

Лабораторная Работа №6.

Моделирование сетей передачи данных

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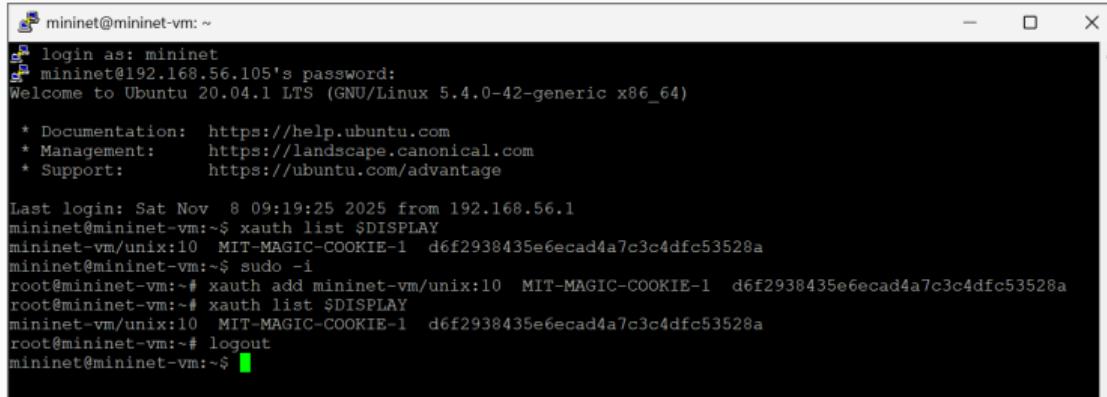
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Цели и задачи

Основной целью работы является знакомство с принципами работы дисциплины очереди Token Bucket Filter, которая формирует входящий/исходящий трафик для ограничения пропускной способности, а также получение навыков моделирования и исследования поведения трафика посредством проведения интерактивного и воспроизводимого экспериментов в Mininet.

Исправление прав запуска



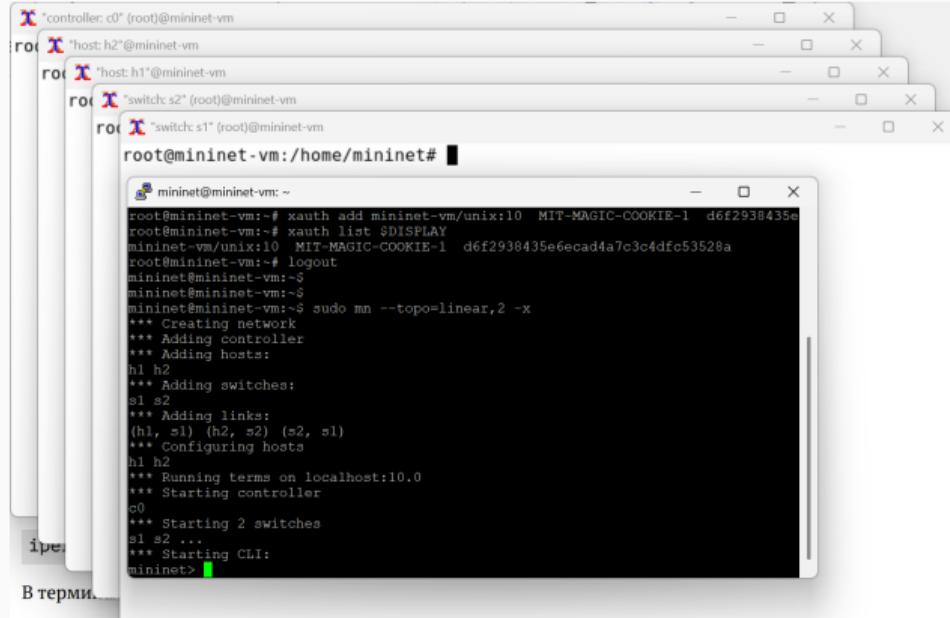
```
mininet@mininet-vm: ~
login as: mininet
mininet@192.168.56.105's password:
Welcome to Ubuntu 20.04.1 LTS (GNU/Linux 5.4.0-42-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:    https://landscape.canonical.com
 * Support:       https://ubuntu.com/advantage

Last login: Sat Nov  8 09:19:25 2025 from 192.168.56.1
mininet@mininet-vm:~$ xauth list $DISPLAY
mininet-vm/unix:10  MIT-MAGIC-COOKIE-1  d6f2938435e6ecad4a7c3c4dfc53528a
mininet@mininet-vm:~$ sudo -i
root@mininet-vm:~# xauth add mininet-vm/unix:10  MIT-MAGIC-COOKIE-1  d6f2938435e6ecad4a7c3c4dfc53528a
root@mininet-vm:~# xauth list $DISPLAY
mininet-vm/unix:10  MIT-MAGIC-COOKIE-1  d6f2938435e6ecad4a7c3c4dfc53528a
root@mininet-vm:~# logout
mininet@mininet-vm:~$
```

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

Создание топологии



The screenshot shows a terminal window titled "root@mininet-vm:/home/mininet#". Inside the terminal, the user runs the command "xauth add mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 d6f2938435e". This is followed by "xauth list \$DISPLAY", which shows the cookie information. Then, "sudo mn --topo=linear,2 -x" is run, which triggers a series of internal log messages:

- *** 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>

Below the terminal window, there are several other windows visible, including "controller: c0" (root)@mininet-vm, "host: h2" (root)@mininet-vm, "host: h1" (root)@mininet-vm, "switch: s2" (root)@mininet-vm, and "switch: s1" (root)@mininet-vm.

