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REDES DE COMUNICAÇÕES 1

Objectives

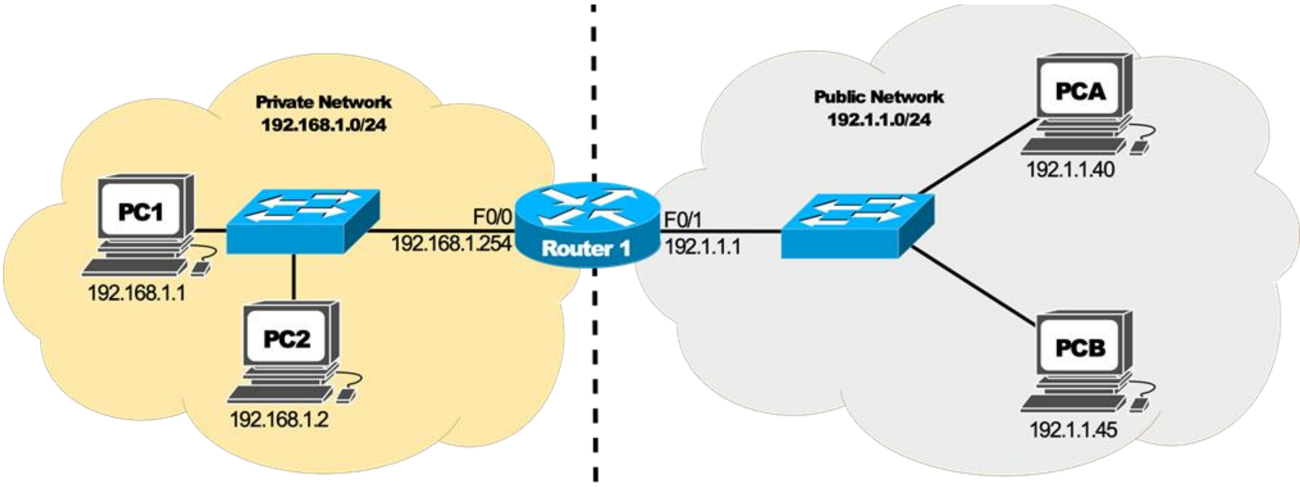
- Study of the NAT/PAT mechanisms.
- Study of DHCP.
- Study of IPv6.

Duration

- 2 weeks

Dynamic NAT

1. Assemble and configure (using the GNS3 and VPCS hosts) the network depicted in the following figure which represents a small company network. The company decided to configure IP private addressing using the network 192.168.1.0/24 and NAT mechanism (without PAT) to manage all Internet accesses. IP addresses and the respective gateway addresses must be manually configured. The company has only 2 public addresses (192.1.1.1/24 and 192.1.1.21/24).
Consider Router 1 with the model 7200.
Configure the network and its addresses before starting the NAT configuration.



Dynamic NAT Configuration

In order to define a pool of global addresses to be allocated by the dynamic NAT process, issue the following command on Router 1:

```
Router1(config)# ip nat pool MYNATPOOL 192.1.1.21 192.1.1.21 netmask 255.255.255.0
```

that defines a pool with a single public address (192.1.1.21).

The name MYNATPOOL is the name of the address pool. The first 192.1.1.21 in the command is the first IP address in the pool, and the second 192.1.1.21 is the last IP address in the pool (this command creates a pool that contains only a single address).
Next, configure a standard access list to define which internal source addresses can be translated. Since any users on the private network are being translated, use the following command:

```
Router1(config)# access-list 2 permit 192.168.1.0 0.0.0.255
```

To establish the dynamic source translation, link the access list to the name of the NAT pool, as shown in the following:

```
Router1(config)# ip nat inside source list 2 pool MYNATPOOL
```

Finally, specify an interface on the Router to be used by inside network hosts requiring address translation:

```
Router1(config)# interface f0/0
                #change the interface name to the one used in your router
Router1(config-if)# ip nat inside
```

Also, specify an interface to be used as the outside NAT interface as follows:

```
Router1(config)#interface f0/1
                #change the interface name to the one used in your router
Router1(config-if)#ip nat outside
```

2. Start a packet capture on the public network and another on the private network. At PC1 execute a ping to 192.1.1.45, and on PC2 execute a ping to 192.1.1.45. Verify (on the router) the active NAT

translations and NAT activity statistics, use the commands

```
Router1# show ip nat translations
Router1# show ip nat statistics
```

>> Which packets had the source IP addresses translated? Explain the obtained results.

