

INSTITUTO SUPERIOR TÉCNICO

REDES E SERVIÇOS INTERNET

Laboratório 3 - Multicast

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16 de Novembro de 2019



TÉCNICO
LISBOA

2.1

b)

```
PC4#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
PC4(config)#no ip routing
PC4(config)#interface fastEthernet 0/0
PC4(config-if)#ip address 192.168.1.4 255.255.255.0
PC4(config-if)#no shutdown
PC4(config-if)#end
*Oct 30 15:44:31.655: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Oct 30 15:44:32.655: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
PC4(config-if)#end
PC4#
*Oct 30 15:44:38.055: %SYS-5-CONFIG_I: Configured from console by console
PC4#write
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
Building configuration...
```

Figura 1: Comandos inseridos para configurar o PC4.

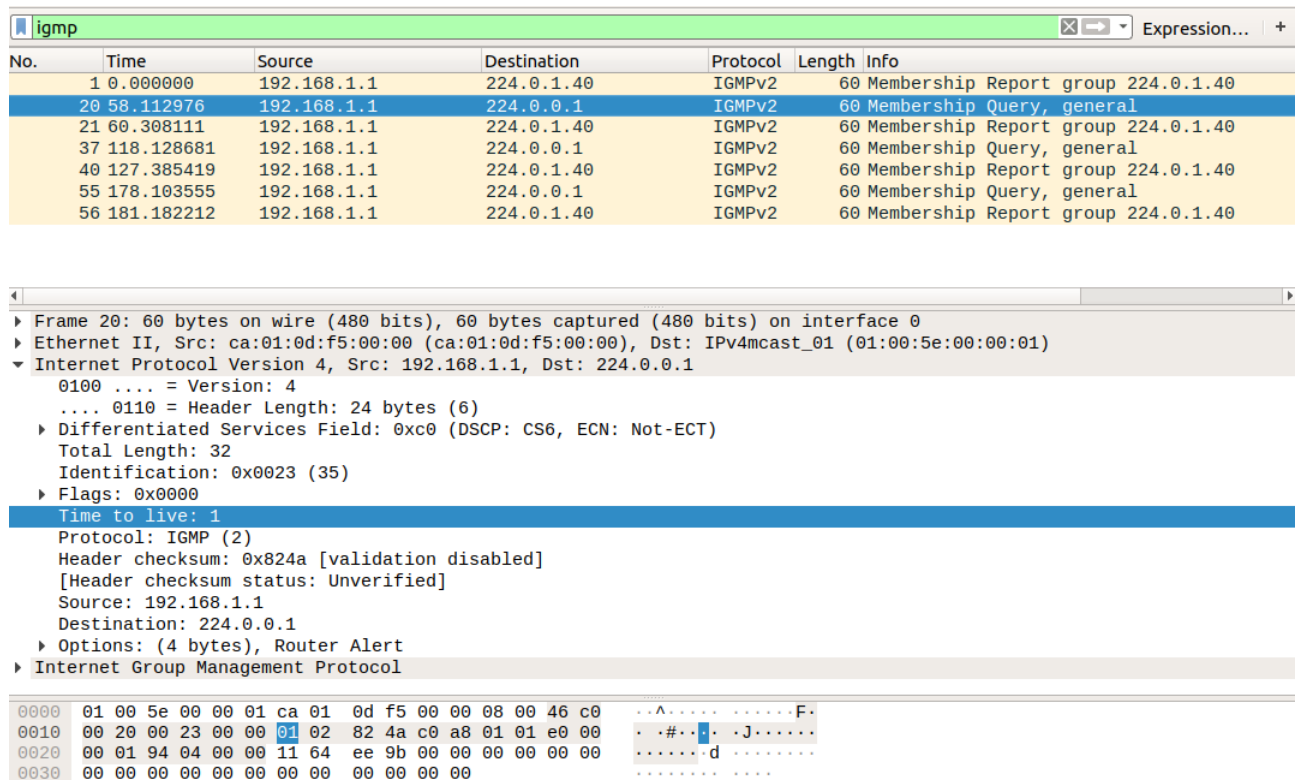
d)

```
R2#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#ip multicast-routing
R2(config)#interface fastEthernet 0/0
R2(config-if)#ip address 192.168.1.2 255.255.255.0
R2(config-if)#ip pim dense-mode
R2(config-if)#no shutdown
R2(config-if)#end
*Oct 30 15:48:48.003: %PIM-5-NBRCHG: neighbor 192.168.1.1 UP on interface FastEthernet0/0
R2(config-if)#end
*Oct 30 15:48:49.103: %PIM-5-DRCHG: DR change from neighbor 0.0.0.0 to 192.168.1.2 on interface FastEthernet0/0
R2(config-if)#end
*Oct 30 15:48:49.911: %LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
*Oct 30 15:48:50.911: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0, changed state to up
R2(config-if)#end
R2#w
*Oct 30 15:48:54.579: %SYS-5-CONFIG_I: Configured from console by console
R2#write
Warning: Attempting to overwrite an NVRAM configuration previously written
by a different version of the system image.
Overwrite the previous NVRAM configuration?[confirm]
Building configuration...
```

Figura 2: Comandos inseridos para configurar o router R2.

2.2

a)



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	192.168.1.1	224.0.1.40	IGMPv2	60	Membership Report group 224.0.1.40
20	58.112976	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
21	60.308111	192.168.1.1	224.0.1.40	IGMPv2	60	Membership Report group 224.0.1.40
37	118.128681	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
40	127.385419	192.168.1.1	224.0.1.40	IGMPv2	60	Membership Report group 224.0.1.40
55	178.103555	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
56	181.182212	192.168.1.1	224.0.1.40	IGMPv2	60	Membership Report group 224.0.1.40

Frame 20: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
Ethernet II, Src: ca:01:0d:f5:00:00 (ca:01:0d:f5:00:00), Dst: IPv4mcast_01 (01:00:5e:00:00:01)
Internet Protocol Version 4, Src: 192.168.1.1, Dst: 224.0.0.1
0100 = Version: 4
.... 0110 = Header Length: 24 bytes (6)
Differentiated Services Field: 0xc0 (DSCP: CS6, ECN: Not-ECT)
Total Length: 32
Identification: 0x0023 (35)
Flags: 0x0000
Time to live: 1
Protocol: IGMP (2)
Header checksum: 0x824a [validation disabled]
[Header checksum status: Unverified]
Source: 192.168.1.1
Destination: 224.0.0.1
Options: (4 bytes), Router Alert
Internet Group Management Protocol

0000 01 00 5e 00 00 01 ca 01 0d f5 00 00 08 00 46 c0 ..^.....F.
0010 00 20 00 23 00 00 01 02 82 4a c0 a8 01 01 e0 00 . .#.. .J.....
0020 00 01 94 04 00 00 11 64 ee 9b 00 00 00 00 00 00d
0030 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

Figura 3: Captura do tráfego utilizando o Wireshark em f0/0 do PC3.