Figure 2: Создание топологии с двумя хостами и двумя коммутаторами

Отображение информации

The image shows five terminal windows from a Linux host (mininet-vm) displaying the output of the `ifconfig` command for different network interfaces. The interfaces listed are `eth0`, `eth1`, `lo`, `h1-eth0`, and `h1-eth1`. Each window shows the interface name, flags, MTU, IP address, netmask, broadcast address, and various statistics (RX/TX bytes, errors, dropped, overruns, frame, carrier, collisions).

```
root@mininet-vm:/home/mininet# ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.56.105 netmask 255.255.255.0 broadcast 192.168.56.255
        ether 08:00:27:e8:3d:b9 txqueuelen 1000  (Ethernet)
        RX packets 1394 bytes 517885 (517.8 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 1319 bytes 882631 (882.6 KB)
        TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.2.15 netmask 255.255.255.0 broadcast 10.0.0.2.255
        ether 08:00:27:e8:3d:b3 txqueuelen 1000  (Ethernet)
        RX packets 335 bytes 43935 (43.9 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 354 bytes 32550 (32.5 KB)
        TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
root@mininet-vm:/home/mininet# ifconfig
h1-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.56.105 netmask 255.255.255.0 broadcast 192.168.56.255
        ether 6a:aa:ec:fa:3b:6c 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 1228 bytes 283284 (283.2 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 1228 bytes 283284 (283.2 KB)
        TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet# ifconfig
h1-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 10.0.0.1 netmask 255.0.0.0 broadcast 10.255.255.255
        ether 62:77:e9:40:c8:a8 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 976 bytes 262452 (262.4 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 976 bytes 262452 (262.4 KB)
        TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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

Figure 3: Отображение информации сетевых интерфейсов и IP-адресов

Проверка подключения между хостами h1 и h2

The screenshot shows two terminal windows side-by-side. The left window is titled "host: h2" and the right window is titled "host: h1". Both windows are running on a host named "mininet-vm".

Host h2 (Left Window):

```
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=1.88 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.090 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.078 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.096 ms

--- 10.0.0.1 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3046ms
rtt min/avg/max/mdev = 0.078/0.535/1.878/0.775 ms
root@mininet-vm:/home/mininet#
```

Host h1 (Right Window):

```
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=6.52 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.309 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.245 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.076 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3059ms
rtt min/avg/max/mdev = 0.076/1.788/6.524/2.735 ms
root@mininet-vm:/home/mininet#
```

Figure 4: Проверка подключения между хостами h1 и h2

Запуск iPerf3 в режиме сервера на хосте h2

```
root@mininet-vm:/home/mininet# iperf3 -s
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
```

Figure 5: Запуск iPerf3 в режиме сервера на хосте h2

Запуск iPerf3 в режиме клиента на хосте h1

```
X "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=6.52 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.309 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.245 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.076 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3059ms
rtt min/avg/max/mdev = 0.076/1.788/6.524/2.735 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 58354 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr  Cwnd
[ 7]  0.00-1.00   sec  3.66 GBytes  31.4 Gbytes/sec  0  8.09 MBytes
[ 7]  1.00-2.00   sec  3.57 GBytes  30.7 Gbytes/sec  0  8.09 MBytes
[ 7]  2.00-3.00   sec  3.85 GBytes  33.1 Gbytes/sec  0  8.09 MBytes
[ 7]  3.00-4.00   sec  3.29 GBytes  28.2 Gbytes/sec  0  8.09 MBytes
[ 7]  4.00-5.00   sec  3.71 GBytes  31.9 Gbytes/sec  0  8.09 MBytes
[ 7]  5.00-6.00   sec  3.73 GBytes  32.0 Gbytes/sec  0  8.09 MBytes
[ 7]  6.00-7.00   sec  3.37 GBytes  29.0 Gbytes/sec  0  8.09 MBytes
[ 7]  7.00-8.00   sec  3.66 GBytes  31.4 Gbytes/sec  1  8.09 MBytes
[ 7]  8.00-9.00   sec  3.25 GBytes  27.9 Gbytes/sec  0  8.09 MBytes
[ 7]  9.00-10.00  sec  3.78 GBytes  32.4 Gbytes/sec  0  8.09 MBytes
[ 7]  0.00-10.00  sec  35.9 GBytes  30.8 Gbits/sec  1             sender
[ 7]  0.00-10.00  sec  35.9 GBytes  30.8 Gbits/sec               receiver
iperf Done.
root@mininet-vm:/home/mininet#
```

Figure 6: Запуск iPerf3 в режиме клиента на хосте h1

Остановка iPerf3

