

Лабораторная работа № 6

Настройка пропускной способности глобальной сети с помощью Token Bucket Filter

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Информация

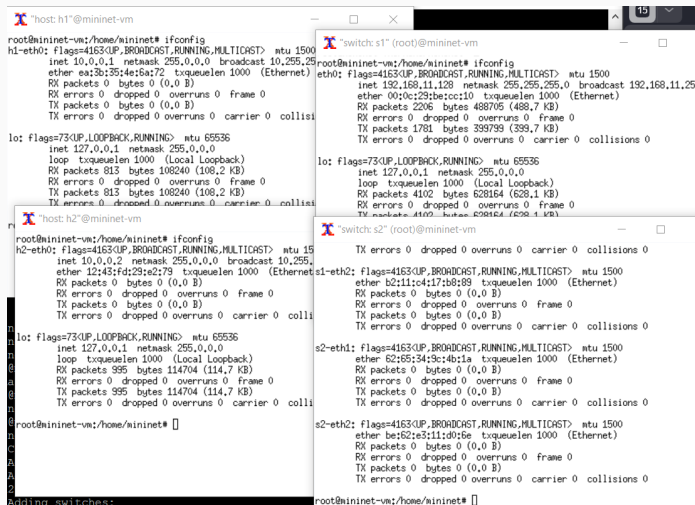
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Основной целью работы является знакомство с принципами работы дисциплины очереди Token Bucket Filter, которая формирует входящий/исходящий трафик для ограничения пропускной способности, а также получение навыков моделирования и исследования поведения 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



```
host: h1" @mininet-vm
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 10.255.255.0
    ether ea:3b:35:4e:6a:72 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 813 bytes 108240 (108.2 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 813 bytes 108240 (108.2 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet#

host: h2" @mininet-vm
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 10.255.255.0
    ether 12:43:fd:29:e2:79 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 995 bytes 114704 (114.7 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 995 bytes 114704 (114.7 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet#

Adding switches:

switch: s1" (root) @mininet-vm
root@mininet-vm:/home/mininet# ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.11.128 netmask 255.255.255.0 broadcast 192.168.11.255
    ether 00:0c:29:b6:cc:10 txqueuelen 1000 (Ethernet)
    RX packets 2206 bytes 488705 (488.7 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 1781 bytes 399799 (399.7 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 4102 bytes 628164 (628.1 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 4102 bytes 628164 (628.1 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

s1-eth2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    ether b2:11:c4:17:b8:89 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 62:65:34:9c:4b:1a 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 be:62:e3:11:d0:6e 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#
```

Рис. 1: Задание топологии

Выполнение лабораторной работы

```

"host: h1"@mininet-vm
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet# ping -c 4
ping: usage error: Destination address required
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=15.6 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=0.707 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.118 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.096 ms

--- 10.0.0.2 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3055ms
rtt min/avg/max/mdev = 0.096/4.133/15.637/6.642 ms
root@mininet-vm:/home/mininet#

"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 995 bytes 114704 (114.7 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 995 bytes 114704 (114.7 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=23.9 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.099 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.255 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.114 ms

--- 10.0.0.1 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3038ms
rtt min/avg/max/mdev = 0.099/6.099/23.928/10.293 ms
root@mininet-vm:/home/mininet#
```

Рис. 2: ifconfig на хостах

Выполнение лабораторной работы

```
host: h1" @mininet-vm
rtt min/avg/max/ndev = 0,096/4,139/15,637/6,642 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 32826 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  1.29 GBytes 11,0 Gbits/sec  0    379 KBytes
[ 7] 1.00-2.00 sec  1.11 GBytes 9,55 Gbits/sec  0    379 KBytes
[ 7] 2.00-3.01 sec  966 MBytes 8,05 Gbits/sec  0    379 KBytes
[ 7] 3.01-4.00 sec  1.12 GBytes 9,73 Gbits/sec  0    560 KBytes
[ 7] 4.00-5.00 sec  980 MBytes 8,36 Gbits/sec  0    560 KBytes
[ 7] 5.00-6.00 sec  784 MBytes 6,59 Gbits/sec  0    3,37 MBytes
[ 7] 6.00-7.00 sec  878 MBytes 7,36 Gbits/sec  0    6,66 MBytes
[ 7] 7.00-8.00 sec  1.24 GBytes 10,7 Gbits/sec  0    8,10 MBytes
[ 7] 8.00-9.00 sec  1.20 GBytes 10,3 Gbits/sec  0    8,10 MBytes
[ 7] 9.00-10.00 sec 1.11 GBytes 9,53 Gbits/sec  0    8,10 MBytes
-----
[ ID] Interval      Transfer    Bitrate      Retr
[ 7] 0.00-10.00 sec 10,6 GBytes 9,12 Gbits/sec  0
                                     sender
[ 7] 0.00-10.00 sec 10,6 GBytes 9,12 Gbits/sec
                                     receiver

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

host: h2" @mininet-vm
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 32824
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 32826
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec  1.28 GBytes 11,0 Gbits/sec
[ 7] 1.00-2.00 sec  1.11 GBytes 9,55 Gbits/sec
[ 7] 2.00-3.00 sec  966 MBytes 8,11 Gbits/sec
[ 7] 3.00-4.00 sec  1.12 GBytes 9,66 Gbits/sec
[ 7] 4.00-5.00 sec  997 MBytes 8,37 Gbits/sec
[ 7] 5.00-6.00 sec  785 MBytes 6,58 Gbits/sec
[ 7] 6.00-7.00 sec  877 MBytes 7,36 Gbits/sec
[ 7] 7.00-8.00 sec  1.24 GBytes 10,6 Gbits/sec
[ 7] 8.00-9.00 sec  1.20 GBytes 10,3 Gbits/sec
[ 7] 9.00-10.00 sec 1.11 GBytes 9,53 Gbits/sec
[ 7] 10.00-10.00 sec 704 KBytes 5,39 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00 sec 10,6 GBytes 9,12 Gbits/sec
                                     receiver

Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
```

