

# РОССИЙСКИЙ УНИВЕРСИТЕТ ДРУЖБЫ НАРОДОВ

Факультет физико-математических и естественных наук

Кафедра прикладной информатики и теории вероятностей

## ОТЧЕТ

### ПО ЛАБОРАТОРНОЙ РАБОТЕ № 6

дисциплина: Моделирование сетей передачи данных

Студент: Саинт-Амур Измаэль

Группа: НПИбд-01-20

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## Постановка задачи

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

## Выполнение работы

### 6.4.1. Запуск лабораторной топологии

1. Запустите виртуальную среду с mininet.
2. Из основной ОС подключитесь к виртуальной машине
3. В виртуальной машине mininet при необходимости исправьте права запуска

X-соединения. Скопируйте значение куки (MIT magic cookie)1

своего пользователя mininet в файл для пользователя root:

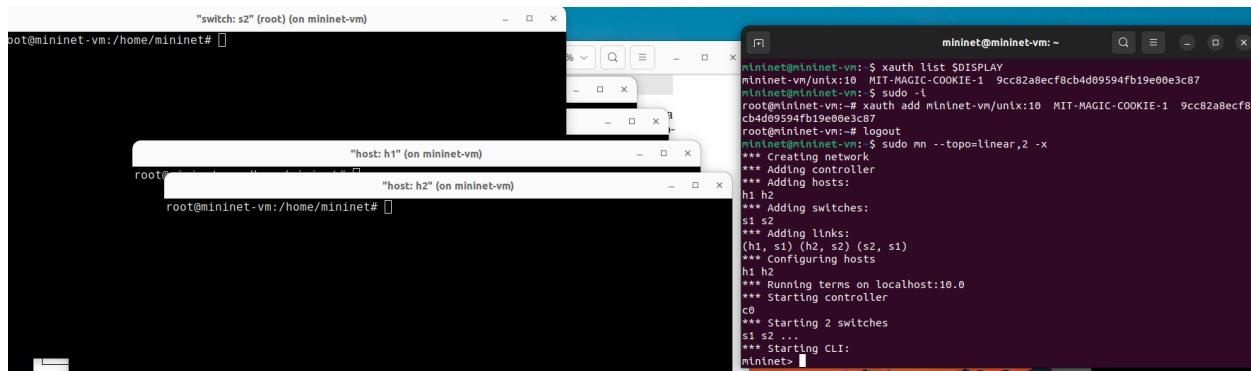
:

```
marc@Ismael:~$ ssh -Y mininet@192.168.56.101
mininet@192.168.56.101's password:
Welcome to Ubuntu 20.04.1 LTS (GNU/Linux 5.4.0-42-generic x86_64)

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

Last login: Sat Dec 16 08:24:23 2023 from 192.168.56.1
mininet@mininet-vm:~$ xauth list $DISPLAY
mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 9cc82a8ecf8cb4d09594fb19e00e3c87
mininet@mininet-vm:~$ sudo -i
root@mininet-vm:~# xauth add mininet-vm/unix:10 MIT-MAGIC-COOKIE-1 9cc82a8ecf8cb4d09594fb19e00e3c87
root@mininet-vm:~# logout
mininet@mininet-vm:~$
```

