

Network Operating System and Services Coursework 1



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

AI MUTWALY Rim

Table of content

Introduction	3
I. Research	3
1. Hypervisor	3
a- Hypervisors and their architecture.....	3
b- Characteristics and aspects of hypervisors	4
c- Overview of hypervisor solutions on the market	4
2. IP address.....	5
a- Importance of IP addresses and its function	5
b- Different versions of IP addresses	5
c- Role of routers and switches in data flow.....	6
d- Subnetting	7
3. Routing	7
a- Role and function of routing	7
b- Static and dynamic routing protocol	7
c- Deployment of routing protocols in real time network.....	7
4. Network Services.....	8
a- VPN	8
b- DHCP	8
c- Active Directory Domain Services	8
d- Certificate Authorities	9
II. Technical documentation	9
1. Hypervisor choice.....	9
2. Hypervisor setup	9
3. IP address configuration.....	14
4. Test and troubleshoot	17
III. Reflections.....	19
1. Technical reflections	19
2. Personal reflection.....	19
IV. References	20

Introduction

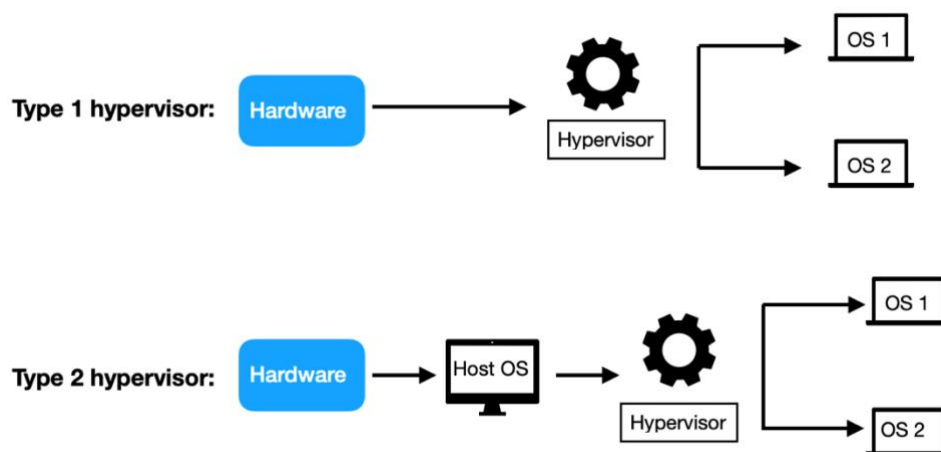
Networking is a key part of modern IT infrastructure, allowing systems to communicate and share data efficiently. In this coursework, we take on the role of an IT professional hired by a Multinational Corporation operating on Swansea and Cardiff. Our task is to ensure a reliable network connectivity between the two networks. First, we are asked to do research about fundamental networking concept to get a clearer understanding of how these components interact to support network communication. Then, we will build a virtualized network by setting up and managing a hypervisor depending on a specific topology. This practical experience will help us better understand virtualized environments and how they connect within the network.

I. Research

1. Hypervisor

a- Hypervisors and their architecture

A hypervisor allows multiple virtual machines to share a single server's resources. There are two different types of hypervisors: the type 1 that runs directly on the host machine's physical hardware, while type 2 operates on top of an existing host OS, acting as an intermediary between the hypervisor and the hardware.



b- Characteristics and aspects of hypervisors

A hypervisor acts like a conductor for a computer, taking the physical resources of the machine (processor, memory, storage, network connection) and sharing them among multiple virtual machines. These virtual machines can run as if they were real, independent computers, even though they are using the same physical resources. Each virtual machines works independently and is separated from the others. This separation means that if there is an issue in one virtual machine, it will not impact the others, which ensure security and stability. Hypervisors have many requirements regarding the version used but regardless of the hypervisor features we want to use, we need:

- A 64-bit processor with second-level address translation (SLAT)
- Virtual machine Monitor Mode extensions
- At least 4 GB of RAM to have enough memory for the host and all virtual machines that will run at the same time
- Hardware-assisted virtualization
- Hardware-enforced Data execution Prevention (DEP).

Type 1 hypervisors can handle many virtual machines depending on hardware capacity by sharing CPU power and memory resources based on demand. They can group many physical servers making it easier to add machines. In contrary, virtual machines on a type 2 hypervisor runs depending on the host OS and they lack multi-host support so if the host crashes, all the virtual machines go down. Also, storage scalability depends on the host's capacity, requiring hardware upgrades if the storage go down.

c- Overview of hypervisor solutions on the market

One of the most used type 1 hypervisors on the market is VMware ESXI that is high in performance and efficiency, has an enterprise-grade scalability, it also has a high availability, and it is very secure. Then, some of the most used type 2 hypervisors on the market is Oracle VirtualBox that can run on multi-platform (Windows, MacOS, Linux...), it is free and open source, it is possible to save the state of a VirtualBox and restore it later thanks to snapshots, it has also a seamless mode and a multiple networking mode for a more flexible connectivity. *(1)*

2. IP address

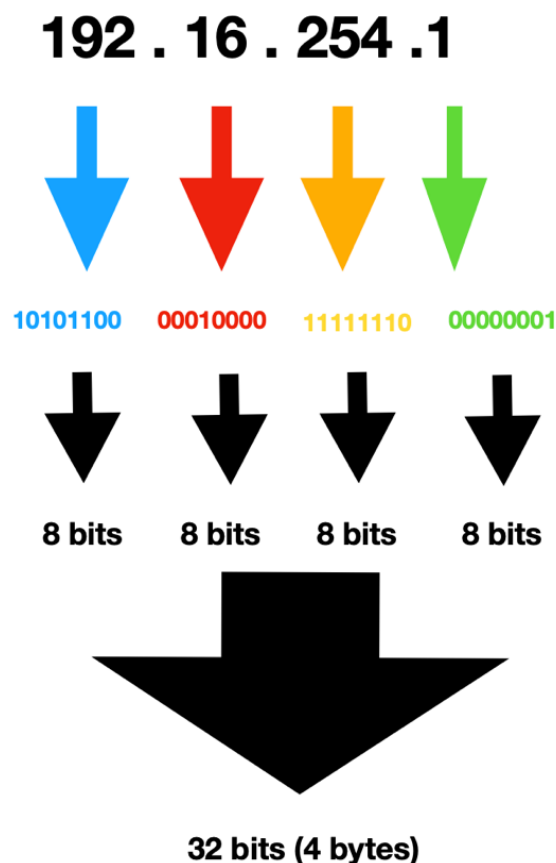
a- Importance of IP addresses and its function

An IP Address is a device's unique number in a network. It is represented as a unique string of numbers separated by periods or colons, depending on the version used, that serve to identify devices on a network which makes them crucial to ensure data exchange in network communication. It proceeds by broking data information into packets that contains source and destination of IP addresses. After that, routers will use this information to determine the best path for data to reach its intendent device.

b- Different versions of IP addresses

There are two different versions of IP addresses, there is IPv4 and IPv6. The IPv4 is the first and the most used version with 32-bit address space which means that it can support up to 4,3 billion unique addresses. It consists of 4 octets (8 bits each), that can have a value between 0 and 255, and it is represented in dotted decimal notation with each octet separated with a dot. Also, IPv4 addresses are divided into different classes that determine their range and purpose. (2)

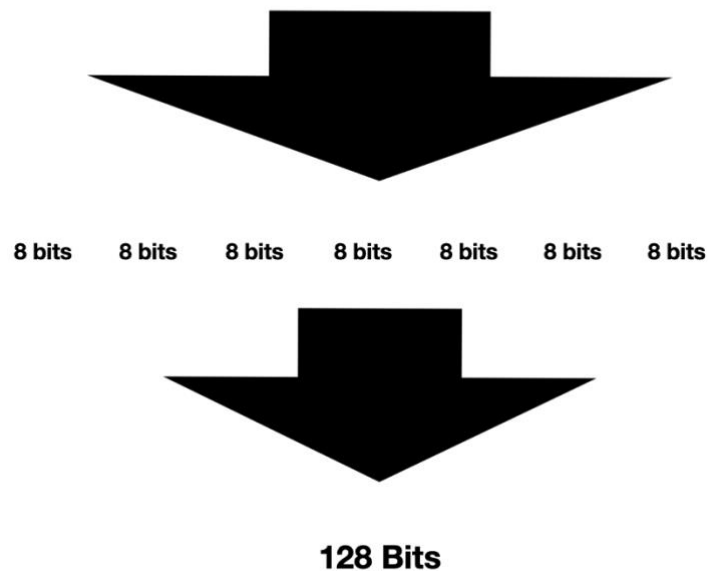
Format of IPv4:



