

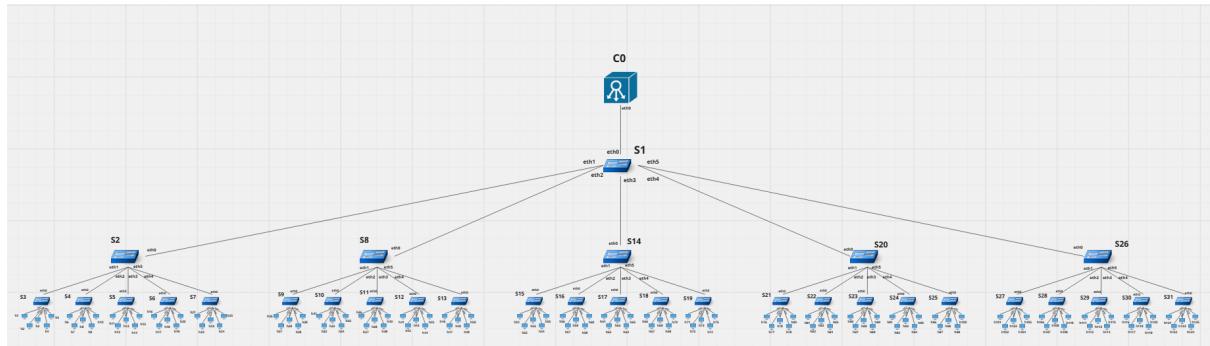
Trabalho Final - Mininet

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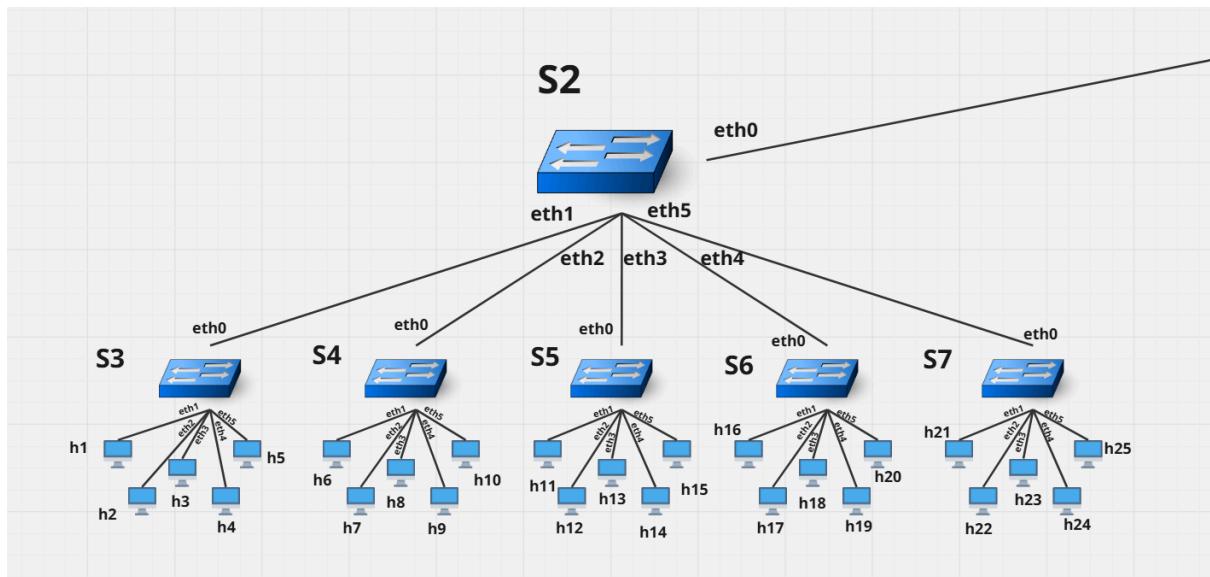
Questão 1.

Topologia:

A primeira topologia utilizada foi a de uma árvore com profundidade três e ramificação cinco, gerando 31 switches e 125 hosts no total. Como especificação, foi utilizado o modo de endereço MAC padronizado e larguras de banda de 30 Mbps. Para criar esta topologia, no terminal do PuTTY, utilizamos o comando “sudo mn –mac –topo=tree,depth=3,fanout=5 –link tc,bw=30”.



Topologia geral.



Topologia aproximada da primeira ramificação do switch s1, com a relação de portas utilizadas em cada conexão dos switches. Em todos os hosts, as portas utilizadas para conexão foram “eth0”.

```

mininet@mininet-vm:~$ sudo mn --mac --topo=tree,depth=3,fanout=5 --link tc,bw=30
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3 h4 h5 h6 h7 h8 h9 h10 h11 h12 h13 h14 h15 h16 h17 h18 h19 h20 h21 h22 h
23 h24 h25 h26 h27 h28 h29 h30 h31 h32 h33 h34 h35 h36 h37 h38 h39 h40 h41 h42 h
43 h44 h45 h46 h47 h48 h49 h50 h51 h52 h53 h54 h55 h56 h57 h58 h59 h60 h61 h62 h
63 h64 h65 h66 h67 h68 h69 h70 h71 h72 h73 h74 h75 h76 h77 h78 h79 h80 h81 h82 h
83 h84 h85 h86 h87 h88 h89 h90 h91 h92 h93 h94 h95 h96 h97 h98 h99 h100 h101 h10
2 h103 h104 h105 h106 h107 h108 h109 h110 h111 h112 h113 h114 h115 h116 h117 h11
8 h119 h120 h121 h122 h123 h124 h125
*** Adding switches:
s1 s2 s3 s4 s5 s6 s7 s8 s9 s10 s11 s12 s13 s14 s15 s16 s17 s18 s19 s20 s21 s22 s
23 s24 s25 s26 s27 s28 s29 s30 s31
*** Adding links:
(30.00Mbit) (30.00Mbit) (s1, s2) -

```

Execução do comando de criação da topologia.

Inspecções:

A fim de verificar se a topologia foi criada corretamente, executamos alguns comandos, como “nodes” para verificar os nós (hosts, switches e controladores) gerados, “net” para visualizar a relação de portas nas ligações entre nós da rede, “dump” a fim de ver os endereços IP dos componentes, e “x ifconfig -a” (considerando x como um host ou switch qualquer) para ver o endereço MAC de cada nó e as configurações de suas portas.

```

mininet> nodes
available nodes are:
c0 h1 h10 h100 h101 h102 h103 h104 h105 h106 h107 h108 h109 h11 h110 h111 h112 h
113 h114 h115 h116 h117 h118 h119 h12 h120 h121 h122 h123 h124 h125 h13 h14 h15
h16 h17 h18 h19 h2 h20 h21 h22 h23 h24 h25 h26 h27 h28 h29 h3 h30 h31 h32 h33 h3
4 h35 h36 h37 h38 h39 h4 h40 h41 h42 h43 h44 h45 h46 h47 h48 h49 h5 h50 h51 h52
h53 h54 h55 h56 h57 h58 h59 h6 h60 h61 h62 h63 h64 h65 h66 h67 h68 h69 h7 h70 h7
1 h72 h73 h74 h75 h76 h77 h78 h79 h8 h80 h81 h82 h83 h84 h85 h86 h87 h88 h89 h9
h90 h91 h92 h93 h94 h95 h96 h97 h98 h99 s1 s10 s11 s12 s13 s14 s15 s16 s17 s18 s
19 s2 s20 s21 s22 s23 s24 s25 s26 s27 s28 s29 s3 s30 s31 s4 s5 s6 s7 s8 s9
mininet>