O período das mensagens QUERY é de 60 segundos. As mensagens multicast são enviadas pelo router R1 (192.168.1.1) para o endereço multicast 224.0.0.1. Este endereço destina-se a "All Hosts on this Subnet". O valor do campo TTL do cabeçalho IP é 1, dado que são mensagens para a LAN.

d)

(igmp or icmp or arp) and !ip.addr==224.0.1.40							Expression...	+
No.	Time	Source	Destination	Protocol	Length	Info		
89	298.115367	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general		
108	358.141882	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general		
126	418.138216	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general		
145	478.116493	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general		
163	538.146480	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general		
181	598.142365	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general		
200	658.119908	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general		
207	672.288791	192.168.1.3	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2		
208	672.298830	192.168.1.3	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2		

▶	Frame 207: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
▶	Ethernet II, Src: ca:03:0e:13:00:00 (ca:03:0e:13:00:00), Dst: IPv4mcast_01:02 (01:00:5e:00:01:02)
▶	Internet Protocol Version 4, Src: 192.168.1.3, Dst: 239.0.1.2
▼	Internet Group Management Protocol
	[IGMP Version: 2]
	Type: Membership Report (0x16)
	Max Resp Time: 0,0 sec (0x00)
	Checksum: 0xf9fc [correct]
	[Checksum Status: Good]
	Multicast Address: 239.0.1.2

0000	01 00 5e 00 01 02 ca 03 0e 13 00 00 08 00 46 c0	..^.....F.
0010	00 20 00 28 00 00 01 02 72 42 c0 a8 01 03 ef 00	..(.....rB.....
0020	01 02 94 04 00 00 16 00 f9 fc ef 00 01 02 00 00	.....
0030	00 00 00 00 00 00 00 00 00 00 00 00 00 00	.....

Figura 4: Mensagem obtida a partir do PC3.

A mensagem originada é "Membership report", a partir do PC3 (192.168.1.3) para o endereço multicast 239.0.1.2. Não há resposta a esta mensagem.

e)

```
PC5#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
PC5(config)#interface fastEthernet 0/0
PC5(config-if)#ip igmp join-group 239.0.1.2
PC5(config-if)#end
PC5#
*Oct 30 16:09:04.447: %SYS-5-CONFIG_I: Configured from console by console
```

Figura 5: Comandos utilizados para o PC5 juntar-se ao grupo de multicast 239.0.1.2.

(igmp or icmp or arp) and !ip.addr==224.0.1.40							Expression...	+
No.	Time	Source	Destination	Protocol	Length	Info		
244	783.800278	192.168.1.3	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2		
258	838.136751	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general		
260	838.498845	192.168.1.3	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2		
263	847.864688	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2		
264	847.874789	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2		
279	898.131795	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general		
282	906.059257	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2		
287	916.792605	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2		
288	916.792664	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2		

▶ Frame 287: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
▶ Ethernet II, Src: ca:05:0e:31:00:00 (ca:05:0e:31:00:00), Dst: IPv4mcast_01:02 (01:00:5e:00:01:02)
▼ Internet Protocol Version 4, Src: 192.168.1.5, Dst: 239.0.1.2
0100 = Version: 4
.... 0110 = Header Length: 24 bytes (6)
▶ Differentiated Services Field: 0xc0 (DSCP: CS6, ECN: Not-ECT)
Total Length: 32
Identification: 0x000a (10)
Flags: 0x0000
Time to live: 1
Protocol: IGMP (2)
Header checksum: 0x725e [validation disabled]
[Header checksum status: Unverified]
Source: 192.168.1.5
Destination: 239.0.1.2
▶ Options: (4 bytes), Router Alert
▼ Internet Group Management Protocol
[IGMP Version: 2]

0000	01 00 5e 00 01 02 ca 05 0e 31 00 00 08 00 46 c0	..^.....1...F.
0010	00 20 00 0a 00 00 01 02 72 5e c0 a8 01 05 ef 00	.....rA.....
0020	01 02 94 04 00 00 16 00 f9 fc ef 00 01 02 00 00	.....
0030	00 00 00 00 00 00 00 00 00 00 00 00 00 00	.....

Figura 6: Mensagens observadas após o PC4 e o PC5 se terem juntado ao grupo de multicast.

Sim, as mensagens observadas são "Membership report group 239.0.1.2", a partir dos PC4 (192.168.1.4) e PC5 (192.168.1.5). Não existem respostas a estas mensagens.

f)

```
PC3#ping 239.0.1.2
Type escape sequence to abort.
Sending 1, 100-byte ICMP Echos to 239.0.1.2, timeout is 2 seconds:

Reply to request 0 from 192.168.1.3, 4 ms
Reply to request 0 from 192.168.1.4, 32 ms
Reply to request 0 from 192.168.1.5, 20 ms
PC3#ping 239.0.1.2
Type escape sequence to abort.
Sending 1, 100-byte ICMP Echos to 239.0.1.2, timeout is 2 seconds:

Reply to request 0 from 192.168.1.3, 1 ms
Reply to request 0 from 192.168.1.5, 12 ms
Reply to request 0 from 192.168.1.4, 8 ms
```

Figura 7: Execução do ping do PC3 para o grupo de multicast 239.0.1.2.