However, because of the increasing number of connected devices, IPv4 began to run out so a new version was created which is the IPv6. The IPv6 provides a much larger address space and improve network efficiency with 128-bit addressing system which means that it can support up to 340 undecillion addresses, each address consists of 8 groups of 4 hexadecimal digits separated by columns. (3)

Format of IPv6:

2001 : 0DC8 : E004 : 0001 : 0000 : 0000 : F00A



c- Role of routers and switches in data flow

The role of a switch is to simplify the sharing of information by connecting all the devices in a local area, that can share information and talk to each other. Thanks to switches, it is possible to create a network and when a device send data, the switch identifies the address of the destination so it can forward data only to that specific device. Unlike switches, a router connects multiple switches, and their network, to form a larger network. In fact, a router direct data by forwarding IP packets between networks for efficient transfer. (4)

d- Subnetting

Subnetting is a network within a network, it allows network segmentation thus breaking a larger network into multiple networks. It makes network more efficient because network traffic can travel a shorter distance without going unnecessary routers to reach its destination. Also, proper subnetting allows better control of network traffic and it improves network efficiency. (5)

3. Routing

a- Role and function of routing

Routers have two functions: it determines the best path to forward packets (routing table), and it forwards these packets to the right destination. They connect many networks to the internet through multiple interfaces, each belonging to a different IP network. Referred as the default gateway, a router routes traffic between the local network and the internet using a routing table that stores information on connected and remote network. The default gateway does not require configuration, and it is only used when forwarding packets to remote network. (6)

b- Static and dynamic routing protocol

Static routing is used when we know the IP address of the end device it wants to reach and the gateway through which we can reach it. It is done manually so it should always be maintained continuously. In consequence, if the IP address is changed so the static route will not be able to provide access to a device. In opposition, dynamic routing will automatically deploy a mass of desired routes. In this type of routing, many routers are connected to many endpoint devices and interconnect them to a WAN (Wide Area Network). In result, if there is a problem with one router, it will not disrupt network. This type of routing selects the best path to the end device by picking the route with the lowest cost among the others. (7)

c- Deployment of routing protocols in real time network

OSPF is used by Cisco that uses its own Cisco routers in its infrastructure, it is deployed using a hierarchical structure, where the network is divided into OSPF areas. First, the Backbone Area is the central area that all other areas must be connected to it. Then, there is all the other areas that are connected to the central area and that can be designed to optimize routing and reduce OSPF overhead. Each router is configured for a specific OSPF process and interfaces are added to the OSPF configuration. (8)

Meta, the world largest social media platform, must handle massive amount of data and traffic daily using advanced networking technique including Border Gateway Protocol (BGP). To deploy BGP, it deploys high-performance border router and core switches in data centers, each assigned with an Autonomous System Number (ASN) along with BGP route reflectors for internal traffic management. BGP enable routing between different distinct networks allowing them to share information on reaching IP addresses blocks across the internet. (9)

4. Network Services

a- VPN

VPNs are used to secure our data and ensure a better privacy and freedom to access region-bound content, it also makes the location and browsing history untraceable. To do so, VPN creates a link between the computer and the VPN server that will encrypt personal data and will mask IP address in the encrypted tunnel. Thanks to VPN, remote work is possible because we can have access to resources over a private connection from anywhere as long as we can get online. (10)

b- DHCP

DHCP (Dynamic Host Configuration Services) is used to provide IP addresses and many network services, such as subnet mask or default gateway, to devices. Without DHCP, IP addresses must be configured manually for computers that are moved from one subnet to another and new ones. This process is automated thanks to DHCP server that maintain a pool of IP addresses and leases an address to every DHCP-enable client and IP addresses that are no longer in use are automatically returned to the pool for reallocation. (11)

c- Active Directory Domain Services

AD DS (Active Directory Domain Services) can be compared to a data store that stores information objects on the network that will be easier for administrators and users to find and use them. It is structured as the basis for a logical, hierarchical organization of directory information. It also contains information about Active Directory objects which includes shared resources such as servers, volumes, printers and network user and computer accounts. (12)

d- Certificate Authorities

CA (Certificate Authorities) are used to verify the identity of websites, individuals, or organizations to secure online communication using encryption and authentication. It issues digital certificates to websites, businesses and individuals. Whenever a website begins by “HTTPS”, it means that a CA has verified the site and issued a certificate to ensure connection. (13)

II. Technical documentation

1. Hypervisor choice

I chose to work on a type 2 hypervisor to complete this network using Oracle VM VirtualBox. The first thing that influenced my choice is that type 2 hypervisor are easy to install on regular software because it runs on an existing OS compared to type 1 hypervisor that needs a separate dedicated hardware. Type 2 hypervisors provide a graphical interface and has some features such as snapshots that makes it easier for students to test different OS environment.

Also, the fact that it runs on an existing host means that it uses the host operating system's driver and hardware capability, it also means that users can run many OS environments on a single machine without affecting the host OS. Choosing a type 2 hypervisor is the best solution for someone that is starting to learn network and that is a beginner because it is easier to use it than a type 1 hypervisor that is ideal for large scale virtualization. In top of that, I had to choose a hypervisor that suit our need in the coursework so chose Oracle VirtualBox because it is free and it supports multiple OS, which is what we need for the coursework since we are going to download four Operating Systems.

2. Hypervisor setup

For the setup of the type 2 hypervisor, we first had to download the VirtualBox for our computer using the Windows host package on the official website.

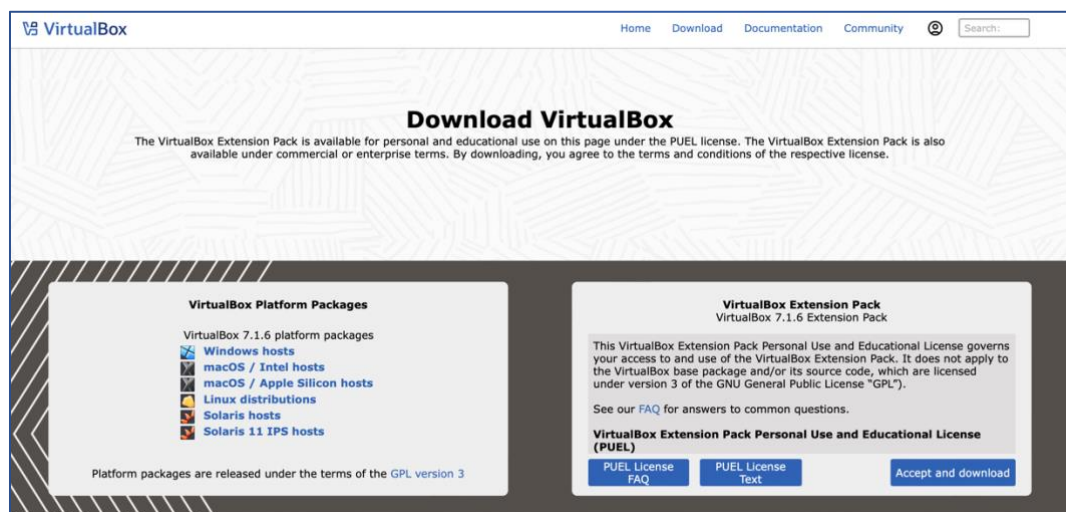


Figure 1: Oracle VirtualBox installation

Now that our VirtualBox is setup, we had to download the Operating Systems following the topology represented by the diagram below and we can see that we have two areas: LAN Swansea and LAN Cardiff that are both connected to the external network. In the two areas there are two OS with one server that is connected to a client and to the external network, also each of the OS's are connected to the network.

