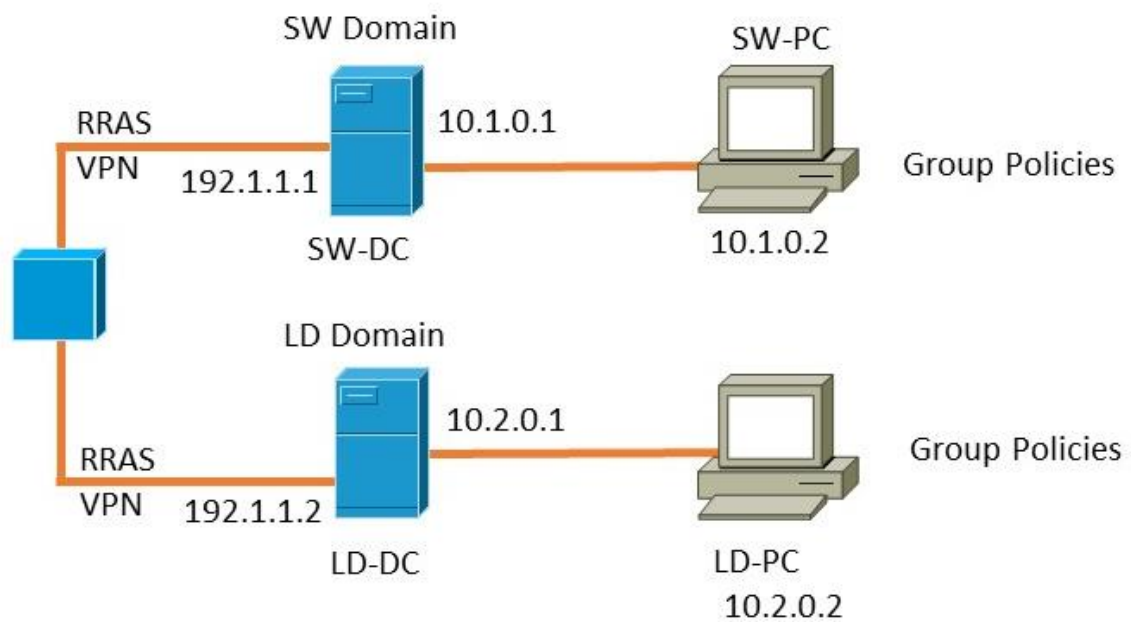




Network Operating Systems and Services

Build, and deploy, a Type 2 Hypervisor platform based Virtualised network.



Summary

1) Hypervisor.....	3
a) Introduction.....	3
b) Types of Hypervisors and architecture.....	3
c) Hypervisor of type 1 or 2?.....	4
d) Conclusion on Hypervisor.....	5
2) Choice of the Hypervisor.....	5
a) Features.....	5
b) Oracle VM VirtualBox Manager.....	6
3) Machines setup.....	6
4) Network setup.....	7
5) IP Addressing.....	10
a) Internet Protocol.....	10
b) Subnetting.....	11
c) IPv4 and IPv6.....	11
6) IP addresses configuration.....	12
7) Troubleshooting and network testing.....	13
7.2) Connectivity.....	14
Sources.....	17

1) Hypervisor

a) Introduction

Hypervisor, also known as Virtual Machine Monitor (VMM) is a computer software that can runs virtual machines. Virtual Machines are virtualized computers: it means that they are an isolated and virtualized environment working in a physical machine, thus used as emulation of an actual physical computer. Hypervisor are using the concept of virtualization: it makes it possible to run multiple machines with different operating system on a single hardware. Hypervisor manages the virtual machine and the physical hardware. They run their own operating system (Windows, Linux...) but use the equipment of the physical machine they belong to (CPU, RAM, hard drive...). [1-4]

b) Types of Hypervisors and architecture

There are two types of hypervisors:

- Type 1 Hypervisor:

Named “bare metal” hypervisor, they run directly on the physical host machine, it means that the hardware is used only for virtualization. It does not allow any other applications to run on it. Hypervisors of type 1 are mostly used in business environment to virtualize company services. The most common Type 1 Hypervisors are: KVM, Red Hat Virtualization, Citrix XenServer, Microsoft Windows Server Hyper-V, and VMware ESXI. [1-5]

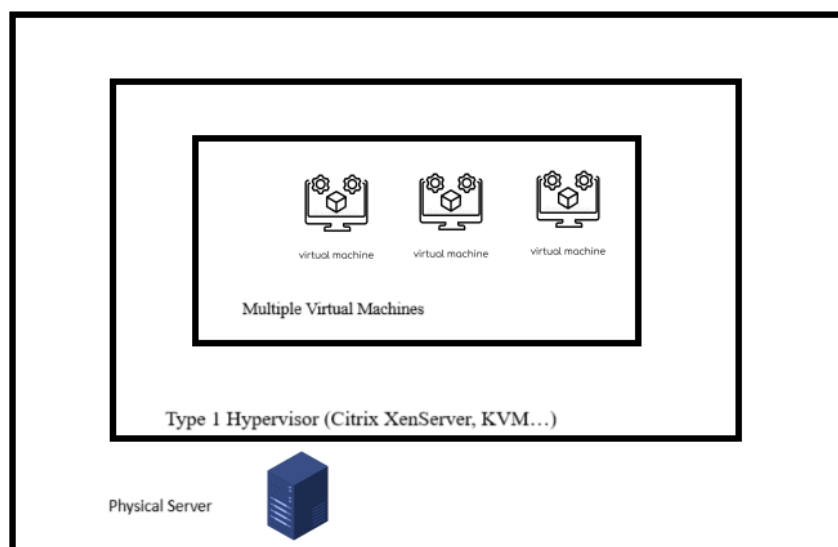


Figure 1, diagram I made to understand architecture of Type 1 Hypervisor

- Type 2 Hypervisor:

They run on top of the operating system; they are hosted hypervisor. It means that they run like an application. They share the equipment of the computer they run on, but the hosting operating system will always focus on his functions and applications, that is Type 2 Hypervisor are less powerful than Type 1. They are usually used for specific uses cases, for example to test applications in an isolated environment. The most common Type 2 Hypervisors are: Microsoft Virtual PC, Oracle Virtual Box, VMware Workstation. [1-5]

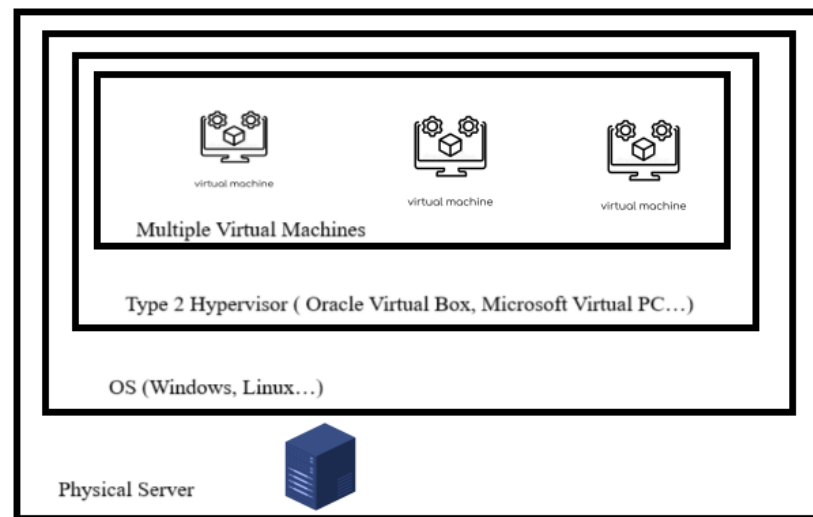


Figure 2, diagram I made to understand architecture of Type 2 Hypervisor

- Hybrid Hypervisor:

Also called type 1.5 Hypervisor, are a compromise between type 1 and 2 Hypervisors. They run on a minimal host operating system, optimized for virtualization and with direct access to the hardware. [6] The hypervisor controls the CPU and the memory directly, and the service OS provides guests access to input/output devices. [7]

- c) Hypervisor of type 1 or 2?

