Tópicos Avançados de Redes 2020/2021

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Resumo

O presente documento descreve os trabalhos desenvolvidos no âmbito da unidade curricular Tópicos Avançados de Redes pertence à licenciatura em Engenharia Informática e descreve a configuração de um cenário de rede utilizado através do simulador GNS3 e onde são configurados endereços IPv4 e IPv6, bem como protocolos de encaminhamento como o RIP e OSPF.

Palavras-chave: IPv4, IPv6, RIP, OSPF, GNS3.

1. Topologia da rede

Na figura 1, é possível visualizar a topologia da rede utilizada na elaboração deste projeto. No cenário existem três principais áreas, que simulam redes de diversos operadores. Existe uma rede que pretende simular operadores que operam a nível mundial (Tier 1). A representar os operadores que operam a nível continental encontram-se as redes representadas por Tier 2 (A) e Tier 2 (B). Como forma de representar os operadores Tier 3, encontra-se a área denominada Tier 3.

Na área Tier 1, que é uma OSPFv3 Single Area, encontram-se configurados equipamentos com os endereços IPv4 e IPv6 bem como o protocolo de encaminhamento OSPF. Na área Tier 2 (A), que representa uma OSPFv3 Single Area, os equipamentos presentes encontram-se, também, configurados com endereços IPv4 e IPv6, sendo o protocolo de encaminhamento implementado o OSPF. Na área Tier 2 (B), o protocolo de encaminhamento é o protocolo RIP para endereços IPv4 e RIPng para endereços IPv6. Por fim, na área Tier 3, encontra-se configurada uma OSPFv3 Multi Area, em que existem configuradas várias áreas: área de Backbone, Totally Stub Area, Stub Area e ligações virtuais, utilizando endereços IPv4 e IPv6.

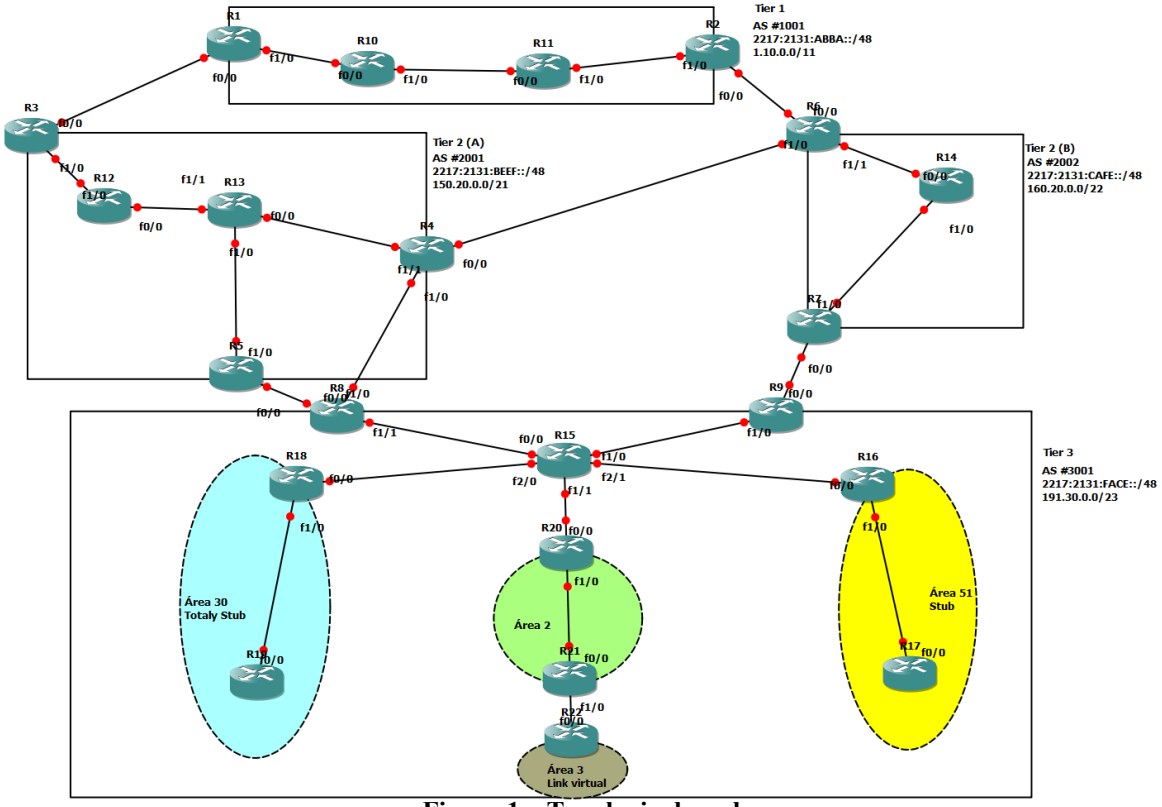

Figura 1 – Topologia da rede

2. Tabela de endereçamento

Nas tabelas 1, 2, 3 e 4 é possível visualizar os endereços IPv4 e IPv6 escolhidos para implementar no cenário representado pela figura 1. É ainda possível visualizar qual a máscara de rede para os endereços IPv4 e qual os endereços do tipo Link-local utilizados.

