

Лабораторная работа №6
Моделирование сетей передачи данных

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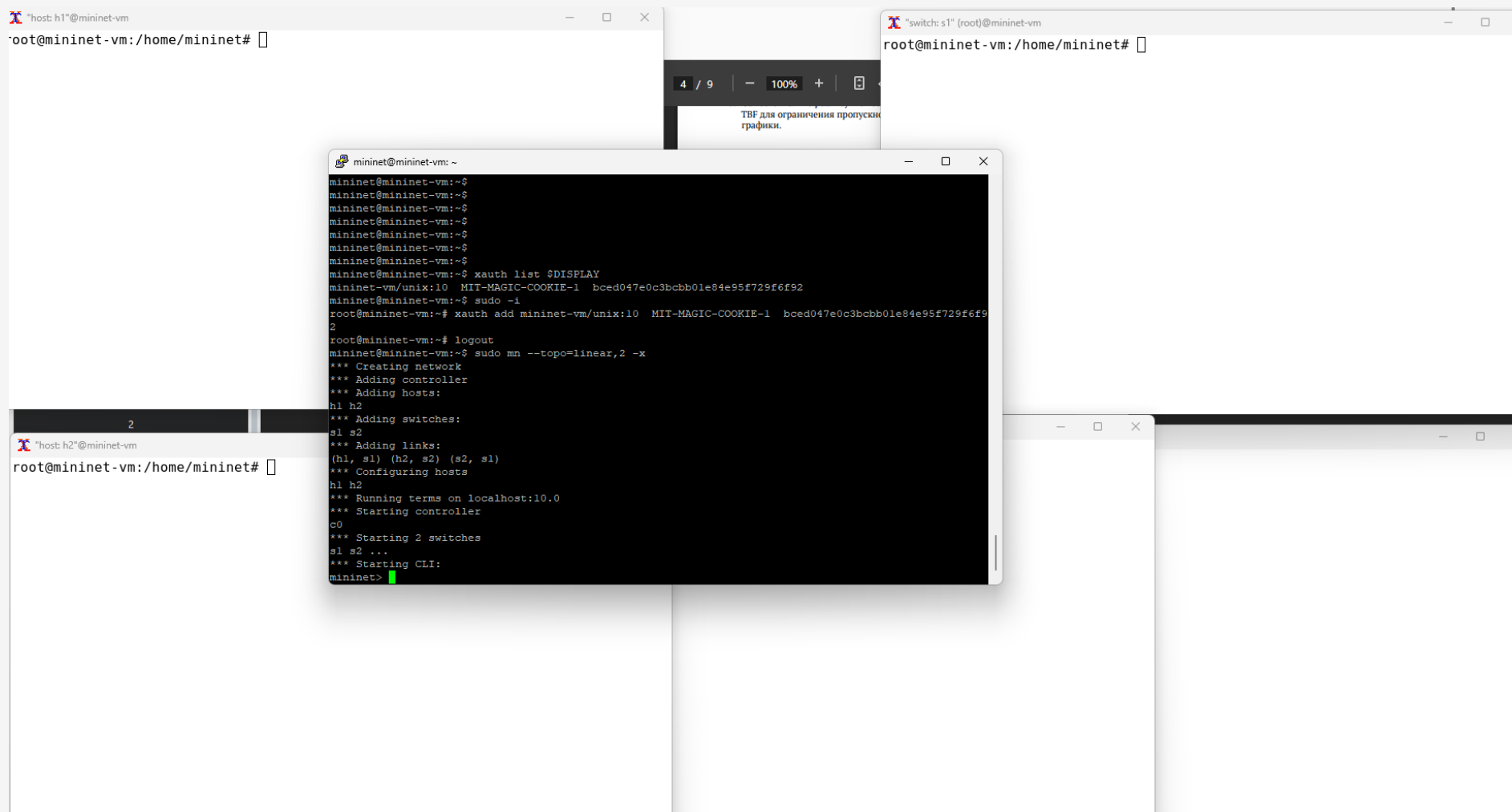
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Запуск лабораторной топологии

```
mininet@mininet-vm:~$ xauth list $DISPLAY
mininet-vm/unix:10  MIT-MAGIC-COOKIE-1  bced047e0c3bcbb01e84e95f729f6f92
mininet@mininet-vm:~$ sudo -i
root@mininet-vm:~# xauth add mininet-vm/unix:10  MIT-MAGIC-COOKIE-1  bced047e0c3bcbb01e84e95f729f6f9
2
root@mininet-vm:~# logout
mininet@mininet-vm:~$
```

Рис. 1: Исправление прав запуска X-соединения в виртуальной машине mininet

Запуск лабораторной топологии



The image shows a Mininet virtual network environment with three terminal windows. The central window, titled 'mininet@mininet-vm: ~', displays the following commands and output:

```
mininet@mininet-vm:~$  
mininet@mininet-vm:~$  
mininet@mininet-vm:~$  
mininet@mininet-vm:~$  
mininet@mininet-vm:~$  
mininet@mininet-vm:~$  
mininet@mininet-vm:~$  
mininet@mininet-vm:~$ xauth list $DISPLAY  
mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 bced047e0c3bcb01e84e95f729f6f92  
mininet@mininet-vm:~$ sudo -i  
root@mininet-vm:~# xauth add mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 bced047e0c3bcb01e84e95f729f6f92  
root@mininet-vm:~# logout  
mininet@mininet-vm:~$ sudo mn --topo=linear,2 -x  
*** Creating network  
*** Adding controller  
*** Adding hosts:  
h1 h2  
*** Adding switches:  
s1 s2  
*** Adding links:  
(h1, s1) (h2, s2) (s2, s1)  
*** Configuring hosts  
h1 h2  
*** Running terms on localhost:10.0  
*** Starting controller  
c0  
*** Starting 2 switches  
s1 s2 ...  
*** Starting CLI:  
mininet>
```

The top-left terminal window, titled '"host: h1" @mininet-vm', shows the prompt 'root@mininet-vm:/home/mininet#'. The top-right terminal window, titled '"switch: s1" (root) @mininet-vm', also shows the prompt 'root@mininet-vm:/home/mininet#'. The bottom-left terminal window, titled '"host: h2" @mininet-vm', shows the prompt 'root@mininet-vm:/home/mininet#'. A small window in the background shows a PDF document with the text 'ТБФ для ограничения пропускной графики.'

Рис. 2: Создание топологии с двумя хостами и двумя коммутаторами

Запуск лабораторной топологии

The image displays a network configuration lab setup. It features three terminal windows showing the configuration of network interfaces and a central document with instructions.

Terminal 1 (host: h1):

```
root@mininet-vm:/home/mininet# ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.1 netmask 255.0.0.0 broadcast 10.255.255.255
    ether 8e:52:6f:6d:25:0c txqueuelen 1000 (Ethernet)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    loop txqueuelen 1000 (Local Loopback)
    RX packets 1226 bytes 260900 (260.9 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1226 bytes 260900 (260.9 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet#
```

Terminal 2 (host: h2):

```
root@mininet-vm:/home/mininet# ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.2 netmask 255.0.0.0 broadcast 10.255.255.255
    ether 8e:76:d8:e4:10:73 txqueuelen 1000 (Ethernet)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    loop txqueuelen 1000 (Local Loopback)
    RX packets 1206 bytes 258872 (258.8 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1206 bytes 258872 (258.8 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet#
```

Terminal 3 (switch: s1):

```
root@mininet-vm:/home/mininet# ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.56.103 netmask 255.255.255.0 broadcast 192.168.56.255
    ether 08:00:27:d6:ca:6f txqueuelen 1000 (Ethernet)
    RX packets 65009 bytes 8505568 (8.5 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 77062 bytes 57129711 (57.1 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.2.15 netmask 255.255.255.0 broadcast 10.0.2.255
    ether 08:00:27:d0:e5:b3 txqueuelen 1000 (Ethernet)
    RX packets 142652 bytes 207351468 (207.3 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 9587 bytes 714417 (714.4 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    loop txqueuelen 1000 (Local Loopback)
    RX packets 78877 bytes 56115385 (56.1 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 78877 bytes 56115385 (56.1 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Terminal 4 (switch: s2):

```
root@mininet-vm:/home/mininet# ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.56.103 netmask 255.255.255.0 broadcast 192.168.56.255
    ether 08:00:27:d6:ca:6f txqueuelen 1000 (Ethernet)
    RX packets 65090 bytes 8518882 (8.5 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 77146 bytes 57164209 (57.1 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.2.15 netmask 255.255.255.0 broadcast 10.0.2.255
    ether 08:00:27:d0:e5:b3 txqueuelen 1000 (Ethernet)
    RX packets 142655 bytes 207351712 (207.3 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 9590 bytes 714657 (714.6 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    loop txqueuelen 1000 (Local Loopback)
    RX packets 79065 bytes 56157973 (56.1 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 79065 bytes 56157973 (56.1 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Central Document:

6.4.1. Запуск лабораторной топологии

1. Запустите виртуальную среду с помощью команды `sudo docker-compose up`.
2. Из основной ОС подключитесь к виртуальной машине `mininet` с помощью команды `ssh -Y mininet@192.168.56.103`.
3. В виртуальной машине `mininet` выполните команду `mininet> add` для добавления хостов. Скопируйте значения IP-адресов хостов в файл `hosts` для последующего использования.
4. Задайте топологию сети, состоящую из хостов `h1`, `h2` и коммутатора `s1` с назначением по умолчанию параметров интерфейсов.
5. На хостах `h1`, `h2` и на коммутаторе `s1` выполните команду `ifconfig` для отображения информации об интерфейсах и их IP-адресах. В дальнейшем эта информация будет использоваться для проверки работоспособности сети.
6. Проверьте подключение между хостами с помощью команды `ping`.
7. В терминале хоста `h2` запустите команду `iperf3 -s` для запуска сервера тестирования.
8. В терминале хоста `h1` запустите команду `iperf3 -c 10.0.0.2` для запуска клиента тестирования.
9. После завершения работы IP-тестирования нажмите `Ctrl-C`. В отчете зафиксированы результаты тестирования.