As said previously, the aim of type 1 and 2 Hypervisors is to run virtual machines, but the main difference between the two types is on one hand, type 1 directly run on the physical machine (they have access to hardware resources), and on the other, type 2 run like it is an application and get along with the other things the system must deal with. That is why, type 1 is much more powerful and efficient than type 2 hypervisors.

In fact, it is the same for resources allocation. Type 1 have directly access to machine resources and can apply their own strategies of resources management. Contrary, type 2 must negotiate with the operating system to share resources allocation and it means lower efficiency.

Then, type 1 Hypervisor are usually used for huge workloads with large quantities of resources. Type 2 Hypervisors are used for development environments, testing...

Another advantage of type 1 Hypervisors is the security, (way more secure than type 2),

because no other application is running.

Finally, type 1 Hypervisors are much more difficult to administrate than type 2 and needs certain knowledge due to its complexity. [8]

d) Conclusion on Hypervisor

Finally, Hypervisor and Virtual Machines are great alternatives to physical machines for both organizations and individual users: they are very flexible. By running multiple virtual machines, it improves workloads, less energy consumption, less infrastructures cost, and maintenance by using fewer overall servers, (one physical machine with multiple virtual machines instead of multiple physical machines) [9]. However, we must be careful with risk regarding security, a machine that can run multiple virtual machines is more vulnerable than a single physical machine. In the same way, if the physical machine is broken down, you can not access anymore to the virtual machines. [10]

2) Choice of the Hypervisor

As an IT-professional hired by a Multinational Corporation, we must choose wisely our Hypervisor to bring up the best solution:

a) Features

Hypervisors have specific hardware requirements.

The Microsoft Hypervisor (Hyper-V) is a type 1 Hypervisor. To run properly, it needs: a 64-bit processor with second-level address translation (SLAT), and at least 4GB of RAM [11]. It offers:

Live and storage migration (a very useful feature that makes it possible to move running Virtual Machines from one Hyper-V host to another one and it is the same principle for the storage), it also offers VM Replication, dynamic memory, extensible virtual switch, high availability.

It can scale up to 320 logical processors, with 4TB of memory, 2048 virtual CPUs per host, 64 vCPUs per Virtual Machines, and 64 nodes / 8000 Virtual Machines per cluster. [12]

Likely for a VMware Hypervisor called VMware SD-WAN, the minimum requirements are very specific: CPU Intel XEON with 10 cores minimum to run a single 8-core gateway Virtual Machine. A minimum of 4GB free RAM must be available for the server system aside from the memory assigned to the PGW (Packet Data Network Gateway) Virtual Machines and one gateway requires at least 16GB RAM... [13]

We can conclude that such features are useful for organizations with large workload and cannot be managed by a PC-user.

On the other hand, VirtualBox, a type 2 Hypervisor developed by Oracle is way more flexible:

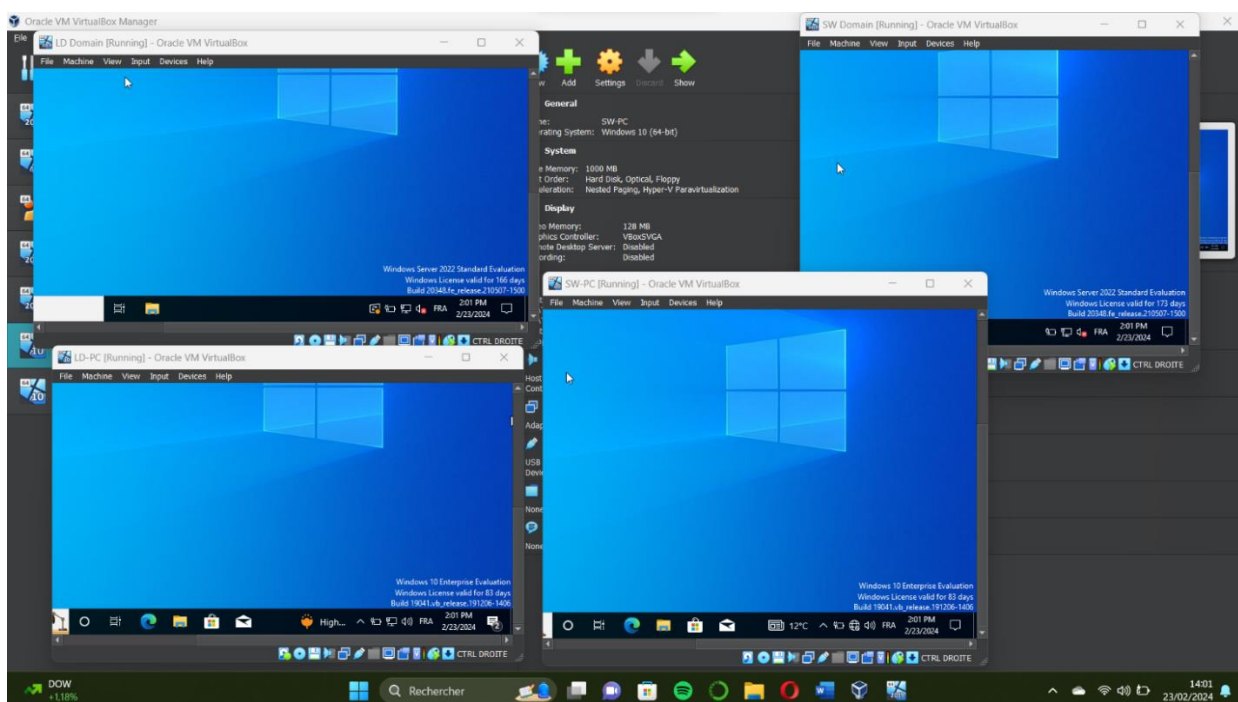
It supports 32- and 64-bit version of Windows It runs on Intel and AMD processors even if they don't support their manufacturers' VT-x or AMD -V virtualization technologies. It only needs at least 1GB of RAM to run the software (in addition to what is needed to support the computer processes) [14]. The VirtualBox installer is less than 100MB and even if it needs space to install Windows or Linux to run virtual computers you do not need that much space as the previous examples of type 1 Hypervisor required. This kind of requirement are easily reachable for a PC-user,

b) Oracle VM VirtualBox Manager

After various research, I have chosen to use a type 2 Hypervisor called VM VirtualBox Manager developed by Oracle (we already have started to discuss about it above). We know that a PC-user like me requires type 2 Hypervisor. Then this Hypervisor is completely free and still offers multiple features: Portability (can run alongside existing applications on my host). It does not require hardware virtualization (such as Intel VT-x or AMD-V). Guest additions with shared folders, seamless windows..., It also offers great hardware support with Guest multiprocessing, USB device support, hardware compatibility, full ACPI support, multiscreen resolutions. It has Multigeneration branched snapshots (allows to go back in time and revert the virtual machine to any such snapshot). [15]