3. Execute on the router the command to clear the NAT translation table:

```
Router1# clear ip nat translation *
```

and execute again at PC2 a ping to 192.1.1.40.
>> Explain the observed results.

4. Change NAT timeout to 60 seconds and clear the NAT translations table:

```
Router1(config)# ip nat translation timeout 60
Router1# clear ip nat translation *
```

At PC1 execute a ping to 192.1.1.40, and immediately after, at PC2 execute repeatedly a ping to 192.1.1.40. How much time does it take to obtain connectivity between PC2 and host 192.1.1.40?
>> Explain the observed results.

Restore NAT timeout value to 86400 seconds (24 hours):

```
Router1(config)# ip nat translation timeout 86400
```

Dynamic NAT/PAT

5. The most powerful feature of NAT is address overloading, or port address translation (PAT). Overloading allows multiple inside addresses to map to a single global address. With PAT, the NAT router keeps track of the different conversations by mapping TCP and UDP port numbers.
After defining the pool of global addresses to be allocated by the dynamic NAT process and configuring the standard access list that defines which internal source addresses can be translated, configure address overloading on Router with the following command:

```
Router1(config)#ip nat inside source list 2 pool MYNATPOOL overload
```

Note: You may have to reset the active NAT translations: `clear ip nat translation *`
Repeat experience 2.
>>Which are the advantages of using NAT and PAT mechanisms?

6. From PC1 (and PC2) try to establish UDP and TCP connections (ports 80 and 22) to the host 192.1.1.40:

```
PC> ping 192.1.1.40 -2 -p 80          ! UDP port 80
PC> ping 192.1.1.40 -2 -p 22          ! UDP port 22
PC> ping 192.1.1.40 -3 -p 80          ! TCP port 80
PC> ping 192.1.1.40 -3 -p 22          ! TCP port 22
```

Note: The option -p must have a space after (before the port number).
>> Verify (on the router) the active NAT translations and NAT activity statistics. Explain the obtained results.

Static NAT/PAT Translations

7. Try to ping the private network machines from PCA.

8. Suppose that now you have another public IP address available (192.1.1.201), configure the router in order to allow the PCA to access PC1.
A static translation between the inside local address of a host and one of the inside global addresses can be created using the following commands:

```
Router(config)#ip nat inside source static 192.168.1.1 192.1.1.201
```

From PCA, ping PC1's static public address (192.1.1.201)

```
PCA> ping 192.1.1.201
```

>> Analyze the captured packets on the private network and explain the obtained results.
>> Discuss a scenario where static NAT/PAT is required.

2. The packets that had the source IP addresses translated were the packets from 192.168.1.1 (PC 1). PC2 couldn't make the ping because it was only defined one IP at the NAT table on the Router configuration. That's why only the PC that got registered first at the NAT translation table, is able to communicate to outside.

3. After clearing the NAT translation table I was able with PC2 to ping to 192.1.1.40 (PC A). Since there is no registered IPs at the NAT translation table, when PC2 made the ping, the Router registered his IP on his table making possible for PC2 to communicate outside. But now PC1 can't communicate.

4. Since the NAT timeout was changed to 60 seconds, it takes 60 seconds to get connectivity between PC2 and 192.1.1.40 (PC A). What it means is that the Router clears his NAT translation table after 60 seconds (clears PC1 IP).

