SWitCH – Sistemas de Computação e Redes (SCOMRED)

2020/2021

Laboratory 02

DEI private cloud. Ubuntu Server 20.04 LTS in a container (LXC). Managing a Linux server from the command line shell. Network configurations of the Linux server. The Apache web server. The BASH and command line utilities.

1. Using Linux Containers in the DEI private cloud

Virtualization concepts, embracing hardware virtualization (Virtual Machines), operating system virtualization (Containers) and network virtualization (Virtual Switches), are used together to establish what is known as cloud computing.

Cloud computing platforms provide a user friendly way to create and manage virtual servers and virtual networks at a high level without handling on how they are implemented.

Several platforms are publicly available, among others: Amazon Web Services (AWS), Google Cloud Platform, Microsoft Azure, IBM Bluemix, and Alibaba Cloud.

Among others, at least three types of services may be provided:

- IaaS (Infrastructure as a Service)
- PaaS (Platform as a Service)
- SaaS (Software as a Service)

The costumer skills required for each service are rather different, for IaaS, usually it's up to costumer installing and managing the operating system. For PaaS, the operating system is already installed and is only partially managed by the costumer, the costumer will be however responsible for installing and managing applications. For SaaS, the costumer is provided with an already installed application and is limited to manage that application.

At DEI, an experimental cloud computing platform it available, the front end web page is:

https://vs-ctl.dei.isep.ipp.pt/

Warning: this service is available within DEI networks only, if you are somewhere on the internet or connected to a wireless network in ISEP, first you need to establish a VPN connection with DEI.

PRACTICE:

a) Use your DEI credentials to login, on the start page you have some documentation to read later.

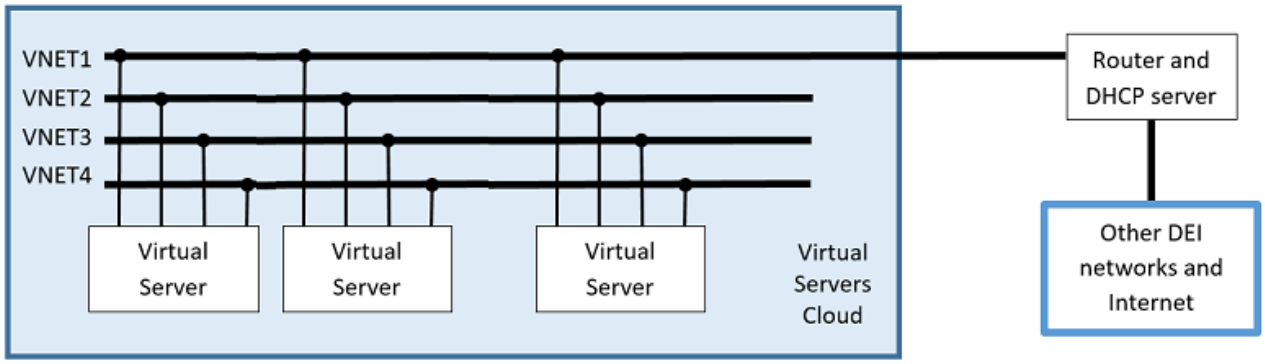
b) Create your own virtual server:

Go to **Available Virtual Server Templates (VST)**, find template number **31**, the template is named **LAMP on Ubuntu 20.04 LTS - All VNETs** it's an LXC **container**. The type of service provided is Platform as a Service (PaaS).

Click **Create a new VS from this template**.

In this experimental platform, virtual servers may be connected to up to four virtual networks (virtual switches), they are named VNET1, VNET2, VNET3, and VNET4. From those, VNET1 is mandatory because it's through it the virtual server will be accessed for administration. Other networks can be freely used.

Of key benefit is every virtual server has a unique static network configuration assigned to it on VNET1, in addition, each virtual server's dedicated IPv4 address is mapped in DNS to the virtual server's name.



The selected template is connected to all four virtual networks, so there will be four network interfaces for the operating system to manage. Network interface **eth0** is connected to **VNET1**, network interface **eth1** is connected to **VNET2**, network interface **eth2** is connected to **VNET3**, and network interface **eth3** is connected to **VNET4**.

c) Start and manage the Virtual Server

Click on the virtual server name to manage it, initially the same as the template name. Now you are on **Virtual Server Details** page for your virtual server, click the **START** button to boot your Virtual Server, once started new options become available.