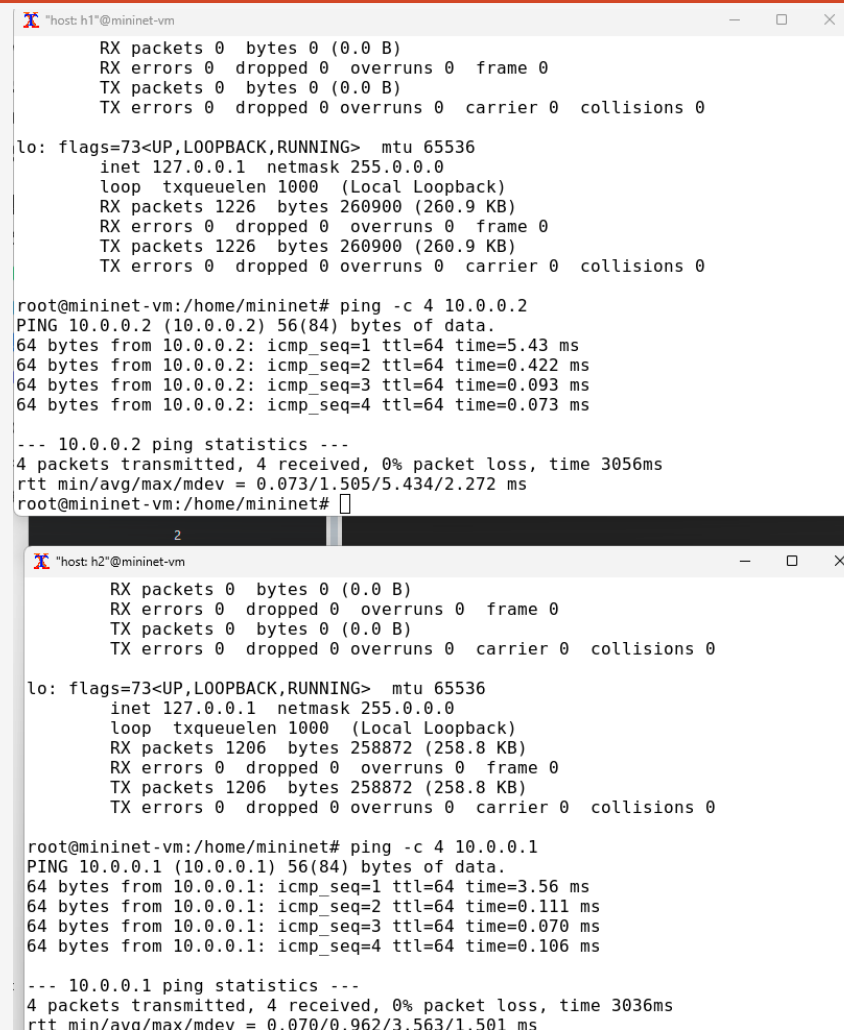
После выполнения этих действий запустятся терминалы двух хостов, двух коммутаторов и контроллера. В терминалах хостов и коммутаторов будут отображены IP-адреса. В дальнейшем эта информация будет использоваться для проверки работоспособности сети.

Значение для MIT-MAGIC-COOKIE-1

Корольков А. В., Кузнецов Д. С. Моделирование

Рис. 3: Отображение информации сетевых интерфейсов и IP-адресов

Запуск лабораторной топологии



```
"host: h1"@mininet-vm
RX packets 0 bytes 0 (0.0 B)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 0 bytes 0 (0.0 B)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
inet 127.0.0.1 netmask 255.0.0.0
loop txqueuelen 1000 (Local Loopback)
RX packets 1226 bytes 260900 (260.9 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 1226 bytes 260900 (260.9 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet# ping -c 4 10.0.0.2
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=5.43 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.422 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.093 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.073 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3056ms
rtt min/avg/max/mdev = 0.073/1.505/5.434/2.272 ms
root@mininet-vm:/home/mininet#

2

"host: h2"@mininet-vm
RX packets 0 bytes 0 (0.0 B)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 0 bytes 0 (0.0 B)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

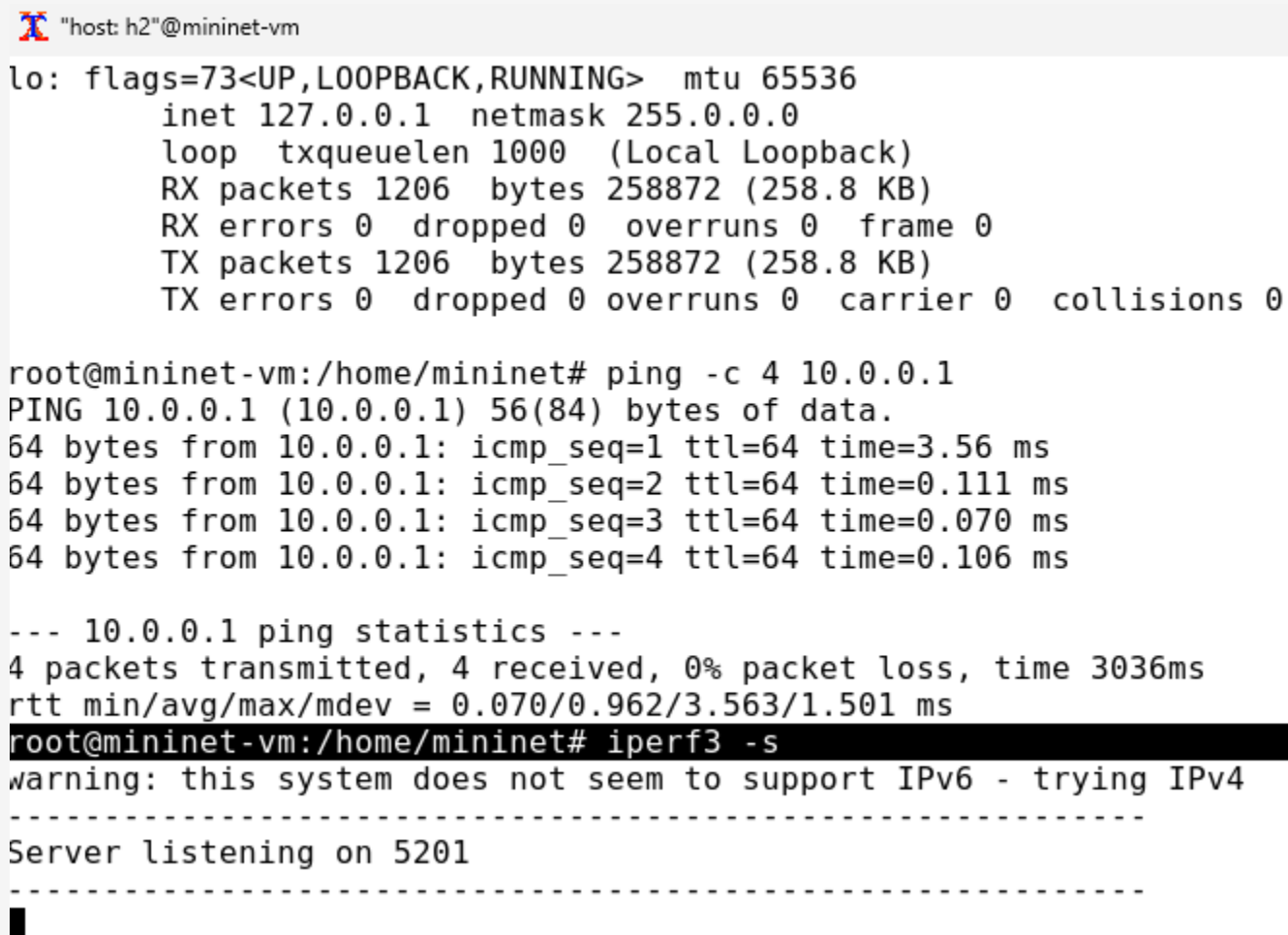
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
inet 127.0.0.1 netmask 255.0.0.0
loop txqueuelen 1000 (Local Loopback)
RX packets 1206 bytes 258872 (258.8 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 1206 bytes 258872 (258.8 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet# ping -c 4 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=3.56 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.111 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.070 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.106 ms

--- 10.0.0.1 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3036ms
rtt min/ava/max/mdev = 0.070/0.962/3.563/1.501 ms
```

Рис. 4: Проверка подключения между хостами h1 и h2

Запуск лабораторной топологии



A terminal window titled '"host: h2"@mininet-vm' displays the following output:

```
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    loop txqueuelen 1000 (Local Loopback)
    RX packets 1206 bytes 258872 (258.8 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1206 bytes 258872 (258.8 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet# ping -c 4 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=3.56 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.111 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.070 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.106 ms

--- 10.0.0.1 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3036ms
rtt min/avg/max/mdev = 0.070/0.962/3.563/1.501 ms
root@mininet-vm:/home/mininet# iperf3 -s
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
```