5. Multiple internal devices share a single public IP using unique ports, conserving IPv4 addresses. Internal IPs are hidden, making it harder for external threats to directly target individual devices. Internal IPs can remain consistent, even if public IPs change, easing network expansions and transitions. Allows devices with private IPs to connect to the internet without needing unique public IPs.

6.

```
R1#show ip nat translations
Pro Inside global      Inside local       Outside local      Outside global
tcp 192.1.1.21:5449    192.168.1.1:5449   192.1.1.40:22      192.1.1.40:22
tcp 192.1.1.21:12404   192.168.1.1:12404  192.1.1.40:80      192.1.1.40:80
udp 192.1.1.21:14503   192.168.1.1:14503  192.1.1.40:80      192.1.1.40:80
udp 192.1.1.21:28458   192.168.1.1:28458  192.1.1.40:22      192.1.1.40:22
udp 192.1.1.21:22675   192.168.1.2:22675  192.1.1.40:22      192.1.1.40:22
tcp 192.1.1.21:33899   192.168.1.2:33899  192.1.1.40:80      192.1.1.40:80
udp 192.1.1.21:47570   192.168.1.2:47570  192.1.1.40:80      192.1.1.40:80
tcp 192.1.1.21:61022   192.168.1.2:61022  192.1.1.40:22      192.1.1.40:22

R1#show ip nat statistics
Total active translations: 4 (0 static, 4 dynamic; 4 extended)
Peak translations: 10, occurred 00:12:53 ago
Outside interfaces:
  FastEthernet1/0
Inside interfaces:
  GigabitEthernet0/0
Hits: 280  Misses: 0
CEF Translated packets: 280, CEF Punted packets: 35
Expired translations: 35
Dynamic mappings:
-- Inside Source
[Id: 1] access-list 2 pool MYNATPOOL refcount 4
 pool MYNATPOOL: netmask 255.255.255.0
        start 192.1.1.21 end 192.1.1.21
        type generic, total addresses 1, allocated 1 (100%), misses 35

Total doors: 0
Appl doors: 0
Normal doors: 0
Queued Packets: 0
```

7.

192.1.1.40	192.168.1.1	ICMP	98 Echo (ping) request
192.168.1.1	192.1.1.40	ICMP	98 Echo (ping) reply
192.1.1.40	192.168.1.1	ICMP	98 Echo (ping) request
192.168.1.1	192.1.1.40	ICMP	98 Echo (ping) reply
192.1.1.40	192.168.1.1	ICMP	98 Echo (ping) request
192.168.1.1	192.1.1.40	ICMP	98 Echo (ping) reply

At Private network

192.1.1.40	192.1.1.201	ICMP	98 Echo (ping) request
192.1.1.201	192.1.1.40	ICMP	98 Echo (ping) reply
192.1.1.40	192.1.1.201	ICMP	98 Echo (ping) request
192.1.1.201	192.1.1.40	ICMP	98 Echo (ping) reply
192.1.1.40	192.1.1.201	ICMP	98 Echo (ping) request
192.1.1.201	192.1.1.40	ICMP	98 Echo (ping) reply

At public network

8.

