



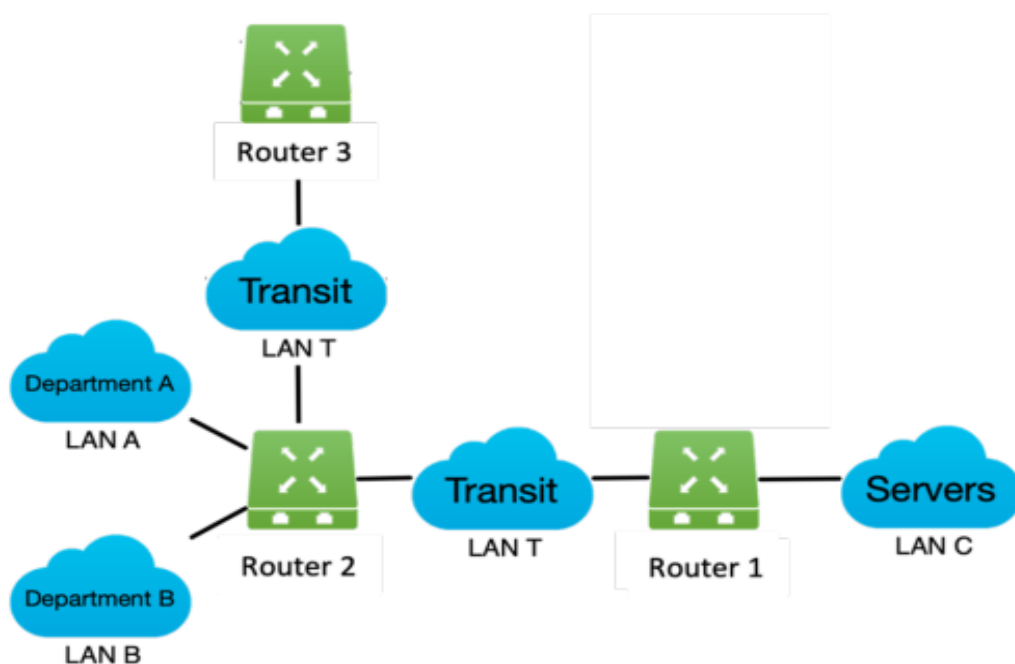
# Instituto Superior de Engenharia de Lisboa

Licenciatura em Engenharia Informática e Multimédia

Redes de Computadores - 2022/2023 SV

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## 3ª Fase - Connecting Multiple Networks



Docente Nelson Costa

Realizado por grupo 5:

Diogo Lobo 48168

Pedro Silva 48965

Diogo Santos 48626

28 de maio de 2023

# Conteúdo

<b>1</b>	<b>Introdução</b>	<b>I</b>
<b>2</b>	<b>Atribuição de Endereços IP</b>	<b>I</b>
<b>3</b>	<b>Configuração das LANs A e B</b>	<b>III</b>
<b>4</b>	<b>Configuração da LAN Transit A</b>	<b>V</b>
<b>5</b>	<b>Configuração da LAN C</b>	<b>VII</b>
<b>6</b>	<b>Configuração da LAN Transit B</b>	<b>VIII</b>
<b>7</b>	<b>Testes</b>	<b>X</b>
<b>8</b>	<b>Conclusões</b>	<b>XII</b>

## Lista de Figuras

1	Topologia da Rede . . . . .	I
2	Formula para calcular clientes . . . . .	I
3	Formula preenchida em python . . . . .	I
4	Intervalo de endereços IP . . . . .	II
5	Configuração PCs . . . . .	III
6	Configuração Cisco LANs A e B . . . . .	III
7	Ping PCs . . . . .	IV
8	Ligação Router 2 com Router 1 . . . . .	V
9	Atribuição IPs Router 1 . . . . .	V
10	Rota de Router 1 para as LANs A e B . . . . .	VI
11	Ping Router 1 - PC A e PC C . . . . .	VI
12	Configuração - Servidores . . . . .	VII
13	Ping Router 2 - Servidores . . . . .	VII
14	Rota Router 3 para Router 2 . . . . .	VIII
15	Rotas default Router 1 e Router 2 . . . . .	VIII
16	Pings Router 3 . . . . .	IX
17	Pings PC A . . . . .	X
18	Trace PC A . . . . .	X
19	Tabela arp Router 1 . . . . .	XI
20	Tabela arp Router 2 . . . . .	XI
21	Tabela arp Router 3 . . . . .	XI

# 1 Introdução

Este projeto tem como objetivo o desenvolvimento de uma Rede de Computadores. Começamos por criar um servidor web, depois uma LAN para dois PCs usando um switch e finalmente evoluímos de forma a conectar a nossa LAN a outros e criar uma típica rede empresarial. Nesta terceira fase vamos começar a expandir a nossa rede ao conectar as nossas duas LANs (criadas na fase anterior) a um servidor LAN usando uma "Transit Network". A nova LAN T vai ser a nossa rede de transito que vai fazer a ligação entre o Router 2 e o Router 1. As nossas LANs vão ser convertidas em departamentos e numa nova LAN C vamos ter os servidores. Também vamos ter uma LAN de transito que faz a ligação do Router 2 ao Router 3 de forma a simular a conectividade fora da nossa rede. A figura a baixo demonstra-nos a topologia da rede descrita anteriormente.

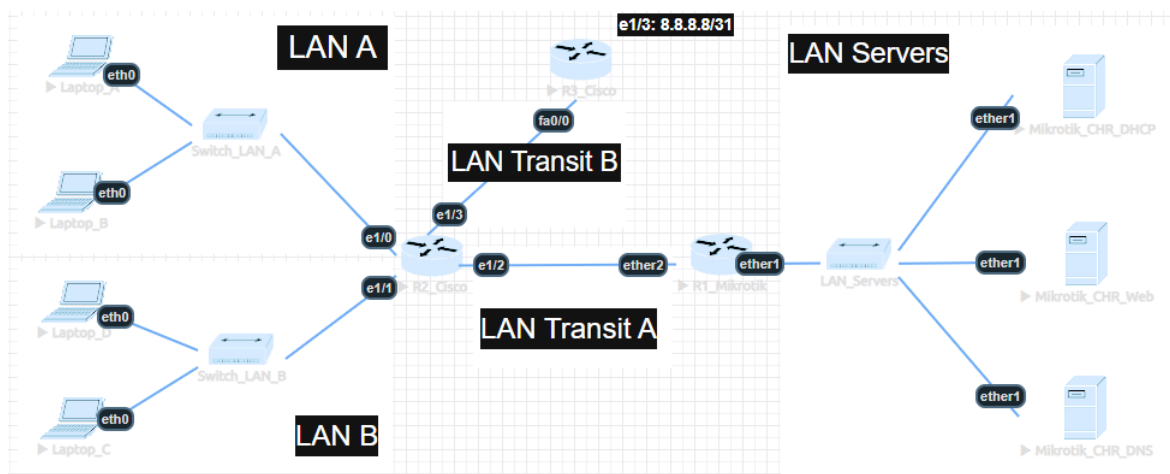


Figura 1: Topologia da Rede

## 2 Atribuição de Endereços IP

Como agora temos mais LANs, vamos ter que mudar outra vez a sub-rede feita na fase anterior. Para obter o número de clientes ligado à LAN A e B usamos a fórmula seguinte:

$$\text{Clients}_{LAN_A} = \max(20, \left( \sum_{k=0}^n \text{studentnumber}_k \right) \bmod 100)$$

Figura 2: Formula para calcular clientes

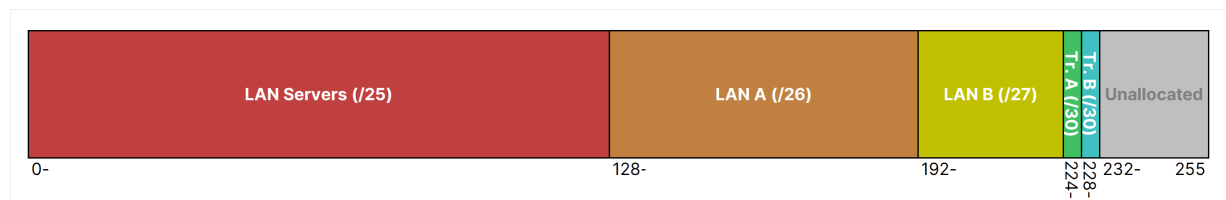
Esta fórmula vai ser o somatório dos números de aluno de cada elemento do nosso grupo multiplicando pelo módulo de 100. Se o número for inferior a 20 usamos 20. Substituindo agora pela nossa informação temos:

```
print(max(20,mod(sum([48168,48965,48626]),(100))))
```

Figura 3: Formula preenchida em python

O resultado obtido foi 59, ou seja, já temos o número de endereços IP disponíveis para clientes em ambas as LANs, 59 para a LAN A e 29 para a LAN B (metade da LAN A).

