

## NOSS - Coursework 1



## Table of contents

|                                                                           |    |
|---------------------------------------------------------------------------|----|
| Introduction .....                                                        | 4  |
| <b>I- Research</b>                                                        |    |
| 1- Hypervisor .....                                                       | 5  |
| a- Types of hypervisors .....                                             | 5  |
| b- Architecture of hypervisors .....                                      | 6  |
| c- Hardware requirements .....                                            | 6  |
| d- Advantages of hypervisor .....                                         | 6  |
| e- Scalability, and compatibility of hypervisor .....                     | 7  |
| f- Different types of hypervisor solutions available in the market .....  | 7  |
| 2- IP Addressing                                                          |    |
| a- Meaning and functionality .....                                        | 8  |
| b- The Role of Routers and Switches in Data Transmission .....            | 8  |
| c- Structure, format and representation of IPv4 and IPv6 addressing ..... | 8  |
| d- Concept of Subnetting .....                                            | 9  |
| 3- Routing                                                                |    |
| a- Fundamental concepts of routing protocols .....                        | 10 |
| b- Key differences between static and dynamic routing protocols .....     | 10 |
| c- Deployment in Real-Time network: Benefits and Challenges .....         | 11 |
| 4- Network Services                                                       |    |
| a- Key concepts, features and best practices with:                        |    |
| • VPNs .....                                                              | 11 |
| • DHCP .....                                                              | 11 |
| • Active Directory Domain Services .....                                  | 12 |
| • Certificate Authorities .....                                           | 12 |
| <b>II- Technical documentation</b>                                        |    |
| 1- Choice of the Hypervisor .....                                         | 12 |
| 2- Download and setup .....                                               | 13 |
| 3- Configure IP Addressing .....                                          | 18 |
| 4- Test and Troubleshoot .....                                            | 21 |
| <b>III- Personal and Technical Reflection</b>                             |    |
| 1- Technical Reflection .....                                             | 25 |
| 2- Personal Reflection .....                                              | 25 |
| References .....                                                          | 26 |

## Introduction

Nowadays, networking has become very important especially in our dynamic world of digital communication. In fact, during our project, we will understand key concepts such as IP addresses, subnetting and even the different types of hypervisors.

These concepts will help us understand how network devices communicate with each other. We will also cover new topics that will help us to better understand the project such as various networking components, functionalities and even architectures and the enhancements in Network Operating systems.

Our project will be carried out in two stages. In the first stage, we will do some research, followed by building and deploying a virtualized network. Then, in the second stage, we will configure and manage the virtualized network.

## I- Research

### 1- Hypervisor

#### a- Types of hypervisors

The hypervisor is an essential element of virtualization. In fact, it is a software that is used to run multiple virtual machines on a single physical machine by efficiently distributing hardware resources such as CPU, storage and memory among different virtual machines.

There are two types of hypervisors:

- Type 1 acts like a small, efficient and uses minimal resources operating system. It is designed for high availability and scalability.
- Type 2 runs on any hardware supported by the host OS. (1)

| Type 1 hypervisor                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Type 2 hypervisor                                                                                                                                                                                                                                                                                                                                                                      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"><li>• Installed directly on the top of a hardware (server, computer, supercomputer...)</li><li>• A minimum level of technical skills is required</li><li>• When talking about security, availability and efficiency, Type 1 is better than Type 2</li><li>• High stability because no other services and applications affect the hardware</li><li>• Can be managed from any web-browser</li><li>• Examples:<br/>VMware ESXI<br/>Microsoft Hyper-v</li></ul> | <ul style="list-style-type: none"><li>• Runs on any host operating system</li><li>• Easier to manage than Type 1 hypervisor</li><li>• Less secure because issues with any other application may crash host OS</li><li>• Lower performance than Type 1 due to resource sharing with other applications</li><li>• Examples:<br/>VMware Workstation Player<br/>Sun's VirtualBox</li></ul> |

*Figure 1: Type of hypervisors*

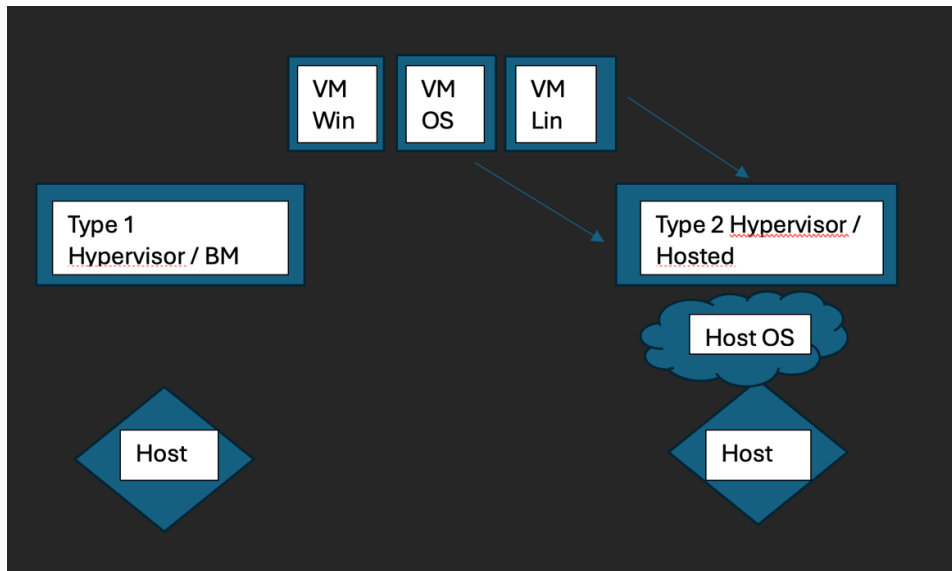


*Figure 2: Architecture of Hypervisors*

#### b- Architecture of hypervisors

Hypervisor type 1 is installed directly on top of the physical server's hardware, without an operating system or any software layer in between. The kernel determines how the hypervisor interacts with hardware and manages system resources.

Hypervisor type 2 is hosted on the operating system and runs on that layer as another software to enable virtualization. (2)

#### c- Hardware requirements

For type 1:

- Minimum 2 Gb of RAM
- Network card
- SSD disk, minimum 25 GB of storage

For type 2:

- Any processor with x86 architecture only
- A supported host OS
- Minimum of 2 Gb of RAM

#### d- Advantages of hypervisor

A type 1 hypervisor delivers the best performance for VMs and their workloads because it directly accesses the computer's hardware resources. Moreover, this type of hypervisor efficiently control CPU and memory, allowing demanding operations to run smoothly without experiencing delays.

With a type 2 hypervisor, there is no need to install a separate software package. Additionally, the interfaces are designed to be easily handled by beginners. (3)

e- Scalability and security of hypervisor

Type 1 hypervisors can handle large-scale deployments, supporting hundreds of virtual machines on a single physical server. This type of hypervisor offers enhanced security features by operating directly on hardware. Thanks to its architecture, type 1 hypervisor can operate in node groups or clusters.

Type 2 hypervisor inherit vulnerabilities from their host, making them less suitable for high-security applications. The security of a type 2 hypervisor depends on the security measures of the host system and is not fully customizable. (4)

f- Different types of hypervisor solutions available in the market

VMware vSphere:

- High availability
- vMotion: technology that enables live migration of a virtual machine from one physical server to another without any downtime.
- vSphere Data Protection: used for backup and restore virtual machines

Oracle VirtualBox:

- Simplify software distribution: distribute applications inside a VirtualBox
  - Works on different host OS platforms
  - Has an extremely modular design with well-defined internal programming interfaces.
- (5)

## 2- IP addressing

### a- Meaning and functionality

Every computer network uses a unique IP address to communicate with other computers, websites and all part of cyberspace. Thanks to their IP address, computers could contribute to finding data or content by making every machine easily identifiable. When a request is sent, the device divides the data into packets. These packets travel through a series of routers and switches and finally reach its destination. (6)

### b- The Role of Routers and Switches in Data Transmission

A router is a networking device that forwards data packets between different computer networks.

Once the packets are created, they are sent over the Internet through many switches and routers. Thanks to the routers, data can easily find their path between all the different networks. So, routers make sure that web traffic gets to the appropriate device. A switch connects devices within same network. Unlike routers, switches use MAC addresses to sends data to the appropriate device. (7)

### c- Structure and representation of IPv4 and IPv6 addressing

IPv4, known also as Internet Protocol Version 4, is the First Internet Protocol to be deployed. It uses a 32-bit address system, allowing for approximately 4.3 billion unique addresses. It is expressed in dotted-decimal notation and is separate by periods. IPv4 address is divided into two parts for subnetting purpose into network and host field.