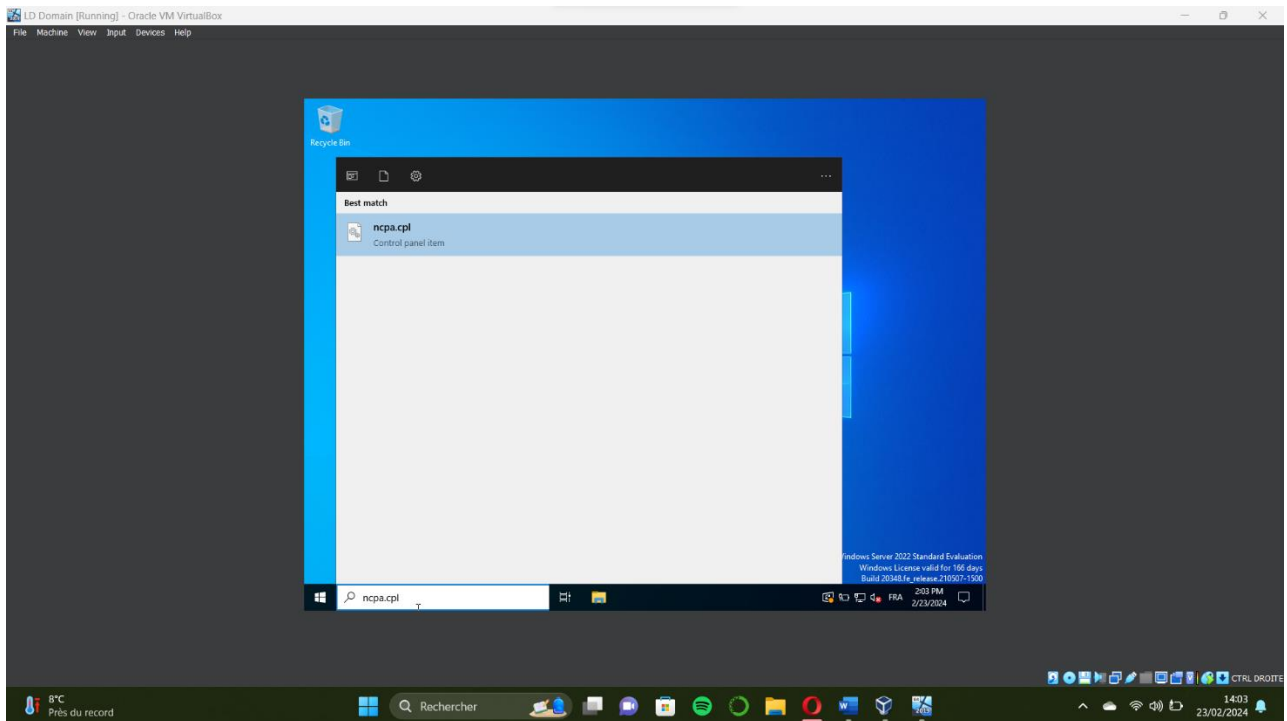
Finally, the well designed and defined internal programming interface makes it very easy to use VM VirtualBox Manager, and it does not need as much knowledge as a type 1 needs, that is why I choose this Hypervisor.

3) Machines setup

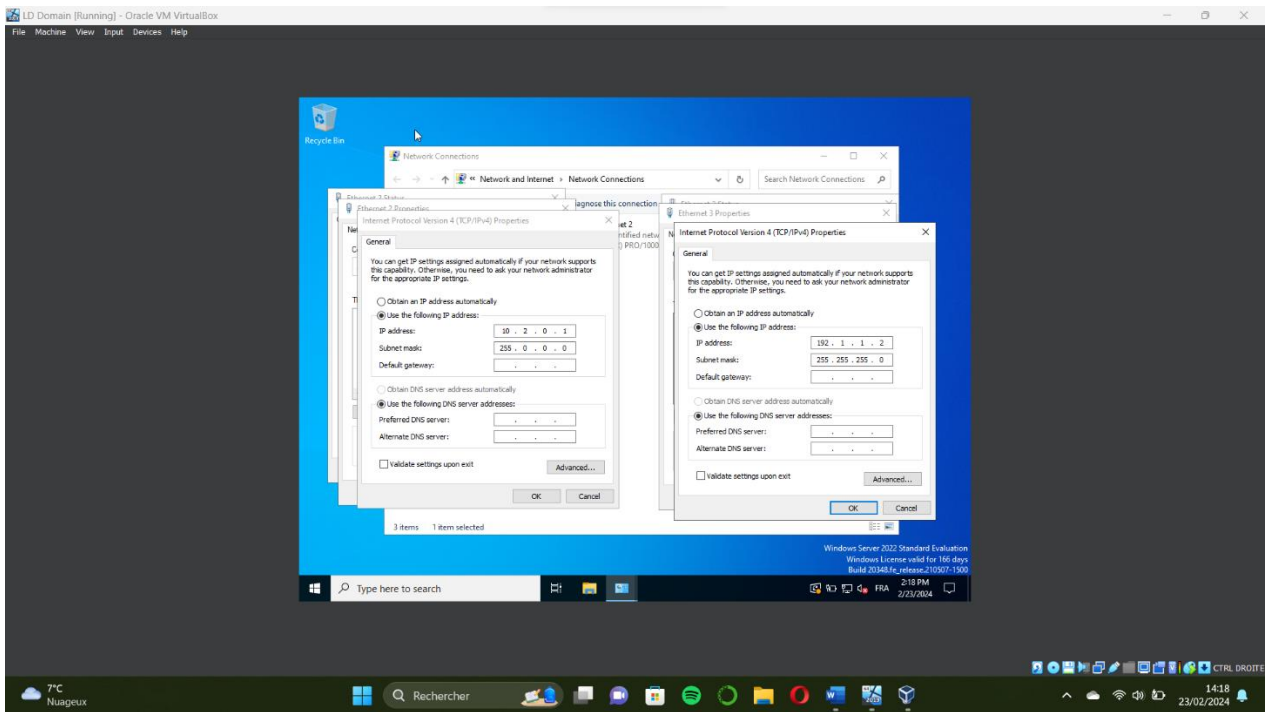


To setup the virtualized network, I downloaded iso files: Windows Server 2022 (64-bit) and Windows Client 10 (64-bit). They are all running properly, and we can now start to configurate them.