Filter: (igmp or icmp or arp) and ip.addr==224.0.1.40						
No.	Time	Source	Destination	Protocol	Length	Info
288	916.792664	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
299	958.153290	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
300	960.198669	192.168.1.3	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
320	1018.147625	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
322	1022.095537	192.168.1.3	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
324	1024.000233	192.168.1.3	239.0.1.2	ICMP	114	Echo (ping) request id=0x0007, seq=0/0, ttl=255 (multicast)
333	1046.480386	192.168.1.5	192.168.1.3	ICMP	114	Echo (ping) reply id=0x0007, seq=0/0, ttl=255
334	1046.484138	192.168.1.4	192.168.1.3	ICMP	114	Echo (ping) reply id=0x0007, seq=0/0, ttl=255
335	1051.465706	192.168.1.3	239.0.1.2	ICMP	114	Echo (ping) request id=0x0008, seq=0/0, ttl=255 (multicast)
336	1051.467246	192.168.1.4	192.168.1.3	ICMP	114	Echo (ping) reply id=0x0008, seq=0/0, ttl=255
337	1051.474082	192.168.1.5	192.168.1.3	ICMP	114	Echo (ping) reply id=0x0008, seq=0/0, ttl=255
345	1078.154059	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
348	1082.869285	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
367	1138.136803	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
369	1141.809462	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2

Frame 332: 114 bytes on wire (912 bits), 114 bytes captured (912 bits) on interface 0
Ethernet II, Src: ca:03:0e:13:00:00 (ca:03:0e:13:00:00), Dst: IPv4mcast_01:02 (01:00:5e:00:01:02)
Internet Protocol Version 4, Src: 192.168.1.3, Dst: 239.0.1.2
0100 = Version: 4
.... 0101 = Header Length: 20 bytes (5)
Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
Total Length: 100
Identification: 0x0023 (35)
Flags: 0x0000
Time to live: 255
Protocol: ICMP (1)
Header checksum: 0x09c8 [validation disabled]
[Header checksum status: Unverified]
Source: 192.168.1.3
Destination: 239.0.1.2
Internet Control Message Protocol

0000	01 00 5e 00 01 02 ca 03 0e 13 00 00 00 45 00	.....E..
0010	00 04 00 23 00 00 ff 01 09 c8 c0 a8 01 03 ef 00	...d#.....
0020	01 02 00 00 7c 52 00 07 00 00 00 00 00 1d	...|R.....
0030	01 d4 ab cd ab cd ab cd ab cd ab cd ab cd ab cd	.....
0040	ab cd ab cd ab cd ab cd ab cd ab cd ab cd ab cd	.....
0050	ab cd ab cd ab cd ab cd ab cd ab cd ab cd ab cd	.....
0060	ab cd ab cd ab cd ab cd ab cd ab cd ab cd ab cd	.....
0070	ab cd	..

Figura 8: Captura de tráfego de modo a observar os protocolos utilizados durante a execução do ping.

O PC3 recebeu três respostas ao ping multicast, uma de cada PC (incluindo o próprio PC3). As mensagens ping foram enviadas para o endereço IP 239.0.1.2 e endereço MAC 01:00:5e:00:01:02. O endereço MAC de destino é obtido através do endereço IP multicast: os primeiros 3 bytes são o prefixo OUI (01:00:5E), depois existe um bit a 0 e os 23 bits menos significativos são copiados dos 23 bits menos significativos do endereço IP multicast (0.1.2). Não é utilizado o protocolo ARP. Como podemos observar na imagem 8, as respostas ao ping são enviadas diretamente para o endereço do PC3 (192.168.1.3), pelo que são unicast.

g)

```
R1#show ip igmp groups
```

IGMP Connected Group Membership						
Group Address	Interface	Uptime	Expires	Last Reporter	Group Accounted	
239.0.1.2	FastEthernet0/0	00:15:51	00:02:54	192.168.1.5		
224.0.1.40	FastEthernet0/0	00:32:06	00:02:57	192.168.1.1		

Figura 9: Execução do comando "show igmp groups" no router R1.

```
R2#show ip igmp groups
```

IGMP Connected Group Membership						
Group Address	Interface	Uptime	Expires	Last Reporter	Group Accounted	
239.0.1.2	FastEthernet0/0	00:14:26	00:02:20	192.168.1.5		
224.0.1.40	FastEthernet0/0	00:28:24	00:02:25	192.168.1.1		

Figura 10: Execução do comando "show igmp groups" no router R2.

Através do resultado do comando "show ip igmp groups" nos dois routers nas figuras 9 e 10, verificamos que os routers não têm conhecimento acerca dos endereços de todos os membros do grupo multicast nem quantos são: apenas têm informação acerca do endereço do último membro a responder a um query.

h)

No.	Time	Source	Destination	Protocol	Length	Info
445	1385.684882	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
460	1438.135448	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
461	1448.496886	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
478	1498.146886	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
479	1499.012690	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
497	1558.154281	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
500	1560.268880	192.168.1.3	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
516	1618.156127	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
517	1618.609882	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
536	1678.153751	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
537	1680.107811	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
550	1738.163959	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
557	1738.623233	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
576	1798.140638	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
578	1804.481577	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2

No.	Time	Source	Destination	Protocol	Length	Info
15	48.195965	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
16	49.759020	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
33	108.212309	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
35	112.136269	192.168.1.3	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
51	168.190824	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
52	168.936880	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2

Figura 11: Captura do tráfego de modo a observar as respostas a cada query.

Observando a figura 11, verificamos que cada query apenas tem uma resposta, que pode vir de qualquer um dos PCs e o intervalo entre a query e a resposta é sempre diferente. Isto acontece porque, ao receberem uma query, os PCs definem um intervalo de tempo que irão esperar para responder (abaixo de 10 segundos) e apenas enviam se nenhum dos outros PCs já tiver respondido. Desta forma, o PC que envia a resposta é o que escolheu o intervalo de tempo mais curto e esse intervalo é escolhido de forma aleatória.

2.3

a)

No.	Time	Source	Destination	Protocol	Length	Info
15	48.195965	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
16	49.759020	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
33	108.212309	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
35	112.136269	192.168.1.3	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
51	168.190824	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
52	168.936880	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2


```

PC3
File Edit View Search Terminal Help
PC3#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
PC3(config)#interface fastEthernet 0/0
PC3(config-if)#no ip igmp join-group 239.0.1.2
PC3(config-if)#end
  
```

Figura 12: Comandos para a saída do PC3 do grupo de multicast 239.0.1.2 e captura do tráfego após a saída.