```

A rede possui 31 switches, um controlador e 125 hosts.

```

mininet> net
h1 h1-eth0:s3-eth1
h2 h2-eth0:s3-eth2
h3 h3-eth0:s3-eth3
h4 h4-eth0:s3-eth4
h5 h5-eth0:s3-eth5
h6 h6-eth0:s4-eth1
h7 h7-eth0:s4-eth2
h8 h8-eth0:s4-eth3
h9 h9-eth0:s4-eth4
h10 h10-eth0:s4-eth5
h11 h11-eth0:s5-eth1
h12 h12-eth0:s5-eth2
h13 h13-eth0:s5-eth3
h14 h14-eth0:s5-eth4
h15 h15-eth0:s5-eth5

```

Links entre as portas eth0 dos hosts h1-h5 em s3, h6-h10 em s4, h11-h15 em s5, e assim por diante.

```

mininet> dump
<Host h1: h1-eth0:10.0.0.1 pid=3193>
<Host h2: h2-eth0:10.0.0.2 pid=3195>
<Host h3: h3-eth0:10.0.0.3 pid=3197>
<Host h4: h4-eth0:10.0.0.4 pid=3199>
<Host h5: h5-eth0:10.0.0.5 pid=3201>
<Host h6: h6-eth0:10.0.0.6 pid=3203>
<Host h7: h7-eth0:10.0.0.7 pid=3205>
<Host h8: h8-eth0:10.0.0.8 pid=3207>
<Host h9: h9-eth0:10.0.0.9 pid=3209>
<Host h10: h10-eth0:10.0.0.10 pid=3211>
<Host h11: h11-eth0:10.0.0.11 pid=3213>
<Host h12: h12-eth0:10.0.0.12 pid=3215>
<Host h13: h13-eth0:10.0.0.13 pid=3217>
<Host h14: h14-eth0:10.0.0.14 pid=3219>
<Host h15: h15-eth0:10.0.0.15 pid=3221>
<Host h16: h16-eth0:10.0.0.16 pid=3223>
<Host h17: h17-eth0:10.0.0.17 pid=3225>
<Host h18: h18-eth0:10.0.0.18 pid=3227>
<Host h19: h19-eth0:10.0.0.19 pid=3229>
<Host h20: h20-eth0:10.0.0.20 pid=3231>
<Host h21: h21-eth0:10.0.0.21 pid=3233>
<Host h22: h22-eth0:10.0.0.22 pid=3235>
<Host h23: h23-eth0:10.0.0.23 pid=3237>
<Host h24: h24-eth0:10.0.0.24 pid=3239>

```

Endereços IP dos 25 primeiros hosts.

```

<Host h120: h120-eth0:10.0.0.120 pid=3431>
<Host h121: h121-eth0:10.0.0.121 pid=3433>
<Host h122: h122-eth0:10.0.0.122 pid=3435>
<Host h123: h123-eth0:10.0.0.123 pid=3437>
<Host h124: h124-eth0:10.0.0.124 pid=3439>
<Host h125: h125-eth0:10.0.0.125 pid=3441>
<QVSSwitch s1: lo:127.0.0.1,s1-eth1:None,s1-eth2:None,s1-eth3:None,s1-eth4:None,
s1-eth5:None pid=3446>
<QVSSwitch s2: lo:127.0.0.1,s2-eth1:None,s2-eth2:None,s2-eth3:None,s2-eth4:None,
s2-eth5:None,s2-eth6:None pid=3449>
<QVSSwitch s3: lo:127.0.0.1,s3-eth1:None,s3-eth2:None,s3-eth3:None,s3-eth4:None,
s3-eth5:None,s3-eth6:None pid=3452>
<QVSSwitch s4: lo:127.0.0.1,s4-eth1:None,s4-eth2:None,s4-eth3:None,s4-eth4:None,
s4-eth5:None,s4-eth6:None pid=3455>
<QVSSwitch s5: lo:127.0.0.1,s5-eth1:None,s5-eth2:None,s5-eth3:None,s5-eth4:None,
s5-eth5:None,s5-eth6:None pid=3458>
<QVSSwitch s6: lo:127.0.0.1,s6-eth1:None,s6-eth2:None,s6-eth3:None,s6-eth4:None,
s6-eth5:None,s6-eth6:None pid=3461>
<QVSSwitch s7: lo:127.0.0.1,s7-eth1:None,s7-eth2:None,s7-eth3:None,s7-eth4:None,
s7-eth5:None,s7-eth6:None pid=3464>
<QVSSwitch s8: lo:127.0.0.1,s8-eth1:None,s8-eth2:None,s8-eth3:None,s8-eth4:None,
s8-eth5:None,s8-eth6:None pid=3467>
<QVSSwitch s9: lo:127.0.0.1,s9-eth1:None,s9-eth2:None,s9-eth3:None,s9-eth4:None,
s9-eth5:None,s9-eth6:None pid=3470>
<QVSSwitch s10: lo:127.0.0.1,s10-eth1:None,s10-eth2:None,s10-eth3:None,s10-eth4:
None,s10-eth5:None,s10-eth6:None pid=3473>
<QVSSwitch s11: lo:127.0.0.1,s11-eth1:None,s11-eth2:None,s11-eth3:None,s11-eth4:
None,s11-eth5:None,s11-eth6:None pid=3476>
<QVSSwitch s12: lo:127.0.0.1,s12-eth1:None,s12-eth2:None,s12-eth3:None,s12-eth4:
None,s12-eth5:None,s12-eth6:None pid=3479>

```

Endereços IP e informações de portas dos switches.

```

mininet> h25 ifconfig -a
h25-eth0 Link encap:Ethernet HWaddr 00:00:00:00:00:19
          inet addr:10.0.0.25 Bcast:10.255.255.255 Mask:255.0.0.0
                  UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
                  RX packets:0 errors:0 dropped:0 overruns:0 frame:0
                  TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
                  collisions:0 txqueuelen:1000
                  RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)

lo      Link encap:Local Loopback
          inet addr:127.0.0.1 Mask:255.0.0.0
                  UP LOOPBACK RUNNING MTU:65536 Metric:1
                  RX packets:0 errors:0 dropped:0 overruns:0 frame:0
                  TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
                  collisions:0 txqueuelen:0
                  RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)

```

Informações específicas referentes às portas do host h25; MAC address = 00:00:00:00:00:19.

```

mininet> s1 ifconfig -a
eth0      Link encap:Ethernet HWaddr 08:00:27:7e:0f:24
          inet addr:192.168.56.104 Bcast:192.168.56.255 Mask:255.255.255.0
                  UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
                  RX packets:2 errors:0 dropped:0 overruns:0 frame:0
                  TX packets:2 errors:0 dropped:0 overruns:0 carrier:0
                  collisions:0 txqueuelen:1000
                  RX bytes:1180 (1.1 KB) TX bytes:684 (684.0 B)

eth1      Link encap:Ethernet HWaddr 08:00:27:a7:c9:40
          inet addr:10.0.2.15 Bcast:10.0.2.255 Mask:255.255.255.0
                  UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
                  RX packets:346 errors:0 dropped:0 overruns:0 frame:0
                  TX packets:351 errors:0 dropped:0 overruns:0 carrier:0
                  collisions:351 errors:0 dropped:0 overruns:0 carrier:0
                  collisions:0 txqueuelen:1000
                  RX bytes:32884 (32.8 KB) TX bytes:31110 (31.1 KB)

lo      Link encap:Local Loopback
          inet addr:127.0.0.1 Mask:255.0.0.0
                  UP LOOPBACK RUNNING MTU:65536 Metric:1
                  RX packets:25479 errors:0 dropped:0 overruns:0 frame:0
                  TX packets:25479 errors:0 dropped:0 overruns:0 carrier:0
                  collisions:0 txqueuelen:0
                  RX bytes:1362720 (1.3 MB) TX bytes:1362720 (1.3 MB)

qus-sistem Link encap:Ethernet HWaddr 92:f9:86:5f:ac:5e

```

Informações específicas referentes às portas do switch s1; MAC address = 08:00:27:7e:0f:24.

