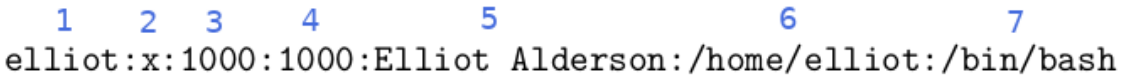
Controlling the Population

Linux is a multiuser operating system, which means that many users are allowed to access the system at the same time. In real life, you barely find a Linux server with just one user. On the contrary, you see a lot of users on one server. So let's get real and populate our system with various users and groups. In this chapter, you will learn how to add users and groups to your Linux system. You will also learn how to manage user and group accounts in all sorts of ways. Furthermore, you will also learn how to manage Linux file permissions.

The /etc/passwd file

In Linux, user information is stored in the [/etc/passwd] file. Every line in [/etc/passwd] corresponds to exactly one user. When you first open [/etc/passwd], you will see a lot of users, and you will wonder, *where are all these users coming from?* The answer is simple: most of these users are service users, and they are used by your system to start up various applications and services. However, our main focus of this chapter will be system users; those are real people like you and me!

Every line in [/etc/passwd] consists of 7 fields, each separated by a colon, and each field represents a user attribute. For example, the entry for user [elliot] will look something like this:



The following table breaks down those seven fields in [/etc/passwd] and explains each one of them:

Field	What does it store?
1	This field stores the username.
2	This field usually has an `X` in it, which means the user's password is encrypted and stored in the file `/etc/shadow`.
3	This field stores the **UID** (**User ID**) number.
4	This field stores the primary **GID** (**Group ID**) of the user.
5	This field stores a comment on the user, which is usually the user's first and last name.
6	This field stores the path of the user's home directory.
7	This field stores the user's default shell.

Adding users

Before you can add a user on your system, you have to become [root]:

```
elliot@ubuntu-linux:~$ su -
Password:
root@ubuntu-linux:~#
```

Now, we are ready to add users. We all love Tom & Jerry, so let's begin by adding user [tom]. To do that, you need to run the command [useradd -m tom]:

```
root@ubuntu-linux:~# useradd -m tom
```

And just like that, the user [tom] is now added to our system. You will also see a new line added to the end of the [/etc/passwd] file for the new user [tom]; let's view it with the lovely [tail] command:

```
root@ubuntu-linux:~# tail -n 1 /etc/passwd
tom:x:1007:1007::/home/tom:/bin/sh
```

We used the [-m] option with the [useradd] command to ensure that a new home directory will be created for user [tom]. So let's try to change to the [/home/tom] directory to make sure it's indeed created:

```
root@ubuntu-linux:~# cd /home/tom
root@ubuntu-linux:/home/tom# pwd
/home/tom
```

Awesome! We verified that [/home/tom] is created.

The first thing you may want to do after creating a new user is to set the user's password. You can set [tom]'s password by running the command [passwd tom]:

```
root@ubuntu-linux:~# passwd tom
Enter new UNIX password:
Retype new UNIX password:
passwd: password updated successfully
```

Now, let's create user [jerry]. But this time, we will choose the following attributes for user [jerry]:

UID [777] Comment [Jerry the Mouse] Shell [/bin/bash]

This is easy to do with the [useradd] command:

```
root@ubuntu-linux:~# useradd -m -u 777 -c "Jerry the Mouse" -s /bin/bash jerry
```

The [-u] option is used to set the UID for [jerry]. We also used the [-c] option to add a comment for user [jerry], and finally we used the [-s] option to set the default shell for [jerry].

Now, let's view the last two lines of the [/etc/passwd] file to make some comparisons:

```
root@ubuntu-linux:~# tail -n 2 /etc/passwd
tom:x:1007:1007::/home/tom:/bin/sh
jerry:x:777:1008:Jerry the Mouse:/home/jerry:/bin/bash
```

Notice how the comment field for user [tom] is empty as we didn't add any comments while creating user [tom], and notice how the UID for user [tom] was chosen by the system, but we have chosen [777] for user [jerry]. Also, notice that the default shell for user [tom] is chosen by the system to be [/bin/sh], which is an older version of [/bin/bash]. However, we chose the newer shell [/bin/bash] for user [jerry].

Now, let's set the password for user [jerry]:

```
root@ubuntu-linux:~# passwd jerry
Enter new UNIX password:
Retype new UNIX password:
passwd: password updated successfully
```

Amazing! We have now created two users: [tom] and [jerry]. Now, let's switch to user [tom]:

```
root@ubuntu-linux:~# su - tom
$ whoami tom
$ pwd
/home/tom
$
```

We were able to switch to user [tom], but as you can see, the shell looks so much different as the command prompt doesn't display the username or the hostname. That's because the default shell for user [tom] is [/bin/sh]. You can use the [echo $SHELL] command to display the user's default shell:

```
$ echo $SHELL
/bin/sh
```

As you can see, it displayed [/bin/sh]. Now, let's exit and switch to user [jerry]:

```
$ exit
root@ubuntu-linux:~# su - jerry
jerry@ubuntu-linux:~$ whoami
jerry
jerry@ubuntu-linux:~$ echo $SHELL
/bin/bash
```

Everything looks better with user [jerry] as we did set his default shell to be [/bin/bash]. Alright, now let's switch back to the [root] user:

```
jerry@ubuntu-linux:~$ exit
logout
root@ubuntu-linux:~#
```

Modifying user attributes

So we are not happy that the default shell for user [tom] is [/bin/sh], and we want to change it to [/bin/bash]. We can use the [usermod] command to modify user attributes.