```
terminal "host: h2"@"mininet-vm"
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 58352
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 58354
[ ID] Interval           Transfer     Bitrate
[ 7]  0.00-1.00   sec  3.66 GBytes  31.5 Gbits/sec
[ 7]  1.00-2.00   sec  3.56 GBytes  30.6 Gbits/sec
[ 7]  2.00-3.00   sec  3.85 GBytes  33.1 Gbits/sec
[ 7]  3.00-4.00   sec  3.29 GBytes  28.3 Gbits/sec
[ 7]  4.00-5.00   sec  3.71 GBytes  31.9 Gbits/sec
[ 7]  5.00-6.00   sec  3.73 GBytes  32.0 Gbits/sec
[ 7]  6.00-7.00   sec  3.37 GBytes  29.0 Gbits/sec
[ 7]  7.00-8.00   sec  3.66 GBytes  31.5 Gbits/sec
[ 7]  8.00-9.00   sec  3.25 GBytes  27.9 Gbits/sec
[ 7]  9.00-10.00  sec  3.78 GBytes  32.4 Gbits/sec
[ 7] 10.00-10.00  sec  4.00 MBytes  12.9 Gbits/sec
-----
[ ID] Interval           Transfer     Bitrate
[ 7]  0.00-10.00  sec  35.9 GBytes  30.8 Gbits/sec
                                                receiver
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#
```

Figure 7: Остановка iPerf3

Изменение пропускной способности хоста h1

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root tb  
f rate 10gbit burst 5000000 limit 1500000  
Error: Exclusivity flag on, cannot modify.  
root@mininet-vm:/home/mininet# █
```

Figure 8: Изменение пропускной способности хоста h1

Установка значения всплеска

```
root@mininet-vm:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config-`uname -r`  
CONFIG_HZ_250=y  
root@mininet-vm:/home/mininet# █
```

Свернуть все с

Figure 9: Установка значения всплеска при ограничении скорости для фильтра tbf

Запуск iPerf3

```
root@mininet-vm:/home/mininet# iperf3 -s
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
```

Figure 10: Запуск iPerf3 в режиме сервера на хосте h2

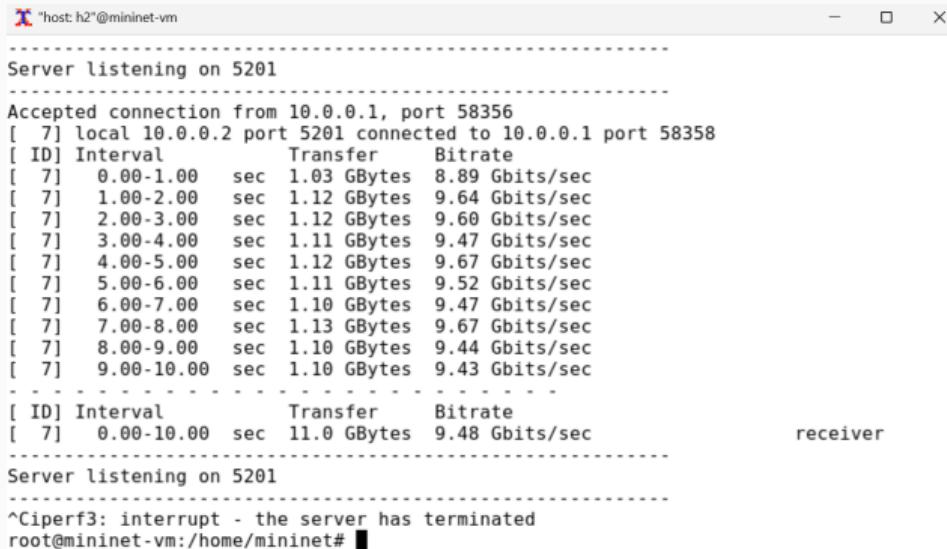
Запуск iPerf3

```
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 58358 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr  Cwnd
[ 7]  0.00-1.00   sec  1.05 GBytes  9.05 Gbits/sec  121  1.12 MBy
[ 7]  1.00-2.00   sec  1.12 GBytes  9.58 Gbits/sec    0  1.62 MBy
[ 7]  2.00-3.00   sec  1.11 GBytes  9.58 Gbits/sec    0  1.93 MBy
[ 7]  3.00-4.00   sec  1.11 GBytes  9.57 Gbits/sec    0  2.17 MBy
[ 7]  4.00-5.00   sec  1.11 GBytes  9.57 Gbits/sec    0  2.32 MBy
[ 7]  5.00-6.00   sec  1.11 GBytes  9.56 Gbits/sec    0  2.48 MBy
[ 7]  6.00-7.00   sec  1.11 GBytes  9.58 Gbits/sec    0  2.61 MBy
[ 7]  7.00-8.00   sec  1.11 GBytes  9.54 Gbits/sec    0  2.75 MBy
[ 7]  8.00-9.00   sec  1.11 GBytes  9.55 Gbits/sec    0  2.82 MBy
[ 7]  9.00-10.00  sec  1.09 GBytes  9.37 Gbits/sec   0  2.92 MBy
[ ID] Interval          Transfer     Bitrate      Retr
[ 7]  0.00-10.00  sec  11.1 GBytes  9.49 Gbits/sec  121
[ 7]  0.00-10.00  sec  11.0 GBytes  9.48 Gbits/sec

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

Figure 11: Запуск iPerf3 в режиме клиента на хосте h1

Остановка iPerf3



The screenshot shows a terminal window titled "host: h2"@"mininet-vm". The window displays the output of an iPerf3 test. The test shows a connection from host h2 to host h1. The transfer rate fluctuates between 8.89 Gbits/sec and 9.67 Gbits/sec, with a total transfer of 11.0 GBytes over 10 seconds. The test is interrupted by a signal, indicated by the message "Ciperf3: interrupt - the server has terminated".