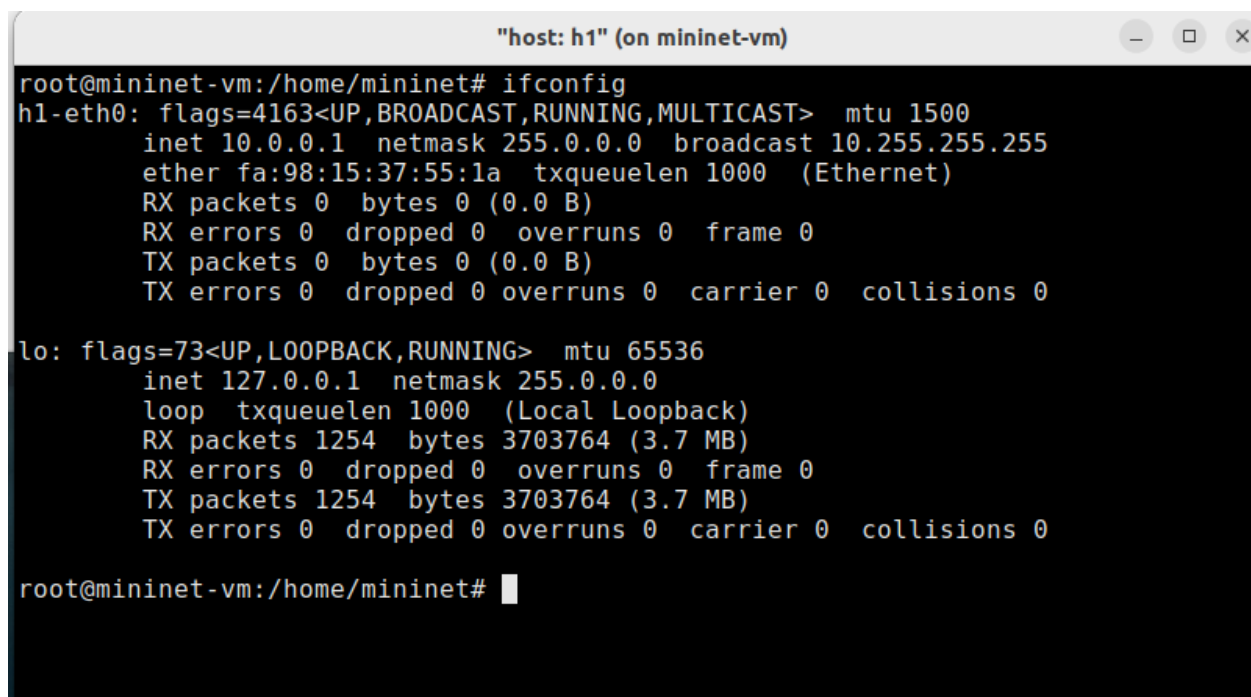
4. Задайте топологию сети, состоящую из двух хостов и двух коммутаторов с назначенной по умолчанию mininet сетью 10.0.0.0/8:



5. На хостах h1, h2 и на коммутаторах s1, s2 введите команду `ifconfig`, чтобы отобразить информацию, относящуюся к их сетевым интерфейсам и назначенным им IP-адресам. В дальнейшем при работе с NETEM и командой `tc`

будут использоваться интерфейсы h1-eth0, h2-eth0, s1-eth2.

6. Проверьте подключение между хостами h1 и h2 с помощью команды `ping` с параметром `-c 4`



```
"switch: s1" (root) (on mininet-virtual-machine)

TX errors 0   dropped 0 overruns 0   carrier 0   collisions 0

s1-eth2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
ether 6a:d4:52:a1:5e:39 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 12:fc:11:b7:f2:5b 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 1e:9b:e0:a0:50:67 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-virtual-machine:/home/mininet#
```

8. В терминале хоста h1 запустите iPerf3 в режиме клиента:

```
"host: h2" (on mininet-virtual-machine)

root@mininet-virtual-machine:/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 a2:4c:a6:5f:46:a2 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 1134 bytes 3695172 (3.6 MB)
RX errors 0   dropped 0 overruns 0   frame 0
TX packets 1134 bytes 3695172 (3.6 MB)
TX errors 0   dropped 0 overruns 0   carrier 0   collisions 0

root@mininet-virtual-machine:/home/mininet#
```

```
"switch: s2" (root) (on mininet-virtual-machine)

TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

s1-eth2: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
ether 6a:d4:52:a1:5e:39 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 12:fc:11:b7:f2:5b 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 1e:9b:e0:a0:50:67 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#
```