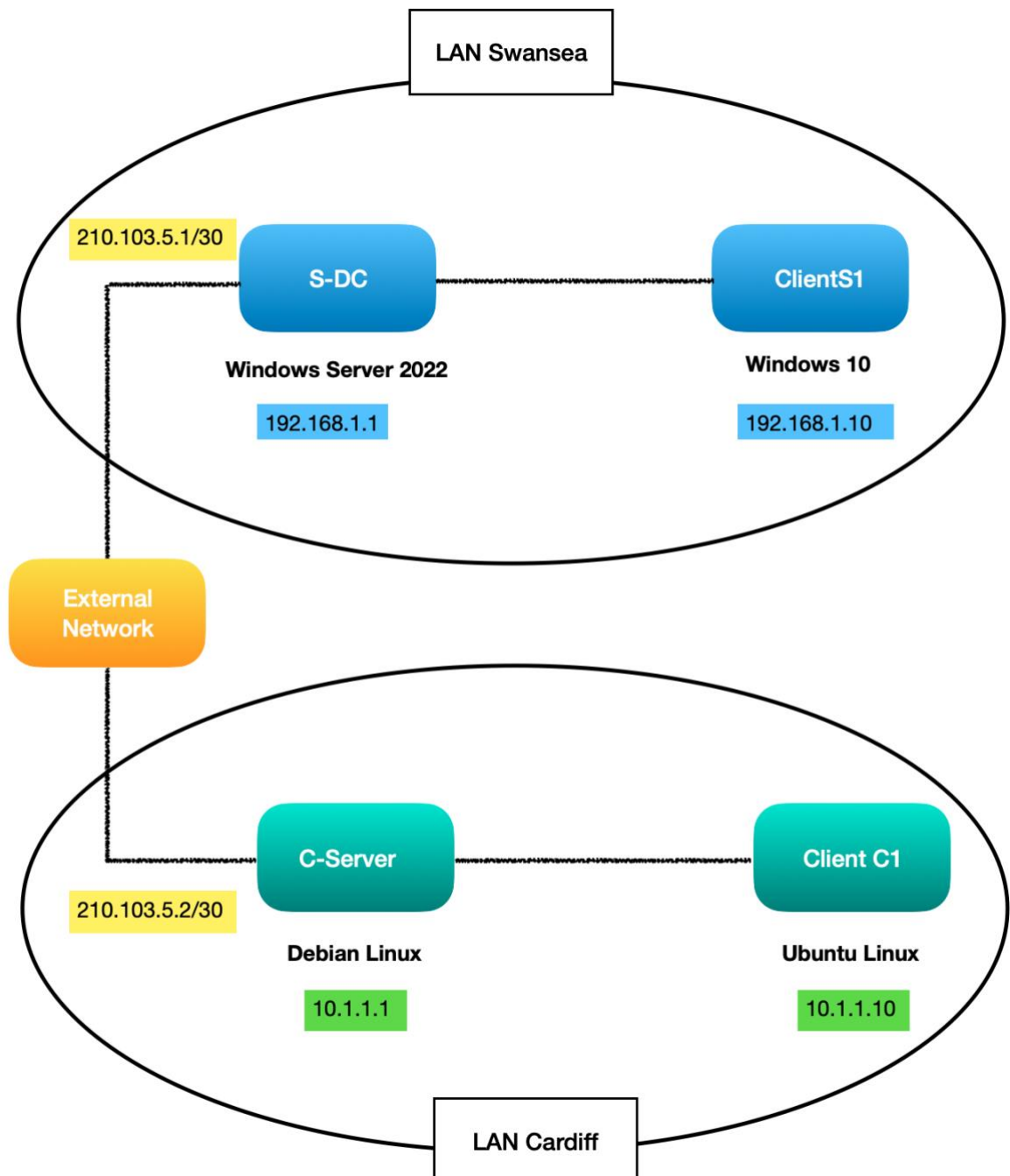


Figure 2: Coursework topology

Based on the topology, we started by downloading and setting up the windows server which is Window Server 2022 on the official website of Microsoft.

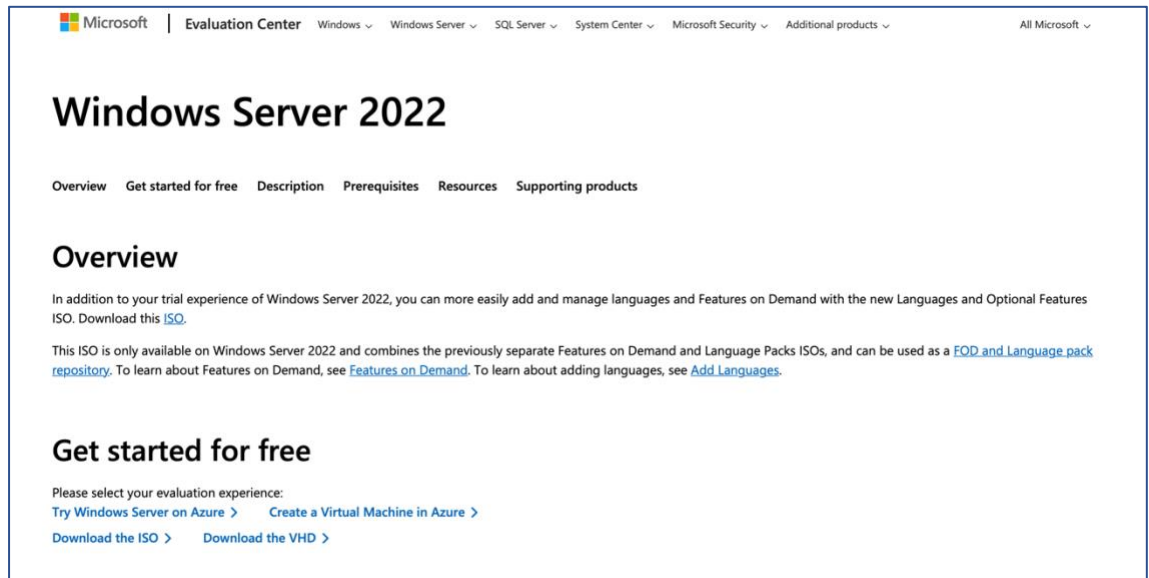
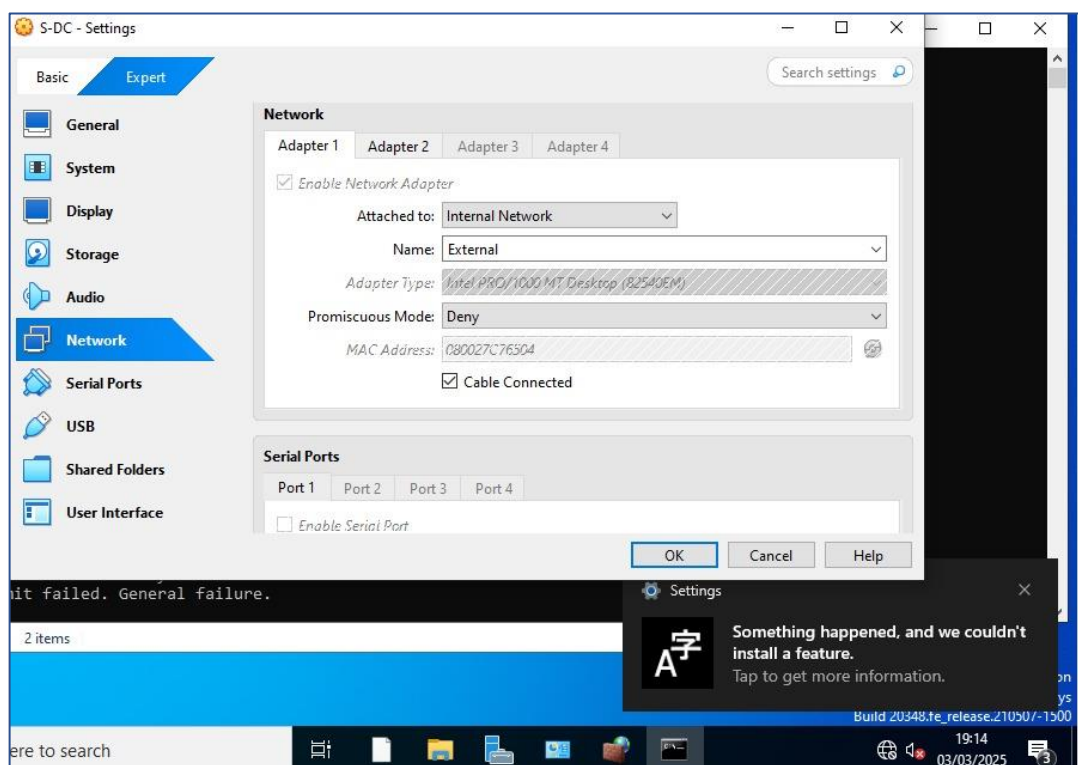


Figure 3: Windows Server 2022 installation

After adding it on the VirtualBox, we had to do its settings by adding the ISO file that we already downloaded and by setting the memory to 8 GB and four processors to have enough storage on the OS. Then, because Windows server is connected to the external network and to windows client, we had to put two adaptors that are internal adaptors.



