Trabalho de C115
Mininet - Trabalho Final

Gualter Machado Mesquita - 1601 - GEC

Trabalho Parte 1 - Topologia linear com 6 hosts

- Com uso de linha de comando padrão do Mininet, crie a topologia considerando o endereço MAC padronizado, larguras de banda bw de 5Mbps e controlador do Mininet (não precisa especificar).
- Inspecione informações das interfaces, endereços MAC, IP e portas através de linhas de comando.
- Crie um desenho ilustrativo da topologia com todas as informações obtidas no item anterior
- Execute testes de ping entre os diferentes nós, mostre os pacotes chegando nos nós com uso do comando tcpdump.
- Especifique que o host 1 na porta 5555 vai ser um servidor TCP e o host 2 um cliente e execute testes de iperf, considere um relatório por segundo com teste de 15 segundos. Faça os testes para larguras de banda bw de 2, 10, 15 e 20 Mbps.

Topologia

```
mininet@mininet-vm:~$ sudo mn --mac --topo=linear,6 --link tc,bw=5
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3 h4 h5 h6
*** Adding switches:
s1 s2 s3 s4 s5 s6
*** Adding links:
(5.00Mbit) (5.00Mbit) (h1, s1) (5.00Mbit) (5.00Mbit) (h2, s2) (5.00Mbit) (5.00Mbit) (h3, s3) (5.00Mb
it) (5.00Mbit) (h4, s4) (5.00Mbit) (5.00Mbit) (h5, s5) (5.00Mbit) (5.00Mbit) (h6, s6) (5.00Mbit) (5.
00Mbit) (s2, s1) (5.00Mbit) (5.00Mbit) (s3, s2) (5.00Mbit) (5.00Mbit) (s4, s3) (5.00Mbit) (5.00Mbit)
 (s5, s4) (5.00Mbit) (5.00Mbit) (s6, s5)
*** Configuring hosts
h1 h2 h3 h4 h5 h6
*** Starting controller
c0
*** Starting 6 switches
s1 s2 s3 s4 s5 s6 ...(5.00Mbit) (5.00Mbit) (5.00Mbit) (5.00Mbit) (5.00Mbit) (5.00Mbit) (5
.00Mbit) (5.00Mbit) (5.00Mbit) (5.00Mbit) (5.00Mbit) (5.00Mbit) (5.00Mbit) (5.00Mbit)
*** Starting CLI:
mininet>
```

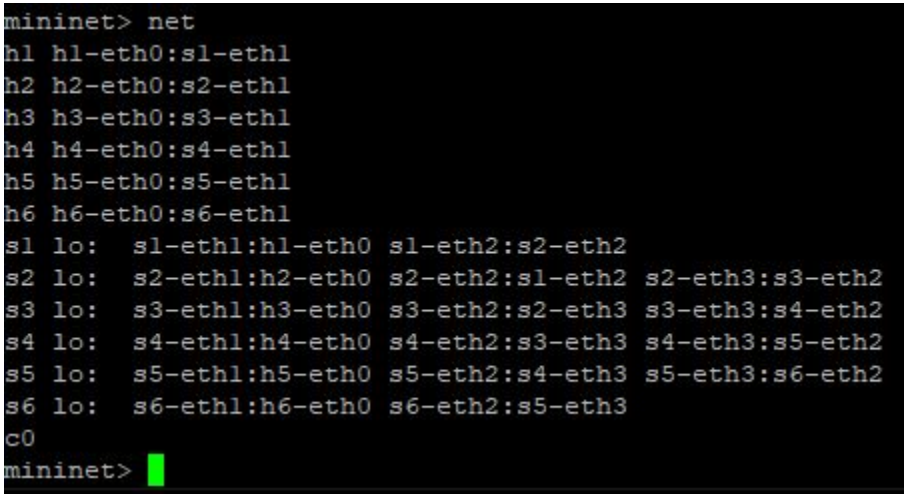
Nós da topologia

```
mininet> nodes
available nodes are:
c0 h1 h2 h3 h4 h5 h6 s1 s2 s3 s4 s5 s6
```

Informações das interfaces

```
mininet> dump
<Host h1: h1-eth0:10.0.0.1 pid=15291>
<Host h2: h2-eth0:10.0.0.2 pid=15294>
<Host h3: h3-eth0:10.0.0.3 pid=15297>
<Host h4: h4-eth0:10.0.0.4 pid=15300>
<Host h5: h5-eth0:10.0.0.5 pid=15303>
<Host h6: h6-eth0:10.0.0.6 pid=15306>
<OVSSwitch s1: lo:127.0.0.1,s1-eth1:None,s1-eth2:None pid=15312>
<OVSSwitch s2: lo:127.0.0.1,s2-eth1:None,s2-eth2:None,s2-eth3:None pid=15315>
<OVSSwitch s3: lo:127.0.0.1,s3-eth1:None,s3-eth2:None,s3-eth3:None pid=15318>
<OVSSwitch s4: lo:127.0.0.1,s4-eth1:None,s4-eth2:None,s4-eth3:None pid=15321>
<OVSSwitch s5: lo:127.0.0.1,s5-eth1:None,s5-eth2:None,s5-eth3:None pid=15324>
<OVSSwitch s6: lo:127.0.0.1,s6-eth1:None,s6-eth2:None pid=15327>
<Controller c0: 127.0.0.1:6653 pid=15284>
mininet>
```

Conexão entre as interfaces



Interfaces, endereços de IP e MAC

```
mininet> h1 ifconfig -a
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: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:1
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

mininet>
```