For example, to change the default shell for user [tom] to be [/bin/bash], you can run the command [usermod -s /bin/bash tom]:

```
root@ubuntu-linux:~# usermod -s /bin/bash tom
```

Notice that you can also use the full name for the command option; so you can use [--shell] instead of [-s]. Anyways, let's see if we successfully changed the default shell for user [tom]:

```
root@ubuntu-linux:~# su - tom
tom@ubuntu-linux:~$ whoami
tom
tom@ubuntu-linux:~$ echo $SHELL
/bin/bash
```

Great! We successfully did it. You can also change the UID of [tom] to [444] by running the command [usermod -u 444 tom]:

```
root@ubuntu-linux:~# usermod -u 444 tom
```

And we can indeed check that the UID of [tom] has changed by taking a peek at the [/etc/passwd] file:

```
root@ubuntu-linux:~# tail -n 2 /etc/passwd
tom:x:444:1007::/home/tom:/bin/bash
jerry:x:777:1008:Jerry the Mouse:/home/jerry:/bin/bash
```

We can even modify the comment field of user [tom]. Right now, it's empty, but you can set the comment field of user [tom] to ["Tom the Cat"] by running the command:

```
root@ubuntu-linux:~# usermod --comment "Tom the Cat" tom
```

And again, we can verify that the comment is changed by looking at the [/etc/passwd] file:

```
root@ubuntu-linux:~# tail -n 2 /etc/passwd
tom:x:444:1007:Tom the Cat:/home/tom:/bin/bash
jerry:x:777:1008:Jerry the Mouse:/home/jerry:/bin/bash
```

Defining the skeleton

If you list the contents of [/home/jerry] and [/home/tom], you will see that they are empty:

```
root@ubuntu-linux:~# ls -l /home/tom
total 0
root@ubuntu-linux:~# ls -l /home/jerry
total 0
```

The reason that both [/home/jerry] and [/home/tom] are empty is that the skeleton file [/etc/skel] is also empty:

```
root@ubuntu-linux:~# ls -l /etc/skel
total 0
```

WHAT IS /etc/skel?

This is the skeleton file. Any file or directory you create in [/etc/skel] will be copied to the home directory of any new user created.

Now, with your favorite text editor, create the file [welcome.txt] in [/etc/skel] and insert the line ["Hello Friend!"] in it:

```
root@ubuntu-linux:/etc/skel# ls
welcome.txt
root@ubuntu-linux:/etc/skel# cat welcome.txt
Hello Friend!
```

Alright, so now you have created the file [welcome.txt] in [/etc/skel], which means that any new user created will now have the file [welcome.txt] in their home directory. To demonstrate, let's create a new user named [edward] and then we will take a peek at his home directory:

```
root@ubuntu-linux:~# useradd -m -c "Edward Snowden" -s /bin/bash edward
```

Now, let's set the password for user [edward]:

```
root@ubuntu-linux:~# passwd edward
Enter new UNIX password:
```

```
Retype new UNIX password:
passwd: password updated successfully
```

Now, the moment of truth comes! Let's switch to user [edward] and list the contents of his home directory:

```
root@ubuntu-linux:~# su - edward
edward@ubuntu-linux:~$ ls
welcome.txt
edward@ubuntu-linux:~$ cat welcome.txt
Hello Friend!
```

You can see that the file [welcome.txt] is copied to [edward]'s home directory. Every new user created on the system will now have a cool greeting message! Notice that old users like [tom] and [jerry] will not have the file [welcome.txt] in their home directory as they were created before we added the file [welcome.txt] in [/etc/skel].

Changing the defaults

We are too tired of specifying the default shell every time we create a new user. But luckily, there is a file where you can specify the default shell for any new user created. This amazing file is [/etc/default/useradd].

Open up the file [/etc/default/useradd] and look for the following line:

```
SHELL=/bin/sh
```

Change it to:

```
SHELL=/bin/bash
```

Awesome! Now, any new user created will have [/bin/bash] as the default shell. Let's test it by creating a new user named [spy]:

```
root@ubuntu-linux:~# useradd -m spy
```

Now, set the password for user [spy]:

```
root@ubuntu-linux:~# passwd spy
Enter new UNIX password:
Retype new UNIX password:
passwd: password updated successfully
```

Finally, let's switch to user [spy] and check the default shell:

```
root@ubuntu-linux:~# su - spy
spy@ubuntu-linux:~$ echo $SHELL
/bin/bash
spy@ubuntu-linux:~$ exit
logout
root@ubuntu-linux:~#
```

Hooray! We can see that [bash] is the default shell for user [spy].

Keep in mind that [/bin/sh] and [/bin/bash] are not the only two valid shells on your system; there are more! Check out the file [/etc/shells] to see a complete list of all the valid shells on your system:

```
root@ubuntu-linux:~# cat /etc/shells
# /etc/shells: valid login shells
/bin/sh
/bin/bash
/bin/rbash
/bin/dash
```

You can change other user defaults in [/etc/default/useradd], including:

- The default [home] directory ([HOME=/home])
- The default [skel] directory ([SKEL=/etc/skel])

I will leave that for you to do as an exercise.

Removing users

Sometimes a user is no longer needed to be on the system, for example, an employee leaving the company or a user that only needed temporary access to a server. In any case, you need to know how to delete users.

The last user we created was [spy], right? Well, we don't need any spies on our system, so let's delete the user [spy]; you can delete user [spy] by running the command [userdel spy]:

```
root@ubuntu-linux:~# userdel spy
```

And just like that, user [spy] is deleted. However, the home directory of [spy] still exists:

```
root@ubuntu-linux:~# ls -ld /home/spy
drwxr-xr-x 2 1008 1010 4096 Apr 17 10:24 /home/spy
```

We would have to manually delete it:

```
root@ubuntu-linux:~# rm -r /home/spy
```

But this is inconvenient. Imagine after every user you delete, you then have to go and manually remove their home directory. Luckily, there is a better solution; you can use the [-r] option to automatically remove the user's home directory.

