

# **Лабораторная работа № 6**

Настройка пропускной способности глобальной сети с помощью Token Bucket Filter

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# Информация

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## Цель работы

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.

## Задание

1. Задайте топологию, состоящую из двух хостов и двух коммутаторов с назначенной по умолчанию mininet сетью 10.0.0.0/8.
2. Проведите интерактивные эксперименты по ограничению пропускной способности сети с помощью TBF в эмулируемой глобальной сети.
3. Самостоятельно реализуйте воспроизводимые эксперимент по применению TBF для ограничения пропускной способности. Постройте соответствующие графики.

# Выполнение лабораторной работы

```
mininet@mininet-vm:~/work$ xauth list $DISPLAY
mininet-vm/unix:12 MIT-MAGIC-COOKIE-1 9713b86bb098fbfdb897dd6199ab032e
mininet@mininet-vm:~/work$ sudo -i
root@mininet-vm:~# xauth list $DISPLAY
mininet-vm/unix:12 MIT-MAGIC-COOKIE-1 9713b86bb098fbfdb897dd6199ab032e
root@mininet-vm:~# logout
mininet@mininet-vm:~/work$ 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:12.0
*** Starting controller
c0
*** Starting 2 switches
s1 s2 ...
*** Starting CLI:
```

**Рис. 1:** Задание топологии

# Выполнение лабораторной работы

The screenshot shows two terminal windows side-by-side. Both windows have a title bar with the host name and a close button.

**Host h1 Terminal:**

```
root@mininet-vm:/home/mininet/work# ifconfig
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 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/work# 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=6.13 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.071 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.073 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.085 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3057ms
rtt min/avg/max/mdev = 0.071/1.590/6.133/2.622 ms
root@mininet-vm:/home/mininet/work# 
```

**Host h2 Terminal:**

```
root@mininet-vm:/home/mininet/work# ifconfig
loop  txqueuelen 1000  (Local Loopback)
RX packets 948  bytes 257136 (257.1 KB)
RX errors 0  dropped 0  overruns 0  frame 0
TX packets 948  bytes 257136 (257.1 KB)
TX errors 0  dropped 0  overruns 0  carrier 0  collisions 0

root@mininet-vm:/home/mininet/work# ping c -4 10.0.0.1
ping: c: Temporary failure in name resolution
root@mininet-vm:/home/mininet/work# 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=9.76 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.589 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.068 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.074 ms

--- 10.0.0.1 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3041ms
```

# Выполнение лабораторной работы

```
"host: h1"
--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3057ms
rtt min/avg/max/mdev = 0.071/1.590/6.133/2.622 ms
root@mininet-vm:/home/mininet/work# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 35388 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr Cwnd
[ 7]  0.00-1.00   sec  2.73 GBytes  23.4 Gbytes/sec  0  8.10 MBytes
[ 7]  1.00-2.00   sec  2.80 GBytes  24.0 Gbits/sec  0  8.10 MBytes
[ 7]  2.00-3.00   sec  2.81 GBytes  24.2 Gbits/sec  0  8.10 MBytes
[ 7]  3.00-4.00   sec  2.89 GBytes  24.8 Gbits/sec  0  8.10 MBytes
[ 7]  4.00-5.00   sec  2.88 GBytes  24.7 Gbits/sec  0  8.10 MBytes
[ 7]  5.00-6.00   sec  2.79 GBytes  24.0 Gbits/sec  0  8.10 MBytes
[ 7]  6.00-7.00   sec  3.00 GBytes  25.8 Gbits/sec  0  8.10 MBytes
[ 7]  7.00-8.00   sec  2.85 GBytes  24.5 Gbits/sec  0  8.10 MBytes
[ 7]  8.00-9.00   sec  3.08 GBytes  26.5 Gbits/sec  0  8.10 MBytes
[ 7]  9.00-10.00  sec  2.82 GBytes  24.2 Gbits/sec  0  8.10 MBytes
[ 7]  10.00-10.01 sec               0          sender
[ 7]  0.00-10.01  sec  28.7 GBytes  24.6 Gbits/sec  receiver
iperf Done.
root@mininet-vm:/home/mininet/work#
```

```
"host: h2"
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 35386
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 35388
[ ID] Interval           Transfer     Bitrate      Retr Cwnd
[ 7]  0.00-1.00   sec  2.73 GBytes  23.4 Gbytes/sec  0  8.10 MBytes
[ 7]  1.00-2.00   sec  2.79 GBytes  23.9 Gbits/sec
[ 7]  2.00-3.00   sec  2.82 GBytes  24.2 Gbits/sec
[ 7]  3.00-4.00   sec  2.89 GBytes  24.8 Gbits/sec
[ 7]  4.00-5.00   sec  2.87 GBytes  24.7 Gbits/sec
[ 7]  5.00-6.00   sec  2.80 GBytes  24.0 Gbits/sec
[ 7]  6.00-7.00   sec  3.01 GBytes  25.8 Gbits/sec
[ 7]  7.00-8.00   sec  2.85 GBytes  24.5 Gbits/sec
[ 7]  8.00-9.00   sec  3.08 GBytes  26.5 Gbits/sec
[ 7]  9.00-10.00  sec  2.82 GBytes  24.2 Gbits/sec
[ 7]  10.00-10.01 sec  11.1 MBytes  18.1 Gbits/sec
[ 7]  10.00-10.01 sec               0          receiver
-----
Server listening on 5201
```

