm`	Uninstalls the package.
`-h`	Displays a progress bar.
`-v`	Informs about the progress of the operation.
`--test`	Tests the command without executing it.

The `rpm` command also allows you to query the system package database by adding the `-q` option.

It is possible to execute several types of queries to obtain different information about the installed packages. The RPM database is located in the directory `/var/lib/rpm`.

Example:

```
rpm -qa
```

This command queries all the packages installed on the system.

```
rpm -q [-a][-i][-l] package [-f] file
```

Example:

```
rpm -qil package
rpm -qf /path/to/file
```

Option	Description
`-a`	Lists all packages installed on the system.
`-i __package__`	Displays the package information.
`-l __package__`	Lists the files contained in the package.
`-f`	Shows the name of the package containing the specified file.
`--last`	The list of packages is given by installation date (the last installed packages appear first).

Warning

After the `-q` option, the package name must be exact. Metacharacters (wildcards) are not supported.

Tip

However, it is possible to list all installed packages and filter with the `grep` command.

Example: list the last installed packages:

```
sudo rpm -qa --last | head
NetworkManager-config-server-1.26.0-13.el8.noarch Mon 24 May 2021 02:34:00 PM
CEST
iwl2030-firmware-18.168.6.1-101.el8.1.noarch  Mon 24 May 2021 02:34:00 PM CEST
iwl2000-firmware-18.168.6.1-101.el8.1.noarch  Mon 24 May 2021 02:34:00 PM CEST
iwl135-firmware-18.168.6.1-101.el8.1.noarch   Mon 24 May 2021 02:34:00 PM CEST
iwl105-firmware-18.168.6.1-101.el8.1.noarch   Mon 24 May 2021 02:34:00 PM CEST
iwl100-firmware-39.31.5.1-101.el8.1.noarch    Mon 24 May 2021 02:34:00 PM CEST
iwl1000-firmware-39.31.5.1-101.el8.1.noarch   Mon 24 May 2021 02:34:00 PM CEST
alsa-sof-firmware-1.5-2.el8.noarch            Mon 24 May 2021 02:34:00 PM CEST
iwl7260-firmware-25.30.13.0-101.el8.1.noarch  Mon 24 May 2021 02:33:59 PM CEST
iwl6050-firmware-41.28.5.1-101.el8.1.noarch   Mon 24 May 2021 02:33:59 PM CEST
```

Example: list the installation history of the kernel:

```
sudo rpm -qa --last kernel
kernel-4.18.0-305.el8.x86_64                  Tue 25 May 2021 06:04:56 AM CEST
kernel-4.18.0-240.22.1.el8.x86_64             Mon 24 May 2021 02:33:35 PM CEST
```

Example: list all installed packages with a specific name using `grep`:

```
sudo dnf list installed | grep httpd
centos-logos-httpd.noarch           80.5-2.el8
@baseos
httpd.x86_64                        2.4.37-30.module_el8.3.0+561+97fdbbcc
@appstream
httpd-filesystem.noarch             2.4.37-30.module_el8.3.0+561+97fdbbcc
@appstream
httpd-tools.x86_64                  2.4.37-30.module_el8.3.0+561+97fdbbcc
@appstream
```

14.3 DNF: Dandified Yum

DNF (**Dandified Yum**) is a software package manager, successor of **YUM** (**Y**ellow dog **U**pdater **M**odified). It works with **RPM** packages grouped in a local or remote repository (a directory for storing packages). For the most common commands, its usage is identical to that of `yum`.

The `dnf` command allows the management of packages by comparing those installed on the system with those in the repositories defined on the server. It also automatically installs dependencies, if they are also present in the repositories.

`dnf` is the manager used by many RedHat based distributions (RockyLinux, Fedora, CentOS, ...). Its equivalent in the Debian world is **APT** (**A**dvanced **P**ackaging **T**ool).

14.3.1 `dnf` command

The `dnf` command allows you to install a package by specifying only the short name.

```
dnf [install][remove][list all][search][info] package
```

Example:

```
dnf install tree
```

Only the short name of the package is required.

Option	Description
`install`	Installs the package.
`remove`	Uninstall the package.
`list all`	Lists the packages already in the repository.
`search`	Search for a package in the repository.
`provides */command_name`	Search for a command.
`info`	Displays the package information.
`autoremove`	Removes all packages installed as dependencies but no longer needed.

The `dnf install` command allows you to install the desired package without worrying about its dependencies, which will be resolved directly by `dnf` itself.

```
dnf install nginx
Last metadata expiration check: 3:13:41 ago on Wed 23 Mar 2022 07:19:24 AM CET.
Dependencies resolved.
================================================================================
================================================
 Package                              Architecture
Version                                        Repository         Size
================================================================================
================================================
Installing:
 nginx                                aarch64         1:
1.14.1-9.module+el8.4.0+542+81547229         appstream         543 k
Installing dependencies:
 nginx-all-modules                    noarch          1:
1.14.1-9.module+el8.4.0+542+81547229         appstream          22 k
 nginx-mod-http-image-filter          aarch64         1:
1.14.1-9.module+el8.4.0+542+81547229         appstream          33 k
 nginx-mod-http-perl                  aarch64         1:
1.14.1-9.module+el8.4.0+542+81547229         appstream          44 k
 nginx-mod-http-xslt-filter           aarch64         1:
1.14.1-9.module+el8.4.0+542+81547229         appstream          32 k
 nginx-mod-mail                       aarch64         1:
1.14.1-9.module+el8.4.0+542+81547229         appstream          60 k
 nginx-mod-stream                     aarch64         1:
1.14.1-9.module+el8.4.0+542+81547229         appstream          82 k

Transaction Summary
================================================================================
================================================
Install  7 Packages
```

```
Total download size: 816 k
Installed size: 2.2 M
Is this ok [y/N]:
```

In case you don't remember the exact name of the package, you can search for it with the command `dnf search name`. As you can see, there is a section that contains the exact name and another one that contains the package correspondence, all of which are highlighted for easier searching.

```
dnf search nginx
Last metadata expiration check: 0:20:55 ago on Wed 23 Mar 2022 10:40:43 AM CET.
================================================ Name Exactly Matched: nginx
================================================
nginx.aarch64 : A high performance web server and reverse proxy server
============================================== Name & Summary Matched: nginx
==============================================
collectd-nginx.aarch64 : Nginx plugin for collectd
munin-nginx.noarch : NGINX support for Munin resource monitoring
nginx-all-modules.noarch : A meta package that installs all available Nginx
modules
nginx-filesystem.noarch : The basic directory layout for the Nginx server
nginx-mod-http-image-filter.aarch64 : Nginx HTTP image filter module
nginx-mod-http-perl.aarch64 : Nginx HTTP perl module
nginx-mod-http-xslt-filter.aarch64 : Nginx XSLT module
nginx-mod-mail.aarch64 : Nginx mail modules
nginx-mod-stream.aarch64 : Nginx stream modules
pagure-web-nginx.noarch : Nginx configuration for Pagure
pcp-pmda-nginx.aarch64 : Performance Co-Pilot (PCP) metrics for the Nginx
Webserver
python3-certbot-nginx.noarch : The nginx plugin for certbot
```

Another way to search for a package by entering an additional search key is to send the result of the `dnf` command through a pipe to the grep command with the desired key.

```
dnf search nginx | grep mod
Last metadata expiration check: 3:44:49 ago on Wed 23 Mar 2022 06:16:47 PM CET.
nginx-all-modules.noarch : A meta package that installs all available Nginx
modules
nginx-mod-http-image-filter.aarch64 : Nginx HTTP image filter module
nginx-mod-http-perl.aarch64 : Nginx HTTP perl module
nginx-mod-http-xslt-filter.aarch64 : Nginx XSLT module
```

```
nginx-mod-mail.aarch64 : Nginx mail modules
nginx-mod-stream.aarch64 : Nginx stream modules
```