No.	Time	Source	Destination	Protocol	Length	Info
15	48.195965	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
16	49.759020	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
33	108.212309	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
35	112.136269	192.168.1.3	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
51	168.190824	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
52	168.936880	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
71	228.184449	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
72	229.057528	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
92	288.192207	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
98	297.074263	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2

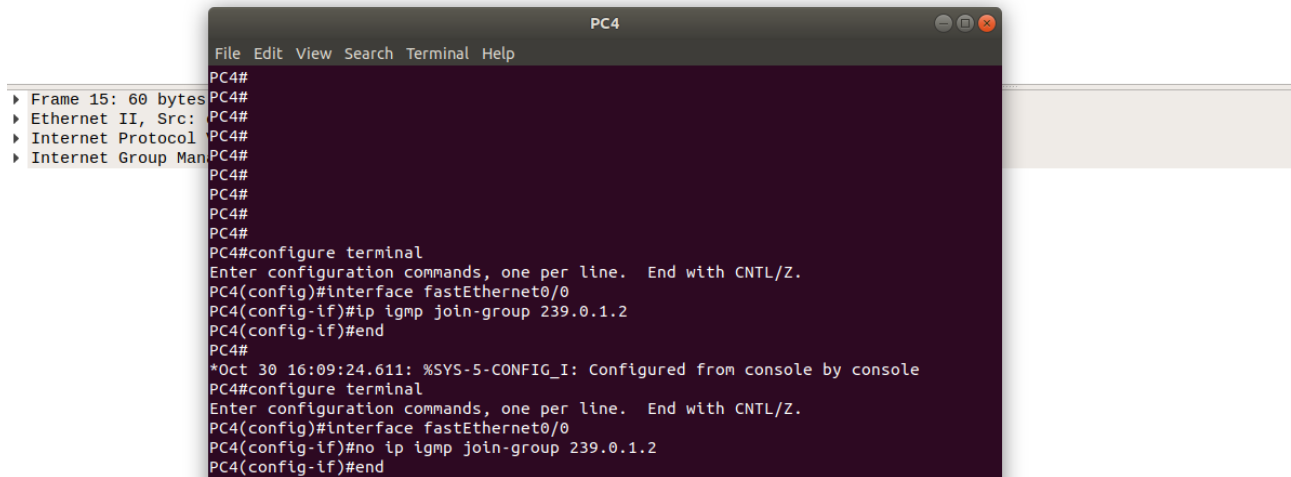


Figura 13: Comandos para a saída do PC4 do grupo de multicast 239.0.1.2 e captura do tráfego após a saída.

No.	Time	Source	Destination	Protocol	Length	Info
33	108.212309	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
35	112.136269	192.168.1.3	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
51	168.190824	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
52	168.936880	192.168.1.4	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
71	228.184449	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
72	229.057528	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
92	288.192207	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
98	297.074263	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
112	348.179455	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
114	350.250595	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
130	408.180445	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
137	418.167174	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
138	420.602749	192.168.1.5	224.0.0.2	IGMPv2	60	Leave Group 239.0.1.2
139	420.610938	192.168.1.1	239.0.1.2	IGMPv2	60	Membership Query, specific for group 239.0.1.2
140	421.672275	192.168.1.1	239.0.1.2	IGMPv2	60	Membership Query, specific for group 239.0.1.2

Figura 14: Comandos para a saída do PC5 do grupo de multicast 239.0.1.2 e captura do tráfego após a saída..

Nas imagens 12, 13 e 14 podemos ver, sucessivamente o tráfego no wireshark quando ocorre a saída do PC3, PC4 e PC5 do grupo multicast. Nos dois primeiros casos, verificamos que não existe qualquer tipo de resposta de saída uma vez que a resposta ao último query não foi feita pelo PC que saiu (quando o PC3 saiu, o último query tinha sido respondido pelo PC4 e quando o PC4 saiu, o último query tinha sido respondido pelo PC5). Já quando foi o PC5 a sair, verificamos que este envia uma mensagem "Leave Group 239.0.1.2" para o endereço 224.0.0.2. Ao contrário dos casos anteriores, o PC5 tinha sido o último a responder a um query, por isso existe

a necessidade de este enviar a mensagem "Leave Group". Este endereço para o qual foi enviada a mensagem "Leave Group" (224.0.0.2) tem o significado "All Routers on this Subnet". Após o PC5 sair do grupo, o router R1 envia imediatamente duas mensagens "Membership Query" para determinar se ainda existem membros do grupo naquela subrede.

b)

No.	Time	Source	Destination	Protocol	Length	Info
71	228.184449	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
72	229.057528	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
92	288.192207	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
98	297.074263	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
112	348.179455	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
114	350.250595	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
130	408.180445	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
137	418.167174	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
138	420.602749	192.168.1.5	224.0.0.2	IGMPv2	60	Leave Group 239.0.1.2
139	420.610938	192.168.1.1	239.0.1.2	IGMPv2	60	Membership Query, specific for group 239.0.1.2
140	421.672275	192.168.1.1	239.0.1.2	IGMPv2	60	Membership Query, specific for group 239.0.1.2
153	468.185679	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
170	528.201190	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
187	588.173853	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
220	708.191980	192.168.1.2	224.0.0.1	IGMPv2	60	Membership Query, general

▶ Frame 220: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
 ▶ Ethernet II, Src: ca:02:0e:04:00:00 (ca:02:0e:04:00:00), Dst: IPv4mcast_01 (01:00:5e:00:00:01)
 ▶ Internet Protocol Version 4, Src: 192.168.1.2, Dst: 224.0.0.1
 ▶ Internet Group Management Protocol

```

R1
File Edit View Search Terminal Help
R1#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#interface fastEthernet 0/0
R1(config-if)#no ip pim dense-mode
R1(config-if)#
*Oct 30 16:34:40.455: %PIM-5-NBRCHG: neighbor 192.168.1.2 DOWN on interface Fast
Ethernet0/0 DR
R1(config-if)#end
  
```

Figura 15: Comandos para a saída do modo de multicast do router R1 e captura do tráfego para a saída.