O intervalo de endereços IP atribuído às várias LANs são:



**Figura 4:** Intervalo de endereços IP

O intervalo de endereços IP atribuído à sub-rede LAN A foi 192.168.5.128/26:

- 192.168.5.128 Sub-Rede
- 192.168.5.129 Gateway
- 192.168.5.190 Computador A
- 192.168.5.189 Computador B

O intervalo de endereços IP atribuído à sub-rede LAN B foi 192.168.5.192/27:

- 192.168.5.192 Sub-Rede
- 192.168.5.193 Gateway
- 192.168.5.222 Computador C
- 192.168.5.221 Computador D

Pretendeu-se que a LAN C contenha o maior intervalo possível ocupando 128 endereços IP dos 256 disponíveis. O intervalo de endereços IP atribuído à sub-rede LAN C foi 192.168.5.0/25:

- 192.168.5.0 Sub-Rede
- 192.168.5.1 Gateway
- 192.168.5.2 Servidor DHCP
- 192.168.5.3 Servidor WEB
- 192.168.5.4 Servidor DNS

O intervalo de endereços IP atribuído à sub-rede LAN Transit A foi 192.168.5.224/30:

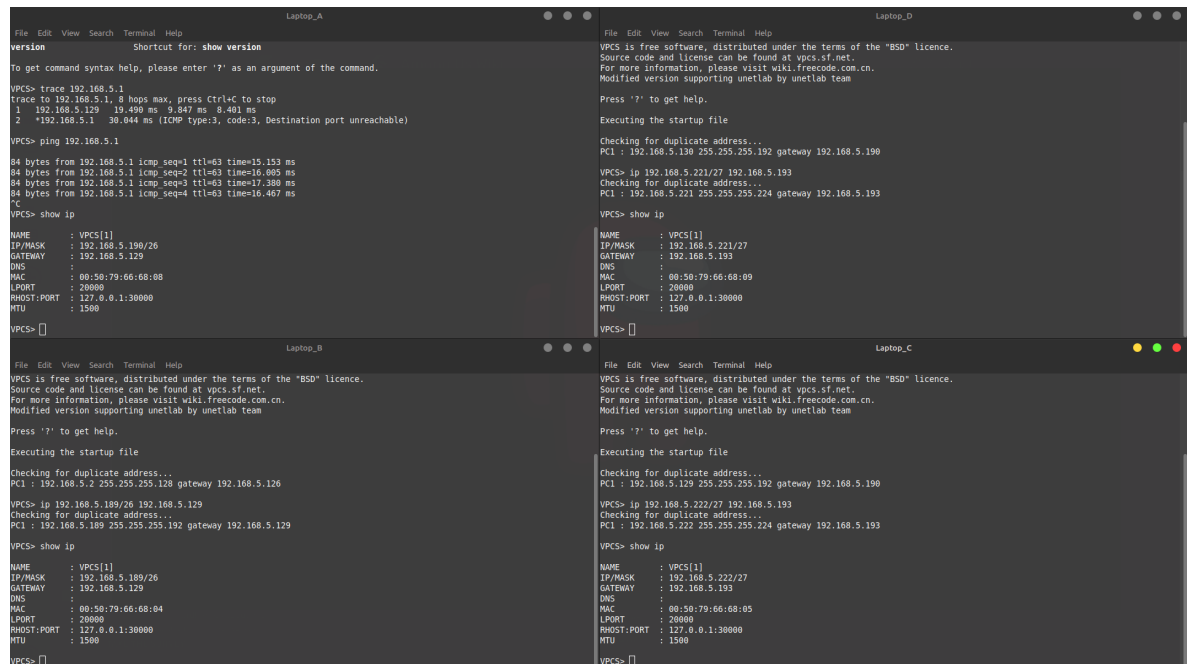
- 192.168.5.224 Sub-Rede
- 192.168.5.225 ether2 Router 1
- 192.168.5.226 e1/2 Router 2

O intervalo de endereços IP atribuído à sub-rede LAN Transit B foi 192.168.5.228/30:

- 192.168.5.228 Sub-Rede
- 192.168.5.229 fa0/0 Router 3
- 192.168.5.230 e1/3 Router 2

### 3 Configuração das LANs A e B

Configurámos os dispositivos das LAN A e B, de acordo com a atribuição de endereços IP realizada anteriormente utilizando os métodos da fase anterior.



```
File Edit View Search Terminal Help
version
Shortcut for: show version
To get command syntax help, please enter '?' as an argument of the command.

VPCS> trace 192.168.5.1
Trace to 192.168.5.1, 0 hops max, press Ctrl+C to stop
  1  192.168.5.129    30.490 ms  9.647 ms  8.403 ms
  2  *192.168.5.1    30.044 ms  (ICMP type:3, code:3, Destination port unreachable)

VPCS> ping 192.168.5.1
64 bytes from 192.168.5.1 icmp_seq=1 ttl=63 time=15.153 ms
64 bytes from 192.168.5.1 icmp_seq=2 ttl=63 time=16.095 ms
64 bytes from 192.168.5.1 icmp_seq=3 ttl=63 time=17.380 ms
64 bytes from 192.168.5.1 icmp_seq=4 ttl=63 time=16.467 ms
^C
VPCS> show ip
NAME      : VPCS[1]
IP/MASK   : 192.168.5.190/26
GATEWAY   : 192.168.5.129
DNS       :
MAC       : 00:50:79:66:68:08
LPORT     : 20000
RHOST:PORT : 127.0.0.1:30000
MTU       : 1500
VPCS> []

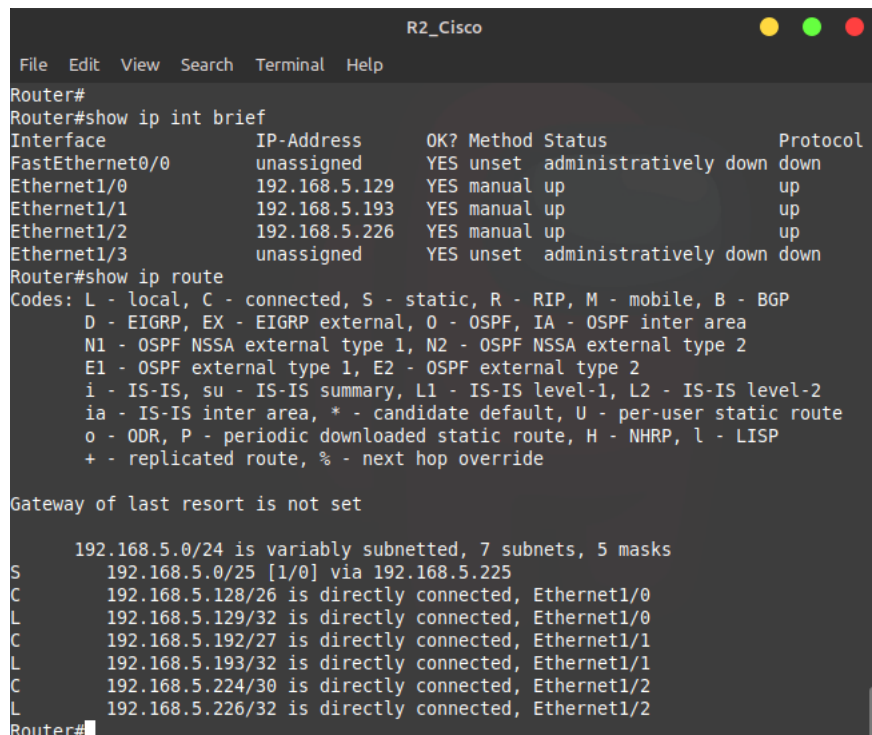
File Edit View Search Terminal Help
VPCS is free software, distributed under the terms of the "BSD" licence.
Source code and license can be found at vpcs.sf.net.
For more information, please visit wiki.freecode.com.cn.
Modified version supporting unetlab by unetlab team
Press '?' to get help.
Executing the startup file
Checking for duplicate address...
PC1 : 192.168.5.130 255.255.255.192 gateway 192.168.5.190
VPCS> ip 192.168.5.221/27 192.168.5.193
Checking for duplicate address...
PC1 : 192.168.5.221 255.255.255.224 gateway 192.168.5.193
VPCS> show ip
NAME      : VPCS[1]
IP/MASK   : 192.168.5.221/27
GATEWAY   : 192.168.5.193
DNS       :
MAC       : 00:50:79:66:68:09
LPORT     : 20000
RHOST:PORT : 127.0.0.1:30000
MTU       : 1500
VPCS> []

File Edit View Search Terminal Help
VPCS is free software, distributed under the terms of the "BSD" licence.
Source code and license can be found at vpcs.sf.net.
For more information, please visit wiki.freecode.com.cn.
Modified version supporting unetlab by unetlab team
Press '?' to get help.
Executing the startup file
Checking for duplicate address...
PC1 : 192.168.5.2 255.255.255.128 gateway 192.168.5.126
VPCS> ip 192.168.5.189/26 192.168.5.129
Checking for duplicate address...
PC1 : 192.168.5.189 255.255.255.192 gateway 192.168.5.129
VPCS> show ip
NAME      : VPCS[1]
IP/MASK   : 192.168.5.189/26
GATEWAY   : 192.168.5.129
DNS       :
MAC       : 00:50:79:66:68:04
LPORT     : 20000
RHOST:PORT : 127.0.0.1:30000
MTU       : 1500
VPCS> []

File Edit View Search Terminal Help
VPCS is free software, distributed under the terms of the "BSD" licence.
Source code and license can be found at vpcs.sf.net.
For more information, please visit wiki.freecode.com.cn.
Modified version supporting unetlab by unetlab team
Press '?' to get help.
Executing the startup file
Checking for duplicate address...
PC1 : 192.168.5.129 255.255.255.192 gateway 192.168.5.190
VPCS> ip 192.168.5.222/27 192.168.5.193
Checking for duplicate address...
PC1 : 192.168.5.222 255.255.255.224 gateway 192.168.5.193
VPCS> show ip
NAME      : VPCS[1]
IP/MASK   : 192.168.5.222/27
GATEWAY   : 192.168.5.193
DNS       :
MAC       : 00:50:79:66:68:05
LPORT     : 20000
RHOST:PORT : 127.0.0.1:30000
MTU       : 1500
VPCS> []
```

