

Лабораторная работа 6

Настройка пропускной способности глобальной сети с помощью Token Bucket Filter

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Информация

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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.

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

Выполнение лабораторной работы

```
login as: mininet
mininet@172.16.176.128'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

Failed to connect to https://changelogs.ubuntu.com/meta-release-lts. Check your
Internet connection or proxy settings

Last login: Sat Sep 20 12:34:52 2025 from 172.16.176.1
mininet@mininet-vm:~$ xauth list $DISPLAY
mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 5fe0a3201a9b14974249409217666a2a
mininet@mininet-vm:~$ sudo -i
root@mininet-vm:~# xauth add ^C
root@mininet-vm:~# xauth add mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 5fe0a3201a9b14974249409217666a2a
root@mininet-vm:~# logout
mininet@mininet-vm:~$
```

Рис. 1: Исправление MIT magic cookie

Выполнение лабораторной работы



```
mininet@mininet-vm:~$ sudo mn --topo=linear,2 -R
*** Creating network
*** Adding controller
*** Addi
h1 h2
*** Addi
s1 s2
*** Addi
(h1, s1)
*** Conf
h1 h2
*** Runn
*** Star
c0
***
s1 s2
***
mininet
root@mininet-vm:/home/mininet#
root@mininet-vm:/home/mininet#
root@mininet-vm:/home/mininet#
root@mininet-vm:/home/mininet#
root@mininet-vm:/home/mininet#
```

Рис. 2: Простейшая топология

Выполнение лабораторной работы

```
X root@mininet-vm:/home/mininet# ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 172.18.178.128 netmask 255.255.255.0 broadcast 172.18.1
    ether 00:0c:29:64:ca:c6 txqueuelen 1000 (Ethernet)
    RX packets 30731 bytes 48063329 (45.8 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 81960 bytes 48708864 (46.7 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 172.18.18.128 netmask 255.255.255.0 broadcast 172.18.18.1
    ether 00:0c:29:64:ca:c6 txqueuelen 1000 (Ethernet)
    RX packets 30778 bytes 48063329 (45.8 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 78460 bytes 4890033 (4.6 MB)
    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 71630 bytes 43086715 (42.4 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 71630 bytes 43086715 (42.4 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

sl-eth3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    ether c2:73:70:76:a1:5c txqueuelen 1000 (Ethernet)
    RX packets 8 bytes 0 (8.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 8 bytes 0 (8.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

sl-eth2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    ether 06:07:a1:1b:07:c3 txqueuelen 1000 (Ethernet)
    RX packets 8 bytes 0 (8.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0

X root@mininet-vm:/home/mininet# ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 172.18.178.128 netmask 255.255.255.0 broadcast 172.18.178.255
    ether 00:0c:29:64:ca:c6 txqueuelen 1000 (Ethernet)
    RX packets 30806 bytes 4821880 (4.6 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 82016 bytes 48708864 (46.7 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 172.18.18.128 netmask 255.255.255.0 broadcast 172.18.18.255
    ether 00:0c:29:64:ca:c6 txqueuelen 1000 (Ethernet)
    RX packets 30778 bytes 48063329 (45.8 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 78460 bytes 4890033 (4.6 MB)
    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 71653 bytes 43086715 (42.4 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 71653 bytes 43086715 (42.4 MB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

sl-eth3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    ether c2:73:70:76:a1:5c txqueuelen 1000 (Ethernet)
    RX packets 8 bytes 0 (8.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 8 bytes 0 (8.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

sl-eth2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    ether 06:07:a1:1b:07:c3 txqueuelen 1000 (Ethernet)
    RX packets 8 bytes 0 (8.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
```

Рис. 3: ifconfig на коммутаторах s1 и s2

Выполнение лабораторной работы

```
root@mininet-vm:/home/mininet# ifconfig
h1-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 36:cc:ad:5b:ce:ad 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 1222 bytes 291544 (291.5 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1222 bytes 291544 (291.5 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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