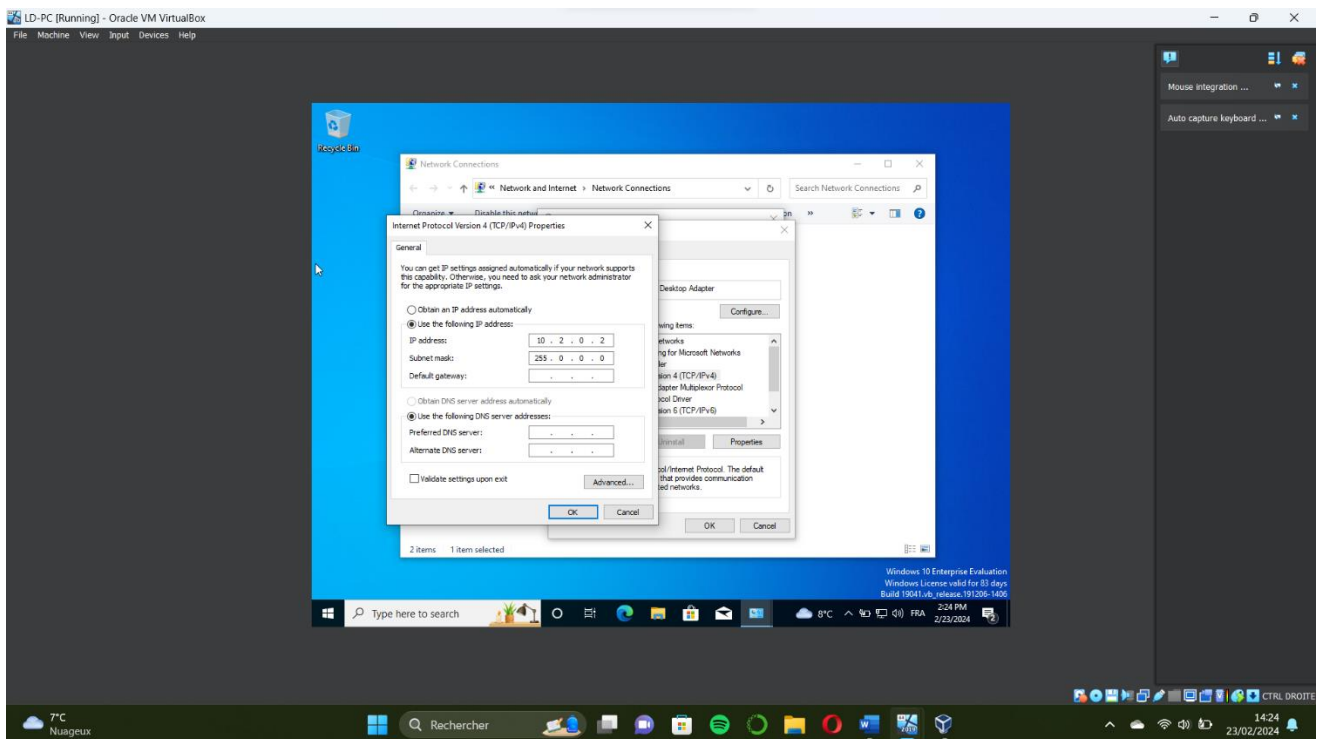
4) Network setup



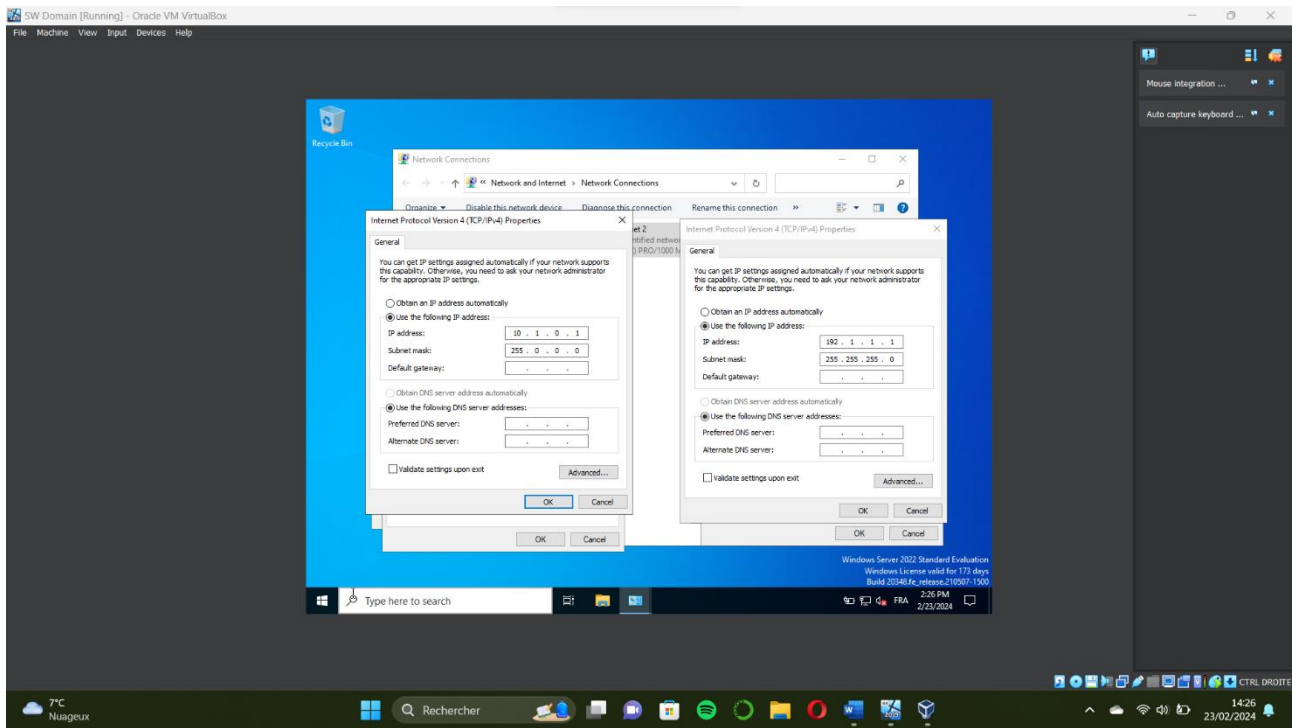
Using the ncpa.cpl command we have direct access to the network connections. Then we type the IP Adresses as the given topology ask:



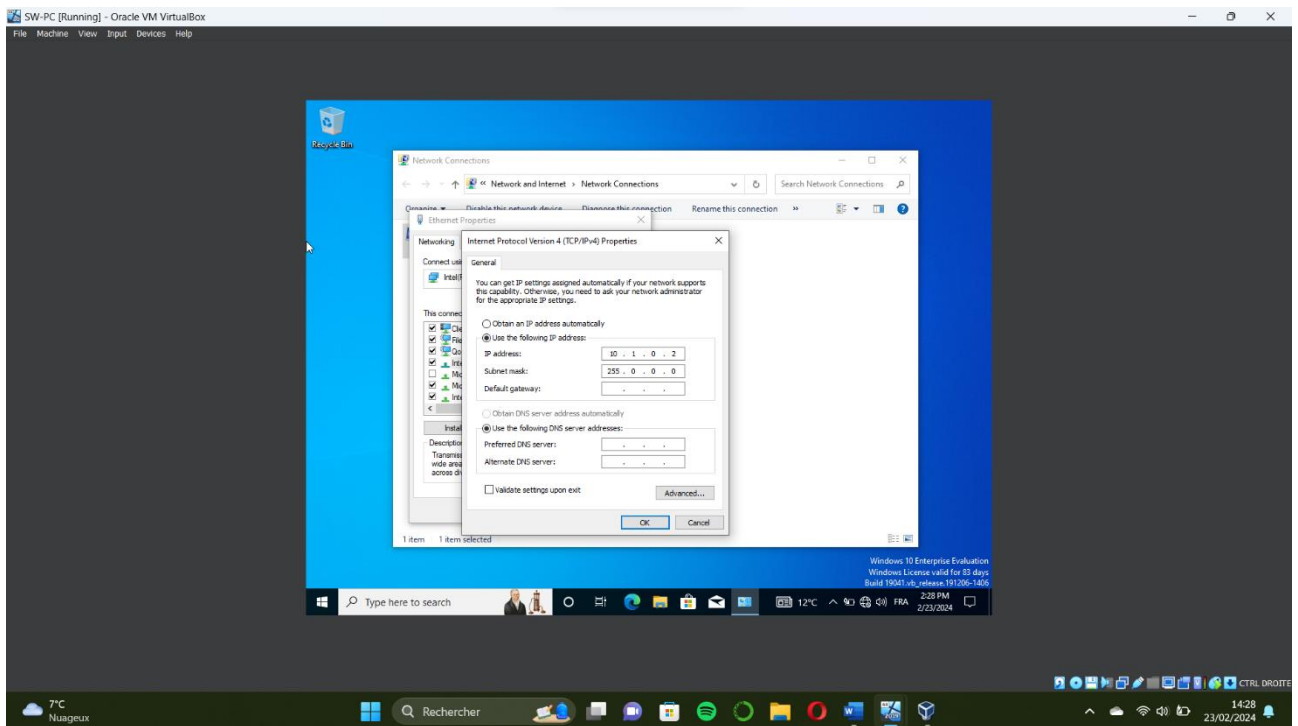
IP Address configuration for LD Server



IP Address configuration for LD Machine



IP Address configuration for SW Server



IP Address configuration for SW Machine

5) IP Addressing

a) Internet Protocol

To send data from one computer to another on the internet, it uses a method called Internet Protocol (IP). This set of rules, (commonly referred to as TCP/IP), is essential so the data can travel across the network and arrive to the correct destination. Each computer has an IP address that identifies it from all other computers. The principal task of it is the identification of a host, or a network, and identifying the location of a device. [16-18] IP address is a primary component of communication: it provides the network and host information.

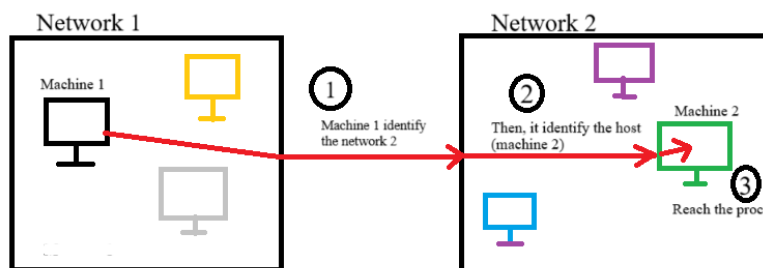


Figure 3, Diagram of communication establishment between a computer 1 and a computer 2

An IP address is a 32-bit number in dotted decimal format and is expressed as a set of four numbers (separated by periods). The decimal numbers separated by periods are the octets converted from binary to decimal notation, each number in the set can range from 0 to 255 (with 8 bits, you can have $2^8=256$ possible values).

The IP address space is managed by the Internet Assigned Numbers Authority (IANA), and by five regional Internet registries (RIRs) that are responsible for assignment to local Internet registries. [18]

For example, an IP address, can be: 192.168.101.156. It has two parts, the first is used as a network address and the second as a host address. Here 192.168.101.0 is the network address and 0.0.0.156 is the host address. [16]

Then, the subnet mask is used to determine whether the host is on a local subnet or on a remote network. Subnetting is the technique for logically partitioning a single physical network into multiple smaller sub-networks [19]. Network and host addresses are the part of IP addresses that are not fixed. They are determined by the subnet mask, another 32-bit number, that sets host bits to all 0s and network ones by 1s.

b) Subnetting

IP addresses are divided into 5 classes: A, B, C, D and E (but only A, B and C are the most common and used).

- Class A networks use a default subnet mask 255.0.0.0 (0-127 at their first octet)
- Class B networks use a default subnet mask 255.255.0.0 (128-191)
- Class C networks use a default subnet mask 255.255.255.0 (192-223)

For our example above, 192.168.101.156 is a class C network.

Subnetting makes it easier to narrow down the IP address to a limited range of devices.

With Subnetting, comes routers. Routers are devices that connect two or more packet-switched networks or subnetworks. Their tasks are to manage traffic between the networks or subnetworks and to allow multiple devices to use the same Internet connection.

Routers usually pass data through local area networks (LANs) and wide area networks (WANs), that are respectively a group of connected devices in a specific geographic area for LANs and over vast geographic area for WANs.

A router directs packets into their destination. Using an internal routing table, the router reads the packet's header and after consulting his routing table, it determines the path to forward packets to.[20]

Then, a switch will only send data to a single device, (not to multiple devices like routers).

Network switches use MAC addresses and not IP addresses. MAC addresses are unique physical addresses that are required to locate the device, and they are not part of Internet traffic. Switches use MAC addresses tables to direct traffic in a local network.

c) IPv4 and IPv6

Nowadays, IPv4 is the fourth version of the IP. Deployed for the first time in 1983 on the ARPANET, it routes most of the internet traffic thanks to its ease of deployment. As we saw earlier, IPv4 addresses are 32-bit integers in dotted decimal format (ex: 192.150.10.153), it provides 4,294,967,296 unique addresses (we have $2^{8 \times 4}$ because four 8-bit octets). In the four billion, about 18 million are reserved for private networks use [21]. IPv4s addresses are facing challenges and particularly the address space exhaustion: There are not enough IPv4 addresses available for all IP use cases (private IP addresses, public, dynamic, static, shared...) and in 2011 the last unique IP addresses were allocated. To solve this exhaustion,[22]

IPv6 addresses are being introduced in the communication protocols. It is the most recent version of IP, and it allows 3.4×10^{38} addresses. The main issue with this IP is that it is not designed to be interoperable and direct communication between IPv4 and IPv6 is impossible. IPv6 are represented as eight groups of four hexadecimal digits (separated by colons): 1050:0000:0000:0000:0005:0600:300c:326b is an IPv6 address.