Let's give it a try with user [edward]:

```
root@ubuntu-linux:~# userdel -r edward
```

Now, let's check to see if the home directory for user [edward] still exists:

```
root@ubuntu-linux:~# ls -ld /home/edward
ls: cannot access '/home/edward': No such file or directory
```

And as you can see, [edward]'s home directory is removed.

The /etc/group file

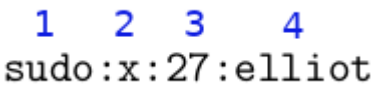
In schools, kids are usually grouped into different groups. For example, kids who like dancing will be part of the dance group. The geeky kids will form the science group. In case you are wondering, I used to be part of the sports group because I was pretty damn fast!

We have the same concept in Linux as users who share similar characteristics are placed in the same group.

WHAT IS A GROUP?

A group is a collection of users who share the same role or purpose.

All groups have their information stored in the file [/etc/group]. And just like with the [/etc/passwd] file, every line in [/etc/group] corresponds to exactly one group, and each line consists of [4] fields. For example, one of the most famous groups in Linux is the [sudo] group:



The following table breaks down those four fields in [/etc/group] and explains each one of them:

Field	What does it store?
1	This field stores the group name.
2	This field usually has an `X` in it, which means the group password is encrypted and stored in the file `/etc/gshadow`.
3	This field stores the **GID (Group ID)** number.
4	This field stores the usernames of the group members.

Adding groups

Let's create a group named [cartoon]. To do that, you need to run the command [groupadd cartoon]:

```
root@ubuntu-linux:~# groupadd cartoon
```

Notice that a new line with the group information will be added to the end of the file [/etc/group]:

```
root@ubuntu-linux:~# tail -n 1 /etc/group
cartoon:x:1009:
```

Notice that the group [cartoon] currently has no members, and that's why the fourth field is currently empty.

Let's create another group named [developers], but this time, we will specify a GID of [888]:

```
root@ubuntu-linux:~# groupadd --gid 888 developers
```

Let's check the [developers] group entry in [/etc/group]:

```
root@ubuntu-linux:~# tail -n 1 /etc/group
developers:x:888:
```

And it looks just like we expect it to be. Cool!

Adding group members

Users [tom] and [jerry] are both cartoon characters, so it makes sense to add them both to the [cartoon] group.

To add [tom] to the [cartoon] group, you simply run the command [usermod -aG cartoon tom]:

```
root@ubuntu-linux:~# usermod -aG cartoon tom
```

Likewise, you can add [jerry] to the [cartoon] group:

```
root@ubuntu-linux:~# usermod -aG cartoon jerry
```

Now, let's have a peek at the [/etc/group] file:

```
root@ubuntu-linux:~# tail -n 2 /etc/group
cartoon:x:1009:tom,jerry
developers:x:888:
```

As you can see, both [tom] and [jerry] are now listed as members of the [cartoon] group.

You can use the [id] command to view the group memberships of any user on the system. For example, if you want to check which groups [tom] belongs to, you can run the command [id tom]:

```
root@ubuntu-linux:~# id tom
uid=444(tom) gid=1007(tom) groups=1007(tom),1009(cartoon)
```

Let's do some more practice by creating three new users -- [sara], [peter], and [rachel]:

```
root@ubuntu-linux:~# useradd -m sara
root@ubuntu-linux:~# useradd -m peter
root@ubuntu-linux:~# useradd -m rachel
```

And remember to set the password for each user:

```
root@ubuntu-linux:~# passwd sara
Enter new UNIX password:
Retype new UNIX password:
passwd: password updated successfully
root@ubuntu-linux:~# passwd peter
Enter new UNIX password:
Retype new UNIX password:
passwd: password updated successfully
root@ubuntu-linux:~# passwd rachel
Enter new UNIX password:
Retype new UNIX password:
passwd: password updated successfully
root@ubuntu-linux:~#
```

Now imagine if all the three new users are software developers; this means that they have the same role, and so they should be members of the same group. So let's add all three users to the [developers] group:

```
root@ubuntu-linux:~# usermod -aG developers sara
root@ubuntu-linux:~# usermod -aG developers peter
root@ubuntu-linux:~# usermod -aG developers rachel
```

Now, let's have a peek at the [/etc/group] file:

```
root@ubuntu-linux:~# tail -n 5 /etc/group
cartoon:x:1009:tom,jerry
developers:x:888:sara,peter,rachel
sara:x:1001:
peter:x:1002:
rachel:x:1003:
```

We can see that the group [developers] now has the three members -- [sara], [peter], and [rachel]. But there is something strange! It seems like when we have created the users [sara], [peter], and [rachel], it also created them as groups! But why did this happen? Well, let me explain it to you in the next section.

Primary versus secondary groups

Every user in Linux must be a member of a primary group. Primary groups are also referred to as login groups. By default, whenever a new user is created, a group is also created with the same name as the user, and this group becomes the primary group of the new user.

On the other hand, a user may or may not be a member of a secondary group. Secondary groups are also sometimes referred to as supplementary groups. You can think of a secondary group as any group that a user is a member of aside from the user's primary group.

Do not worry if you don't understand the concept of primary and secondary groups just yet; it will become crystal clear by the end of this chapter.

Let's create a new user named [dummy]:

```
root@ubuntu-linux:~# useradd -m dummy
```

Now, if you look at the last line of the [/etc/group] file, you will see that a group named [dummy] is also created:

```
root@ubuntu-linux:~# tail -n 1 /etc/group
dummy:x:1004:
```

This [dummy] group is the primary group of user [dummy]; and if you run the [id] command on user [dummy]:

```
root@ubuntu-linux:~# id dummy
uid=1004(dummy) gid=1004(dummy) groups=1004(dummy)
```

You will see that user [dummy] is indeed a member of the [dummy] group. Now, let's add user [dummy] to the [cartoon] group:

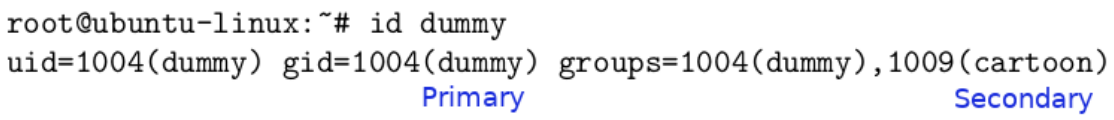
```
root@ubuntu-linux:~# usermod -aG cartoon dummy
```

Let's run the [id] command on user [dummy] again:

```
root@ubuntu-linux:~# id dummy
uid=1004(dummy) gid=1004(dummy) groups=1004(dummy),1009(cartoon)
```

You can see that user [dummy] is a member of two groups: [dummy] and [cartoon]. However, [dummy] is the primary group and [cartoon] is the secondary group.