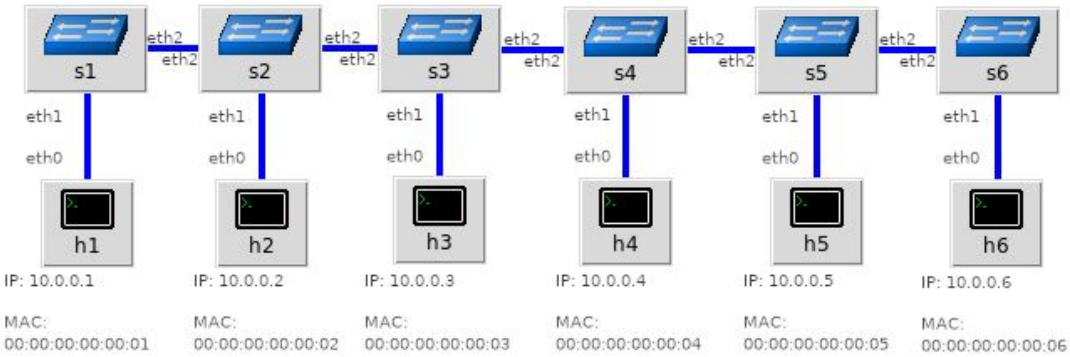
Host h1 possui endereços IP e MAC terminados em 1

Interfaces, endereços de IP e MAC

```
mininet> h6 ifconfig -a
h6-eth0   Link encap:Ethernet  HWaddr 00:00:00:00:00:06
          inet addr:10.0.0.6  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:1
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

mininet>
```

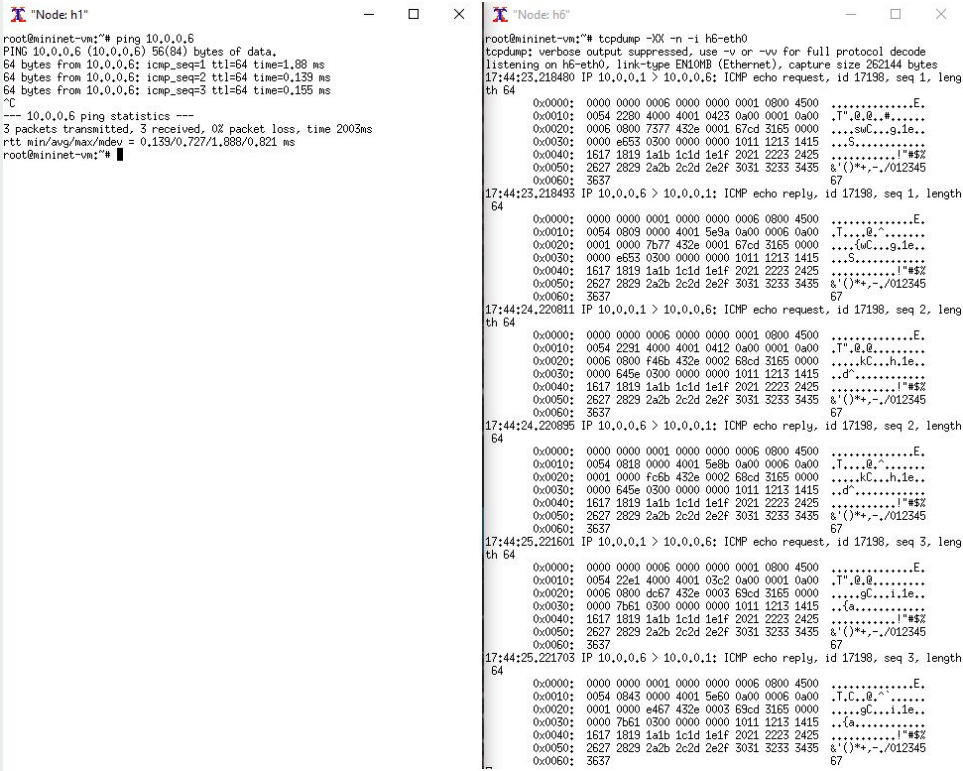
Host h6 possui endereços IP e MAC terminados em 6

Ilustração da topologia



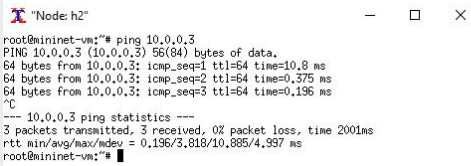
Ping de h1 para h6

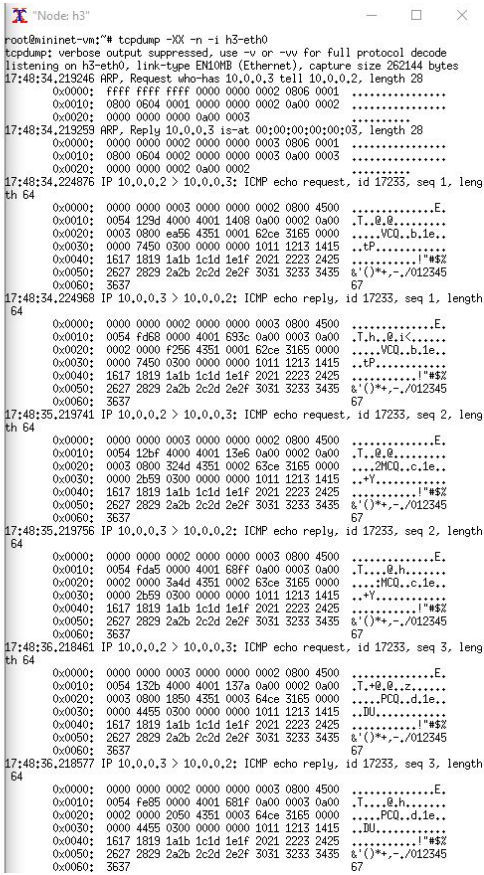
H6 mostra o fluxo da rede através do TCPDUMP.