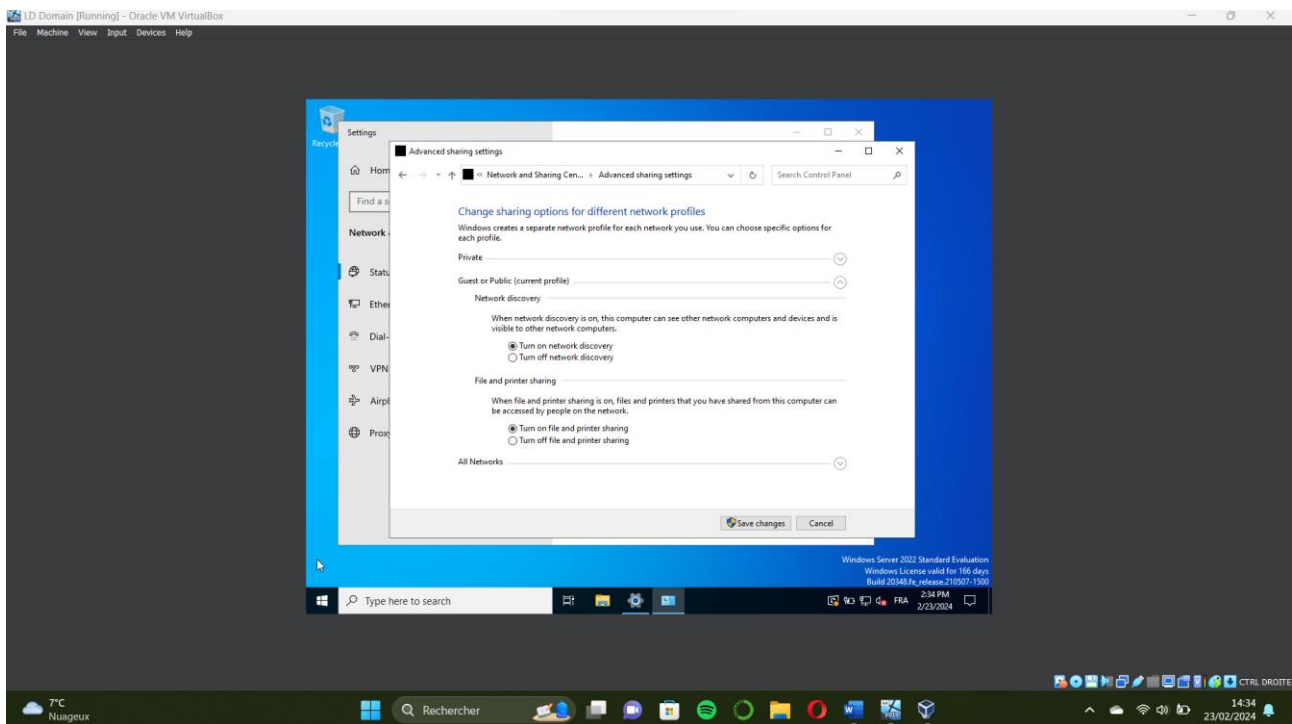
IPv6 addresses offer more addresses and more features: It simplifies address configuration, network renumbering, processing of packets, end-to-end connectivity, auto-configuration, the information in the front part of the header is enough for quick routing decisions, thus it is faster forwarding or routing, and finally it is more secure by using Internet protocol security (IPSec), it is used as the network processing layer to secure the network.[23-24]

In conclusion, IP addressing is essential for the functionality and effectiveness of the

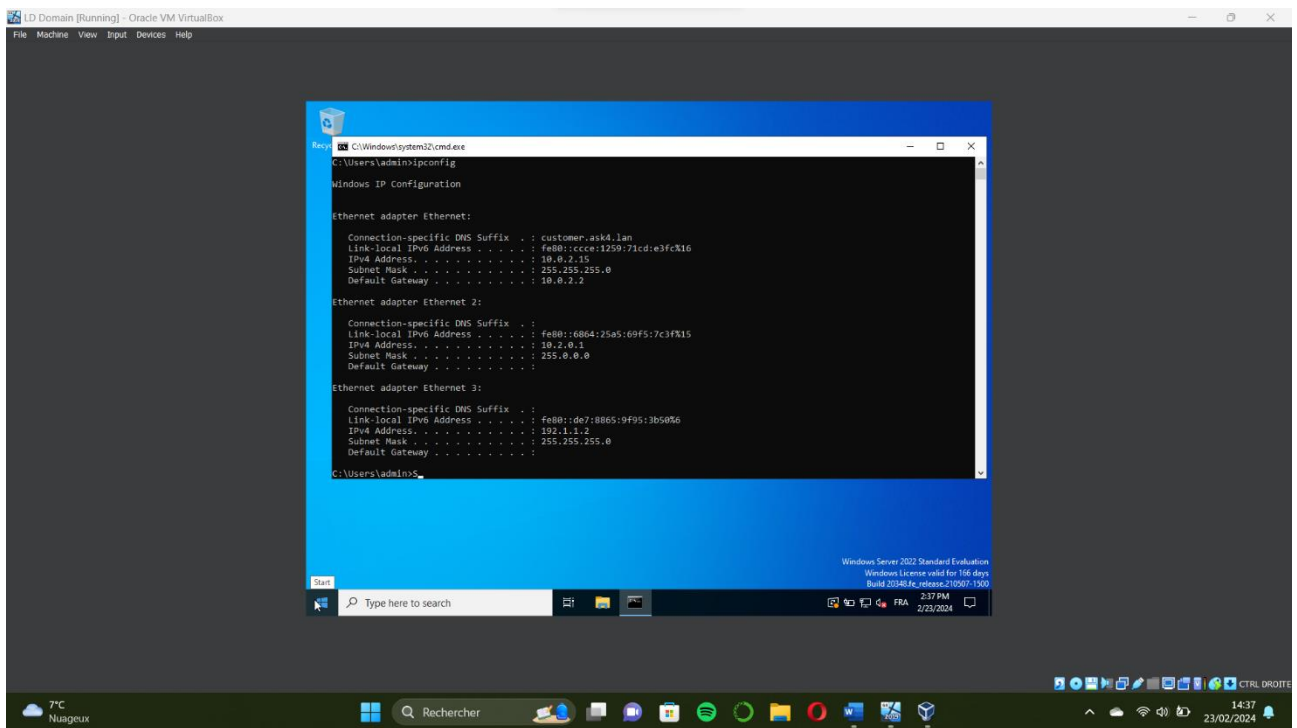
network. By identifying the host, and locating the location, IP addresses are mandatory components of communication and enable transmission of data across the Internet. Routers and switches facilitate data flow between networks. However, IP addresses are facing challenges, especially for IP exhaustion, and vulnerability exploits, DDoS attacks that shutdown the network..., and deployment of IPv6 should be the long-term solution for these challenges.

6) IP addresses configuration

To communicate with other machine, we must turn on the Change sharing options for different network profiles.



With the command terminal, typing ipconfig we can see the ip addresses of the server.



7) Troubleshooting and network testing

Network troubleshooting is the systematic process of identifying, analysing, and resolving network issues [25]. Troubleshooting means to rectify problems related to connectivity, security, or performance, (all aspects linked to network).

IP network problems are linked with incorrect configuration:

- Incorrect Subnet Mask
- Incorrect IP Address
- Incorrect Default Gateway

If computers with IP addresses that are not in the same IP subnet, they will not be able to communicate. To correct this, it must be corrected in a way that all the IP addresses are on the same IP subnet. Same for the Subnet Mask, it has to be the same one for all the computers.