The primary group is always preceded by [gid=] in the output of the [id] command:



Now let's add user [dummy] to the [developers] group:

```
root@ubuntu-linux:~# usermod -aG developers dummy
```

Next, run the [id] command on user [dummy] again:

```
root@ubuntu-linux:~# id dummy
uid=1004(dummy) gid=1004(dummy) groups=1004(dummy),1009(cartoon),888(developers)
```

As you can see, user [dummy] is a member of two secondary groups: [cartoon] and [developers].

Alright! Enough with all this dummy stuff. Let's remove the user [dummy]:

```
root@ubuntu-linux:~# userdel -r dummy
```

Every user must be a member of only one primary group; however, there are no restrictions on the choice of the primary group!

To demonstrate, let's create a user named [smurf] with [cartoon] being the primary group of user [smurf]. This can easily be done by using the [--gid] option with the [useradd] command:

```
root@ubuntu-linux:~# useradd -m --gid cartoon smurf
```

Now, take a peek at the [/etc/group] file:

```
root@ubuntu-linux:~# tail -n 1 /etc/group
rachel:x:1003:
```

You will see that there is no group created with the name [smurf]. Amazing! That's because we already specified another primary group for user [smurf].

Now let's check user [smurf]'s group memberships:

```
root@ubuntu-linux:~# id smurf
uid=1004(smurf) gid=1009(cartoon) groups=1009(cartoon)
```

As you can see, [smurf] is only a member of the group [cartoon], which is also his primary group, of course.

You can also change the primary group of existing users. For example, you can set the [developers] group to be the primary group of user [smurf] as follows:

```
root@ubuntu-linux:~# usermod -g developers smurf
root@ubuntu-linux:~# id smurf
uid=1004(smurf) gid=888(developers) groups=888(developers)
```

Removing groups

You can remove a group if it is no longer needed. To demonstrate, let's create a group named [temp]:

```
root@ubuntu-linux:~# groupadd temp
```

Now, you can use the [groupdel] command to remove the [temp] group:

```
root@ubuntu-linux:~# groupdel temp
```

Now, let's try removing the group [sara]:

```
root@ubuntu-linux:~# groupdel sara
groupdel: cannot remove the primary group of user 'sara'
```

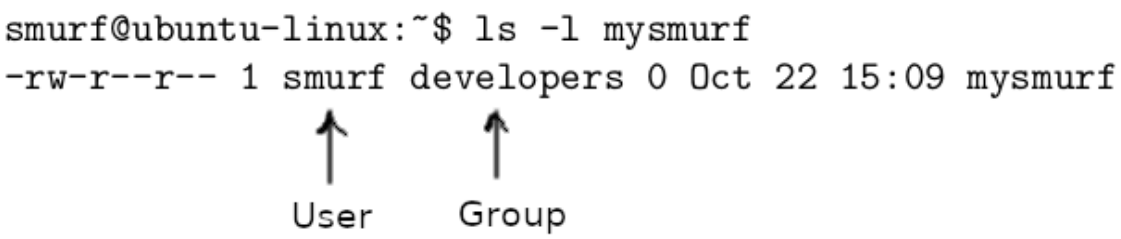
We get an error message as we are not allowed to remove primary groups of existing users.

File ownership and permissions

Every file in Linux is owned by a specific user and a specific group. To demonstrate, let's switch to user [smurf], and create a file named [mysmurf] in [smurf]'s home directory:

```
root@ubuntu-linux:~# su - smurf
smurf@ubuntu-linux:~$ touch mysmurf
```

Now do a long listing on the file [mysmurf]:



You will see the name of the user (the user owner) who owns the file in the third column of the output, which is, by default, the user who created the file.

On the fourth column of the output, you will see the name of the group (the group owner) of the file, which is, by default, the primary group of the user owner.

The [developers] group is the primary group of user [smurf], and hence [developers] became the group owner of the file [mysmurf].

If you do a long listing on the [sports] directory that's inside [elliot]'s home directory:

```
smurf@ubuntu-linux:~$ ls -ld /home/elliot/sports
drwxr-xr-x 2 elliot elliot 4096 Oct 22 12:56 /home/elliot/sports
```

You will see that user [elliot] is the user owner, and the group [elliot] is the group owner; that's because the group [elliot] is the primary group of user [elliot].

Changing file ownership

You can use the [chown] command to change a file's ownership. In general, the syntax of the [chown] command is as follows:

```
chown  user:group file
```

For example, you can change the ownership of the file [mysmurf], so that user [elliot] is the owner, and group [cartoon] is the group owner, as follows:

```
smurf@ubuntu-linux:~$
smurf@ubuntu-linux:~$ chown elliot:cartoon mysmurf
chown: changing ownership of 'mysmurf': Operation not permitted
```

Oh! Only the [root] user can do it; let's switch to the [root] user and try again:

```
smurf@ubuntu-linux:~$ su -
Password:
root@ubuntu-linux:~# cd /home/smurf
root@ubuntu-linux:/home/smurf# chown elliot:cartoon mysmurf
```

Success! Now let's view the ownership of the file [mysmurf]:

```
root@ubuntu-linux:/home/smurf# ls -l mysmurf
-rw-r--r-- 1 elliot cartoon 0 Oct 22 15:09 mysmurf
```

As you can see, we have successfully changed the ownership of [mysmurf]. Also, you can change the user owner without changing the group owner. For example, if you want the user [root] to be the owner of [mysmurf], you can run the following command:

```
root@ubuntu-linux:/home/smurf# chown root mysmurf
root@ubuntu-linux:/home/smurf# ls -l mysmurf
-rw-r--r-- 1 root cartoon 0 Oct 22 15:09 mysmurf
```

As you can see, only the user owner is changed to [root], but [cartoon] remains the group owner.