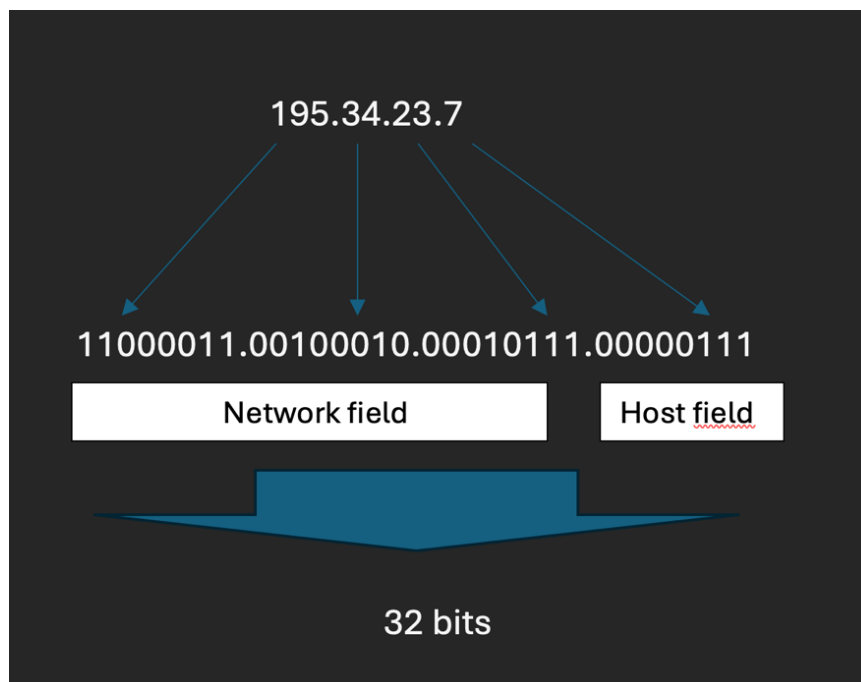


Figure 3: Structure of IPv4

In the early 1990s, the Internet Engineering Task Force started to worry about the issues of IPv4 and began to look for a replacement.

IPv6, or Internet Protocol Version 6, has been developed based on the using of IPv4. It uses a longer 128-bit addressing system and they are represented in hexadecimal format, divided by colons. It provides therefore a larger address space than the IPv4 address. It represented as eight groups of four hexadecimal digits, separated by colons. (8)



*Figure 4: Structure of IPv6*

#### d- Concept of Subnetting

Subnetting is a method used to split a single IP network into multiple smaller networks. This method boosts security and make it easier to manage the network as routing works more efficiency.

Subnetting separate the network portion and the host portion, allowing a single IP network to be divided into multiple subnetworks. Subnetting enhances network performance optimization by reducing routing table complexity and improving address allocation efficiency. (9)

### 3- Routing

#### a- Fundamental concepts of routing protocols

A routing protocol is a software designed to enable routers to exchange routing information, allowing them to determine the best routes between any two nodes on a computer network. The main purpose of a routing protocol is to identify networks destinations.

They first determine all available paths that data can follow to reach its destination. Then, they assess these paths by considering factors such as speed and congestion. And when a path become congested, routing protocols adapt dynamically and find new best paths. (7)

#### b- Key differences between static and dynamic routing protocol

Static Routes define an explicit path between two networking devices. Unlike a dynamic routing protocol, they are not automatically updated and must be manually reconfigured if the network topology changes. Also, they use less bandwidth than dynamics routing protocols.

However, the main disadvantage of static routing protocols is the lack of automatic reconfiguration if the network topology changes.

Dynamics routing protocols are used by routers to automatically share information about the reachability and status of remote networks. It is more complex than static routing protocols because it creates more possible routes to send packets across the network and, they consume more bandwidth than static routing. (7) (10)

| Static routing                                                                                                                                                                                                                                                                                      | Dynamic routing                                                                                                                                                                                                                                                                                   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"><li>• Easy to configure and manage on smaller networks</li><li>• Easy to configure on sub networks</li><li>• More secure</li><li>• Hard to manage on larger networks</li><li>• The routers must be updated manually if there is a change in the network</li></ul> | <ul style="list-style-type: none"><li>• No need for manual route calculations or management</li><li>• New routes are automatically added</li><li>• Extremely adaptable</li><li>• Need some initial setup to function properly</li><li>• Less security</li><li>• Requires more bandwidth</li></ul> |

*Figure 5: Static Routing vs Dynamic Routing*

c- Exploring Real-World examples of Routing Protocol Deployment in Real-Time network: Benefits and Challenges (8)

BGP (Border Gateway Protocol) is the routing protocol used on the Internet to route traffic between different autonomous systems.

Akamai, which is one of world's leading content delivery network providers, uses this type of protocol to provide users with a path that is closer to the data center, ensuring fast access to content with minimal delay. BGP can scale to hundreds and thousands of routes, making it the most scalable routing protocol ever developed. However, information exchanges may fail if the data is improperly formatted. Routers could also be slow and run out of storage. (12)

EIGRP (Enhanced Interior Gateway Routing Protocol) is a dynamic routing that allows routers to automatically exchange routing information.

Coca-Cola is an example of a large retail chain that use EIGRP for efficient routing across its network. This enterprise has many stores spread across the country, so it requires a network capable of managing communication between its head office, distribution centers, and store locations. It is an advanced protocol that helps in configurations in a computer network. While it can be easy to configure, it can be very difficult to manage it. (11)

#### 4- Network Services

a- VPNs

The Virtual Private Networks (VPNs) is an encrypted connection from a device to a network over the Internet, ensuring that data is safely transmitted.

VPNs secure communication and protect against threats. It can also help maintain user privacy and anonymity online.

Some of the best practices of VPNs include first choosing a VPN that uses strong encryption protocols to defend data against hackers or unauthorized access. Then, it is crucial to hide the IP address and routing the traffic via a remote server. (13)

b- DHCP

DHCP is a network management protocol that automatically assigns an IP address to devices or nodes on a network, enabling them to communicate via IP. It automatically assigns new IP addresses when devices move, eliminating the need for manual configuration or reconfiguration by network administrators.

The key features of DHCP are the following:

- It monitors all IP addresses on the network to ensure no two devices share the same one.
- It assigns IP addresses only when necessary and reclaims them when devices disconnect from the network.
- It provides extra information, such as the subnet mask and DNS server addresses.

Also, DHCP can allocate IP address ranges carefully to prevent conflicts and ensure enough IPs for all devices. It can also involve setting up DHCP failover or multiple servers to maintain IP address assignment if one server fails. (14)

### c- Active Directory Domain Services

An Active Directory Domain Services (AD DS) is a directory service that runs on Microsoft Windows Server that enables users to authenticate and access resources on the network. This service serves especially for authentication and authorization. It usually checks the user ID and password of the user, and it allow each user to access only the data they are allowed to use.

Some of the AD DS best practices are:

- Keep the number of privileged users to a minimum
- Protect account with administrator privileged
- Use a strong password on service accounts (15)

### d- Certificate Authorities

A Certificate Authorities (CA) is a company or organization that provides digital certificates to verify the identities of websites, email addresses or even companies. It also helps protect online communication by issuing certificates that enable encryption, ensuring that data remains private. (16)

## II- Technical documentation

### 1- Choice of the Hypervisor

For this coursework, I have decided to use a type 2 hypervisor, Oracle VM VirtualBox, for several reasons.

One of the main reasons I chose this hypervisor is that it is easy to install and manage. Installing this type of hypervisor does not require any skills unlike a type 1 hypervisor. It is exactly the same as installing a software application on a computer. So, there is no need for complex server setups and to have a strong base knowledge in hypervisors. Any beginner can use a type 2 hypervisor, whereas a type 1 hypervisor requires much expertise.

It is loaded in an OS running on a hardware so that why sometimes it has a slow performance because it relies on the host OS. (17)

Even though a type 1 hypervisor is known for its better performance, security and reliability, I chose a type 2 hypervisor because it is cheaper. Generally, a type 2 hypervisor is more affordable than a type 1 hypervisor because it does not require advanced features such as a specialized infrastructure. For this project, we have used VirtualBox Oracle, which is free, making it the perfect choice for type 2 hypervisor, as it saves a lot of money.(18)

Moreover, a type 2 hypervisor is known for its flexibility and combability. It supports a diverse selection of guest operating system such as Linux, Windows and MacOS. This will be very useful for our next Coursework, as we have to manage different network services.

Also, we can do snapshots on VirtualBox, so it makes troubleshooting easier.

To save all the virtual disk files, we can move them to a drive, which can be very useful, especially for beginners who are unfamiliar with VirtualBox.

Finally, this is why I have chosen a type 2 hypervisor. Even though a type 1 hypervisor has many advantages, a type 2 hypervisor is still the best choice, especially for beginners.

## 2- Download and setup

First, we had to install the VirtualBox on the computer.