Рис. 5: Запуск iPerf3 в режиме сервера на хосте h2

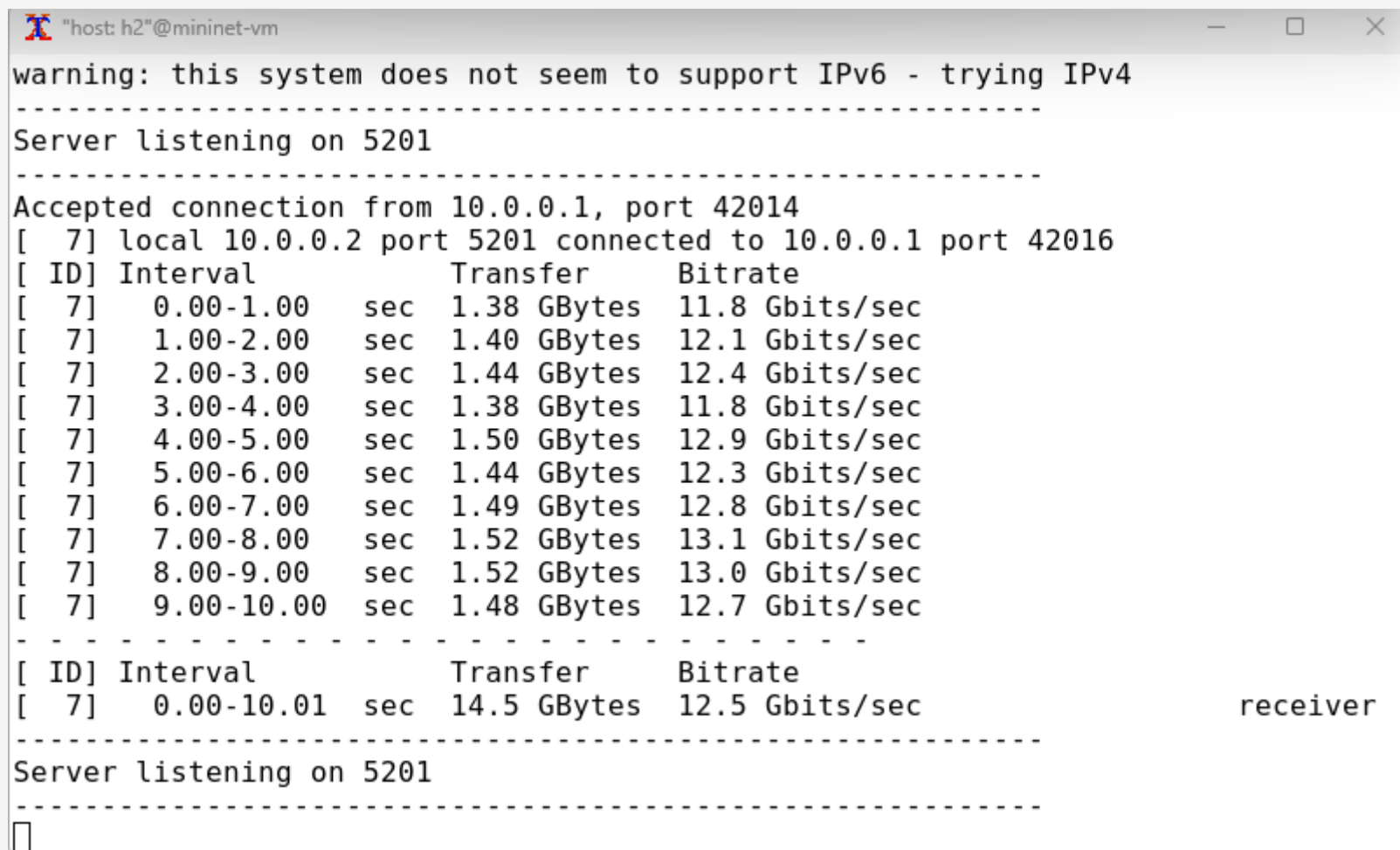
Запуск лабораторной топологии

```
"host: h1"@mininet-vm
--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3056ms
rtt min/avg/max/mdev = 0.073/1.505/5.434/2.272 ms
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 42016 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr   Cwnd
[ 7]  0.00-1.01    sec   1.39 GBytes  11.8 Gbits/sec    0   8.03 MBytes
[ 7]  1.01-2.01    sec   1.39 GBytes  12.0 Gbits/sec    0   8.03 MBytes
[ 7]  2.01-3.00    sec   1.44 GBytes  12.4 Gbits/sec    0   8.03 MBytes
[ 7]  3.00-4.00    sec   1.38 GBytes  11.9 Gbits/sec    0   8.03 MBytes
[ 7]  4.00-5.00    sec   1.49 GBytes  12.8 Gbits/sec    0   8.03 MBytes
[ 7]  5.00-6.01    sec   1.44 GBytes  12.3 Gbits/sec    0   8.03 MBytes
[ 7]  6.01-7.00    sec   1.49 GBytes  12.8 Gbits/sec    0   8.03 MBytes
[ 7]  7.00-8.00    sec   1.52 GBytes  13.1 Gbits/sec    0   8.03 MBytes
[ 7]  8.00-9.01    sec   1.52 GBytes  13.0 Gbits/sec    0   8.03 MBytes
[ 7]  9.01-10.00   sec   1.47 GBytes  12.7 Gbits/sec    0   8.03 MBytes
- - - - -
[ ID] Interval           Transfer     Bitrate      Retr
[ 7]  0.00-10.00   sec   14.5 GBytes  12.5 Gbits/sec    0
[ 7]  0.00-10.01   sec   14.5 GBytes  12.5 Gbits/sec    0
                                     sender
                                     receiver

iperf Done.
root@mininet-vm:/home/mininet#
```

Рис. 6: Запуск iPerf3 в режиме клиента на хосте h1

Запуск лабораторной топологии



```
"host: h2@mininet-vm"
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 42014
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 42016
[ ID] Interval            Transfer      Bitrate
[ 7]  0.00-1.00    sec   1.38 GBytes  11.8 Gbits/sec
[ 7]  1.00-2.00    sec   1.40 GBytes  12.1 Gbits/sec
[ 7]  2.00-3.00    sec   1.44 GBytes  12.4 Gbits/sec
[ 7]  3.00-4.00    sec   1.38 GBytes  11.8 Gbits/sec
[ 7]  4.00-5.00    sec   1.50 GBytes  12.9 Gbits/sec
[ 7]  5.00-6.00    sec   1.44 GBytes  12.3 Gbits/sec
[ 7]  6.00-7.00    sec   1.49 GBytes  12.8 Gbits/sec
[ 7]  7.00-8.00    sec   1.52 GBytes  13.1 Gbits/sec
[ 7]  8.00-9.00    sec   1.52 GBytes  13.0 Gbits/sec
[ 7]  9.00-10.00   sec   1.48 GBytes  12.7 Gbits/sec
-----
[ ID] Interval            Transfer      Bitrate
[ 7]  0.00-10.01   sec  14.5 GBytes  12.5 Gbits/sec
-----
Server listening on 5201
-----
□
```

receiver

Рис. 7: Остановка iPerf3

Интерактивные эксперименты

```
"host: h1"@mininet-vm
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 42016 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr   Cwnd
[ 7]  0.00-1.01    sec   1.39 GBytes  11.8 Gbits/sec    0   8.03 MBytes
[ 7]  1.01-2.01    sec   1.39 GBytes  12.0 Gbits/sec    0   8.03 MBytes
[ 7]  2.01-3.00    sec   1.44 GBytes  12.4 Gbits/sec    0   8.03 MBytes
[ 7]  3.00-4.00    sec   1.38 GBytes  11.9 Gbits/sec    0   8.03 MBytes
[ 7]  4.00-5.00    sec   1.49 GBytes  12.8 Gbits/sec    0   8.03 MBytes
[ 7]  5.00-6.01    sec   1.44 GBytes  12.3 Gbits/sec    0   8.03 MBytes
[ 7]  6.01-7.00    sec   1.49 GBytes  12.8 Gbits/sec    0   8.03 MBytes
[ 7]  7.00-8.00    sec   1.52 GBytes  13.1 Gbits/sec    0   8.03 MBytes
[ 7]  8.00-9.01    sec   1.52 GBytes  13.0 Gbits/sec    0   8.03 MBytes
[ 7]  9.01-10.00   sec   1.47 GBytes  12.7 Gbits/sec    0   8.03 MBytes
- - - - -
[ ID] Interval           Transfer     Bitrate      Retr
[ 7]  0.00-10.00   sec   14.5 GBytes  12.5 Gbits/sec    0
[ 7]  0.00-10.01   sec   14.5 GBytes  12.5 Gbits/sec    0
                                     sender
                                     receiver

iperf Done.
root@mininet-vm:/home/mininet# ^C
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root tbf rate 10gb
it burst 5000000 limit 15000000
root@mininet-vm:/home/mininet#
```

Рис. 8: Изменение пропускной способности хоста h1

Интерактивные эксперименты

```

[  7]    0.00-1.01    sec    1.39 GBytes    11.8 Gbits/sec    0    8.03 MBytes
[  7]    1.01-2.01    sec    1.39 GBytes    12.0 Gbits/sec    0    8.03 MBytes
[  7]    2.01-3.00    sec    1.44 GBytes    12.4 Gbits/sec    0    8.03 MBytes
[  7]    3.00-4.00    sec    1.38 GBytes    11.9 Gbits/sec    0    8.03 MBytes
[  7]    4.00-5.00    sec    1.49 GBytes    12.8 Gbits/sec    0    8.03 MBytes
[  7]    5.00-6.01    sec    1.44 GBytes    12.3 Gbits/sec    0    8.03 MBytes
[  7]    6.01-7.00    sec    1.49 GBytes    12.8 Gbits/sec    0    8.03 MBytes
[  7]    7.00-8.00    sec    1.52 GBytes    13.1 Gbits/sec    0    8.03 MBytes
[  7]    8.00-9.01    sec    1.52 GBytes    13.0 Gbits/sec    0    8.03 MBytes
[  7]    9.01-10.00   sec    1.47 GBytes    12.7 Gbits/sec    0    8.03 MBytes
- - - - -
[ ID] Interval          Transfer          Bitrate          Retr
[  7]  0.00-10.00    sec    14.5 GBytes    12.5 Gbits/sec    0
[  7]  0.00-10.01    sec    14.5 GBytes    12.5 Gbits/sec
                                     sender
                                     receiver

iperf Done.
root@mininet-vm:/home/mininet# ^C
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root tbf rate 10gb
it burst 5000000 limit 15000000
root@mininet-vm:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config-'uname -r'
grep: /boot/config-uname -r: No such file or directory
root@mininet-vm:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config-`uname -r`
CONFIG_HZ_250=y
root@mininet-vm:/home/mininet#

```

Рис. 9: Установка значения всплеска при ограничении скорости для фильтра tbf

Интерактивные эксперименты

```
"host: h2"@mininet-vm
[ 7]  2.00-3.00  sec  1.44 GBytes  12.4 Gbits/sec
[ 7]  3.00-4.00  sec  1.38 GBytes  11.8 Gbits/sec
[ 7]  4.00-5.00  sec  1.50 GBytes  12.9 Gbits/sec
[ 7]  5.00-6.00  sec  1.44 GBytes  12.3 Gbits/sec
[ 7]  6.00-7.00  sec  1.49 GBytes  12.8 Gbits/sec
[ 7]  7.00-8.00  sec  1.52 GBytes  13.1 Gbits/sec
[ 7]  8.00-9.00  sec  1.52 GBytes  13.0 Gbits/sec
[ 7]  9.00-10.00 sec  1.48 GBytes  12.7 Gbits/sec
- - - - -
[ ID] Interval          Transfer      Bitrate
[ 7]  0.00-10.01  sec  14.5 GBytes  12.5 Gbits/sec
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config-'uname -r'
grep: /boot/config-uname -r: No such file or directory
root@mininet-vm:/home/mininet# iperf3 -s
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
```

