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REDES DE COMUNICAÇÕES 1

Objectives

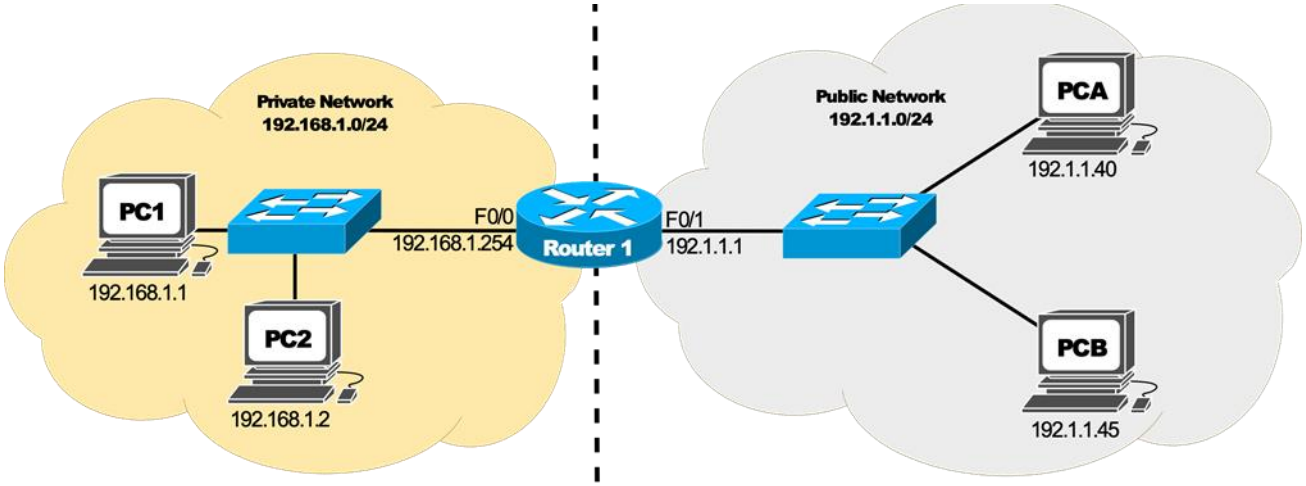
- Study of the NAT/PAT mechanisms.
- Study of DHCP.
- Study of IPv6.

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

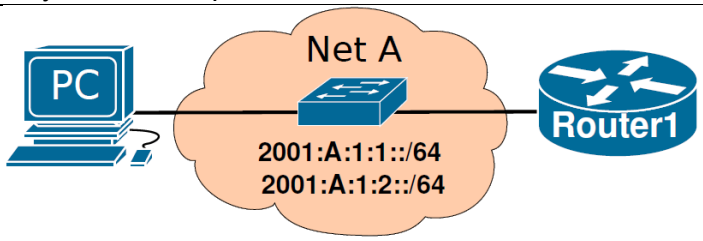
1. Considering the following network, start by connecting the PC (a VirtualBox VM Linux) to the switch without any other connections (check Annex A)
To avoid incompatibilities, disable the Linux network manager (if active):

```
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.

1.

17	44.575368	::	ff02::16	ICMPv6	110 Multicast Listener Report Message v2
20	44.659627	::	ff02::1:ff0c:cd2c	ICMPv6	86 Neighbor Solicitation for fe80::a00:27ff:fe0c:cd2c
25	45.333815	::	ff02::16	ICMPv6	110 Multicast Listener Report Message v2
27	45.685658	fe80::a00:27ff:fe0c…	ff02::16	ICMPv6	110 Multicast Listener Report Message v2
28	45.686638	fe80::a00:27ff:fe0c…	ff02::2	ICMPv6	70 Router Solicitation from 08:00:27:0c:cd:2c
29	45.688591	fe80::a00:27ff:fe0c…	ff02::2	ICMPv6	62 Router Solicitation
30	45.697932	fe80::a00:27ff:fe0c…	ff02::16	ICMPv6	110 Multicast Listener Report Message v2

Multicast Listener Discovery:

Permite que o dispositivo informe seu interesse em receber tráfego multicast para grupos específicos.

Neighbor Solicitation:
Similar ao ARP no IPv4, este pacote é usado para descobrir o endereço MAC de um vizinho IPv6.

Router Solicitation:
Usado para solicitar informações de configuração de rede de routers disponíveis.
Quando um dispositivo conecta-se à rede, ele envia um RS para obter um Router Advertisement e autoconfigurar o endereço IPv6.

2.