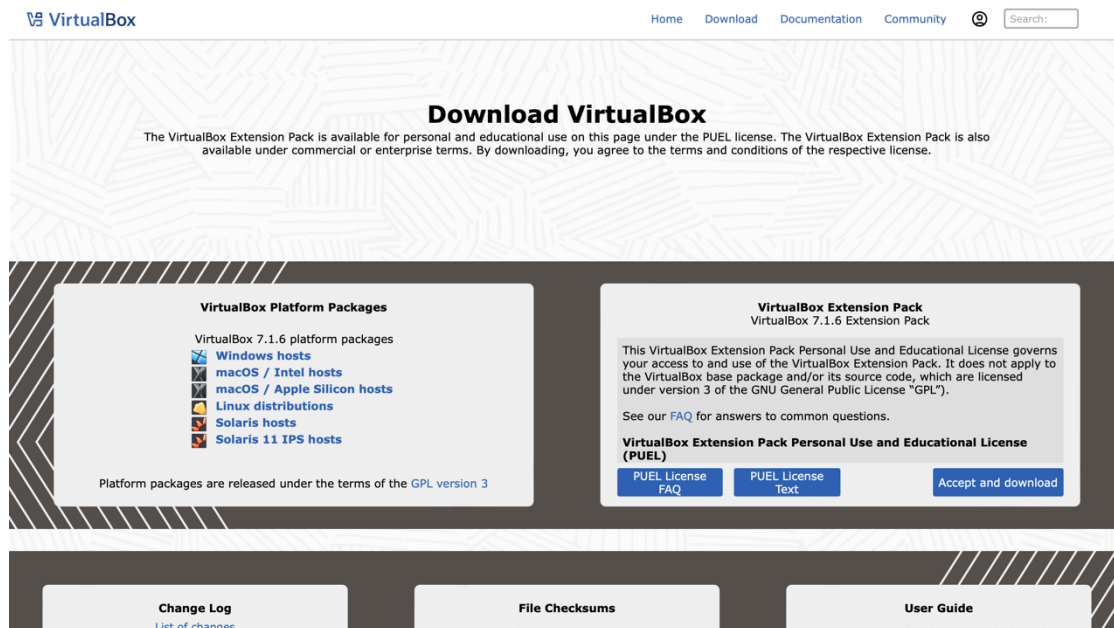


*Figure 6: Screenshot of the Installation of VirtualBox*

The main objective of this coursework is to connect the LAN SWANSEA to the LAN CARDIFF. In other words, Windows machines are connected to the LAN SWANSEA and the LINUX machines are connected to the LAN CARDIFF. Each operating system is connected to its respective network and only the Windows Server 2022 and Debian servers are connected to the external network.

The diagram below illustrates the topology, including the IP addresses assigned to each operating system.

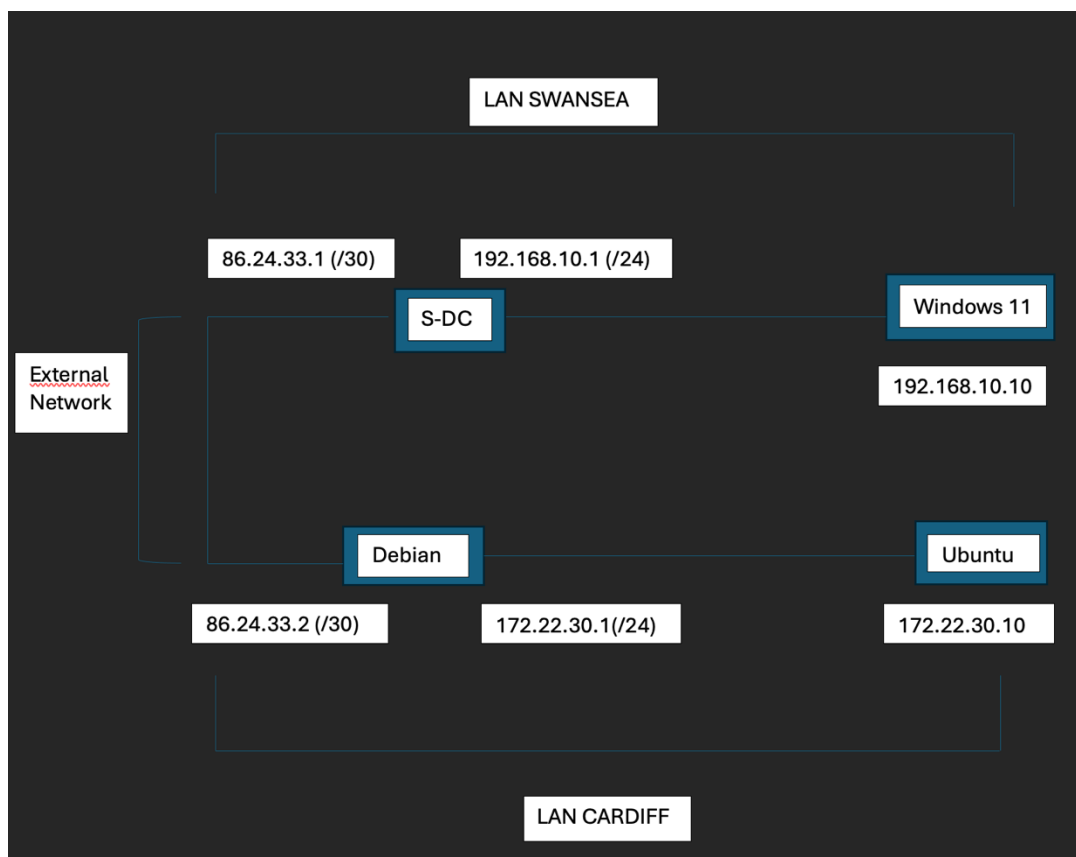


Figure 7: Topology of the network

To install the Type 2 hypervisor on VirtualBox, we started by downloading the Windows Server 2022, S-DC. After tapping Windows Server 2022 Evaluation in the browser, we downloaded 64-bit ISO edition.

In VirtualBox settings, we allocated 8000 MB of base memory and 4 processors, as this server requires a good amount of memory to run efficiently without overloading the host machine.

Microsoft
Evaluation Center
Windows
Windows Server
SQL Server
System Center
Microsoft Security
Additional products
All Microsoft

## Please select your Windows Server 2022 download

|                         |                                 |                                |                            |                                    |
|-------------------------|---------------------------------|--------------------------------|----------------------------|------------------------------------|
| English (United States) | ISO downloads<br>64-bit edition | VHD download<br>64-bit edition | Try on Azure<br>Learn more | Create a VM in Azure<br>Learn more |
| Chinese (Simplified)    | ISO downloads<br>64-bit edition |                                |                            |                                    |
| French                  | ISO downloads<br>64-bit         |                                |                            |                                    |

Figure 8: Download of Windows Server 2022

Then, we set only 2 adapters both named “Internal Network”.  
In the System, we unchecked the floppy box and reversed the Optical and Hard disk box.