Figura 5: Configuração PCs

Uma vez configurados os dispositivos das duas LANs, procedeu-se à configuração do router 2. Foram atribuídos às interfaces e1/0 e e1/1 os endereços de Gateway das LAN A e B respetivamente.



```
R2_Cisco
File Edit View Search Terminal Help
Router#
Router#show ip int brief
Interface      IP-Address      OK? Method Status      Protocol
FastEthernet0/0 unassigned      YES unset   administratively down down
Ethernet1/0     192.168.5.129   YES manual  up          up
Ethernet1/1     192.168.5.193   YES manual  up          up
Ethernet1/2     192.168.5.226   YES manual  up          up
Ethernet1/3     unassigned      YES unset   administratively down down
Router#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      192.168.5.0/24 is variably subnetted, 7 subnets, 5 masks
S       192.168.5.0/25 [1/0] via 192.168.5.225
C       192.168.5.128/26 is directly connected, Ethernet1/0
L       192.168.5.129/32 is directly connected, Ethernet1/0
C       192.168.5.192/27 is directly connected, Ethernet1/1
L       192.168.5.193/32 is directly connected, Ethernet1/1
C       192.168.5.224/30 is directly connected, Ethernet1/2
L       192.168.5.226/32 is directly connected, Ethernet1/2
Router#
```

Figura 6: Configuração Cisco LANs A e B

De forma a testar se as ligações estão bem configuradas realizámos testes com o comando "ping" em cada uma das máquinas para a sua simétrica.

The image shows four terminal windows, each representing a different laptop (Laptop\_A, Laptop\_B, Laptop\_C, and Laptop\_D). Each window displays the output of a series of commands executed in a VPCS environment. The commands include checking for duplicate addresses, setting IP addresses and gateways, showing IP configurations, and performing ping tests to various destinations. The ping tests show successful connections with response times and TTL values. For example, Laptop\_A pings 192.168.5.1 and 192.168.5.222, while Laptop\_D pings 192.168.5.190. The configurations for each laptop are as follows:

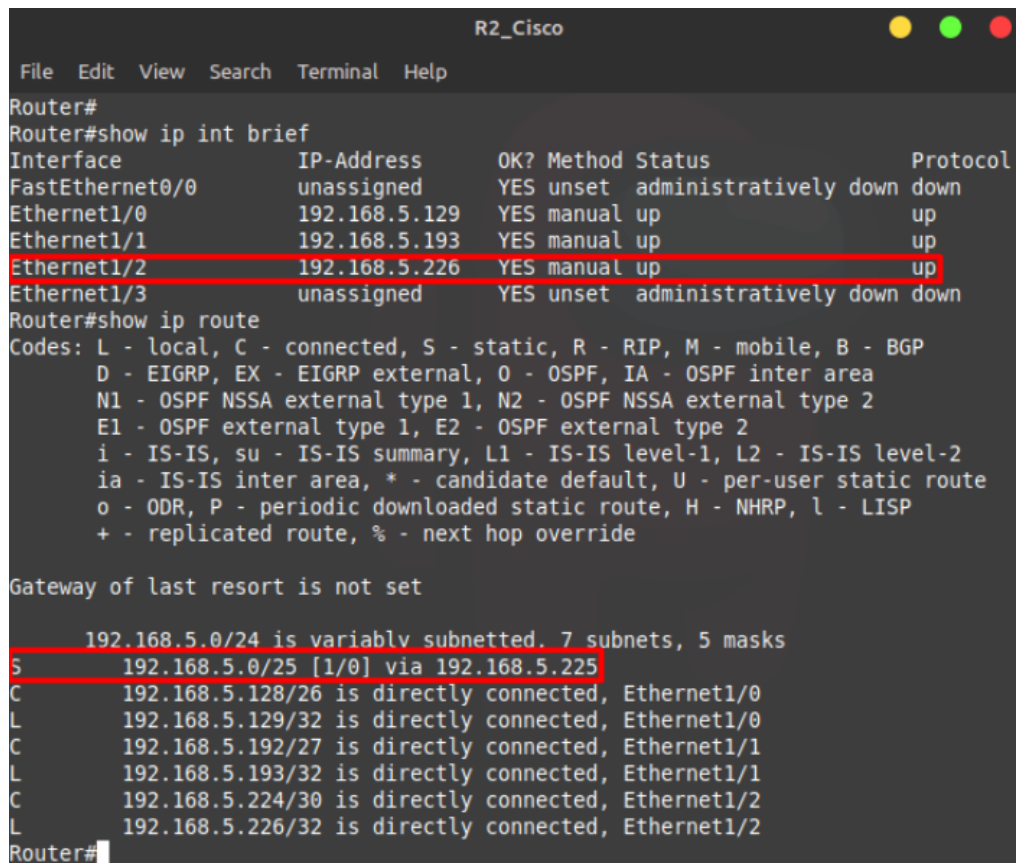
Laptop	IP	Mask	Gateway	DNS	MAC	Port	RHOST:PORT	MTU
Laptop_A	192.168.5.1	26	192.168.5.129	-	08:50:79:66:68:08	20000	127.0.0.1:30000	1500
Laptop_B	192.168.5.189	26	192.168.5.129	-	08:50:79:66:68:04	20000	127.0.0.1:30000	1500
Laptop_C	192.168.5.222	27	192.168.5.193	-	08:50:79:66:68:05	20000	127.0.0.1:30000	1500
Laptop_D	192.168.5.190	27	192.168.5.193	-	08:50:79:66:68:09	20000	127.0.0.1:30000	1500

Figura 7: Ping PCs

Como podemos observar pela imagem a conexão entre os dispositivos das LANs A e B foi configurada com sucesso, à semelhança do que foi realizado na fase anterior do projeto.