The **root** user (super user) is allowed to access through SSH, a random password was established and is available on the web page, it can be changed.

The Virtual Server command line (Shell) may be accessed by using a standard SSH client (e.g. Putty), but it can also be accessed through by using a standard web browser, three alternatives are available, two of them can even be used without providing the **root** user password.

Enable the **Terminal in the browser: GoTTY (no login required)**, then click the link.

```
You now have a command line (shell) terminal session on your browser,
let's do some explorations about the networking environment surrounding
your virtual server.


In the previous lab class, we took the wider perspective of the network
infrastructure as a set of interconnected intermediate nodes, it's the
network administrator's point of view. Today we take the end node
administrator's point of view, we trust the network infrastructure
operates appropriately, and we are concerned our end node is configured
properly to use such network infrastructure.
```

Intermediate nodes forward data, for instance, switches and routers are intermediate nodes. **End nodes** are the source and the final destination of the useful data being transferred through the network infrastructure, typical end nodes are servers and workstations.

2. Network configurations in Linux

2.1. The node's IP addresses

Start by listing your virtual server's **network interfaces**, use the following command:

```
ip addr
```

There's a lot of data to understand here:

- There are 5 network interfaces: **lo; eth0; eth1; eth2; eth3**
- The **lo** is the loopback interface, the loopback interface exists on most network nodes, it's used for communications within the node itself, it's not connected to anything else.
- We can see interfaces have both IPv4 and IPv6 addresses assigned to them. Yes, this is a **dual-stack node.**
- IPv6 addresses started by **fe80::** are self-assigned with link-local scope (they allow communications within the same local network only). You may notice the rightmost part of these addresses is derived from the MAC address of the interface.
- Beyond the **lo** interface, the **eth0** interface is the only one with an IPv4 address, and an IPv6 address that is not link-local. All communications and interactions you are taking with your VS are passing through this **eth0** interface.
- The **eth0** interface has one IPv4 address belonging to network **10.9.0.0/16** and an IPv6 address belonging to the network **fd1e:2bae:c6fd:1009::/64**. Again, you may notice the rightmost part of the IPv6 address is derived from the MAC address of the interface.

2.2. Routing

As we already known, the configuration data listed above allows this node to communicate only with directly connected networks (local networks), in this case they are: **10.9.0.0/16** and **fd1e:2bae:c6fd:1009::/64**.

To reach nodes that don't belong to local networks, neighbour routers must be used, the information about such neighbour routers is stored in routing tables.

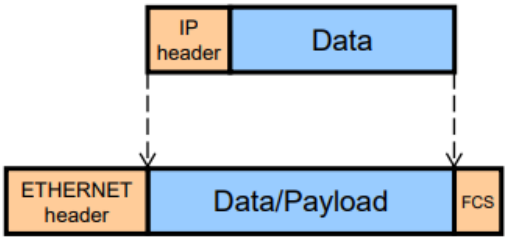
Every IP node has routing tables, for an end node like a server they are usually very simple. Use the following two commands to see the IPv4 and the IPv6 routing tables:

```
ip route

ip -6 route
```

You may surmise the IPv4 default-gateway is **10.9.0.1** and the IPv6 default-gateway is **fd1e:2bae:c6fd:1009::1**. Notice that the routers in the routing tables are always neighbour nodes, meaning they belong to a local network (a directly connected network).

2.3. IP addresses to layer two addresses mapping

Within a local network, IPv4 and IPv6 packets are transported by layer two frames, for such transportation to be possible the layer two destination address has to be properly set in the layer two header so that the packet is delivered where intended.



Two cases may be highlighted:

If the IP packet's destination address belong to the same local network, then the layer two destination address is set to the layer two address of that node, this is because the packet can be directly delivered to the final destination node.

If the IP packet's destination address doesn't belong to the same local network, then the layer two destination address is set to the layer two address of a router that will forward the IP packet.

Either case, given an IP address of a neighbour node that node's layer two address has to be determined, with IPv4 addresses, ARP is used, with IPv6 addresses, ICMPv6 is used. As these mappings between IP addresses and layer two addresses are determined (by using ARP or ICMPv6), they are cached in tables. Use the following command to see such tables:

```
ip neigh
```

Certainly, one node that will be there is the IPv4 default-gateway (10.9.0.1).