Рис. 10: Запуск iPerf3 в режиме сервера на хосте h2

Интерактивные эксперименты

```
"host: h1"@mininet-vm
grep: /boot/config-uname -r: No such file or directory
root@mininet-vm:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config-`uname -r`
CONFIG_HZ_250=y
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 42020 connected to 10.0.0.2 port 5201
[ ID] Interval            Transfer          Bitrate          Retr  Cwnd
[ 7]  0.00-1.00    sec   1.12 GBytes    9.54 Gbits/sec      0   8.25 MBytes
[ 7]  1.00-2.00    sec   1.11 GBytes    9.57 Gbits/sec      0   8.25 MBytes
[ 7]  2.00-3.00    sec   1.08 GBytes    9.30 Gbits/sec      0   8.25 MBytes
[ 7]  3.00-4.00    sec   1.03 GBytes    8.88 Gbits/sec      0   8.25 MBytes
[ 7]  4.00-5.00    sec   1.05 GBytes    9.01 Gbits/sec      0   8.25 MBytes
[ 7]  5.00-6.00    sec   1.04 GBytes    8.96 Gbits/sec      0   8.25 MBytes
[ 7]  6.00-7.00    sec   1.06 GBytes    9.10 Gbits/sec      0   8.25 MBytes
[ 7]  7.00-8.00    sec   1.08 GBytes    9.31 Gbits/sec      0   8.25 MBytes
[ 7]  8.00-9.00    sec   1.05 GBytes    8.97 Gbits/sec      0   8.25 MBytes
[ 7]  9.00-10.00   sec   1.08 GBytes    9.30 Gbits/sec      0   8.25 MBytes
- - - - -
[ ID] Interval            Transfer          Bitrate          Retr
[ 7]  0.00-10.00   sec   10.7 GBytes    9.19 Gbits/sec      0
[ 7]  0.00-10.02   sec   10.7 GBytes    9.18 Gbits/sec
sender
receiver

iperf Done.
root@mininet-vm:/home/mininet#
```

Рис. 11: Запуск iPerf3 в режиме клиента на хосте h1

Интерактивные эксперименты

```
"host: h2"@mininet-vm
-----
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 42018
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 42020
[ ID] Interval          Transfer      Bitrate
[ 7]  0.00-1.00    sec   1.10 GBytes   9.45 Gbits/sec
[ 7]  1.00-2.00    sec   1.11 GBytes   9.55 Gbits/sec
[ 7]  2.00-3.00    sec   1.09 GBytes   9.36 Gbits/sec
[ 7]  3.00-4.01    sec   1.03 GBytes   8.77 Gbits/sec
[ 7]  4.01-5.00    sec   1.05 GBytes   9.09 Gbits/sec
[ 7]  5.00-6.01    sec   1.04 GBytes   8.90 Gbits/sec
[ 7]  6.01-7.01    sec   1.06 GBytes   9.07 Gbits/sec
[ 7]  7.01-8.00    sec   1.10 GBytes   9.50 Gbits/sec
[ 7]  8.00-9.00    sec   1.05 GBytes   8.99 Gbits/sec
[ 7]  9.00-10.01   sec   1.06 GBytes   9.05 Gbits/sec
[ 7] 10.01-10.02   sec   11.3 MBytes   13.8 Gbits/sec
-----
[ ID] Interval          Transfer      Bitrate
[ 7]  0.00-10.02   sec   10.7 GBytes   9.18 Gbits/sec
-----
Server listening on 5201
-----
█
```

receiver

Рис. 12: Остановка iPerf3

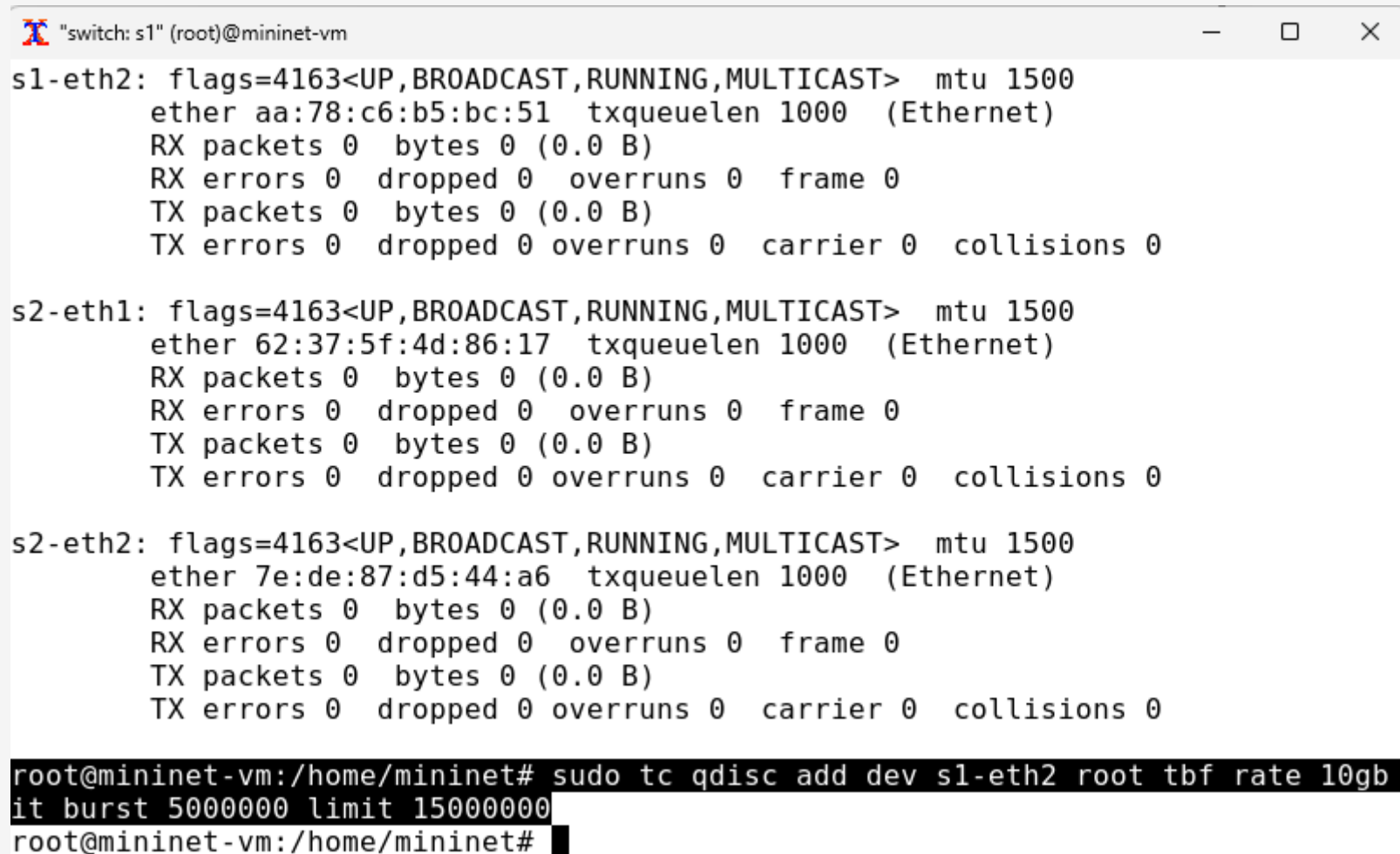
Интерактивные эксперименты

```
"host: h1"@mininet-vm
root@mininet-vm:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config-`uname -r`
CONFIG_HZ_250=y
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 42020 connected to 10.0.0.2 port 5201
[ ID] Interval            Transfer        Bitrate        Retr   Cwnd
[ 7]  0.00-1.00    sec   1.12 GBytes   9.54 Gbits/sec    0   8.25 MBytes
[ 7]  1.00-2.00    sec   1.11 GBytes   9.57 Gbits/sec    0   8.25 MBytes
[ 7]  2.00-3.00    sec   1.08 GBytes   9.30 Gbits/sec    0   8.25 MBytes
[ 7]  3.00-4.00    sec   1.03 GBytes   8.88 Gbits/sec    0   8.25 MBytes
[ 7]  4.00-5.00    sec   1.05 GBytes   9.01 Gbits/sec    0   8.25 MBytes
[ 7]  5.00-6.00    sec   1.04 GBytes   8.96 Gbits/sec    0   8.25 MBytes
[ 7]  6.00-7.00    sec   1.06 GBytes   9.10 Gbits/sec    0   8.25 MBytes
[ 7]  7.00-8.00    sec   1.08 GBytes   9.31 Gbits/sec    0   8.25 MBytes
[ 7]  8.00-9.00    sec   1.05 GBytes   8.97 Gbits/sec    0   8.25 MBytes
[ 7]  9.00-10.00   sec   1.08 GBytes   9.30 Gbits/sec    0   8.25 MBytes
- - - - -
[ ID] Interval            Transfer        Bitrate        Retr
[ 7]  0.00-10.00   sec   10.7 GBytes   9.19 Gbits/sec    0
[ 7]  0.00-10.02   sec   10.7 GBytes   9.18 Gbits/sec    0
sender
receiver

iperf Done.
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root
root@mininet-vm:/home/mininet#
```