The `dnf remove` command removes a package from the system and its dependencies. Below is an excerpt of the **dnf remove httpd** command.

```
dnf remove httpd
Dependencies resolved.
================================================================================
================================================
 Package                         Architecture
Version                                                 Repository          Size
================================================================================
================================================
Removing:
 httpd                           aarch64         2.
4.37-43.module+el8.5.0+727+743c5577.1           @appstream         8.9 M
Removing dependent packages:
 mod_ssl                         aarch64         1:
2.4.37-43.module+el8.5.0+727+743c5577.1         @appstream         274 k
 php                             aarch64         7.
4.19-1.module+el8.5.0+696+61e7c9ba              @appstream         4.4 M
 python3-certbot-apache          noarch          1.
22.0-1.el8                                      @epel              539 k
Removing unused dependencies:
 apr                             aarch64         1.
6.3-12.el8                                      @appstream         299 k
 apr-util                        aarch64         1.
6.1-6.el8.1                                     @appstream         224 k
 apr-util-bdb                    aarch64         1.
6.1-6.el8.1                                     @appstream          67 k
 apr-util-openssl                aarch64         1.
6.1-6.el8.1                                     @appstream          68 k
 augeas-libs                     aarch64         1.
12.0-6.el8                                      @baseos            1.4 M
 httpd-filesystem                noarch          2.
4.37-43.module+el8.5.0+727+743c5577.1           @appstream         400
 httpd-tools                     aarch64         2.
4.37-43.module+el8.5.0+727+743c5577.1
...
```

The `dnf list` command lists all the packages installed on the system and present in the repository. It accepts several parameters:

Parameter	Description
`all`	Lists the installed packages and then those available on the repositories.
`available`	Lists only the packages available for installation.
`updates`	Lists packages that can be upgraded.
`obsoletes`	Lists the packages made obsolete by higher versions available.
`recent`	Lists the latest packages added to the repository.

The `dnf info` command, as you might expect, provides detailed information about a package:

```
dnf info firewalld
Last metadata expiration check: 15:47:27 ago on Tue 22 Mar 2022 05:49:42 PM
CET.
Installed Packages
Name         : firewalld
Version      : 0.9.3
Release      : 7.el8
Architecture : noarch
Size         : 2.0 M
Source       : firewalld-0.9.3-7.el8.src.rpm
Repository   : @System
From repo    : baseos
Summary      : A firewall daemon with D-Bus interface providing a dynamic
firewall
URL          : http://www.firewalld.org
License      : GPLv2+
Description  : firewalld is a firewall service daemon that provides a dynamic
customizable
             : firewall with a D-Bus interface.

Available Packages
Name         : firewalld
Version      : 0.9.3
Release      : 7.el8_5.1
Architecture : noarch
Size         : 501 k
Source       : firewalld-0.9.3-7.el8_5.1.src.rpm
Repository   : baseos
Summary      : A firewall daemon with D-Bus interface providing a dynamic
firewall
URL          : http://www.firewalld.org
```

```
License      : GPLv2+
Description  : firewalld is a firewall service daemon that provides a dynamic
customizable
             : firewall with a D-Bus interface.
```

Sometimes you only know the executable you want to use but not the package that contains it, in this case you can use the command `dnf provides */package_name` which will search the database for you for the desired match.

Example of a search for the `semanage` command:

```
dnf provides */semanage
Last metadata expiration check: 1:12:29 ago on Wed 23 Mar 2022 10:40:43 AM CET.
libsemanage-devel-2.9-6.el8.aarch64 : Header files and libraries used to build
policy manipulation tools
Repo        : powertools
Matched from:
Filename    : /usr/include/semanage

policycoreutils-python-utils-2.9-16.el8.noarch : SELinux policy core python
utilities
Repo        : baseos
Matched from:
Filename    : /usr/sbin/semanage
Filename    : /usr/share/bash-completion/completions/semanage
```

The `dnf autoremove` command does not need any parameters. Dnf takes care of searching for candidate packages for removal.

```
dnf autoremove
Last metadata expiration check: 0:24:40 ago on Wed 23 Mar 2022 06:16:47 PM CET.
Dependencies resolved.
Nothing to do.
Complete!
```

14.3.2 Other useful `dnf` options

Option	Description
`repolist`	Lists the repositories configured on the system.
`grouplist`	Lists available package collections.
`clean`	Removes temporary files.

The `dnf repolist` command lists the repositories configured on the system. By default, it lists only the enabled repositories but can be used with these parameters:

Parameter	Description
`--all`	Lists all the repositories.
`--enabled`	Default
`--disabled`	Lists only disabled repositories.

Example:

```
dnf repolist
repo id                                                    repo name
appstream                                                  Rocky Linux 8 -
AppStream
baseos                                                     Rocky Linux 8 - BaseOS
epel                                                       Extra Packages for
Enterprise Linux 8 - aarch64
epel-modular                                               Extra Packages for
Enterprise Linux Modular 8 - aarch64
extras                                                     Rocky Linux 8 - Extras
powertools                                                 Rocky Linux 8 -
PowerTools
rockyrpi                                                   Rocky Linux 8 -
Rasperry Pi
```

And an excerpt of the command with the `--all` flag.

```
dnf repolist --all

...
repo id                                                repo
name
status
appstream                                              Rocky Linux 8 -
AppStream
enabled
appstream-debug                                        Rocky Linux 8 - AppStream
- Source                                                                 disabled
appstream-source                                       Rocky Linux 8 - AppStream
- Source                                                                 disabled
baseos                                                 Rocky Linux 8 -
BaseOS
enabled
```

```
baseos-debug                                    Rocky Linux 8 - BaseOS -
Source                                                             disabled
baseos-source                                   Rocky Linux 8 - BaseOS -
Source                                                             disabled
devel                                           Rocky Linux 8 - Devel
WARNING! FOR BUILDROOT AND KOJI USE
disabled
epel                                            Extra Packages for
Enterprise Linux 8 - aarch64
enabled
epel-debuginfo                                  Extra Packages for
Enterprise Linux 8 - aarch64 - Debug
disabled
epel-modular                                    Extra Packages for
Enterprise Linux Modular 8 - aarch64
enabled
epel-modular-debuginfo                          Extra Packages for
Enterprise Linux Modular 8 - aarch64 - Debug
disabled
epel-modular-source                             Extra Packages for
Enterprise Linux Modular 8 - aarch64 - Source
...
```

And below is an excerpt from the list of disabled repositories.

```
dnf repolist --disabled
repo id                                 repo name
appstream-debug                         Rocky Linux 8 - AppStream - Source
appstream-source                        Rocky Linux 8 - AppStream - Source
baseos-debug                            Rocky Linux 8 - BaseOS - Source
baseos-source                           Rocky Linux 8 - BaseOS - Source
devel                                   Rocky Linux 8 - Devel WARNING! FOR
BUILDROOT AND KOJI USE
epel-debuginfo                          Extra Packages for Enterprise Linux 8
- aarch64 - Debug
epel-modular-debuginfo                  Extra Packages for Enterprise Linux
Modular 8 - aarch64 - Debug
epel-modular-source                     Extra Packages for Enterprise Linux
Modular 8 - aarch64 - Source
epel-source                             Extra Packages for Enterprise Linux 8
- aarch64 - Source
epel-testing                            Extra Packages for Enterprise Linux 8
- Testing - aarch64
...
```

Using the `-v` option enhances the list with a lot of additional information. Below you can see part of the result of the command.

```
dnf repolist -v

...
Repo-id            : powertools
Repo-name          : Rocky Linux 8 - PowerTools
Repo-revision      : 8.5
Repo-distro-tags      : [cpe:/o:rocky:rocky:8]:  ,  , 8, L, R, c, i, k, n, o,
u, x, y
Repo-updated       : Wed 16 Mar 2022 10:07:49 PM CET
Repo-pkgs          : 1,650
Repo-available-pkgs: 1,107
Repo-size          : 6.4 G
Repo-mirrors       : https://mirrors.rockylinux.org/mirrorlist?
arch=aarch64&repo=PowerTools-8
Repo-baseurl       : https://example.com/pub/rocky/8.8/PowerTools/x86_64/os/
(30 more)
Repo-expire        : 172,800 second(s) (last: Tue 22 Mar 2022 05:49:24 PM CET)
Repo-filename      : /etc/yum.repos.d/Rocky-PowerTools.repo
...
```

Using Groups

Groups are a collection of a set of packages (you can think of them as a virtual packages) that logically groups a set of applications to accomplish a purpose (a desktop environment, a server, development tools, etc.).