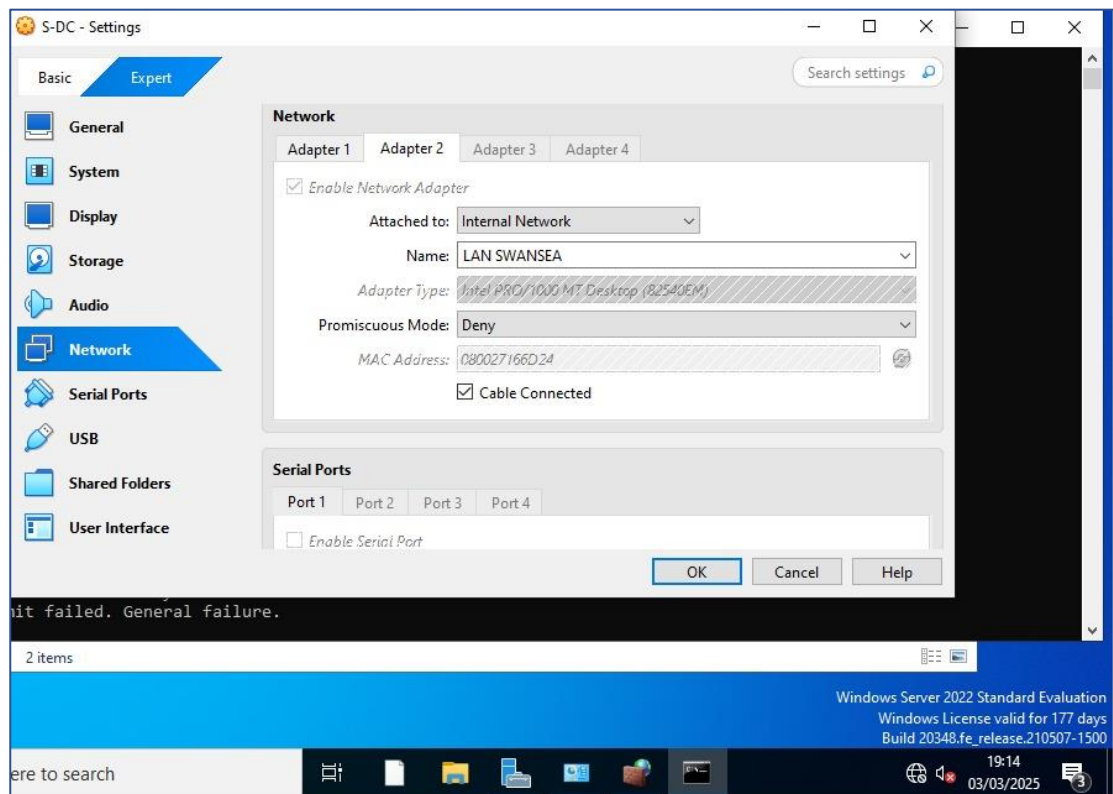


Figure 5: Windows Server 2022 settings

Then we had to download the windows client and chose to download the window 10 version.

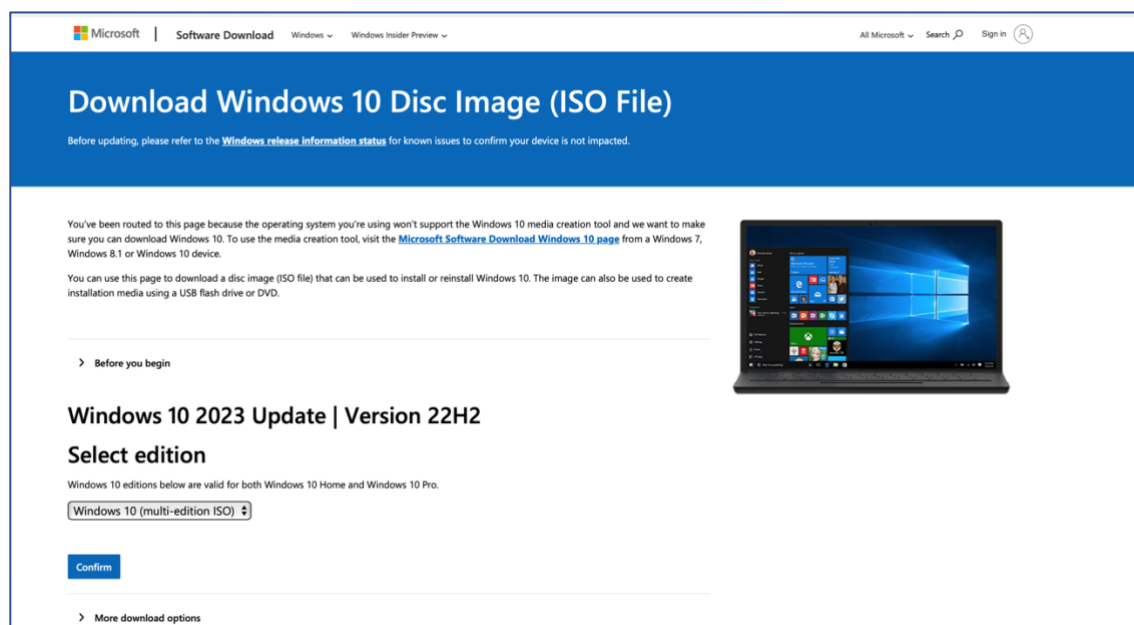


Figure 6: Windows 10 installation

For the settings, we had to put 4 GB for the memory and two processors which is less than the server because the client do not need as much memory as the server that can be connected to many clients so it needs more memory. For the adaptors, we put one adaptor because it is only connected to the server.

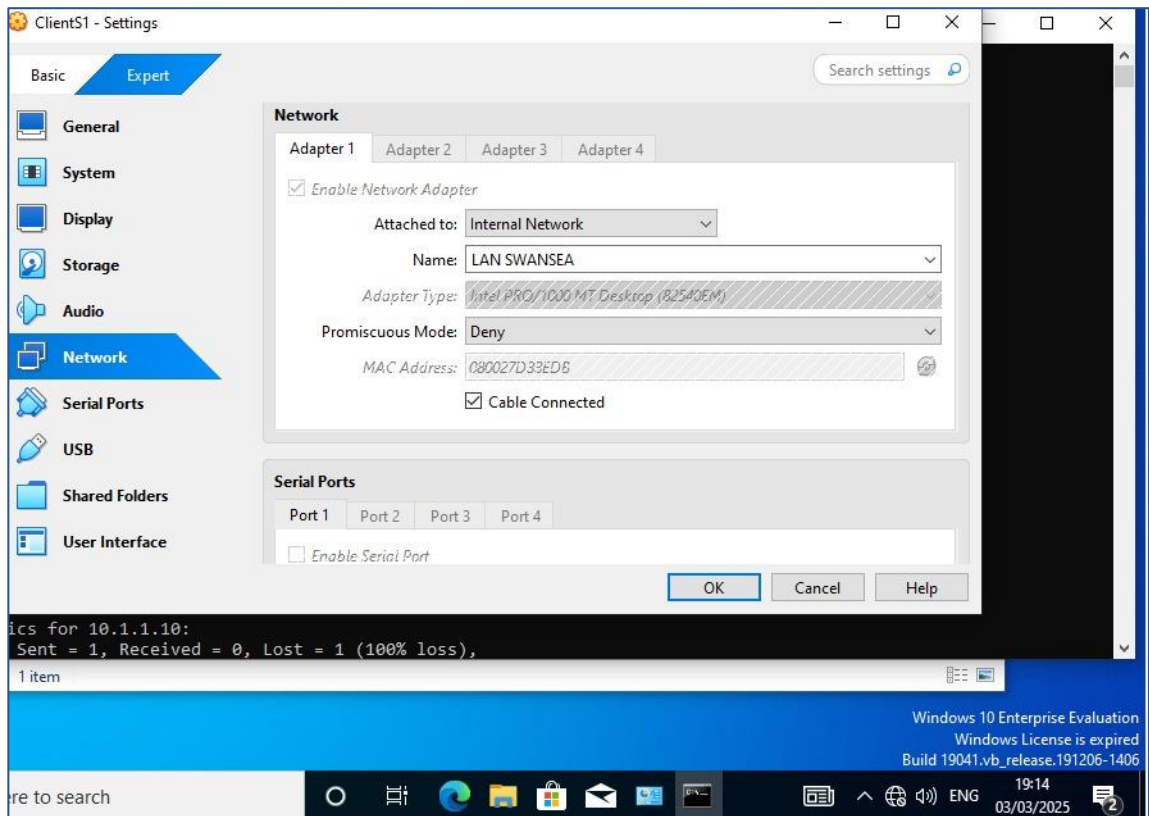


Figure 7: Windows 10 settings

The LAN Swansea network is setup, we now have to setup the LAN Cardiff network setup by beginning with the download of the Linux server which is Debian. For its settings, we had to put 8 GB and four processors because it is the server. Juste as for windows, we had to put two adaptors.