7. В терминале хоста h2 запустите iPerf3 в режиме сервера:

```
"host: h2" (on 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 10.255.255.255
ether a2:4c:a6:5f:46:a2 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 1134 bytes 3695172 (3.6 MB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 1134 bytes 3695172 (3.6 MB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

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

8. В терминале хоста h1 запустите iPerf3 в режиме клиента:

```

"host: h1" (on mininet-vm)

TX packets 1254  bytes 3703764 (3.7 MB)
TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

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 54746 connected to 10.0.0.2 port 5201
[ ID] Interval            Transfer        Bitrate        Retr  Cwnd
[ 7]  0.00-1.00    sec    399 MBytes    3.35 Gbits/sec    0    4.28 MBytes
[ 7]  1.00-2.00    sec    344 MBytes    2.87 Gbits/sec    0    5.58 MBytes
[ 7]  2.00-3.00    sec    354 MBytes    2.98 Gbits/sec    0    5.86 MBytes
[ 7]  3.00-4.00    sec    390 MBytes    3.27 Gbits/sec    0    6.15 MBytes
[ 7]  4.00-5.00    sec    310 MBytes    2.60 Gbits/sec    0    6.15 MBytes
[ 7]  5.00-6.00    sec    329 MBytes    2.75 Gbits/sec    0    6.15 MBytes
[ 7]  6.00-7.00    sec    245 MBytes    2.06 Gbits/sec    0    6.15 MBytes
[ 7]  7.00-8.00    sec    266 MBytes    2.23 Gbits/sec    0    6.46 MBytes
[ 7]  8.00-9.01    sec    294 MBytes    2.46 Gbits/sec    0    7.48 MBytes
[ 7]  9.01-10.01   sec    285 MBytes    2.38 Gbits/sec    0    7.85 MBytes
-----
[ ID] Interval            Transfer        Bitrate        Retr
[ 7]  0.00-10.01   sec    3.14 GBytes    2.70 Gbits/sec    0
[ 7]  0.00-10.02   sec    3.14 GBytes    2.69 Gbits/sec
sender
receiver

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

```

ите пропускную способность хоста h1, установив пропускную способ-

9. После завершения работы iPerf3 на хосте h1 остановите iPerf3 на хосте h2, нажав Ctrl + c . В отчёте зафиксируйте результат отработки iPerf3 на данном этапе проведения эксперимента, когда отсутствуют ограничения скорости передачи данных.

```

"host: h2" (on mininet-vm)

TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

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 54744
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 54746
[ ID] Interval            Transfer        Bitrate
[ 7]  0.00-1.00    sec    396 MBytes    3.32 Gbits/sec
[ 7]  1.00-2.00    sec    343 MBytes    2.87 Gbits/sec
[ 7]  2.00-3.00    sec    356 MBytes    2.98 Gbits/sec
[ 7]  3.00-4.00    sec    390 MBytes    3.27 Gbits/sec
[ 7]  4.00-5.00    sec    308 MBytes    2.58 Gbits/sec
[ 7]  5.00-6.00    sec    329 MBytes    2.76 Gbits/sec
[ 7]  6.00-7.00    sec    247 MBytes    2.08 Gbits/sec
[ 7]  7.00-8.00    sec    262 MBytes    2.20 Gbits/sec
[ 7]  8.00-9.00    sec    293 MBytes    2.46 Gbits/sec
[ 7]  9.00-10.00   sec    288 MBytes    2.41 Gbits/sec
[ 7] 10.00-10.02   sec    4.00 MBytes    1.48 Gbits/sec
-----
[ ID] Interval            Transfer        Bitrate
[ 7]  0.00-10.02   sec    3.14 GBytes    2.69 Gbits/sec
receiver

```



#### 6.4.2.1. Ограничение скорости на конечных хостах

Команду `tc` можно применить к сетевому интерфейсу устройства для формирования исходящего трафика. Требуется ограничить скорость отправки данных

с конечного хоста с помощью фильтра Token Bucket Filter (tbf).

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