There are multiple network troubleshooting tools:

- Ping
- Tracert/ Trace Route
- Ipconfig/ ifconfig
- Netstat
- Nslookup
- Pathping/ MTR
- Route
- PuTTY

The Ping tool is a network troubleshooting tool that let you assess if a device is reachable on

the network, that means to verify that the target host is available. It reports on error such as packet loss, round-trip-time... [26]

Ping works by sending an Internet Control Message Protocol (ICMP) echo request to a specified device on the network. When the target host receives the echo request, it responds by sending an echo reply packet.

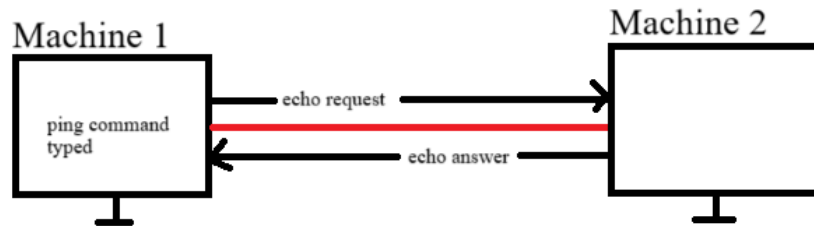
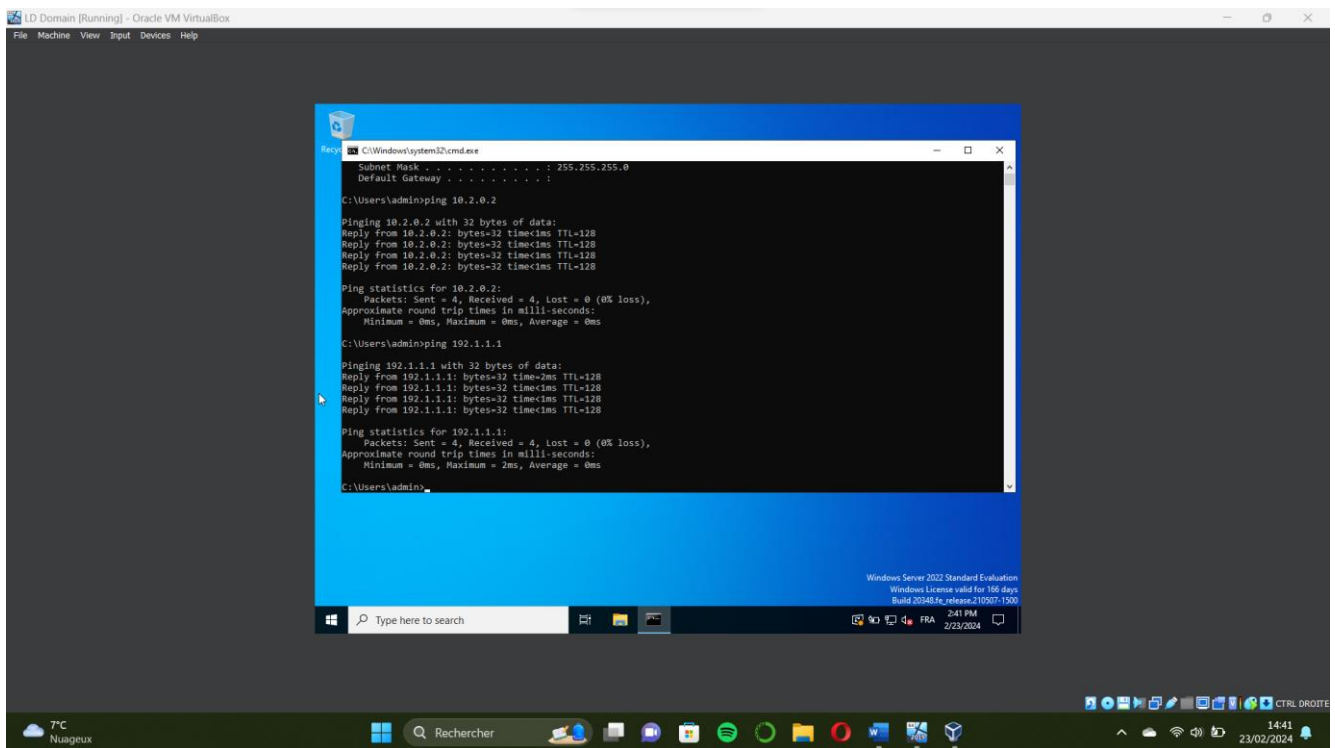