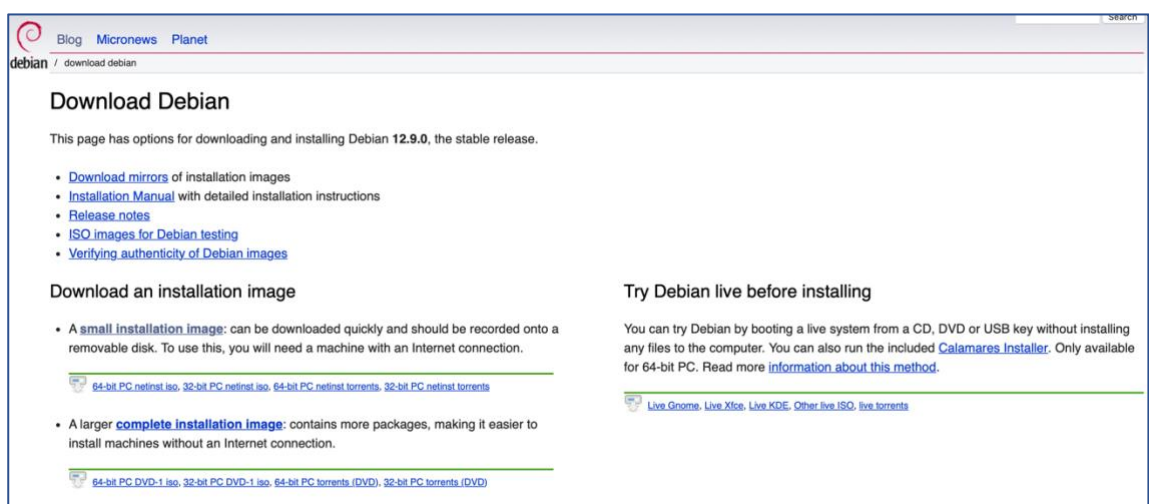


Figure 8: Debian installation

Finally, we downloaded Ubuntu that is the Linux client for Cardiff network. Just as for windows client, we had to put for the settings 4 GB and two processors. Because it is only connected to the server, we put only one adaptor.

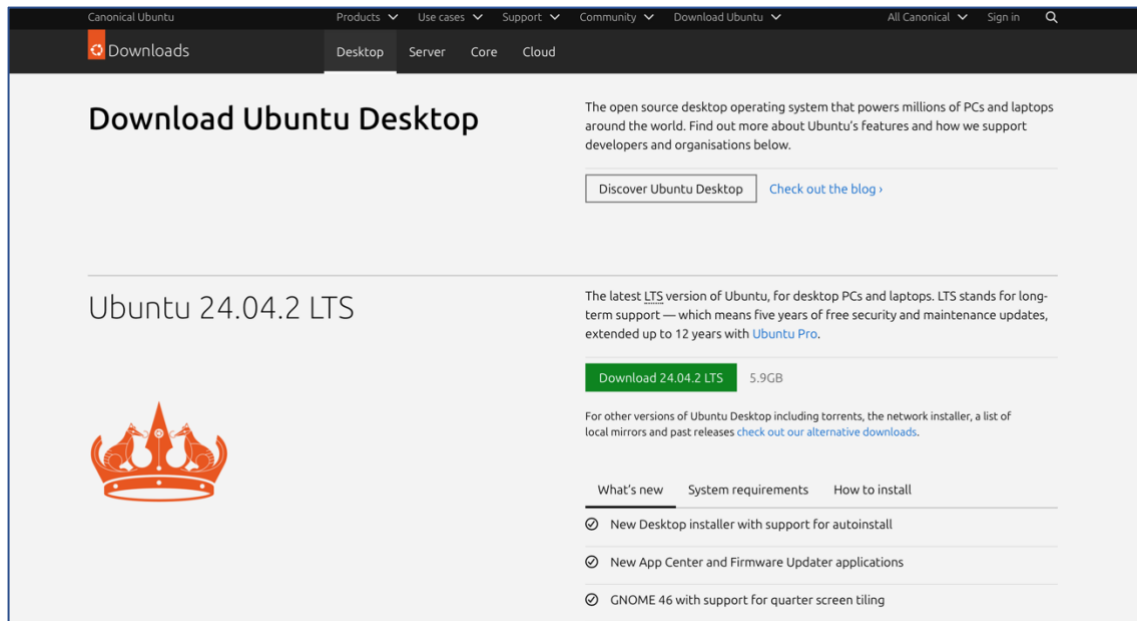


Figure 9: Ubuntu installation

3. IP address configuration

For each OS's, we had to configure an IP address, I chose to keep the same IP addresses that were used in the course. We had to configure the IP addresses manually on the OS's network connections and we can check if it was changed or not by looking for it on the command by tapping *ipconfig*.