The `dnf grouplist` command lists all available groups.

```
dnf grouplist
Last metadata expiration check: 1:52:00 ago on Wed 23 Mar 2022 02:11:43 PM CET.
Available Environment Groups:
   Server with GUI
   Server
   Minimal Install
   KDE Plasma Workspaces
   Custom Operating System
Available Groups:
   Container Management
   .NET Core Development
   RPM Development Tools
   Development Tools
   Headless Management
   Legacy UNIX Compatibility
   Network Servers
```

```
   Scientific Support
   Security Tools
   Smart Card Support
   System Tools
   Fedora Packager
   Xfce
```

The `dnf groupinstall` command allows you to install one of these groups.

```
dnf groupinstall "Network Servers"
Last metadata expiration check: 2:33:26 ago on Wed 23 Mar 2022 02:11:43 PM CET.
Dependencies resolved.
================================================================================
=
 Package           Architecture     Version             Repository         Size
================================================================================
=
Installing Groups:
 Network Servers

Transaction Summary
================================================================================
=

Is this ok [y/N]:
```

Note that it is good practice to enclose the group name in double quotes as without the command it will only execute correctly if the group name does not contain spaces.

So a `dnf groupinstall Network Servers` produces the following error.

```
dnf groupinstall Network Servers
Last metadata expiration check: 3:05:45 ago on Wed 23 Mar 2022 02:11:43 PM CET.
Module or Group 'Network' is not available.
Module or Group 'Servers' is not available.
Error: Nothing to do.
```

The corresponding command to remove a group is `dnf groupremove "name group"`.

The `dnf clean` command cleans all caches and temporary files created by `dnf`. It can be used with the following parameters.

Parameters	Description
`all`	Removes all temporary files created for enabled repositories.
`dbcache`	Removes cache files for the repository metadata.
`expire-cache`	Remove the local cookie files.
`metadata`	Removes all the repositories metadata.
`packages`	Removes any cached packages.

14.3.3 How DNF works

The DNF manager relies on one or more configuration files to target the repositories containing the RPM packages.

These files are located in `/etc/yum.repos.d/` and must end with `.repo` in order to be used by DNF.

Example:

```
/etc/yum.repos.d/Rocky-BaseOS.repo
```

Each `.repo` file consists of at least the following information, one directive per line.

Example:

```
[baseos] # Short name of the repository
name=Rocky Linux $releasever - BaseOS # Short name of the repository #Detailed
name
mirrorlist=http://mirrors.rockylinux.org/mirrorlist?arch=$basearch&repo=BaseOS-
$releasever # http address of a list or mirror
#baseurl=http://dl.rockylinux.org/$contentdir/$releasever/BaseOS/$basearch/os/
# http address for direct access
gpgcheck=1 # Repository requiring a signature
enabled=1 # Activated =1, or not activated =0
gpgkey=file:///etc/pki/rpm-gpg/RPM-GPG-KEY-rockyofficial # GPG public key path
```

By default, the `enabled` directive is absent which means that the repository is enabled. To disable a repository, you must specify the `enabled=0` directive.

14.4 DNF modules

Modules were introduced in Rocky Linux 8 by the upstream. In order to use modules, the AppStream repository must exist and be enabled.

Package Confusion

The creation of module streams in the AppStream repository caused a lot of people confusion. Since modules are packaged within a stream (see our examples below), a particular package would show up in our RPMs, but if an attempt was made to install it without enabling the module, nothing would happen. Remember to look at modules if you attempt to install a package and it fails to find it.

14.4.1 What are modules

Modules come from the AppStream repository and contain both streams and profiles. These can be described as follows:

- **module streams:** A module stream can be thought of as a separate repository within the AppStream repository that contains different application versions. These module repositories contain the application RPMs, dependencies, and documentation for that particular stream. An example of a module stream in Rocky Linux 8 would be `postgresql`. If you install `postgresql` using the standard `sudo dnf install postgresql` you will get version 10. However, using modules, you can instead install versions 9.6, 12 or 13.
- **module profiles:** What a module profile does is take into consideration the use case for the module stream when installing the package. Applying a profile adjusts the package RPMs, dependencies and documentation to account for the module's use. Using the same `postgresql` stream in our example, you can apply a profile of either "server" or "client". Obviously, you do not need the same packages installed on your system if you are just going to use `postgresql` as a client to access a server.

14.4.2 Listing modules

You can obtain a list of all modules by executing the following command:

```
dnf module list
```

This will give you a long list of the available modules and the profiles that can be used for them. The thing is you probably already know what package you are interested in, so to find out if there are modules for a particular package, add the package name after "list". We will use our `postgresql` package example again here:

```
dnf module list postgresql
```

This will give you output that looks like this:

```
Rocky Linux 8 - AppStream
Name                        Stream
Profiles
Summary
postgresql                  9.6                     client, server
[d]                 PostgreSQL server and client module
postgresql                  10 [d]                  client, server
[d]                 PostgreSQL server and client module
postgresql                  12                      client, server
[d]                 PostgreSQL server and client module
postgresql                  13                      client, server
[d]                 PostgreSQL server and client module
```

Notice in the listing the "[d]". This means that this is the default. It shows that the default version is 10 and that regardless of which version you choose, if you do not specify a profile, then the server profile will be the profile used, as it is the default as well.

14.4.3 Enabling Modules

Using our example `postgresql` package, let's say that we want to enable version 12. To do this, you simply use the following:

```
dnf module enable postgresql:12
```

Here the enable command requires the module name followed by a ":" and the stream name.

To verify that you have enabled `postgresql` module stream version 12, use your list command again which should show you the following output:

```
Rocky Linux 8 - AppStream
Name                        Stream
Profiles
Summary
postgresql                  9.6                     client, server
[d]                 PostgreSQL server and client module
postgresql                  10 [d]                  client, server
[d]                 PostgreSQL server and client module
postgresql                  12 [e]                  client, server
[d]                 PostgreSQL server and client module
postgresql                  13                      client, server
[d]                 PostgreSQL server and client module
```

Here we can see the "[e]" for "enabled" next to stream 12, so we know that version 12 is enabled.

14.4.4 Installing packages from the module stream

Now that our module stream is enabled, the next step is to install `postgresql`, the client application for the postgresql server. This can be achieved by running the following command:

```
dnf install postgresql
```

Which should give you this output:

```
================================================================================
================================================================
 Package                    Architecture
Version
Repository                 Size
================================================================================
================================================================
Installing group/module packages:
 postgresql                 x86_64                  12.
12-1.module+el8.6.0+1049+f8fc4c36                appstream                1.
5 M
Installing dependencies:
 libpq                      x86_64                  13.
5-1.el8                                           appstream
197 k

Transaction Summary
```

```
================================================================================
================================================
Install  2 Packages
Total download size: 1.7 M
Installed size: 6.1 M
Is this ok [y/N]:
```

After approving by typing "y" you installed the application.