	Equipamento	Interface	IP	Máscara de rede	IPv6	Link-local
Tier 1	R1	fa0/0	1.0.0.1	255.255.255.252	2001:7f8:a:13::1/64	FE80::1
		fa1/0	1.0.0.5	255.255.255.252	2217:2131:ABBA:110::1/64	FE80::1
		lo0	1.1.1.1	255.255.255.255	2217:2131:ABBA:1::1/128	FE80::1
	R10	fa0/0	1.0.0.6	255.255.255.252	2217:2131:ABBA:110::10/64	FE80::10
		fa1/0	1.0.0.9	255.255.255.252	2217:2131:ABBA:1011::10/64	FE80::10
		lo0	10.10.10.10	255.255.255.255	2217:2131:ABBA:10::10/128	FE80::10
	R11	fa0/0	1.0.0.10	255.255.255.252	2217:2131:ABBA:1011::11/64	FE80::11
		fa1/0	1.0.0.13	255.255.255.252	2217:2131:ABBA:112::11/64	FE80::11
		lo0	11.11.11.11	255.255.255.255	2217:2131:ABBA:11::11/128	FE80::11
	R2	fa0/0	1.0.0.17	255.255.255.252	2001:7f8:a:26::2/64	FE80::2
		fa1/0	1.0.0.14	255.255.255.252	2217:2131:ABBA:112::2/64	FE80::2
		lo0	2.2.2.2	255.255.255.255	2217:2131:ABBA:2::2/128	FE80::2

Tabela 1 - Endereços IP - Tier 1

	Equipamento	Interface	IP	Máscara de rede	IPv6	Link-local
Tier 2 (A)	R3	fa0/0	1.0.0.2	255.255.255.252	2001:7f8:a:13::3/64	FE80::3
		fa1/0	150.20.0.1	255.255.255.252	2217:2131:BEEF:312::3/64	FE80::3
		lo0	3.3.3.3	255.255.255.255	2217:2131:BEEF:3::3/128	FE80::3
	R12	fa0/0	150.20.0.5	255.255.255.252	2217:2131:BEEF:1213::12/64	FE80::12
		fa1/0	150.20.0.2	255.255.255.252	2217:2131:BEEF:312::12/64	FE80::12
		lo0	12.12.12.12	255.255.255.255	2217:2131:BEEF:12::12/128	FE80::12
	R13	fa0/0	150.20.0.9	255.255.255.252	2217:2131:BEEF:134::13/64	FE80::13
		fa1/0	150.20.0.13	255.255.255.252	2217:2131:BEEF:135::13/64	FE80::13
		fa1/1	150.20.0.6	255.255.255.252	2217:2131:BEEF:1213::13/64	FE80::13
		lo0	13.13.13.13	255.255.255.255	2217:2131:BEEF:13::13/128	FE80::13
	R4	fa0/0	150.20.0.25	255.255.255.252	2001:7f8:a:46::4/64	FE80::4
		fa1/0	150.20.0.21	255.255.255.252	2001:7f8:a:48::4/64	FE80::4
		fa1/1	150.20.0.10	255.255.255.252	2217:2131:BEEF:134::4/64	FE80::4
		lo0	4.4.4.4	255.255.255.255	2217:2131:BEEF:4::4/128	FE80::4
	R5	fa0/0	150.20.0.17	255.255.255.252	2001:7f8:a:58::5/64	FE80::5
		fa1/0	150.20.0.14	255.255.255.252	2217:2131:BEEF:135::5/64	FE80::5
		lo0	5.5.5.5	255.255.255.255	2217:2131:BEEF:5::5/128	FE80::5

Tabela 2 - Endereços IP - Tier 2 (A)

	Equipameno	Interface	IP	Máscara de rede	IPv6	Link-local
Tier 2 (B)	R6	fa0/0	1.0.0.18	255.255.255.252	2001:7f8:a:26::6/64	FE80::6
		fa1/0	150.20.0.26	255.255.255.252	2001:7f8:a:46::6/64	FE80::6
		fa1/1	160.20.0.1	255.255.255.252	2217:2131:CAFE:614::6/64	FE80::6
		lo0	6.6.6.6	255.255.255.255	2217:2131:CAFE:6::6/128	FE80::6
	R14	fa0/0	160.20.0.2	255.255.255.252	2217:2131:CAFE:614::14/64	FE80::14
		fa1/0	160.20.0.5	255.255.255.252	2217:2131:CAFE:147::14/64	FE80::14
		lo0	14.14.14.14	255.255.255.255	2217:2131:CAFE:14::14/128	FE80::14
	R7	fa0/0	160.20.0.9	255.255.255.252	2001:7f8:a:79::7/64	FE80::7
		fa1/0	160.20.0.6	255.255.255.252	2217:2131:CAFE:147::7/64	FE80::7
		lo0	7.7.7.7	255.255.255.255	2217:2131:CAFE:7::7/128	FE80::7

Tabela 4 - Endereços IP - Tier 2 (B)