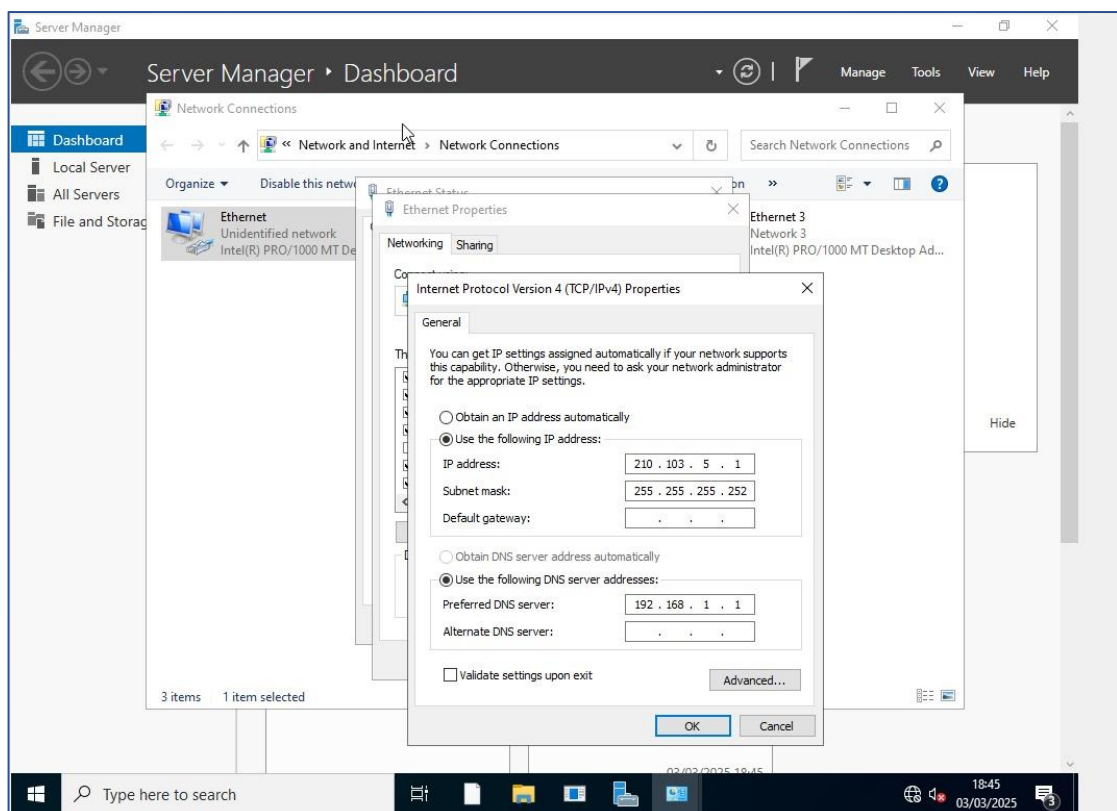


Figure 10: Windows server external IP configuration

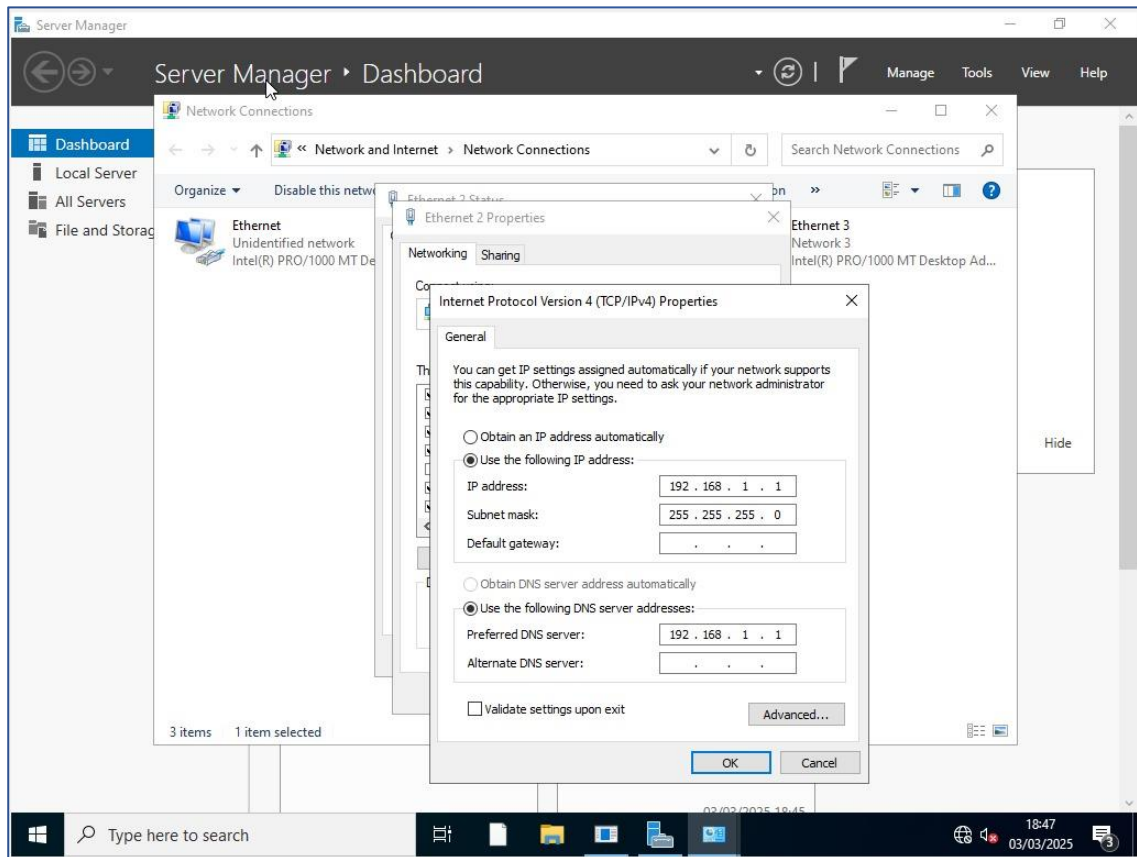


Figure 11: Windows server internal IP configuration

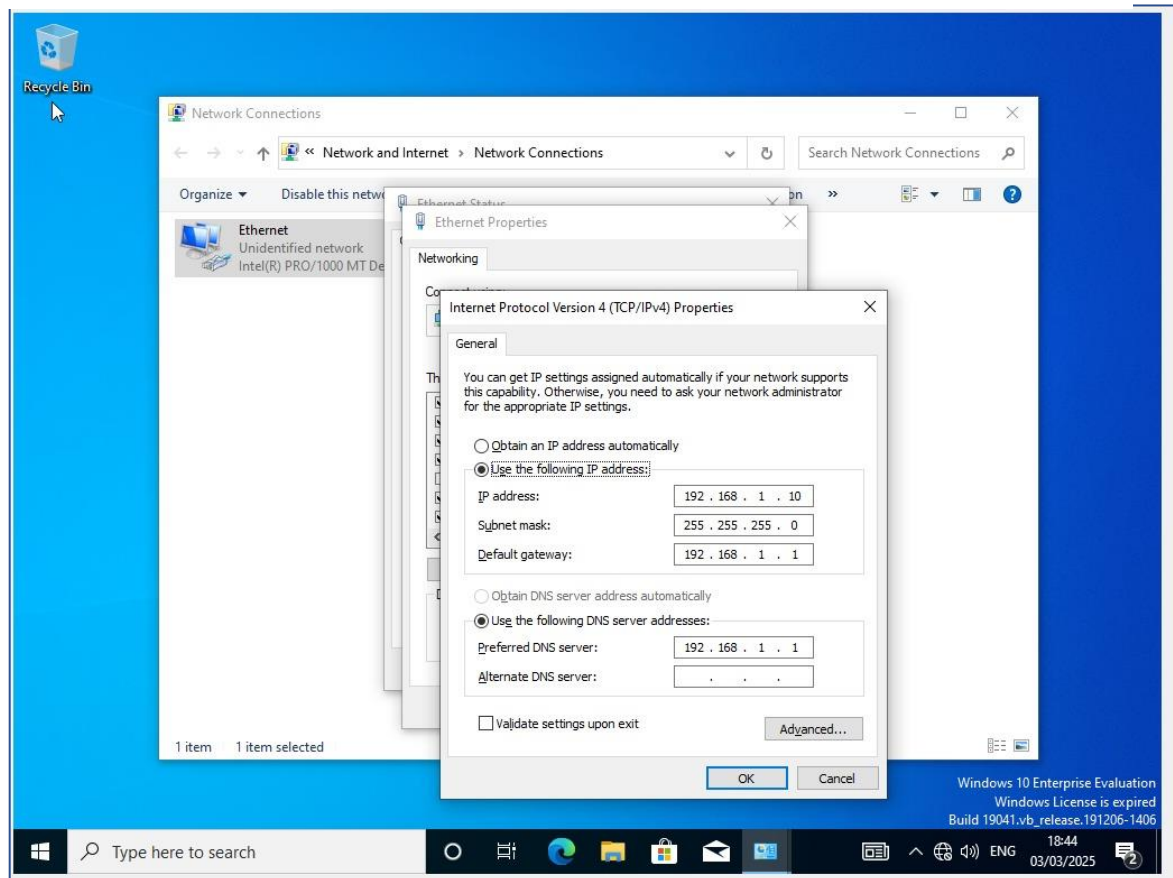


Figure 12: Windows client IP configuration

```
# and how to activate them. For more information, see interfaces(5).
source /etc/network/interfaces.d/*

# The loopback network interface
auto lo
iface lo inet loopback

# The primary nat network interface
allow-hotplug enp0s3
iface enp0s3 inet dhcp
# This is an autoconfigured IPv6 interface
#iface enp0s3 inet6 auto

#this is your external interface
auto enp0s3
iface enp0s3 inet static
address 210.103.5.2
netmask 255.255.255.252

#this is your internal interface
auto enp0s8
iface enp0s8 inet static
address 10.1.1.1
netmask 255.255.255.0

competitor@competitor:~$ date
Mon  3 Mar 19:08:35 GMT 2025
competitor@competitor:~$
```