14.4.5 Installing packages from module stream profiles

It's also possible to directly install packages without even having to enable the module stream! In this example, let's assume that we only want the client profile applied to our installation. To do this, we simply enter this command:

```
dnf install postgresql:12/client
```

Which should give you this output:

```
================================================================================
================================================
 Package                    Architecture
Version
Repository                 Size
================================================================================
================================================
Installing group/module packages:
 postgresql                 x86_64                  12.
12-1.module+el8.6.0+1049+f8fc4c36                appstream                1.
5 M
Installing dependencies:
 libpq                      x86_64                  13.
5-1.el8                                          appstream
197 k
Installing module profiles:
 postgresql/client
Enabling module streams:
 postgresql                                       12

Transaction Summary
================================================================================
================================================
Install  2 Packages
```

```
Total download size: 1.7 M
Installed size: 6.1 M
Is this ok [y/N]:
```

Answering "y" to the prompt will install everything you need to use postgresql version 12 as a client.

14.4.6 Module Removal and Reset or Switch-To

After you install, you may decide that for whatever reason, you need a different version of the stream. The first step is to remove your packages. Using our example `postgresql` package again, we would do this with:

```
dnf remove postgresql
```

This will display similar output as the install procedure above, except it will be removing the package and all of its dependencies. Answer "y" to the prompt and hit enter to uninstall `postgresql`.

Once this step is complete, you can issue the reset command for the module using:

```
dnf module reset postgresql
```

Which will give you output like this:

```
Dependencies resolved.
================================================================================
================================================
 Package                        Architecture
Version                          Repository                        Size
================================================================================
================================================
Disabling module profiles:
 postgresql/
client
Resetting modules:

postgresql

Transaction Summary
================================================================================
================================================
```

```
Is this ok [y/N]:
```

Answering "y" to the prompt will then reset `postgresql` back to the default stream with the stream that we had enabled (12 in our example) no longer enabled:

```
Rocky Linux 8 - AppStream
Name                        Stream
Profiles
Summary
postgresql                  9.6                     client, server
[d]                 PostgreSQL server and client module
postgresql                  10 [d]                  client, server
[d]                 PostgreSQL server and client module
postgresql                  12                      client, server
[d]                 PostgreSQL server and client module
postgresql                  13                      client, server
[d]                 PostgreSQL server and client module
```

Now you can use the default.

You can also use the switch-to sub-command to switch from one enabled stream to another. Using this method not only switches to the new stream, but installs the needed packages (either downgrade or upgrade) without a separate step. To use this method to enable `postgresql` stream version 13 and use the "client" profile, you would use:

```
dnf module switch-to postgresql:13/client
```

14.4.7 Disable a module stream

There may be times when you wish to disable the ability to install packages from a module stream. In the case of our `postgresql` example, this could be because you want to use the repository directly from PostgreSQL so that you could use a newer version (at the time of this writing, versions 14 and 15 are available from this repository). Disabling a module stream, makes installing any of those packages impossible without first enabling them again.

To disable the module streams for `postgresql` simply do:

```
dnf module disable postgresql
```

And if you list out the `postgresql` modules again, you will see the following showing all `postgresql` module versions disabled:

```
Rocky Linux 8 - AppStream
Name                        Stream
Profiles
Summary
postgresql                  9.6 [x]                 client, server
[d]                PostgreSQL server and client module
postgresql                  10 [d][x]               client, server
[d]                PostgreSQL server and client module
postgresql                  12 [x]                  client, server
[d]                PostgreSQL server and client module
postgresql                  13 [x]                  client, server
[d]                PostgreSQL server and client module
```

14.5 The EPEL repository

14.5.1 What is EPEL and how is it used?

EPEL (**E**xtra **P**ackages for **E**nterprise **L**inux) is an open-source and free community-based repository maintained by the EPEL Fedora Special Interest Group that provides a set of additional packages for RHEL (and CentOS, Rocky Linux, and others) from the Fedora sources.

It provides packages that are not included in the official RHEL repositories. These are not included because they are not considered necessary in an enterprise environment or deemed outside the scope of RHEL. We must not forget that RHEL is an enterprise class distribution, and desktop utilities or other specialized software may not be a priority for an enterprise project.

14.5.2 Installation

Installation of the necessary files can be easily done with the package provided by default from Rocky Linux.

If you are behind an internet proxy:

```
export http_proxy=http://172.16.1.10:8080
```

Then:

```
dnf install epel-release
```

Once installed you can check that the package has been installed correctly with the command `dnf info`.

```
dnf info epel-release
Last metadata expiration check: 1:30:29 ago on Thu 24 Mar 2022 09:36:42 AM CET.
Installed Packages
Name         : epel-release
Version      : 8
Release      : 14.el8
Architecture : noarch
Size         : 32 k
Source       : epel-release-8-14.el8.src.rpm
Repository   : @System
From repo    : epel
Summary      : Extra Packages for Enterprise Linux repository configuration
URL          : http://download.fedoraproject.org/pub/epel
License      : GPLv2
Description  : This package contains the Extra Packages for Enterprise Linux
             : (EPEL) repository GPG key as well as configuration for yum.
```

The package, as you can see from the package description above, does not contain executables, libraries, etc... but only the configuration files and GPG keys for setting up the repository.

Another way to verify the correct installation is to query the rpm database.

```
rpm -qa | grep epel
epel-release-8-14.el8.noarch
```

Now you need to run an update to let `dnf` recognize the repository. You will be asked to accept the GPG keys of the repositories. Clearly, you have to answer YES in order to use them.

```
dnf update
```

Once the update is complete you can check that the repository has been configured correctly with the `dnf repolist` command which should now list the new repositories.

```
dnf repolist
repo id            repo name
...
epel               Extra Packages for Enterprise Linux 8 - aarch64
epel-modular       Extra Packages for Enterprise Linux Modular 8 - aarch64
...
```

The repository configuration files are located in `/etc/yum.repos.d/`.

```
ll /etc/yum.repos.d/ | grep epel
-rw-r--r--. 1 root root 1485 Jan 31 17:19 epel-modular.repo
-rw-r--r--. 1 root root 1422 Jan 31 17:19 epel.repo
-rw-r--r--. 1 root root 1584 Jan 31 17:19 epel-testing-modular.repo
-rw-r--r--. 1 root root 1521 Jan 31 17:19 epel-testing.repo
```

And below we can see the contents of the file `epel.repo`.

```
[epel]
name=Extra Packages for Enterprise Linux $releasever - $basearch
# It is much more secure to use the metalink, but if you wish to use a local
mirror
# place its address here.
#baseurl=https://download.example/pub/epel/$releasever/Everything/$basearch
metalink=https://mirrors.fedoraproject.org/metalink?repo=epel-
$releasever&arch=$basearch&infra=$infra&content=$contentdir
enabled=1
gpgcheck=1
countme=1
gpgkey=file:///etc/pki/rpm-gpg/RPM-GPG-KEY-EPEL-8

[epel-debuginfo]
name=Extra Packages for Enterprise Linux $releasever - $basearch - Debug
# It is much more secure to use the metalink, but if you wish to use a local
mirror
# place its address here.
#baseurl=https://download.example/pub/epel/$releasever/Everything/$basearch/
debug
metalink=https://mirrors.fedoraproject.org/metalink?repo=epel-debug-
$releasever&arch=$basearch&infra=$infra&content=$contentdir
enabled=0
gpgkey=file:///etc/pki/rpm-gpg/RPM-GPG-KEY-EPEL-8
```

```
gpgcheck=1

[epel-source]
name=Extra Packages for Enterprise Linux $releasever - $basearch - Source
# It is much more secure to use the metalink, but if you wish to use a local
mirror
# place it's address here.
#baseurl=https://download.example/pub/epel/$releasever/Everything/source/tree/
metalink=https://mirrors.fedoraproject.org/metalink?repo=epel-source-
$releasever&arch=$basearch&infra=$infra&content=$contentdir
enabled=0
gpgkey=file:///etc/pki/rpm-gpg/RPM-GPG-KEY-EPEL-8
gpgcheck=1
```