3	37.042626	ca:01:41:04:00:08	Broadcast	ARP	60 Who has 192.168.1.1? Tell 192.168.1.254
4	37.042626	Private_66:68:00	ca:01:41:04:00:08	ARP	60 192.168.1.1 is at 00:50:79:66:68:00
5	37.058132	192.1.1.40	192.168.1.1	ICMP	98 Echo (ping) request id=0xd9f7, seq=1/256, ttl=63 (reply in 6)
6	37.058132	192.168.1.1	192.1.1.40	ICMP	98 Echo (ping) reply id=0xd9f7, seq=1/256, ttl=64 (request in 5)
7	38.116620	192.1.1.40	192.168.1.1	ICMP	98 Echo (ping) request id=0xdaf7, seq=2/512, ttl=63 (reply in 8)
8	38.116620	192.168.1.1	192.1.1.40	ICMP	98 Echo (ping) reply id=0xdaf7, seq=2/512, ttl=64 (request in 7)
9	39.172599	192.1.1.40	192.168.1.1	ICMP	98 Echo (ping) request id=0xdbf7, seq=3/768, ttl=63 (reply in 10)
10	39.172599	192.168.1.1	192.1.1.40	ICMP	98 Echo (ping) reply id=0xdbf7, seq=3/768, ttl=64 (request in 9)
11	40.228620	192.1.1.40	192.168.1.1	ICMP	98 Echo (ping) request id=0xdcf7, seq=4/1024, ttl=63 (reply in 12)
12	40.228620	192.168.1.1	192.1.1.40	ICMP	98 Echo (ping) reply id=0xdcf7, seq=4/1024, ttl=64 (request in 11)
13	41.285624	192.1.1.40	192.168.1.1	ICMP	98 Echo (ping) request id=0xddf7, seq=5/1280, ttl=63 (reply in 14)
14	41.285624	192.168.1.1	192.1.1.40	ICMP	98 Echo (ping) reply id=0xddf7, seq=5/1280, ttl=64 (request in 13)

ARP Requests and Responses:

ARP Request: The capture shows that an ARP request was sent to identify the MAC address of 192.168.1.1 (PC1's IP) from 192.168.1.254 (Router 1's private interface).
ARP Reply: PC1 responds with its MAC address to Router 1, establishing between them communication.

ICMP Requests and Replies:

ICMP Request: We see a series of ICMP requests from 192.1.1.40 (PCA's IP) directed to 192.1.1.201, which gets translated by NAT on Router 1 to reach PC1 as 192.168.1.1.
ICMP Reply: PC1 responds to each ICMP request, and the reply goes back to PCA.

The successful sequence of ICMP requests and replies confirms that:

NAT is functioning correctly: The static NAT rule is translating 192.1.1.201 to 192.168.1.1 for requests and vice versa for replies.

A scenario where static NAT/PAT is required is when a company hosts a web server or application server on its private network that needs to be accessible from the internet. By using static NAT, the server is assigned a consistent public IP, allowing external users to reach it without exposing the private network's internal IP addresses.

DHCP

9. Configure Router 1 as DHCP server for the private network. Assume that you want to dynamically assign addresses from the range 192.168.1.100 to 192.168.1.200.

```
Router1(config)# service dhcp
Router1(config)# ip dhcp excluded-address 192.168.1.1 192.168.1.99
Router1(config)# ip dhcp excluded-address 192.168.1.201 192.168.1.254
Router1(config)# ip dhcp pool 1
Router1(dhcp-config)#network 192.168.1.0 255.255.255.0
Router1(dhcp-config)#default-router 192.168.1.254
```

Adicionar ainda => lease 0 0 1 (dias horas minutos)

Use the following commands to verify the configuration and status of the DHCP server:

```
show ip dhcp pool
show ip dhcp server statistics
show ip dhcp binding
```

10. Start a capture on Router 1's F0/0 interface. Configure PC1 to acquire the IPv4 address dynamically:

```
PC1> ip dhcp
```

Configure PC1 to renew the IPv4 address dynamically:

```
PC1> ip dhcp -r
```

Configure PC1 to release the IPv4 address dynamically:

```
PC1> ip dhcp -x
```

Configure PC1 to acquire again the IPv4 address dynamically:

```
PC1> ip dhcp
```

>> In each step, analyze the exchanged DHCP packets and the contents of the DHCP Bindings at Router 1.