Ping de h2 para h3

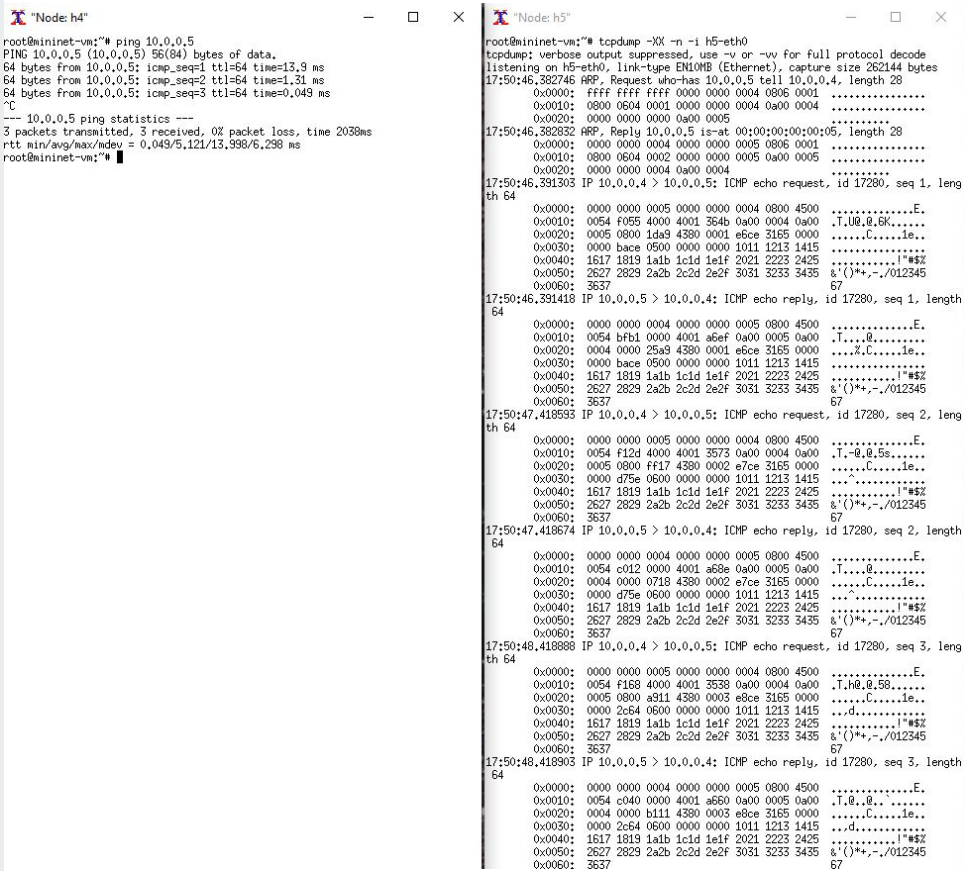
H3 mostra o fluxo da rede através do TCPDUMP.





Ping de h4 para h5

H5 mostra o fluxo da rede através do TCPDUMP.



Simulação Servidor/Cliente TCP: bw = 2 Mbps

"Node: h1"

```
root@mininet-vm:~# iperf -s -p 5555 -i 1
------------------------------------------------------------
Server listening on TCP port 5555
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[ 32] local 10.0.0.1 port 5555 connected with 10.0.0.2 port 35388
[ ID] Interval       Transfer     Bandwidth
[ 32]  0.0- 1.0 sec   235 KBytes  1.92 Mbits/sec
[ 32]  1.0- 2.0 sec   229 KBytes  1.88 Mbits/sec
[ 32]  2.0- 3.0 sec   228 KBytes  1.87 Mbits/sec
[ 32]  3.0- 4.0 sec   232 KBytes  1.90 Mbits/sec
[ 32]  4.0- 5.0 sec   232 KBytes  1.90 Mbits/sec
[ 32]  5.0- 6.0 sec   233 KBytes  1.91 Mbits/sec
[ 32]  6.0- 7.0 sec   235 KBytes  1.92 Mbits/sec
[ 32]  7.0- 8.0 sec   232 KBytes  1.90 Mbits/sec
[ 32]  8.0- 9.0 sec   233 KBytes  1.91 Mbits/sec
[ 32]  9.0-10.0 sec   232 KBytes  1.90 Mbits/sec
[ 32] 10.0-11.0 sec   232 KBytes  1.90 Mbits/sec
[ 32] 11.0-12.0 sec   228 KBytes  1.87 Mbits/sec
[ 32] 12.0-13.0 sec   229 KBytes  1.88 Mbits/sec
[ 32] 13.0-14.0 sec   230 KBytes  1.89 Mbits/sec
[ 32] 14.0-15.0 sec   229 KBytes  1.88 Mbits/sec
[ 32] 15.0-16.0 sec   219 KBytes  1.80 Mbits/sec
[ 32] 16.0-17.0 sec   143 KBytes  1.17 Mbits/sec
[ 32]  0.0-17.0 sec  3.75 MBytes  1.85 Mbits/sec
```

"Node: h2"

```
root@mininet-vm:~# iperf -c 10.0.0.1 -p 5555 -i 1 -t15
------------------------------------------------------------
Client connecting to 10.0.0.1, TCP port 5555
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[ 31] local 10.0.0.2 port 35388 connected with 10.0.0.1 port 5555
[ ID] Interval       Transfer     Bandwidth
[ 31]  0.0- 1.0 sec   512 KBytes  4.19 Mbits/sec
[ 31]  1.0- 2.0 sec   256 KBytes  2.10 Mbits/sec
[ 31]  2.0- 3.0 sec   128 KBytes  1.05 Mbits/sec
[ 31]  3.0- 4.0 sec   256 KBytes  2.10 Mbits/sec
[ 31]  4.0- 5.0 sec   128 KBytes  1.05 Mbits/sec
[ 31]  5.0- 6.0 sec   256 KBytes  2.10 Mbits/sec
[ 31]  6.0- 7.0 sec   256 KBytes  2.10 Mbits/sec
[ 31]  7.0- 8.0 sec   256 KBytes  2.10 Mbits/sec
[ 31]  8.0- 9.0 sec   256 KBytes  2.10 Mbits/sec
[ 31]  9.0-10.0 sec   256 KBytes  2.10 Mbits/sec
[ 31] 10.0-11.0 sec   128 KBytes  1.05 Mbits/sec
[ 31] 11.0-12.0 sec   256 KBytes  2.10 Mbits/sec
[ 31] 12.0-13.0 sec   256 KBytes  2.10 Mbits/sec
[ 31] 13.0-14.0 sec   256 KBytes  2.10 Mbits/sec
[ 31] 14.0-15.0 sec   256 KBytes  2.10 Mbits/sec
[ 31]  0.0-16.1 sec  3.75 MBytes  1.96 Mbits/sec
root@mininet-vm:~#
```