## **Интерактивные эксперименты**

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## Ограничение скорости на конечных хостах

Изменим пропускную способность хоста h1, установив пропускную способность на 10 Гбит/с на интерфейсе h1-eth0 и параметры TBF-фильтра.

## Ограничение скорости на конечных хостах

```
root@mininet-vm:/home/mininet/work# sudo tc qdisc add dev h1-eth0 root tbf rate  
10gbit burst 5000000 limit 15000000  
root@mininet-vm:/home/mininet/work# egrep '^CONFIG_HZ_[0-9]+*' /boot/config-`un  
ame -r`  
grep: /boot/config-: No such file or directory  
grep: 5.4.0-42-generic: No such file or directory  
root@mininet-vm:/home/mininet/work# egrep '^CONFIG_HZ_[0-9]+*' /boot/config-`una  
me -r`  
CONFIG_HZ_250=y  
root@mininet-vm:/home/mininet/work# iperf3 -c 10.0.0.2
```

Рис. 4: Ограничение скорости на конечных хостах

# Ограничение скорости на конечных хостах

```
"host: h1"
root@mininet-vm:/home/mininet/work# egrep '^CONFIG_HZ_[0-9]+=' /boot/config-una
me -r
CONFIG_HZ_250=y
root@mininet-vm:/home/mininet/work# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 35392 connected to 10.0.0.2 port 5201
[ 7] Interval Transfer Bitrate Retr Cwnd
[ 7] 0.00-1.00 sec 1.13 GBytes 9.67 Gbits/sec 0 7.34 MBytes
[ 7] 1.00-2.00 sec 1.11 GBytes 9.55 Gbits/sec 0 8.12 MBytes
[ 7] 2.00-3.00 sec 1.11 GBytes 9.58 Gbits/sec 0 8.12 MBytes
[ 7] 3.00-4.00 sec 1.11 GBytes 9.54 Gbytes/sec 0 8.12 MBytes
[ 7] 4.00-5.00 sec 1.11 GBytes 9.58 Gbits/sec 0 8.12 MBytes
[ 7] 5.00-6.00 sec 1.11 GBytes 9.54 Gbits/sec 0 8.12 MBytes
[ 7] 6.00-7.00 sec 1.11 GBytes 9.60 Gbytes/sec 0 8.12 MBytes
[ 7] 7.00-8.00 sec 1.11 GBytes 9.57 Gbits/sec 0 8.12 MBytes
[ 7] 8.00-9.00 sec 1.11 GBytes 9.54 Gbits/sec 0 8.12 MBytes
[ 7] 9.00-10.00 sec 1.11 GBytes 9.57 Gbits/sec 0 8.12 MBytes
[ 7] 0.00-10.00 sec 11.1 GBytes 9.57 Gbits/sec 0
[ 7] 0.00-10.01 sec 11.1 GBytes 9.56 Gbits/sec
sender
receiver
iperf Done.
root@mininet-vm:/home/mininet/work# 

-----"host: h2"
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 35390
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 35392
[ 7] Interval Transfer Bitrate
[ 7] 0.00-1.00 sec 1.11 GBytes 9.56 Gbits/sec
[ 7] 1.00-2.00 sec 1.11 GBytes 9.50 Gbits/sec
[ 7] 2.00-3.00 sec 1.12 GBytes 9.56 Gbits/sec
[ 7] 3.00-4.00 sec 1.12 GBytes 9.62 Gbits/sec
[ 7] 4.00-5.01 sec 1.10 GBytes 9.45 Gbits/sec
[ 7] 5.01-6.00 sec 1.12 GBytes 9.67 Gbits/sec
[ 7] 6.00-7.00 sec 1.11 GBytes 9.58 Gbits/sec
[ 7] 7.00-8.00 sec 1.11 GBytes 9.58 Gbits/sec
[ 7] 8.00-9.00 sec 1.11 GBytes 9.52 Gbits/sec
[ 7] 9.00-10.01 sec 1.11 GBytes 9.55 Gbits/sec
[ 7] 0.00-10.01 sec 11.1 GBytes 9.56 Gbits/sec
receiver
-----
Server listening on 5201
```

## Ограничение скорости на коммутаторах

Применим правило ограничения скорости tbf с параметрами rate = 10gbit, burst = 5,000,000, limit= 15,000,000 к интерфейсу s1-eth2 коммутатора s1, который соединяет его с коммутатором s2.