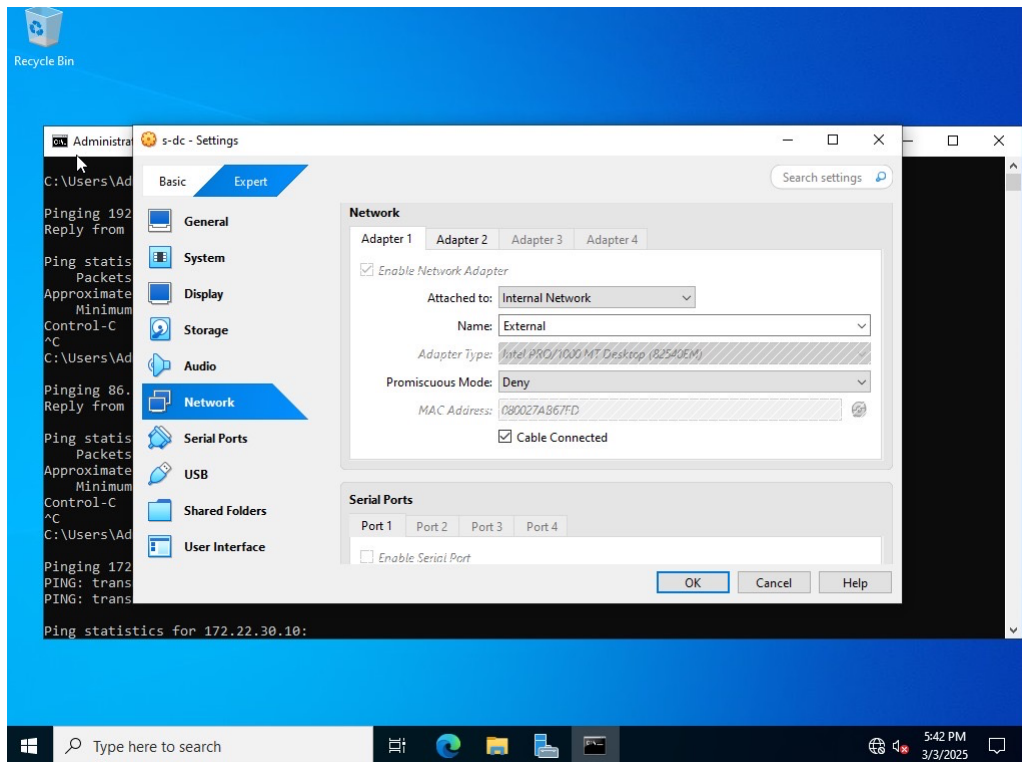


Figure 9: S-DC Settings Adapter 1

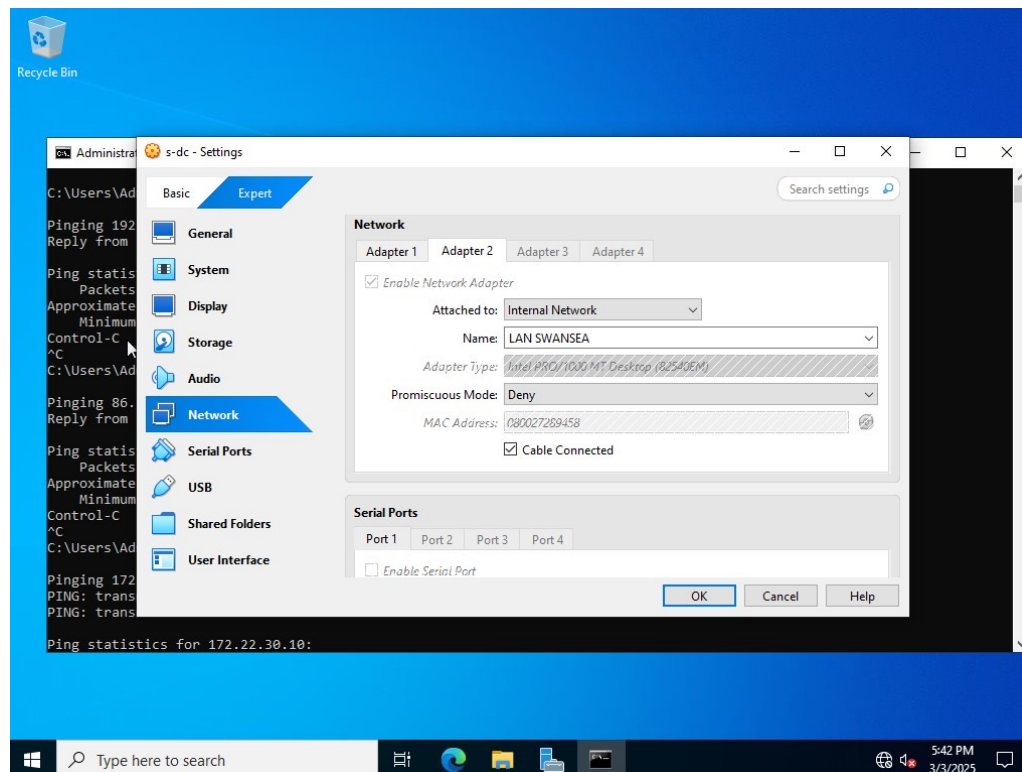


Figure 10: S-DC Settings Adapter 2

After doing this, we run the Virtual machine, and we had to check boxes such as the language. Then we selected Windows Server 2022 Standard Evaluation (Desktop Experience) because it is the best option for beginners, as it is easier for users to interact with the system and then we chose the Custom option. After that, the Installation began.

Then we had to install the Windows Client (Windows 11).

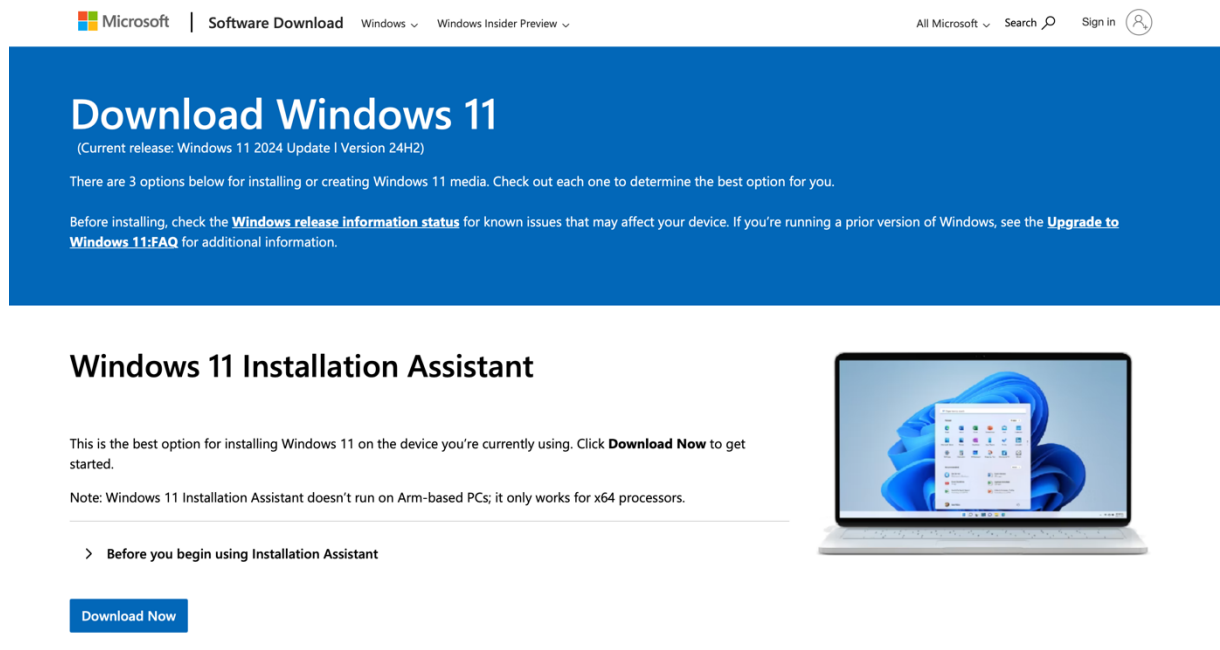


*Figure 11: Download Windows Client (Windows 11)*

For the Client Windows, we had to use just one adapter. And on the settings, we have put 4GB of Memory and 2 processors.

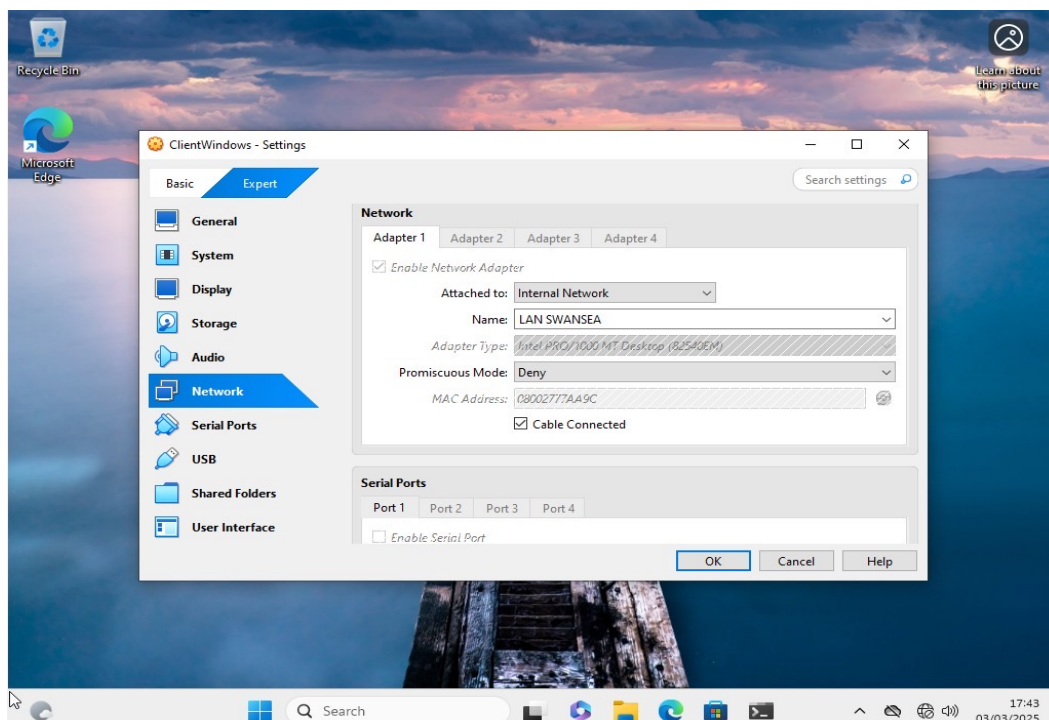


Figure 12: Windows 11 Settings Adapter 1

After downloading all Windows, we have to download and setup Linux. For Debian, we have decided to take the complete installation even though we could get the small installation. We have use 4GB for the Memory and 4 processors.

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## Download Debian

This page has options for downloading and installing Debian 12.9.0, the stable release.