You can also change the group owner without changing the user owner. For example, if you want the group [developers] to be the group owner of [mysmurf], then you can run:

```
root@ubuntu-linux:/home/smurf# chown :developers mysmurf
root@ubuntu-linux:/home/smurf# ls -l mysmurf
-rw-r--r-- 1 root developers 0 Oct 22 15:09 mysmurf
```

FOR YOUR INFORMATION

[chgrp] can also be used to change the group owner of a file. I will leave that for you to do as an exercise!

Understanding file permissions

In Linux, every file is assigned access permissions for three different entities; these entities are:

- The user owner of the file
- The group owner of the file
- Everyone else (also referred to as others/world)

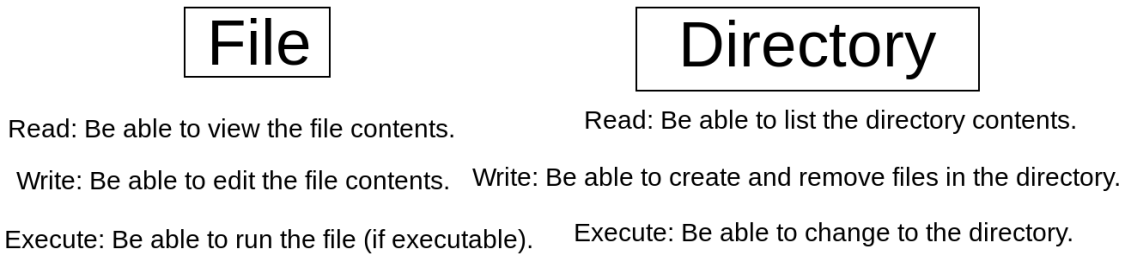
We are already familiar with the user owner and the group owner; everyone else refers to any user on the system who is not the user owner and not the group owner.

You can think of these three entities like you, your friends, and everyone else. There are some things that you don't like to share with anyone, other things you like to share with your friends, and things you may like to share with everyone.

Each file has three types of access permissions:

- Read
- Write
- Execute

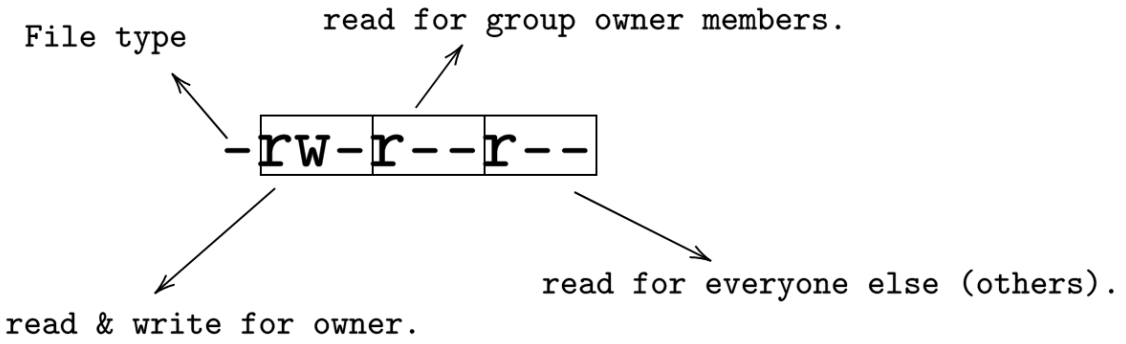
The meaning of each of these access permissions is not the same for files and directories. The following diagram explains the differences between access permissions for files versus directories:



You can view the permissions of a file by doing a long listing. For example, to see the current permissions set on the [mysmurf] file, you can run:

```
root@ubuntu-linux:~# ls -l /home/smurf/mysmurf
-rw-r--r-- 1 root developers 0 Oct 22 15:09 /home/smurf/mysmurf
```

Now pay attention to the first column of the output, which is [-rw-r--r--]. Notice that it consists of ten slots; the first slot determines the type of the file. The remaining nine slots are divided into three sets, each with three slots, just like in the following diagram:



Notice the first slot determines the file type; it can be:

- [-] for regular files
- [d] for directories
- [l] for soft links
- [b] for block devices

- [c] for character devices

The next three slots determine the permissions granted for the owner of the file. The first of these slots determines the read permission; it can either be:

- [r] for read access
- [-] for no read access

The second of these slots determines the write permission; it can either be:

- [w] for write access
- [-] for no write access

The third slot determines the execute permission; it can either be:

- [x] for execute access
- [-] for no execute access

The same logic is applied to the next three slots, which determine the permissions for the group owner, and lastly, the final three slots, which determine the permissions for everyone else.