Simulação Servidor/Cliente TCP: bw = 10 Mbps

"Node: h1"

```
root@mininet-vm:~# iperf -s -p 5555 -i 1
------------------------------------------------------------
Server listening on TCP port 5555
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[ 32] local 10.0.0.1 port 5555 connected with 10.0.0.2 port 35536
[ ID] Interval       Transfer     Bandwidth
[ 32]  0.0- 1.0 sec   826 KBytes  6.77 Mbits/sec
[ 32]  1.0- 2.0 sec   769 KBytes  6.30 Mbits/sec
[ 32]  2.0- 3.0 sec   689 KBytes  5.64 Mbits/sec
[ 32]  3.0- 4.0 sec   905 KBytes  7.41 Mbits/sec
[ 32]  4.0- 5.0 sec   935 KBytes  7.66 Mbits/sec
[ 32]  5.0- 6.0 sec   969 KBytes  7.94 Mbits/sec
[ 32]  6.0- 7.0 sec   987 KBytes  8.09 Mbits/sec
[ 32]  7.0- 8.0 sec   950 KBytes  7.78 Mbits/sec
[ 32]  8.0- 9.0 sec   979 KBytes  8.02 Mbits/sec
[ 32]  9.0-10.0 sec   936 KBytes  7.67 Mbits/sec
[ 32] 10.0-11.0 sec   660 KBytes  5.41 Mbits/sec
[ 32] 11.0-12.0 sec   184 KBytes  1.51 Mbits/sec
[ 32] 12.0-13.0 sec   180 KBytes  1.47 Mbits/sec
[ 32] 13.0-14.0 sec   146 KBytes  1.19 Mbits/sec
[ 32] 14.0-15.0 sec   291 KBytes  2.39 Mbits/sec
[ 32] 15.0-16.0 sec   136 KBytes  1.11 Mbits/sec
[ 32] 16.0-17.0 sec   467 KBytes  3.82 Mbits/sec
[ 32]  0.0-17.2 sec  10.8 MBytes  5.23 Mbits/sec
```

"Node: h2"

```
root@mininet-vm:~# iperf -c 10.0.0.1 -p 5555 -i 1 -t15
------------------------------------------------------------
Client connecting to 10.0.0.1, TCP port 5555
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[ 31] local 10.0.0.2 port 35536 connected with 10.0.0.1 port 5555
[ ID] Interval       Transfer     Bandwidth
[ 31]  0.0- 1.0 sec  1.12 MBytes  9.44 Mbits/sec
[ 31]  1.0- 2.0 sec   768 KBytes  6.29 Mbits/sec
[ 31]  2.0- 3.0 sec   768 KBytes  6.29 Mbits/sec
[ 31]  3.0- 4.0 sec  1.00 MBytes  8.39 Mbits/sec
[ 31]  4.0- 5.0 sec   896 KBytes  7.34 Mbits/sec
[ 31]  5.0- 6.0 sec  1.00 MBytes  8.39 Mbits/sec
[ 31]  6.0- 7.0 sec   896 KBytes  7.34 Mbits/sec
[ 31]  7.0- 8.0 sec  1.00 MBytes  8.39 Mbits/sec
[ 31]  8.0- 9.0 sec   896 KBytes  7.34 Mbits/sec
[ 31]  9.0-10.0 sec  1.00 MBytes  8.39 Mbits/sec
[ 31] 10.0-11.0 sec   512 KBytes  4.19 Mbits/sec
[ 31] 11.0-12.0 sec   128 KBytes  1.05 Mbits/sec
[ 31] 12.0-13.0 sec   256 KBytes  2.10 Mbits/sec
[ 31] 13.0-14.0 sec   128 KBytes  1.05 Mbits/sec
[ 31] 14.0-15.0 sec   384 KBytes  3.15 Mbits/sec
[ 31] 15.0-16.0 sec  0.00 Bytes  0.00 bits/sec
[ 31]  0.0-16.3 sec  10.8 MBytes  5.55 Mbits/sec
root@mininet-vm:~#
```

Simulação Servidor/Cliente TCP: bw = 15 Mbps

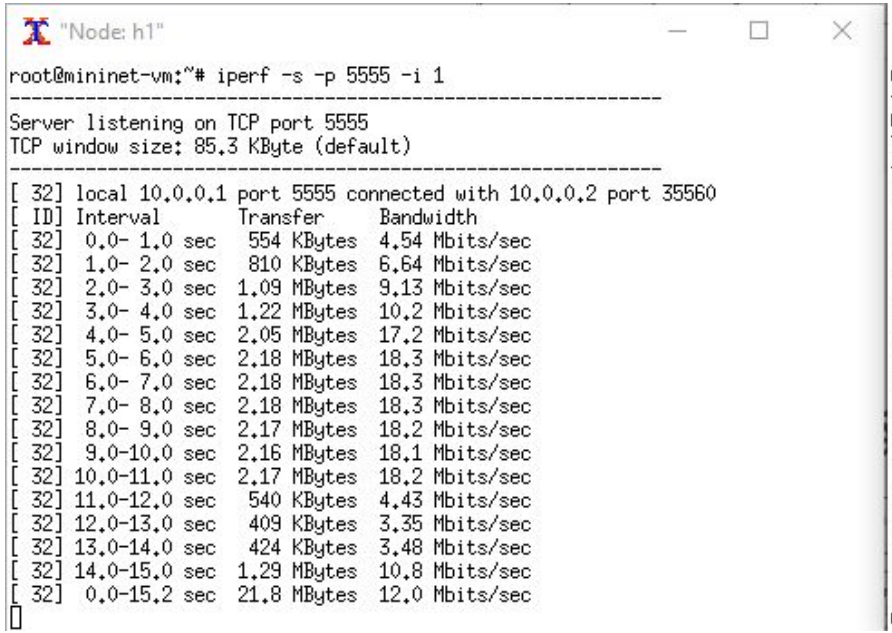
"Node: h1"