	Equipameno	Interface	IP	Máscara de rede	IPv6	Link-local
Tier 3	R8	fa0/0	150.20.0.18	255.255.255.252	2001:7f8:a:58::8/64	FE80::8
		fa1/0	150.20.0.22	255.255.255.252	2001:7f8:a:48::8/64	FE80::8
		fa1/1	191.30.0.1	255.255.255.252	2217:2131:FACE:815::8/64	FE80::8
		lo0	8.8.8.8	255.255.255.255	2217:2131:FACE:8::8/128	FE80::8
	R9	fa0/0	160.20.0.10	255.255.255.252	2001:7f8:a:79::9/64	FE80::9
		fa1/0	191.30.0.5	255.255.255.252	2217:2131:FACE:915::9/64	FE80::9
		lo0	9.9.9.9	255.255.255.255	2217:2131:FACE:9::9/128	FE80::9
	R15	fa0/0	191.30.0.2	255.255.255.252	2217:2131:FACE:815::15/64	FE80::15
		fa1/0	191.30.0.6	255.255.255.252	2217:2131:FACE:915::15/64	FE80::15
		fa1/1	191.30.0.9	255.255.255.252	2217:2131:FACE:1520::15/64	FE80::15
		fa2/0	191.30.0.13	255.255.255.252	2217:2131:FACE:1518::15/64	FE80::15
		fa2/1	191.30.0.17	255.255.255.252	2217:2131:FACE:1516::15/64	FE80::15
		lo0	15.15.15.15	255.255.255.255	2217:2131:FACE:15::15/128	FE80::15
	R16	fa0/0	191.30.0.18	255.255.255.252	2217:2131:FACE:1516::16/64	FE80::16
		fa1/0	191.30.0.21	255.255.255.252	2217:2131:FACE:1617::16/64	FE80::16
		lo0	16.16.16.16	255.255.255.255	2217:2131:FACE:16::16/128	FE80::16
	R17	fa0/0	191.30.0.22	255.255.255.252	2217:2131:FACE:1617::17/64	FE80::17
		lo0	17.17.17.17	255.255.255.255	2217:2131:FACE:17::17/128	FE80::17
	R18	fa0/0	191.30.0.14	255.255.255.252	2217:2131:FACE:1518::18/64	FE80::18
		fa1/0	191.30.0.25	255.255.255.252	2217:2131:FACE:1819::18/64	FE80::18
		lo0	18.18.18.18	255.255.255.255	2217:2131:FACE:18::18/128	FE80::18
	R19	fa0/0	191.30.0.26	255.255.255.252	2217:2131:FACE:1819::19/64	FE80::19
		lo0	19.19.19.19	255.255.255.255	2217:2131:FACE:19::19/128	FE80::19
	R20	fa0/0	191.30.0.10	255.255.255.252	2217:2131:FACE:1520::20/64	FE80::20
		f1/0	191.30.0.29	255.255.255.252	2217:2131:FACE:2021::20/64	FE80::20
		lo0	20.20.20.20	255.255.255.255	2217:2131:FACE:20::20/128	FE80::20
	R21	fa0/0	191.30.0.30	255.255.255.252	2217:2131:FACE:2021::21/64	FE80::21
		fa1/0	191.30.0.33	255.255.255.252	2217:2131:FACE:2122::21/64	FE80::21
		lo0	21.21.21.21	255.255.255.255	2217:2131:FACE:21::21/128	FE80::21
	R22	fa0/0	191.30.0.34	255.255.255.252	2217:2131:FACE:2122::22/64	FE80::22
		lo0	22.22.22.22	255.255.255.255	2217:2131:FACE:22::22/128	FE80::22

Tabela 3 - Endereços IP - Tier 3

3. Configurações nos protocolos de encaminhamento

De forma a que todo o cenário ficasse funcional e houvesse conetividade entre os diferentes routers de cada área, foi necessário utilizar protocolos de encaminhamento, o RIP e o OSPF nos diferentes Tier do cenário.

Assim, no protocolo RIP foi configurado:

- Um processo RIP destinado aos endereços IPv4
- Um processo RIP destinado aos endereços IPv6, denominado Tier 2

No protocolo OSPF foi configurado:

- OSPF v3 Single Area, em que foi configurado apenas a área de backbone
- OSPF Multi-Area, em que foi configurado a área de backbone, uma área stub (área 51), uma área totaly stub (área 30), uma área standard (área 2) e uma ligação virtual entre a área 0 e a área 3.

4. Conetividade

As imagens abaixo, comprovam a existência de conetividade entre os nós da rede.

```
R1#ping 2.2.2.2 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2.2.2.2, timeout is 2 seconds:
Packet sent with a source address of 1.1.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/92/124 ms
```

```
R1#traceroute 2.2.2.2 source lo0
Type escape sequence to abort.
Tracing the route to 2.2.2.2
VRF info: (vrf in name/id, vrf out name/id)
  1 1.0.0.6 36 msec 28 msec 28 msec
  2 1.0.0.10 28 msec 56 msec 60 msec
  3 1.0.0.14 100 msec 88 msec 84 msec
```

```
R1#ping 2217:2131:abba:2::2 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2217:2131:ABBA:2::2, timeout is 2 seconds:
Packet sent with a source address of 2217:2131:ABBA:1::1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 36/56/84 ms
```

```
R1#traceroute 2217:2131:abba:2::2
Type escape sequence to abort.
Tracing the route to 2217:2131:ABBA:2::2

  1 2217:2131:ABBA:110::10 40 msec 28 msec 24 msec
  2 2217:2131:ABBA:1011::11 28 msec 36 msec 64 msec
  3 2217:2131:ABBA:112::2 60 msec 56 msec 56 msec
```