Na figura 15 observamos o tráfego wireshark quando R1 saiu do processo de multicast. Como podemos ver, não existe qualquer mensagem quando R1 sai. O router que passou a enviar as queries foi R2, cerca de 2 minutos (2*Query period) depois do último query de R1.

c)

No.	Time	Source	Destination	Protocol	Length	Info
92	288.192207	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
98	297.074263	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
112	348.179455	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
114	350.250595	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
130	408.180445	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
137	418.167174	192.168.1.5	239.0.1.2	IGMPv2	60	Membership Report group 239.0.1.2
138	420.602749	192.168.1.5	224.0.0.2	IGMPv2	60	Leave Group 239.0.1.2
139	420.610938	192.168.1.1	239.0.1.2	IGMPv2	60	Membership Query, specific for group 239.0.1.2
140	421.672275	192.168.1.1	239.0.1.2	IGMPv2	60	Membership Query, specific for group 239.0.1.2
153	468.185679	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
170	528.201190	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
187	588.173853	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general
220	708.191980	192.168.1.2	224.0.0.1	IGMPv2	60	Membership Query, general
236	768.209470	192.168.1.2	224.0.0.1	IGMPv2	60	Membership Query, general
239	769.522892	192.168.1.1	224.0.0.1	IGMPv2	60	Membership Query, general

▶ Frame 239: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
 ▶ Ethernet II, Src: ca:01:0d:f5:00:00 (ca:01:0d:f5:00:00), Dst: IPv4mcast_01 (01:00:5e:00:00:01)
 ▶ Internet Protocol Version 4, Src: 192.168.1.1, Dst: 224.0.0.1
 ▶ Internet Group Management Protocol

```

R1
File Edit View Search Terminal Help
R1#
*Oct 30 16:34:44.839: %SYS-5-CONFIG_I: Configured from console by console
R1#
R1#
R1#
R1#
R1#
R1#
R1#
R1#
R1#
R1#
R1#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#interface fastEthernet 0/0
R1(config-if)#ip pim dense-mode
R1(config-if)#
*Oct 30 16:37:33.435: %PIM-5-NBRCHG: neighbor 192.168.1.2 UP on interface FastEthernet0/0
0000 01 00 5e 00 00 *Oct 30 16:37:33.443: %PIM-5-DRCHG: DR change from neighbor 0.0.0.0 to 192.168.1
0010 00 20 00 bc.2 on interface FastEthernet0/0
0020 00 01 94 00 R1(config-if)#end
0030 00 00 00 00
  
```

Figura 16: Comandos para o router R1 voltar ao modo de multicast e captura do tráfego.

Quando o router R1 se volta a juntar ao processo multicast, verificamos que este envia imediatamente uma query IGMP. Podemos concluir que a eleição do router que irá fazer as queries é feita sempre com base no IP dos routers existentes no processo: é escolhido o router com menor IP.

3.2

a)

```
PC3#ping 192.168.6.9
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.6.9, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 72/84/92 ms
PC3#ping 192.168.1.4
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.4, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 56/82/92 ms
PC3#ping 192.168.1.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.1.5, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 56/82/96 ms
PC3#ping 192.168.5.8
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.5.8, timeout is 2 seconds:
.!!!!
Success rate is 80 percent (4/5), round-trip min/avg/max = 88/333/1060 ms
```

Figura 17: Realização do ping do PC3 para todos os outros PCs.

```

R1#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 01:00:43/stopped, RP 0.0.0.0, flags: DC
Incoming interface: Null, RPF nbr 0.0.0.0
Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:56:00/stopped
    FastEthernet0/0, Forward/Dense, 01:00:43/stopped

(192.168.6.9, 239.0.1.2), 00:02:45/00:00:14, flags: T
Incoming interface: FastEthernet1/0, RPF nbr 192.168.4.7
Outgoing interface list:
    FastEthernet0/0, Forward/Dense, 00:02:45/stopped, A

(*, 224.0.1.40), 01:00:45/00:02:17, RP 0.0.0.0, flags: DCL
Incoming interface: Null, RPF nbr 0.0.0.0
Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:56:00/stopped
    FastEthernet0/0, Forward/Dense, 01:00:45/stopped

```

Figura 18: Realização do comando "show ip mroute" no router R1.

```

R6#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 00:02:18/stopped, RP 0.0.0.0, flags: D
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:02:18/stopped
    FastEthernet0/0, Forward/Dense, 00:02:18/stopped

(192.168.6.9, 239.0.1.2), 00:02:18/00:00:41, flags: T
  Incoming interface: FastEthernet0/0, RPF nbr 192.168.3.7
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:02:18/stopped

(*, 224.0.1.40), 00:54:39/00:02:27, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:54:38/stopped
    FastEthernet0/0, Forward/Dense, 00:54:39/stopped

```

Figura 19: Realização do comando "show ip mroute" no router R6.

```

R2#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 00:56:40/stopped, RP 0.0.0.0, flags: DC
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet2/0, Forward/Dense, 00:54:25/stopped
    FastEthernet1/0, Forward/Dense, 00:56:40/stopped
    FastEthernet0/0, Forward/Dense, 00:56:40/stopped

(192.168.6.9, 239.0.1.2), 00:02:06/00:00:53, flags: T
  Incoming interface: FastEthernet2/0, RPF nbr 192.168.2.6
  Outgoing interface list:
    FastEthernet0/0, Prune/Dense, 00:02:06/00:00:53
    FastEthernet1/0, Forward/Dense, 00:02:06/stopped

(*, 224.0.1.40), 00:56:42/00:02:56, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet2/0, Forward/Dense, 00:54:25/stopped
    FastEthernet0/0, Forward/Dense, 00:56:42/stopped

```

Figura 20: Realização do comando "show ip mroute" no router R2.

```

R7#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 00:55:41/stopped, RP 0.0.0.0, flags: DC
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet2/0, Forward/Dense, 00:54:47/stopped
    FastEthernet1/0, Forward/Dense, 00:55:41/stopped
    FastEthernet0/0, Forward/Dense, 00:55:41/stopped

(192.168.6.9, 239.0.1.2), 00:02:27/00:00:32, flags: T
  Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:02:27/stopped
    FastEthernet2/0, Forward/Dense, 00:02:27/stopped

(*, 224.0.1.40), 00:55:42/00:02:25, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet2/0, Forward/Dense, 00:54:47/stopped
    FastEthernet1/0, Forward/Dense, 00:55:42/stopped
    FastEthernet0/0, Forward/Dense, 00:55:42/stopped

```

Figura 21: Realização do comando "show ip mroute" no router R7.