14.5.3 Using EPEL

At this point, once configured, we are ready to install the packages from EPEL. To start, we can list the packages available in the repository with the command:

```
dnf --disablerepo="*" --enablerepo="epel" list available
```

And an excerpt of the command

```
dnf --disablerepo="*" --enablerepo="epel" list available | less
Last metadata expiration check: 1:58:22 ago on Fri 25 Mar 2022 09:23:29 AM CET.
Available Packages
3proxy.aarch64                                                  0.
8.13-1.el8                                      epel
AMF-devel.noarch                                                1.
4.23-2.el8                                      epel
AMF-samples.noarch                                              1.
4.23-2.el8                                      epel
AusweisApp2.aarch64                                             1.
22.3-1.el8                                      epel
AusweisApp2-data.noarch                                         1.
22.3-1.el8                                      epel
AusweisApp2-doc.noarch                                          1.
22.3-1.el8                                      epel
BackupPC.aarch64                                                4.
4.0-1.el8                                       epel
BackupPC-XS.aarch64                                             0.
62-1.el8                                        epel
BibTool.aarch64                                                 2.
68-1.el8                                        epel
CCfits.aarch64                                                  2.
```

```
5-14.el8                                        epel
CCfits-devel.aarch64                                                2.
5-14.el8                                        epel
...
```

From the command we can see that to install from EPEL we must force **dnf** to query the requested repository with the options `--disablerepo` and `--enablerepo`, this is because otherwise a match found in other optional repositories (RPM Fusion, REMI, ELRepo, etc.) could be newer and therefore have priority. These options are not necessary if you have only installed EPEL as an optional repository because the packages in the repository will never be available in the official ones. At least in the same version!

Support consideration

One aspect to consider regarding support (updates, bug fixes, security patches) is that EPEL packages have no official support from RHEL and technically their life could last the space of a development of Fedora (six months) and then disappear. This is a remote possibility but one to consider.

So, to install a package from the EPEL repositories you would use:

```
dnf --disablerepo="*" --enablerepo="epel" install nmon
Last metadata expiration check: 2:01:36 ago on Fri 25 Mar 2022 04:28:04 PM CET.
Dependencies resolved.
================================================================================
================================================================================
 Package                            Architecture
Version                                    Repository
Size
================================================================================
================================================================================
Installing:
 nmon                               aarch64
16m-1.el8                                  epel
71 k

Transaction Summary
================================================================================
================================================================================
Install  1 Package

Total download size: 71 k
Installed size: 214 k
Is this ok [y/N]:
```

14.5.4 Conclusion

EPEL is not an official repository for RHEL, but it can be useful for administrators and developers who work with RHEL or derivatives and need some utilities prepared for RHEL from a source they can feel confident about.

14.6 DNF Plugins

The `dnf-plugins-core` package adds plugins to `dnf` that will be useful for managing your repositories.

> **Note**
>
> See more informations here: https://dnf-plugins-core.readthedocs.io/en/latest/index.html

Install the package on your system:

```
dnf install dnf-plugins-core
```

Not all plugins will be presented here but you can refer to the package documentation for a complete list of plugins and detailed information.

14.6.1 `config-manager` plugin

Manage DNF options, add repos, or disable them.

Examples:

- Download a `.repo` file and use it:

```
dnf config-manager --add-repo https://packages.centreon.com/ui/native/rpm-
standard/23.04/el8/centreon-23.04.repo
```

- You can also set an url as a base url for a repo:

```
dnf config-manager --add-repo https://repo.rocky.lan/repo
```

- Enable or disable one or more repos:

```
dnf config-manager --set-enabled epel centreon
dnf config-manager --set-disabled epel centreon
```

- Add a proxy to your config file:

```
dnf config-manager --save --setopt=*.proxy=http://proxy.rocky.lan:3128/
```

14.6.2 `copr` plugin

`copr` is an automatic rpm forge, providing a repo with built packages.

- Activate a copr repo:

```
copr enable xxxx
```

14.6.3 `download` plugin

Download rpm package instead of installing it:

```
dnf download ansible
```

If you just want to obtain the remote location url of the package:

```
dnf download --url ansible
```

Or if you want to also download the dependencies:

```
dnf download --resolv --alldeps ansible
```

14.6.4 `needs-restarting` plugin

After running a `dnf update`, the running processes will continue to run but with the old binaries. In order to take into account the code changes and especially the security updates, they have to be restarted.

The `needs-restarting` plugin will allow you to detect processes that are in this case.

```
dnf needs-restarting [-u] [-r] [-s]
```

Options	Description
`-u`	Only consider processes belonging to the running user.
`-r`	to check if a reboot may be required.
`-s`	to check if services need restarting.
`-s -r`	to do both in one run.

14.6.5 `versionlock` plugin

Sometimes it is useful to protect packages from all updates or to exclude certain versions of a package (because of known problems for example). For this purpose, the versionlock plugin will be of great help.

You need to install an extra package:

```
dnf install python3-dnf-plugin-versionlock
```

Examples:

- Lock the ansible version:

```
dnf versionlock add ansible
Adding versionlock on: ansible-0:6.3.0-2.el9.*
```

- List locked packages:

```
dnf versionlock list
ansible-0:6.3.0-2.el9.*
```

All of the examples in this document use root actions, with ordinary users actions commented separately. In the markdown code block, the command description will be indicated with # on the previous line.

15. Review basic permissions

It is well known that the basic permissions of GNU/Linux can be viewed using `ls -l`:

```
Shell > ls -l
-  rwx  r-x  r-x  1  root  root    1358  Dec 31 14:50  anaconda-ks.cfg
↓   ↓    ↓    ↓   ↓   ↓     ↓       ↓         ↓             ↓
1   2    3    4   5   6     7       8         9             10
```

Their meanings are as follows:

Part	Description
1	File type. `-` indicates that this is an ordinary file. Seven file types will be introduced later.
2	Permissions of owner user, the meaning of rwx respectively means: read, write, execute.
3	Permissions of the owner group.
4	Permissions of other users.
5	Number of subdirectories (`.` and `..` included). For a file, it represents the number of hard links, and 1 represents itself.
6	Name of the owner user.
7	Name of the owner group.
8	For files, it shows the size of the file. For directories, it shows the fixed value of 4096 bytes occupied by the file naming. To calculate the total size of a directory, use `du -sh`
9	Last modified date.
10	The name of the file (or directory).

15.1 Seven file types

File types	Description
-	Represents an ordinary file. Including plain text files (ASCII); binary files (binary); data format files (data); various compressed files.
d	Represents a directory file. By default, there is one in every directory `.` and `..`.
b	Block device file. Including all kinds of hard drives, USB drives and so on.
c	Character device file. Interface device of serial port, such as mouse, keyboard, etc.
s	Socket file. It is a file specially used for network communication.
p	Pipe file. It is a special file type, the main purpose is to solve the errors caused by multiple programs accessing a file at the same time. FIFO is the abbreviation of first-in-first-out.
l	Soft link files, also called symbolic link files, are similar to shortcuts in Windows. Hard link file, also known as physical link file.

15.2 The meaning of basic permissions

For file:

Digital representation	Permissions	Description
4	r(read)	Indicates that you can read this file. You can use commands such as `cat`, `head`, `more`, `less`, `tail`, etc.
2	w(write)	Indicates that the file can be modified. Commands such as `vim` can be used.
1	x(execution)	Permissions for executable files (such as scripts or binaries).

For directory:

Digital representation	Permissions	Description
4	r(read)	Indicates that the contents of the directory can be listed, such as `ls -l`.
2	w(write)	Indicates that you can create, delete, and rename files in this directory, such as commands `mkdir`, `touch`, `rm`, etc.
1	x(execute)	Indicates that you can enter the directory, such as the command `cd`.