# Ограничение скорости на коммутаторах

"switch: s1" (root)

```
root@mininet-vm:/home/mininet/work# sudo tc qdisc add dev s1-eth2 root tbf rate 92.168.48.5
10gbit burst 5000000 limit 15000000
root@mininet-vm:/home/mininet/work#
```

"host: h1"

```
rtt min/avg/max/mdev = 0.137/1.002/2.493/1.058 ms
root@mininet-vm:/home/mininet/work# iperf3 -c 10.0.0.2
iperf3: error - unable to connect to server: Connection refused
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 35422 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate   Retr Cwnd
[ 7]  0.00-1.00  sec  1.11 GBytes   9.64 Gbits/sec  0  8.00 MBytes
[ 7]  1.00-2.00  sec  1.11 GBytes   9.54 Gbits/sec  0  8.00 MBytes
[ 7]  2.00-3.00  sec  1.11 GBytes   9.57 Gbits/sec  0  8.00 MBytes
[ 7]  3.00-4.00  sec  1.11 GBytes   9.56 Gbits/sec  0  8.00 MBytes
[ 7]  4.00-5.00  sec  1.11 GBytes   9.56 Gbits/sec  0  8.00 MBytes
[ 7]  5.00-6.00  sec  1.11 GBytes   9.55 Gbytes/sec 0  8.00 MBytes
[ 7]  6.00-7.00  sec  1.11 GBytes   9.53 Gbytes/sec 0  8.00 MBytes
[ 7]  7.00-8.00  sec  1.12 GBytes   9.58 Gbytes/sec 0  8.00 MBytes
[ 7]  8.00-9.00  sec  1.11 GBytes   9.55 Gbytes/sec 0  8.00 MBytes
[ 7]  9.00-10.00 sec  1.12 GBytes   9.58 Gbytes/sec 0  8.00 MBytes
[ 7]  10.00-11.00 sec  1.11 GBytes   9.57 Gbytes/sec 0  8.00 MBytes
[ 7]  11.00-12.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  12.00-13.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  13.00-14.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  14.00-15.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  15.00-16.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  16.00-17.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  17.00-18.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  18.00-19.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  19.00-20.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  20.00-21.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  21.00-22.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  22.00-23.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  23.00-24.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  24.00-25.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  25.00-26.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  26.00-27.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  27.00-28.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  28.00-29.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  29.00-30.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  30.00-31.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  31.00-32.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  32.00-33.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  33.00-34.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  34.00-35.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  35.00-36.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  36.00-37.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  37.00-38.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  38.00-39.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  39.00-40.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  40.00-41.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  41.00-42.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  42.00-43.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  43.00-44.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  44.00-45.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  45.00-46.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  46.00-47.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  47.00-48.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  48.00-49.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  49.00-50.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  50.00-51.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  51.00-52.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  52.00-53.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  53.00-54.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  54.00-55.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  55.00-56.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  56.00-57.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  57.00-58.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  58.00-59.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  59.00-60.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  60.00-61.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  61.00-62.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  62.00-63.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  63.00-64.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  64.00-65.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  65.00-66.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  66.00-67.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  67.00-68.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  68.00-69.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  69.00-70.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  70.00-71.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  71.00-72.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  72.00-73.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  73.00-74.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  74.00-75.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  75.00-76.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  76.00-77.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  77.00-78.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  78.00-79.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  79.00-80.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  80.00-81.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  81.00-82.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  82.00-83.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  83.00-84.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  84.00-85.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  85.00-86.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  86.00-87.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  87.00-88.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  88.00-89.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  89.00-90.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  90.00-91.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  91.00-92.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  92.00-93.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  93.00-94.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  94.00-95.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  95.00-96.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  96.00-97.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  97.00-98.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  98.00-99.00 sec  1.11 GBytes   9.54 Gbytes/sec 0  8.00 MBytes
[ 7]  99.00-100.00 sec 1.11 GBytes  9.54 Gbytes/sec 0  8.00 MBytes
iperf Done.
```

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

Рис. 6: Ограничение скорости на коммутаторах

## Объединение NETEM и TBF

Объединим NETEM и TBF, введя на интерфейсе s1-eth2 коммутатора s1 задержку, джиттер, повреждение пакетов и указав скорость.