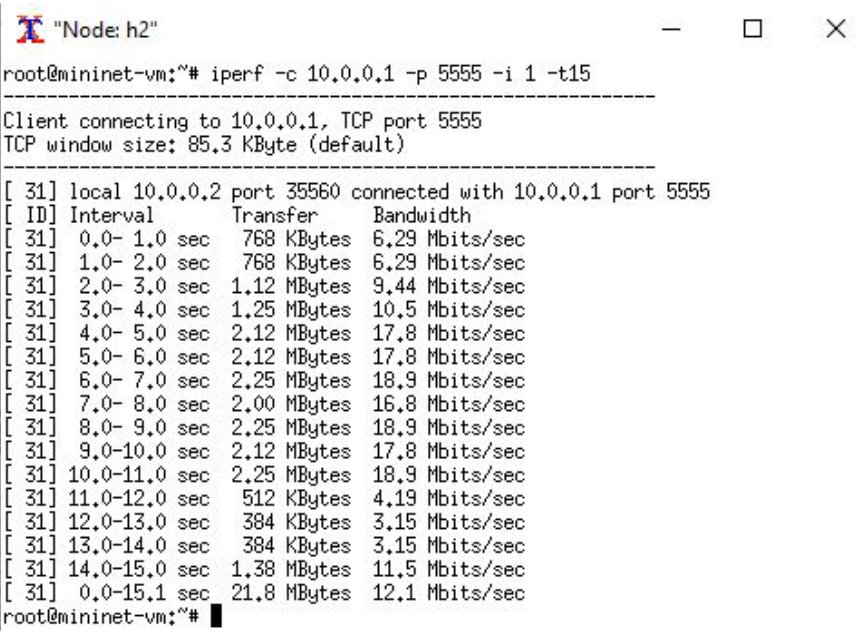
```
root@mininet-vm:~# iperf -s -p 5555 -i 1
------------------------------------------------------------
Server listening on TCP port 5555
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[ 32] local 10.0.0.1 port 5555 connected with 10.0.0.2 port 35496
[ ID] Interval       Transfer     Bandwidth
[ 32]  0.0- 1.0 sec  1.68 MBytes  14.1 Mbits/sec
[ 32]  1.0- 2.0 sec  1.66 MBytes  13.9 Mbits/sec
[ 32]  2.0- 3.0 sec  1.67 MBytes  14.0 Mbits/sec
[ 32]  3.0- 4.0 sec  1.66 MBytes  14.0 Mbits/sec
[ 32]  4.0- 5.0 sec  1.67 MBytes  14.0 Mbits/sec
[ 32]  5.0- 6.0 sec  1.69 MBytes  14.2 Mbits/sec
[ 32]  6.0- 7.0 sec  1.67 MBytes  14.0 Mbits/sec
[ 32]  7.0- 8.0 sec  1.66 MBytes  13.9 Mbits/sec
[ 32]  8.0- 9.0 sec  1.56 MBytes  13.1 Mbits/sec
[ 32]  9.0-10.0 sec   699 KBytes  5.72 Mbits/sec
[ 32] 10.0-11.0 sec   882 KBytes  7.23 Mbits/sec
[ 32] 11.0-12.0 sec  1.00 MBytes  8.42 Mbits/sec
[ 32] 12.0-13.0 sec   908 KBytes  7.44 Mbits/sec
[ 32] 13.0-14.0 sec  1.58 MBytes  13.2 Mbits/sec
[ 32] 14.0-15.0 sec  1.67 MBytes  14.0 Mbits/sec
[ 32]  0.0-15.8 sec  21.9 MBytes  11.6 Mbits/sec
```

"Node: h2"

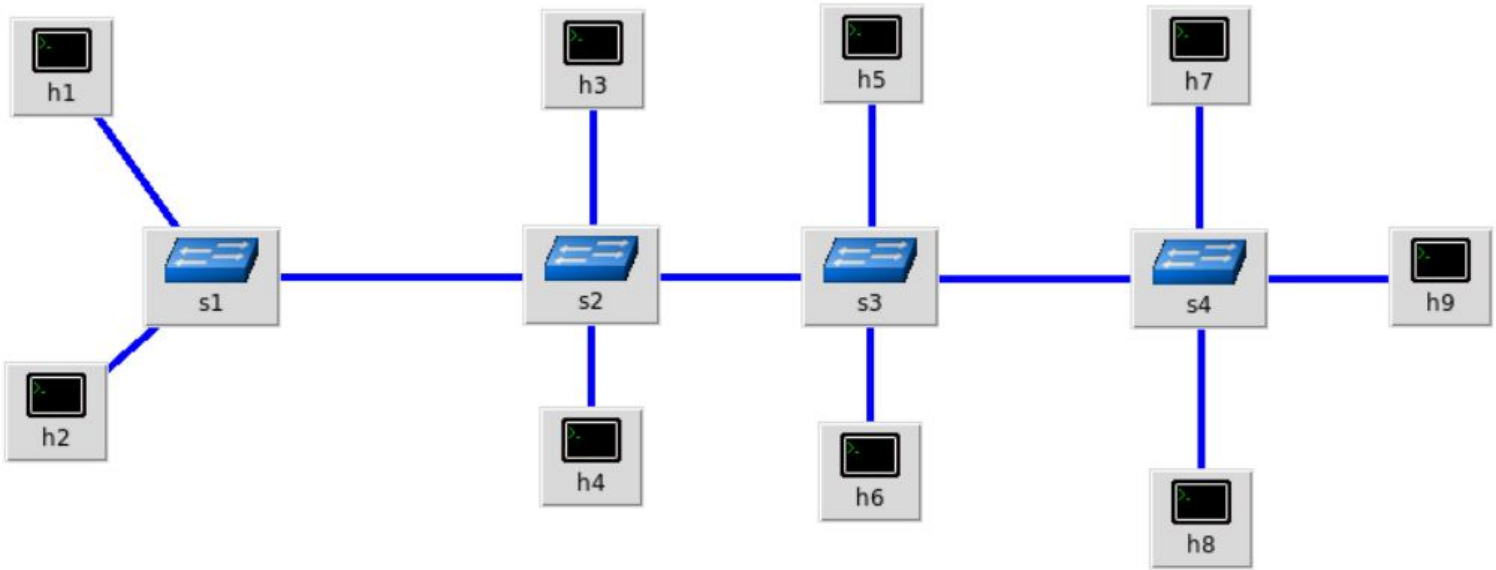
```
root@mininet-vm:~# iperf -c 10.0.0.1 -p 5555 -i 1 -t15
------------------------------------------------------------
Client connecting to 10.0.0.1, TCP port 5555
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
[ 31] local 10.0.0.2 port 35496 connected with 10.0.0.1 port 5555
[ ID] Interval       Transfer     Bandwidth
[ 31]  0.0- 1.0 sec  1.88 MBytes  15.7 Mbits/sec
[ 31]  1.0- 2.0 sec  1.62 MBytes  13.6 Mbits/sec
[ 31]  2.0- 3.0 sec  1.62 MBytes  13.6 Mbits/sec
[ 31]  3.0- 4.0 sec  1.75 MBytes  14.7 Mbits/sec
[ 31]  4.0- 5.0 sec  1.62 MBytes  13.6 Mbits/sec
[ 31]  5.0- 6.0 sec  1.75 MBytes  14.7 Mbits/sec
[ 31]  6.0- 7.0 sec  1.62 MBytes  13.6 Mbits/sec
[ 31]  7.0- 8.0 sec  1.75 MBytes  14.7 Mbits/sec
[ 31]  8.0- 9.0 sec  1.50 MBytes  12.6 Mbits/sec
[ 31]  9.0-10.0 sec   640 KBytes  5.24 Mbits/sec
[ 31] 10.0-11.0 sec   896 KBytes  7.34 Mbits/sec
[ 31] 11.0-12.0 sec  1.00 MBytes  8.39 Mbits/sec
[ 31] 12.0-13.0 sec   896 KBytes  7.34 Mbits/sec
[ 31] 13.0-14.0 sec  1.62 MBytes  13.6 Mbits/sec
[ 31] 14.0-15.0 sec  1.62 MBytes  13.6 Mbits/sec
[ 31]  0.0-15.1 sec  21.9 MBytes  12.2 Mbits/sec
root@mininet-vm:~#
```