Рис. 13: Удаление модифицированной конфигурации на хосте h1

Интерактивные эксперименты



```
"switch: s1" (root)@mininet-vm
s1-eth2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
ether aa:78:c6:b5:bc:51 txqueuelen 1000 (Ethernet)
RX packets 0 bytes 0 (0.0 B)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 0 bytes 0 (0.0 B)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

s2-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
ether 62:37:5f:4d:86:17 txqueuelen 1000 (Ethernet)
RX packets 0 bytes 0 (0.0 B)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 0 bytes 0 (0.0 B)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

s2-eth2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
ether 7e:de:87:d5:44:a6 txqueuelen 1000 (Ethernet)
RX packets 0 bytes 0 (0.0 B)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 0 bytes 0 (0.0 B)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root tbf rate 10gb
it burst 5000000 limit 15000000
root@mininet-vm:/home/mininet#
```

Рис. 14: Применение правила ограничения скорости tbf

Интерактивные эксперименты

```
"host: h2"@mininet-vm
[ 7] 0.00-1.00 sec 1.10 GBytes 9.45 Gbits/sec
[ 7] 1.00-2.00 sec 1.11 GBytes 9.55 Gbits/sec
[ 7] 2.00-3.00 sec 1.09 GBytes 9.36 Gbits/sec
[ 7] 3.00-4.01 sec 1.03 GBytes 8.77 Gbits/sec
[ 7] 4.01-5.00 sec 1.05 GBytes 9.09 Gbits/sec
[ 7] 5.00-6.01 sec 1.04 GBytes 8.90 Gbits/sec
[ 7] 6.01-7.01 sec 1.06 GBytes 9.07 Gbits/sec
[ 7] 7.01-8.00 sec 1.10 GBytes 9.50 Gbits/sec
[ 7] 8.00-9.00 sec 1.05 GBytes 8.99 Gbits/sec
[ 7] 9.00-10.01 sec 1.06 GBytes 9.05 Gbits/sec
[ 7] 10.01-10.02 sec 11.3 MBytes 13.8 Gbits/sec
- - - - -
[ ID] Interval          Transfer      Bitrate
[ 7] 0.00-10.02 sec 10.7 GBytes 9.18 Gbits/sec
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet# iperf3 -s
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
```

Рис. 15: Запуск iPerf3 в режиме сервера на хосте h2

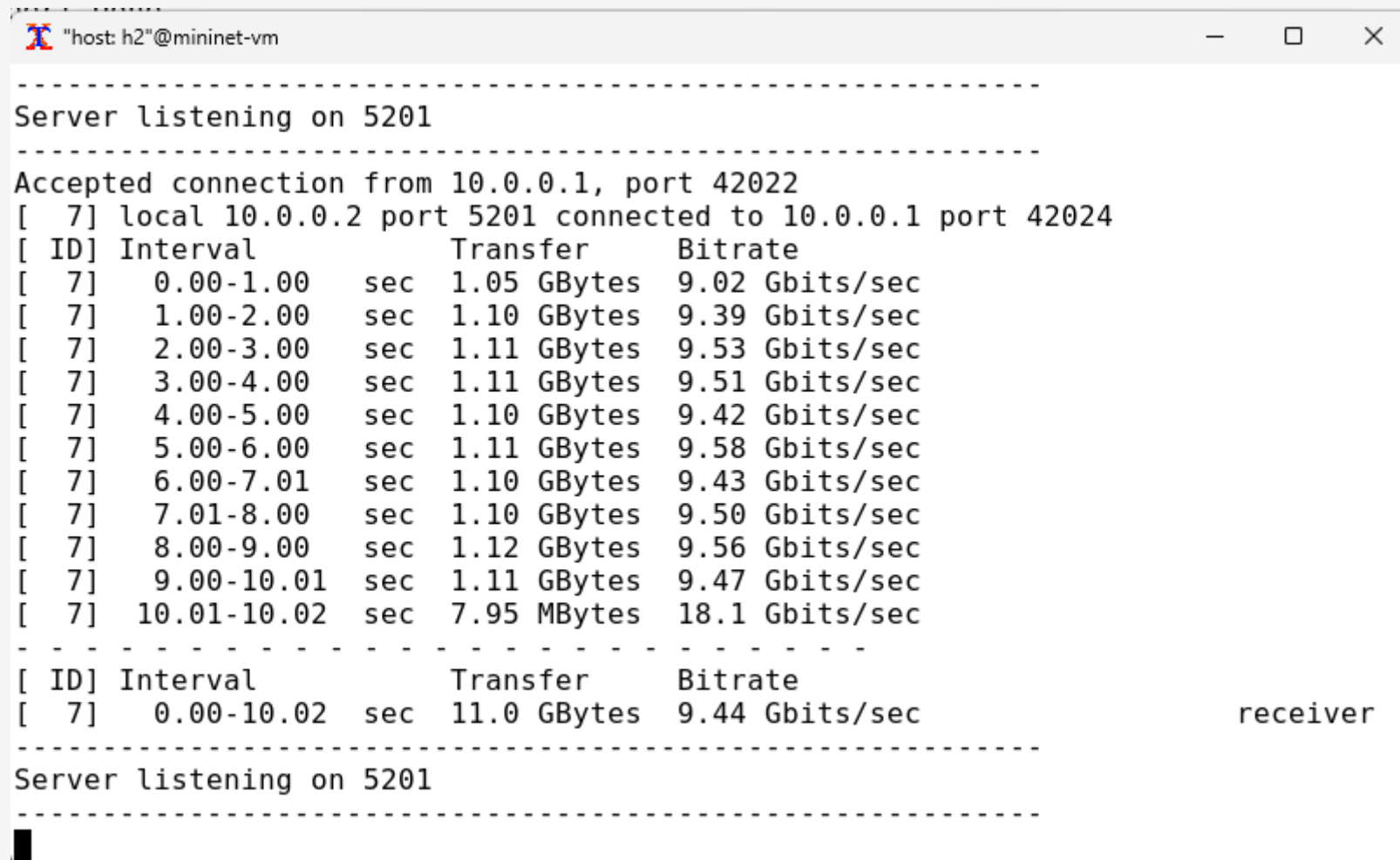
Интерактивные эксперименты

```
"host: h1"@mininet-vm
Cannot find device "sl-eth2"
root@mininet-vm:/home/mininet# sudo tc qdisc add dev sl-eth2 root tbf rate 10gbi
t burst 5000000 limit 15000000^C
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 42024 connected to 10.0.0.2 port 5201
[ ID] Interval            Transfer          Bitrate          Retr   Cwnd
[ 7]  0.00-1.00    sec   1.07 GBytes    9.17 Gbits/sec    27    19.8 MBytes
[ 7]  1.00-2.00    sec   1.09 GBytes    9.37 Gbits/sec     0    19.8 MBytes
[ 7]  2.00-3.00    sec   1.11 GBytes    9.50 Gbits/sec     0    19.8 MBytes
[ 7]  3.00-4.00    sec   1.11 GBytes    9.49 Gbits/sec     0    19.8 MBytes
[ 7]  4.00-5.00    sec   1.10 GBytes    9.51 Gbits/sec     0    19.8 MBytes
[ 7]  5.00-6.00    sec   1.11 GBytes    9.51 Gbits/sec     0    19.8 MBytes
[ 7]  6.00-7.00    sec   1.10 GBytes    9.48 Gbits/sec     0    19.8 MBytes
[ 7]  7.00-8.00    sec   1.11 GBytes    9.52 Gbits/sec     0    19.8 MBytes
[ 7]  8.00-9.00    sec   1.11 GBytes    9.57 Gbits/sec     0    19.8 MBytes
[ 7]  9.00-10.00   sec   1.11 GBytes    9.53 Gbits/sec     0    19.8 MBytes
- - - - -
[ ID] Interval            Transfer          Bitrate          Retr
[ 7]  0.00-10.00   sec   11.0 GBytes    9.46 Gbits/sec    27
[ 7]  0.00-10.02   sec   11.0 GBytes    9.44 Gbits/sec
sender
receiver

iperf Done.
root@mininet-vm:/home/mininet#
```