```
root@mininet-vm:/home/mininet# ifconfig
h2-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 2a:50:35:b2:28:62 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 1164 bytes 290696 (290.6 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1164 bytes 290696 (290.6 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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

Рис. 4: ifconfig на хостат h1 и h2

```
root@mininet-vm:/home/mininet# ping 10.0.0.2 -c 4
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=26.2 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.204 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.245 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3022ms
rtt min/avg/max/mdev = 0.204/6.927/26.183/11.122 ms
root@mininet-vm:/home/mininet#
```

Рис. 5: Проверка соединения между хостами

Выполнение лабораторной работы

```
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 35052
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 35054
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec    275 MBytes  2.30 Gbits/sec
[ 7] 1.00-2.00 sec    234 MBytes  1.97 Gbits/sec
[ 7] 2.00-3.00 sec    250 MBytes  2.10 Gbits/sec
[ 7] 3.00-4.00 sec    224 MBytes  1.88 Gbits/sec
[ 7] 4.00-5.00 sec    177 MBytes  1.49 Gbits/sec
X host: h1@mininet-vm
--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3022ms
rtt min/avg/max/mdev = 0.204/6.927/26.183/11.122 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 35054 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate    Retr    Cwnd
[ 7] 0.00-1.00 sec    278 MBytes  2.32 Gbits/sec    0    4.74 MBytes
[ 7] 1.00-2.01 sec    234 MBytes  1.94 Gbits/sec    0    4.98 MBytes
[ 7] 2.01-3.00 sec    251 MBytes  2.13 Gbits/sec    0    4.98 MBytes
[ 7] 3.00-4.01 sec    224 MBytes  1.87 Gbits/sec    0    4.98 MBytes
[ 7] 4.01-5.01 sec    176 MBytes  1.47 Gbits/sec    0    4.98 MBytes
[ 7] 5.01-6.01 sec    198 MBytes  1.65 Gbits/sec    0    4.98 MBytes
[ 7] 6.01-7.01 sec    138 MBytes  1.16 Gbits/sec    0    4.98 MBytes
[ 7] 7.01-8.01 sec    231 MBytes  1.94 Gbits/sec    0    4.98 MBytes
[ 7] 8.01-9.01 sec    275 MBytes  2.30 Gbits/sec    0    4.98 MBytes
[ 7] 9.01-10.01 sec   265 MBytes  2.23 Gbits/sec    0    4.98 MBytes
-----
[ ID] Interval      Transfer    Bitrate    Retr
[ 7] 0.00-10.01 sec  2.22 GBytes  1.90 Gbits/sec    0
[ 7] 0.00-10.02 sec  2.22 GBytes  1.90 Gbits/sec    0
sender
receiver

iperf Done.
```

Рис. 6: Запуск iperf3 на хостах

Выполнение лабораторной работы

```
root@mininet-virtual-machine:/home/mininet# sudo tc qdisc add dev h1-eth0 root tbf rate 10gb  
it burst 5000000 limit 15000000  
Error: Exclusivity flag on, cannot modify.  
root@mininet-virtual-machine:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config-`uname -r`  
CONFIG_HZ_250=y  
root@mininet-virtual-machine:/home/mininet#
```