Testes de conexão:

Para averiguar o funcionamento da rede na troca de dados, realizamos um teste de ping com 5 pacotes entre os hosts h1 e h2 e um teste de tcpdump entre os hosts h1 e h2, h25 e h26.

```

mininet> h1 ping -c 5 h2
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=13.9 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.138 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.051 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.043 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.044 ms

--- 10.0.0.2 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4002ms
rtt min/avg/max/mdev = 0.043/2.835/13.902/5.533 ms
mininet>

```

Conexão bem-sucedida no envio de dados de h1 para h2.

```

mininet> h1 ifconfig
h1-eth0 Link encap:Ethernet HWaddr 00:00:00:00:00:01
          inet addr:10.0.0.1 Bcast:10.255.255.255 Mask:255.0.0.0
                  UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
                  RX packets:7 errors:0 dropped:0 overruns:0 frame:0
                  TX packets:7 errors:0 dropped:0 overruns:0 carrier:0
                  collisions:0 txqueuelen:1000
                  RX bytes:574 (574.0 B) TX bytes:574 (574.0 B)

lo      Link encap:Local Loopback
          inet addr:127.0.0.1 Mask:255.0.0.0
                  UP LOOPBACK RUNNING MTU:65536 Metric:1
                  RX packets:0 errors:0 dropped:0 overruns:0 frame:0
                  TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
                  collisions:0 txqueuelen:0
                  RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)

mininet> h1 tcpdump -i h1-eth0

```

Verificação do endereço IP de h1 para possibilitar o envio de pacotes por parte de h25 e a escuta em tcpdump no host 1.

T "Node: h2"

```
root@mininet-vm:~# ping h1
ping: unknown host h1
root@mininet-vm:~# h2 ping h1
h2: command not found
root@mininet-vm:~# ping 10.0.0.1
PING 10.0.0.1 (10.0.0.1) 56(84) bytes of data.
64 bytes from 10.0.0.1: icmp_seq=1 ttl=64 time=66.9 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.859 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.106 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.093 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=0.082 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=0.132 ms
64 bytes from 10.0.0.1: icmp_seq=7 ttl=64 time=0.553 ms
64 bytes from 10.0.0.1: icmp_seq=8 ttl=64 time=0.298 ms
64 bytes from 10.0.0.1: icmp_seq=9 ttl=64 time=0.124 ms
64 bytes from 10.0.0.1: icmp_seq=10 ttl=64 time=0.117 ms
64 bytes from 10.0.0.1: icmp_seq=11 ttl=64 time=0.104 ms
64 bytes from 10.0.0.1: icmp_seq=12 ttl=64 time=0.094 ms
64 bytes from 10.0.0.1: icmp_seq=13 ttl=64 time=0.126 ms
64 bytes from 10.0.0.1: icmp_seq=14 ttl=64 time=0.105 ms
64 bytes from 10.0.0.1: icmp_seq=15 ttl=64 time=0.104 ms
64 bytes from 10.0.0.1: icmp_seq=16 ttl=64 time=0.118 ms
64 bytes from 10.0.0.1: icmp_seq=17 ttl=64 time=0.094 ms
64 bytes from 10.0.0.1: icmp_seq=18 ttl=64 time=0.053 ms
```

Execução do comando de ping para o IP 10.0.0.1 (host h1) pelo nó h2.

mininet@mininet-vm: ~

```
mininet> h1 tcpdump -i h1-eth0
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on h1-eth0, link-type EN10MB (Ethernet), capture size 262144 bytes
17:39:20.440990 ARP, Request who-has 10.0.0.1 tell 10.0.0.2, length 28
17:39:20.441209 ARP, Reply 10.0.0.1 is-at 00:00:00:00:00:01 (oui Ethernet), length 28
17:39:20.491698 IP 10.0.0.2 > 10.0.0.1: ICMP echo request, id 11324, seq 1, length 64
17:39:20.491808 IP 10.0.0.1 > 10.0.0.2: ICMP echo reply, id 11324, seq 1, length 64
17:39:21.432848 IP 10.0.0.2 > 10.0.0.1: ICMP echo request, id 11324, seq 2, length 64
17:39:21.432886 IP 10.0.0.1 > 10.0.0.2: ICMP echo reply, id 11324, seq 2, length 64
17:39:22.431387 IP 10.0.0.2 > 10.0.0.1: ICMP echo request, id 11324, seq 3, length 64
17:39:22.431423 IP 10.0.0.1 > 10.0.0.2: ICMP echo reply, id 11324, seq 3, length 64
17:39:23.430379 IP 10.0.0.2 > 10.0.0.1: ICMP echo request, id 11324, seq 4, length 64
17:39:23.430410 IP 10.0.0.1 > 10.0.0.2: ICMP echo reply, id 11324, seq 4, length 64
17:39:24.429374 IP 10.0.0.2 > 10.0.0.1: ICMP echo request, id 11324, seq 5, length 64
```

Recepção dos pacotes enviados pelo host h2.

Node: h25

```
root@mininet-vm:~# ping 10.0.0.26
PING 10.0.0.26 (10.0.0.26) 56(84) bytes of data.
64 bytes from 10.0.0.26: icmp_seq=1 ttl=64 time=81.2 ms
64 bytes from 10.0.0.26: icmp_seq=2 ttl=64 time=1.75 ms
64 bytes from 10.0.0.26: icmp_seq=3 ttl=64 time=0.100 ms
64 bytes from 10.0.0.26: icmp_seq=4 ttl=64 time=0.452 ms
64 bytes from 10.0.0.26: icmp_seq=5 ttl=64 time=0.138 ms
64 bytes from 10.0.0.26: icmp_seq=6 ttl=64 time=0.124 ms
64 bytes from 10.0.0.26: icmp_seq=7 ttl=64 time=1.15 ms
64 bytes from 10.0.0.26: icmp_seq=8 ttl=64 time=0.139 ms
64 bytes from 10.0.0.26: icmp_seq=9 ttl=64 time=0.274 ms
64 bytes from 10.0.0.26: icmp_seq=10 ttl=64 time=0.132 ms
64 bytes from 10.0.0.26: icmp_seq=11 ttl=64 time=0.141 ms
64 bytes from 10.0.0.26: icmp_seq=12 ttl=64 time=0.133 ms
64 bytes from 10.0.0.26: icmp_seq=13 ttl=64 time=0.162 ms
64 bytes from 10.0.0.26: icmp_seq=14 ttl=64 time=0.337 ms
64 bytes from 10.0.0.26: icmp_seq=15 ttl=64 time=0.141 ms
64 bytes from 10.0.0.26: icmp_seq=16 ttl=64 time=0.131 ms
64 bytes from 10.0.0.26: icmp_seq=17 ttl=64 time=0.137 ms
64 bytes from 10.0.0.26: icmp_seq=18 ttl=64 time=0.132 ms
^C
--- 10.0.0.26 ping statistics ---
18 packets transmitted, 18 received, 0% packet loss, time 17010ms
rtt min/avg/max/mdev = 0.100/4.825/81.280/18.547 ms
```