## **Объединение NETEM и TBF**

```

root@mininet-vm:/home/mininet/work# sudo tc qdisc add dev s1-eth2 root handle 1
: netem delay 10ms
root@mininet-vm:/home/mininet/work# sudo tc qdisc add dev s1-eth2 handle 1
  root@mininet-vm:~# logout
  mininet@win-inet-vm:~/work$ 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:12.0
  *** Starting controller
  c0
  *** Starting 2 switches
  s1 s2 ...
  *** Starting CLI:
  mininet> exit
  *** Stopping 1 controllers
  c0
  *** Stopping 10 terms
  *** Stopping 3 links
  mininet> ping -c 5 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=12.9 ms
  64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=11.6 ms
  64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=10.5 ms
  64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=10.3 ms
  64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=11.0 ms
  --- 10.0.0.2 ping statistics ---
  5 packets transmitted, 5 received, 0% packet loss, time 4008ms
  rtt min/avg/max/mdev = 10.340/11.270/12.881/0.915 ms
  root@mininet-vm:/home/mininet/work# tc

```

**Рис. 7:** Объединение NETEM и TBF

## Объединение NETEM и TBF

Добавим второе правило на коммутаторе s1, которое задаёт ограничение скорости с помощью tbf с параметрами rate=2gbit, burst=1,000,000, limit=2,000,000: и проверим.

# Объединение NETEM и TBF

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

Рис. 8: Объединение NETEM и TBF

## Объединение NETEM и TBF

Проверим конфигурацию с помощью iperf3.

# Объединение NETEM и TBF

```
"host: h1"

--- 10.0.0.2 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4008ms
rtt min/avg/max/mdev = 10.340/11.270/12.881/0.915 ms
root@mininet-vm:/home/mininet/work# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 35426 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr  Cwnd
[ 7]  0.00-1.00   sec    146 MBytes   1.22 Gbits/sec  745  1.74 MBytes
[ 7]  1.00-2.00   sec    151 MBytes   1.27 Gbits/sec   0  1.83 MBytes
[ 7]  2.00-3.00   sec    156 MBytes   1.31 Gbits/sec   0  1.89 MBytes
[ 7]  3.00-4.00   sec    120 MBytes   1.01 Gbits/sec  76  1.40 MBytes
[ 7]  4.00-5.00   sec    122 MBytes   1.03 Gbits/sec   0  1.48 MBytes
[ 7]  5.00-6.00   sec    126 MBytes   1.06 Gbits/sec   0  1.54 MBytes
[ 7]  6.00-7.00   sec    135 MBytes   1.13 Gbits/sec   0  1.58 MBytes
[ 7]  7.00-8.00   sec    136 MBytes   1.14 Gbits/sec   0  1.60 MBytes
[ 7]  8.00-9.00   sec    136 MBytes   1.14 Gbits/sec   0  1.66 MBytes
[ 7]  9.00-10.00  sec    141 MBytes   1.19 Gbits/sec   0  1.72 MBytes
[ ID] Interval          Transfer     Bitrate      Retr
[ 7]  0.00-10.00  sec   1.34 GBytes  1.15 Gbits/sec  821
[ 7]  0.00-10.02  sec   1.33 GBytes  1.14 Gbits/sec

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

Рис. 9: Результат эксперимента

## **Воспроизводимые эксперименты**

---

# Ограничение скорости на конечных хостах

```
mininet@mininet-vm:~/work$ mkdir -p lab_netem_iii
mininet@mininet-vm:~/work$ cd lab_netem_iii
mininet@mininet-vm:~/work/lab_netem_iii$ mkdir -p host_tbf
mininet@mininet-vm:~/work/lab_netem_iii$ cd host_tbf
mininet@mininet-vm:~/work/lab_netem_iii$ cp ~/work/lab_netem_ii/simple-drop/Makefile ~/work/lab_netem_iii/host_tbf/Makefile
mininet@mininet-vm:~/work/lab_netem_iii$ host_tbf$ ls
Makefile
mininet@mininet-vm:~/work/lab_netem_iii$ host_tbf$ cp ~/work/lab_netem_ii/simple-drop/lab_netem_ii.py ~/work/lab_netem_iii/host_tbf/lab_netem_iii.py
mininet@mininet-vm:~/work/lab_netem_iii$ host_tbf$ ls
lab_netem_iii.py Makefile
mininet@mininet-vm:~/work/lab_netem_iii$ host_tbf$ cp ~/work/lab_netem_i/simple-drop/Makefile ~/work/lab_netem_iii/host_tbf/Makefile
cp: cannot stat '/home/mininet/work/lab_netem_i/simple-drop/Makefile': No such file or directory
mininet@mininet-vm:~/work/lab_netem_iii$ host_tbf$ cp ~/work/lab_netem_i/simple-delay/Makefile ~/work/lab_netem_iii/host_tbf/Makefile
mininet@mininet-vm:~/work/lab_netem_iii$ host_tbf$ ls
lab_netem_iii.py Makefile
mininet@mininet-vm:~/work/lab_netem_iii$ host_tbf$ cp ~/work/lab_netem_i/simple-delay/ping_plot ~/work/lab_netem_iii/host_tbf/ping_plot
mininet@mininet-vm:~/work/lab_netem_iii$ host_tbf$ ls
lab_netem_iii.py Makefile ping_plot
mininet@mininet-vm:~/work/lab_netem_iii$ host_tbf$ mcedit lab_netem_iii.py
```

Рис. 10: Создание каталога для эксперимента

# Ограничение скорости на конечных хостах