- [Download mirrors](#) of installation images
- [Installation Manual](#) with detailed installation instructions
- [Release notes](#)
- [ISO images for Debian testing](#)
- [Verifying authenticity of Debian images](#)

### Download an installation image

- A [small installation image](#): can be downloaded quickly and should be recorded onto a removable disk. To use this, you will need a machine with an Internet connection.
 

[64-bit PC netinst iso](#), [32-bit PC netinst iso](#), [64-bit PC netinst torrents](#), [32-bit PC netinst torrents](#)
- A larger [complete installation image](#): contains more packages, making it easier to install machines without an Internet connection.
 

[64-bit PC DVD-1 iso](#), [32-bit PC DVD-1 iso](#), [64-bit PC torrents \(DVD\)](#), [32-bit PC torrents \(DVD\)](#)

[Buy CDs, DVDs or USB sticks from a vendor of Debian installation media](#)

Many of the vendors sell the distribution for less than US\$5 plus shipping (but not always internationally). Here are the basic advantages of CDs:

### Try Debian live before installing

You can try Debian by booting a live system from a CD, DVD or USB key without installing any files to the computer. You can also run the included [Calamares Installer](#). Only available for 64-bit PC. Read more [information about this method](#).

[Live Gnome](#), [Live Xfce](#), [Live KDE](#), [Other live ISO](#), [live torrents](#)

### Use a Debian cloud image

An official [cloud image](#), built by the cloud team, can be used on:

- your OpenStack provider, in qcow2 or raw formats.

[64-bit AMD/Intel \(qcow2, raw\)](#), [64-bit ARM \(qcow2, raw\)](#), [64-bit Little Endian PowerPC \(qcow2, raw\)](#)

Figure 13: Download Debian

And finally, we have download Ubuntu which is the Client of Debian.

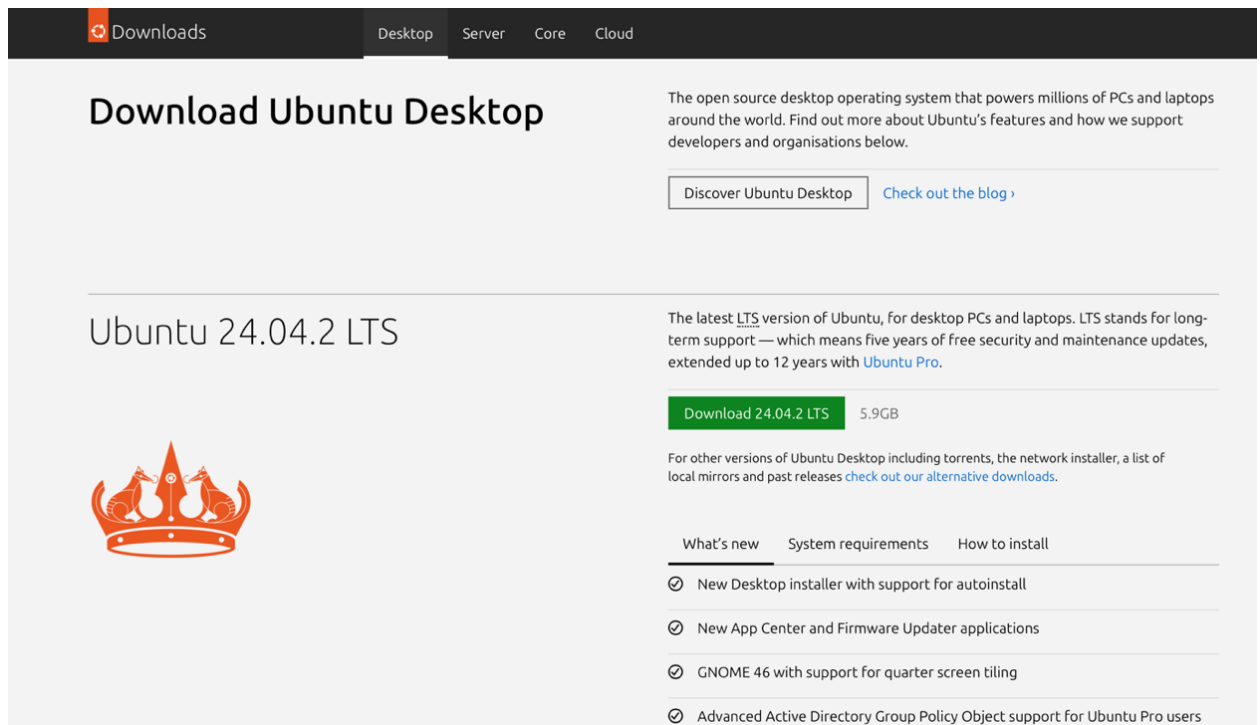


*Figure 14: Download Ubuntu*

### 3- Configure IP Addressing

Once all the Windows and Linux systems were installed and configured, we needed to configure the IP addresses of each system.

For the Windows Server 2022, we ran the virtual machine and entered the command “ncpa.cpl” to access to the two Ethernets connections. Then, we configured the IP address in the network connection panel in windows, as shown in the photo below.

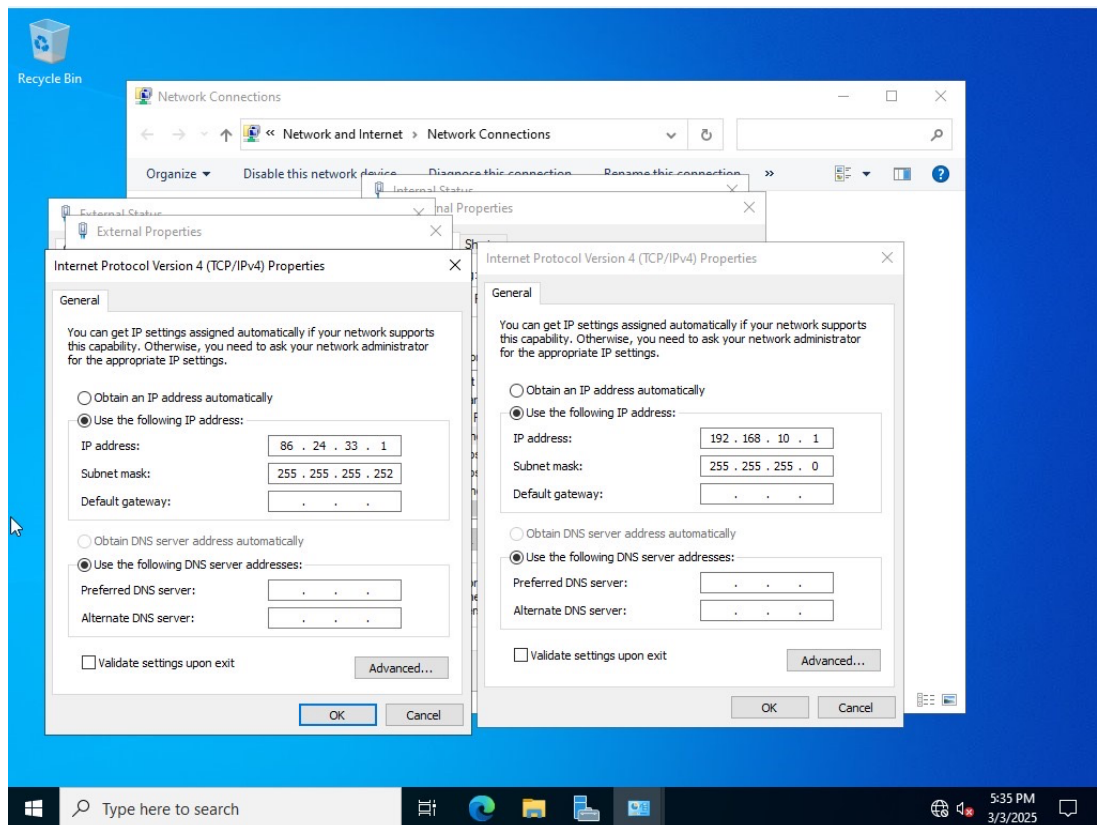


Figure 15: Configuration of IP addresses Windows Server 2022

Based on information from Wikipedia, we can find a wide range of IP addresses that can be used. According to the available address ranges, we assigned IP addresses to each operating system. (19)