Now interact with a new local node:

```
ping -c 2 10.9.20.124
```

Check the neighbour tables again:

```
ip neigh
```

As expected you will see the address targeted by the ping command, this new entry will not persist for ever, if there's no further interaction with that node it will be removed after some time.

2.4. DNS node names resolution

As with any network node connected to the internet, your virtual server uses DNS servers to transform node names into IP addresses, let's check a DNS node name we have used in the previous lab class (**rede**), we can use the **host** command, it's a DNS client:

```
host rede
```

What have we learned from this command's output:

- An unqualified name (**rede**) was used, but because the default domain in this virtual server is **dei.isep.ipp.pt**, it was automatically transformed into the fully qualified domain name (f.q.d.n.) **rede.dei.isep.ipp.pt**.
- The DNS name **rede.dei.isep.ipp.pt** is an alias, not the canonical DNS name of the server node, the canonical (real) name is **vsrv7.dei.isep.ipp.pt**.
- The node **vsrv7.dei.isep.ipp.pt** is dual stack, it has an IPv4 address and an IPv6 address.

Both your virtual server and the **rede.dei.isep.ipp.pt** server are dual-stack, so they can talk with each other either by using IPv4 or IPv6, truly, in this kind of scenario most of the time users don't know whether IPv4 or IPv6 is being used because they refer nodes by DNS names and not IP addresses.

Let's check:

```
ping rede
```

The name **rede**, we already know, stands for the node with DNS name **vsrv7.dei.isep.ipp.pt**, and it's mapped to both an IPv4 and an IPv6 address.

In these cases, **the standard is prioritize IPv6 over IPv4** to allow the IPv6 takeover of the internet.

If you want to test the connectivity through IPv4 you must avoid the DNS resolution of the name and use the IP address:

```
ping 192.168.62.32
```

We can also explicitly ask the ping command to use IPv4 or IPv6, try it:

```
ping -4 rede


ping -6 rede
```

2.5. Network configuration persistency

During the boot of a Linux system, several initialization scripts are run to enforce the intended system configuration, such configuration is stored in configuration files.

Some of the configuration files used in Linux are pretty standard, like for instance the **/etc/fstab** file that has a list of filesystems to be mounted on boot, however other configuration files are very dependent on the Linux distribution, and this is the case for network configurations.

In **Ubuntu 20.04 LTS**, the network configuration is enforced on boot by the **netplan** command, in your virtual server it will use the **/etc/netplan/10-lxc.yaml** configuration file, let's simply check its content, it's a text file, so we can see the content by using the **cat** command:

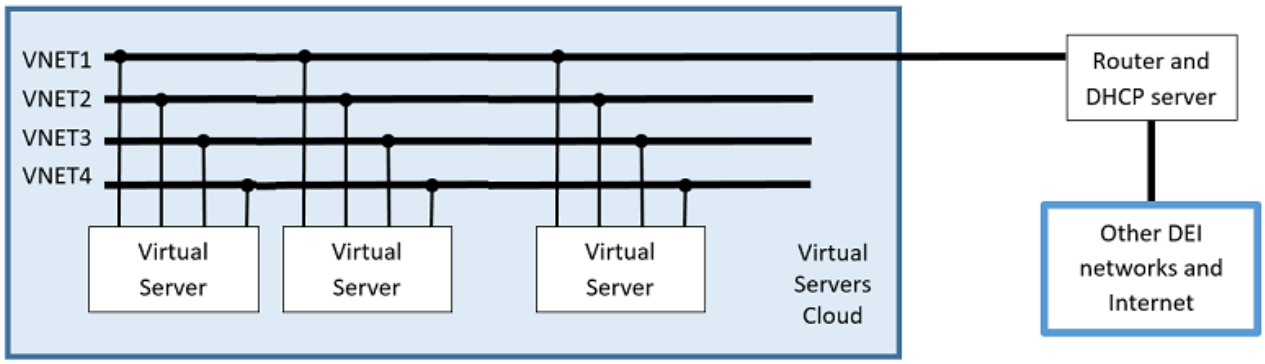
```
cat /etc/netplan/10-lxc.yaml
```

Most configuration data we have seen before is present here and is enforced on every boot by the **netplan** command.