Рис. 7: Ограничение скорости на конечных хостах

Выполнение лабораторной работы

```
host: h2"@"mininet-vm
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 35060
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 35062
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec   459 MBytes  3.85 Gbits/sec
[ 7] 1.00-2.00 sec   474 MBytes  3.97 Gbits/sec
[ 7] 2.00-3.00 sec   482 MBytes  4.04 Gbits/sec
[ 7] 3.00-4.00 sec   476 MBytes  3.99 Gbits/sec
[ 7] 4.00-5.00 sec   466 MBytes  3.91 Gbits/sec
[ 7] 5.00-6.00 sec   466 MBytes  3.91 Gbits/sec
[ 7] 6.00-7.00 sec   478 MBytes  4.01 Gbits/sec
[ 7] 7.00-8.00 sec   477 MBytes  4.00 Gbits/sec
[ 7] 8.00-9.00 sec   481 MBytes  4.04 Gbits/sec
[ 7] 9.00-10.00 sec  481 MBytes  4.03 Gbits/sec
[ 7] 10.00-10.00 sec 1.00 MBytes  2.11 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00 sec 4.63 GBytes  3.97 Gbits/sec
receiver

host: h1"@"mininet-vm

iperf Done.
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 35062 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate  Retr  Cwnd
[ 7] 0.00-1.00 sec   467 MBytes  3.92 Gbits/sec    0   513 KBytes
[ 7] 1.00-2.00 sec   474 MBytes  3.97 Gbits/sec    0   513 KBytes
[ 7] 2.00-3.00 sec   482 MBytes  4.04 Gbits/sec    0   513 KBytes
[ 7] 3.00-4.00 sec   475 MBytes  3.99 Gbits/sec    0   513 KBytes
[ 7] 4.00-5.00 sec   468 MBytes  3.92 Gbits/sec    0   513 KBytes
[ 7] 5.00-6.00 sec   465 MBytes  3.91 Gbits/sec    0   513 KBytes
[ 7] 6.00-7.00 sec   477 MBytes  4.00 Gbits/sec    0   513 KBytes
[ 7] 7.00-8.00 sec   477 MBytes  4.00 Gbits/sec    0   513 KBytes
[ 7] 8.00-9.00 sec   481 MBytes  4.04 Gbits/sec    0   513 KBytes
[ 7] 9.00-10.00 sec   481 MBytes  4.04 Gbits/sec    0   513 KBytes
-----
[ ID] Interval      Transfer    Bitrate  Retr
[ 7] 0.00-10.00 sec 4.64 GBytes  3.98 Gbits/sec    0
[ 7] 0.00-10.00 sec 4.63 GBytes  3.97 Gbits/sec
sender
receiver
```

Рис. 8: Проверка пропускной способности

Выполнение лабораторной работы

```
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 35080
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 35082
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec    444 MBytes    3.73 Gbits/sec
[ 7] 1.00-2.00 sec    567 MBytes    4.25 Gbits/sec
[ 7] 2.00-3.00 sec    499 MBytes    4.19 Gbits/sec
[ 7] 3.00-4.00 sec    484 MBytes    4.05 Gbits/sec
[ 7] 4.00-5.01 sec    499 MBytes    4.18 Gbits/sec
[ 7] 5.01-6.00 sec    495 MBytes    4.16 Gbits/sec
[ 7] 6.00-7.00 sec    504 MBytes    4.23 Gbits/sec
[ 7] 7.00-8.00 sec    503 MBytes    4.22 Gbits/sec
[ 7] 8.00-9.00 sec    515 MBytes    4.31 Gbits/sec
[ 7] 9.00-10.00 sec   472 MBytes    3.97 Gbits/sec
-----
X host: h1@mininet-vm

iperf Done.
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 35082 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr      Cwnd
[ 7] 0.00-1.00 sec    470 MBytes    3.94 Gbits/sec    0      2.79 MBytes
[ 7] 1.00-2.00 sec    508 MBytes    4.25 Gbits/sec    0      2.79 MBytes
[ 7] 2.00-3.00 sec    499 MBytes    4.18 Gbits/sec    0      2.79 MBytes
[ 7] 3.00-4.00 sec    484 MBytes    4.06 Gbits/sec    0      2.79 MBytes
[ 7] 4.00-5.00 sec    499 MBytes    4.19 Gbits/sec    0      2.79 MBytes
[ 7] 5.00-6.00 sec    495 MBytes    4.15 Gbits/sec    0      2.79 MBytes
[ 7] 6.00-7.00 sec    504 MBytes    4.22 Gbits/sec    0      2.93 MBytes
[ 7] 7.00-8.00 sec    502 MBytes    4.22 Gbits/sec    0      2.93 MBytes
[ 7] 8.00-9.00 sec    515 MBytes    4.32 Gbits/sec    0      2.93 MBytes
[ 7] 9.00-10.00 sec   471 MBytes    3.95 Gbits/sec    0      2.93 MBytes
-----
[ ID] Interval      Transfer      Bitrate      Retr      sender
[ 7] 0.00-10.00 sec  4.83 GBytes    4.15 Gbits/sec    0
[ 7] 0.00-10.01 sec  4.81 GBytes    4.13 Gbits/sec    0      receiver
```