```
/home/mininet/work/lab_neterm_iii/host_tbf/lab_neterm_iii.py [-H--] 32 L:[ 1+47 -48/ 53] *(1342/1222b) 10 0x06A
#!/usr/bin/env python

"""
Simple experiment.
Output: ping.dat
"""

from mininet.net import Mininet
from mininet.node import Controller
from mininet.cli import CLI
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 switches\n')
    s1 = net.addSwitch( 's1' )
    s2 = net.addSwitch( 's2' )

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

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

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

    time.sleep(10)

    info('*** Traffic generation\n')
    h2.cmdPrint('iperf3 -s &')
    h2.cmdPrint('iperf3 -c ' + h2.IP() + ' | grep "MBytes" | awk \'{print $7}\' > ping.dat')

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

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

## Ограничение скорости на конечных хостах

```
/home/mininet/work/lab_netem_iii/host_tbf/ping_plot [-M  
#!/usr/bin/gnuplot --persist  
  
set terminal png crop  
set output 'ping.png'  
set xlabel "Packet number"  
set ylabel "Rate (Gbytes/sec)"  
set grid  
plot "ping.dat" with lines
```

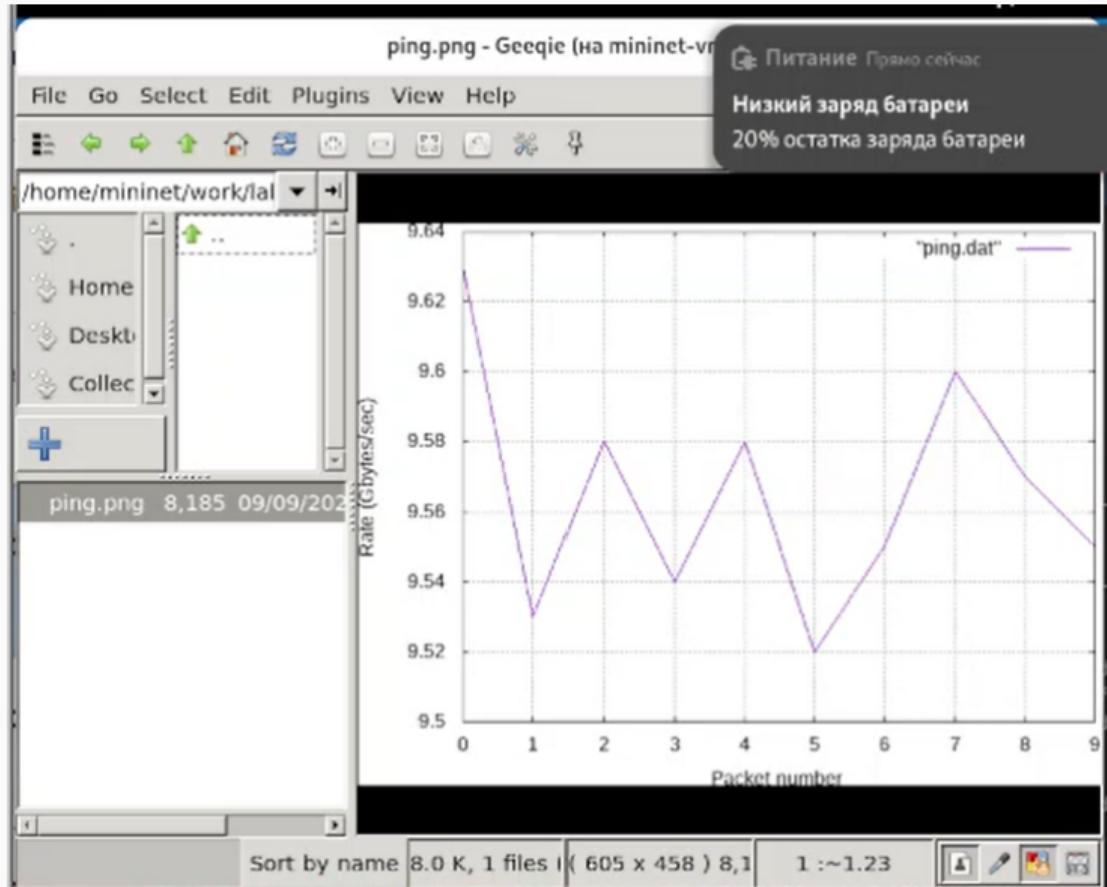
**Рис. 12:** Скрипт для отрисовки графика