2.6. Setting up a non-persistent network configuration

For the sake of testing, we can change the running network configuration directly from the command line, these changes will not persist if the server is restarted. To enforce persistent changes, configuration files would have to be edited.

The following image describes the immediate network neighbourhood of the virtual servers being used in the class.



Each virtual server is connected to four networks, however, by now only one is being used: **VNET1** to which the **eth0** network interface of your server is connected.

Let's establish two IPv4 networks over **VNET2**, (to which the **eth1** network interface of your server is connected), the networks are going to be **10.200.8.0/24** and **10.200.9.0/24**, some students will use an IPv4 address belonging to one network and others an IPv4 address belonging to the other network.

The teacher will provide a list of IP addresses to be used by each student.

Once you know the IPv4 address you are supposed to use (10.200.X.Y), you may then type the command:

```
ip addr add 10.200.X.Y/24 dev eth1
```

Let's check the configuration has been enforced:

```
ip addr

ip route
```

(Please, wait until your classmates have set the IP configuration)

Use the ping command to send ICMP echo requests to other IP addresses in the provided list.

```
ping …
ping …
…
```

Check that you are able to reach other virtual servers on the same IPv4 network, but not in the other IPv4 network.

(Please, wait until your classmates are done with the testing)

Now we are going to make a small change in the configuration: **reduce one bit to these networks' prefix-length** (**/23** instead of **/24**).

First, let's remove the address we have added:

```
ip addr del 10.200.X.Y/24 dev eth1
```

And now add the same address again, but with a **/23** prefix-length:

```
ip addr add 10.200.X.Y/23 dev eth1
```

(Please, wait until your classmates have set the IP configuration)

Use the ping command to send ICMP echo requests to other IP addresses in the provided list.

```
ping …
ping …
…
```

Now you should be able to reach every virtual server, simply because now there's only one IPv4 network and not two anymore, the new IPv4 network is: **10.200.8.0/23**

The difference between these network prefixes 10.200.8.0 and 10.200.9.0 lays on 23rd bit being zero on the former and one on the later. By setting the prefix-length to 23 bits, that bit no longer belongs to the network prefix, so the network prefix becomes the same.

3. HTTP (Hyper Text Transfer Protocol) and the Apache server

HTTP is the protocol through which contents are transferred between **web servers** (HTTP servers) and **web browsers** (HTTP clients) around the internet. HTTPS (HTTP secure) is HTTP running over a secure connection, so in fact it's not a different protocol.

Your virtual server already has an HTTP servers running (Apache 2), but we will start by using HTTP clients.

3.1. HTTP clients

Your virtual server (a container) is connected to VNET1 in bridge mode, meaning no address translations (NAT) are being enforced within the DEI networks infrastructure.

If that is so, when we access a server, our real address is not masked and will be visible to the server, let's show this by calling our comrade **rede.dei.isep.ipp.pt**.

First, we will install a **standard web browser** that is able to run in a terminal, it's called **lynx**. In this Linux system, we can manage software packages through the APT (Advanced Packaging Tool).

As with other Linux distributions, for Ubuntu there are several servers in the internet, usually referred to as repositories or simply mirrors, they make available updated software packages. APT stores locally a list of the available software packages in each repository. Before installing software packages it's better to be sure the list is updated:

```
apt update
```

Remember this command doesn't update any software, it updates the list of the available packages and where they are available to be fetched.

Use the **apt** command to install **lynx**:

```
apt install lynx
```

Now use **lynx** to access the web page **https://rede.dei.isep.ipp.pt/myip**

Just type:

```
lynx rede/myip
```

Why is **rede/myip** enough?

We already know the name **rede** is going to be resolved by the DNS system into an IP address.

It´s enough because the default DNS domain in your virtual server is **dei.isep.ipp.pt**, and by default lynx adds the **http://** prefix. This web server itself redirects any http request to https, so the browser ends up with **https://rede.dei.isep.ipp.pt/myip**.

We can see your requests, as seen by server **rede.dei.isep.ipp.pt,** seem to be coming from an address that is exactly the IP address your virtual server has. This proves NAT is not being used, also you can see your server is reachable from server **rede.dei.isep.ipp.pt**, your virtual server has replied to the ICMP echo request sent by server **rede.dei.isep.ipp.pt**.