```
R1#show ipv6 interface
GigabitEthernet0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::C801:34FF:FECC:8
  No Virtual link-local address(es):
  No global unicast address is configured
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FFCC:8
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ICMP unreachables are sent
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds (using 30000)
  ND advertised reachable time is 0 (unspecified)
  ND advertised retransmit interval is 0 (unspecified)
  ND router advertisements are sent every 200 seconds
  ND router advertisements live for 1800 seconds
  ND advertised default router preference is Medium
  Hosts use stateless autoconfig for addresses.
```

```
R1#show ipv6 interface brief
Ethernet0/0                [administratively down/down]
    unassigned
GigabitEthernet0/0         [up/up]
    FE80::C801:34FF:FECC:8
FastEthernet1/0            [administratively down/down]
    unassigned
FastEthernet1/1            [administratively down/down]
    unassigned
FastEthernet2/0            [administratively down/down]
    unassigned
FastEthernet2/1            [administratively down/down]
    unassigned
```

```
labcom@LabComServer:~$ sudo ifconfig enp0s3
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.2.102  netmask 255.255.255.0  broadcast 0.0.0.0
        ether 08:00:27:0c:cd:2c  txqueuelen 1000  (Ethernet)
        RX packets 9  bytes 894 (894.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 100  bytes 16238 (15.8 KiB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

```
    16 160.457027    ::                  ff02::16            ICMPv6    110 Multicast Listener Report Message v2
    18 160.669905    ::                  ff02::1:ff0c:cd2c   ICMPv6     86 Neighbor Solicitation for fe80::a00:27ff:fe0c:cd2c
    21 160.825323    ::                  ff02::16            ICMPv6    110 Multicast Listener Report Message v2
    26 161.688913    fe80::a00:27ff:fe0c… ff02::16           ICMPv6    110 Multicast Listener Report Message v2
    27 161.690724    fe80::a00:27ff:fe0c… ff02::2            ICMPv6     70 Router Solicitation from 08:00:27:0c:cd:2c
    28 161.700909    fe80::a00:27ff:fe0c… ff02::16           ICMPv6    110 Multicast Listener Report Message v2
    29 161.765260    fe80::c801:34ff:fec… ff02::1            ICMPv6     86 Router Advertisement from ca:01:34:cc:00:08
    30 161.784478    fe80::a00:27ff:fe0c… ff02::16           ICMPv6    110 Multicast Listener Report Message v2
    31 161.857004    fe80::a00:27ff:fe0c… ff02::16           ICMPv6    110 Multicast Listener Report Message v2
```

Multicast Listener Discovery:

Multiple MLD messages show the PC maintaining or updating its multicast group memberships.

Neighbor Solicitation:

Neighbor Solicitation message, as the PC attempts to discover neighbors or verify the reachability of fe80::a00:27ff:fe0c:cd2c.

Router Solicitation:

The PC sends a Router Solicitation message to request network configuration information from any available router on the network.

Router Advertisement:

A Router Advertisement from Router1, identified by its link-layer address ca:01:34:cc:00:08. This message informs the PC of the router's presence and provides network configuration details for IPv6, such as the prefix and lifetime information.

```
R1#show ipv6 interface brief
Ethernet0/0                [administratively down/down]
    unassigned
GigabitEthernet0/0         [up/up]
    FE80::C801:34FF:FECC:8
FastEthernet1/0            [administratively down/down]
    unassigned
FastEthernet1/1            [administratively down/down]
    unassigned
FastEthernet2/0            [administratively down/down]
    unassigned
FastEthernet2/1            [administratively down/down]
    unassigned
```

```
R1#show ipv6 route
IPv6 Routing Table - default - 1 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, HA - Home Agent, MR - Mobile Router, R - RIP
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       D - EIGRP, EX - EIGRP external, NM - NEMO, ND - Neighbor Discovery
       l - LISP
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
L   FF00::/8 [0/0]
     via Null0, receive
```

3.

1	0.000000	fe80::c801:34ff:fec…	ff02::1	ICMPv6	86 Router Advertisement from ca:01:34:cc:00:08
3	11.080765	fe80::c801:34ff:fec…	ff02::16	ICMPv6	90 Multicast Listener Report Message v2
4	11.090901	::	ff02::1:ff00:100	ICMPv6	78 Neighbor Solicitation for 2001:a:1:1::100
5	11.465741	fe80::c801:34ff:fec…	ff02::16	ICMPv6	90 Multicast Listener Report Message v2
6	12.098536	2001:a:1:1::100	ff02::1	ICMPv6	86 Neighbor Advertisement 2001:a:1:1::100 (rtr, ovr) is at ca:01:34:cc:00:08

Explanation of the IPv6 Address Configuration Process

Router Solicitation and Advertisement:
The PC starts by listening for Router Advertisements or sending Router Solicitations to prompt any routers on the network to advertise their presence. In this case, the Router Advertisement is received in packet 1.