```
host: h2"@"mininet-vm
-----
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 58356
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 58358
[ ID] Interval           Transfer     Bitrate
[ 7]  0.00-1.00   sec  1.03 GBytes  8.89 Gbits/sec
[ 7]  1.00-2.00   sec  1.12 GBytes  9.64 Gbits/sec
[ 7]  2.00-3.00   sec  1.12 GBytes  9.60 Gbits/sec
[ 7]  3.00-4.00   sec  1.11 GBytes  9.47 Gbits/sec
[ 7]  4.00-5.00   sec  1.12 GBytes  9.67 Gbits/sec
[ 7]  5.00-6.00   sec  1.11 GBytes  9.52 Gbits/sec
[ 7]  6.00-7.00   sec  1.10 GBytes  9.47 Gbits/sec
[ 7]  7.00-8.00   sec  1.13 GBytes  9.67 Gbits/sec
[ 7]  8.00-9.00   sec  1.10 GBytes  9.44 Gbits/sec
[ 7]  9.00-10.00  sec  1.10 GBytes  9.43 Gbits/sec
-----
[ ID] Interval          Transfer     Bitrate
[ 7]  0.00-10.00  sec  11.0 GBytes  9.48 Gbits/sec
                                         receiver
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#
```

Figure 12: Остановка iPerf3

Удаление конфигурации

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

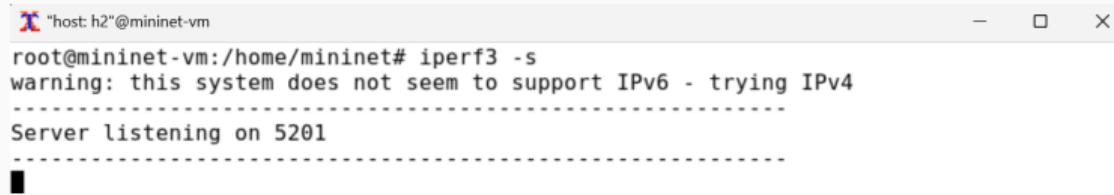
Figure 13: Удаление модифицированной конфигурации на хосте h1

Применение правила

```
switch: s1" (root)@mininet-vm
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#
```

Figure 14: Применение правила ограничения скорости tbf

Запуск iPerf3

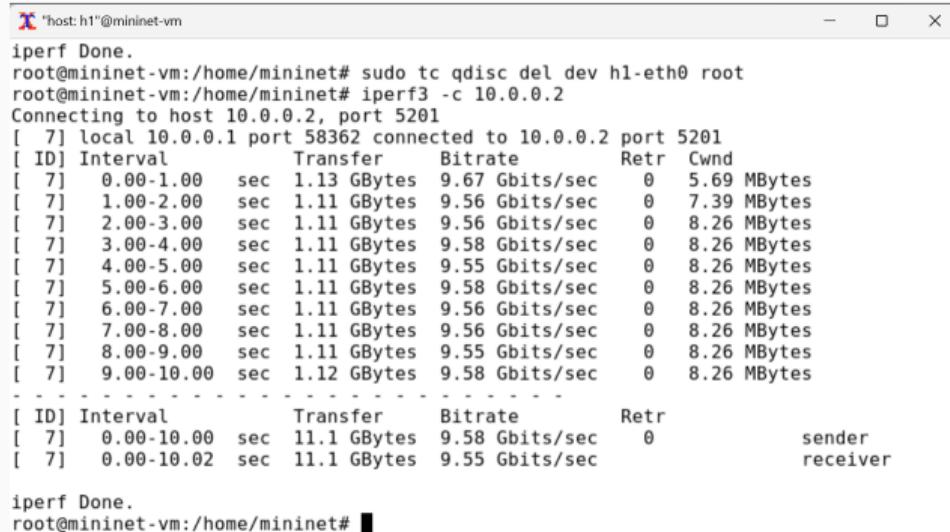


A terminal window titled "host: h2" running on a mininet-vm. The window contains the following text:

```
root@mininet-vm:/home/mininet# iperf3 -s
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
```

Figure 15: Запуск iPerf3 в режиме сервера на хосте h2

Запуск iPerf3



The screenshot shows a terminal window titled "host: h1" running on a Mininet VM. The window displays the results of an iPerf3 test between host h1 and host h2. The test shows a stable bandwidth of approximately 9.58 Gbytes/sec over a 10-second interval.