One other useful command to test HTTP servers is **curl**, it's an HTTP client, however, unlike lynx, **curl** is intended mostly for testing and debugging by software developers. Install the curl command in your virtual server:

```
apt install curl
```

Test the same access as before, now with curl:

```
curl rede/myip
```

The curl command also assumes by default the use of HTTP, thus, as before this result in **http://rede.dei.isep.ipp.pt/myip**, however, it doesn't follow the server indication to redirect the requests to HTTPS (this is something standard web browsers are supposed to do).

With curl you must do it yourself:

```
curl https://rede.dei.isep.ipp.pt/myip
```

This is a testing and debugging command, and has many useful features that standard browsers don't have, for instance you can select the use of IPv4 or IPv6:

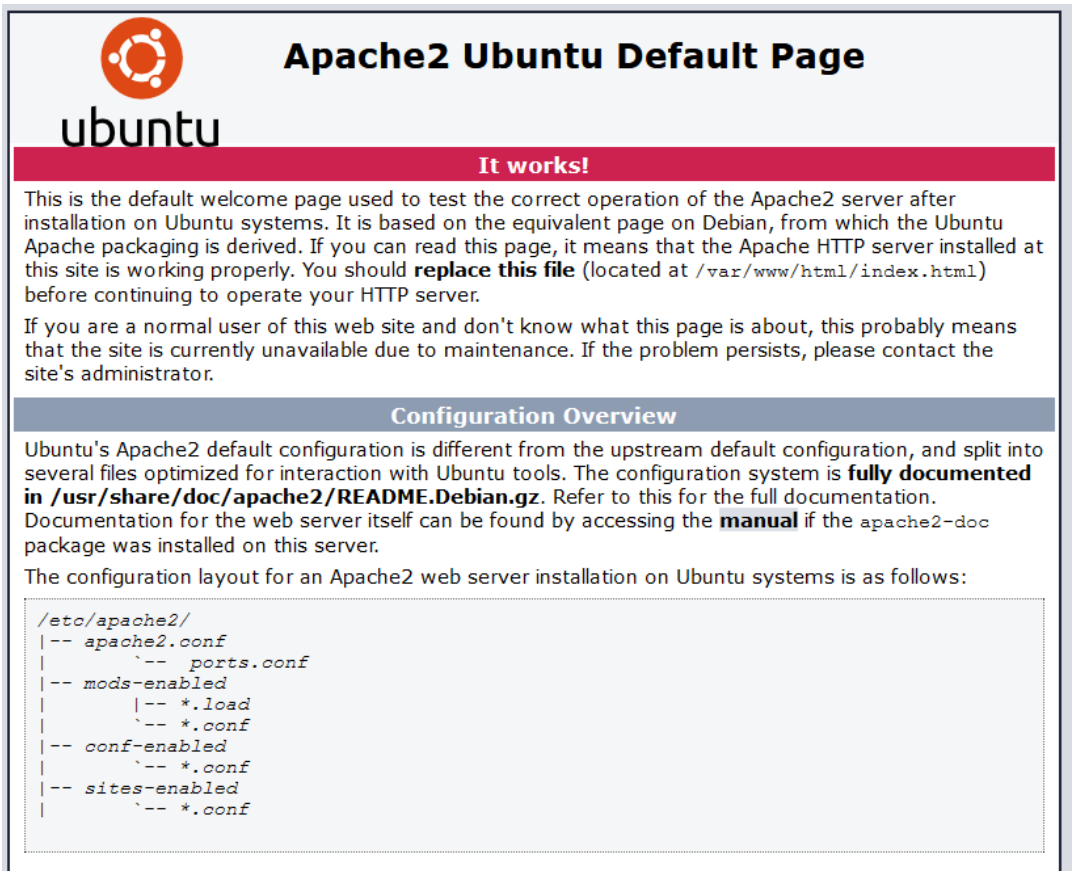
```
curl -4 https://rede.dei.isep.ipp.pt/myip

curl -6 https://rede.dei.isep.ipp.pt/myip
```

3.2. The Apache web server

Your Virtual Server has the Apache web server installed and running, the most basic operation of a web server is providing clients (web browsers) the content of static files.

Those static files are referred by clients following the web server name, if no filename is provided by the client, the server assumes a default filename, usually **index.html**.

Go to your **Virtual Server Details** page and click the link to access your HTTP server, you'll get the Apache Default Web Page, for now this is the default page of your web server.