Рис. 16: Запуск iPerf3 в режиме клиента на хосте h1

Интерактивные эксперименты



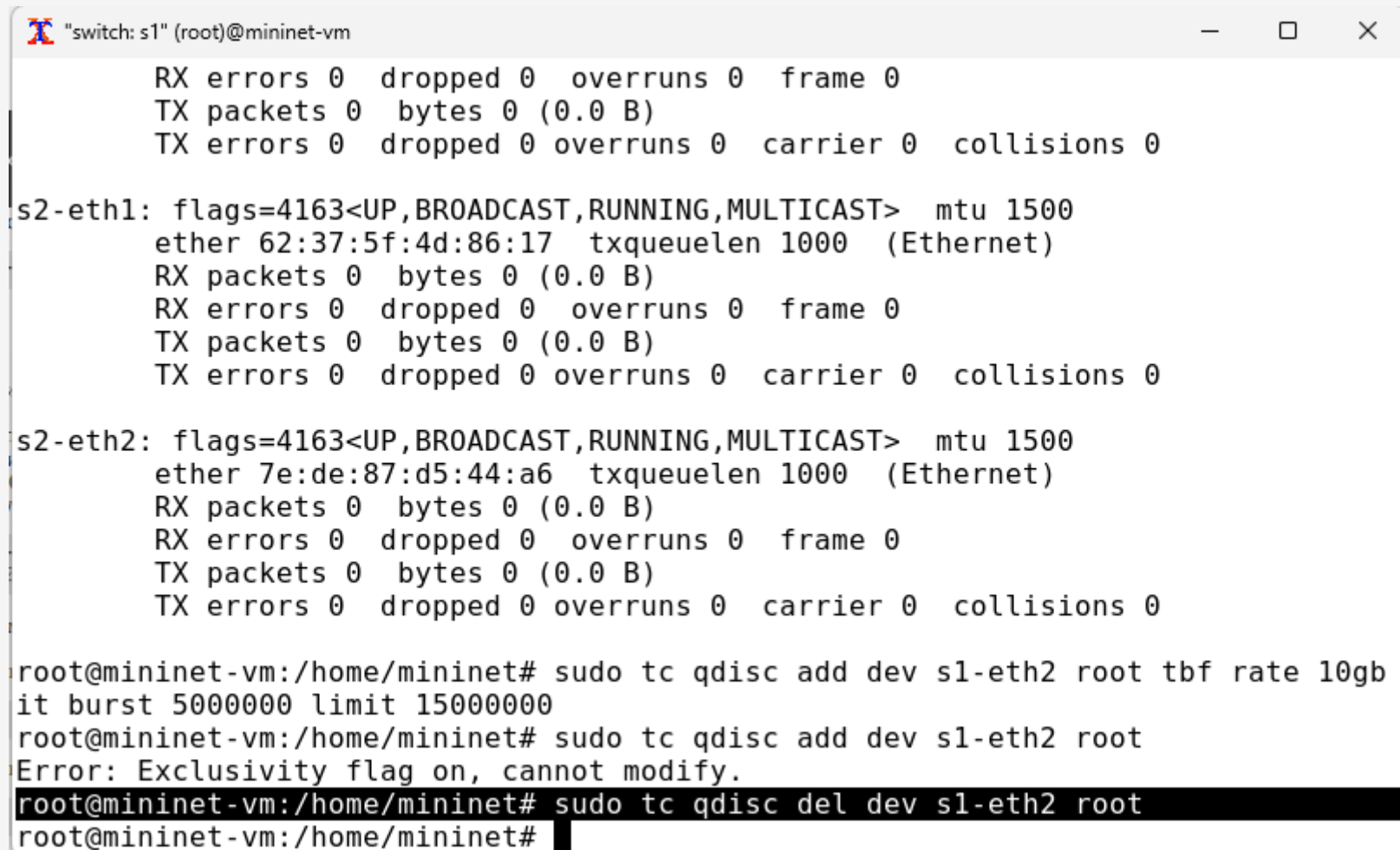
```
"host: h2"@mininet-vm

-----
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 42022
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 42024
[ ID] Interval           Transfer     Bitrate
[ 7]  0.00-1.00      sec   1.05 GBytes   9.02 Gbits/sec
[ 7]  1.00-2.00      sec   1.10 GBytes   9.39 Gbits/sec
[ 7]  2.00-3.00      sec   1.11 GBytes   9.53 Gbits/sec
[ 7]  3.00-4.00      sec   1.11 GBytes   9.51 Gbits/sec
[ 7]  4.00-5.00      sec   1.10 GBytes   9.42 Gbits/sec
[ 7]  5.00-6.00      sec   1.11 GBytes   9.58 Gbits/sec
[ 7]  6.00-7.01      sec   1.10 GBytes   9.43 Gbits/sec
[ 7]  7.01-8.00      sec   1.10 GBytes   9.50 Gbits/sec
[ 7]  8.00-9.00      sec   1.12 GBytes   9.56 Gbits/sec
[ 7]  9.00-10.01     sec   1.11 GBytes   9.47 Gbits/sec
[ 7] 10.01-10.02     sec    7.95 MBytes   18.1 Gbits/sec
-----
[ ID] Interval           Transfer     Bitrate
[ 7]  0.00-10.02     sec   11.0 GBytes   9.44 Gbits/sec
-----
Server listening on 5201
-----
```

receiver

Рис. 17: Остановка iPerf3

Интерактивные эксперименты



```
"switch: s1" (root)@mininet-vm
RX errors 0   dropped 0   overruns 0   frame 0
TX packets 0   bytes 0 (0.0 B)
TX errors 0   dropped 0   overruns 0   carrier 0   collisions 0

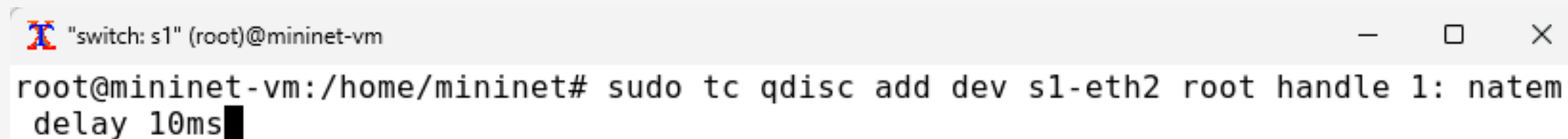
s2-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
ether 62:37:5f:4d:86:17  txqueuelen 1000  (Ethernet)
RX packets 0   bytes 0 (0.0 B)
RX errors 0   dropped 0   overruns 0   frame 0
TX packets 0   bytes 0 (0.0 B)
TX errors 0   dropped 0   overruns 0   carrier 0   collisions 0

s2-eth2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
ether 7e:de:87:d5:44:a6  txqueuelen 1000  (Ethernet)
RX packets 0   bytes 0 (0.0 B)
RX errors 0   dropped 0   overruns 0   frame 0
TX packets 0   bytes 0 (0.0 B)
TX errors 0   dropped 0   overruns 0   carrier 0   collisions 0

root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root tbf rate 10gb
it burst 5000000 limit 15000000
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root
Error: Exclusivity flag on, cannot modify.
root@mininet-vm:/home/mininet# sudo tc qdisc del dev s1-eth2 root
root@mininet-vm:/home/mininet#
```

Рис. 18: Удаление модифицированной конфигурации на коммутаторе s1

Интерактивные эксперименты




A terminal window titled '"switch: s1" (root)@mininet-vm' with standard window controls. The prompt is 'root@mininet-vm:/home/mininet#'. The command entered is 'sudo tc qdisc add dev s1-eth2 root handle 1: netem delay 10ms'. The cursor is at the end of the command line.

```
"switch: s1" (root)@mininet-vm  
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root handle 1: netem  
delay 10ms
```

Рис. 19: Объединение NETEM и TBF

Интерактивные эксперименты

 "host: h1"@mininet-vm

```
root@mininet-vm:/home/mininet# ping -c 4 10.0.0.2
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=5.22 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.839 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.092 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.130 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3010ms
rtt min/avg/max/mdev = 0.092/1.569/5.218/2.127 ms
root@mininet-vm:/home/mininet#
```

Рис. 20: Проверка задержки

Интерактивные эксперименты

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 parent 1: handle 2:  
tbf rate 2gbit burst 1000000 limit 2000000  
root@mininet-vm:/home/mininet# █
```

Рис. 21: Добавление второго правила на коммутаторе s1

Интерактивные эксперименты


```
 "host: h2"@mininet-vm  
root@mininet-vm:/home/mininet# iperf3 -s  
warning: this system does not seem to support IPv6 - trying IPv4  
-----  
Server listening on 5201  
-----  
^Ciperf3: interrupt - the server has terminated  
root@mininet-vm:/home/mininet# iperf3 -s  
warning: this system does not seem to support IPv6 - trying IPv4  
-----  
Server listening on 5201  
-----  
█
```

Рис. 22: Запуск iPerf3 в режиме сервера на хосте h2

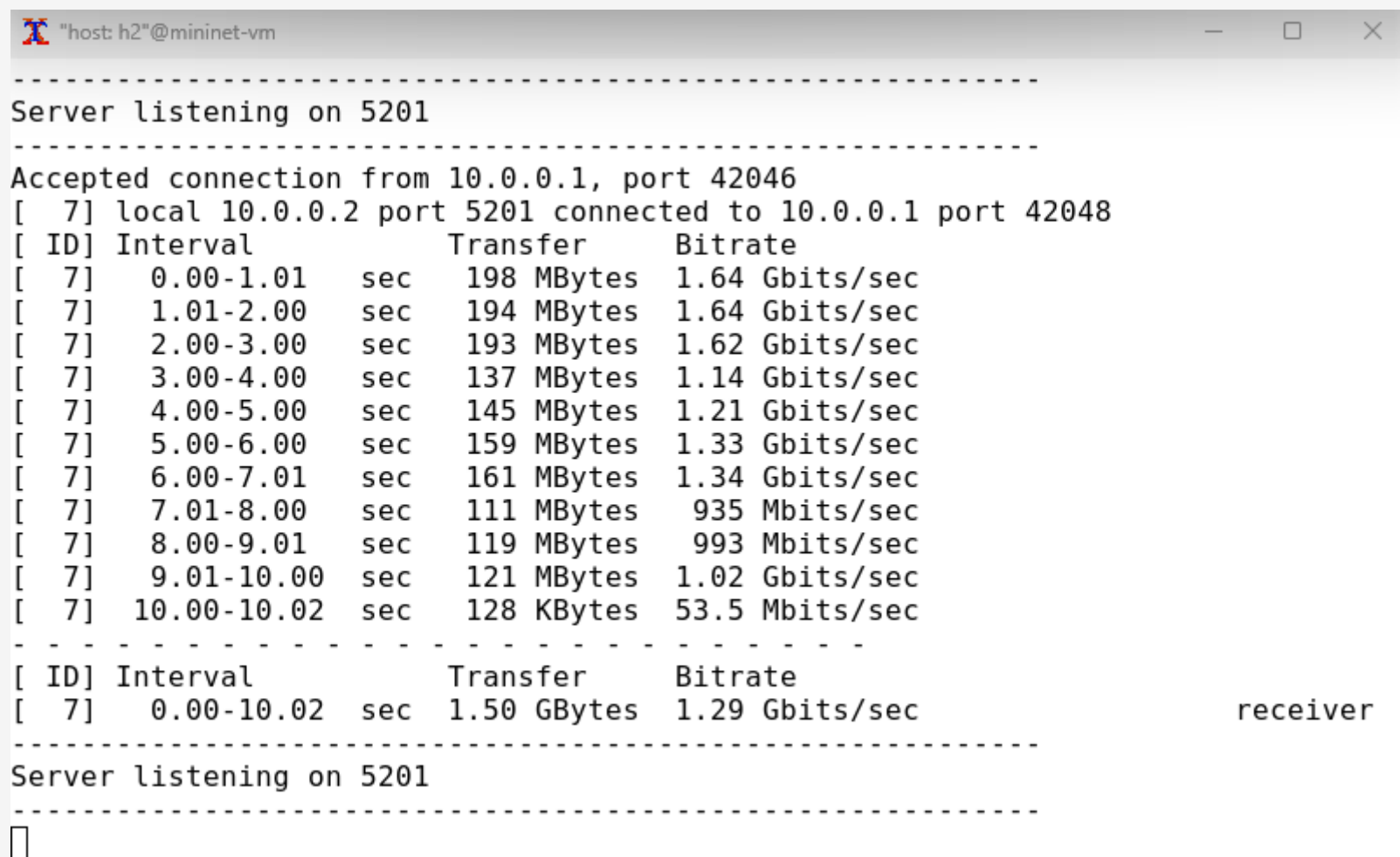
Интерактивные эксперименты