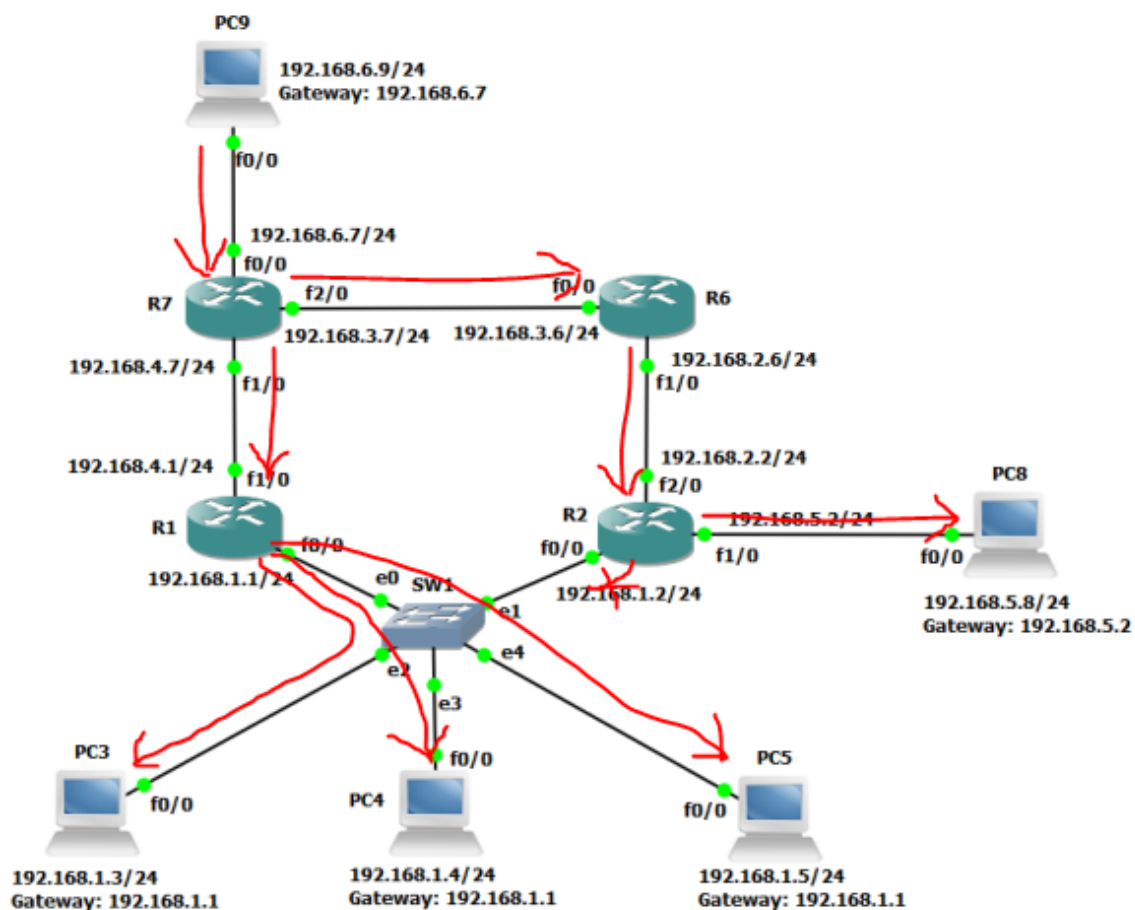


Figura 22: Desenho da árvore de multicast para o grupo 239.0.1.2.

Com base no resultado dos comando "show ip mroute" em todos os routers (figuras 18, 19, 20 e 21), conseguimos desenhar a árvore multicast com origem no PC9 (figura 22),

b)

```
R1#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 00:13:17/stopped, RP 0.0.0.0, flags: DC
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:12:48/stopped
    FastEthernet0/0, Forward/Dense, 00:13:17/stopped

(192.168.6.9, 239.0.1.2), 00:00:22/00:02:37, flags: T
  Incoming interface: FastEthernet1/0, RPF nbr 192.168.4.7
  Outgoing interface list:
    FastEthernet0/0, Forward/Dense, 00:00:22/stopped, A

(192.168.1.3, 239.0.1.2), 00:00:47/00:02:12, flags: T
  Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:00:47/stopped

(*, 224.0.1.40), 00:13:17/00:02:49, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:12:48/stopped
    FastEthernet0/0, Forward/Dense, 00:13:17/stopped
```

Figura 23: Realização do comando "show ip mroute" no router R1.

```

R2#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 00:10:47/stopped, RP 0.0.0.0, flags: DC
Incoming interface: Null, RPF nbr 0.0.0.0
Outgoing interface list:
  FastEthernet1/0, Forward/Dense, 00:10:46/stopped
  FastEthernet2/0, Forward/Dense, 00:10:47/stopped
  FastEthernet0/0, Forward/Dense, 00:10:47/stopped

(192.168.6.9, 239.0.1.2), 00:00:21/00:02:38, flags: T
Incoming interface: FastEthernet2/0, RPF nbr 192.168.2.6
Outgoing interface list:
  FastEthernet0/0, Prune/Dense, 00:00:21/00:02:38
  FastEthernet1/0, Forward/Dense, 00:00:21/stopped

(192.168.1.3, 239.0.1.2), 00:00:38/00:02:21, flags: T
Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
Outgoing interface list:
  FastEthernet2/0, Prune/Dense, 00:00:37/00:02:22
  FastEthernet1/0, Forward/Dense, 00:00:38/stopped

(*, 224.0.1.40), 00:10:48/00:02:45, RP 0.0.0.0, flags: DCL
Incoming interface: Null, RPF nbr 0.0.0.0
Outgoing interface list:
  FastEthernet2/0, Forward/Dense, 00:10:48/stopped
  FastEthernet0/0, Forward/Dense, 00:10:48/stopped