## 4 Configuração da LAN Transit A

Para configurarmos a LAN Transit A atribuímos à interface e1/2 do Router 2 o endereço IP 192.168.5.226, a máscara de sub-rede 255.255.255.255 e criada uma rota onde a interface ether2, à qual o router 1 está conectado, é o Gateway para pacotes cujo endereço IP de destino esteja compreendido no intervalo de endereços IP definido para a LAN C (192.168.5.0/25).



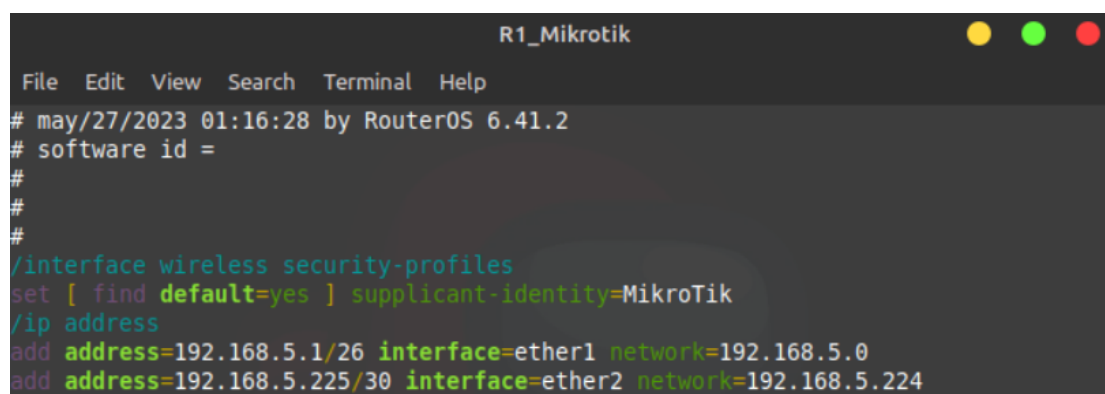
```
R2_Cisco
File Edit View Search Terminal Help
Router#
Router#show ip int brief
Interface                IP-Address      OK? Method Status      Protocol
FastEthernet0/0          unassigned      YES unset   administratively down  down
Ethernet1/0              192.168.5.129   YES manual  up          up
Ethernet1/1              192.168.5.193   YES manual  up          up
Ethernet1/2              192.168.5.226   YES manual  up          up
Ethernet1/3              unassigned      YES unset   administratively down  down
Router#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

    192.168.5.0/24 is variably subnetted, 7 subnets, 5 masks
S       192.168.5.0/25 [1/0] via 192.168.5.225
C       192.168.5.128/26 is directly connected, Ethernet1/0
L       192.168.5.129/32 is directly connected, Ethernet1/0
C       192.168.5.192/27 is directly connected, Ethernet1/1
L       192.168.5.193/32 is directly connected, Ethernet1/1
C       192.168.5.224/30 is directly connected, Ethernet1/2
L       192.168.5.226/32 is directly connected, Ethernet1/2
Router#
```

Figura 8: Ligação Router 2 com Router 1

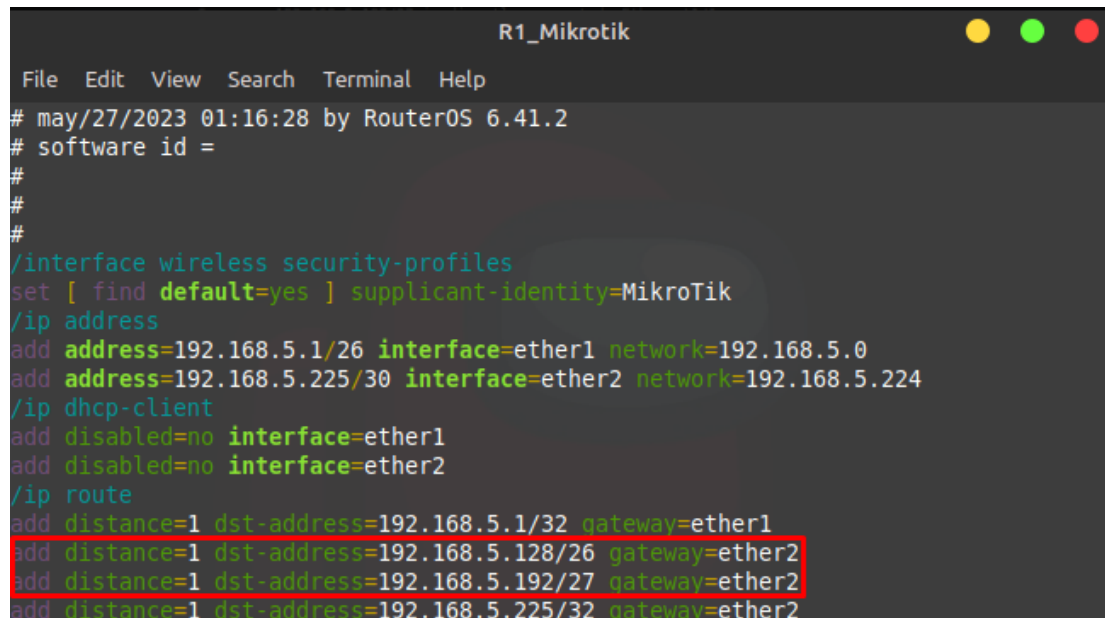
Agora vamos configurar o router 1 onde vamos atribuir à interface ether1 o endereço IP 192.168.5.1, a máscara de sub-rede 255.255.255.128 e à interface ether2 o endereço IP 192.168.5.225, a máscara de sub-rede 255.255.255.252.



```
R1_Mikrotik
File Edit View Search Terminal Help
# may/27/2023 01:16:28 by RouterOS 6.41.2
# software id =
#
#
#
/interface wireless security-profiles
set [ find default=yes ] supplicant-identity=MikroTik
/ip address
add address=192.168.5.1/26 interface=ether1 network=192.168.5.0
add address=192.168.5.225/30 interface=ether2 network=192.168.5.224
```