```
"host: h1"@mininet-vm
--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3010ms
rtt min/avg/max/mdev = 0.092/1.569/5.218/2.127 ms
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 42048 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr   Cwnd
[ 7]  0.00-1.01   sec    210 MBytes  1.75 Gbits/sec  1822   2.93 MBytes
[ 7]  1.01-2.00   sec    194 MBytes  1.63 Gbits/sec   90   2.17 MBytes
[ 7]  2.00-3.00   sec    192 MBytes  1.62 Gbits/sec    0   2.28 MBytes
[ 7]  3.00-4.00   sec    136 MBytes  1.14 Gbits/sec   90   1.70 MBytes
[ 7]  4.00-5.00   sec    146 MBytes  1.23 Gbits/sec    0   1.79 MBytes
[ 7]  5.00-6.00   sec    158 MBytes  1.32 Gbits/sec    0   1.85 MBytes
[ 7]  6.00-7.00   sec    161 MBytes  1.35 Gbits/sec    0   1.89 MBytes
[ 7]  7.00-8.00   sec    111 MBytes   934 Mbits/sec   21   1.41 MBytes
[ 7]  8.00-9.00   sec    119 MBytes   997 Mbits/sec    0   1.48 MBytes
[ 7]  9.00-10.00  sec    121 MBytes  1.02 Gbits/sec    0   1.54 MBytes
- - - - -
[ ID] Interval           Transfer     Bitrate      Retr
[ 7]  0.00-10.00  sec    1.51 GBytes  1.30 Gbits/sec  2023
[ 7]  0.00-10.02  sec    1.50 GBytes  1.29 Gbits/sec
                                     sender
                                     receiver

iperf Done.
root@mininet-vm:/home/mininet#
```

Рис. 23: Запуск iPerf3 в режиме клиента на хосте h1

Интерактивные эксперименты



```
"host: h2"@mininet-vm
-----
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 42046
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 42048
[ ID] Interval            Transfer      Bitrate
[ 7]  0.00-1.01    sec    198 MBytes  1.64 Gbits/sec
[ 7]  1.01-2.00    sec    194 MBytes  1.64 Gbits/sec
[ 7]  2.00-3.00    sec    193 MBytes  1.62 Gbits/sec
[ 7]  3.00-4.00    sec    137 MBytes  1.14 Gbits/sec
[ 7]  4.00-5.00    sec    145 MBytes  1.21 Gbits/sec
[ 7]  5.00-6.00    sec    159 MBytes  1.33 Gbits/sec
[ 7]  6.00-7.01    sec    161 MBytes  1.34 Gbits/sec
[ 7]  7.01-8.00    sec    111 MBytes   935 Mbits/sec
[ 7]  8.00-9.01    sec    119 MBytes   993 Mbits/sec
[ 7]  9.01-10.00   sec    121 MBytes  1.02 Gbits/sec
[ 7] 10.00-10.02   sec     128 KBytes  53.5 Mbits/sec
-----
[ ID] Interval            Transfer      Bitrate
[ 7]  0.00-10.02   sec    1.50 GBytes  1.29 Gbits/sec
-----
Server listening on 5201
-----
█
```

receiver

Рис. 24: Остановка iPerf3

Интерактивные эксперименты



```
"switch: s1" (root)@mininet-vm
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 parent 1: handle 2:
tbfbf rate 2gbit burst 1000000 limit 2000000
Error: Failed to find specified qdisc.
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 parent 1: handle 2:
tbfbf rate 2gbit burst 1000000 limit 2000000
Error: Failed to find specified qdisc.
root@mininet-vm:/home/mininet# ^C
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root handle 1: netem
delay 10ms
root@mininet-vm:/home/mininet# sudo tc qdisc show dev s1-eth2
qdisc netem 1: root refcnt 2 limit 1000 delay 10.0ms
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 parent 1: handle 2:
tbfbf rate 2gbit burst 1000000 limit 2000000
root@mininet-vm:/home/mininet# sudo tc qdisc del dev s1-eth2 root
root@mininet-vm:/home/mininet#
```

Рис. 25: Удаление модифицированной конфигурации на коммутаторе s1

Воспроизводимые эксперименты

```
mininet@mininet-vm:~$ ls
mininet  mininet.orig  oflops  oftest  openflow  pox  work
mininet@mininet-vm:~$ cd work/
mininet@mininet-vm:~/work$ ls
lab_iperf3  lab_netem_i  lab_netem_ii  lesson1.mn
mininet@mininet-vm:~/work$ mkdir lab6
mininet@mininet-vm:~/work$ ls
lab6  lab_iperf3  lab_netem_i  lab_netem_ii  lesson1.mn
mininet@mininet-vm:~/work$ cd lab6
mininet@mininet-vm:~/work/lab6$ mkdir exp1
mininet@mininet-vm:~/work/lab6$ mkdir exp2
mininet@mininet-vm:~/work/lab6$ ls
exp1  exp2
mininet@mininet-vm:~/work/lab6$
```

Рис. 26: Создание необходимых каталогов

Воспроизводимые эксперименты

```
mininet@mininet-vm: ~/work/lab6/exp1
GNU nano 4.8
#!/usr/bin/env python

"""
This example shows how to create an empty Mininet object
(without a topology object) and add nodes to it manually.
"""

from mininet.net import Mininet
from mininet.node import Controller
from mininet.cli import CLI
from mininet.log import setLogLevel, info

def emptyNet():

    "Create an empty network and add nodes to it."

    net = Mininet( controller=Controller, waitConnected=True )

    info( '*** Adding controller\n' )
    net.addController( 'c0' )

    info( '*** Adding hosts\n' )
    h1 = net.addHost( 'h1', ip='10.0.0.1' )
    h2 = net.addHost( 'h2', ip='10.0.0.2' )

    info( '*** Adding switch\n' )
    s1 = net.addSwitch( 's1' )
    s2 = net.addSwitch( 's2' )

    s1.cmd('ip link del s1-eth2')
    s2.cmd('ip link del s2-eth1')

    info( '*** Creating links\n' )
    net.addLink( h1, s1 )
    net.addLink( h2, s1 )
    net.addLink( s1, s2 )

    info( '*** Starting network\n' )
    net.start()

    s1.cmdPrint('sudo tc qdisc add dev s1-eth2 root handle 1: netem delay 10ms')
    s2.cmdPrint('sudo tc qdisc add dev s1-eth2 parent 1: handle 2: tbf rate 2gbit burst 1000000 limit 2000000')

    info( '*** Running CLI\n' )
    h2.cmdPrint('iperf3 -s -D -l')
    time.sleep(10) # Wait 10 seconds
    h1.cmdPrint('iperf3 -s -D -l')
    h1.cmdPrint('iperf3 -s -D -l')

    info( '*** Stopping network' )
    net.stop()

if __name__ == '__main__':
    setLogLevel( 'info' )
    emptyNet()
```

Рис. 27: Написание 1 скрипта

Воспроизводимые эксперименты

```
mininet@mininet-vm: ~/work/lab6/exp2
GNU nano 4.8
all: ping.dat ping.png


ping.dat
    sudo python expl.py
    suod chown mininet:mininet ping.dat

ping.png:
    ./ping_plot

clean:
    -rm -f *.dat *.png *.json
```

Рис. 28: Написание 2 скрипта

Воспроизводимые эксперименты

 mininet@mininet-vm: ~/work/lab6/exp2

```
GNU nano 4.8
#!/usr/bin/gnuplot --persist

set terminal png crop
set output 'ping.png'
set xlabel "Sequence number"
set ylabel "Delay (ms)"
set grid
plot "ping.dat" with lines
```

Рис. 29: Написание 3 скрипта

Воспроизводимые эксперименты

```
mininet@mininet-vm: ~/work/lab6/exp1
mininet@mininet-vm:~/work/lab6/exp1$ make
sudo python lab6_exp1.py
*** Adding controller
*** Adding hosts
*** Adding switch
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 2 switches
s1 s2 ...
*** Waiting for switches to connect
s1 s2
*** Set delay
*** s1 : ('tc qdisc add dev s1-eth2 root handle 1: netem delay 10ms',)
*** s2 : ('tc qdisc add dev s1-eth2 parent 1: handle 2: tbf rate 2gbit burst 1000000 limit 2000000',)
*** Traffic generation
*** h2 : ('iperf3 -s -D -1',)
*** h1 : ('iperf3 -c', '10.0.0.2', '-J > iperf_result.json')
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "time=" | awk \'{print $5, $7}\\' | sed -e \'s/time=//g\' -e \'s/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 3 links
...
*** Stopping 2 switches
s1 s2
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
mininet@mininet-vm:~/work/lab6/exp1$ ls
iperf_result.json lab6_exp1.py Makefile ping.dat ping_plot ping.png
mininet@mininet-vm:~/work/lab6/exp1$
```

Рис. 30: Выполнение скриптов

Воспроизводимые эксперименты

```
mininet@mininet-vm: ~/work/lab6/exp1
/home/mininet/work/lab6/exp1/lab6_exp1.py [-M--] 92 L:[ 12+32 44/ 58] *(1029/1469b) 39 0x027
from mininet.log import setLogLevel, info
import time

def emptyNet():

    "Create an empty network and add nodes to it."