Envio de pacotes do nó h25 para o host h26.

```
mininet@mininet-vm: ~
RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)

mininet> xterm h25 h26
mininet> h26 tcpdump -i h26-eth0
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on h26-eth0, link-type EN10MB (Ethernet), capture size 262144 bytes
17:44:42.796875 ARP, Request who-has 10.0.0.26 tell 10.0.0.25, length 28
17:44:42.797077 ARP, Reply 10.0.0.26 is-at 00:00:00:00:00:1a (oui Ethernet), length 28
17:44:42.842471 IP 10.0.0.25 > 10.0.0.26: ICMP echo request, id 11441, seq 1, length 64
17:44:42.842607 IP 10.0.0.26 > 10.0.0.25: ICMP echo reply, id 11441, seq 1, length 64
17:44:43.782303 IP 10.0.0.25 > 10.0.0.26: ICMP echo request, id 11441, seq 2, length 64
17:44:43.782369 IP 10.0.0.26 > 10.0.0.25: ICMP echo reply, id 11441, seq 2, length 64
17:44:44.783502 IP 10.0.0.25 > 10.0.0.26: ICMP echo request, id 11441, seq 3, length 64
17:44:44.783525 IP 10.0.0.26 > 10.0.0.25: ICMP echo reply, id 11441, seq 3, length 64
17:44:45.782814 IP 10.0.0.25 > 10.0.0.26: ICMP echo request, id 11441, seq 4, length 64
17:44:45.782865 IP 10.0.0.26 > 10.0.0.25: ICMP echo reply, id 11441, seq 4, length 64
```

Recebimento dos pacotes de h25 por h26 no modo de escuta tcpdump.

Além dos testes de envio de pacotes, executamos dois testes de iperf (um de 30Mbps e o outro de 40Mbps de largura de banda) com o host h1 atuando como servidor TCP na porta 5555 e h2 como seu cliente.

30 Mbps:

X "Node: h1"

```
root@mininet-vm:~# h1 tcpdump -i h1-eth0
h1: command not found
root@mininet-vm:~# iperf -s -p 5555 -i 1
-----
Server listening on TCP port 5555
TCP window size: 85.3 KByte (default)

[320] local 10.0.0.1 port 5555 connected with 10.0.0.2 port 44968
[ ID] Interval Transfer Bandwidth
[320] 0.0- 1.0 sec 2.59 MBytes 21.7 Mbits/sec
[320] 1.0- 2.0 sec 3.16 MBytes 26.5 Mbits/sec
[320] 2.0- 3.0 sec 3.08 MBytes 25.9 Mbits/sec
[320] 3.0- 4.0 sec 3.15 MBytes 26.4 Mbits/sec
[320] 4.0- 5.0 sec 3.09 MBytes 25.9 Mbits/sec
[320] 5.0- 6.0 sec 3.11 MBytes 26.1 Mbits/sec
[320] 6.0- 7.0 sec 3.17 MBytes 26.6 Mbits/sec
[320] 7.0- 8.0 sec 3.17 MBytes 26.6 Mbits/sec
[320] 8.0- 9.0 sec 3.17 MBytes 26.6 Mbits/sec
[320] 9.0-10.0 sec 3.09 MBytes 26.0 Mbits/sec
[320] 10.0-11.0 sec 3.11 MBytes 26.1 Mbits/sec
[320] 11.0-12.0 sec 3.10 MBytes 26.0 Mbits/sec
[320] 12.0-13.0 sec 3.17 MBytes 26.6 Mbits/sec
[320] 13.0-14.0 sec 3.14 MBytes 26.4 Mbits/sec
```

X "Node: h2"

```
50 packets transmitted, 50 received, 0% packet loss, time 49006ms
rtt min/avg/max/mdev = 0.053/1.483/66.996/9.359 ms
root@mininet-vm:~# iperf -c 10.0.0.1 -p 5555 -i 1 -t 20
-----
```

```
Client connecting to 10.0.0.1, TCP port 5555
TCP window size: 85.3 KByte (default)
```

```
[319] local 10.0.0.2 port 44968 connected with 10.0.0.1 port 5555
[ ID] Interval Transfer Bandwidth
[319] 0.0- 1.0 sec 2.75 MBytes 23.1 Mbits/sec
[319] 1.0- 2.0 sec 3.38 MBytes 28.3 Mbits/sec
[319] 2.0- 3.0 sec 3.00 MBytes 25.2 Mbits/sec
[319] 3.0- 4.0 sec 3.12 MBytes 26.2 Mbits/sec
[319] 4.0- 5.0 sec 3.25 MBytes 27.3 Mbits/sec
[319] 5.0- 6.0 sec 3.00 MBytes 25.2 Mbits/sec
[319] 6.0- 7.0 sec 3.12 MBytes 26.2 Mbits/sec
[319] 7.0- 8.0 sec 3.12 MBytes 26.2 Mbits/sec
[319] 8.0- 9.0 sec 3.25 MBytes 27.3 Mbits/sec
[319] 9.0-10.0 sec 3.12 MBytes 26.2 Mbits/sec
[319] 10.0-11.0 sec 3.12 MBytes 26.2 Mbits/sec
[319] 11.0-12.0 sec 3.25 MBytes 27.3 Mbits/sec
[319] 12.0-13.0 sec 3.12 MBytes 26.2 Mbits/sec
[319] 13.0-14.0 sec 3.12 MBytes 26.2 Mbits/sec
```

Resultados do teste bem-sucedido.

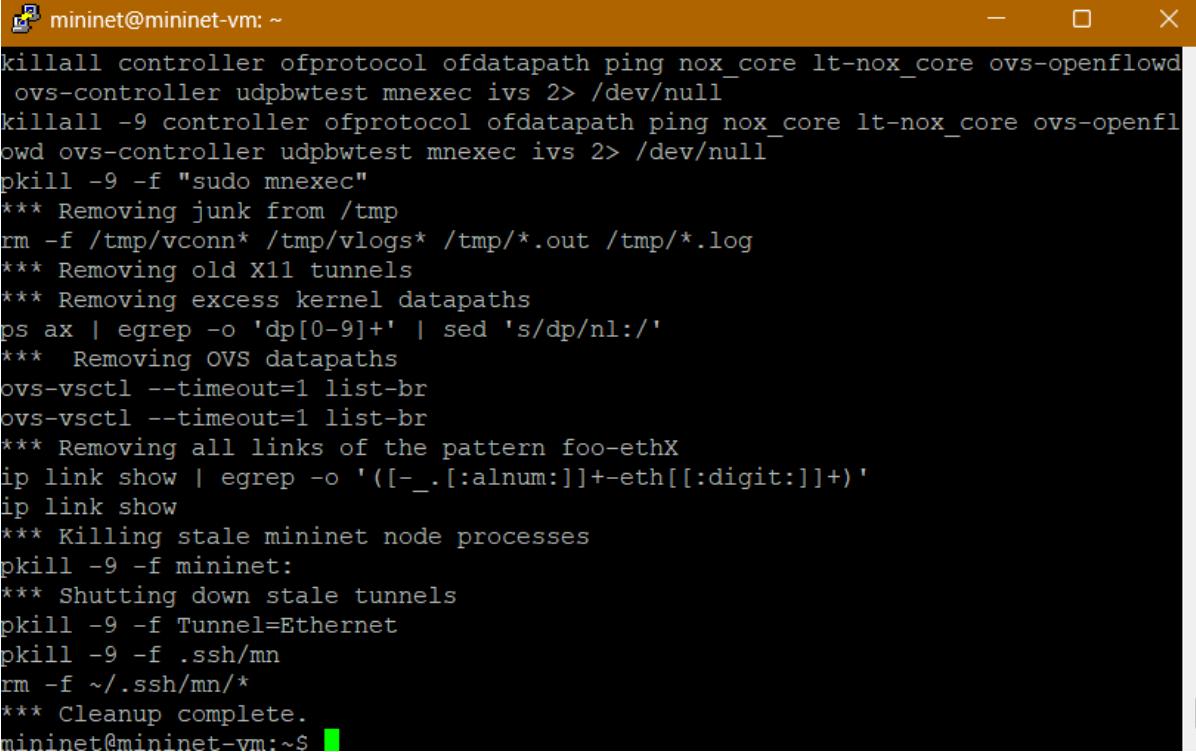
40 Mbps:

```

mininet> exit
*** Stopping 1 controllers
c0
*** Stopping 8 terms
*** Stopping 155 links
.....
.....
*** Stopping 31 switches
s1 s2 s3 s4 s5 s6 s7 s8 s9 s10 s11 s12 s13 s14 s15 s16 s17 s18 s19 s20 s21 s22 s
23 s24 s25 s26 s27 s28 s29 s30 s31
*** Stopping 125 hosts
h1 h2 h3 h4 h5 h6 h7 h8 h9 h10 h11 h12 h13 h14 h15 h16 h17 h18 h19 h20 h21 h22 h
23 h24 h25 h26 h27 h28 h29 h30 h31 h32 h33 h34 h35 h36 h37 h38 h39 h40 h41 h42 h
43 h44 h45 h46 h47 h48 h49 h50 h51 h52 h53 h54 h55 h56 h57 h58 h59 h60 h61 h62 h
63 h64 h65 h66 h67 h68 h69 h70 h71 h72 h73 h74 h75 h76 h77 h78 h79 h80 h81 h82 h
83 h84 h85 h86 h87 h88 h89 h90 h91 h92 h93 h94 h95 h96 h97 h98 h99 h100 h101 h10
2 h103 h104 h105 h106 h107 h108 h109 h110 h111 h112 h113 h114 h115 h116 h117 h11
8 h119 h120 h121 h122 h123 h124 h125
*** Done
completed in 1799.746 seconds
mininet@mininet-vm:~$ sudo mn -c
*** Removing excess controllers/ofprotocols/ofdatapaths/pings/noxes