Stateless Address Autoconfiguration:
The Router Advertisement from Router1 includes the prefix 2001:A:1:1::/64, which allows the PC to generate its own IPv6 address using this prefix combined with its interface identifier. This process is called Stateless Address Autoconfiguration.

Neighbor Discovery:
The PC sends a Neighbor Solicitation message to confirm the uniqueness of the newly generated IPv6 address or to discover the link-layer address of Router1's 2001:a:1:1::100 address. Router1 responds with a Neighbor Advertisement, completing the address resolution.

4. EUI-64 IPv6 Address Generation

The router generates an IPv6 address using the EUI-64 method as follows:

Extracting MAC Address: The router obtains the 48-bit MAC address of the interface it wants to configure.
Modifying MAC Address: The first 48 bits of the MAC address are inserted into bits 24 to 63 of the EUI-64 address.
Setting Universal/Local Bit: Bit 7 of the EUI-64 address is set to 0 for universal (global) addresses.
Adding Prefix: The specified IPv6 prefix (e.g., 2001:A:1:2::/64) is prepended to the modified MAC address.

Disadvantage of EUI-64 at Routers
Privacy Concerns: EUI-64 addresses are derived from the MAC address, which can potentially reveal the router's physical location and configuration.

Impact on PC's IPv6 Address Acquisition
The PC's IPv6 address acquisition process remains largely unaffected by the router's use of EUI-64. The PC still uses DHCPv6 or SLAAC to obtain its IPv6 addresses. The router's EUI-64 address is used in router advertisements and other network communications, but it doesn't directly influence the PC's address assignment.

```
R1#show ipv6 route
IPv6 Routing Table - default - 5 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, HA - Home Agent, MR - Mobile Router, R - RIP
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       D - EIGRP, EX - EIGRP external, NM - NEMO, ND - Neighbor Discovery
       l - LISP
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
C   2001:A:1:1::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:A:1:1::100/128 [0/0]
     via GigabitEthernet0/0, receive
C   2001:A:1:2::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:A:1:2:C801:34FF:FECC:8/128 [0/0]
     via GigabitEthernet0/0, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