Info

For directories, **r** and **x** permissions usually appear at the same time.

15.3 Special authority

In GNU/Linux, in addition to the basic permissions mentioned above, there are also some special permissions, which we will introduce one by one.

15.3.1 ACL permissions

What is ACL? ACL(Access Control List), the purpose is to solve the problem that the three identities under Linux can not meet the needs of resource permission allocation.

For example, the teacher gives lessons to the students, and the teacher creates a directory under the root directory of OS. Only the students in this class are allowed to upload and download, and others are not allowed. At this point, the permissions for the directory are 770. One day, a student from another school came to listen to the teacher, how should permissions be assigned? If you put this student in the **owner group**, he will have the same permissions as the students in this class - **rwx**. If the student is put into the **other users**, he will not have any permissions. At this time, the basic permission allocation cannot meet the requirements, and you need to use ACL.

There is a similar feature in the Windows operating system. For example, to assign permissions to a user for a file, for a user-defined directory/file, **right-click** ---> **Properties** ---> **Security** ---> **Edit** ---> **Add** ---> **Advanced** ---> **Find now**, find the corresponding user/group ---> assign specific permissions ---> **apply**, and complete.

The same is true of GNU/Linux: add the specified user/group to the file/directory and grant the appropriate permissions to complete the ACL permission assignment.

How do I enable an ACL? You need to find the file name of the device where the mount point is located and its partition number. For example, on my machine, you could do something like this:

```
Shell > df -hT
Filesystem     Type      Size  Used  Avail Use% Mounted on
devtmpfs       devtmpfs  3.8G     0  3.8G    0% /dev
tmpfs          tmpfs     3.8G     0  3.8G    0% /dev/shm
tmpfs          tmpfs     3.8G  8.9M  3.8G    1% /run
```

```
tmpfs          tmpfs     3.8G     0  3.8G    0% /sys/fs/cgroup
/dev/nvme0n1p2 ext4       47G   11G   35G   24% /
/dev/nvme0n1p1 xfs      1014M  187M  828M   19% /boot
tmpfs          tmpfs     774M     0  774M    0% /run/user/0

Shell > dumpe2fs /dev/nvme0n1p2 | head -n 10
dumpe2fs 1.45.6 (20-Mar-2020)
Filesystem volume name:   <none>
Last mounted on:          /
Filesystem UUID:          c8e6206d-2892-4c22-a10b-b87d2447a885
Filesystem magic number:  0xEF53
Filesystem revision #:    1 (dynamic)
Filesystem features:      has_journal ext_attr resize_inode dir_index filetype
needs_recovery extent 64bit flex_bg sparse_super large_file huge_file
dir_nlink extra_isize metadata_csum
Filesystem flags:         signed_directory_hash
Default mount options:    user_xattr acl
Filesystem state:         clean
Errors behavior:          Continue
```

When you see the line **"Default mount options: user_xattr acl"**, it indicates that ACL has been enabled. If it is not enabled, you can also enable it temporarily -- `mount -o remount,acl /`. It can also be enabled permanently:

```
Shell > vim /etc/fstab
UUID=c8e6206d-2892-4c22-a10b-b87d2447a885  /   ext4    defaults,acl        1 1

Shell > mount -o remount /
# or
Shell > reboot
```

Viewing and setting of ACL

To view ACL, you need to use the `getfacle` command -- `getfacle FILE_NAME`

If you want to set ACL permissions, you need to use the `setfacl` command.

```
Shell > setfacl <option> <FILE_NAME>
```

Option	Description
-m	modify the current ACL(s) of file(s)
-x	remove entries from the ACL(s) of file(s)
-b	remove all extended ACL entries
-d	operations apply to the default ACL
-k	remove the default ACL
-R	recurse into subdirectories

Use the teacher's example mentioned at the beginning of the article to illustrate the use of ACL.

```
# The teacher is the root user
Shell > groupadd class1
Shell > mkdir /project
Shell > chown root:class1 /project
Shell > chmod 770 /project
Shell > ls -ld /project/
drwxrwx--- 2 root class1 4096 Jan  12 12:58 /project/

# Put the students in the class into the class1 group
Shell > useradd frank
Shell > passwd frank
Shell > useradd aron
Shell > passwd aron
Shell > gpasswd -a frank class1
Shell > gpasswd -a aron class1

# A student from another school came to listen to the teacher
Shell > useradd tom
Shell > passwd tom
# If it is a group, "u" here should be replaced by "g"
Shell > setfacle -m u:tom:rx  /project

# "+" sign is added in the output message
Shell > ls -ld /project/
drwxrwx---+ 2 root class1 4096 Jan  12 12:58 /project/

Shell > getfacl -p /project/
# file: /project/
# owner: root
# group: class1
user::rwx
```

```
user:tom:r-x
group::rwx
mask::rwx
other::---
```

Maximum valid permissions of ACL

When using the `getfacl` command, what does the "mask:: rwx" in the output message mean? The **mask** is used to specify the maximum valid permissions. The permissions given to the user are not real permissions, the real permissions can only be obtained by using the "logical and" of the user's permissions and mask permissions.

Info

"Logical and" means: that if all are true, the result is true; if there is one false, the result is false.

Permissions set by users	Mask permissions	Result
r	r	r
r	-	-
-	r	-
-	-	-

Info

Because the default mask is rwx, for any user's ACL permissions, the result is their own permissions.

You can also adjust mask permissions:

```
Shell > setfacl -m u:tom:rwx /project
Shell > setfacl -m m:rx /project

Shell > getfacl  -p /project/
# file: project/
# owner: root
# group: class1
user::rwx
user:tom:rwx                    #effective:r-x
group::rwx                      #effective:r-x
mask::r-x
other::---
```

Delete ACL permission

```
# Delete the ACL permissions of user/group in the specified directory
Shell > setfacl -x u:USER_NAME FILE_NAME
Shell > setfacl -x g:GROUP_NAME FILE_NAME

# Removes all ACL permissions for the specified directory
Shell > setfacl -b FILE_NAME
```

Default and recursion of ACL permissions

What is the recursion of ACL permissions? For ACL permissions, this means that when the parent directory sets ACL permissions, all subdirectories and sub-files will have the same ACL permissions.

> **Info**
>
> Recursion is suitable for files/directories that already exist in the directory.

Look at the following example:

```
Shell > setfacl -m m:rwx /project
Shell > setfacl -m u:tom:rx /project

Shell > cd /project
Shell > touch file1 file2
# Because there is no recursion, the file here does not have ACL permission.
Shell > ls -l
-rw-r--r-- 1 root root 0 Jan  12 14:35 file1
-rw-r--r-- 1 root root 0 Jan  12 14:35 file2

Shell > setfacl -m u:tom:rx -R /project
Shell > ls -l /project
-rw-r-xr--+ 1 root root 0 Jan  12 14:35 file1
-rw-r-xr--+ 1 root root 0 Jan  12 14:35 file2
```

Now there is a question: if I create a new file in this directory, does it have ACL permission? The answer is no, because the newly created file is after the command `setfacl-m u:tom:rx -R /project` is executed.

```
Shell > touch /project/file3
Shell > ls -l /project/file3
-rw-r--r-- 1 root root 0 Jan  12 14:52 /project/file3
```

If you want the newly created directory/file to also have ACL permissions, you need to use default ACL permissions.

```
Shell > setfacl -m d:u:tom:rx  /project
Shell > cd /project && touch file4 && ls -l
-rw-r-xr--+ 1 root root 0 Jan  12 14:35 file1
-rw-r-xr--+ 1 root root 0 Jan  12 14:35 file2
-rw-r--r--  1 root root 0 Jan  12 14:52 file3
-rw-rw----+ 1 root root 0 Jan  12 14:59 file4

Shell > getfacl -p /project
# file: /project
# owner: root
# group: class1
user::rwx
user:tom:r-x
group::rwx
mask::rwx
other::---
default:user::rwx
default:user:tom:r-x
default:group::rwx
default:mask::rwx
default:other::---
```