Figura 2 - Teste à conetividade entre o router 1 e router 2

```
R1#sh ip route ospf
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

      1.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
O        1.0.0.8/30 [110/2] via 1.0.0.6, 00:12:33, FastEthernet1/0
O        1.0.0.12/30 [110/3] via 1.0.0.6, 00:12:33, FastEthernet1/0
      2.0.0.0/32 is subnetted, 1 subnets
O        2.2.2.2 [110/4] via 1.0.0.6, 00:12:33, FastEthernet1/0
      10.0.0.0/32 is subnetted, 1 subnets
O        10.10.10.10 [110/2] via 1.0.0.6, 00:12:43, FastEthernet1/0
      11.0.0.0/32 is subnetted, 1 subnets
O        11.11.11.11 [110/3] via 1.0.0.6, 00:12:33, FastEthernet1/0
```

```
R1#sh ipv6 route ospf
IPv6 Routing Table - default - 11 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, 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 - LISP
O   2217:2131:ABBA:2::2/128 [110/3]
     via FE80::10, FastEthernet1/0
O   2217:2131:ABBA:10::10/128 [110/1]
     via FE80::10, FastEthernet1/0
O   2217:2131:ABBA:11::11/128 [110/2]
     via FE80::10, FastEthernet1/0
O   2217:2131:ABBA:112::/64 [110/3]
     via FE80::10, FastEthernet1/0
O   2217:2131:ABBA:1011::/64 [110/2]
     via FE80::10, FastEthernet1/0
```

Figura 3 - Tabela de encaminhamento OSPF (IPv4 e IPv8) no router 1

```
R1#sh 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

      1.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
C        1.0.0.0/30 is directly connected, FastEthernet0/0
L        1.0.0.1/32 is directly connected, FastEthernet0/0
C        1.0.0.4/30 is directly connected, FastEthernet1/0
L        1.0.0.5/32 is directly connected, FastEthernet1/0
O        1.0.0.8/30 [110/2] via 1.0.0.6, 00:15:21, FastEthernet1/0
O        1.0.0.12/30 [110/3] via 1.0.0.6, 00:15:21, FastEthernet1/0
C        1.1.1.1/32 is directly connected, Loopback0
      2.0.0.0/32 is subnetted, 1 subnets
O        2.2.2.2 [110/4] via 1.0.0.6, 00:15:21, FastEthernet1/0
      10.0.0.0/32 is subnetted, 1 subnets
O        10.10.10.10 [110/2] via 1.0.0.6, 00:15:31, FastEthernet1/0
      11.0.0.0/32 is subnetted, 1 subnets
O        11.11.11.11 [110/3] via 1.0.0.6, 00:15:21, FastEthernet1/0
```

```
R1#sh ipv6 route
IPv6 Routing Table - default - 11 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, 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 - LISP
C   2001:7F8:A:13::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:7F8:A:13::1/128 [0/0]
     via FastEthernet0/0, receive
LC  2217:2131:ABBA:1::1/128 [0/0]
     via Loopback0, receive
O   2217:2131:ABBA:2::2/128 [110/3]
     via FE80::10, FastEthernet1/0
O   2217:2131:ABBA:10::10/128 [110/1]
     via FE80::10, FastEthernet1/0
O   2217:2131:ABBA:11::11/128 [110/2]
     via FE80::10, FastEthernet1/0
C   2217:2131:ABBA:110::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2217:2131:ABBA:110::1/128 [0/0]
     via FastEthernet1/0, receive
O   2217:2131:ABBA:112::/64 [110/3]
     via FE80::10, FastEthernet1/0
O   2217:2131:ABBA:1011::/64 [110/2]
     via FE80::10, FastEthernet1/0
L   FF00::/8 [0/0]
     via Null0, receive
```

Figura 4 - Tabela de encaminhamento do router 1

```
R3#ping 4.4.4.4 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 4.4.4.4, timeout is 2 seconds:
Packet sent with a source address of 3.3.3.3
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 84/94/108 ms
```

```
R3#traceroute 4.4.4.4 source lo0
Type escape sequence to abort.
Tracing the route to 4.4.4.4
VRF info: (vrf in name/id, vrf out name/id)
  1 150.20.0.2 16 msec 28 msec 28 msec
  2 150.20.0.6 28 msec 56 msec 48 msec
  3 150.20.0.10 92 msec 88 msec 80 msec
```

```
R3#ping 2217:2131:beef:4::4 so
R3#ping 2217:2131:beef:4::4 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2217:2131:BEEF:4::4, timeout is 2 seconds:
Packet sent with a source address of 2217:2131:BEEF:3::3
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 48/56/68 ms
```

```
R3#traceroute 2217:2131:beef:4::4
Type escape sequence to abort.
Tracing the route to 2217:2131:BEEF:4::4

  1 2217:2131:BEEF:312::12 72 msec 40 msec 32 msec
  2 2217:2131:BEEF:1213::13 24 msec 48 msec 48 msec
  3 2217:2131:BEEF:134::4 56 msec 56 msec 56 msec
```