The web server searches for filenames referred by clients in a base folder, often called the **document root**, in this specific apache configuration the document root is **/var/www/html**. The **index.html** for the Apache Default Web Page should be there.

Let's create our own default web page, and meanwhile get familiar with some important concepts and commands.

Many command line operations encompass objects in the filesystem, which as we know is organized as a tree of directories or folders. In MS-Windows systems there may be several filesystems, each starting at one drive letter (e.g. C:\ E:\).

In UNIX systems (that include Linux) a single file system exists, its starting point is the root, represented by a forward slash (/). To absolutely identify an object in the filesystem we can represent its location path starting from the root of the filesystem, this is called the absolute path, such representation is always started by a forward slash (/), for instance **/var/www/html/index.html**.

One concept that exists in command line environments that operate over a file system is the current working directory (CWD), when a user accesses the system in a command line environment the CWD is set to the user's home directory (a private folder belonging to the user).

You may see the CWD by using the **pwd** command, standing for Print Working Directory. You can change the CWD by using the **cd** command, standing for Change Directory.

Check your CWD:

```
pwd
```

List the contents of the **/var/www/html/** folder without changing the CWD:

```
ls -l /var/www/html/
```

Jump into the apache document root, this means change the CWD to **/var/www/html/**:

```
cd /var/www/html
```

Check your CWD again:

```
pwd
```

List the CWD folder's content:

```
ls -l
```

There it the **index.html** file.

Let's replace it by our own. First rename it:

```
mv index.html oldindex.html
```

Now we must use a text editor to create the new **index.html** file, the default text editor in UNIX systems is **vi**, however, it's not easy for beginners, an alternative is **nano**, if required install it:

```
apt install nano
```

Now, create the new **index.html** file:

```
nano index.html
```

Notice that this Virtual Server includes the **Ultra Basic CGI based File Manager**, and it may as well be used to undertake most of these actions.

Establish the following HTML content for the text file:

```
<html><head>
<title>My Web server default page</title>
</head>
<body bgcolor=green>
<h1>My Web server default page</h1>
<hr>
<p>The original Apache Default Web Page is available <a href=oldindex.html>here</a>
<hr>
</body>
</html>
```

Save the file, in **nano** use [CTRL]+[X], then [Y], then [ENTER].

This file uses HTML tags, the main purpose of HTML tags is establishing presentation formatting, so it's mostly about text fonts and colours. The <a> tag is used to create a clickable live link, in this case pointing to the old HTML page.

Now, go back to the default page of your web server and reload it. Match what you see with the HTML content above, test the link to the old page.

Soon in this course we will be talking about HTML (Hyper Text Mark-up Language) in more detail.

4. The BASH and command line utilities

We have already learned about some important commands and concepts in the BASH command line environment, in the next lecture a more systematic approach to some important concepts will be undertaken but meanwhile let's introduce some more commands and concepts.

4.1. Users and groups of users

In a multiuser system like Linux, different users with different roles are allowed to interact with the system, because different users have different roles, they also have different permissions (things they are allowed to do).

In a UNIX and Linux systems the user which has all the permissions is the **root** user, often referred as the super user or simply the administrator.

The **id** command tells how you are:

```
id
```

Yes, you are the **root** user, the super user.

Each user has a unique number in the system, the UID (User Identifier), the **root** user has always UID zero. Each belongs to a primary group of users, the primary group of the **root** user is group **root**. Despite having the same name, the **root** user and the **root** group are two different things, each group

has a unique number in the system, the GID (Group Identifier), and the GID zero is used by the **root** group.

Groups are very useful to assign a set of permissions to several users at a time. Imagine you want the users of a department to have a specific set of permissions over some parts of the system, this is a very common scenario, and the best solution is creating a group, assigning to the group the required set of permissions and making those users members of the group. Now imagine later you have to change that set of permissions, it's easy, you only have to change it in one place, the group.

Traditionally in Ubuntu systems for each user there's a group with the same name, such group is created along with the user to be the user's primary group.

In this system there's a user named **ubuntu**, check it:

```
id ubuntu
```

This user has the **ubuntu** group as primary group, but it's also a member of the **sudo** group. Being a member of this group turns this user into an administrator because it grants the permission to use the **sudo** command.