```
"host: h1"@mininet-vm
iperf Done.
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root
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 58362 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr  Cwnd
[ 7]  0.00-1.00   sec   1.13 GBytes   9.67 Gbits/sec  0  5.69 MBytes
[ 7]  1.00-2.00   sec   1.11 GBytes   9.56 Gbits/sec  0  7.39 MBytes
[ 7]  2.00-3.00   sec   1.11 GBytes   9.56 Gbits/sec  0  8.26 MBytes
[ 7]  3.00-4.00   sec   1.11 GBytes   9.58 Gbits/sec  0  8.26 MBytes
[ 7]  4.00-5.00   sec   1.11 GBytes   9.55 Gbits/sec  0  8.26 MBytes
[ 7]  5.00-6.00   sec   1.11 GBytes   9.58 Gbits/sec  0  8.26 MBytes
[ 7]  6.00-7.00   sec   1.11 GBytes   9.56 Gbits/sec  0  8.26 MBytes
[ 7]  7.00-8.00   sec   1.11 GBytes   9.56 Gbits/sec  0  8.26 MBytes
[ 7]  8.00-9.00   sec   1.11 GBytes   9.55 Gbits/sec  0  8.26 MBytes
[ 7]  9.00-10.00  sec   1.12 GBytes   9.58 Gbits/sec  0  8.26 MBytes
[ ID] Interval          Transfer     Bitrate      Retr
[ 7]  0.00-10.00  sec  11.1 GBytes   9.58 Gbits/sec  0
[ 7]  0.00-10.02  sec  11.1 GBytes   9.55 Gbits/sec
                                                               sender
                                                               receiver
iperf Done.
root@mininet-vm:/home/mininet#
```

Figure 16: Запуск iPerf3 в режиме клиента на хосте h1

Остановка iPerf3

```
"host: h2"@mininet-vm
-----
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 58360
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 58362
[ ID] Interval          Transfer     Bitrate
[ 7]  0.00-1.00   sec  1.11 GBytes  9.57 Gbits/sec
[ 7]  1.00-2.00   sec  1.11 GBytes  9.57 Gbits/sec
[ 7]  2.00-3.00   sec  1.11 GBytes  9.54 Gbits/sec
[ 7]  3.00-4.00   sec  1.12 GBytes  9.55 Gbits/sec
[ 7]  4.00-5.00   sec  1.11 GBytes  9.60 Gbits/sec
[ 7]  5.00-6.00   sec  1.11 GBytes  9.54 Gbits/sec
[ 7]  6.00-7.00   sec  1.12 GBytes  9.58 Gbits/sec
[ 7]  7.00-8.00   sec  1.11 GBytes  9.57 Gbits/sec
[ 7]  8.00-9.00   sec  1.11 GBytes  9.56 Gbits/sec
[ 7]  9.00-10.00  sec  1.11 GBytes  9.57 Gbits/sec
[ 7] 10.00-10.02  sec  1.93 MBytes  1.04 Gbits/sec
-----
[ ID] Interval          Transfer     Bitrate
[ 7]  0.00-10.02  sec  11.1 GBytes  9.55 Gbits/sec
-----                                         receiver
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#
```

Figure 17: Остановка iPerf3

Удаление конфигурации



```
switch: s1" (root)@mininet-vm
it burst 5000000 limit 15000000
root@mininet-vm:/home/mininet# sudo tc qdisc del dev s1-eth2 root
root@mininet-vm:/home/mininet#
```

A screenshot of a terminal window titled "switch: s1" (root)@mininet-vm. The window contains a command-line session. The user has run the command "sudo tc qdisc del dev s1-eth2 root". The command is partially visible at the bottom of the window.

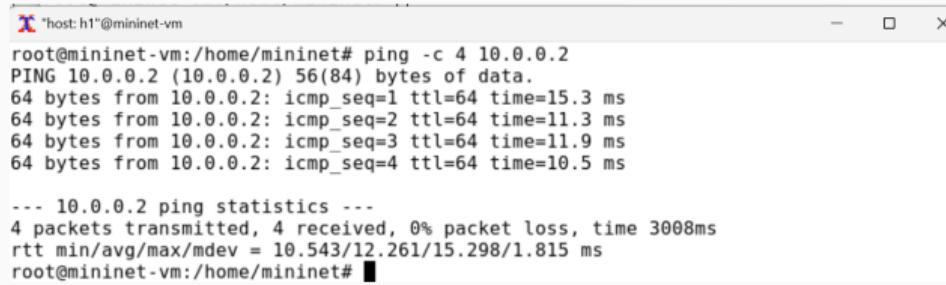
Figure 18: Удаление модифицированной конфигурации на коммутаторе s1

Объединение NETEM и TBF

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

Figure 19: Объединение NETEM и TBF

Проверка задержки