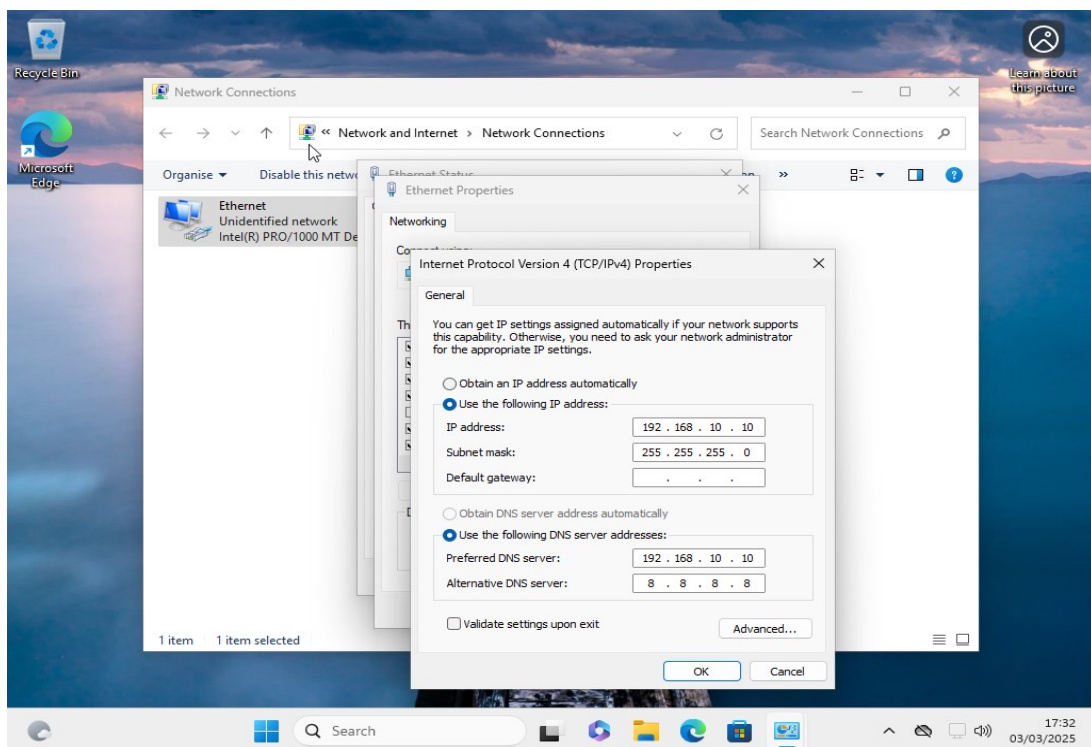


Figure 16: Configuration of IP addresses Windows 11

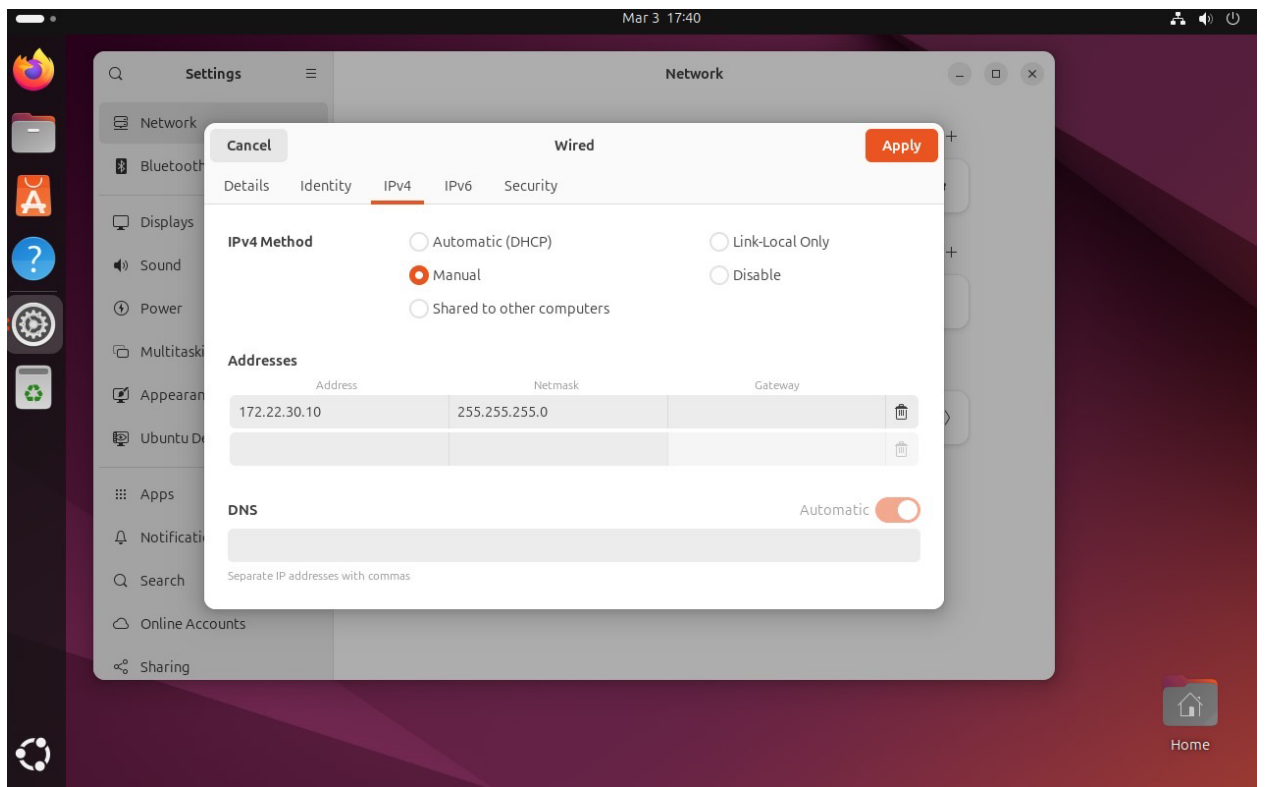


Figure 17: Configuration of IP addresses Ubuntu

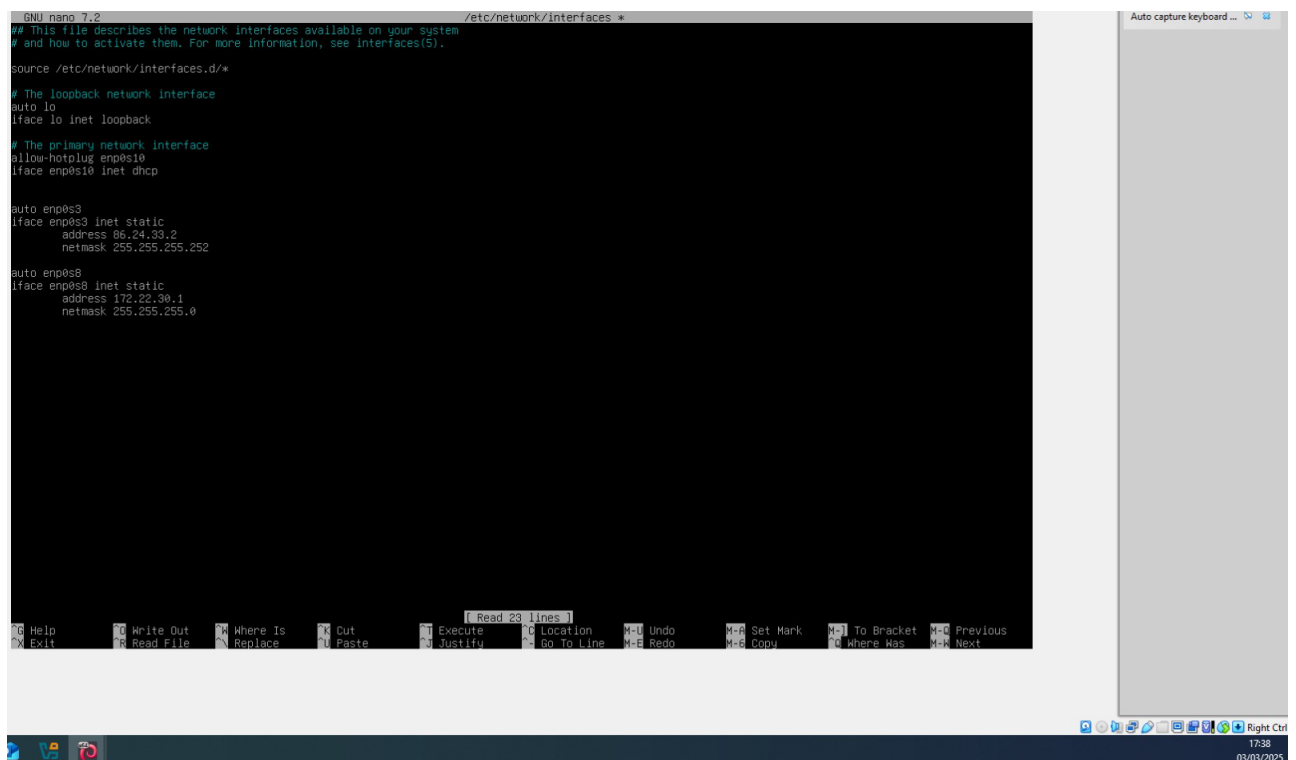


Figure 18: Configuration of IP addresses Debian

#### 4- Test and Troubleshoot

Once we configured all the IP addresses for each operating system, we tested the connectivity by pinging the IP addresses.

First, to allow ping request, we needed to enable the firewall, as shown below.