Рис. 3: Запуск iperf3 на хостах

Выполнение лабораторной работы

```
host h1@mininet-vm
iperf Done.
root@mininet-vm:/home/mininet# sudo tc qdisc add dev hi-eth0 root tbf rate 10gb
lt burst 5000000 limit 15000000
root@mininet-vm:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config-`uname -r`
CONFIG_HZ_250=y
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 32830 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer    Bitrate    Retr  Cwnd
[ 7] 0.00-1.00 sec  1002 MBytes  8.39 Gbits/sec  0    5.40 MBytes
[ 7] 1.00-2.00 sec   760 MBytes  6.37 Gbits/sec  0    5.67 MBytes
[ 7] 2.00-3.00 sec   939 MBytes  8.36 Gbits/sec  0    7.60 MBytes
[ 7] 3.00-4.00 sec  1.09 GBytes  9.36 Gbits/sec  0    7.97 MBytes
[ 7] 4.00-5.00 sec  1006 MBytes  8.45 Gbits/sec  0    8.37 MBytes
[ 7] 5.00-6.00 sec   936 MBytes  7.85 Gbits/sec  0    8.37 MBytes
[ 7] 6.00-7.00 sec   969 MBytes  8.13 Gbits/sec  0    8.37 MBytes
[ 7] 7.00-8.00 sec  1021 MBytes  8.57 Gbits/sec  0    8.37 MBytes
[ 7] 8.00-9.00 sec   982 MBytes  8.23 Gbits/sec  0    8.37 MBytes
[ 7] 9.00-10.00 sec  1.05 GBytes  9.02 Gbits/sec  0    8.37 MBytes
-----
[ ID] Interval      Transfer    Bitrate    Retr
[ 7] 0.00-10.00 sec  9.63 GBytes  8.27 Gbits/sec  0
[ 7] 0.00-10.00 sec  9.63 GBytes  8.27 Gbits/sec
sender
receiver
iperf Done.
root@mininet-vm:/home/mininet#
@mininet-vm:~# zauth list $DISPLAY
IX packets 0
TV ----- 0

host h2@mininet-vm
[ 7] 0.00-10.00 sec 10.6 GBytes 9.12 Gbits/sec
receiver
-----
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
-----
Accepted connection from 10.0.0.1, port 32828
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 32830
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-1.00 sec   989 MBytes  8.30 Gbits/sec
[ 7] 1.00-2.00 sec   771 MBytes  6.47 Gbits/sec
[ 7] 2.00-3.00 sec   984 MBytes  8.26 Gbits/sec
[ 7] 3.00-4.00 sec  1.10 GBytes  9.46 Gbits/sec
[ 7] 4.00-5.00 sec  1007 MBytes  8.44 Gbits/sec
[ 7] 5.00-6.00 sec   935 MBytes  7.83 Gbits/sec
[ 7] 6.00-7.00 sec   959 MBytes  8.06 Gbits/sec
[ 7] 7.00-8.00 sec  1.00 GBytes  8.61 Gbits/sec
[ 7] 8.00-9.00 sec   976 MBytes  8.20 Gbits/sec
[ 7] 9.00-10.00 sec  1.06 GBytes  9.11 Gbits/sec
[ 7] 10.00-10.00 sec  1.00 MBytes  2.54 Gbits/sec
-----
[ ID] Interval      Transfer    Bitrate
[ 7] 0.00-10.00 sec  9.63 GBytes  8.27 Gbits/sec
receiver
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
```