Figura 9: Atribuição IPs Router 1

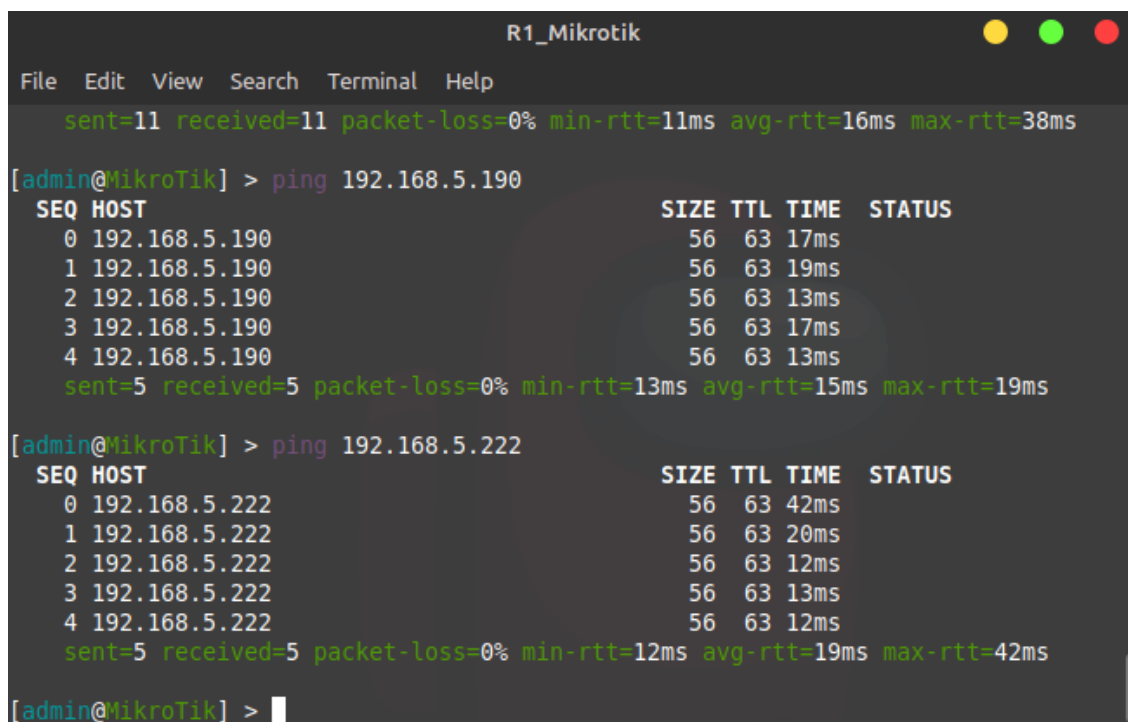
Foi criada uma rota para que os pacotes cujo endereço IP pertence à LAN A (192.168.5.128/26) fossem encaminhados para o router 2 através da interface ether2 representada pelo IP 192.168.5.255. O mesmo foi feito para a LAN B (193.168.5.192/27). Utilizamos o comando "ip route add" para realizar esta operação. Na imagem abaixo conseguimos observar que esta atribuição foi realizada com sucesso.



```
R1_Mikrotik
File Edit View Search Terminal Help
# may/27/2023 01:16:28 by RouterOS 6.41.2
# software id =
#
#
#
/interface wireless security-profiles
set [ find default=yes ] supplicant-identity=MikroTik
/ip address
add address=192.168.5.1/26 interface=ether1 network=192.168.5.0
add address=192.168.5.225/30 interface=ether2 network=192.168.5.224
/ip dhcp-client
add disabled=no interface=ether1
add disabled=no interface=ether2
/ip route
add distance=1 dst-address=192.168.5.1/32 gateway=ether1
add distance=1 dst-address=192.168.5.128/26 gateway=ether2
add distance=1 dst-address=192.168.5.192/27 gateway=ether2
add distance=1 dst-address=192.168.5.225/32 gateway=ether2
```

**Figura 10:** Rota de Router 1 para as LANs A e B

De forma a confirmar que a configuração foi bem sucedida vamos tentar comunicar com os computadores A e C através do Router 1 utilizando os comandos "ping 192.168.5.190" e "ping 193.168.5.222", respectivamente.



```
R1_Mikrotik
File Edit View Search Terminal Help
sent=11 received=11 packet-loss=0% min-rtt=11ms avg-rtt=16ms max-rtt=38ms
[admin@MikroTik] > ping 192.168.5.190
  SEQ HOST                      SIZE TTL TIME  STATUS
  0 192.168.5.190                 56 63 17ms
  1 192.168.5.190                 56 63 19ms
  2 192.168.5.190                 56 63 13ms
  3 192.168.5.190                 56 63 17ms
  4 192.168.5.190                 56 63 13ms
sent=5 received=5 packet-loss=0% min-rtt=13ms avg-rtt=15ms max-rtt=19ms
[admin@MikroTik] > ping 192.168.5.222
  SEQ HOST                      SIZE TTL TIME  STATUS
  0 192.168.5.222                 56 63 42ms
  1 192.168.5.222                 56 63 20ms
  2 192.168.5.222                 56 63 12ms
  3 192.168.5.222                 56 63 13ms
  4 192.168.5.222                 56 63 12ms
sent=5 received=5 packet-loss=0% min-rtt=12ms avg-rtt=19ms max-rtt=42ms
[admin@MikroTik] >
```

**Figura 11:** Ping Router 1 - PC A e PC C



## 5 Configuração da LAN C

Para configurarmos a LAN C, começamos por configurar cada um dos 3 servidores, utilizando os mesmos métodos que antes, ou seja, utilizando o comando "ip address add" de acordo com os endereços anunciados previamente. A seguir adicionamos uma rota uma rota a cada servidor, de forma que a resposta enviada pelo servidor para endereços IP fora da LAN C seja enviada para a Gateway da LAN C que é a interface ether1 do Router 1.

```
[admin@microtik] > ip route add dst-address=0.0.0.0/0 gateway=ether1
[admin@microtik] > ip route print
Flags: X - disabled, A - active, D - dynamic,
C - connect, S - static, r - rip, b - bgp, o - ospf, m - mme,
B - blackhole, U - unreachable, P - prohibit
# DST-ADDRESS      PREF-SRC  GATEWAY      DISTANCE
0 A S 0.0.0.0/0     192.168.5.2 ether1        0
[admin@microtik] > ip route edit 0
value-name: gateway
[admin@microtik] > ip route print
Flags: X - disabled, A - active, D - dynamic,
C - connect, S - static, r - rip, b - bgp, o - ospf, m - mme,
B - blackhole, U - unreachable, P - prohibit
# DST-ADDRESS      PREF-SRC  GATEWAY      DISTANCE
0 A S 0.0.0.0/0     192.168.5.1 ether1        0
[admin@microtik] > ip address print
Flags: X - disabled, I - invalid, D - dynamic
# ADDRESS          NETWORK    INTERFACE
0 192.168.5.2/25     192.168.5.0 ether1
[admin@microtik] > ip route print
Flags: X - disabled, A - active, D - dynamic,
C - connect, S - static, r - rip, b - bgp, o - ospf, m - mme,
B - blackhole, U - unreachable, P - prohibit
# DST-ADDRESS      PREF-SRC  GATEWAY      DISTANCE
0 A S 0.0.0.0/0     192.168.5.1 ether1        0
[admin@microtik] > [

[admin@microtik] > ip route print
Flags: X - disabled, A - active, D - dynamic,
C - connect, S - static, r - rip, b - bgp, o - ospf, m - mme,
B - blackhole, U - unreachable, P - prohibit
# DST-ADDRESS      PREF-SRC  GATEWAY      DISTANCE
0 A S 0.0.0.0/0     192.168.5.3 ether1        0
[admin@microtik] > ip route remove 1
[admin@microtik] > ip route add dst-address=0.0.0.0/0 gateway=192.168.5.1
[admin@microtik] > ip route print
Flags: X - disabled, A - active, D - dynamic,
C - connect, S - static, r - rip, b - bgp, o - ospf, m - mme,
B - blackhole, U - unreachable, P - prohibit
# DST-ADDRESS      PREF-SRC  GATEWAY      DISTANCE
0 A S 0.0.0.0/0     192.168.5.3 ether1        0
[admin@microtik] > ip address print
Flags: X - disabled, I - invalid, D - dynamic
# ADDRESS          NETWORK    INTERFACE
0 192.168.5.3/25     192.168.5.0 ether1
[admin@microtik] > ip route print
Flags: X - disabled, A - active, D - dynamic,
C - connect, S - static, r - rip, b - bgp, o - ospf, m - mme,
B - blackhole, U - unreachable, P - prohibit
# DST-ADDRESS      PREF-SRC  GATEWAY      DISTANCE
0 A S 0.0.0.0/0     192.168.5.1 ether1        0
[admin@microtik] > [

[admin@microtik] > ip route print
Flags: X - disabled, A - active, D - dynamic,
C - connect, S - static, r - rip, b - bgp, o - ospf, m - mme,
B - blackhole, U - unreachable, P - prohibit
# DST-ADDRESS      PREF-SRC  GATEWAY      DISTANCE
0 A S 0.0.0.0/0     192.168.5.4 ether1        0
[admin@microtik] > ip address print
Flags: X - disabled, I - invalid, D - dynamic
# ADDRESS          NETWORK    INTERFACE
0 192.168.5.4/25     192.168.5.0 ether1
[admin@microtik] > ip route print
Flags: X - disabled, A - active, D - dynamic,
C - connect, S - static, r - rip, b - bgp, o - ospf, m - mme,
B - blackhole, U - unreachable, P - prohibit
# DST-ADDRESS      PREF-SRC  GATEWAY      DISTANCE
0 A S 0.0.0.0/0     192.168.5.1 ether1        0
[admin@microtik] > [

ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
+ - replicated route, % - next hop override

Gateway of last resort is not set

192.168.5.0/24 is variably subnetted, 7 subnets, 5 masks
S    192.168.5.0/25 [1/0] via 192.168.5.225
C    192.168.5.128/26 is directly connected, Ethernet1/0
L    192.168.5.129/32 is directly connected, Ethernet1/0
C    192.168.5.192/27 is directly connected, Ethernet1/1
L    192.168.5.193/32 is directly connected, Ethernet1/1
C    192.168.5.224/30 is directly connected, Ethernet1/2
L    192.168.5.226/32 is directly connected, Ethernet1/2
Router#ping 192.168.5.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.5.2, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/60/68 ms
Router#ping 192.168.5.3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.5.3, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 52/56/60 ms
Router#ping 192.168.5.4
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.5.4, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/58/84 ms
Router#
```