```

Reinicialização da topologia.



```

mininet@mininet-vm: ~
killall controller ofprotocol ofdatapath ping nox_core lt-nox_core ovs-openflowd
ovs-controller udpbwtest mnexec ivs 2> /dev/null
killall -9 controller ofprotocol ofdatapath ping nox_core lt-nox_core ovs-openfl
owd ovs-controller udpbwtest mnexec ivs 2> /dev/null
pkill -9 -f "sudo mnexec"
*** Removing junk from /tmp
rm -f /tmp/vconn* /tmp/vlogs* /tmp/*.out /tmp/*.log
*** Removing old X11 tunnels
*** Removing excess kernel datapaths
ps ax | egrep -o 'dp[0-9]+' | sed 's/dp/nl:/'
*** Removing OVS datapaths
ovs-vsctl --timeout=1 list-br
ovs-vsctl --timeout=1 list-br
*** Removing all links of the pattern foo-ethX
ip link show | egrep -o '([-_.[:alnum:]]+-eth[[:digit:]]+)'
ip link show
*** Killing stale mininet node processes
pkill -9 -f mininet:
*** Shutting down stale tunnels
pkill -9 -f Tunnel=Ethernet
pkill -9 -f .ssh/mn
rm -f ~/.ssh/mn/*
*** Cleanup complete.
mininet@mininet-vm:~$ 

```

Topologia anterior apagada, vista em “Cleanup complete”.

```
mininet@mininet-vm:~$ sudo mn --mac --topo=tree,depth=3,fanout=5 --link tc,bw=40  
*** Creating network  
*** Adding controller  
*** Adding hosts:  
h1 h2 h3 h4 h5 h6 h7 h8 h9 h10 h11 h12 h13 h14 h15 h16 h17 h18 h19 h20 h21 h22 h  
23 h24 h25 h26 h27 h28 h29 h30 h31 h32 h33 h34 h35 h36 h37 h38 h39 h40 h41 h42 h  
43 h44 h45 h46 h47 h48 h49 h50 h51 h52 h53 h54 h55 h56 h57 h58 h59 h60 h61 h62 h  
63 h64 h65 h66 h67 h68 h69 h70 h71 h72 h73 h74 h75 h76 h77 h78 h79 h80 h81 h82 h  
83 h84 h85 h86 h87 h88 h89 h90 h91 h92 h93 h94 h95 h96 h97 h98 h99
```

Recriação da mesma topologia, mas agora com largura de banda de 40Mbps.

X "Node: h1"

```
root@mininet-vm:~# iperf -s -p 5555 -i 1
-----
Server listening on TCP port 5555
TCP window size: 85.3 KByte (default)

[320] local 10.0.0.1 port 5555 connected with 10.0.0.2 port 45366
[ ID] Interval Transfer Bandwidth
[320] 0.0- 1.0 sec 4.04 MBytes 33.9 Mbits/sec
[320] 1.0- 2.0 sec 3.32 MBytes 27.8 Mbits/sec
[320] 2.0- 3.0 sec 1.86 MBytes 15.6 Mbits/sec
[320] 3.0- 4.0 sec 2.75 MBytes 23.1 Mbits/sec
[320] 4.0- 5.0 sec 4.02 MBytes 33.7 Mbits/sec
[320] 5.0- 6.0 sec 4.00 MBytes 33.5 Mbits/sec
[320] 6.0- 7.0 sec 4.18 MBytes 35.1 Mbits/sec
[320] 7.0- 8.0 sec 4.27 MBytes 35.8 Mbits/sec
[320] 8.0- 9.0 sec 4.24 MBytes 35.6 Mbits/sec
[320] 9.0-10.0 sec 4.29 MBytes 36.0 Mbits/sec
[320] 10.0-11.0 sec 4.26 MBytes 35.7 Mbits/sec
[320] 11.0-12.0 sec 4.33 MBytes 36.3 Mbits/sec
[320] 12.0-13.0 sec 4.27 MBytes 35.8 Mbits/sec
[320] 13.0-14.0 sec 4.24 MBytes 35.6 Mbits/sec
[320] 14.0-15.0 sec 4.21 MBytes 35.3 Mbits/sec
[320] 15.0-16.0 sec 4.19 MBytes 35.1 Mbits/sec
[320] 16.0-17.0 sec 4.20 MBytes 35.2 Mbits/sec
```

T "Node: h2"

```
root@mininet-vm:~# iperf -c 10.0.0.1 -p 5555 -i 1 -t 20
-----
Client connecting to 10.0.0.1, TCP port 5555
TCP window size: 85.3 KByte (default)

[319] local 10.0.0.2 port 45366 connected with 10.0.0.1 port 5555
[ ID] Interval Transfer Bandwidth
[319] 0.0- 1.0 sec 4.50 MBytes 37.7 Mbits/sec
[319] 1.0- 2.0 sec 3.38 MBytes 28.3 Mbits/sec
[319] 2.0- 3.0 sec 2.00 MBytes 16.8 Mbits/sec
[319] 3.0- 4.0 sec 2.75 MBytes 23.1 Mbits/sec
[319] 4.0- 5.0 sec 4.00 MBytes 33.6 Mbits/sec
[319] 5.0- 6.0 sec 4.00 MBytes 33.6 Mbits/sec
[319] 6.0- 7.0 sec 4.38 MBytes 36.7 Mbits/sec
[319] 7.0- 8.0 sec 4.00 MBytes 33.6 Mbits/sec
[319] 8.0- 9.0 sec 4.38 MBytes 36.7 Mbits/sec
[319] 9.0-10.0 sec 4.38 MBytes 36.7 Mbits/sec
[319] 10.0-11.0 sec 4.38 MBytes 36.7 Mbits/sec
[319] 11.0-12.0 sec 4.00 MBytes 33.6 Mbits/sec
[319] 12.0-13.0 sec 4.38 MBytes 36.7 Mbits/sec
[319] 13.0-14.0 sec 4.38 MBytes 36.7 Mbits/sec
[319] 14.0-15.0 sec 4.00 MBytes 33.6 Mbits/sec
[319] 15.0-16.0 sec 4.38 MBytes 36.7 Mbits/sec
[319] 16.0-17.0 sec 4.00 MBytes 33.6 Mbits/sec
```

Resultado bem-sucedido do novo teste de iperf (com a mesma lógica do anterior de 30Mbps).