```
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=15.3 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=11.3 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=11.9 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=10.5 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3008ms
rtt min/avg/max/mdev = 10.543/12.261/15.298/1.815 ms
root@mininet-vm:/home/mininet#
```

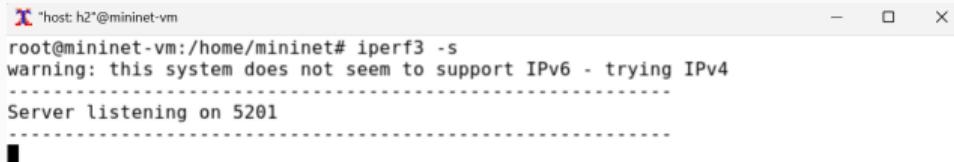
Figure 20: Проверка задержки

Добавление второго правила на коммутаторе s1

```
X "switch: s1" (root)@mininet-vm
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# █
```

Figure 21: Добавление второго правила на коммутаторе s1

Запуск iPerf3



A terminal window titled "host h2" running on a mininet-vm host. The window contains the following text:

```
root@mininet-vm:/home/mininet# iperf3 -s
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
```

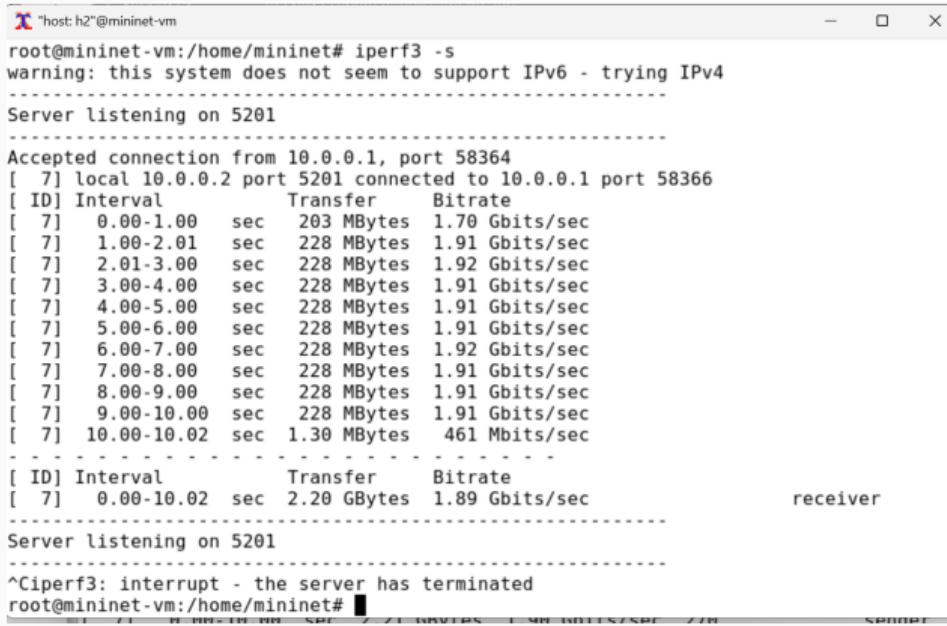
Figure 22: Запуск iPerf3 в режиме сервера на хосте h2

Запуск iPerf3

```
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 58366 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer     Bitrate      Retr  Cwnd
[ 7]  0.00-1.00    sec   215 MBytes   1.80 Gbits/sec  225  3.24 MBytes
[ 7]  1.00-2.00    sec   228 MBytes   1.91 Gbits/sec   0  3.48 MBytes
[ 7]  2.00-3.00    sec   228 MBytes   1.91 Gbits/sec   0  3.68 MBytes
[ 7]  3.00-4.00    sec   229 MBytes   1.92 Gbits/sec  45  2.71 MBytes
[ 7]  4.00-5.00    sec   228 MBytes   1.91 Gbits/sec   0  2.85 MBytes
[ 7]  5.00-6.00    sec   229 MBytes   1.92 Gbits/sec   0  2.96 MBytes
[ 7]  6.00-7.00    sec   228 MBytes   1.91 Gbits/sec   0  3.04 MBytes
[ 7]  7.00-8.00    sec   228 MBytes   1.91 Gbits/sec   0  3.10 MBytes
[ 7]  8.00-9.00    sec   229 MBytes   1.92 Gbits/sec   0  3.14 MBytes
[ 7]  9.00-10.00   sec   228 MBytes   1.91 Gbits/sec   0  3.17 MBytes
[ ID] Interval      Transfer     Bitrate      Retr
[ 7]  0.00-10.00   sec   2.21 GBytes  1.90 Gbits/sec  270
[ 7]  0.00-10.02   sec   2.20 GBytes  1.89 Gbits/sec
                                         sender
                                         receiver
iperf Done.
root@mininet-vm:/home/mininet#
```

Figure 23: Запуск iPerf3 в режиме клиента на хосте h1

Остановка iPerf3



The screenshot shows a terminal window titled "host: h2" running on a mininet-vm. The command "iperf3 -s" is executed, resulting in the following output:

```
"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
-----
Accepted connection from 10.0.0.1, port 58364
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 58366
[ ID] Interval Transfer Bitrate
[ 7] 0.00-1.00 sec 203 MBytes 1.70 Gbits/sec
[ 7] 1.00-2.01 sec 228 MBytes 1.91 Gbits/sec
[ 7] 2.01-3.00 sec 228 MBytes 1.92 Gbits/sec
[ 7] 3.00-4.00 sec 228 MBytes 1.91 Gbits/sec
[ 7] 4.00-5.00 sec 228 MBytes 1.91 Gbits/sec
[ 7] 5.00-6.00 sec 228 MBytes 1.91 Gbits/sec
[ 7] 6.00-7.00 sec 228 MBytes 1.92 Gbits/sec
[ 7] 7.00-8.00 sec 228 MBytes 1.91 Gbits/sec
[ 7] 8.00-9.00 sec 228 MBytes 1.91 Gbits/sec
[ 7] 9.00-10.00 sec 228 MBytes 1.91 Gbits/sec
[ 7] 10.00-10.02 sec 1.30 MBytes 461 Mbits/sec
-----
[ ID] Interval Transfer Bitrate
[ 7] 0.00-10.02 sec 2.20 GBytes 1.89 Gbits/sec
                                receiver
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#
```

Figure 24: Остановка iPerf3

Удаление конфигурации

```
X "switch: s1" (root)@mininet-vm
: tbf rate 2gbit burst 1000000 limit 2000000
root@mininet-vm:/home/mininet# sudo tc qdisc del dev s1-eth2 root
root@mininet-vm:/home/mininet#
```

Figure 25: Удаление модифицированной конфигурации на коммутаторе s1

Создание необходимых каталогов

```
mininet@mininet-vm:~$ ls
Desktop  Downloads  mininet.orig  oflops  openflow  pox      Templates  work
Documents  mininet  Music          oftest  Pictures  Public  Videos
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$ cd lab6
mininet@mininet-vm:~/work/lab6$ mkdir expl
mininet@mininet-vm:~/work/lab6$ mkdir exp2
mininet@mininet-vm:~/work/lab6$ ls
expl  exp2
mininet@mininet-vm:~/work/lab6$ |
```

Figure 26: Создание необходимых каталогов

Написание 1 скрипта

```
GNU nano 4.8                         expl.py                                Modified

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

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

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

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

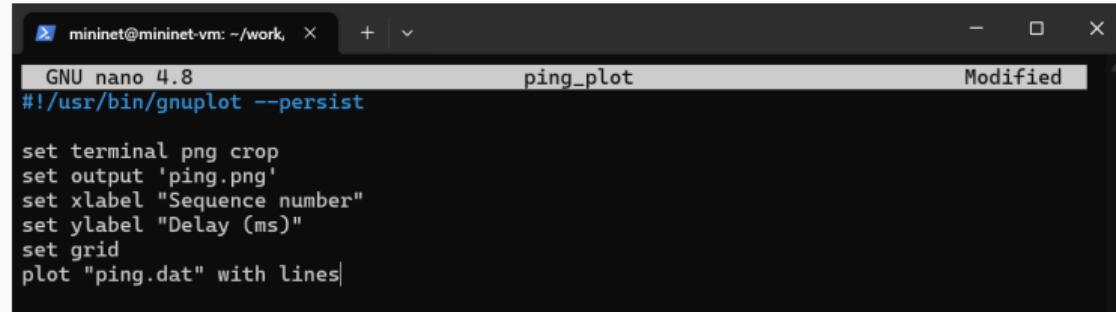
Написание 2 скрипта

```
GNU nano 4.8                                Makefile                                Modified
all: ping.dat ping.png

ping.dat:
    sudo python expl.py
    sudo chown mininet:mininet ping.dat
ping.png:
    ./ping_plot
clean:
    -rm -f *.dat *.png *.json
```

Figure 28: Написание 2 скрипта

Написание 3 скрипта



The screenshot shows a terminal window titled "mininet@mininet-vm: ~/work". The file being edited is named "ping_plot" and has the status "Modified". The content of the file is a gnuplot script:

```
GNU nano 4.8          ping_plot          Modified
#!/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|
```

Figure 29: Написание 3 скрипта

Выполнение скриптов

```
mininet@mininet-vm:~/work/lab6/expl$ make
sudo python expl.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 li
mit 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, $7}\'' | sed -e
's/time=/g\' -e '/s/icmp_seq=/g\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 3 links
...
*** Stopping 2 switches
s1 s2
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
mininet@mininet-vm:~/work/lab6/expl$
```

Свернуть все окна

Figure 30: Выполнение скриптов

Изменение параметров

```
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 10gbps burst 5000000 limit 15000000' )

    info( '*** Traffic generation\n' )
    h2.cmdPrint( 'iperf3 -s -D -l 1' )
    time.sleep(10) # Wait 10 seconds for servers to start
    h1.cmdPrint( 'iperf3 -c', h2.IP(), '-J > iperf_result.json' )
    h1.cmdPrint( 'ping -c 100', h2.IP(), '| grep "time=" | awk \'{print $6, $7}\' | sed -e \'s/time=/g\' -e \'s/icmp_seq=/g\' > ping.dat' )

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

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

Figure 31: Изменение параметров

Выполнение скриптов