# Ограничение скорости на конечных хостах

```
mininet@mininet-vm:~/work/lab_netem_iii/host_tbf$ make
sudo python lab_netem_iii.py
*** Adding controller
*** Adding hosts
*** Adding switches
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 2 switches
s1 s2 ...
*** Waiting for switches to connect
s1 s2
*** Set rate
*** h1 : ('sudo tc qdisc add dev h1-eth0 root tbf rate 10gbit burst 5000000 limit 15000000',)
*** Traffic generation
*** h2 : ('iperf3 -s &')
*** h1 : ('iperf3 -c ', '10.0.0.2', '| grep "MBytes" | awk \'{print $7}\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 3 links
...
*** Stopping 2 switches
s1 s2
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
mininet@mininet-vm:~/work/lab_netem_iii/host_tbf$ ls
lab_netem_iii.py Makefile ping.dat ping_plot ping.png
mininet@mininet-vm:~/work/lab_netem_iii/host_tbf$ geeqie ping.png
```

Рис. 13: Запуск эксперимента

# Ограничение скорости на конечных хостах



# Ограничение скорости на коммутаторах

```
mininet@mininet-vm:~/work/lab_neten_iii/host_tbf$ cd ..
mininet@mininet-vm:~/work/lab_neten_iii$ mkdir -p switch_tbf
mininet@mininet-vm:~/work/lab_neten_iii$ cd switch_tbf
mininet@mininet-vm:~/work/lab_neten_iii/switch_tbf$ cp ~/work/lab_neten_iii/host_tbf/lab_neten_iii.py ~/work/lab_neten_iii/switch_tbf/lab_neten_iii.py
mininet@mininet-vm:~/work/lab_neten_iii/switch_tbf$ cp ~/work/lab_neten_iii/host_tbf/Makefile ~/work/lab_neten_iii/switch_tbf/Makefile
mininet@mininet-vm:~/work/lab_neten_iii/switch_tbf$ cp ~/work/lab_neten_iii/host_tbf/ping_plot ~/work/lab_neten_iii/switch_tbf/ping_plot
mininet@mininet-vm:~/work/lab_neten_iii/switch_tbf$ mcedit lab_neten_iii.py
```

**Рис. 15:** Создание каталога для эксперимента

# Ограничение скорости на коммутаторах

```
/home/mininet/work/lab_neterm_iii/switch_tbf/lab_neterm_iii.py  (----)  0 L:[ 1+37 38/ 53] *(803 /1222b)  16 0x0A
#!/usr/bin/env python

"""
Simple experiment.
Output: ping.dat
"""

from mininet.net import Mininet
from mininet.node import Controller
from mininet.cli import CLI
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 switches\n')
    s1 = net.addSwitch( 's1' )
    s2 = net.addSwitch( 's2' )

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

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

    info('*** Set rate\n')
    s1.cmdPrint('sudo tc qdisc add dev s1-eth2 root tbf rate 10gbit burst 5000000 limit 15000000')

    time.sleep(10)

    info('*** Traffic generation\n')
    h2.cmdPrint('iperf3 -s 8')
    h1.cmdPrint('iperf3 -c ', h2.IP(), '| grep "HBytes" | awk \'{print $7}\'' > ping.dat')

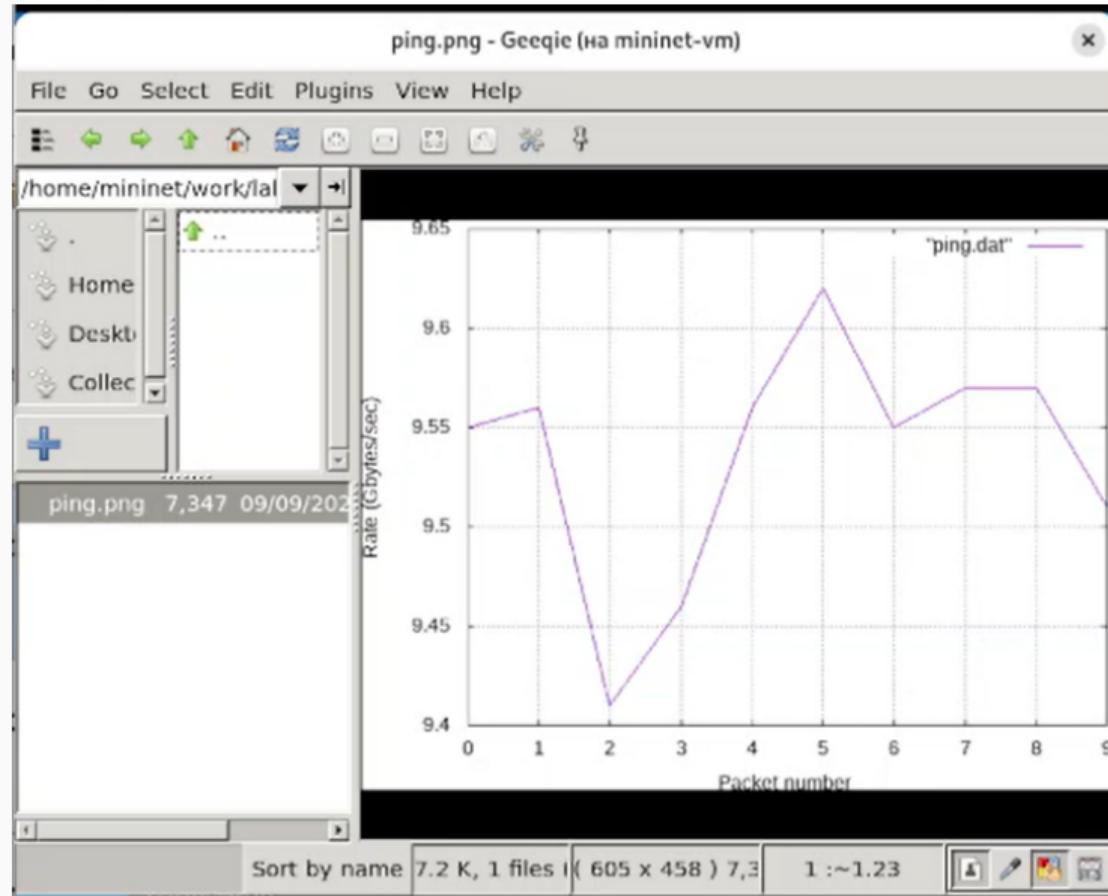
    info('*** Stopping network')
    net.stop()

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

# Ограничение скорости на коммутаторах