Рис. 9: Ограничение скорости на коммутаторах

Выполнение лабораторной работы

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev sl-eth2 root handle 1: netem delay 10ms
```

```
host: h1" @mininet-vm
```

```
iperf Done.
```

```
root@mininet-vm:/home/mininet# ping 10.0.0.2 -c 4
```

```
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=23.4 ms
```

```
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=15.1 ms
```

```
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=12.3 ms
```

```
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=10.9 ms
```

```
--- 10.0.0.2 ping statistics ---
```

```
4 packets transmitted, 4 received, 0% packet loss, time 3008ms
```

```
rtt min/avg/max/mdev = 10.908/15.438/23.424/4.847 ms
```

Рис. 10: Объединение NETEM и TBF

Выполнение лабораторной работы

```
Accepted connection from 10.0.0.1, port 35100
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 35102
[ ID] Interval      Transfer    Bitrate
[ 7]  0.00-1.00 sec  175 MBytes  1.45 Gbits/sec
[ 7]  1.01-2.01 sec  226 MBytes  1.89 Gbits/sec
[ 7]  2.01-3.01 sec  227 MBytes  1.90 Gbits/sec
[ 7]  3.01-4.00 sec  218 MBytes  1.84 Gbits/sec
[ 7]  4.00-5.01 sec  217 MBytes  1.80 Gbits/sec
[ 7]  5.01-6.00 sec  152 MBytes  1.29 Gbits/sec
[ 7]  6.00-7.00 sec  119 MBytes  998 Mbits/sec
[ 7]  7.00-8.00 sec  101 MBytes  847 Mbits/sec
[ 7]  8.00-9.00 sec   111 MBytes  929 Mbits/sec

root@mininet-vm: /home/mininet-vm
root@mininet-vm: /home/mininet-vm# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 35102 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7]  0.00-1.00 sec  187 MBytes  1.57 Gbits/sec  135  3.21 MBytes
[ 7]  1.00-2.00 sec  226 MBytes  1.90 Gbits/sec   0  3.46 MBytes
[ 7]  2.00-3.00 sec  226 MBytes  1.90 Gbits/sec   0  3.67 MBytes
[ 7]  3.00-4.00 sec  218 MBytes  1.83 Gbits/sec  180  2.71 MBytes
[ 7]  4.00-5.00 sec  216 MBytes  1.81 Gbits/sec   0  2.83 MBytes
[ 7]  5.00-6.00 sec  151 MBytes  1.27 Gbits/sec  270  2.10 MBytes
[ 7]  6.00-7.00 sec  120 MBytes  1.01 Gbits/sec   23  1.56 MBytes
[ 7]  7.00-8.00 sec  101 MBytes  849 Mbits/sec   0  1.65 MBytes
[ 7]  8.00-9.00 sec  110 MBytes  923 Mbits/sec   0  1.72 MBytes
[ 7]  9.00-10.00 sec 120 MBytes  1.01 Gbits/sec   0  1.76 MBytes
- - - - -
[ ID] Interval      Transfer    Bitrate      Retr  sender receiver
[ 7]  0.00-10.00 sec  1.64 GBytes  1.41 Gbits/sec  608
[ 7]  0.00-10.01 sec  1.63 GBytes  1.40 Gbits/sec

iperf Done.
```

Рис. 11: Объединение NETEM и TBF

Выполнение лабораторной работы