The list of users known to the system is stored in the **/etc/passwd** file, it's a text file, each user account is a line with a set of colon separated fields, check its content:

```
cat /etc/passwd
```

The fields are:

- login name
- password hash code
- UID
- GID of the user's primary group
- long name or account description
- user's home directory
- initial program or login shell

Check the lines for user **root** and for user **ubuntu**.

One thing you may have noticed is the **password hash code** is filled with an **x**, for security sake they have been transferred to the shadow file: **/etc/shadow**. Unlike what happens with the **/etc/passwd** file, the **/etc/shadow** file can only be read by the **root** user.

This means you (root) can read it, so let's check its content:

```
cat /etc/shadow
```

You will notice only the **root** user has a password, this means it's the only user that can login into your system, nevertheless, as root you can impersonate any user even without a password. Use the su command to impersonate the ubuntu user:

```
su -l ubuntu
```

The **-l** option forces the execution of the login scripts to mimic a normal login into the system, check who you are now, check that you can read the **/etc/passwd** file, but not the **/etc/shadow** file:

```
id

cat /etc/passwd

cat /etc/shadow
```

Type **exit** to leave the session as **ubuntu** and return to your **root** session:

```
exit
```

Establish a password for user **ubuntu** so it will be able to login normally:

```
passwd ubuntu
```

Check the **/etc/shadow** file content:

```
cat /etc/shadow
```

Run the login command and login as **ubuntu**:

```
login
```

As you see, the **ubuntu** user is now able to login into your system, for instance through SSH.

Type **exit** to leave the session as **ubuntu** and return to your **root** session:

```
exit
```

The list of groups known to the system is stored in the **/etc/group** file, it's a text file, each group account is a line with a set of colon separated fields, check its content:

```
cat /etc/group
```

The fields are:

- group name
- password hash code (currently not used in Linux)
- GID
- comma separated list of users than belong to the group beyond the primary group

Check for instance the **sudo** group.

In Linux, there are several commands available to manage users and groups:

```
useradd; userdel; usermod; groupadd; groupdel; groupmod; adduser; addgroup
```

Create a new user named **scomreduser1**:

```
useradd -m scomreduser1
```

By default a group with the same name as the user is created, it will be the user's primary group.

The **-m** option enforces the creation of the user's home directory, let's check it:

```
ls -l /home
```

Create a new group named **scomredgroup1**:

```
groupadd scomredgroup1
```

Add the **scomreduser1** user to the **scomredgroup1** group, don't change the user's primary group:

```
usermod scomreduser1 -G scomredgroup1
```

Check the created user:

```
id scomreduser1
```

4.2. Getting help about a command

Most Linux commands support the **--help** option to provide information about how they operate and possible command line arguments, try getting help about the **ls** command with this tactic:

```
ls --help
```

Because the output may have more lines than the ones being displayed in your window, it may be useful to pass the result through a pipe to the less command:

```
ls --help|less
```

With the less command, among other options, like search a string, you can navigate up and down, use the lowercase **q** to quit and return to the command line prompt.

One other option to get help about a something is searching in in the manual pages, simply provide what you want to know about as argument of the **man** command. Examples:

```
man ls


man group
```

```
man shadow
```

The **less** command is automatically used, so to leave the manual page use the lowercase **q**.

4.3. The filesystem

We already know in UNIX and Linux there's a single filesystem, the aim of a filesystem is storing objects, for instance files.

One very important type of object is the folder or directory, such object type has the single purpose of containing other objects, which may be themselves folders, thus we end up with a tree of folders. The starting point of this tree is called the **root folder** and represented by the forward slash (/).

When a new filesystem is created it's completely empty, meaning it has no objects, but in fact the root folder is already there.

Objects in the directory tree may be referred by specifying the path starting from the root folder, this is an **absolute path**.

Objects may also be referred by specifying the path starting from the current working directory, this is a **relative path**.

When using a relative path we can specify one level toward the root by using the folder name **../**

Do on your own:

a) List the contents of the **/etc/apache2/** folder using an absolute path (started by /).

b) Print the current working directory.

c) List the contents of the **/etc/apache2/** folder using a relative path (not started by /).

d) Change the current working directory to **/etc**.

e) List the contents of the **/etc/pam.d/** folder using a relative path (not started by /).

f) Change the current working directory to your home directory.

g) Create a sub-folder named **testing123**, use the **mkdir** command.