Simulação Servidor/Cliente TCP: bw = 20 Mbps





Trabalho Parte 2 - Topologia customizada



Trabalho Parte 2 - Topologia customizada

- Com uso de linha de comando padrão do Mininet, crie a topologia customizada considerando o endereço MAC padronizado e controlador manual.
- Inspecione informações das interfaces, endereços MAC, IP e portas através de linhas de comando.
- Crie um desenho ilustrativo da topologia com todas as informações obtidas no item anterior.
- Faça testes de ping considerando os switches normais.
- Apague as regras anteriores e crie regras baseadas em endereços MAC para alguns nós. (Deve-se comunicar hosts dos diferentes switches).
- Faça testes de ping para demonstrar que as regras foram bem implementadas.

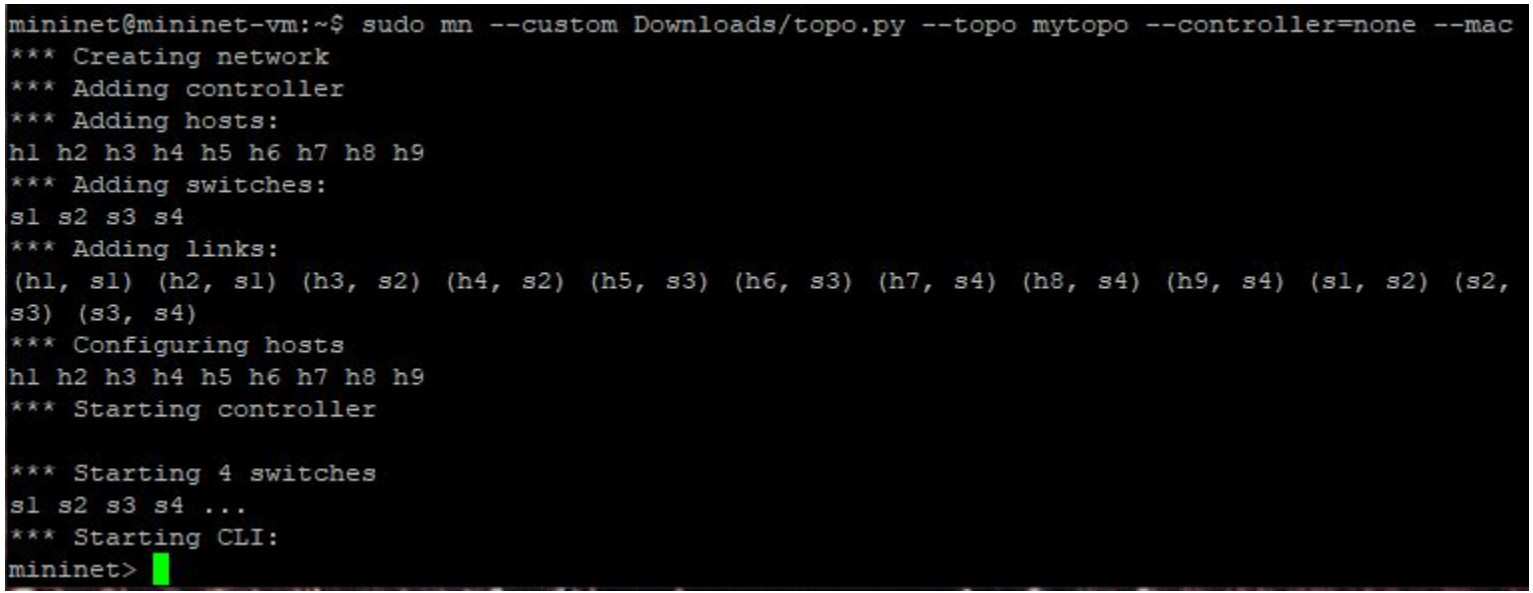
Criação da Topologia em Python

```python
from mininet.topo import Topo

class MyTopo(Topo):
    """
    MyTopo cria uma topologia de rede customizada, de acordo com a segunda parte do trabalho final de Mininet.
    """

    def __init__(self):
        # Inicializando a topologia
        Topo.__init__(self)

        # Adicionando os Hosts da topologia
        h1 = self.addHost('h1')
        h2 = self.addHost('h2')
        h3 = self.addHost('h3')
        h4 = self.addHost('h4')
        h5 = self.addHost('h5')
        h6 = self.addHost('h6')
        h7 = self.addHost('h7')
        h8 = self.addHost('h8')
        h9 = self.addHost('h9')

        # Adicionando os Switches da topologia
        s1 = self.addSwitch('s1')
        s2 = self.addSwitch('s2')
        s3 = self.addSwitch('s3')
        s4 = self.addSwitch('s4')
```

