

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.

Задачи

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



Рис. 2: Простейшая топология

Выполнение лабораторной работы

```
# touch ifconfig.log
root@mininet-vm:/home/mininet# ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
        inet 172.16.10.128 netmask 255.255.255.0 broadcast 172.16.10.255
          ether 00:0c:29:6d:c0:cb brd 0xffffffffffff
          RX packets 33771 bytes 889305 (8.6 MB)
          RX errors 0 dropped 0 overruns 0 frame 0
          TX packets 81600 bytes 44706464 (44.7 MB)
            TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

wlan1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
        inet 172.16.10.128 netmask 255.255.255.0 broadcast 172.16.10.255
          ether 00:0c:29:6d:c0:05 brd 0xffffffffffff
          RX packets 76439 bytes 42639575 (42.6 MB)
          RX errors 0 dropped 0 overruns 0 frame 0
          TX packets 76439 bytes 42639575 (42.6 MB)
          TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73UP,LOOPBACK,RUNNING mtu 65536
        inet 127.0.0.1 netmask 255.0.0.0
          loop 0 brd 0xffffffffffff
          RX packets 76439 bytes 42639575 (42.6 MB)
          RX errors 0 dropped 0 overruns 0 frame 0
          TX packets 76439 bytes 42639575 (42.6 MB)
          TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

sl-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
        inet 10.0.7.1 brd 10.0.7.255 netmask 255.255.255.0 broadcast 10.0.7.255
          ether 00:0c:29:7b:07:07 brd 0xffffffffffff
          RX packets 0 bytes 0 (0.0 B)
          RX errors 0 dropped 0 overruns 0 frame 0
          TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

sl-eth2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
        inet 10.0.7.1 brd 10.0.7.255 netmask 255.255.255.0 broadcast 10.0.7.255
          ether 00:0c:29:7b:07:07 brd 0xffffffffffff
          RX packets 0 bytes 0 (0.0 B)
          RX errors 0 dropped 0 overruns 0 frame 0
          TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

root@mininet-vm:/home/mininet# ifconfig
eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
        inet 172.16.10.128 netmask 255.255.255.0 broadcast 172.16.10.255
          ether 00:0c:29:6d:c0:cb brd 0xffffffffffff
          RX packets 33771 bytes 889305 (8.6 MB)
          RX errors 0 dropped 0 overruns 0 frame 0
          TX packets 81618 bytes 44706464 (44.7 MB)
            TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

wlan1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
        inet 172.16.10.128 netmask 255.255.255.0 broadcast 172.16.10.255
          ether 00:0c:29:6d:c0:05 brd 0xffffffffffff
          RX packets 76452 bytes 42639673 (42.6 MB)
          RX errors 0 dropped 0 overruns 0 frame 0
          TX packets 76452 bytes 42639673 (42.6 MB)
          TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

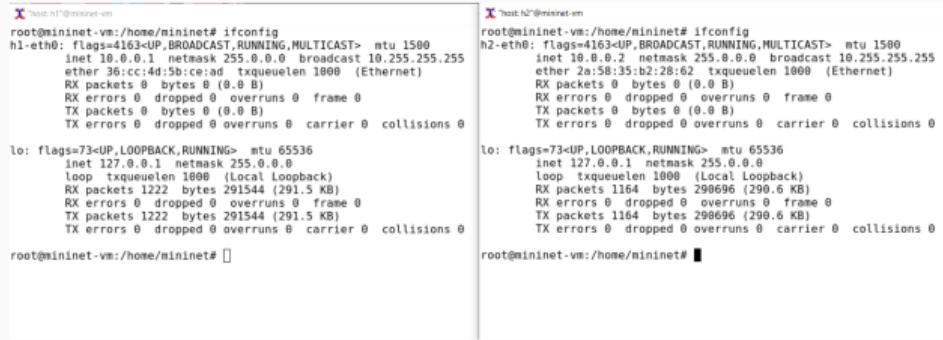
lo: flags=73UP,LOOPBACK,RUNNING mtu 65536
        inet 127.0.0.1 netmask 255.0.0.0
          loop 0 brd 0xffffffffffff
          RX packets 76452 bytes 42639673 (42.6 MB)
          RX errors 0 dropped 0 overruns 0 frame 0
          TX packets 76452 bytes 42639673 (42.6 MB)
          TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

sl-eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
        inet 10.0.7.1 brd 10.0.7.255 netmask 255.255.255.0 broadcast 10.0.7.255
          ether 00:0c:29:7b:07:07 brd 0xffffffffffff
          RX packets 0 bytes 0 (0.0 B)
          RX errors 0 dropped 0 overruns 0 frame 0
          TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

sl-eth2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
        inet 10.0.7.1 brd 10.0.7.255 netmask 255.255.255.0 broadcast 10.0.7.255
          ether 00:0c:29:7b:07:07 brd 0xffffffffffff
          RX packets 0 bytes 0 (0.0 B)
          RX errors 0 dropped 0 overruns 0 frame 0
          TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Рис. 3: ifconfig на коммутаторах s1 и s2

Выполнение лабораторной работы



The image shows two terminal windows side-by-side, each displaying the output of the `ifconfig` command on a host machine named `mininet-vm`. The left window is for host `h1` and the right window is for host `h2`.

Host h1 Output:

```
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:4d:5b:c0: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#
```

Host h2 Output:

```
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:58:35: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 298696 (298.6 KB)
        RX errors 0 dropped 0 overruns 0 frame 0
        TX packets 1164 bytes 298696 (298.6 KB)
        TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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