Рис. 4: Ограничение скорости на конечных хостах

Выполнение лабораторной работы

```
"switch: s1" (root)@mininet-vm
tbtf: illegal value for "burst": "sudo"
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root tb rate 10gbit burst 100k
root@mininet-vm:/home/mininet#

"host: h1" @mininet-vm
[ 7] 9,00-10,00 sec 1,03 GBytes 8,86 Gbits/sec 0 8,03 MBytes

[ ID] Interval      Transfer      Bitrate      Retr
[ 7] 0,00-10,00 sec 10,0 GBytes 8,63 Gbits/sec 0
[ 7] 0,00-10,00 sec 10,0 GBytes 8,63 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# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 32838 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr Cwnd
[ 7] 0,00-1,00 sec 960 MBytes 8,04 Gbits/sec 0 2,32 MBytes
[ 7] 1,00-2,00 sec 1,04 GBytes 8,96 Gbits/sec 0 6,78 MBytes
[ 7] 2,00-3,00 sec 1,06 GBytes 9,15 Gbits/sec 0 7,47 MBytes
[ 7] 3,00-4,00 sec 921 MBytes 7,73 Gbits/sec 0 8,24 MBytes
[ 7] 4,00-5,00 sec 955 MBytes 8,01 Gbits/sec 0 8,24 MBytes
[ 7] 5,00-6,00 sec 1,05 GBytes 9,01 Gbits/sec 0 8,24 MBytes
[ 7] 6,00-7,00 sec 1,11 GBytes 9,52 Gbits/sec 0 8,24 MBytes
[ 7] 7,00-8,00 sec 1,12 GBytes 9,59 Gbits/sec 0 8,24 MBytes
[ 7] 8,00-9,00 sec 1,08 GBytes 9,24 Gbits/sec 0 8,24 MBytes
[ 7] 9,00-10,00 sec 1,08 GBytes 9,25 Gbits/sec 0 8,24 MBytes

[ ID] Interval      Transfer      Bitrate      Retr
[ 7] 0,00-10,00 sec 10,3 GBytes 8,85 Gbits/sec 0
[ 7] 0,00-10,00 sec 10,3 GBytes 8,84 Gbits/sec 0 sender
receiver

"host: h2" @mininet-vm
[ ID] Interval      Transfer      Bitrate
[ 7] 0,00-10,00 sec 10,0 GBytes 8,63 Gbits/sec

Server listening on 5201

iperf3: 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

Accepted connection from 10.0.0.1, port 32836
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 32838
[ ID] Interval      Transfer      Bitrate
[ 7] 0,00-1,00 sec 959 MBytes 8,05 Gbits/sec
[ 7] 1,00-2,00 sec 1,04 GBytes 8,95 Gbits/sec
[ 7] 2,00-3,00 sec 1,05 GBytes 9,05 Gbits/sec
[ 7] 3,00-4,00 sec 932 MBytes 7,82 Gbits/sec
[ 7] 4,00-5,00 sec 952 MBytes 7,99 Gbits/sec
[ 7] 5,00-6,00 sec 1,04 GBytes 8,95 Gbits/sec
[ 7] 6,00-7,00 sec 1,11 GBytes 9,54 Gbits/sec
[ 7] 7,00-8,00 sec 1,11 GBytes 9,56 Gbits/sec
[ 7] 8,00-9,00 sec 1,08 GBytes 9,27 Gbits/sec
[ 7] 9,00-10,00 sec 1,08 GBytes 9,26 Gbits/sec
[ 7] 10,00-10,00 sec 3,73 MBytes 8,77 Gbits/sec

[ ID] Interval      Transfer      Bitrate
[ 7] 0,00-10,00 sec 10,3 GBytes 8,84 Gbits/sec

Server listening on 5201

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

Рис. 5: Ограничение скорости на коммутаторах

Выполнение лабораторной работы

```
"switch: s1" (root)@mininet-vm
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root tbf rate 10gbit burst 5000000 limit 15000000
root@mininet-vm:/home/mininet# sudo tc qdisc del dev s1-eth2 root
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 add dev s1-eth2 parent 1: handle 2: tbf rate 2gbit burst 1000000
limit 2000000
root@mininet-vm:/home/mininet#

"host: h1" @mininet-vm
4 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=14.5 ns
4 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=12.0 ns
4 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=11.1 ns
4 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=10.5 ns