Info

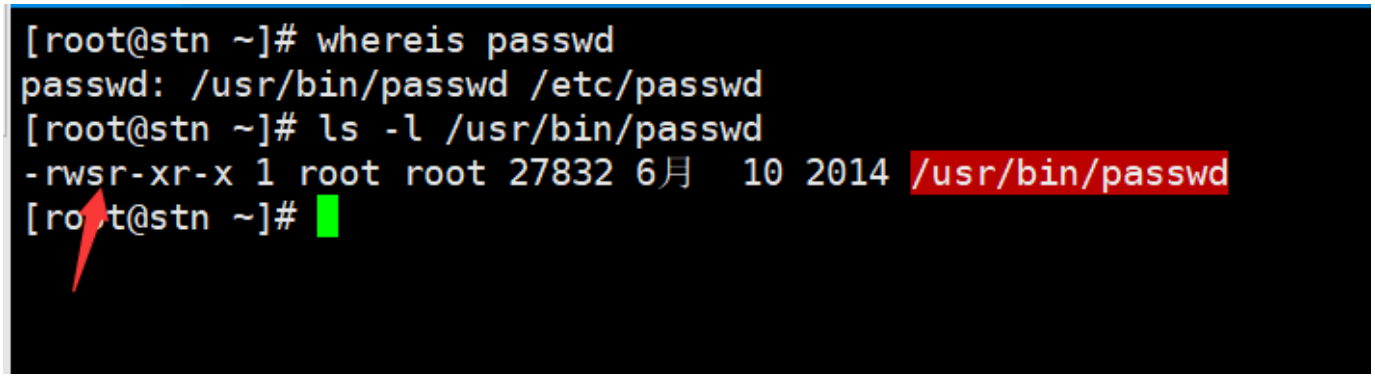
The default and recursion of using ACL permissions require that the operating object of the command be a directory! If the operation object is a file, an error prompt will be output.

15.3.2 SetUID

The role of "SetUID":

- Only executable binaries can set SUID permissions.
- The executor of the command should have x permission to the program.
- The executor of the command obtains the identity of the owner of the program file when executing the program.
- The identity change is only valid during execution, and once the binary program is finished, the executor's identity is restored to the original identity.

Why does GNU/Linux need such strange permissions? Take the most common `passwd` command as an example:



As you can see, the ordinary users only has r and x, but the owner's x becomes s, proving that the `passwd` command has SUID permissions.

It is well known that the ordinary users (uid >= 1000) can change his own password. The real password is stored in the **/etc/shadow** file, but the permission of the shadows file is 000, and the ordinary users does not have any permissions.

```
Shell > ls -l /etc/shadow
---------- 1 root root 874 Jan  12 13:42 /etc/shadow
```

Since the ordinary users can change their password, they must have written the password to the **/etc/shadow** file. When an ordinary user executes the `passwd` command, it will temporarily change to the owner of the file -- **root**. For **shadow** file, **root** can not be restricted by permissions. This is why `passwd` command needs SUID permission.

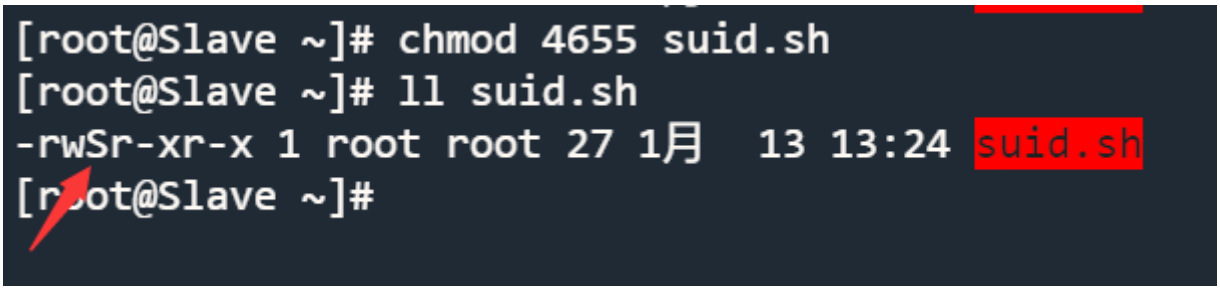
As mentioned earlier, basic permissions can be represented by numbers, such as 755, 644, and so on. SUID is represented by **4**. For executable binaries, you can set permissions like this -- **4755**.

```
# Set SUID permissions
Shell > chmod 4755 FILE_NAME
# or
Shell > chmod u+s FILE_NAME

# Remove SUID permission
Shell > chmod 755 FILE_NAME
# or
Shell > chmod u-s FILE_NAME
```

Warning

When the owner of an executable binary file/program does not have **x**, the use of capital **S** means that the file cannot use SUID permissions.

```
# Suppose this is an executable binary file
Shell > vim suid.sh
#!/bin/bash
cd /etc && ls

Shell > chmod 4644 suid.sh
```



Warning

Because SUID can temporarily change the Ordinary users to root, you need to be especially careful with files with this permission when maintaining the server. You can find files with SUID permissions by using the following command:

```
Shell > find / -perm -4000 -a -type f -exec ls -l  {} \;
```

15.3.3 SetGID

The role of "SetGID":

- Only executable binaries can set SGID permissions.
- The executor of the command should have x permission to the program.
- The executor of the command obtains the identity of the owner group of the program file when executing the program.
- The identity change is only valid during execution, and once the binary program is finished, the executor's identity is restored to the original identity.

Take the `locate` command for example:

```
Shell > rpm -ql mlocate
/usr/bin/locate
...
/var/lib/mlocate/mlocate.db

Shell > ls -l /var/lib/mlocate/mlocate.db
-rw-r----- 1 root slocate 4151779 1   14 11:43 /var/lib/mlocate/mlocate.db

Shell > ll /usr/bin/locate
-rwx--s--x. 1 root slocate 42248 4   12 2021 /usr/bin/locate
```

The `locate` command uses the **mlocate.db** database file to quickly search for files.

Because the `locate` command has SGID permission, when the executor (ordinary users) executes the `locate` command, the owner group is switched to **slocate**. `slocate` has r permission for the **/var/lib/mlocate/mlocate.db** file.

The SGID is indicated by the number **2**, so the `locate` command has a permission of 2711.

```
# Set SGID permissions
Shell > chmod 2711 FILE_NAME
# or
Shell > chmod g+s FILE_NAME

# Remove SGID permission
Shell > chmod 711 FILE_NAME
```

```
# or
Shell > chmod g-s FILE_NAME
```

Warning

When the owner group of an executable binary file/program does not have **x**, use uppercase **S** to indicate that the file's SGID permissions cannot be used correctly.

```
# Suppose this is an executable binary file
Shell > touch sgid

Shell > chmod 2741 sgid
Shell > ls -l sgid
-rwxr-S--x  1 root root         0 Jan  14 12:11 sgid
```

SGID can be used not only for executable binary file/program, but also for directories, but it is rarely used.

- Ordinary users must have rwx permissions on the directory.
- For files created by ordinary users in this directory, the default owner group is the owner group of the directory.