Figura 12: Configuração - Servidores

De forma a testarmos esta configuração utilizámos o comando ping no Router 2 para cada um dos servidores.

```
ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
+ - replicated route, % - next hop override

Gateway of last resort is not set

192.168.5.0/24 is variably subnetted, 7 subnets, 5 masks
S    192.168.5.0/25 [1/0] via 192.168.5.225
C    192.168.5.128/26 is directly connected, Ethernet1/0
L    192.168.5.129/32 is directly connected, Ethernet1/0
C    192.168.5.192/27 is directly connected, Ethernet1/1
L    192.168.5.193/32 is directly connected, Ethernet1/1
C    192.168.5.224/30 is directly connected, Ethernet1/2
L    192.168.5.226/32 is directly connected, Ethernet1/2
Router#ping 192.168.5.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.5.2, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/60/68 ms
Router#ping 192.168.5.3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.5.3, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 52/56/60 ms
Router#ping 192.168.5.4
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.5.4, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/58/84 ms
Router#
```

Figura 13: Ping Router 2 - Servidores

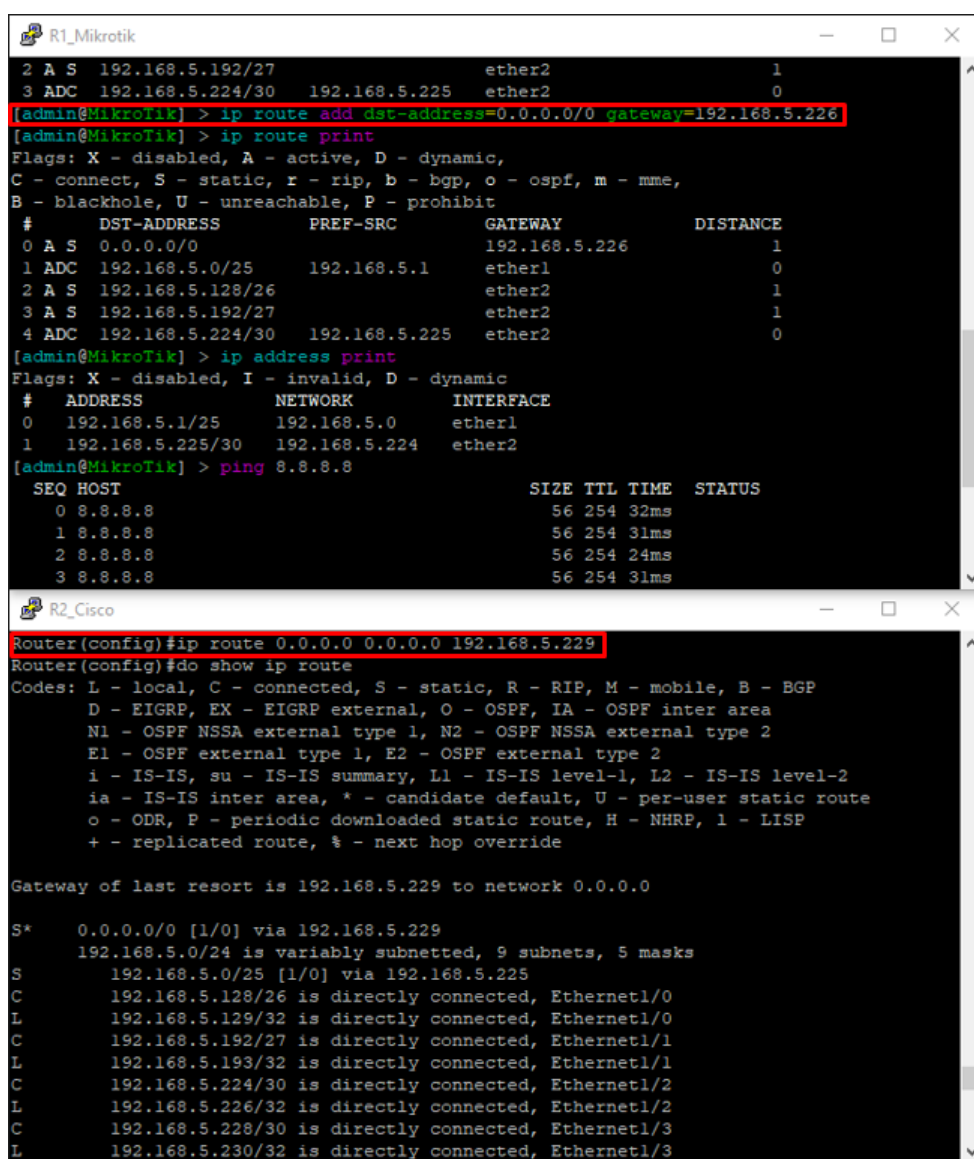
## 6 Configuração da LAN Transit B

Por fim vamos simular a conectividade fora da nossa rede, para isso vamos configurar o Router 3 com o endereço IP 8.8.8.8 na interface e1/3. Também vamos atribuir à interface fa0/0 do Router 3 o endereço estipulado anteriormente. Uma vez configurado temos que estabelecer uma rota default para a interface e1/3 do Router 2.

```
Router(config)#ip route 0.0.0.0 0.0.0.0 192.168.5.230
```