Conclusão:

Através destes testes bem-sucedidos, vê-se que a topologia foi criada corretamente e a rede é operante assim como o esperado.

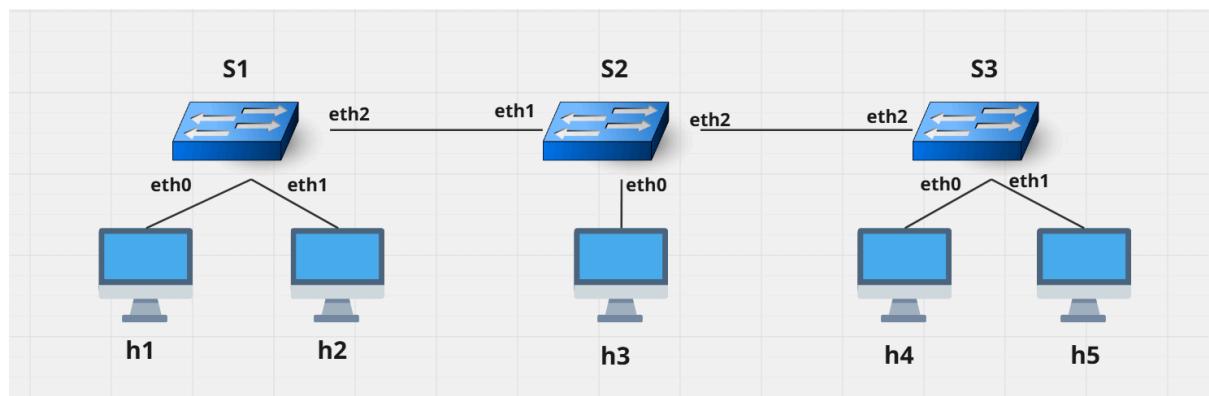
Questão 2.

Abordagem:

Agora, ao invés de utilizarmos puramente linhas de comando em terminal para gerar a rede com Mininet, usaremos a linguagem de programação Python como auxílio para administração da criação e gerenciamento da rede. O código principal referente a essa questão foi nomeado “trabalho-final-mininet_LannaC.py”.

Topologia:

Nesta segunda questão, é feito o uso de uma nova topologia. A mesma é composta por três switches (s1, s2 e s3) e cinco hosts (h1-h5) e as ligações entre nós são feitas de acordo com a imagem a seguir.



Para a replicação da mesma em código, utilizamos a classe “NetworkTopo(Topo)” para adicionar switches e hosts, além de estabelecer as conexões entre eles, com endereços MAC padronizados e controlador manual (visto em “controller=None”).

```
class NetworkTopo( Topo ):
    # Builds network topology
    def build(self, **_opts):

        s1 = self.addSwitch('s1', failMode='standalone')
        s2 = self.addSwitch('s2', failMode='standalone')
        s3 = self.addSwitch('s3', failMode='standalone')

        # Adding hosts
        h1 = self.addHost('h1',ip='192.168.0.1/28',mac='00:00:00:00:00:01')
        h2 = self.addHost('h2',ip='192.168.0.2/28',mac='00:00:00:00:00:02')
        h3 = self.addHost('h3',ip='192.168.0.3/28',mac='00:00:00:00:00:03')
        h4 = self.addHost('h4',ip='192.168.0.4/28',mac='00:00:00:00:00:04')
        h5 = self.addHost('h5',ip='192.168.0.5/28',mac='00:00:00:00:00:05')

        # Connecting hosts to switches
        for d, s in [(h1, s1), (h2, s1), (h3,s2), (h4,s3), (h5,s3)]:
            self.addLink(d, s)

        #Connecting switches
        self.addLink(s1, s2)
        self.addLink(s2, s3)
```

Configuração dos switches e hosts.

```

def run():
    topo = NetworkTopo()
    net = Mininet(topo=topo, controller=None)
    #net.addController('c0')
    net.start()
    CLI( net, script="nodes.sh")
    h1 = net.get('h1')

    print(h1.cmd('sudo ovs-ofctl del-flows s1'))
    print(h1.cmd('sudo ovs-ofctl dump-flows s1'))
    print(h1.cmd('sudo ovs-ofctl del-flows s2'))
    print(h1.cmd('sudo ovs-ofctl dump-flows s2'))
    print(h1.cmd('sudo ovs-ofctl del-flows s3'))
    print(h1.cmd('sudo ovs-ofctl dump-flows s3'))
    #print(h1.cmd('sudo mn --custom topo-3s-5h.py --topo mytopo'))

    #h1 e h2
    net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:02,actions=output:2')
    net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:01,actions=output:1')

    #h1 e h3
    net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:03,actions=output:3')
    net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:03,actions=output:1')
    net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01,actions=output:2')
    net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01,actions=output:1')

    #h1 e h4
    net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:04,actions=output:3')
    net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:04,actions=output:3')
    net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:04,actions=output:1')
    net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:3')
    net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:1')
    net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:2')

    net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:3')
    net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:1')
    net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:2')

    #h4 e h5
    net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:05,actions=output:2')
    net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:04,actions=output:1')

    net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_type=0x806,nw_proto=1,action=flood')
    net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_type=0x806,nw_proto=1,action=flood')
    net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_type=0x806,nw_proto=1,action=flood')

    print(h1.cmd('sudo ovs-ofctl dump-flows s1'))
    print(h1.cmd('sudo ovs-ofctl dump-flows s2'))
    print(h1.cmd('sudo ovs-ofctl dump-flows s3'))

    CLI( net, script="ping.sh")

    net.stop()
    if __name__ == '__main__':
        setLogLevel( 'info' )
        run()

```

Ativação da topologia, execução do script e comandos para terminal.

```

mininet@mininet-vm:~$ sudo python trabalho-final-mininet_LannaC.py
*** Creating network
*** Adding hosts:
h1 h2 h3 h4 h5
*** Adding switches:
s1 s2 s3
*** Adding links:
(h1, s1) (h2, s1) (h3, s2) (h4, s3) (h5, s3) (s1, s2) (s2, s3)
*** Configuring hosts
h1 h2 h3 h4 h5
*** Starting controller

*** Starting 3 switches
s1 s2 s3 ...
*** Starting CLI:
available nodes are:
h1 h2 h3 h4 h5 s1 s2 s3
h1 h1-eth0:s1-eth1
h2 h2-eth0:s1-eth2
h3 h3-eth0:s2-eth1
h4 h4-eth0:s3-eth1
h5 h5-eth0:s3-eth2
s1 lo: s1-eth1:h1-eth0 s1-eth2:h2-eth0 s1-eth3:s2-eth2
s2 lo: s2-eth1:h3-eth0 s2-eth2:s1-eth3 s2-eth3:s3-eth3
s3 lo: s3-eth1:h4-eth0 s3-eth2:h5-eth0 s3-eth3:s2-eth3
<Host h1: h1-eth0:192.168.0.1 pid=2248>
<Host h2: h2-eth0:192.168.0.2 pid=2250>
<Host h3: h3-eth0:192.168.0.3 pid=2254>
<Host h4: h4-eth0:192.168.0.4 pid=2256>
<Host h5: h5-eth0:192.168.0.5 pid=2258>
<OVSSwitch s1: lo:127.0.0.1, s1-eth1:None, s1-eth2:None, s1-eth3:None pid=2263>
<OVSSwitch s2: lo:127.0.0.1, s2-eth1:None, s2-eth2:None, s2-eth3:None pid=2266>
<OVSSwitch s3: lo:127.0.0.1, s3-eth1:None, s3-eth2:None, s3-eth3:None pid=2269>
h1-eth0    Link encap:Ethernet HWaddr 00:00:00:00:00:01
           inet addr:192.168.0.1 Bcast:192.168.0.15 Mask:255.255.255.240
           UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
           RX packets:0 errors:0 dropped:0 overruns:0 frame:0
           TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
           collisions:0 txqueuelen:1000
           RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

lo        Link encap:Local Loopback

```

Criação bem-sucedida da topologia da rede.