For example:

```
Shell > mkdir /SGID_dir
Shell > chmod 2777 /SGID_dir
Shell > ls -ld /SGID_dir
drwxrwsrwx  2 root root      4096 Jan 14 12:17 SGID_dir

Shell > su - tom
Shell(tom) > cd /SGID_dir && touch tom_file && ls -l
-rw-rw-r-- 1 tom root 0 Jan  14 12:26 tom_file
```

Warning

Because SGID can temporarily change the owner group of ordinary users to root, you need to pay special attention to the files with this permission when maintaining the server. You can find files with SGID permissions through the following command:

```
Shell > find / -perm -2000 -a -type f -exec ls -l  {} \;
```

15.3.4 Sticky BIT

The role of "Sticky BIT":

- Only valid for directory.
- Ordinary users have w and x permissions on this directory.
- If there is no Sticky Bit, ordinary users with w permission can delete all files in this directory (including files created by other users). Once the directory is given SBIT permission, only root user can delete all files. Even if ordinary users have w permission, they can only delete files created by themselves (files created by other users cannot be deleted).

SBIT is represented by the number **1**.

Can the file or directory have **7755** permission? No, they are aimed at different objects. SUID is for executable binary files; SGID is used for executable binaries and directories; SBIT is only for directories. That is, you need to set these special permissions according to different objects.

The directory **/tmp** has SBIT permission. The following is an example:

```
# The permissions of the /tmp directory are 1777
Shell > ls -ld /tmp
drwxrwxrwt. 8 root root 4096 Jan  14 12:50 /tmp

Shell > su - tom
Shell > cd /tmp && touch tom_file1
Shell > exit

Shell > su - jack
Shell(jack) > cd /tmp && rm -rf tom_file1
rm: cannot remove 'tom_file1': Operation not permitted
Shell(jack) > exit

# The file has been deleted
Shell > su - tom
Shell(tom) > rm -rf /tmp/tom_file1
```

Info

root (uid=0) users are not restricted by the permissions of SUID, SGID, and SBIT.

15.3.5 chattr

The function of chattr permission: it is used to protect important files or directories in the system from being deleted by misoperation.

Usage of the `chattr` command -- `chattr [ -RVf ] [ -v version ] [ -p project ] [ mode ] files...`

The format of a symbolic mode is +-=[aAcCdDeFijPsStTu].

- "+" means to increase permissions;
- "-" means to reduce permissions;
- "=" means equal to a permission.

The most commonly used permissions (also called attribute) are **a** and **i**.

Description of attribute i

	Delete	Free modification	Append file content	View	Create file
file	×	×	×	√	-
directory	x (Directory and files under the directory)	√ (Files in the directory)	√ (Files in the directory)	√ (Files in the directory)	x

Examples for files:

```
Shell > touch /tmp/filei
Shell > vim /tmp/filei
123

Shell > chattr +i /tmp/filei
Shell > lsattr -a /tmp/filei
----i---------e----- /tmp/filei

Shell > rm -rf /tmp/filei
rm: cannot remove '/tmp/filei': Operation not permitted

# Cannot be modified freely
Shell > vim /tmp/file1

Shell > echo "adcd" >> /tmp/filei
```

```
-bash: /tmp/filei: Operation not permitted

Shell > cat /tmp/filei
123
```

Examples for directories:

```
Shell > mkdir /tmp/diri
Shell > cd /tmp/diri && echo "qwer" > f1

Shell > chattr +i /tmp/diri
Shell > lsattr -ad /tmp/diri
----i---------e----- /tmp/diri

Shell > rm -rf /tmp/diri
rm: cannot remove '/tmp/diri/f1': Operation not permitted

# Allow modification
Shell > vim /tmp/diri/f1
qwer-tom

Shell > echo "jim" >> /tmp/diri/f1
Shell > cat /tmp/diri/f1
qwer-tom
jim

Shell > touch /tmp/diri/file2
touch: settng time of '/tmp/diri/file2': No such file or directory
```

Remove the i attribute from the above example:

```
Shell > chattr -i /tmp/filei /tmp/diri
```

Description of attribute a

	Delete	Free modification	Append file content	View	Create file
file	×	×	√	√	-
directory	x (Directory and files under the directory)	x (Files in the directory)	√ (Files in the directory)	√ (Files in the directory)	√

Examples for files:

```
Shell > touch /etc/tmpfile1
Shell > echo "zxcv" > /etc/tmpfile1

Shell > chattr +a /etc/tmpfile1
Shell > lsattr -a /etc/tmpfile1
-----a--------e----- /etc/tmpfile1

Shell > rm -rf /etc/tmpfile1
rm: cannot remove '/etc/tmpfile1': Operation not permitted

# Cannot be modified freely
Shell > vim /etc/tmpfile1

Shell > echo "new line" >> /etc/tmpfile1
Shell > cat /etc/tmpfile1
zxcv
new line
```

Examples for directories:

```
Shell > mkdir /etc/dira
Shell > cd /etc/dira && echo "asdf" > afile

Shell > chattr +a /etc/dira
Shell > lsattr -ad /etc/dira
-----a--------e----- /etc/dira/

Shell > rm -rf /etc/dira
rm: cannot remove '/etc/dira/afile': Operation not permitted

# Free modification is not allowed
Shell > vim /etc/dira/afile
asdf

Shell > echo "new line" >> /etc/dira/afile
Shell > cat /etc/dira/afile
asdf
new line

# Allow creation of new files
Shell > touch /etc/dira/newfile
```

Remove the a attribute from the above example:

```
Shell > chattr -a /etc/tmpfile1 /etc/dira/
```

Question

What happens when I set the ai attribute on a file? You cannot do anything with the file other than to view it.

What about the directory? Allowed are: free modification, appending file contents, and viewing. Disallowed: delete and create files.

15.3.6 sudo

The role of "sudo":

- Through the root user, assign the commands that can only be executed by the root user (uid=0) to ordinary users for execution.
- The operation object of "sudo" is the system command.

We know that only the administrator root has permission to use the commands under **/sbin/** and **/usr/sbin/** in the GNU/Linux directory. Generally speaking, a company has a team to maintain a set of servers. This set of servers can refer to a single computer room in one geographic location, or it can refer to a computer room in multiple geographical locations. The team leader uses the permissions of the root user, and other team members may only have the permissions of the ordinary user. As the person in charge has a lot of work, there is no time to maintain the daily work of the server, most of the work needs to be maintained by ordinary users. However, ordinary users have many restrictions on the use of commands, and at this point, you need to use sudo permissions.

To grant permissions to ordinary users, **you must use the root user (uid=0)**.

You can empower ordinary users by using the `visudo` command, what you're actually changing is the **/etc/sudoers** file.

```
Shell > visudo
...
88 Defaults    secure_path = /sbin:/bin:/usr/sbin:/usr/bin
89
90 ## Next comes the main part: which users can run what software on
91 ## which machines (the sudoers file can be shared between multiple
92 ## systems).
93 ## Syntax:
94 ##
```

```
95 ##      user    MACHINE=COMMANDS
96 ##
97 ## The COMMANDS section may have other options added to it.
98 ##
99 ## Allow root to run any commands anywhere
100 root    ALL=(ALL)       ALL
     ↓       ↓    ↓          ↓
     1       2    3          4
...
```

Part	Description
1	User name or owner group name. Refers to which user/group is granted permissions. If it is an owner group, you need to write "%", such as **%root**.
2	Which machines are allowed to execute commands. It can be a single IP address, a network segment, or ALL.
3	Indicates which identities can be transformed into.
4	The authorized command, which needs to be represented by an absolute path.

For example:

```
Shell > visudo
...
101 tom  ALL=/sbin/shutdown  -r now
...

# You can use the "-c" option to check for errors in /etc/sudoers writing.
Shell > visudo -c

Shell > su - tom
# View the available sudo commands.
Shell(tom) > sudo -l

# To use the available sudo command, ordinary users need to add sudo before the
command.
Shell(tom) > sudo /sbin/shutdown -r now
```

If your authorization command is `/sbin/shutdown`, it means that authorized users can use any of the options of the command.

Warning

Because sudo is a "ultra vires" operation, you need to be careful when dealing with **/etc/sudoers** files!