```

Figura 24: Realização do comando "show ip mroute" no router R2.

```

R6#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 00:01:08/stopped, RP 0.0.0.0, flags: D
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:01:08/stopped
    FastEthernet0/0, Forward/Dense, 00:01:08/stopped

(192.168.6.9, 239.0.1.2), 00:00:42/00:02:17, flags: T
  Incoming interface: FastEthernet0/0, RPF nbr 192.168.3.7
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:00:42/stopped

(192.168.1.3, 239.0.1.2), 00:01:08/00:01:51, flags: PT
  Incoming interface: FastEthernet1/0, RPF nbr 192.168.2.2
  Outgoing interface list:
    FastEthernet0/0, Prune/Dense, 00:01:08/00:01:51

(*, 224.0.1.40), 00:12:58/00:02:04, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:12:29/stopped
    FastEthernet0/0, Forward/Dense, 00:12:58/stopped

```

Figura 25: Realização do comando "show ip mroute" no router R6.

```

R7#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 00:13:25/stopped, RP 0.0.0.0, flags: DC
Incoming interface: Null, RPF nbr 0.0.0.0
Outgoing interface list:
  FastEthernet1/0, Forward/Dense, 00:12:57/stopped
  FastEthernet2/0, Forward/Dense, 00:12:58/stopped
  FastEthernet0/0, Forward/Dense, 00:13:25/stopped

(192.168.6.9, 239.0.1.2), 00:00:51/00:02:08, flags: T
Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
Outgoing interface list:
  FastEthernet2/0, Forward/Dense, 00:00:51/stopped
  FastEthernet1/0, Forward/Dense, 00:00:51/stopped

(192.168.1.3, 239.0.1.2), 00:01:16/00:01:48, flags: T
Incoming interface: FastEthernet1/0, RPF nbr 192.168.4.1
Outgoing interface list:
  FastEthernet0/0, Forward/Dense, 00:01:16/stopped
  FastEthernet2/0, Prune/Dense, 00:01:16/00:01:45, A

(*, 224.0.1.40), 00:13:26/00:02:57, RP 0.0.0.0, flags: DCL
Incoming interface: Null, RPF nbr 0.0.0.0
Outgoing interface list:
  FastEthernet1/0, Forward/Dense, 00:12:57/stopped
  FastEthernet2/0, Forward/Dense, 00:13:25/stopped
  FastEthernet0/0, Forward/Dense, 00:13:26/stopped

```

Figura 26: Realização do comando "show ip mroute" no router R7.

R2), que são recebidos pelos PCs desta rede. Daí o PC9 receber dois datagramas de cada PC dessa rede (PC2, PC4, PC5) no primeiro ping.

d)

```
R1#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#interface fastEthernet 1/0
R1(config-if)#ip ospf cost 3
R1(config-if)#end
```

Figura 29: Alterações efectuadas de modo a obter o novo percurso.

```
R6#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 00:06:43/stopped, RP 0.0.0.0, flags: D
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:06:43/stopped
    FastEthernet0/0, Forward/Dense, 00:06:43/stopped

(192.168.6.9, 239.0.1.2), 00:00:12/00:02:47, flags: T
  Incoming interface: FastEthernet0/0, RPF nbr 192.168.3.7
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:00:12/stopped

(192.168.1.3, 239.0.1.2), 00:01:06/00:01:53, flags: PT
  Incoming interface: FastEthernet1/0, RPF nbr 192.168.2.2
  Outgoing interface list:
    FastEthernet0/0, Prune/Dense, 00:01:06/00:01:53

(*, 224.0.1.40), 01:02:49/00:02:17, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 01:02:20/stopped
    FastEthernet0/0, Forward/Dense, 01:02:49/stopped
```

Figura 30: Realização do comando "show ip mroute" no router R6 com as alterações.


```

R7#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 01:03:04/stopped, RP 0.0.0.0, flags: DC
Incoming interface: Null, RPF nbr 0.0.0.0
Outgoing interface list:
  FastEthernet1/0, Forward/Dense, 01:02:36/stopped
  FastEthernet2/0, Forward/Dense, 01:02:37/stopped
  FastEthernet0/0, Forward/Dense, 01:03:04/stopped

(192.168.6.9, 239.0.1.2), 00:00:08/00:02:51, flags: T
Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
Outgoing interface list:
  FastEthernet2/0, Forward/Dense, 00:00:08/stopped
  FastEthernet1/0, Prune/Dense, 00:00:08/00:02:51

(192.168.1.3, 239.0.1.2), 00:01:03/00:01:56, flags: T
Incoming interface: FastEthernet1/0, RPF nbr 192.168.4.1
Outgoing interface list:
  FastEthernet0/0, Forward/Dense, 00:01:03/stopped
  FastEthernet2/0, Prune/Dense, 00:01:03/00:01:56, A

(*, 224.0.1.40), 01:03:06/00:02:21, RP 0.0.0.0, flags: DCL
Incoming interface: Null, RPF nbr 0.0.0.0
Outgoing interface list:
  FastEthernet1/0, Forward/Dense, 01:02:36/stopped
  FastEthernet2/0, Forward/Dense, 01:03:04/stopped
  FastEthernet0/0, Forward/Dense, 01:03:06/stopped

```

Figura 31: Realização do comando "show ip mroute" no router R7 com as alterações.

```

R1#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 01:03:37/stopped, RP 0.0.0.0, flags: DC
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 01:03:09/stopped
    FastEthernet0/0, Forward/Dense, 01:03:37/stopped

(192.168.6.9, 239.0.1.2), 00:00:20/00:02:39, flags: PT
  Incoming interface: FastEthernet1/0, RPF nbr 192.168.4.7
  Outgoing interface list:
    FastEthernet0/0, Prune/Dense, 00:00:20/00:02:39

(192.168.1.3, 239.0.1.2), 00:01:15/00:01:44, flags: T
  Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 00:01:15/stopped

(*, 224.0.1.40), 01:03:38/00:02:23, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 01:03:09/stopped
    FastEthernet0/0, Forward/Dense, 01:03:38/stopped