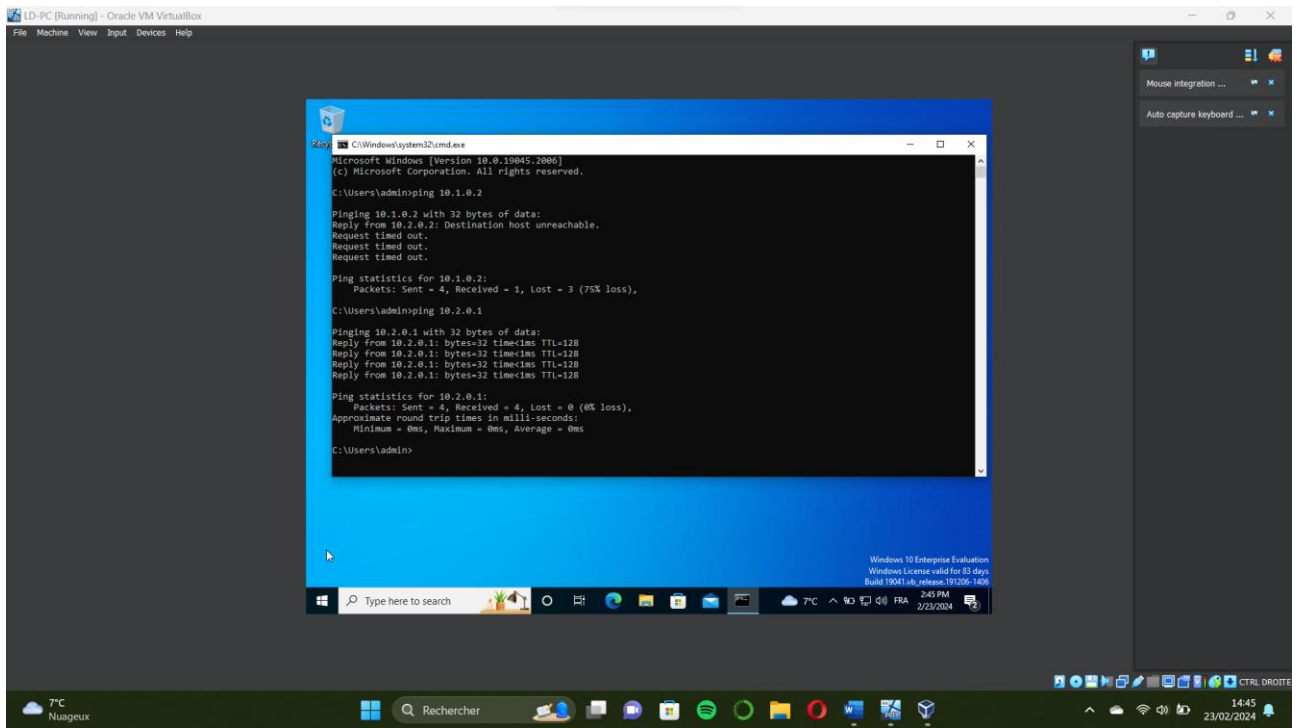
Figure 4, ping troubleshooting tool

7.2) Connectivity

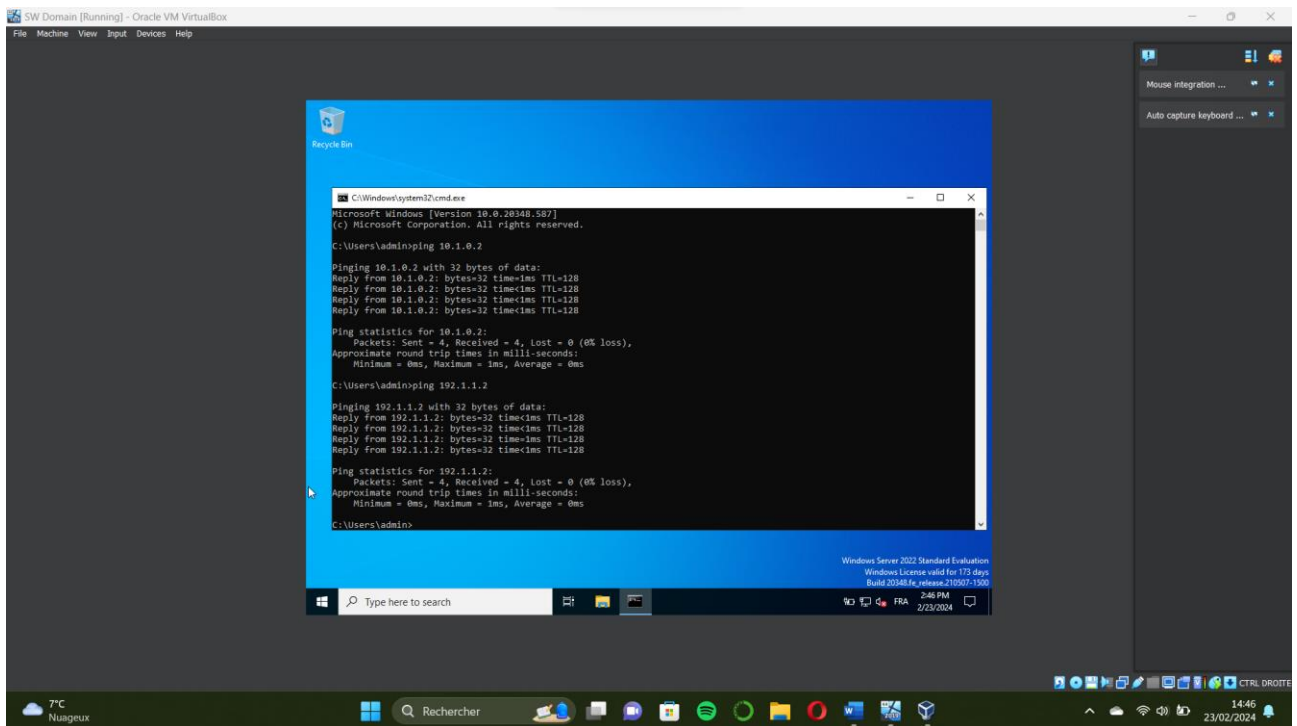
To prove the connectivity, we use the command ping as discussed above.



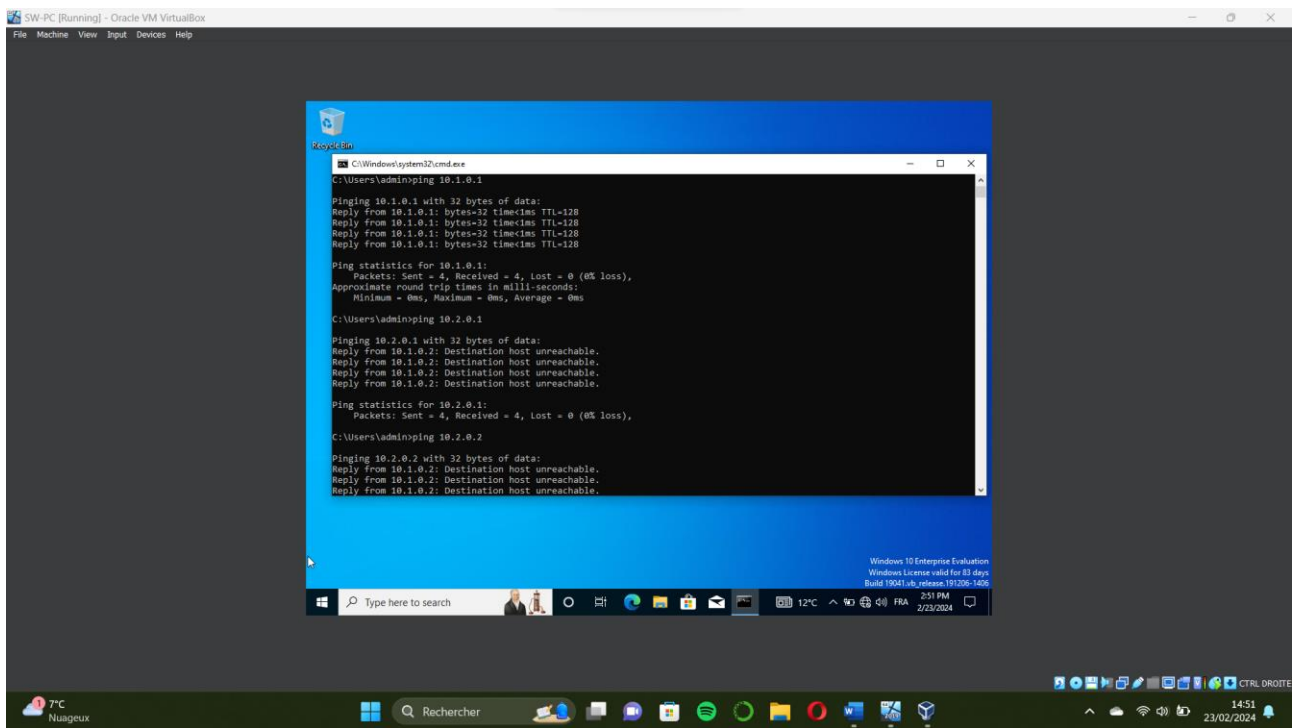
We can see with this screenshot that the pings sent have been received with 0% loss, so everything works. The LD Server can communicate with the SW Server and the LD Machine.



For the LD Machine, everything is working too. It can not ping the other machine (SW-PC) and is able to communicate with the LD Server.



For the SW Server, everything is working too, it can communicate with the LD Server and with the SW Machine.



Finally, it is working for the SW Machine: It can communicate with the SW Server but not with the LD Server and LD Machine.

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