Figura 5 - Teste à conetividade entre o router 3 e router 4

```
R3#ping 5.5.5.5 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 5.5.5.5, timeout is 2 seconds:
Packet sent with a source address of 3.3.3.3
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 72/80/92 ms
```

```
R3#traceroute 5.5.5.5 source lo0
Type escape sequence to abort.
Tracing the route to 5.5.5.5
VRF info: (vrf in name/id, vrf out name/id)
  1 150.20.0.2 20 msec 28 msec 28 msec
  2 150.20.0.6 40 msec 68 msec 28 msec
  3 150.20.0.14 92 msec 84 msec 80 msec
```

```
R3#ping 2217:2131:beef:5::5 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2217:2131:BEEF:5::5, timeout is 2 seconds:
Packet sent with a source address of 2217:2131:BEEF:3::3
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 52/67/108 ms
R3#traceroute 2217:2131:beef:5::5
Type escape sequence to abort.
Tracing the route to 2217:2131:BEEF:5::5

  1 2217:2131:BEEF:312::12 36 msec 24 msec 24 msec
  2 2217:2131:BEEF:1213::13 40 msec 48 msec 40 msec
  3 2217:2131:BEEF:135::5 56 msec 64 msec 52 msec
```

Figura 6 - Teste à conetividade entre o router 3 e router 5

```
R3#sh ip route ospf
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

      4.0.0.0/32 is subnetted, 1 subnets
O        4.4.4.4 [110/4] via 150.20.0.2, 00:13:15, FastEthernet1/0
      5.0.0.0/32 is subnetted, 1 subnets
O        5.5.5.5 [110/4] via 150.20.0.2, 00:13:15, FastEthernet1/0
      12.0.0.0/32 is subnetted, 1 subnets
O        12.12.12.12 [110/2] via 150.20.0.2, 00:13:25, FastEthernet1/0
      13.0.0.0/32 is subnetted, 1 subnets
O        13.13.13.13 [110/3] via 150.20.0.2, 00:13:15, FastEthernet1/0
      150.20.0.0/16 is variably subnetted, 5 subnets, 2 masks
O        150.20.0.4/30 [110/2] via 150.20.0.2, 00:13:15, FastEthernet1/0
O        150.20.0.8/30 [110/3] via 150.20.0.2, 00:13:15, FastEthernet1/0
O        150.20.0.12/30 [110/3] via 150.20.0.2, 00:13:15, FastEthernet1/0
```

```
R3#sh ipv6 route ospf
IPv6 Routing Table - default - 14 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, 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 - LISP
O   2001:7F8:A:48::/64 [110/4]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:4::4/128 [110/3]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:5::5/128 [110/3]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:12::12/128 [110/1]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:13::13/128 [110/2]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:134::/64 [110/3]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:135::/64 [110/3]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:1213::/64 [110/2]
     via FE80::12, FastEthernet1/0
```

Figura 7 - Tabela de encaminhamento OSPF (IPv4 e IPv8) no router 3

```
R3#sh 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

      1.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        1.0.0.0/30 is directly connected, FastEthernet0/0
L        1.0.0.2/32 is directly connected, FastEthernet0/0
      3.0.0.0/32 is subnetted, 1 subnets
C        3.3.3.3 is directly connected, Loopback0
      4.0.0.0/32 is subnetted, 1 subnets
O        4.4.4.4 [110/4] via 150.20.0.2, 00:14:51, FastEthernet1/0
      5.0.0.0/32 is subnetted, 1 subnets
O        5.5.5.5 [110/4] via 150.20.0.2, 00:14:51, FastEthernet1/0
      12.0.0.0/32 is subnetted, 1 subnets
O        12.12.12.12 [110/2] via 150.20.0.2, 00:15:01, FastEthernet1/0
      13.0.0.0/32 is subnetted, 1 subnets
O        13.13.13.13 [110/3] via 150.20.0.2, 00:14:51, FastEthernet1/0
      150.20.0.0/16 is variably subnetted, 5 subnets, 2 masks
C        150.20.0.0/30 is directly connected, FastEthernet1/0
L        150.20.0.1/32 is directly connected, FastEthernet1/0
O        150.20.0.4/30 [110/2] via 150.20.0.2, 00:14:51, FastEthernet1/0
O        150.20.0.8/30 [110/3] via 150.20.0.2, 00:14:51, FastEthernet1/0
O        150.20.0.12/30 [110/3] via 150.20.0.2, 00:14:51, FastEthernet1/0
```

```
R3#sh ipv6 route
IPv6 Routing Table - default - 14 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, 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 - LISP
C   2001:7F8:A:13::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:7F8:A:13::3/128 [0/0]
     via FastEthernet0/0, receive
O   2001:7F8:A:48::/64 [110/4]
     via FE80::12, FastEthernet1/0
LC  2217:2131:BEEF:3::3/128 [0/0]
     via Loopback0, receive
O   2217:2131:BEEF:4::4/128 [110/3]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:5::5/128 [110/3]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:12::12/128 [110/1]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:13::13/128 [110/2]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:134::/64 [110/3]
     via FE80::12, FastEthernet1/0
O   2217:2131:BEEF:135::/64 [110/3]
     via FE80::12, FastEthernet1/0
C   2217:2131:BEEF:312::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2217:2131:BEEF:312::3/128 [0/0]
     via FastEthernet1/0, receive
O   2217:2131:BEEF:1213::/64 [110/2]
     via FE80::12, FastEthernet1/0
L   FF00::/8 [0/0]
     via Null0, receive
```