Explicar o DORA

PC1> ip dhcp

333	3506.417826	0.0.0.0	255.255.255.255	DHCP	406	DHCP Discover - Transaction ID 0x3de3aa13
334	3506.432841	ca:01:41:04:00:08	Broadcast	ARP	60	Who has 192.168.1.100? Tell 192.168.1.254
335	3507.431983	0.0.0.0	255.255.255.255	DHCP	406	DHCP Discover - Transaction ID 0x3de3aa13
336	3508.444617	192.168.1.254	192.168.1.100	DHCP	342	DHCP Offer - Transaction ID 0x3de3aa13
337	3510.440020	0.0.0.0	255.255.255.255	DHCP	406	DHCP Request - Transaction ID 0x3de3aa13
338	3510.455021	192.168.1.254	192.168.1.100	DHCP	342	DHCP ACK - Transaction ID 0x3de3aa13
339	3511.451088	Private_66:68:00	Broadcast	ARP	64	Gratuitous ARP for 192.168.1.100 (Request)
340	3512.462660	Private_66:68:00	Broadcast	ARP	64	Gratuitous ARP for 192.168.1.100 (Request)
341	3513.471663	Private_66:68:00	Broadcast	ARP	64	Gratuitous ARP for 192.168.1.100 (Request)

PC1> ip dhcp -r

354	3611.831130	0.0.0.0	255.255.255.255	DHCP	406	DHCP Discover - Transaction ID 0xfffd9925
355	3611.846130	192.168.1.254	192.168.1.100	DHCP	342	DHCP Offer - Transaction ID 0xfffd9925
356	3612.831716	0.0.0.0	255.255.255.255	DHCP	406	DHCP Request - Transaction ID 0xfffd9925
357	3612.846717	192.168.1.254	192.168.1.100	DHCP	342	DHCP ACK - Transaction ID 0xfffd9925
358	3613.844618	Private_66:68:00	Broadcast	ARP	64	Gratuitous ARP for 192.168.1.100 (Request)
360	3614.855674	Private_66:68:00	Broadcast	ARP	64	Gratuitous ARP for 192.168.1.100 (Request)
361	3615.867517	Private_66:68:00	Broadcast	ARP	64	Gratuitous ARP for 192.168.1.100 (Request)

PC1> ip dhcp -x

381	3783.383630	192.168.1.100	192.168.1.254	DHCP	406	DHCP Release - Transaction ID 0x0

PC1> ip dhcp

397	3874.858545	0.0.0.0	255.255.255.255	DHCP	406	DHCP Discover - Transaction ID 0x5be47909
398	3875.885278	192.168.1.254	192.168.1.101	DHCP	342	DHCP Offer - Transaction ID 0x5be47909
399	3877.864618	0.0.0.0	255.255.255.255	DHCP	406	DHCP Request - Transaction ID 0x5be47909
400	3877.879618	192.168.1.254	192.168.1.101	DHCP	342	DHCP ACK - Transaction ID 0x5be47909
401	3878.876637	Private_66:68:00	Broadcast	ARP	64	Gratuitous ARP for 192.168.1.101 (Request)
402	3879.889618	Private_66:68:00	Broadcast	ARP	64	Gratuitous ARP for 192.168.1.101 (Request)
403	3880.898619	Private_66:68:00	Broadcast	ARP	64	Gratuitous ARP for 192.168.1.101 (Request)

DORA é um acrônimo que representa as quatro fases do processo DHCP:

D (Discover) - Descoberta: O PC envia uma mensagem DHCP Discover em broadcast para encontrar servidores DHCP na rede que possam fornecer um endereço IP.

O (Offer) - Oferta: Um ou mais servidores DHCP respondem com uma mensagem DHCP Offer, oferecendo um endereço IP e outras configurações de rede.

R (Request) - Requisição: O PC responde ao servidor escolhido com uma mensagem DHCP Request, requisitando o endereço IP oferecido.

A (Acknowledge) - Reconhecimento: O servidor DHCP envia uma mensagem DHCP Acknowledgement (ACK), confirmando a concessão do endereço IP para o PC e finalizando a configuração.

Esse processo DORA permite que o dispositivo obtenha um endereço IP e as configurações necessárias (como máscara de sub-rede e gateway) para se conectar à rede.