Criação da Topologia em Python

```
        # Adicionando os links entre as máquinas
        # H1, H2 -> S1
        self.addLink(h1, s1)
        self.addLink(h2, s1)

        # H3, H4 -> S2
        self.addLink(h3, s2)
        self.addLink(h4, s2)

        # H5, H6 -> S3
        self.addLink(h5, s3)
        self.addLink(h6, s3)

        # H7, H8, H9 -> S4
        self.addLink(h7, s4)
        self.addLink(h8, s4)
        self.addLink(h9, s4)

        # Conexão entre os switches
        self.addLink(s1, s2)
        self.addLink(s2, s3)
        self.addLink(s3, s4)

topos = {'mytopo': (lambda: MyTopo())}
```

Criação da Topologia no Mininet



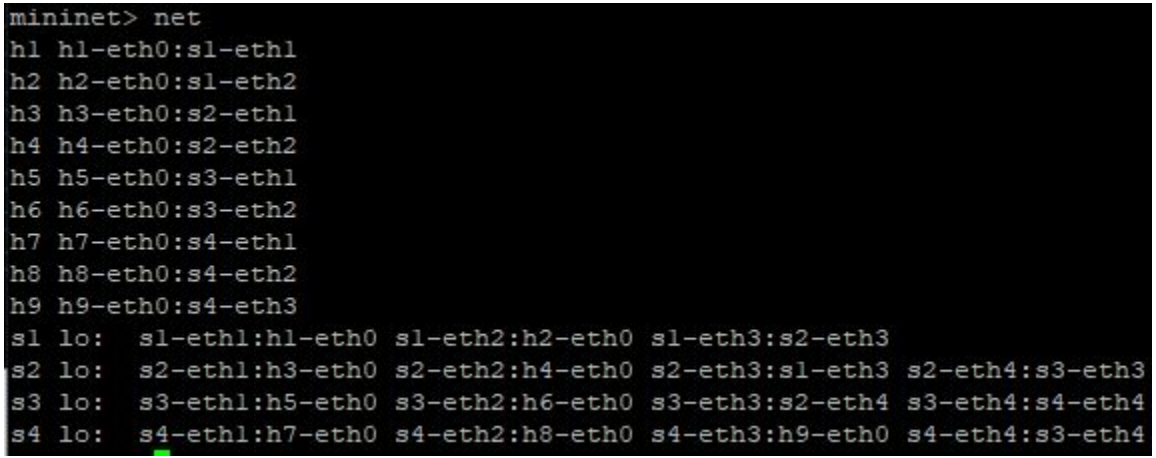
Nós da topologia

```
mininet> nodes
available nodes are:
h1 h2 h3 h4 h5 h6 h7 h8 h9 s1 s2 s3 s4
```

Informações das interfaces

```
mininet> dump
<Host h1: h1-eth0:10.0.0.1 pid=23235>
<Host h2: h2-eth0:10.0.0.2 pid=23238>
<Host h3: h3-eth0:10.0.0.3 pid=23241>
<Host h4: h4-eth0:10.0.0.4 pid=23244>
<Host h5: h5-eth0:10.0.0.5 pid=23247>
<Host h6: h6-eth0:10.0.0.6 pid=23250>
<Host h7: h7-eth0:10.0.0.7 pid=23253>
<Host h8: h8-eth0:10.0.0.8 pid=23256>
<Host h9: h9-eth0:10.0.0.9 pid=23259>
<OVSSwitch s1: lo:127.0.0.1,s1-eth1:None,s1-eth2:None,s1-eth3:None pid=23265>
<OVSSwitch s2: lo:127.0.0.1,s2-eth1:None,s2-eth2:None,s2-eth3:None,s2-eth4:None pid=23268>
<OVSSwitch s3: lo:127.0.0.1,s3-eth1:None,s3-eth2:None,s3-eth3:None,s3-eth4:None pid=23271>
<OVSSwitch s4: lo:127.0.0.1,s4-eth1:None,s4-eth2:None,s4-eth3:None,s4-eth4:None pid=23274>
```

Conexão entre as interfaces



Interfaces, endereços de IP e MAC

```
mininet> h1 ifconfig -a
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: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:1
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)
```

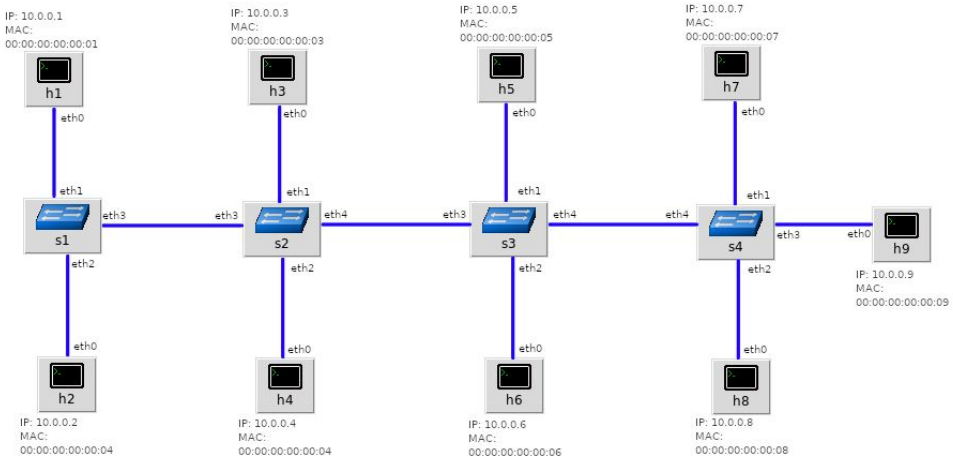
Host h1 possui endereços IP e MAC terminados em 1