Figura 8 - Tabela de encaminhamento do router 3

```
R6#ping 7.7.7.7 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 7.7.7.7, timeout is 2 seconds:
Packet sent with a source address of 6.6.6.6
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 44/76/96 ms
R6#traceroute 7.7.7.7 source lo0
Type escape sequence to abort.
Tracing the route to 7.7.7.7
VRF info: (vrf in name/id, vrf out name/id)
  1 160.20.0.2 64 msec 56 msec 32 msec
  2 160.20.0.6 72 msec 80 msec 88 msec
```

```
R6#ping 2217:2131:cafe:7::7 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2217:2131:CAFE:7::7, timeout is 2 seconds:
Packet sent with a source address of 2217:2131:CAFE:6::6
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 52/56/60 ms
R6#traceroute 2217:2131:cafe:7::7
Type escape sequence to abort.
Tracing the route to 2217:2131:CAFE:7::7

  1 2217:2131:CAFE:614::14 148 msec 36 msec 40 msec
  2 2217:2131:CAFE:147::7 56 msec 56 msec 52 msec
```

Figura 9 - Teste à conetividade entre o router 6 e router 7

```
R6#sh ip route rip
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

      7.0.0.0/32 is subnetted, 1 subnets
R        7.7.7.7 [120/2] via 160.20.0.2, 00:00:33, FastEthernet1/1
      14.0.0.0/32 is subnetted, 1 subnets
R        14.14.14.14 [120/1] via 160.20.0.2, 00:00:33, FastEthernet1/1
      160.20.0.0/16 is variably subnetted, 4 subnets, 2 masks
R        160.20.0.4/30 [120/1] via 160.20.0.2, 00:00:33, FastEthernet1/1
R        160.20.0.8/30 [120/2] via 160.20.0.2, 00:00:33, FastEthernet1/1
```

```
R6#sh ipv6 route rip
IPv6 Routing Table - default - 11 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, 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 - LISP
R   2217:2131:CAFE:7::7/128 [120/3]
     via FE80::14, FastEthernet1/1
R   2217:2131:CAFE:14::14/128 [120/2]
     via FE80::14, FastEthernet1/1
R   2217:2131:CAFE:147::/64 [120/2]
     via FE80::14, FastEthernet1/1
```

Figura 10 - Tabela de encaminhamento RIP (IPv4 e IPv8) no router 3

```
R6#sh 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

      1.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
C        1.0.0.16/30 is directly connected, FastEthernet0/0
L        1.0.0.18/32 is directly connected, FastEthernet0/0
      6.0.0.0/32 is subnetted, 1 subnets
C        6.6.6.6 is directly connected, Loopback0
      7.0.0.0/32 is subnetted, 1 subnets
R        7.7.7.7 [120/2] via 160.20.0.2, 00:00:17, FastEthernet1/1
      14.0.0.0/32 is subnetted, 1 subnets
R        14.14.14.14 [120/1] via 160.20.0.2, 00:00:17, FastEthernet1/1
      150.20.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        150.20.0.24/30 is directly connected, FastEthernet1/0
L        150.20.0.26/32 is directly connected, FastEthernet1/0
      160.20.0.0/16 is variably subnetted, 4 subnets, 2 masks
C        160.20.0.0/30 is directly connected, FastEthernet1/1
L        160.20.0.1/32 is directly connected, FastEthernet1/1
R        160.20.0.4/30 [120/1] via 160.20.0.2, 00:00:17, FastEthernet1/1
R        160.20.0.8/30 [120/2] via 160.20.0.2, 00:00:17, FastEthernet1/1
```

```
R6#sh ipv6 route
IPv6 Routing Table - default - 11 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, 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 - LISP
C   2001:7F8:A:26::/64 [0/0]
     via FastEthernet0/0, directly connected
L   2001:7F8:A:26::6/128 [0/0]
     via FastEthernet0/0, receive
C   2001:7F8:A:46::/64 [0/0]
     via FastEthernet1/0, directly connected
L   2001:7F8:A:46::6/128 [0/0]
     via FastEthernet1/0, receive
LC  2217:2131:CAFE:6::6/128 [0/0]
     via Loopback0, receive
R   2217:2131:CAFE:7::7/128 [120/3]
     via FE80::14, FastEthernet1/1
R   2217:2131:CAFE:14::14/128 [120/2]
     via FE80::14, FastEthernet1/1
R   2217:2131:CAFE:147::/64 [120/2]
     via FE80::14, FastEthernet1/1
C   2217:2131:CAFE:614::/64 [0/0]
     via FastEthernet1/1, directly connected
L   2217:2131:CAFE:614::6/128 [0/0]
     via FastEthernet1/1, receive
L   FF00::/8 [0/0]
     via Null0, receive
```