```
mininet@mininet-vm:~/work/lab6/exp1$ make
sudo python 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 tbfa rate 10gbps burst 5000000 limit 15000000',)
Cannot find device "h1-eth0"
*** Traffic generation
*** h2 : ('iperf3 -s -D -l')
*** h1 : ('iperf3 -c -l 10.0.0.2' '-J > iperf_result.json')
*** h1 : ('ping -c 100' '-l 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
exp1.py iperf_result.json Makefile ping.dat ping_plet ping.png
mininet@mininet-vm:~/work/lab6/exp1$
```

Figure 32: Выполнение скриптов

График №1

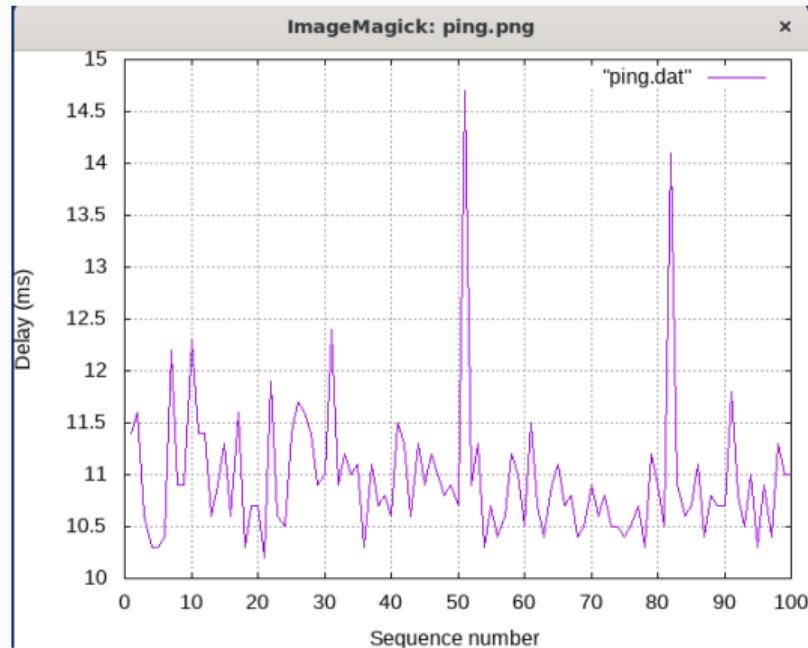


Figure 33: График №1

График №2

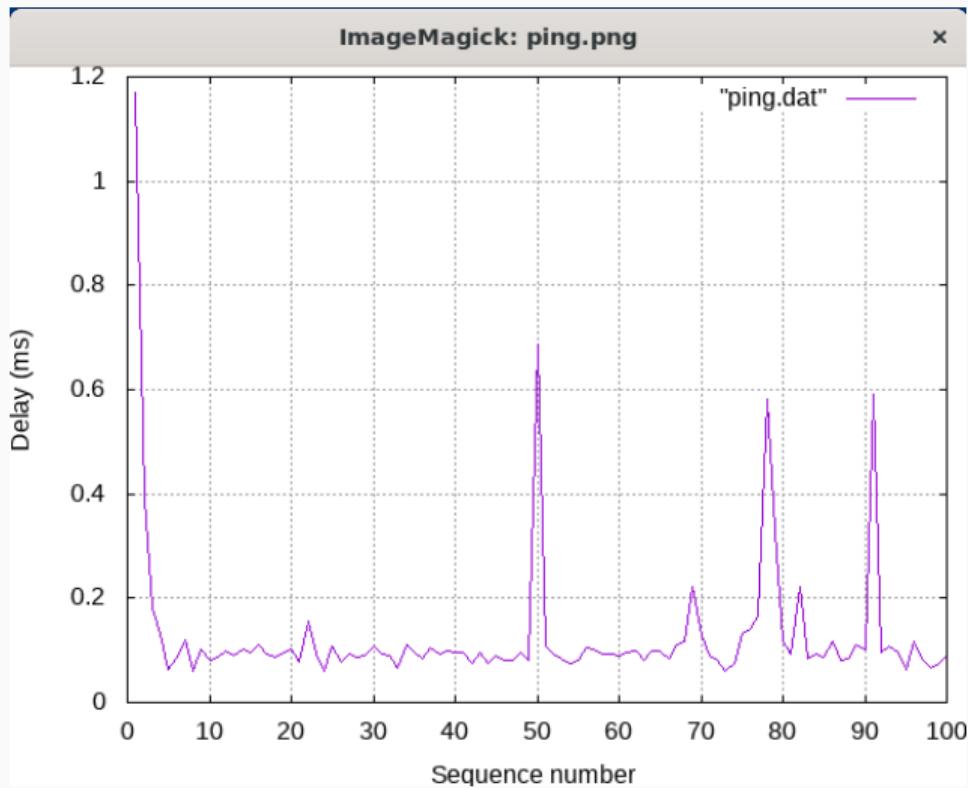


Figure 34: График №2

Вывод

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