    net = Mininet( controller=Controller, waitConnected=True )

    info( '*** Adding controller\n' )
    net.addController( 'c0' )

    info( '*** Adding hosts\n' )
    h1 = net.addHost( 'h1', ip='10.0.0.1' )
    h2 = net.addHost( 'h2', ip='10.0.0.2' )

    info( '*** Adding switch\n' )
    s1 = net.addSwitch( 's1' )
    s2 = net.addSwitch( 's2' )

    s1.cmd('ip link del s1-eth2')
    s2.cmd('ip link del s2-eth1')

    info( '*** Creating links\n' )
    net.addLink( h1, s1 )
    net.addLink( h2, s1 )
    net.addLink( s1, s2 )

    info( '*** Starting network\n' )
    net.start()

    info( '*** Set delay\n' )
    s1.cmdPrint( 'tc qdisc add dev h1-eth0 root tbf rate 10gbit burst 5000000 limit 15000000' )

    info( '*** Traffic generation\n' )
    h2.cmdPrint('iperf3 -s -D -1')
    time.sleep(10) # Wait 10 seconds
    h1.cmdPrint( 'iperf3 -c', h2.IP(), '-J > iperf_result.json' )
    h1.cmdPrint('ping -c 100', h2.IP(), '| grep "time=" | awk \'{print $5, $7}\'' | sed -e 's/time=//g' -e 's/icmp_seq=//g' > ping.dat')

    info( '*** Stopping network' )
    net.stop()

if __name__ == '__main__':
    setLogLevel( 'info' )
    emptyNet()
```

Рис. 31: Изменение параметров

Воспроизводимые эксперименты

```
mininet@mininet-vm: ~/work/lab6/exp1
mininet@mininet-vm:~/work/lab6/exp1$ make
sudo python lab6_exp1.py
*** Adding controller
*** Adding hosts
*** Adding switch
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 2 switches
s1 s2 ...
*** Waiting for switches to connect
s1 s2
*** Set delay
*** s1 : ('tc qdisc add dev h1-eth0 root tbf rate 10gbit burst 5000000 limit 15000000',)
Cannot find device "h1-eth0"
*** Traffic generation
*** h2 : ('iperf3 -s -D -1',)
*** h1 : ('iperf3 -c', '10.0.0.2', '-J > iperf_result.json')
*** h1 : ('ping -c 100', '10.0.0.2', '| grep "time=" | awk \'{print $5, $7}\'' | sed -e \'s/time=//g\' -e \'s/icmp_seq=//g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 3 links
...
*** Stopping 2 switches
s1 s2
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
mininet@mininet-vm:~/work/lab6/exp1$ ls
iperf_result.json  lab6_exp1.py  Makefile  ping.dat  ping_plot  ping.png
mininet@mininet-vm:~/work/lab6/exp1$
```

Рис. 32: Выполнение скриптов

Воспроизводимые эксперименты

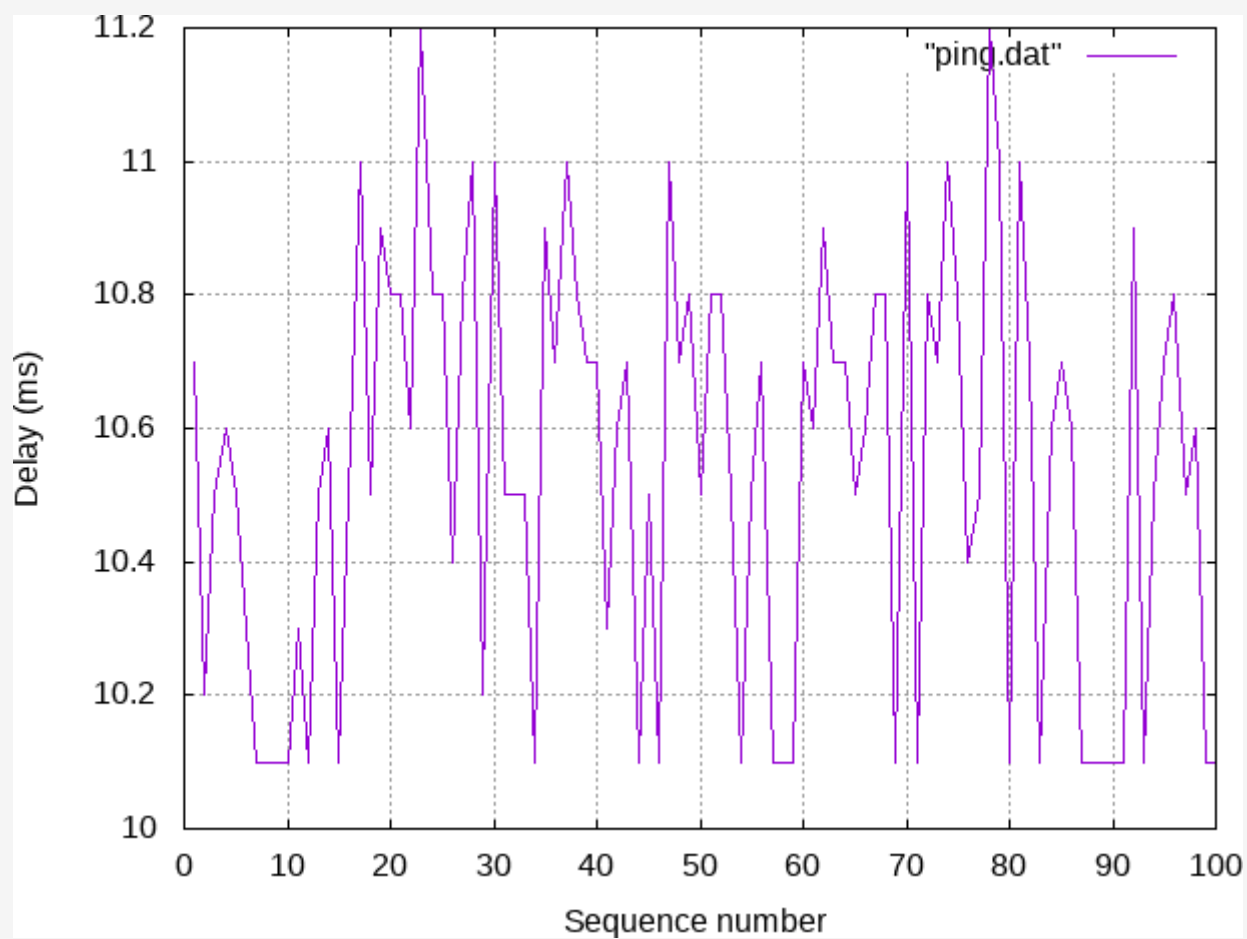


Рис. 33: График №1

Воспроизводимые эксперименты

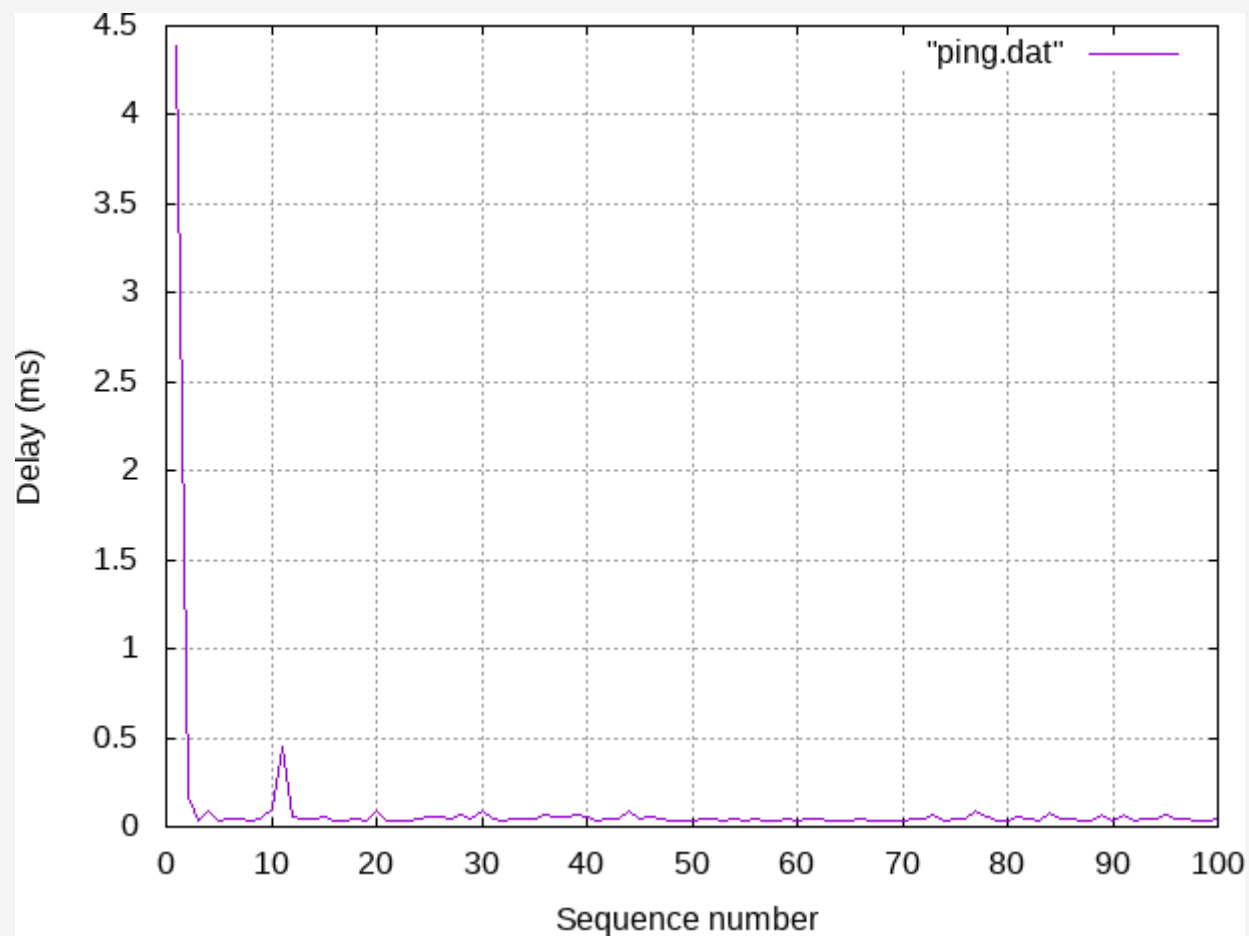


Рис. 34: График №2

Вывод

- В ходе выполнения лабораторной работы познакомились с принципами работы дисциплины очереди Token Bucket Filter, которая формирует входящий/исходящий трафик для ограничения пропускной способности, а также получили навыки моделирования и исследования поведения трафика посредством проведения интерактивного и воспроизводимого экспериментов в Mininet.

Список литературы. Библиография

[1] Mininet: <https://mininet.org/>