Figure 13: Linux server IP configuration

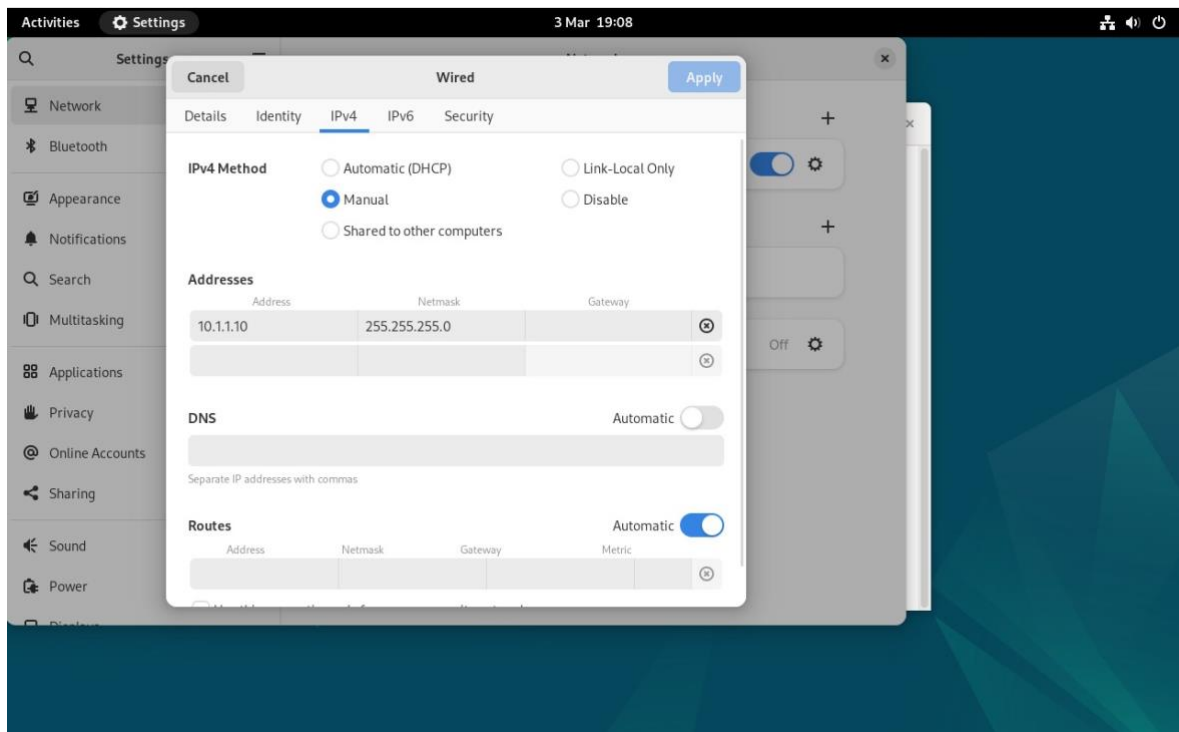


Figure 14: Linux client IP configuration

4. Test and troubleshoot

We tested the connectivity by pinging the gateway for each of the OS's within the same network and then with different network. We started pinging Windows Server but at first it didn't work so we had to go on the firewall to authorize the pinging in Windows.

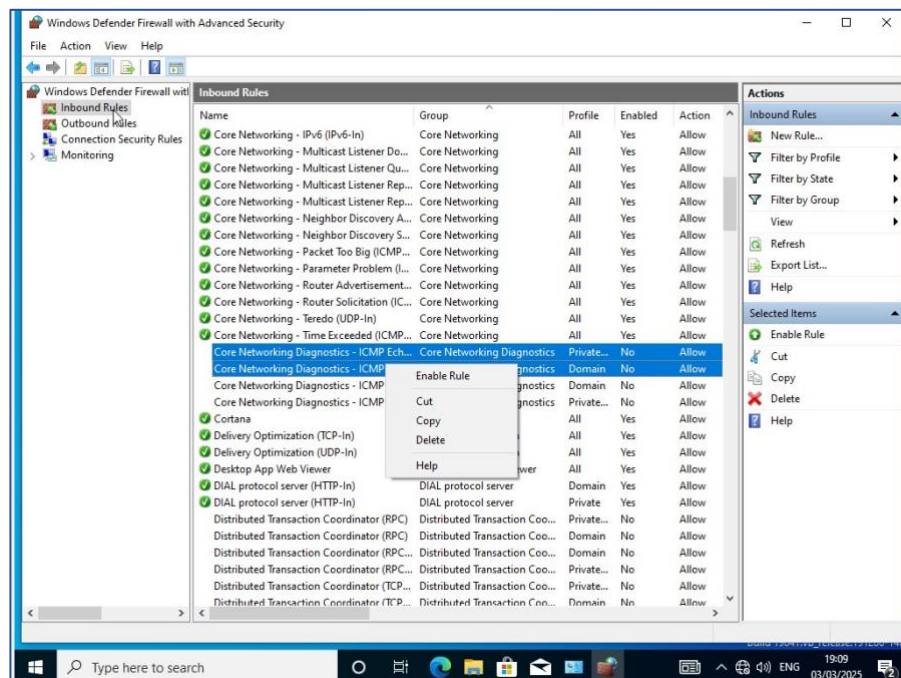


Figure 15: Windows firewall

We can see in the screenshot below that the ping was successful with Windows client and with the external network, but the transmission failed when we tried to ping with Ubuntu that is not in the same network as Windows Server.

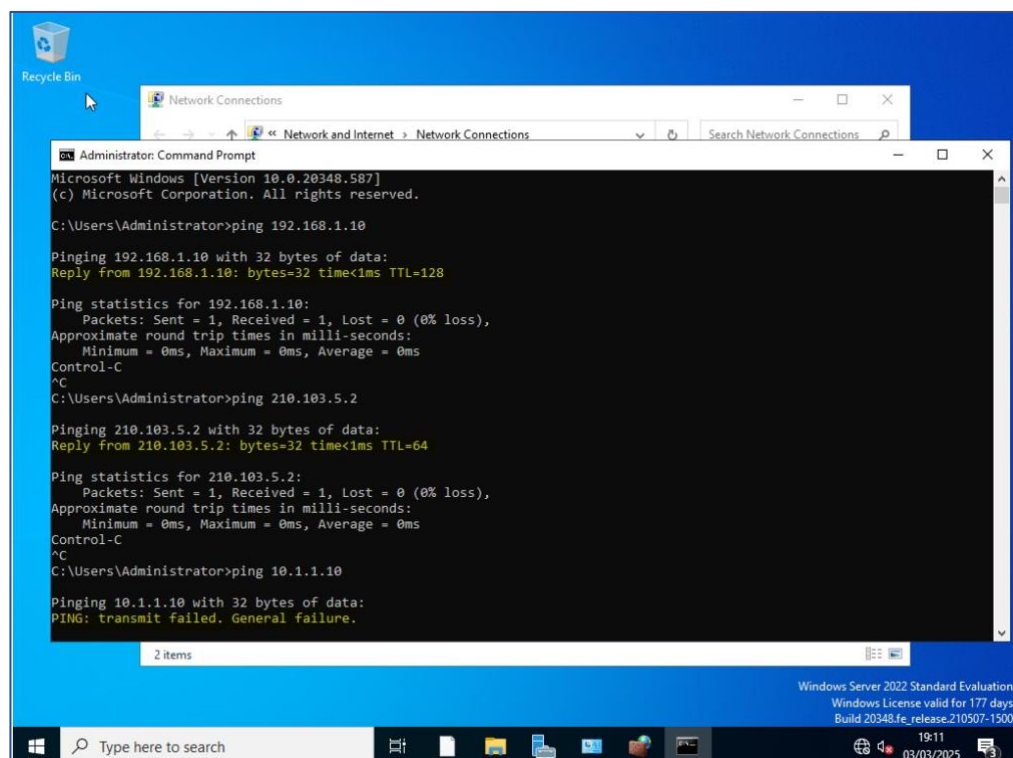


Figure 16: Windows server ping test

Then, we did the same for the client and the ping was successful with the server and we tested to ping with Debian and its client, but it didn't connect because it is a different network.