Figura 11 - Tabela de encaminhamento do router 6

```
R8#ping 17.17.17.17 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 17.17.17.17, timeout is 2 seconds:
Packet sent with a source address of 8.8.8.8
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 104/128/172 ms
R8#traceroute 17.17.17.17 source lo0
Type escape sequence to abort.
Tracing the route to 17.17.17.17
VRF info: (vrf in name/id, vrf out name/id)
  1 191.30.0.2 24 msec 32 msec 36 msec
  2 191.30.0.18 36 msec 56 msec 104 msec
  3 191.30.0.22 100 msec 108 msec 92 msec
```

```
R8#ping 2217:2131:face:17::17 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2217:2131:FACE:17::17, timeout is 2 seconds:
Packet sent with a source address of 2217:2131:FACE:8::8
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 60/68/72 ms
R8#traceroute 2217:2131:face:17::17
Type escape sequence to abort.
Tracing the route to 2217:2131:FACE:17::17

  1 2217:2131:FACE:815::15 88 msec 40 msec 40 msec
  2 2217:2131:FACE:1516::16 60 msec 56 msec 56 msec
  3 2217:2131:FACE:1617::17 72 msec 72 msec 72 msec
```

Figura 13 - Teste à conetividade entre o router 8 e router 17

```
R8#ping 19.19.19.19 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 19.19.19.19, timeout is 2 seconds:
Packet sent with a source address of 8.8.8.8
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 72/109/152 ms
R8#traceroute 19.19.19.19 source lo0
Type escape sequence to abort.
Tracing the route to 19.19.19.19
VRF info: (vrf in name/id, vrf out name/id)
  1 191.30.0.2 84 msec 72 msec 32 msec
  2 191.30.0.14 80 msec 100 msec 64 msec
  3 191.30.0.26 120 msec 116 msec 124 msec
```

```
R8#ping 2217:2131:face:19::19 source lo0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2217:2131:FACE:19::19, timeout is 2 seconds:
Packet sent with a source address of 2217:2131:FACE:8::8
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 68/72/76 ms
R8#traceroute 2217:2131:face:19::19
Type escape sequence to abort.
Tracing the route to 2217:2131:FACE:19::19

  1 2217:2131:FACE:815::15 28 msec 36 msec 28 msec
  2 2217:2131:FACE:1518::18 48 msec 52 msec 60 msec
  3 2217:2131:FACE:1819::19 80 msec 80 msec 68 msec
```

Figura 12 - Teste à conetividade entre o router 8 e router 19

```
R8#sh ipv6 ospf database
            OSPFv3 Router with ID (8.8.8.8) (Process ID 1)

                Router Link States (Area 0)

ADV Router       Age         Seq#       Fragment ID  Link count  Bits
 8.8.8.8         51          0x80000003  0           1           None
 9.9.9.9         2033        0x80000002  0           1           None
 15.15.15.15     2028        0x80000003  0           5           None
 16.16.16.16     2030        0x80000002  0           1           B
 18.18.18.18     2031        0x80000002  0           1           B
 20.20.20.20     2032        0x80000002  0           1           B

                Net Link States (Area 0)

ADV Router       Age         Seq#       Link ID    Rtr count
 15.15.15.15     2032        0x80000001  2          2
 15.15.15.15     2032        0x80000001  3          2
 16.16.16.16     2031        0x80000001  2          2
 18.18.18.18     2031        0x80000001  2          2
 20.20.20.20     2032        0x80000001  2          2

                Inter Area Prefix Link States (Area 0)

ADV Router       Age         Seq#       Prefix
 16.16.16.16     2065        0x80000001  2217:2131:FACE:16::16/128
 16.16.16.16     2065        0x80000001  2217:2131:FACE:1617::/64
 16.16.16.16     2026        0x80000001  2217:2131:FACE:17::17/128
 18.18.18.18     2065        0x80000001  2217:2131:FACE:18::18/128
 18.18.18.18     2065        0x80000001  2217:2131:FACE:1819::/64
 18.18.18.18     2030        0x80000001  2217:2131:FACE:19::19/128
 20.20.20.20     2062        0x80000001  2217:2131:FACE:20::20/128
 20.20.20.20     2062        0x80000001  2217:2131:FACE:2021::/64
 20.20.20.20     2028        0x80000001  2217:2131:FACE:21::21/128

                Link (Type-8) Link States (Area 0)

ADV Router       Age         Seq#       Link ID    Interface
 8.8.8.8         51          0x80000003  4          Fa1/1
 15.15.15.15     2072        0x80000001  2          Fa1/1

                Intra Area Prefix Link States (Area 0)

ADV Router       Age         Seq#       Link ID    Ref-lstype  Ref-LSID
 8.8.8.8         51          0x80000004  0          0x2001      0
 9.9.9.9         2033        0x80000002  0          0x2001      0
 15.15.15.15     2028        0x80000003  0          0x2001      0
 15.15.15.15     2032        0x80000001  2048       0x2002      2
 15.15.15.15     2032        0x80000001  3072       0x2002      3
 16.16.16.16     2031        0x80000001  2048       0x2002      2
 18.18.18.18     2031        0x80000001  2048       0x2002      2
 20.20.20.20     2032        0x80000001  2048       0x2002      2
```