O ARP nesta captura é um Gratuitous ARP um tipo de mensagem ARP onde um dispositivo, neste caso o PC1 com o IP 192.168.1.101, envia uma mensagem para verificar se existe algum outro dispositivo na rede com o mesmo endereço IP.

A Finalidade do Gratuitous ARP é para quando o PC1 receber o IP 192.168.1.101 via DHCP, ele envia um Gratuitous ARP para toda a rede (broadcast). Se outra máquina estiver usando o mesmo IP, essa máquina responderá, indicando um conflito.
Outros dispositivos na rede que receberem este ARP podem atualizar as suas tabelas ARP, associando o IP 192.168.1.101 ao endereço MAC do PC1. É também uma maneira de o PC1 anunciar para a rede que ele agora está utilizando o IP 192.168.1.101.

IPv6 Basic Mechanisms

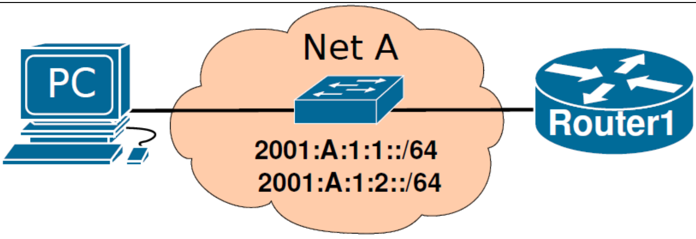
1. Considering the following network, start by connecting the PC (a VirtualBox VM Linux) to the switch without any other connections (check Annex A)
To avoid incompatibilities, disable the Linux network manager (if active):

```
sudo service network-manager stop
```

Note: The commands `sudo service network-manager start` can be used to restart the application/service.
Start a capture in the link between the PC and the Switch. Turn off and on the PC's Ethernet interface:

```
sudo ifconfig eth0 down
sudo ifconfig eth0 up
```

Stop the capture and analyze the IPv6 packets.



2. Connect Router1 to the switch and start a capture in the link between the PC and the Switch. Power on Router1 and configure its interface to network A.

```
Router1(config)# ipv6 unicast-routing
Router1(config)# interface <if-name>
Router1(config-if)# ipv6 enable
Router1(config-if)# no shutdown
```

Verify router's interfaces names and configuration:

```
Router1# show ipv6 interface
Router1# show ipv6 interface brief
```

Restart PC's Ethernet interface and verify its interface information:

```
sudo ifconfig eth0 down          (sudo ifconfig enp4s0 down)
sudo ifconfig eth0 up            (sudo ifconfig enp4s0 up)
ifconfig eth0                    (ifconfig enp4s0)
```

Stop the capture and analyze the IPv6 packets and equipment's information. Use the commands:

```
show ipv6 interface brief
show ipv6 route
```

to verify interfaces' IPv6 addressing and verify router's IPv6 routing table.

3. Re-start a capture in the link between the PC and the Switch. Configure Router's interface with a manually defined IPv6 global address from network 2001:A:1:1::/64.

```
Router1(config)# interface <if-name>
Router1(config-if)# ipv6 address 2001:A:1:1::100/64
Router1(config-if)# no shutdown
```

Verify PC's Ethernet interface information. Stop the capture and analyze the IPv6 packets. Verify the Router's interfaces IPv6 addresses and the router's IPv6 routing table.
>> Explain the process by which the PC obtained the IPv6 addresses.

4 Re-start a capture in the link between the PC and the Switch. Configure Router's interface with a EUI-64 based IPv6 global address from network 2001:A:1:2::/64.

```
Router1(config)# interface <if-name>
Router1(config-if)# ipv6 address 2001:A:1:2::/64 eui-64
Router1(config-if)# no shutdown
```

Verify PC's Ethernet interface information. Stop the capture and analyze the IPv6 packets. Verify the Router's interfaces IPv6 addressing and the router's IPv6 routing table.
>> Explain the process by which the Router completed the last 64 bits of its IPv6 addresses.
>> Discuss a possible disadvantage of using the standard EUI-64 at routers' interfaces.
>> Does the process, by which the PC obtained the IPv6 addresses, change by using the EUI-64 standard at the Router?