Figura 14: Rota Router 3 para Router 2

Necessitamos agora de rotas no sentido contrário, para isso também criamos rotas default no Router 1 e 2, no router 1 para a interface e1/2 do Router 2 e no Router 2 para a interface fa0/0 do Router 3.



```
R1_Mikrotik
2 A S 192.168.5.192/27 ether2 1
3 ADC 192.168.5.224/30 192.168.5.225 ether2 0
[admin@MikroTik] > ip route add dst-address=0.0.0.0/0 gateway=192.168.5.226
[admin@MikroTik] > ip route print
Flags: X - disabled, A - active, D - dynamic,
C - connect, S - static, r - rip, b - bgp, o - ospf, m - mme,
B - blackhole, U - unreachable, P - prohibit
# DST-ADDRESS PREF-SRC GATEWAY DISTANCE
0 A S 0.0.0.0/0 192.168.5.226 1
1 ADC 192.168.5.0/25 192.168.5.1 ether1 0
2 A S 192.168.5.128/26 ether2 1
3 A S 192.168.5.192/27 ether2 1
4 ADC 192.168.5.224/30 192.168.5.225 ether2 0
[admin@MikroTik] > ip address print
Flags: X - disabled, I - invalid, D - dynamic
# ADDRESS NETWORK INTERFACE
0 192.168.5.1/25 192.168.5.0 ether1
1 192.168.5.225/30 192.168.5.224 ether2
[admin@MikroTik] > ping 8.8.8.8
SEQ HOST SIZE TTL TIME STATUS
0 8.8.8.8 56 254 32ms
1 8.8.8.8 56 254 31ms
2 8.8.8.8 56 254 24ms
3 8.8.8.8 56 254 31ms

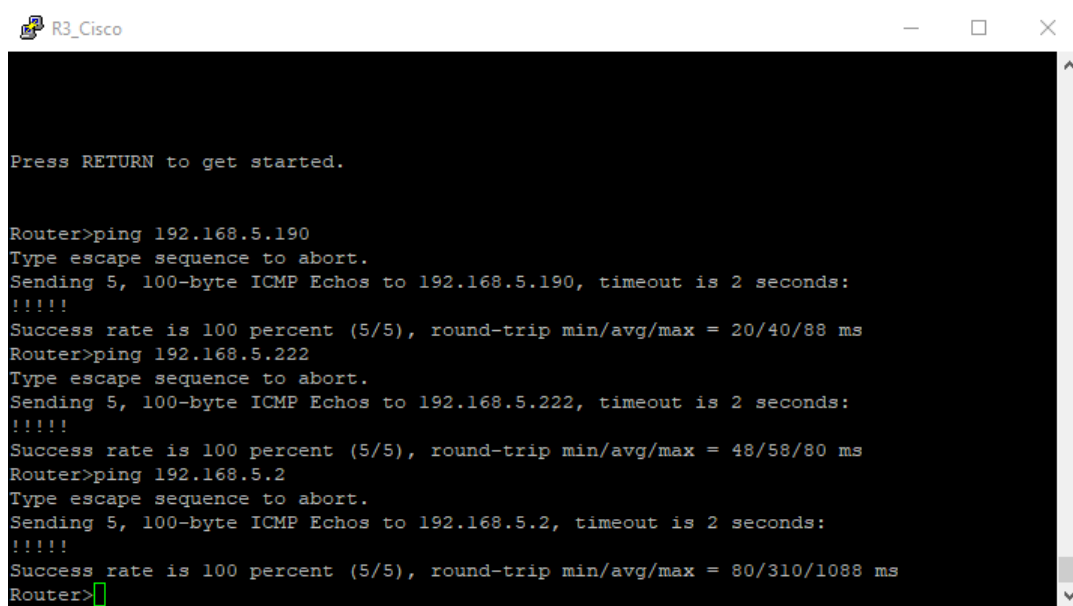
R2_Cisco
Router(config)#ip route 0.0.0.0 0.0.0.0 192.168.5.229
Router(config)#do show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
+ - replicated route, % - next hop override

Gateway of last resort is 192.168.5.229 to network 0.0.0.0

S* 0.0.0.0/0 [1/0] via 192.168.5.229
192.168.5.0/24 is variably subnetted, 9 subnets, 5 masks
S 192.168.5.0/25 [1/0] via 192.168.5.225
C 192.168.5.128/26 is directly connected, Ethernet1/0
L 192.168.5.129/32 is directly connected, Ethernet1/0
C 192.168.5.192/27 is directly connected, Ethernet1/1
L 192.168.5.193/32 is directly connected, Ethernet1/1
C 192.168.5.224/30 is directly connected, Ethernet1/2
L 192.168.5.226/32 is directly connected, Ethernet1/2
C 192.168.5.228/30 is directly connected, Ethernet1/3
L 192.168.5.230/32 is directly connected, Ethernet1/3
```

Figura 15: Rotas default Router 1 e Router 2

De forma a testarmos esta configuração vamos executar o comando ping no Router 3 para um computador de cada LAN e para um dos servidores.



```
R3_Cisco

Press RETURN to get started.

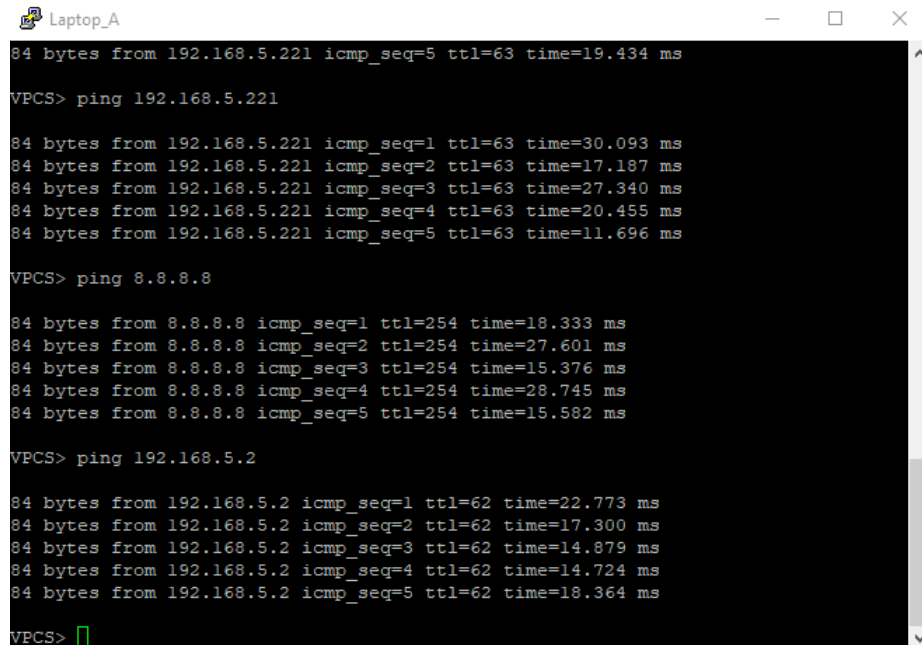
Router>ping 192.168.5.190
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.5.190, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 20/40/88 ms
Router>ping 192.168.5.222
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.5.222, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/58/80 ms
Router>ping 192.168.5.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.5.2, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/310/1088 ms
Router>
```

**Figura 16:** Pings Router 3

Como podemos observar o Router 3 realizou com sucesso ligações com o PC A, PC D e Servidor DHCP.

## 7 Testes

Para finalizar vamos realizar testes com o objetivo de confirmar se tudo está a funcionar corretamente. Vamos começar com a comunicação entre o PC A e os vários dispositivos (PC D, Fora da nossa rede, Servidor DHCP).



```
Laptop_A
84 bytes from 192.168.5.221 icmp_seq=5 ttl=63 time=19.434 ms

VPCS> ping 192.168.5.221

84 bytes from 192.168.5.221 icmp_seq=1 ttl=63 time=30.093 ms
84 bytes from 192.168.5.221 icmp_seq=2 ttl=63 time=17.187 ms
84 bytes from 192.168.5.221 icmp_seq=3 ttl=63 time=27.340 ms
84 bytes from 192.168.5.221 icmp_seq=4 ttl=63 time=20.455 ms
84 bytes from 192.168.5.221 icmp_seq=5 ttl=63 time=11.696 ms

VPCS> ping 8.8.8.8

84 bytes from 8.8.8.8 icmp_seq=1 ttl=254 time=18.333 ms
84 bytes from 8.8.8.8 icmp_seq=2 ttl=254 time=27.601 ms
84 bytes from 8.8.8.8 icmp_seq=3 ttl=254 time=15.376 ms
84 bytes from 8.8.8.8 icmp_seq=4 ttl=254 time=28.745 ms
84 bytes from 8.8.8.8 icmp_seq=5 ttl=254 time=15.582 ms

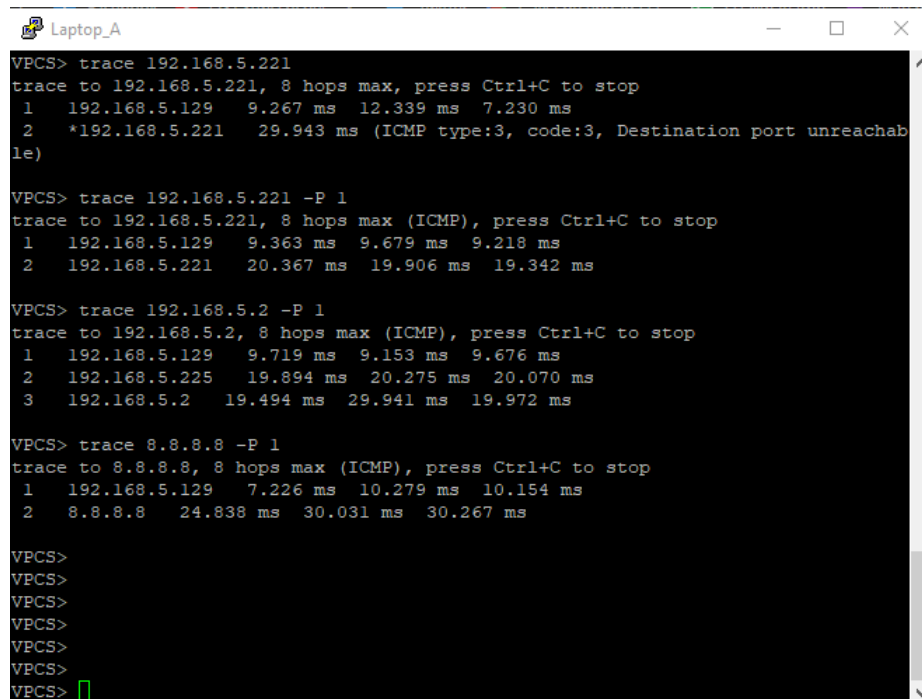
VPCS> ping 192.168.5.2

84 bytes from 192.168.5.2 icmp_seq=1 ttl=62 time=22.773 ms
84 bytes from 192.168.5.2 icmp_seq=2 ttl=62 time=17.300 ms
84 bytes from 192.168.5.2 icmp_seq=3 ttl=62 time=14.879 ms
84 bytes from 192.168.5.2 icmp_seq=4 ttl=62 time=14.724 ms
84 bytes from 192.168.5.2 icmp_seq=5 ttl=62 time=18.364 ms

VPCS>
```