```
R1#show ipv6 interface brief
Ethernet0/0                [administratively down/down]
    unassigned
GigabitEthernet0/0         [up/up]
    FE80::C801:34FF:FECC:8
    2001:A:1:1::100
    2001:A:1:2:C801:34FF:FECC:8
FastEthernet1/0            [administratively down/down]
    unassigned
FastEthernet1/1            [administratively down/down]
    unassigned
FastEthernet2/0            [administratively down/down]
    unassigned
FastEthernet2/1            [administratively down/down]
    unassigned
```

5. Ping6 to Router's Link-Local address

6	74.843816	fe80::a00:27ff:fe0c…	fe80::c801:34ff:fec…	ICMPv6	118 Echo (ping) request id=0x06d4, seq=1, hop limit=64 (reply in 7)
7	74.852051	fe80::c801:34ff:fec…	fe80::a00:27ff:fe0c…	ICMPv6	118 Echo (ping) reply id=0x06d4, seq=1, hop limit=64 (request in 6)
8	75.844879	fe80::a00:27ff:fe0c…	fe80::c801:34ff:fec…	ICMPv6	118 Echo (ping) request id=0x06d4, seq=2, hop limit=64 (reply in 9)
9	75.855323	fe80::c801:34ff:fec…	fe80::a00:27ff:fe0c…	ICMPv6	118 Echo (ping) reply id=0x06d4, seq=2, hop limit=64 (request in 8)
10	76.846739	fe80::a00:27ff:fe0c…	fe80::c801:34ff:fec…	ICMPv6	118 Echo (ping) request id=0x06d4, seq=3, hop limit=64 (reply in 11)
11	76.849660	fe80::c801:34ff:fec…	fe80::a00:27ff:fe0c…	ICMPv6	118 Echo (ping) reply id=0x06d4, seq=3, hop limit=64 (request in 10)
12	77.848616	fe80::a00:27ff:fe0c…	fe80::c801:34ff:fec…	ICMPv6	118 Echo (ping) request id=0x06d4, seq=4, hop limit=64 (reply in 13)
13	77.855034	fe80::c801:34ff:fec…	fe80::a00:27ff:fe0c…	ICMPv6	118 Echo (ping) reply id=0x06d4, seq=4, hop limit=64 (request in 12)

Ping6 to Router's Global address from network 2001:A:1:1::/64.

25	2607.720034	2001:a:1:1:f57b:930…	2001:a:1:1::100	ICMPv6	118 Echo (ping) request id=0x06d7, seq=1, hop limit=64 (reply in 26)
26	2607.728654	2001:a:1:1::100	2001:a:1:1:f57b:930…	ICMPv6	118 Echo (ping) reply id=0x06d7, seq=1, hop limit=64 (request in 25)
27	2608.712282	2001:a:1:1:f57b:930…	2001:a:1:1::100	ICMPv6	118 Echo (ping) request id=0x06d7, seq=2, hop limit=64 (reply in 28)
28	2608.724471	2001:a:1:1::100	2001:a:1:1:f57b:930…	ICMPv6	118 Echo (ping) reply id=0x06d7, seq=2, hop limit=64 (request in 27)
29	2609.714382	2001:a:1:1:f57b:930…	2001:a:1:1::100	ICMPv6	118 Echo (ping) request id=0x06d7, seq=3, hop limit=64 (reply in 30)
30	2609.726420	2001:a:1:1::100	2001:a:1:1:f57b:930…	ICMPv6	118 Echo (ping) reply id=0x06d7, seq=3, hop limit=64 (request in 29)
31	2610.716760	2001:a:1:1:f57b:930…	2001:a:1:1::100	ICMPv6	118 Echo (ping) request id=0x06d7, seq=4, hop limit=64 (reply in 32)
32	2610.718849	2001:a:1:1::100	2001:a:1:1:f57b:930…	ICMPv6	118 Echo (ping) reply id=0x06d7, seq=4, hop limit=64 (request in 31)

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

142	4011.651580	2001:a:1:2:f57b:930…	2001:a:1:2:c801:34f…	ICMPv6	118 Echo (ping) request id=0x0719, seq=1, hop limit=64 (reply in 143)
143	4011.659335	2001:a:1:2:c801:34f…	2001:a:1:2:f57b:930…	ICMPv6	118 Echo (ping) reply id=0x0719, seq=1, hop limit=64 (request in 142)
144	4012.652212	2001:a:1:2:f57b:930…	2001:a:1:2:c801:34f…	ICMPv6	118 Echo (ping) request id=0x0719, seq=2, hop limit=64 (reply in 145)
145	4012.659686	2001:a:1:2:c801:34f…	2001:a:1:2:f57b:930…	ICMPv6	118 Echo (ping) reply id=0x0719, seq=2, hop limit=64 (request in 144)
146	4013.654770	2001:a:1:2:f57b:930…	2001:a:1:2:c801:34f…	ICMPv6	118 Echo (ping) request id=0x0719, seq=3, hop limit=64 (reply in 147)
147	4013.659092	2001:a:1:2:c801:34f…	2001:a:1:2:f57b:930…	ICMPv6	118 Echo (ping) reply id=0x0719, seq=3, hop limit=64 (request in 146)
148	4014.656607	2001:a:1:2:f57b:930…	2001:a:1:2:c801:34f…	ICMPv6	118 Echo (ping) request id=0x0719, seq=4, hop limit=64 (reply in 149)
149	4014.659658	2001:a:1:2:c801:34f…	2001:a:1:2:f57b:930…	ICMPv6	118 Echo (ping) reply id=0x0719, seq=4, hop limit=64 (request in 148)

Resolution of Physical Addresses under IPv6

In IPv6 resolution, a physical address (MAC address) to an IPv6 address is significantly different from IPv4's ARP protocol. To do this in IPv6, the Neighbor Discovery Protocol is used.

NDP Process

Neighbor Solicitation: When a node (like the PC) wants to communicate with another node (like the router), it sends a Neighbor Solicitation message. This message contains the target IPv6 address and a solicited-node multicast address (FF02::1:2).

Neighbor Advertisement: The router, upon receiving the NS message, responds with a Neighbor Advertisement message. This message contains its own IPv6 address and its link-local address.

Cache Update: The PC updates its neighbor cache with the router's IPv6 address and link-local address. This cache is used to map IPv6 addresses to physical addresses for future communication.

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.