5. Re-start a capture in the link between the PC and the Switch. At the PC, using the command *ping6* perform a ping to:

a) Router's Link-Local address (you need to define the output interface with option "`-I eth0`" or "`-I enp4s0`").

b) Router's Global address from network 2001:A:1:1::/64.

c) Router's Global address from network 2001:A:1:2::/64.

Stop the capture and analyze the IPv6/ICMPv6 packets.

>> Explain the physical addresses resolution process in IPv6.

Annex A

Interconnection with virtual machines (VirtualBox)

Go to (Edit-Preferences-VirtualBox-VirtualBox VMs" and create a new VM template based on an existing VirtualBox machine. Use a Debian LXDE VirtualBox appliance available to download in the e-learning (login/password: labcom/labcom).
Note1: To use the VM in GNS3, the VM should be powered off and the network adapter should be "not attached".
Note2: To connect the VM to the Internet, start the VM from VitualBox GUI with the network adapter attached to "NAT".
Note3: To use multiple VM instances, you may clone the original machine.

To add a PC as an end device based on the created VM template, configure its IPv4 address and gateway, as root:

```
ip link set up dev enp1s0
ip addr add 192.168.2.102/24 dev enp1s0
ip route add default via 192.168.2.1
```

Test connectivity to the other GNS3 network elements.
Note: your virtual Ethernet port may have another name. List devices with `ip addr` to identify it.

Interconnection with virtual machines (QEMU)

Go to (Edit-Preferences-QEMU-QEMU VMs" and create a new VM template based on an existing virtual disk image (*.img). Use a Debian LXDE QEMU virtual disk (LabComServer2.qcow2) available to download in the e-learning (login/password: labcom/labcom). Choose console type "none".
Note1: To use the VM in GNS3, the VM should be powered off.
Note2: To connect the VM to the Internet, start the VM from the command line (or *virt-manager*) using the command "*`qemu-system-x86_64 -m 1024 -enable-kvm LabComServer2.qcow2`*".
Note3: To use multiple VM instances, you may copy the original VM disk file "LabComServer2.img" and start another VM.
Note4: In Windows, QEMU requires HAXM, see how to install here. Also, replace option "-enable-kvm" with option "-accel hax" when running from the command line.

To add a PC as an end device based on the created VM template, configure its IPv4 address and gateway, as root:

```
ip link set up dev enp1s0
ip addr add 192.168.2.103/24 dev enp1s0
ip route add default via 192.168.2.1
```

Test connectivity to the other GNS3 network elements.
Note: your virtual Ethernet port may have another name. List devices with `ip addr` to identify it.

Connect an Ubuntu VM to GNS3 in a MacBook M1 (using VMware)

- Verify if you do not have issues running GNS3. It should run normally, as it uses Rosetta x86 emulation.
- Install the free version of VMware Fusion Public Tech Preview. Download from https://customerconnect.vmware.com/downloads/get-download?downloadGroup=FUS-PUBTP-2021H1
- Download Ubuntu 20.04 Arm from https://cdimage.ubuntu.com/focal/daily-live/current/focal-desktop-arm64.iso
- Create Ubuntu Arm VM in VMware using the downloaded Ubuntu image

- Close VMware. On your Mac, go to /Applications folder and rename the app “VMware Fusion Tech Preview” to “VMware Fusion”
- Open GNS3, go to the VMware tab in Preferences, and import the new Ubuntu image.

To add a PC as an end device based on the created VM template, configure its IPv4 address and gateway, as root:

```
ip link set up dev enp1s0
ip addr add 192.168.2.103/24 dev enp1s0
ip route add default via 192.168.2.1
```

Test connectivity to the other GNS3 network elements.
Note: your virtual Ethernet port may have another name. List devices with `ip addr` to identify it.