Рис. 4: ifconfig на хостах h1 и h2

Выполнение лабораторной работы

```
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
[ 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
sender
receiver
iperf Done.
```

Рис. 6: Запуск iperf3 на хостах

Выполнение лабораторной работы

```
root@mininet-vm:/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-vm:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config-`uname -r`
CONFIG_HZ_250=y
root@mininet-vm:/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
                                         sender
[ 7] 0.00-10.00 sec 4.63 GBytes 3.97 Gbits/sec
                                         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 507 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 4.23 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
[ 7] 0.00-10.00 sec 4.83 GBytes 4.15 Gbits/sec 0 sender
[ 7] 0.00-10.01 sec 4.81 GBytes 4.13 Gbits/sec receiver
```

Рис. 9: Ограничение скорости на коммутаторах

Выполнение лабораторной работы

```
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root handle 1: netem delay 10ms
root@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 35100
[ ID] Interval           Transfer     Bitrate
[ 7]  0.00-1.01  sec   175 MBbytes  1.45 Gbits/sec
[ 7]  1.01-2.01  sec   226 MBbytes  1.89 Gbits/sec
[ 7]  2.01-3.01  sec   227 MBbytes  1.99 Gbits/sec
[ 7]  3.00-4.00  sec   210 MBbytes  1.84 Gbits/sec
[ 7]  4.00-5.01  sec   217 MBbytes  1.89 Gbits/sec
[ 7]  5.01-6.00  sec   152 MBbytes  1.29 Gbits/sec
[ 7]  6.00-7.00  sec   119 MBbytes  998 Mbytes/sec
[ 7]  7.00-8.00  sec   101 MBbytes  847 Mbytes/sec
[ 7]  8.00-9.00  sec   111 MBbytes  929 Mbytes/sec

X "root:ht" @mininet-vm

iperf Done.
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ ID] 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   175 MBbytes  1.57 Gbits/sec 138    3.21
[ 7]  1.00-2.00  sec   226 MBbytes  1.99 Gbits/sec 0     3.46 MBbytes
[ 7]  2.00-3.00  sec   226 MBbytes  1.99 Gbits/sec 0     3.67 MBbytes
[ 7]  3.00-4.00  sec   218 MBbytes  1.83 Gbits/sec 180    2.71 MBbytes
[ 7]  4.00-5.00  sec   216 MBbytes  1.81 Gbits/sec 0     2.83 MBbytes
[ 7]  5.00-6.00  sec   151 MBbytes  1.27 Gbits/sec 276    2.18 MBbytes
[ 7]  6.00-7.00  sec   120 MBbytes  1.01 Gbits/sec 23    1.56 MBbytes
[ 7]  7.00-8.00  sec   101 MBbytes  849 Mbytes/sec 0     1.65 MBbytes
[ 7]  8.00-9.00  sec   110 MBbytes  923 Mbytes/sec 0     1.72 MBbytes
[ 7]  9.00-10.00 sec   128 MBbytes  1.01 Gbits/sec 0     1.76 MBbytes

[ ID] Interval           Transfer     Bitrate      Retr
[ 7]  0.00-10.00 sec  1.64 Gbytes  1.41 Gbits/sec 608    sender
[ 7]  0.00-10.01 sec  1.63 Gbytes  1.40 Gbits/sec               receiver

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 netem lli.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 hostan\n' )
    h1 = net.addHost( 'h1', ip='10.0.0.1' )
    h2 = net.addHost( 'h2', ip='10.0.0.2' )

    info( '*** Adding switchn' )
    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

Выполнение лабораторной работы

```
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

Выполнение лабораторной работы

```
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_neterm_iii/simple-tbf$ make
sudo python lab_neterm_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 tbf 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

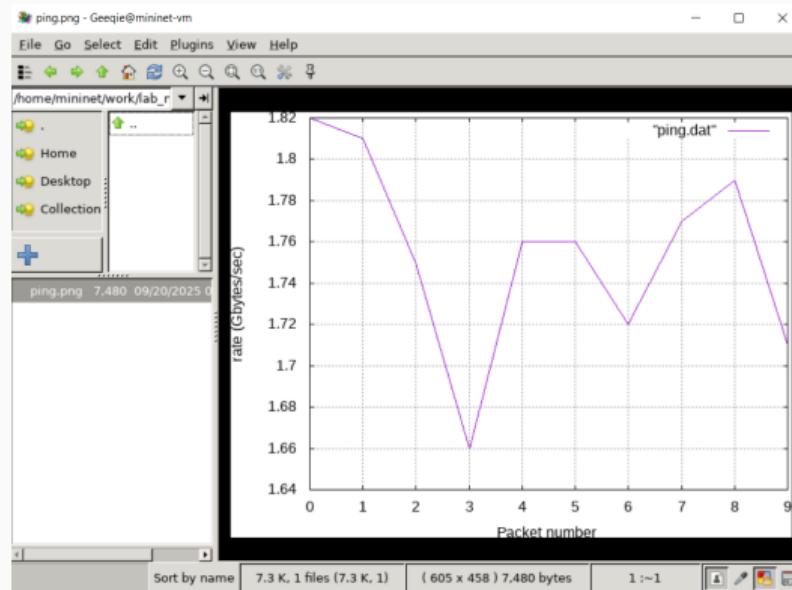


Рис. 17: График изменения скорости передачи

Выводы

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.