Figura 17: Pings PC A

Verificamos as suas rotas:



```
Laptop_A

VPCS> trace 192.168.5.221
trace to 192.168.5.221, 8 hops max, press Ctrl+C to stop
 1 192.168.5.129 9.267 ms 12.339 ms 7.230 ms
 2 *192.168.5.221 29.943 ms (ICMP type:3, code:3, Destination port unreachab
le)

VPCS> trace 192.168.5.221 -P 1
trace to 192.168.5.221, 8 hops max (ICMP), press Ctrl+C to stop
 1 192.168.5.129 9.363 ms 9.679 ms 9.218 ms
 2 192.168.5.221 20.367 ms 19.906 ms 19.342 ms

VPCS> trace 192.168.5.2 -P 1
trace to 192.168.5.2, 8 hops max (ICMP), press Ctrl+C to stop
 1 192.168.5.129 9.719 ms 9.153 ms 9.676 ms
 2 192.168.5.225 19.894 ms 20.275 ms 20.070 ms
 3 192.168.5.2 19.494 ms 29.941 ms 19.972 ms

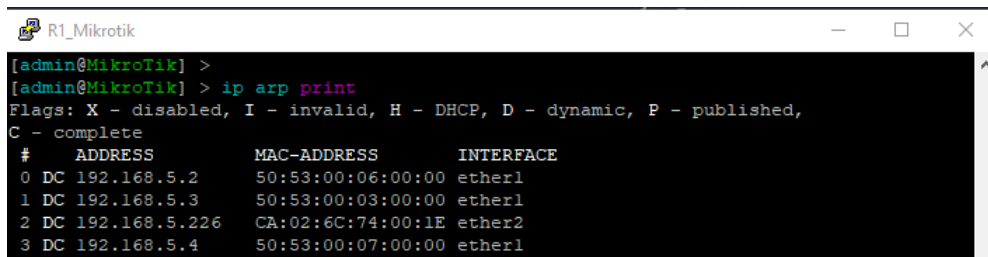
VPCS> trace 8.8.8.8 -P 1
trace to 8.8.8.8, 8 hops max (ICMP), press Ctrl+C to stop
 1 192.168.5.129 7.226 ms 10.279 ms 10.154 ms
 2 8.8.8.8 24.838 ms 30.031 ms 30.267 ms

VPCS>
VPCS>
VPCS>
VPCS>
VPCS>
VPCS>
VPCS>
```

Figura 18: Trace PC A

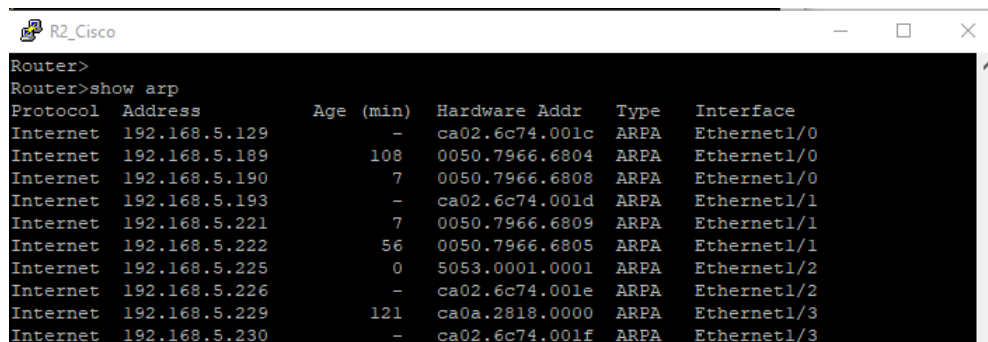
Como podemos observar os pings e os seus caminhos estão a funcionar.

Falta-nos só verificar as tabelas arp de cada Router.



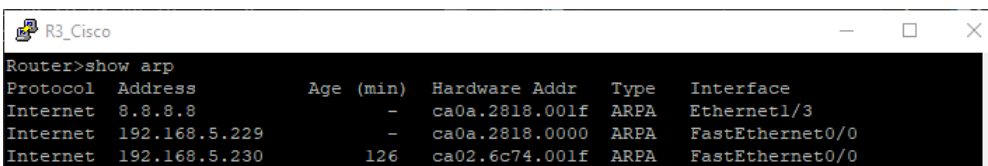
```
R1_Mikrotik
[admin@MikroTik] >
[admin@MikroTik] > ip arp print
Flags: X - disabled, I - invalid, H - DHCP, D - dynamic, P - published,
C - complete
# ADDRESS MAC-ADDRESS INTERFACE
0 DC 192.168.5.2 50:53:00:06:00:00 ether1
1 DC 192.168.5.3 50:53:00:03:00:00 ether1
2 DC 192.168.5.226 CA:02:6C:74:00:1E ether2
3 DC 192.168.5.4 50:53:00:07:00:00 ether1
```

Figura 19: Tabela arp Router 1



```
R2_Cisco
Router>
Router>show arp
Protocol Address Age (min) Hardware Addr Type Interface
Internet 192.168.5.129 - ca02.6c74.001c ARPA Ethernet1/0
Internet 192.168.5.189 108 0050.7966.6804 ARPA Ethernet1/0
Internet 192.168.5.190 7 0050.7966.6808 ARPA Ethernet1/0
Internet 192.168.5.193 - ca02.6c74.001d ARPA Ethernet1/1
Internet 192.168.5.221 7 0050.7966.6809 ARPA Ethernet1/1
Internet 192.168.5.222 56 0050.7966.6805 ARPA Ethernet1/1
Internet 192.168.5.225 0 5053.0001.0001 ARPA Ethernet1/2
Internet 192.168.5.226 - ca02.6c74.001e ARPA Ethernet1/2
Internet 192.168.5.229 121 ca0a.2818.0000 ARPA Ethernet1/3
Internet 192.168.5.230 - ca02.6c74.001f ARPA Ethernet1/3
```

Figura 20: Tabela arp Router 2



```
R3_Cisco
Router>
Router>show arp
Protocol Address Age (min) Hardware Addr Type Interface
Internet 8.8.8.8 - ca0a.2818.001f ARPA Ethernet1/3
Internet 192.168.5.229 - ca0a.2818.0000 ARPA FastEthernet0/0
Internet 192.168.5.230 126 ca02.6c74.001f ARPA FastEthernet0/0
```

Figura 21: Tabela arp Router 3

Como podemos observar os endereços e as interfaces estão todas de acordo com o planeado no início desta fase.

## **8 Conclusões**

O objetivo desta fase do projeto era o de consolidar e aprofundar os conhecimentos adquiridos ao longo de Redes de Computadores mais especificamente como configurar redes locais e tabelas de roteamento, atribuir endereços com sumarização completa e a definição de IP's estáticos. Reforçamos os conceitos de sub-rede e de rota entre hosts o que é fundamental para um melhor domínio das potencialidades das redes, do seu endereçamento, como são particionadas e como é feito o roteamento do tráfego entre elas. Conseguimos atingir todos os requisitos desta fase do projeto demonstrando o domínio que temos sobre a matéria lecionada.