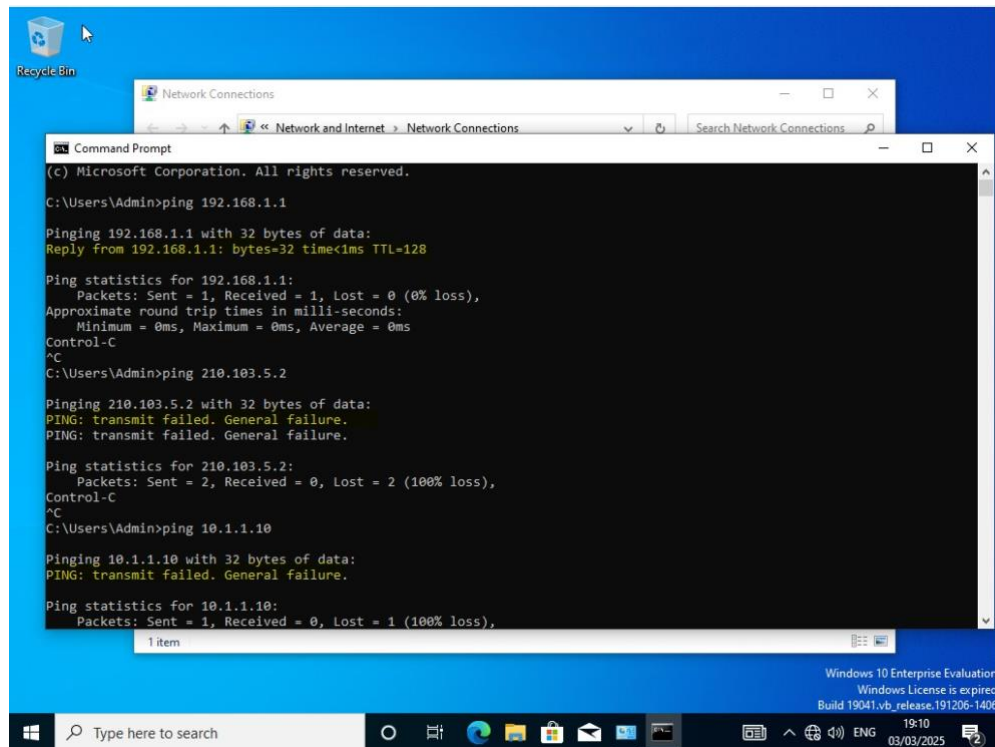


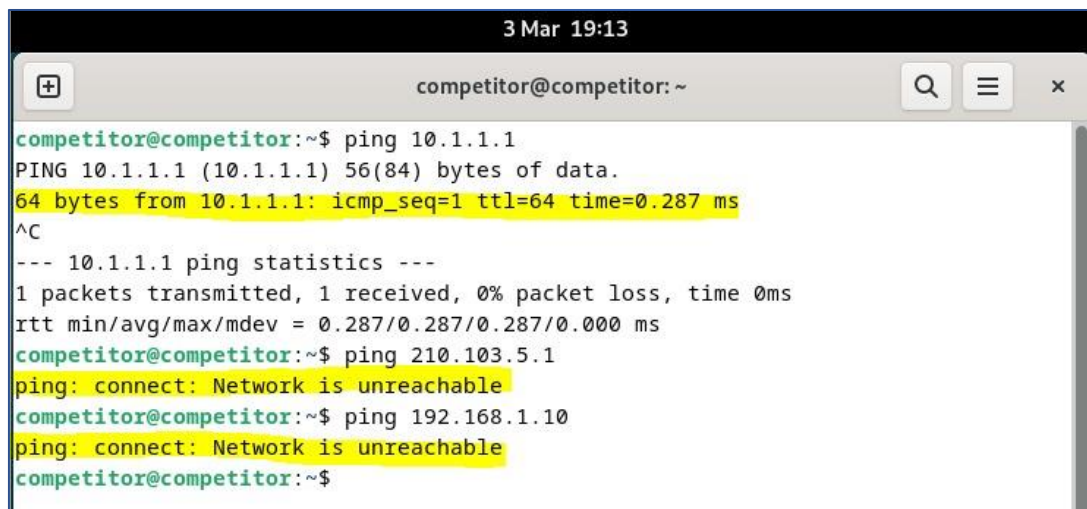
Figure 17: Windows client ping test

We did the ping test on Linux OS's and for Debian both the connectivity with the external network and the Linux client were successful but the connection with Windows client failed.

```
competitor@competitor:~$ ping 210.103.5.1  
PING 210.103.5.1 (210.103.5.1) 56(84) bytes of data.  
64 bytes from 210.103.5.1: icmp_seq=1 ttl=128 time=0.437 ms  
^C  
--- 210.103.5.1 ping statistics ---  
1 packets transmitted, 1 received, 0% packet loss, time 0ms  
rtt min/avg/max/mdev = 0.437/0.437/0.437/0.000 ms  
competitor@competitor:~$ ping 192.168.1.10  
ping: connect: Network is unreachable  
competitor@competitor:~$ ping 10.1.1.10  
PING 10.1.1.10 (10.1.1.10) 56(84) bytes of data.  
64 bytes from 10.1.1.10: icmp_seq=1 ttl=64 time=0.458 ms  
64 bytes from 10.1.1.10: icmp_seq=2 ttl=64 time=0.203 ms  
^C  
--- 10.1.1.10 ping statistics ---  
2 packets transmitted, 2 received, 0% packet loss, time 1022ms  
rtt min/avg/max/mdev = 0.203/0.330/0.458/0.127 ms  
competitor@competitor:~$ date  
Mon 3 Mar 19:12:23 GMT 2025  
competitor@competitor:~$
```

Figure 18: Linux server ping test

Finally, we tested Ubuntu connectivity, it succeeded to ping with Debian, but it didn't connect with the external network and Windows client.

A screenshot of a Linux terminal window titled "competitor@competitor: ~". The window shows the output of a ping command to 10.1.1.1, which is successful. It then shows ping statistics for 10.1.1.1. Finally, it shows two failed ping attempts to 210.103.5.1 and 192.168.1.10, both resulting in "Network is unreachable".

```
3 Mar 19:13
competitor@competitor: ~
competitor@competitor:~$ ping 10.1.1.1
PING 10.1.1.1 (10.1.1.1) 56(84) bytes of data:
64 bytes from 10.1.1.1: icmp_seq=1 ttl=64 time=0.287 ms
^C
--- 10.1.1.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.287/0.287/0.287/0.000 ms
competitor@competitor:~$ ping 210.103.5.1
ping: connect: Network is unreachable
competitor@competitor:~$ ping 192.168.1.10
ping: connect: Network is unreachable
competitor@competitor:~$
```

Figure 19: Linux client ping test

III. Reflections

1. Technical reflections

During this coursework, I had some issues particularly with backing up the OS's. Instead of making a copy of my work and keeping it on the One Drive, I was moving my files which caused problems that forced me to download and set up the OS's again. Because it persisted, I had to switch to another computer to continue my work.

2. Personal reflection

Before this course, I had no experience with networking, making it a bit challenging at first. However, working on this coursework on my own pushed me to research and experiment which helped me learn a lot about networking.

IV. References

- (1) VMware: <https://www.vmware.com/topics/hypervisor#>
 - (2) Fortinet: [https://www.fortinet.com/resources/cyberglossary/what-is-ip-address#:~:text=What%20is%20the%20use%20of,%2Darea%20networks%20\(LANs\).](https://www.fortinet.com/resources/cyberglossary/what-is-ip-address#:~:text=What%20is%20the%20use%20of,%2Darea%20networks%20(LANs).)
 - (3) NordVPN: <https://nordvpn.com/fr/blog/types-of-ip-addresses/>
 - (4) CISCO: <https://www.cisco.com/c/en/us/solutions/small-business/resource-center/networking/how-does-a-router-work.html#:~:text=Routers%20connect%20computers%20and%20other,computers%20get%20priority%20over%20others.>
 - (5) Cloudflare: <https://www.cloudflare.com/fr-fr/learning/network-layer/what-is-a-subnet/>
 - (6) CISCO: <https://www.cisco.com/c/en/us/products/routers/what-is-routing.html>
 - (7) TechTarget: <https://www.techtarget.com/searchnetworking/answer/Static-and-dynamic-routing#:~:text=Static%20routing%20uses%20preconfigured%20routes,do%20the%20two%20methods%20differ%3F&text=Static%20routing%20and%20dynamic%20routing,a%20packet%20toward%20its%20destination.>
 - (8) CISCO: https://www.cisco.com/c/en/us/td/docs/switches/lan/catalyst9400/software/release/16-12/configuration_guide/rtnng/b_1612_rtnng_9400_cg/configuring_ospf.pdf
 - (9) Meta: <https://research.facebook.com/publications/running-bgp-in-data-centers-at-scale/>
 - (10) Microsoft: <https://azure.microsoft.com/en-us/resources/cloud-computing-dictionary/what-is-vpn#:~:text=A%20VPN%2C%20which%20stands%20for%20virtual%20private%20network%2C%20protects%20its,could%20benefit%20from%20a%20VPN.>
 - (11) Microsoft : <https://learn.microsoft.com/en-us/windows-server/networking/technologies/dhcp/dhcp-top>
 - (12) Microsoft : <https://learn.microsoft.com/en-us/windows-server/identity/ad-ds/get-started/virtual-dc/active-directory-domain-services-overview>
 - (13) digicert : <https://www.digicert.com/blog/what-is-a-certificate-authority>
- Allan Johnson, CISCO, *Enterprise Networking, Security, and Automation*
 - Networking Academy, CISCO, *Introduction to Networks*
 - Networking Academy, CISCO, *CCNAv7: Switching, Routing, and Wireless Essentials*