```
mininet@mininet-vm:/work/lab_neterm_iii/switch_tb$ make
sudo python lab_neterm_iii.py
*** Adding controller
*** Adding hosts
*** Adding switches
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 2 switches
s1 s2 ...
*** Waiting for switches to connect
s1 s2
*** Set rate
*** s1 : ('sudo tc qdisc add dev s1-eth2 root tb1 rate 10gbit burst 5000000 limit 15000000',)
*** Traffic generation
*** h2 : ('iperf3 -s &')
*** h1 : ('iperf3 -c '10.0.0.2' | grep "MBytes" | awk '{print $7}' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 3 links
...
*** Stopping 2 switches
s1 s2
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
mininet@mininet-vm:/work/lab_neterm_iii/switch_tb$ geeqie ping.png
Gtk-Message: 17:05:28.022: Failed to load module "canberra-gtk-module"
Gtk-Message: 17:05:28.022: Failed to load module "pk-gtk-module"
mininet@mininet-vm:/work/lab_neterm_iii/switch_tb$ cat ping.dat
9.55
9.56
9.41
9.46
9.56
9.62
9.55
9.57
9.57
9.51
mininet@mininet-vm:/work/lab_neterm_iii/switch_tb$ cd ..
```

# Ограничение скорости на коммутаторах



# Объединение NETEM и TBF

```
mininet@mininet-vm:~/work/lab_netem_iii/switch_tbfs$ cd ..
mininet@mininet-vm:~/work/lab_netem_iii$ mkdir -p simple_netem_tbf
mininet@mininet-vm:~/work/lab_netem_iii$ cd simple_netem_tbf
mininet@mininet-vm:~/work/lab_netem_iii/simple_netem_tbfs$ cp ~/work/lab_netem_iii/host_tbf/lab_netem_iii.py ~/
mininet@mininet-vm:~/work/lab_netem_iii/simple_netem_tbfs$ cp ~/work/lab_netem_iii/host_tbf/Makefile ~/work/lab_netem_iii/simple_netem_tbf/Makefile
mininet@mininet-vm:~/work/lab_netem_iii/simple_netem_tbfs$ cp ~/work/lab_netem_iii/host_tbf/ping_plot ~/work/lab_netem_iii/simple_netem_tbf/ping_plot
mininet@mininet-vm:~/work/lab_netem_iii/simple_netem_tbfs$ ncedit lab_netem_iii.py
```

**Рис. 19:** Создание каталога для эксперимента

# Объединение NETEM и TBF

```
/home/mininet/work/lab_neterm_iii/simple_neterm_tbf/lab_neterm_iii.py [-M--] 76 L:[ 1+39 40/ 54] +(997 /1330b) 109 0x06D
#!/usr/bin/env python

"""
Simple experiment.
Output: ping.dat
"""

from mininet.net import Mininet
from mininet.node import Controller
from mininet.cli import CLI
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 switches\n')
    s1 = net.addSwitch( 's1' )
    s2 = net.addSwitch( 's2' )

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

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

    info('*** Set rate\n')
    s1.cmdPrint('sudo tc qdisc add dev s1-eth2 root handle 1: netem delay 10ms corrupt 0.01%')
    s1.cmdPrint('sudo tc qdisc add dev s1-eth2 parent 1: handle 2: tbf rate 2gbps burst 1000000 limit 2000000')

    time.sleep(10)

    info('*** Traffic generation\n')
    h2.cmdPrint('iperf3 -s &')
    h1.cmdPrint('iperf3 -c %s --port 5201 | grep "MBytes" | awk \'{print $7}\' > ping.dat')