```

Figura 32: Realização do comando "show ip mroute" no router R1 com as alterações.

```

R2#show ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry, E - Extranet,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report,
       Z - Multicast Tunnel, z - MDT-data group sender,
       Y - Joined MDT-data group, y - Sending to MDT-data group,
       V - RD & Vector, v - Vector
Outgoing interface flags: H - Hardware switched, A - Assert winner
Timers: Uptime/Expires
Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 239.0.1.2), 01:00:42/stopped, RP 0.0.0.0, flags: DC
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet1/0, Forward/Dense, 01:00:41/stopped
    FastEthernet2/0, Forward/Dense, 01:00:42/stopped
    FastEthernet0/0, Forward/Dense, 01:00:42/stopped

(192.168.6.9, 239.0.1.2), 00:00:05/00:02:54, flags: T
  Incoming interface: FastEthernet2/0, RPF nbr 192.168.2.6
  Outgoing interface list:
    FastEthernet0/0, Forward/Dense, 00:00:05/stopped, A
    FastEthernet1/0, Forward/Dense, 00:00:05/stopped

(192.168.1.3, 239.0.1.2), 00:00:59/00:02:00, flags: T
  Incoming interface: FastEthernet0/0, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet2/0, Prune/Dense, 00:00:59/00:02:00
    FastEthernet1/0, Forward/Dense, 00:00:59/stopped

(*, 224.0.1.40), 01:00:43/00:02:39, RP 0.0.0.0, flags: DCL
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet2/0, Forward/Dense, 01:00:43/stopped
    FastEthernet0/0, Forward/Dense, 01:00:43/stopped

```

Figura 33: Realização do comando "show ip mroute" no router R2 com as alterações.

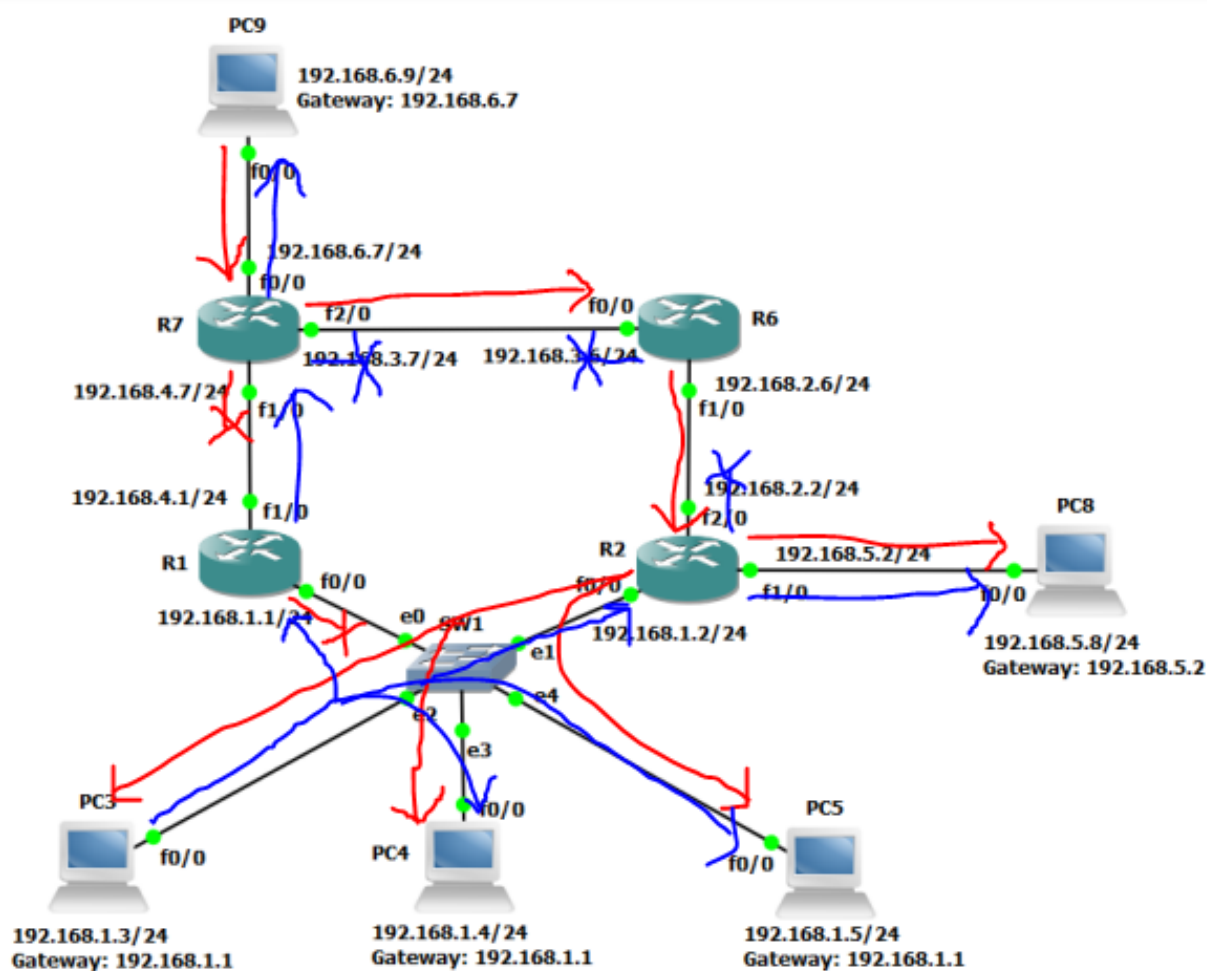


Figura 34: Desenho das novas árvores de multicast após as alterações. Encontra-se a azul a árvore com raiz no PC3 (sem alterações) e a vermelho a com raiz no PC9 (alterada).

Relativamente ao tráfego multicast do PC3 para o PC9, como podemos ver pela árvore, já está a ir por R1, pelo que as alterações a fazer são para que o tráfego multicast com origem no PC9, passe por R6 no seu caminho para o PC3, ou seja, que este siga o caminho $PC9 \rightarrow R7 \rightarrow R6 \rightarrow R2 \rightarrow PC3$ em vez do caminho $PC9 \rightarrow R7 \rightarrow R1 \rightarrow PC3$. Para tal, precisamos de fazer com que o custo inverso do caminho que passa por R6 seja menor que o custo inverso do caminho que passa por R1, ou seja, $R1(f1/0) + R7(f0/0) > R2(f2/0) + R6(f0/0) + R7(f0/0)$. Como todos os custos valem 1, esta condição verifica-se se se alterar o custo de R1(f1/0) para 3 (figura 29). Nas figuras 30, 31, 32 e 33 encontram-se os resultados dos comandos "show ip mroute" em todos os routers depois desta modificação e na figura 34 as árvores resultantes. Como podemos observar, a árvore com raiz no PC3 manteve-se inalterada enquanto que a árvore com raiz no PC9 passa a incluir o caminho por R6.