Inspeções:

Para verificar se a topologia foi criada como o esperado, executamos alguns comandos, como “nodes” para verificar os nós (hosts e switches) gerados, “net” para visualizar a relação de portas nas conexões da rede, “dump” a fim de ver os endereços IP dos dispositivos, e “x ifconfig -a” (considerando x como um host ou switch qualquer) para ver o endereço MAC de cada nó e as configurações de suas portas.

```
nodes
net
dump
h1 ifconfig -a
h2 ifconfig -a
h3 ifconfig -a
h4 ifconfig -a
h5 ifconfig -a
s1 ifconfig -a
s2 ifconfig -a
s3 ifconfig -a
```

Comandos que serão executados no terminal.

```
BROADCAST MULTICAST MTU:1500 Metric:1
RX packets:0 errors:0 dropped:0 overruns:0 frame:0
TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:0
RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)

s1
Link encap:Ethernet HWaddr 62:05:91:98:a9:41
UP BROADCAST RUNNING MTU:1500 Metric:1
RX packets:0 errors:0 dropped:0 overruns:0 frame:0
TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:0
RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)

Link encap:Ethernet HWaddr b2:ea:9f:e5:95:44
UP BROADCAST RUNNING MTU:1500 Metric:1
RX packets:0 errors:0 dropped:0 overruns:0 frame:0
TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:0
RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)

Link encap:Ethernet HWaddr 3e:5c:68:26:4e:47
UP BROADCAST RUNNING MTU:1500 Metric:1
RX packets:0 errors:0 dropped:0 overruns:0 frame:0
TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:0
RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)

Link encap:Ethernet HWaddr 4e:e4:d1:a8:7a:cd
UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
RX packets:0 errors:0 dropped:0 overruns:0 frame:0
TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:1000
RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)

Link encap:Ethernet HWaddr de:22:7c:84:41:88
UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
RX packets:0 errors:0 dropped:0 overruns:0 frame:0
TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:1000
RX bytes:0 (0.0 B) TX bytes:0 (0.0 B)

Link encap:Ethernet HWaddr 52:5b:18:f8:0c:15
UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
RX packets:0 errors:0 dropped:0 overruns:0 frame:0
TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:1000
RX bytes:0 (0.0 B) TX bytes:0
```

Exemplo de execução do comando “ifconfig”.

Testes de conexão:

Para analisar o funcionamento da rede na troca de dados, realizamos testes de ping através do comando “pingall” e do “ping” com o envio de 5 pacotes entre os hosts h1 e h2, h3 e h5.

```

pingall
h1 ping -c 5 h2
h3 ping -c 5 h5

```

Sequência de comandos de envio de pacotes de teste.

```

*** Ping: testing ping reachability
h1 -> h2 h3 h4 h5
h2 -> h1 h3 h4 h5
h3 -> h1 h2 h4 h5
h4 -> h1 h2 h3 h5
h5 -> h1 h2 h3 h4
*** Results: 0% dropped (20/20 received)
PING 192.168.0.2 (192.168.0.2) 56(84) bytes of data.
64 bytes from 192.168.0.2: icmp_seq=1 ttl=64 time=0.038 ms
64 bytes from 192.168.0.2: icmp_seq=2 ttl=64 time=0.041 ms
64 bytes from 192.168.0.2: icmp_seq=3 ttl=64 time=0.071 ms
64 bytes from 192.168.0.2: icmp_seq=4 ttl=64 time=0.049 ms
64 bytes from 192.168.0.2: icmp_seq=5 ttl=64 time=0.038 ms

--- 192.168.0.2 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 3999ms
rtt min/avg/max/mdev = 0.038/0.047/0.071/0.013 ms
PING 192.168.0.5 (192.168.0.5) 56(84) bytes of data.
64 bytes from 192.168.0.5: icmp_seq=1 ttl=64 time=0.027 ms
64 bytes from 192.168.0.5: icmp_seq=2 ttl=64 time=0.039 ms
64 bytes from 192.168.0.5: icmp_seq=3 ttl=64 time=0.072 ms
64 bytes from 192.168.0.5: icmp_seq=4 ttl=64 time=0.041 ms
64 bytes from 192.168.0.5: icmp_seq=5 ttl=64 time=0.041 ms

--- 192.168.0.5 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 3998ms
rtt min/avg/max/mdev = 0.027/0.044/0.072/0.014 ms

NXST_FLOW reply (xid=0x4):

NXST_FLOW reply (xid=0x4):

NXST_FLOW reply (xid=0x4):
NXST_FLOW reply (xid=0x4):
cookie=0x0, duration=0.127s, table=0, n_packets=0, n_bytes=0, idle_age=0, dl_sr

```

Respostas ao comando de “pingall” e pings específicos entre h1 e h2 e h3 e h5.

A seguir, apagamos todas as regras que haviam sobre tráfego de pacotes nos switches com a reinicialização de todos os links da topologia.

```

h1 = net.get('h1')

print(h1.cmd('sudo ovs-ofctl del-flows s1'))
print(h1.cmd('sudo ovs-ofctl dump-flows s1'))
print(h1.cmd('sudo ovs-ofctl del-flows s2'))
print(h1.cmd('sudo ovs-ofctl dump-flows s2'))
print(h1.cmd('sudo ovs-ofctl del-flows s3'))
print(h1.cmd('sudo ovs-ofctl dump-flows s3'))

```

Exclusão apenas dos links da topologia, sem deletá-la.

```

NXST_FLOW reply (xid=0x4):

NXST_FLOW reply (xid=0x4):

NXST_FLOW reply (xid=0x4):
NXST_FLOW reply (xid=0x4):
cookie=0x0, duration=0.127s, table=0, n_packets=0, n_bytes=0, idle_age=0, dl_sr
c=00:00:00:00:00:01,dl_dst=00:00:00:00:00:04 actions=output:3
cookie=0x0, duration=0.194s, table=0, n_packets=0, n_bytes=0, idle_age=0, dl_sr
c=00:00:00:00:00:01,dl_dst=00:00:00:00:00:02 actions=output:2
cookie=0x0, duration=0.138s, table=0, n_packets=0, n_bytes=0, idle_age=0, dl_sr
c=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01 actions=output:1
cookie=0x0, duration=0.182s, table=0, n_packets=0, n_bytes=0, idle_age=0, dl_sr
c=00:00:00:00:00:02,dl_dst=00:00:00:00:00:01 actions=output:1
cookie=0x0, duration=0.171s, table=0, n_packets=0, n_bytes=0, idle_age=0, dl_sr
c=00:00:00:00:00:01,dl_dst=00:00:00:00:00:03 actions=output:3
cookie=0x0, duration=0.082s, table=0, n_packets=0, n_bytes=0, idle_age=0, dl_sr
c=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01 actions=output:1
cookie=0x0, duration=0.034s, table=0, n_packets=0, n_bytes=0, idle_age=0, arp,a
rp_op=1 actions=FLLOOD

NXST_FLOW reply (xid=0x4):
cookie=0x0, duration=0.132s, table=0, n_packets=0, n_bytes=0, idle_age=0, dl_sr
c=00:00:00:00:00:01,dl_dst=00:00:00:00:00:04 actions=output:3
cookie=0x0, duration=0.165s, table=0, n_packets=0, n_bytes=0, idle_age=0, dl_sr
c=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01 actions=output:2
cookie=0x0, duration=0.176s, table=0, n_packets=0, n_bytes=0, idle_age=0, dl_sr
c=00:00:00:00:00:01,dl_dst=00:00:00:00:00:03 actions=output:1
cookie=0x0, duration=0.088s, table=0, n_packets=0, n_bytes=0, idle_age=0, dl_sr
c=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01 actions=output:2

```

Resultados da exclusão.