Now let's get our hands dirty and do some examples to reinforce our understanding of file permissions. Let's first edit the [mysmurf] file and add the following line [Smurfs are blue!] so it looks like this:

```
root@ubuntu-linux:~# cat /home/smurf/mysmurf
Smurfs are blue!
```

Now switch to user [smurf] and try reading the contents of the file [mysmurf]:

```
root@ubuntu-linux:~# su - smurf
smurf@ubuntu-linux:~$ cat mysmurf
Smurfs are blue!
```

Cool! User [smurf] can read the contents of the file [mysmurf]. Keep in mind that user [smurf] is not the owner of the file, but he is a member of the group [developers]:

```
smurf@ubuntu-linux:~$ id smurf
uid=1004(smurf) gid=888(developers) groups=888(developers)
```

So [smurf] can read the file because the group permission of [mysmurf] is [r--]. But can he edit the file? Let's see what will happen if user [smurf] tried to add the line [I am smurf!] to the file [mysmurf]:

```
smurf@ubuntu-linux:~$ echo "I am smurf!" >> mysmurf
bash: mysmurf: Permission denied
```

Permission denied! Yup, that's because there is no write permission for the group owner (or others). Only the user owner has read and write permissions to the file [mysmurf], and the owner happens to be [root] in this case. Now, if we changed the file ownership and made [smurf] the owner of the file [mysmurf], then he will be able to edit the file; so let's change the file ownership first:

```
smurf@ubuntu-linux:~$ su -
Password:
root@ubuntu-linux:~# chown smurf /home/smurf/mysmurf
root@ubuntu-linux:~# ls -l /home/smurf/mysmurf
-rw-r--r-- 1 smurf developers 17 Oct 23 11:06 /home/smurf/mysmurf
```

Now let's switch back to user [smurf] and reattempt to edit the file [mysmurf]:

```
root@ubuntu-linux:~# su - smurf
smurf@ubuntu-linux:~$ echo "I am smurf!" >> mysmurf
smurf@ubuntu-linux:~$ cat mysmurf
Smurfs are blue!
I am smurf!
```

Cool! So user [smurf] has successfully edited the file. Now let's switch to user [elliot] and attempt to add the line [I am not smurf!] to the [mysmurf] file:

```
smurf@ubuntu-linux:~$ su - elliot
Password:
elliot@ubuntu-linux:~$ cd /home/smurf/
elliot@ubuntu-linux:/home/smurf$ echo "I am not smurf!" >> mysmurf
bash: mysmurf: Permission denied
```

Permission denied! Notice that [elliot] is not the user owner and is not even a member of the [developers] group, so he is regarded as everyone else (others). However, he can read the file because others have read permission [r--]:

```
elliot@ubuntu-linux:/home/smurf$ cat mysmurf
Smurfs are blue!
I am smurf!
```

Changing file permissions

Now, what if we want to give [elliot] permission to edit the file [mysmurf] without changing file ownership as we did before? Well! This is very simple; you can use the [chmod] command to change file permissions.

Let's first switch to the [root] user:

```
elliot@ubuntu-linux:/home/smurf$ su -
Password:
root@ubuntu-linux:~# cd /home/smurf
root@ubuntu-linux:/home/smurf#
```

Now you can add the write permission for others (everyone else) by running the command:

```
root@ubuntu-linux:/home/smurf# chmod o+w mysmurf
```

Here [o+w] means **others+write**, which means adding the write permission to others. Now do a long listing on [mysmurf]:

```
root@ubuntu-linux:/home/smurf# ls -l mysmurf
-rw-r--rw- 1 smurf developers 29 Oct 23 11:34 mysmurf
```

As you can see, others can now read and write [rw-] to the [mysmurf] file. Now, switch back to user [elliot] and try to add the line [I am not smurf!] again:

```
root@ubuntu-linux:/home/smurf# su elliot
elliot@ubuntu-linux:/home/smurf$ echo "I am not smurf!" >> mysmurf
elliot@ubuntu-linux:/home/smurf$ cat mysmurf
Smurfs are blue!
```

```
I am smurf!
I am not smurf!
```

Success! User [elliot] can edit the file [mysmurf]. Now it's time to discuss the execute permission; let's go to [elliot]'s home directory, and create a file named [mydate.sh]:

```
elliot@ubuntu-linux:/home/smurf$ cd /home/elliot
elliot@ubuntu-linux:~$ touch mydate.sh
```

Now add the following two lines to the file [mydate.sh]:

```
#!/bin/bash
date
```

You can add both lines by running the following two [echo] commands:

```
elliot@ubuntu-linux:~$ echo '#!/bin/bash' >> mydate.sh
elliot@ubuntu-linux:~$ echo date >> mydate.sh
```

Do not worry about the meaning of the line ['#/bin/bash'] now; I will explain it in a later chapter. Anyways, let's view the content of the file [mydate.sh]:

```
elliot@ubuntu-linux:~$ cat mydate.sh
#!/bin/bash
date
```

Now do a long listing on the file [mydate.sh]:

```
elliot@ubuntu-linux:~$ ls -l mydate.sh
-rw-rw-r-- 1 elliot elliot 17 Oct 23 12:28 mydate.sh
```

Notice the absence of the execute permission here for everyone (the user owner, group owner, and others). Let's add the execute permission to everyone; you can do that by running the following command:

```
elliot@ubuntu-linux:~$ chmod a+x mydate.sh
elliot@ubuntu-linux:~$ ls -l mydate.sh
-rwxrwxr-x 1 elliot elliot 17 Oct 23 12:28 mydate.sh
```

Here [a+x] means **all+execute**, which means add the execute permission to everyone. Also, notice that we were able to run the [chmod] command as user [elliot] only because he is the owner of the file [mydate.sh].