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

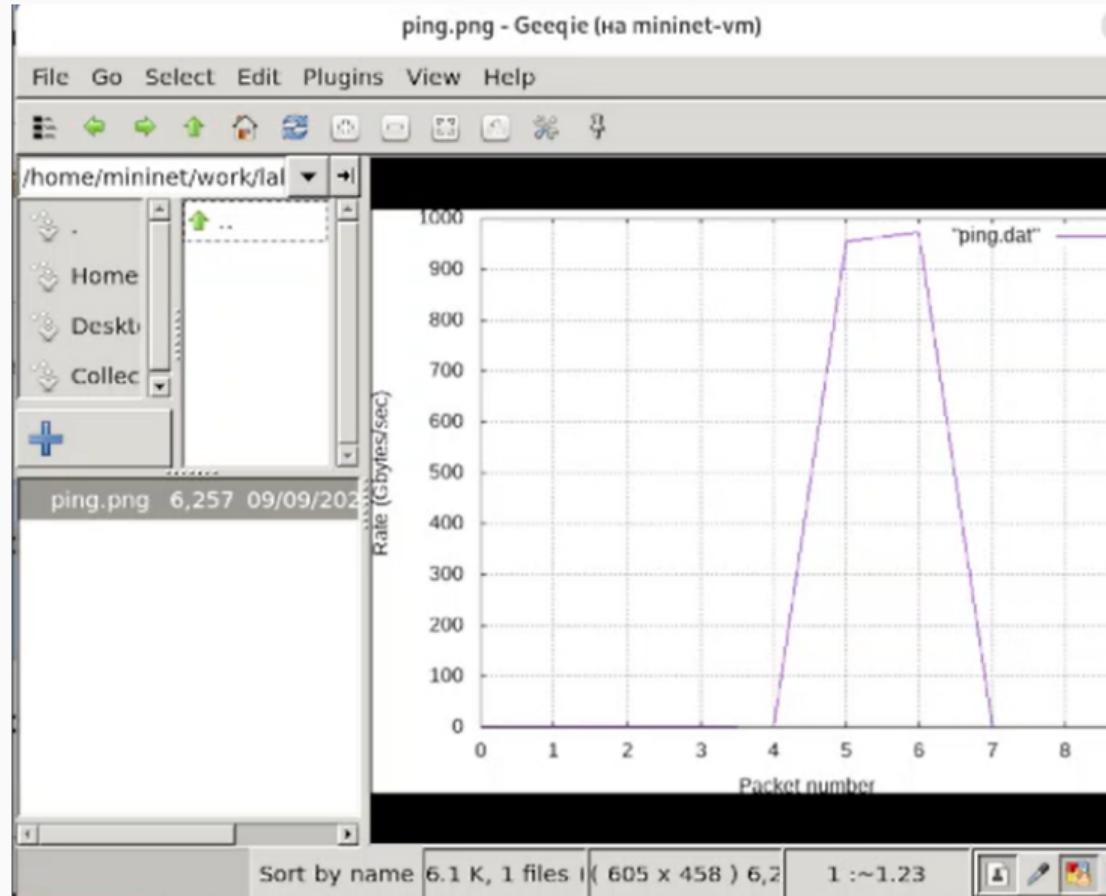
if __name__ == '__main__':
    setLogLevel('info')
    emptyNet()
```



# Объединение NETEM и TBF

```
mininet@mininet-vm:~/work/lab_netem_iii/simple_netem_tbf$ make
sudo python lab_netem_iii.py
*** Adding controller
*** Adding hosts
*** Adding switches
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 2 switches
s1 s2 ...
*** Waiting for switches to connect
s1 s2
*** Set rate
*** s1 : ('sudo tc qdisc add dev s1-eth2 root handle 1: netem delay 10ms corrupt 0.01%')
*** s1 : ('sudo tc qdisc add dev s1-eth2 parent 1: handle 2: tbf rate 2gbit burst 1000000 limit 2000000')
*** Traffic generation
*** h2 : ('iperf3 -s &')
*** h1 : ('iperf3 -c ', '10.0.0.2', '| grep "MBytes" | awk \'{print $7}\' > ping.dat')
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 3 links
...
*** Stopping 2 switches
s1 s2
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
./ping_plot
mininet@mininet-vm:~/work/lab_netem_iii/simple_netem_tbf$ geeqie ping.png
Gtk-Message: 17:13:31.060: Failed to load module "canberra-gtk-module"
Gtk-Message: 17:13:31.060: Failed to load module "pk-gtk-module"
mininet@mininet-vm:~/work/lab_netem_iii/simple_netem_tbf$ cat ping.dat
1.32
1.66
1.65
1.37
1.06
954
973
1.04
1.04
1.11
```

# Объединение NETEM и TBF



## Выводы

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