E, assim, escrevemos algumas novas regras de tráfego com base nos endereços MAC dos hosts para execução no terminal.

```

#h1 e h2
net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:02,actions=output:2')
net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:01,actions=output:1')

#h1 e h3
net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:03,actions=output:3')
net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:03,actions=output:1')
net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01,actions=output:2')
net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01,actions=output:1')

#h1 e h4
net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:04,actions=output:3')
net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:04,actions=output:3')
net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:04,actions=output:1')
net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:3')
net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:1')
net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:2')

net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:3')
net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:1')
net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01,actions=output:2')

#h4 e h5
net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:05,actions=output:2')
net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:04,actions=output:1')

net['s1'].cmd('sudo ovs-ofctl add-flow s1 dl_type=0x806,nw_proto=1,action=flood')
net['s2'].cmd('sudo ovs-ofctl add-flow s2 dl_type=0x806,nw_proto=1,action=flood')
net['s3'].cmd('sudo ovs-ofctl add-flow s3 dl_type=0x806,nw_proto=1,action=flood')

print(h1.cmd('sudo ovs-ofctl dump-flows s1'))
print(h1.cmd('sudo ovs-ofctl dump-flows s2'))
print(h1.cmd('sudo ovs-ofctl dump-flows s3'))

CLI( net, script="ping.sh")

net.stop()
if __name__ == '__main__':
    setLogLevel( 'info' )
    run()

```

Novas regras de tráfego nos switches s1, s2 e s3.

Por fim, para garantir que as novas regras foram contabilizadas e as anteriores foram apagadas, executamos novos testes de ping.

```

pingall
h1 ping -c 5 h2
h3 ping -c 5 h5
h5 ping -c 5 h2
h5 ping -c 5 h1

```

Novos testes de ping.

É importante ressaltar que nem todos os casos do “pingall” devem ser bem-sucedidos, como por exemplo o envio de pacotes de h5 à h1 (“h5 ping -c 5 h1”), já que nem todos os links entre hosts foram restabelecidos. Isso é confirmado no resultado da execução desses comandos, exposto a seguir.


```
*** Starting CLI:  
*** Ping: testing ping reachability  
h1 -> h2 h3 h4 X  
h2 -> h1 X X X  
h3 -> h1 X X X  
h4 -> h1 X X h5  
h5 -> X X X h4  
*** Results: 60% dropped (8/20 received)  
PING 192.168.0.2 (192.168.0.2) 56(84) bytes of data.  
64 bytes from 192.168.0.2: icmp_seq=1 ttl=64 time=0.221 ms  
64 bytes from 192.168.0.2: icmp_seq=2 ttl=64 time=0.043 ms  
64 bytes from 192.168.0.2: icmp_seq=3 ttl=64 time=0.055 ms  
64 bytes from 192.168.0.2: icmp_seq=4 ttl=64 time=0.054 ms  
64 bytes from 192.168.0.2: icmp_seq=5 ttl=64 time=0.036 ms  
  
--- 192.168.0.2 ping statistics ---  
5 packets transmitted, 5 received, 0% packet loss, time 4002ms  
rtt min/avg/max/mdev = 0.036/0.081/0.221/0.070 ms  
PING 192.168.0.5 (192.168.0.5) 56(84) bytes of data.  
  
--- 192.168.0.5 ping statistics ---  
5 packets transmitted, 0 received, 100% packet loss, time 4019ms  
  
PING 192.168.0.2 (192.168.0.2) 56(84) bytes of data.  
From 192.168.0.5 icmp_seq=1 Destination Host Unreachable  
From 192.168.0.5 icmp_seq=2 Destination Host Unreachable  
From 192.168.0.5 icmp_seq=3 Destination Host Unreachable  
From 192.168.0.5 icmp_seq=4 Destination Host Unreachable  
From 192.168.0.5 icmp_seq=5 Destination Host Unreachable
```

```
mininet@mininet-vm: ~
*** Results: 60% dropped (8/20 received)
PING 192.168.0.2 (192.168.0.2) 56(84) bytes of data.
64 bytes from 192.168.0.2: icmp_seq=1 ttl=64 time=0.221 ms
64 bytes from 192.168.0.2: icmp_seq=2 ttl=64 time=0.043 ms
64 bytes from 192.168.0.2: icmp_seq=3 ttl=64 time=0.055 ms
64 bytes from 192.168.0.2: icmp_seq=4 ttl=64 time=0.054 ms
64 bytes from 192.168.0.2: icmp_seq=5 ttl=64 time=0.036 ms

--- 192.168.0.2 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4002ms
rtt min/avg/max/mdev = 0.036/0.081/0.221/0.070 ms
PING 192.168.0.5 (192.168.0.5) 56(84) bytes of data.

--- 192.168.0.5 ping statistics ---
5 packets transmitted, 0 received, 100% packet loss, time 4019ms

PING 192.168.0.2 (192.168.0.2) 56(84) bytes of data.
From 192.168.0.5 icmp_seq=1 Destination Host Unreachable
From 192.168.0.5 icmp_seq=2 Destination Host Unreachable
From 192.168.0.5 icmp_seq=3 Destination Host Unreachable
From 192.168.0.5 icmp_seq=4 Destination Host Unreachable
From 192.168.0.5 icmp_seq=5 Destination Host Unreachable

--- 192.168.0.2 ping statistics ---
5 packets transmitted, 0 received, +5 errors, 100% packet loss, time 4012ms
pipe 3
PING 192.168.0.1 (192.168.0.1) 56(84) bytes of data.
From 192.168.0.5 icmp_seq=1 Destination Host Unreachable
From 192.168.0.5 icmp_seq=2 Destination Host Unreachable
From 192.168.0.5 icmp_seq=3 Destination Host Unreachable
From 192.168.0.5 icmp_seq=4 Destination Host Unreachable
From 192.168.0.5 icmp_seq=5 Destination Host Unreachable

--- 192.168.0.1 ping statistics ---
5 packets transmitted, 0 received, +5 errors, 100% packet loss, time 3998ms
pipe 4
*** Stopping 0 controllers

*** Stopping 7 links
.....
*** Stopping 3 switches
s1 s2 s3
*** Stopping 5 hosts
h1 h2 h3 h4 h5
*** Done
mininet@mininet-vm:~$
```

Execução bem-sucedida com base no esperado para o que foi criado de conexões MAC entre hosts.

Referências:

- <https://vecta.io/symbols/240/cisco-network-topology-icons-3015/241/system-controller>
- <https://www.freeiconspng.com/img/27057>