-- 10.0.0.2 ping statistics --
packets transmitted, 4 received, 0% packet loss, time 3005ms
tt min/avg/max/mdev = 10.506/12.007/14.483/1.521 ms
oot@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 32842 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr  Cwnd
[ 7] 0.00-1.00 sec  212 MBytes  1.77 Gbits/sec  225  3.26 MBytes
[ 7] 1.00-2.00 sec  229 MBytes  1.92 Gbits/sec   0  3.50 MBytes
[ 7] 2.00-3.00 sec  228 MBytes  1.91 Gbits/sec   0  3.70 MBytes
[ 7] 3.00-4.00 sec  228 MBytes  1.91 Gbits/sec  90  2.73 MBytes
[ 7] 4.00-5.00 sec  229 MBytes  1.92 Gbits/sec   0  2.87 MBytes
[ 7] 5.00-6.00 sec  228 MBytes  1.91 Gbits/sec   0  2.97 MBytes
[ 7] 6.00-7.00 sec  229 MBytes  1.92 Gbits/sec   0  3.06 MBytes
[ 7] 7.00-8.00 sec  208 MBytes  1.74 Gbits/sec  405  2.25 MBytes
[ 7] 8.00-9.00 sec  215 MBytes  1.80 Gbits/sec   0  2.36 MBytes
[ 7] 9.00-10.00 sec  225 MBytes  1.89 Gbits/sec   0  2.45 MBytes

[ ID] Interval      Transfer      Bitrate      Retr  sender receiver
[ 7] 0.00-10.00 sec  2.18 GBytes  1.87 Gbits/sec  720
[ 7] 0.00-10.02 sec  2.17 GBytes  1.86 Gbits/sec

perf Done.
oot@mininet-vm:/home/mininet#

"host: h2" @mininet-vm
[ 7] 0.00-10.00 sec  10.3 GBytes  8.84 Gbits/sec receiver

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

Accepted connection from 10.0.0.1, port 32840
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 32842
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec  201 MBytes  1.68 Gbits/sec
[ 7] 1.00-2.00 sec  228 MBytes  1.91 Gbits/sec
[ 7] 2.00-3.00 sec  228 MBytes  1.91 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  1.91 Gbits/sec
[ 7] 7.00-8.00 sec  208 MBytes  1.75 Gbits/sec
[ 7] 8.00-9.00 sec  215 MBytes  1.80 Gbits/sec
[ 7] 9.00-10.00 sec  225 MBytes  1.89 Gbits/sec
[ 7] 10.00-10.02 sec  2.00 MBytes  1.06 Gbits/sec

[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-10.02 sec  2.17 GBytes  1.86 Gbits/sec receiver

Server listening on 5201

^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#
```

Рис. 6: Объединение NETEM и TBF

Выполнение лабораторной работы

```
GNU nano 4.8 lab netem ii.py
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' )

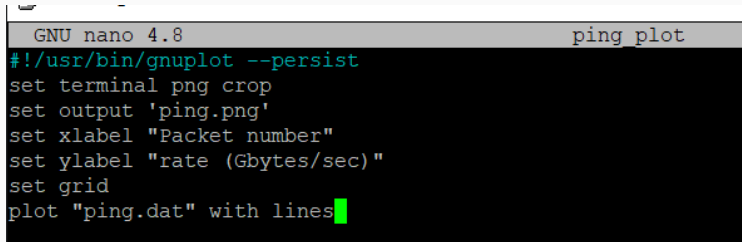
    h1.cmdPrint('tc qdisc add dev h1-eth0 root tbf rate 10gbit burst 5000000 limit 15000000')

    time.sleep(10) # Wait 10 seconds

    info('*** Starting iperf server on h2\n')
    h2.cmdPrint('iperf3 -s &') # Launch server in foreground mode
    info('*** Running iperf client from h1 to h2\n')
    h1.cmdPrint('iperf3 -c ' + h2.IP() + ' | grep "MBytes" | awk \'{print $7}\'} > ping.dat')

    info( '*** Stopping network' )
```

Рис. 7: Скрипт для воспроизводимого 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. 8: Скрипт для отрисовки графика

Выполнение лабораторной работы

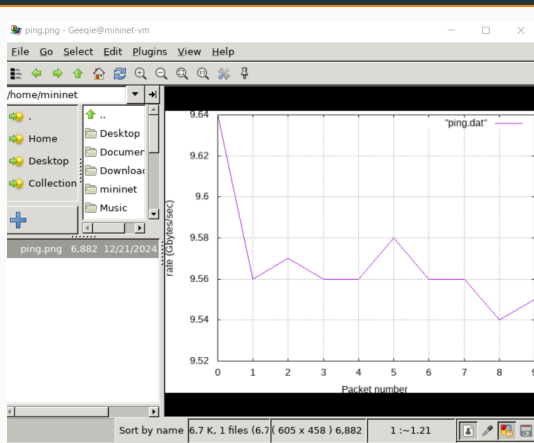


Рис. 9: График изменения скорости передачи

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.

1. Mininet [Электронный ресурс]. Mininet Project Contributors. URL: <http://mininet.org/> (дата обращения: 17.11.2024).