Finally, just enter the full path of [mydate.sh] and hit *Enter*:

```
elliot@ubuntu-linux:~$ /home/elliot/mydate.sh
Wed Oct 23 12:38:51 CST 2019
```

Wow! The current date is displayed! You have created your first Bash script and have run it! Bash scripting will be covered in detail in a later chapter. But now at least you know what it means for a file to be executable. Now remove the execute permission by running the command:

```
elliot@ubuntu-linux:~$ chmod a-x mydate.sh
elliot@ubuntu-linux:~$ ls -l mydate.sh
-rw-rw-r-- 1 elliot elliot 17 Oct 23 12:28 mydate.sh
```

Here [a-x] means **all-execute**, which means remove the execute permission from everyone. Now try to run the script again:

```
elliot@ubuntu-linux:~$ /home/elliot/mydate.sh
bash: /home/elliot/mydate.sh: Permission denied
```

We get a permission denied error! This is because the file [mydate.sh] is no longer executable. Most Linux commands are executable files. For example, take a look at the [date] command. First, we run the [which] command to get the location of the [date] command:

```
elliot@ubuntu-linux:~$ which date
/bin/date
```

Now do a long listing on [/bin/date]:

```
elliot@ubuntu-linux:~$ ls -l /bin/date
-rwxr-xr-x 1 root root 100568 Jan 18 2018 /bin/date
```

As you can see, it has execute permissions for everyone. Now watch what happens when you remove the execute permission:

```
elliot@ubuntu-linux:~$ su -
Password:
root@ubuntu-linux:~# chmod a-x /bin/date
```

Now try running the [date] command:

```
root@ubuntu-linux:~# date
-su: /bin/date: Permission denied
```

The [date] command is no longer working! Please let's fix that by adding the execute permission back:

```
root@ubuntu-linux:~# chmod a+x /bin/date
root@ubuntu-linux:~# date
Wed Oct 23 12:56:15 CST 2019
```

Now let's remove the user owner read permission on the file [mysmurf]:

```
root@ubuntu-linux:~# cd /home/smurf/
root@ubuntu-linux:/home/smurf# chmod u-r mysmurf
root@ubuntu-linux:/home/smurf# ls -l mysmurf
--w-r--rw- 1 smurf developers 45 Oct 23 12:02 mysmurf
```

Here [u-r] means **user-read**, which means remove the read permission from the user owner. Now let's switch to user [smurf] and try to read the file [mysmurf]:

```
root@ubuntu-linux:/home/smurf# su - smurf
smurf@ubuntu-linux:~$ cat mysmurf
cat: mysmurf: Permission denied
```

Poor [smurf]. He can't even read his own file. But since he is the file owner; he can get the read permission back:

```
smurf@ubuntu-linux:~$ chmod u+r mysmurf
smurf@ubuntu-linux:~$ cat mysmurf Smurfs are blue!
```

```
I am smurf!
I am not smurf!
```

You have seen how to add ([+]) and remove ([-]) permissions with the [chmod] command. You can also use the equal sign [=] to set permissions. For example, if you want the group owner ([developers]) of the file [mysmurf] to only have write permission, you can run the command:

```
smurf@ubuntu-linux:~$ chmod g=w mysmurf
smurf@ubuntu-linux:~$ ls -l mysmurf
-rw--w-rw- 1 smurf developers 45 Oct 23 12:02 mysmurf
```

So now, the [developers] group members only has write permission [-w-] to the file [mysmurf]. Here are more examples:

- [chmod ug=rwx mysmurf]: This will give the user owner and group owner full permissions.
- [chmod o-rw mysmurf]: This will remove read and write permissions from others.
- [chmod a= mysmurf]: This will give zero (no) permissions to everyone.
- [chmod go= mysmurf]: This will give zero permissions to the group owner and others.
- [chmod u+rx mysmurf]: This will add read and execute permissions to the user owner.

Let's give zero permissions to everyone:

```
smurf@ubuntu-linux:~$ chmod a= mysmurf
smurf@ubuntu-linux:~$ ls -l mysmurf
---------- 1 smurf developers 45 Oct 23 12:02 mysmurf
```

So now user [smurf] can't read, write, or execute the file:

```
smurf@ubuntu-linux:~$ cat mysmurf
cat: mysmurf: Permission denied
smurf@ubuntu-linux:~$ echo "Hello" >> mysmurf
-su: mysmurf: Permission denied
```

How about the [root] user? Well let's switch to [root] to find out:

```
smurf@ubuntu-linux:~$ su -
Password:
root@ubuntu-linux:~# cd /home/smurf/
root@ubuntu-linux:/home/smurf# cat mysmurf
Smurfs are blue!
I am smurf!
I am not smurf!
root@ubuntu-linux:/home/smurf# echo "I got super powers" >> mysmurf
root@ubuntu-linux:/home/smurf# cat mysmurf
Smurfs are blue!
I am smurf!
I am not smurf!
I got super powers
root@ubuntu-linux:/home/smurf# ls -l mysmurf
---------- 1 smurf developers 64 Oct 23 13:38 mysmurf
```

As you can see, the [root] user can do anything! That's because [root] can bypass file permissions! In other words, file permissions don't apply to the [root] user.

Directory permissions

Now let's see how read, write, and execute permissions work on a directory. The easiest example will be the [root]'s home directory [/root]. Let's do a long listing on [/root]:

```
root@ubuntu-linux:~# ls -ld /root
drwx------ 5 root root 4096 Oct 22 14:28 /root
```

As you can see, full permissions are given to the owner [root] and zero permissions for everyone else. Let's create a file inside [/root] named [gold]:

```
root@ubuntu-linux:~# touch /root/gold
```

Now let's switch to user [smurf] and try to list the contents of the [/root] directory:

```
root@ubuntu-linux:~# su - smurf
smurf@ubuntu-linux:~$ ls /root
ls: cannot open directory '/root': Permission denied
```

User [smurf] gets a permission denied error as he's got no read permissions on the directory [/root]. Now, can [smurf] create a file inside [/root]?

```
smurf@ubuntu-linux:~$ touch /root/silver
touch: cannot touch '/root/silver': Permission denied
```

He cannot since he has no write permissions on [/root]. Can he delete a file inside [/root]?

```
smurf@ubuntu-linux:~$ rm /root/gold
rm: cannot remove '/root/gold': Permission denied
```

Again, no write permissions, so he can't delete a file in [/root]. Finally, can user [smurf] change to the [/root] directory?

```
smurf@ubuntu-linux:~$ cd /root
-su: cd: /root: Permission denied
```