```
mininet@mininet-vm:~$ mkdir -p ~/work/lab_netem_iii/simple-tbf
mininet@mininet-vm:~$ cd ~/work/lab_netem_iii/simple-tbf
mininet@mininet-vm:~/work/lab_netem_iii/simple-tbf$ touch lab_netem_iii.py
mininet@mininet-vm:~/work/lab_netem_iii/simple-tbf$ nano lab_netem_iii.py
```

Рис. 12: Создание рабочего каталога

Выполнение лабораторной работы

```
GNU nano 4.8 lab_caten iii.py
#!/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 switch\n' )
    s1 = net.addSwitch( 's1' )

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

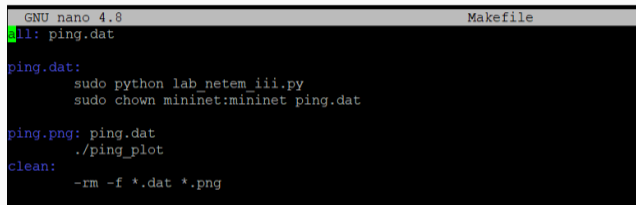
    info( '*** Starting network\n' )
    net.start()

    info( '*** Set rate\n' )
    h1.cmdPrint('tc qdisc add dev h1-eth0 root tbf rate 8gbit burst 5000000 limit 10000000')

    time.sleep(10) # Wait 10 seconds

    info( '*** Starting iperf server on h2\n' )
    h2.cmdPrint('iperf3 -s 4')
    info( '*** Running iperf client from h1 to h2\n' )
    h1.cmdPrint('iperf3 -c ' + h2.IP() + ' | grep "Mbytes" | awk '{print $7}' > ping.dat')
```

Рис. 13: Создание рабочего каталога



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

ping.dat:
    sudo python lab_netem_iii.py
    sudo chown mininet:mininet ping.dat

ping.png: ping.dat
    ./ping_plot

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

Рис. 14: Makefile для управления процессом проведения эксперимента



```
GNU nano 4.8                                ping_plot
#!/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. 15: Создание файла для изображения графика

Выполнение лабораторной работы

```
mininet@mininet-vm:~/work/lab_netem_iii/simple-tbfs$ make
sudo python lab_netem_iii.py
*** Adding controller
*** Adding hosts
*** Adding switch
*** Creating links
*** Starting network
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Waiting for switches to connect
s1
*** Set rate
*** h1 : ('tc qdisc add dev h1-eth0 root tbfb rate 8gbit burst 5000000 limit 10000000',)
*** Starting iperf server on h2
*** h2 : ('iperf3 -s &',)
*** Running iperf client from h1 to h2
*** h1 : ('iperf3 -c 10.0.0.2 | grep "MBytes" | awk '{print $7}' > ping.dat',)
*** Stopping network*** Stopping 1 controllers
c0
*** Stopping 2 links
..
*** Stopping 1 switches
s1
*** Stopping 2 hosts
h1 h2
*** Done
sudo chown mininet:mininet ping.dat
```

Рис. 16: Запуск эксперимента

Выполнение лабораторной работы

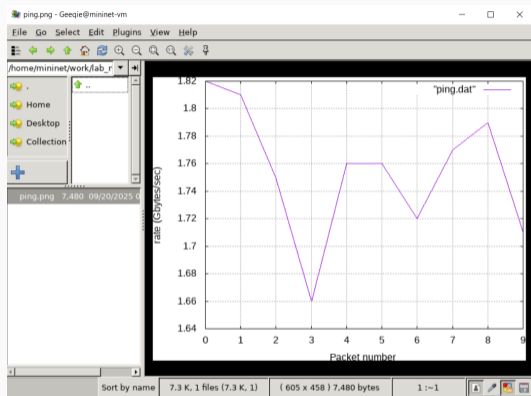


Рис. 17: График изменения скорости передачи

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.