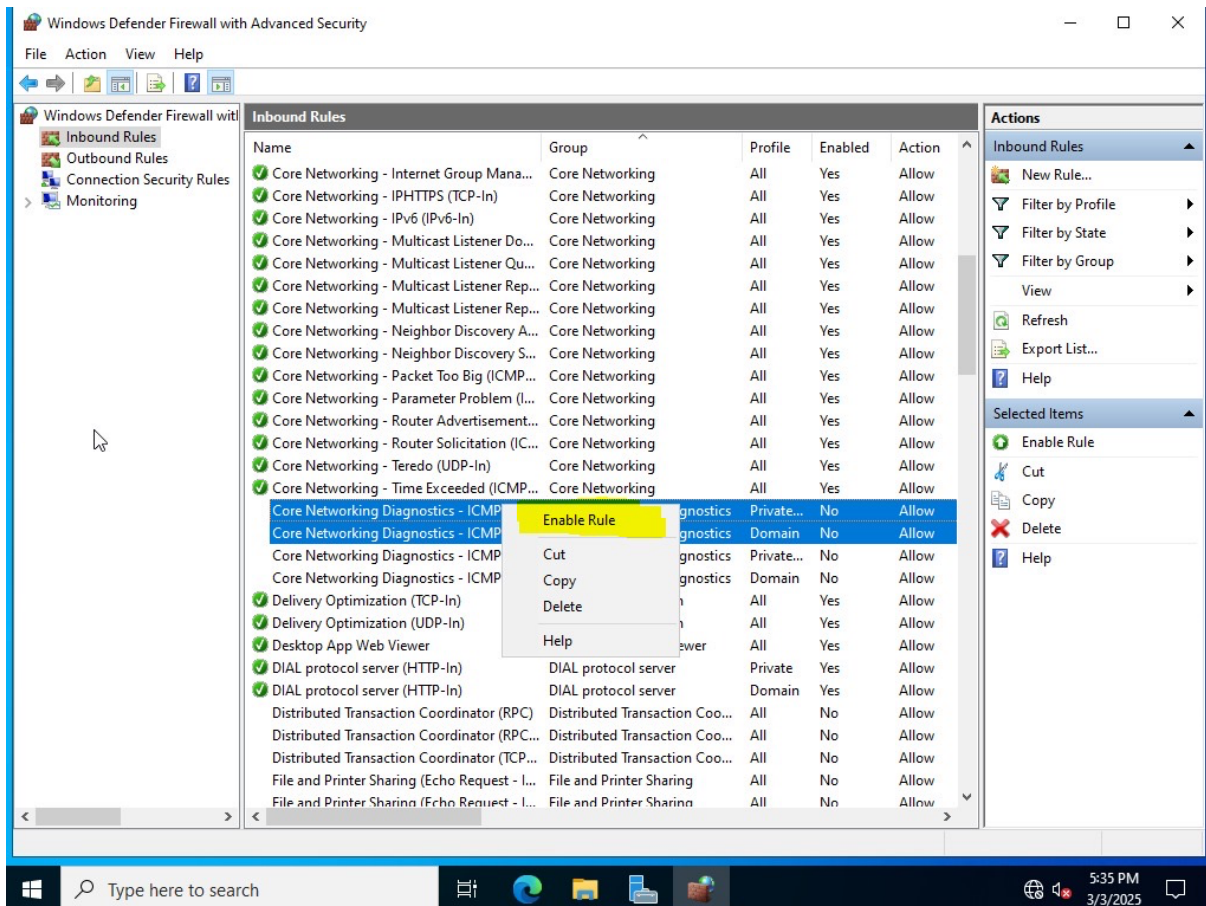


Figure 19: Screenshot of the Firewall

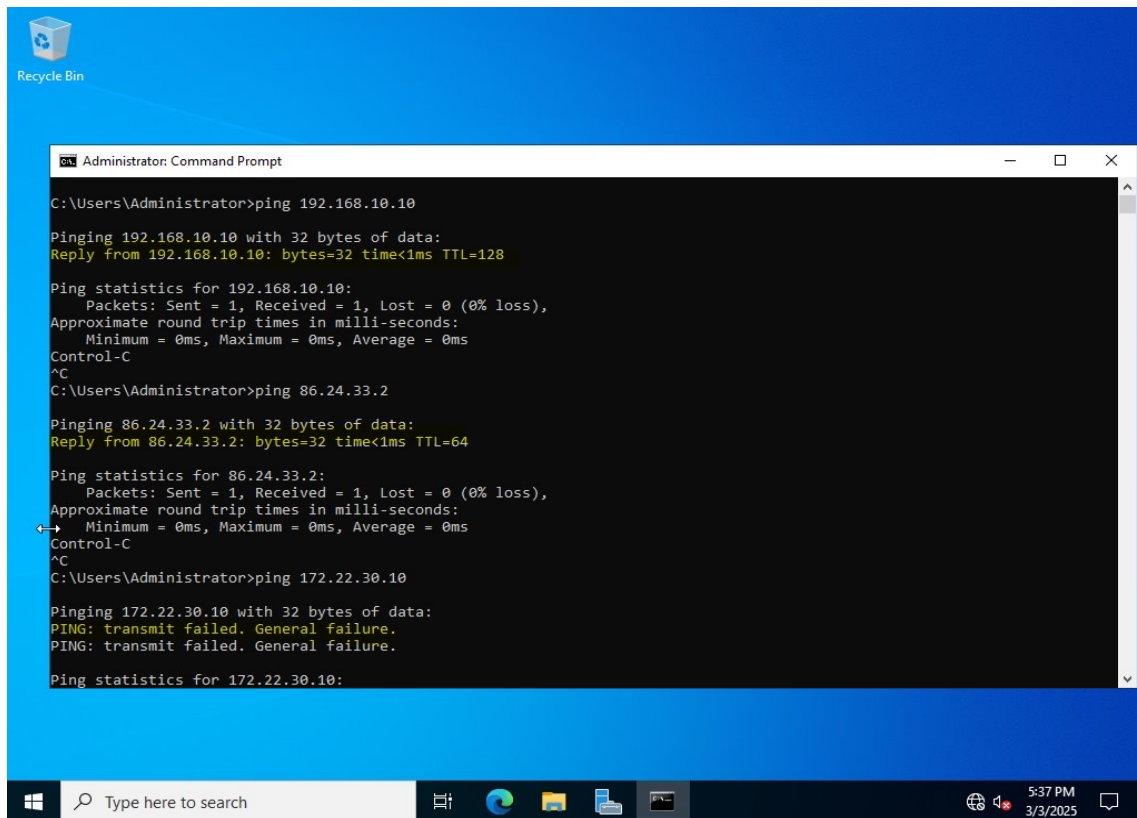
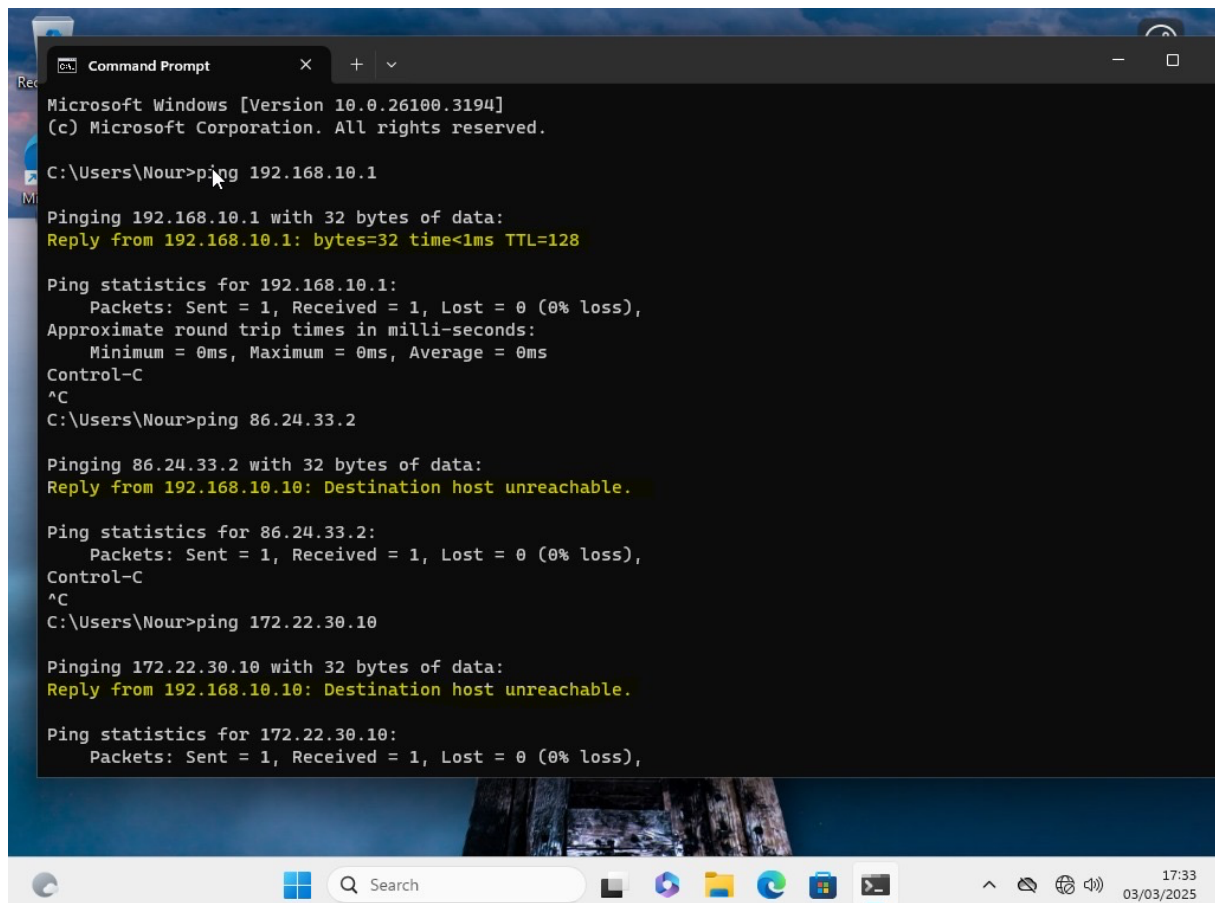