He cannot because [smurf] needs the execute permission to be able to change to the [/root] directory. Now, let's switch back to the [root] user and start adding some permissions:

```
smurf@ubuntu-linux:~$ exit
logout
root@ubuntu-linux:~# chmod o+rx /root
```

Here, we added the read and execute permissions to others, so user [smurf] can now list the contents of the [/root] directory:

```
root@ubuntu-linux:~# su - smurf
smurf@ubuntu-linux:~$ ls /root
gold
```

He can even change to the [/root] directory as we have added the execute permission as well:

```
smurf@ubuntu-linux:~$ cd /root
smurf@ubuntu-linux:/root$
```

But he still has no write permissions, so he can't create or delete files in [/root]:

```
smurf@ubuntu-linux:/root$ rm gold
rm: remove write-protected regular empty file 'gold'? y
rm: cannot remove 'gold': Permission denied
smurf@ubuntu-linux:/root$ touch silver
touch: cannot touch 'silver': Permission denied
```

Let's add the write permission to others:

```
smurf@ubuntu-linux:/root$ su -
Password:
root@ubuntu-linux:~# chmod o+w /root
```

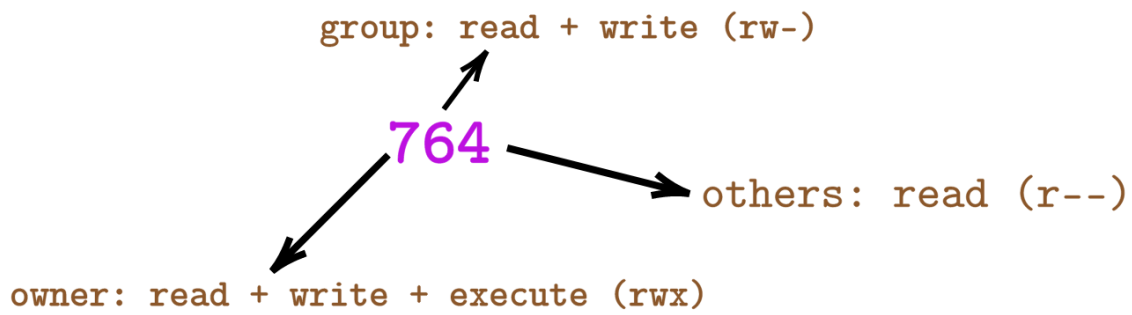
Finally, switch to user [smurf] and try to create or remove a file in [/root]:

```
smurf@ubuntu-linux:~$ cd /root
smurf@ubuntu-linux:/root$ rm gold
rm: remove write-protected regular empty file 'gold'? y
smurf@ubuntu-linux:/root$ touch silver
smurf@ubuntu-linux:/root$ ls
silver
```

So [smurf] can now create and delete files in [/root] as he has the write permission.

Using octal notation

Instead of the letters [r], [w], and [x], you can use the numbers [4], [2], and [1] to set file permissions. Take a look at the following image:



Notice that the first number, [7], is basically the addition of the three numbers: [4 (r) + 2 (w) + 1 (x)], which sets full permissions to the file owner. The second number, [6], is the addition of the two numbers: [4 (r) + 2(w)], which sets the read and write permissions to the group owner. Finally, the third number, [4], which sets the read permission to others.

I know what you are thinking: "Why would I want to do math when I can just use the literal notation [rwx]?" And trust me, I feel you. A lot of people prefer the literal notation over the numeric notation, but some people just love numbers way too much!

Let's do some practice with the octal notation. There are currently zero permissions on the file [mysmurf]:

```
smurf@ubuntu-linux:~$ ls -l mysmurf
---------- 1 smurf developers 64 Oct 23 13:38 mysmurf
```

We can use [777] to give full permissions to everyone:

```
smurf@ubuntu-linux:~$ chmod 777 mysmurf
smurf@ubuntu-linux:~$ ls -l mysmurf
-rwxrwxrwx 1 smurf developers 64 Oct 23 13:38 mysmurf
```

Cool! Now you can use the triplet [421] to give read permission for the owner, write permission for the group owner, and execute permission for others:

```
smurf@ubuntu-linux:~$ chmod 421 mysmurf
smurf@ubuntu-linux:~$ ls -l mysmurf
-r---w---x 1 smurf developers 64 Oct 23 13:38 mysmurf
```

Let's do one more example. What if you want to give full permissions to the owner, read permission for the group owner, and zero permissions for others? That's easy; the correct triplet will be [740]:

```
smurf@ubuntu-linux:~$ chmod 740 mysmurf
smurf@ubuntu-linux:~$ ls -l mysmurf
-rwxr----- 1 smurf developers 64 Oct 23 13:38 mysmurf
```

Numbers are easy to work with once you get the hang of it. Just remember that:

- [4]: Read
- [2]: Write
- [1]: Execute
- [0]: Zero permissions

The following table summarizes all the possible permissions combinations:

Number	Meaning	Literal Equivalence
0	Zero/No Permissions	`---`
1	Execute	`--x`
2	Write	`-w-`
3	Write + Execute	`-wx`
4	Read	`r--`
5	Read + Execute	`r-x`
6	Read + Write	`rw-`
7	Read + Write + Execute	`rwx`

This chapter was a bit lengthy. Go take a break and then come back and attack the knowledge check exercises!

Knowledge check

For the following exercises, open up your Terminal and try to solve the following tasks:

1. Create a new user [abraham] with a user ID of [333].
2. Create a new group [admins].
3. Add user [abraham] to the [admins] group.
4. Make [admins] the group owner of the directory [/home/abraham].
5. Members of the [admins] group can only list the contents of the directory [/home/abraham].

True or false

1. [chmod a=rxw facts.txt] will have the same result as [chmod 777 facts.txt].
2. [chmod a=rw facts.txt] will have the same result as [chmod 665 facts.txt].
3. User [elliot] can have more than one primary group.