Figura 14 - Base de dados OSPF no router 8

```
R8#sh ip route ospf
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

      9.0.0.0/32 is subnetted, 1 subnets
O        9.9.9.9 [110/3] via 191.30.0.2, 00:38:59, FastEthernet1/1
      15.0.0.0/32 is subnetted, 1 subnets
O        15.15.15.15 [110/2] via 191.30.0.2, 00:38:59, FastEthernet1/1
      16.0.0.0/32 is subnetted, 1 subnets
O IA     16.16.16.16 [110/3] via 191.30.0.2, 00:38:49, FastEthernet1/1
      17.0.0.0/32 is subnetted, 1 subnets
O IA     17.17.17.17 [110/4] via 191.30.0.2, 00:38:49, FastEthernet1/1
      18.0.0.0/32 is subnetted, 1 subnets
O IA     18.18.18.18 [110/3] via 191.30.0.2, 00:38:49, FastEthernet1/1
      19.0.0.0/32 is subnetted, 1 subnets
O IA     19.19.19.19 [110/4] via 191.30.0.2, 00:38:49, FastEthernet1/1
      20.0.0.0/32 is subnetted, 1 subnets
O IA     20.20.20.20 [110/3] via 191.30.0.2, 00:38:49, FastEthernet1/1
      21.0.0.0/32 is subnetted, 1 subnets
O IA     21.21.21.21 [110/4] via 191.30.0.2, 00:38:34, FastEthernet1/1
      191.30.0.0/16 is variably subnetted, 10 subnets, 2 masks
O        191.30.0.4/30 [110/2] via 191.30.0.2, 00:38:59, FastEthernet1/1
O        191.30.0.8/30 [110/2] via 191.30.0.2, 00:38:59, FastEthernet1/1
O        191.30.0.12/30 [110/2] via 191.30.0.2, 00:38:59, FastEthernet1/1
O        191.30.0.16/30 [110/2] via 191.30.0.2, 00:38:59, FastEthernet1/1
O IA     191.30.0.20/30 [110/3] via 191.30.0.2, 00:38:49, FastEthernet1/1
O IA     191.30.0.24/30 [110/3] via 191.30.0.2, 00:38:49, FastEthernet1/1
O IA     191.30.0.28/30 [110/3] via 191.30.0.2, 00:38:49, FastEthernet1/1
O IA     191.30.0.32/30 [110/4] via 191.30.0.2, 00:38:34, FastEthernet1/1
```

Figura 15 - Tabela de encaminhamento OSPF (IPv4) no router 8

```
R8#sh ipv6 route ospf
IPv6 Routing Table - default - 23 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
       EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
       NDr - Redirect, 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 - LISP
O   2217:2131:FACE:9::9/128 [110/2]
     via FE80::15, FastEthernet1/1
O   2217:2131:FACE:15::15/128 [110/1]
     via FE80::15, FastEthernet1/1
OI  2217:2131:FACE:16::16/128 [110/2]
     via FE80::15, FastEthernet1/1
OI  2217:2131:FACE:17::17/128 [110/3]
     via FE80::15, FastEthernet1/1
OI  2217:2131:FACE:18::18/128 [110/2]
     via FE80::15, FastEthernet1/1
OI  2217:2131:FACE:19::19/128 [110/3]
     via FE80::15, FastEthernet1/1
OI  2217:2131:FACE:20::20/128 [110/2]
     via FE80::15, FastEthernet1/1
OI  2217:2131:FACE:21::21/128 [110/3]
     via FE80::15, FastEthernet1/1
O   2217:2131:FACE:915::/64 [110/2]
     via FE80::15, FastEthernet1/1
O   2217:2131:FACE:1516::/64 [110/2]
     via FE80::15, FastEthernet1/1
O   2217:2131:FACE:1518::/64 [110/2]
     via FE80::15, FastEthernet1/1
O   2217:2131:FACE:1520::/64 [110/2]
     via FE80::15, FastEthernet1/1
OI  2217:2131:FACE:1617::/64 [110/3]
     via FE80::15, FastEthernet1/1
OI  2217:2131:FACE:1819::/64 [110/3]
     via FE80::15, FastEthernet1/1
OI  2217:2131:FACE:2021::/64 [110/3]
     via FE80::15, FastEthernet1/1
```

Figura 16 - Tabela de encaminhamento OSPF (IPv6) no router 8

```
R20#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
15.15.15.15       1   FULL/BDR        00:00:19    191.30.0.9      FastEthernet0/0
21.21.21.21       0   FULL/  -            -        191.30.0.30     OSPF_VL0
21.21.21.21       1   FULL/DR         00:00:25    191.30.0.30     FastEthernet1/0
R20#sh ip ospf v
R20#sh ip ospf virtual-links
Virtual Link OSPF_VL0 to router 21.21.21.21 is up
  Run as demand circuit
  DoNotAge LSA allowed.
  Transit area 2, via interface FastEthernet1/0
 Topology-MTID    Cost    Disabled     Shutdown      Topology Name
        0           1         no          no            Base
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:05
    Adjacency State FULL (Hello suppressed)
    Index 2/3, retransmission queue length 0, number of retransmission 0
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 0, maximum is 0
    Last retransmission scan time is 0 msec, maximum is 0 msec
```

Figura 17 - Verificação de que o link virtual entre os routers 20 e 22 foi criado