*Figure 20: Pinging from Windows Server 2022*

As shown in the photo above, we received a response from Windows 11 and Debian, but not from Ubuntu. This indicates that Windows Server 2022 is successfully connected to both Windows 11 and Debian.



```
Microsoft Windows [Version 10.0.26100.3194]
(c) Microsoft Corporation. All rights reserved.

C:\Users\Nour>ping 192.168.10.1

Pinging 192.168.10.1 with 32 bytes of data:
Reply from 192.168.10.1: bytes=32 time<1ms TTL=128

Ping statistics for 192.168.10.1:
    Packets: Sent = 1, Received = 1, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 0ms, Average = 0ms
Control-C
^C
C:\Users\Nour>ping 86.24.33.2

Pinging 86.24.33.2 with 32 bytes of data:
Reply from 192.168.10.10: Destination host unreachable.

Ping statistics for 86.24.33.2:
    Packets: Sent = 1, Received = 1, Lost = 0 (0% loss),
Control-C
^C
C:\Users\Nour>ping 172.22.30.10

Pinging 172.22.30.10 with 32 bytes of data:
Reply from 192.168.10.10: Destination host unreachable.

Ping statistics for 172.22.30.10:
    Packets: Sent = 1, Received = 1, Lost = 0 (0% loss),
```

*Figure 21: Pinging from Windows 11*

As shown in the photo above, we received a response only from Windows Server 2022. Debian and Ubuntu are unreachable so the pinging test is correct.

For the OS Debian, we have only 2 interfaces.

```
root@debian:/home/nour# ip a
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
        valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host noprefixroute
        valid_lft forever preferred_lft forever
2: enp0s3: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP group default qlen 1000
    link/ether 08:00:27:0a:53:04 brd ff:ff:ff:ff:ff:ff
    inet 86.24.33.2/30 brd 86.24.33.3 scope global enp0s3
        valid_lft forever preferred_lft forever
    inet6 fe80::a00:27ff:fe0a:5304/64 scope link
        valid_lft forever preferred_lft forever
3: enp0s8: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP group default qlen 1000
    link/ether 08:00:27:88:20:95 brd ff:ff:ff:ff:ff:ff
    inet 172.22.30.1/24 brd 172.22.30.255 scope global enp0s8
        valid_lft forever preferred_lft forever
    inet6 fe80::a00:27ff:fe88:2095/64 scope link
        valid_lft forever preferred_lft forever
root@debian:/home/nour# date
Mon  3 Mar 17:27:04 GMT 2025
root@debian:/home/nour#
```

*Figure 22: Interfaces Debian*

As shown in the photo below, only Ubuntu and Windows Server 2022 are responding. The Windows Client is unreachable, so the ping test is correct.

```
root@debian:/home/nour# ping 172.22.30.10
PING 172.22.30.10 (172.22.30.10) 56(84) bytes of data.
64 bytes from 172.22.30.10: icmp_seq=1 ttl=64 time=0.653 ms
64 bytes from 172.22.30.10: icmp_seq=2 ttl=64 time=0.266 ms
^C
--- 172.22.30.10 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1045ms
rtt min/avg/max/mdev = 0.266/0.459/0.653/0.193 ms
root@debian:/home/nour# ping 86.24.33.1
PING 86.24.33.1 (86.24.33.1) 56(84) bytes of data.
64 bytes from 86.24.33.1: icmp_seq=1 ttl=128 time=0.687 ms
64 bytes from 86.24.33.1: icmp_seq=2 ttl=128 time=0.275 ms
^C
--- 86.24.33.1 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1003ms
rtt min/avg/max/mdev = 0.275/0.481/0.687/0.206 ms
root@debian:/home/nour# ping 192.168.10.10
ping: connect: Network is unreachable
root@debian:/home/nour# ^C
root@debian:/home/nour# date
Mon 3 Mar 17:27:55 GMT 2025
root@debian:/home/nour#
```

*Figure 23: Pinging from Debian*

Finally, only Debian is connected to Ubuntu. The ping test is also correct.

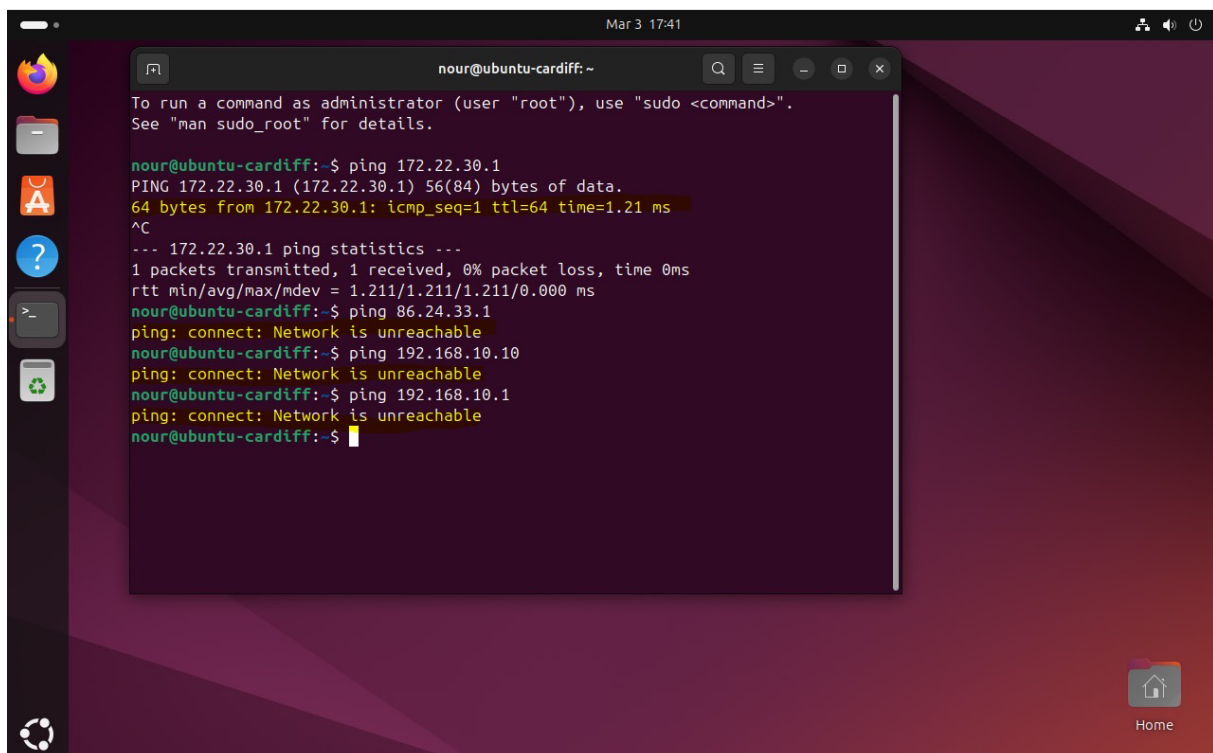


*Figure 24: Pinging from Ubuntu*

### III- Personal and Technical Reflection

#### 1- Technical Reflection

During this coursework, I encountered some challenges, especially during the Task 2.

First, after downloading all the operating systems on VirtualBox and powering off the virtual machines, some of the files became inaccessible. I uploaded the files to OneDrive, but I copied and pasted them incorrectly. As a result, all the files were deleted from the VirtualBox and I had to restart the download and setup process multiple times.

#### 2- Personal Reflection

Before doing this Coursework, the concept of networks and IP addresses was completely unfamiliar to me. But thanks to this project, I was able to reinforce my knowledge and develop new skills.

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