Interfaces, endereços de IP e MAC

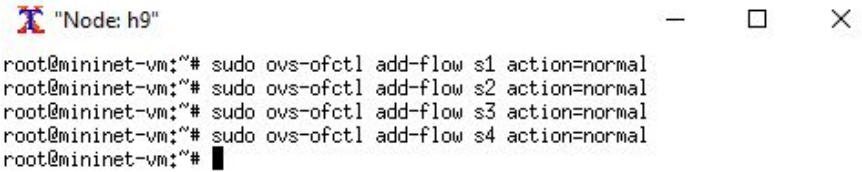
```
mininet> h9 ifconfig -a
h9-eth0   Link encap:Ethernet  HWaddr 00:00:00:00:00:09
          inet addr:10.0.0.9  Bcast:10.255.255.255  Mask:255.0.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 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:1
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)
```

Host h9 possui endereços IP e MAC terminados em 9

Ilustração da topologia



Configuração dos switches para operação normal



Teste (operação normal do switch): ping geral

Teste (operação normal do switch): ping h1 para h9

```
mininet> h1 ping h9
PING 10.0.0.9 (10.0.0.9) 56(84) bytes of data.
64 bytes from 10.0.0.9: icmp_seq=1 ttl=64 time=1.10 ms
64 bytes from 10.0.0.9: icmp_seq=2 ttl=64 time=0.090 ms
64 bytes from 10.0.0.9: icmp_seq=3 ttl=64 time=0.053 ms
64 bytes from 10.0.0.9: icmp_seq=4 ttl=64 time=0.049 ms
64 bytes from 10.0.0.9: icmp_seq=5 ttl=64 time=0.039 ms
^C
--- 10.0.0.9 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4009ms
rtt min/avg/max/mdev = 0.039/0.267/1.108/0.420 ms
```

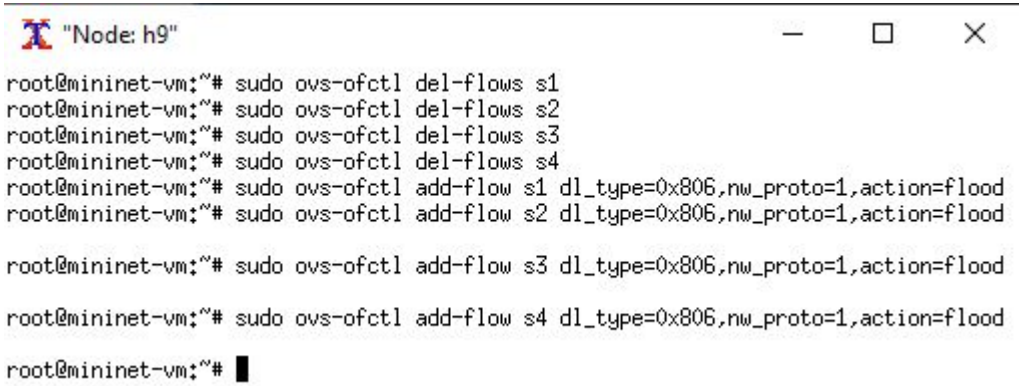
Teste (operação normal do switch): ping h2 para h8

```
mininet> h2 ping h8
PING 10.0.0.8 (10.0.0.8) 56(84) bytes of data.
64 bytes from 10.0.0.8: icmp_seq=1 ttl=64 time=4.56 ms
64 bytes from 10.0.0.8: icmp_seq=2 ttl=64 time=0.047 ms
64 bytes from 10.0.0.8: icmp_seq=3 ttl=64 time=0.043 ms
64 bytes from 10.0.0.8: icmp_seq=4 ttl=64 time=0.037 ms
64 bytes from 10.0.0.8: icmp_seq=5 ttl=64 time=0.045 ms
^C
--- 10.0.0.8 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4015ms
rtt min/avg/max/mdev = 0.037/0.947/4.564/1.808 ms
```

Regras baseadas em endereços MAC

- Configurar os switches com o OVS para permitir a comunicação entre hosts de forma seletiva, a partir do seu endereço MAC.
- De forma a cobrir hosts de todos os switches, mas evidenciar a implementação das regras, os nós que conseguem comunicar entre si são:
  - h1 -> h2, h3, h5, h7
  - h2 -> h1
  - h3 -> h1
  - h5 -> h1
  - h7 -> h1

Apagando regras anteriores e criando novas regras baseadas em endereços MAC



Criando novas regras

"Node: h9"

```
root@mininet-vm:~# 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
root@mininet-vm:~# 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
root@mininet-vm:~#
root@mininet-vm:~# 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
root@mininet-vm:~# 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
root@mininet-vm:~# 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
root@mininet-vm:~# sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01,actions=output:3
root@mininet-vm:~#
root@mininet-vm:~# sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05,actions=output:3
root@mininet-vm:~# sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05,actions=output:4
root@mininet-vm:~# sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05,actions=output:1
root@mininet-vm:~# sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01,actions=output:3
root@mininet-vm:~# sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01,actions=output:3
root@mininet-vm:~# sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01,actions=output:1
root@mininet-vm:~#
root@mininet-vm:~# sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:07,actions=output:3
root@mininet-vm:~# sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:07,actions=output:4
root@mininet-vm:~# sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:07,actions=output:4
root@mininet-vm:~# sudo ovs-ofctl add-flow s4 dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:07,actions=output:1
root@mininet-vm:~# sudo ovs-ofctl add-flow s4 dl_src=00:00:00:00:00:07,dl_dst=00:00:00:00:00:01,actions=output:4
root@mininet-vm:~# sudo ovs-ofctl add-flow s3 dl_src=00:00:00:00:00:07,dl_dst=00:00:00:00:00:01,actions=output:3
root@mininet-vm:~# sudo ovs-ofctl add-flow s2 dl_src=00:00:00:00:00:07,dl_dst=00:00:00:00:00:01,actions=output:3
root@mininet-vm:~# sudo ovs-ofctl add-flow s1 dl_src=00:00:00:00:00:07,dl_dst=00:00:00:00:00:01,actions=output:1
root@mininet-vm:~#
```

Teste (operação por endereço MAC): ping geral