```
"host: h1" (on mininet-vm)
[ 7]  1.00-2.00  sec  344 MBytes  2.87 Gbits/sec  0  5.58 MBytes
[ 7]  2.00-3.00  sec  354 MBytes  2.98 Gbits/sec  0  5.86 MBytes
[ 7]  3.00-4.00  sec  390 MBytes  3.27 Gbits/sec  0  6.15 MBytes
[ 7]  4.00-5.00  sec  310 MBytes  2.60 Gbits/sec  0  6.15 MBytes
[ 7]  5.00-6.00  sec  329 MBytes  2.75 Gbits/sec  0  6.15 MBytes
[ 7]  6.00-7.00  sec  245 MBytes  2.06 Gbits/sec  0  6.15 MBytes
[ 7]  7.00-8.00  sec  266 MBytes  2.23 Gbits/sec  0  6.46 MBytes
[ 7]  8.00-9.01  sec  294 MBytes  2.46 Gbits/sec  0  7.48 MBytes
[ 7]  9.01-10.01 sec  285 MBytes  2.38 Gbits/sec  0  7.85 MBytes
- - - - -
[ ID] Interval      Transfer      Bitrate      Retr
[ 7]  0.00-10.01  sec  3.14 GBytes  2.70 Gbits/sec  0
[ 7]  0.00-10.02  sec  3.14 GBytes  2.69 Gbits/sec
iperf Done.
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root tbf rate 10gbit burst 5000000 limit 15000000
Unknown qdisc "roottbf", hence option "rate" is unparseable
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root tbf rate 10gbit burst 5000000 limit 15000000
Cannot find device "h1-eth0"
root@mininet-vm:/home/mininet# sudo tc qdisc add dev h1-eth0 root tbf rate 10gbit burst 5000000 limit 15000000
root@mininet-vm:/home/mininet#
```

2. Фильтр `tbf` требует установки значения всплеска при ограничении скорости.

Это значение должно быть достаточно высоким, чтобы обеспечить установленную скорость. Она должна быть не ниже указанной частоты, делённой на

`HZ`, где `HZ` — тактовая частота, настроенная как параметр ядра, и может быть извлечена с помощью следующей команды

```
"host: h1" (on mininet-virtual-machine)
[ 7] 0.00-10.02 sec 3.14 GBytes 2.69 Gbits/sec receiver
iperf Done.
root@mininet-virtual-machine:/home/mininet# sudo tc qdisc add dev h1-etho root tbf rate 10gb
t burst 5000000 limit 15000000
Unknown qdisc "root tbf", hence option "rate" is unparsable
root@mininet-virtual-machine:/home/mininet# sudo tc qdisc add dev h1-etho root tbf rate 10gb
it burst 5000000 limit 15000000
Cannot find device "h1-etho"
root@mininet-virtual-machine:/home/mininet# sudo tc qdisc add dev h1-eth0 root tbf rate 10gb
it burst 5000000 limit 15000000
root@mininet-virtual-machine:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config- `uname -r`
>
> ^C
root@mininet-virtual-machine:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config- `uname -r`
grep: /boot/config-: No such file or directory
grep: `uname -r`: No such file or directory
root@mininet-virtual-machine:/home/mininet# egrep '^CONFIG_HZ_[0-9]+' /boot/config- `uname -r`
grep: \boot/config-: No such file or directory
grep: `uname -r`: No such file or directory
root@mininet-virtual-machine:/home/mininet# \
```

3. С помощью iPerf3 проверьте, что значение пропускной способности изменилось:
- В терминале хоста h2 запустите iPerf3 в режиме сервера:

```
"host: h2" (on mininet-virtual-machine)
[ 7] 0.00-1.00 sec 396 MBytes 3.32 Gbits/sec
[ 7] 1.00-2.00 sec 343 MBytes 2.87 Gbits/sec
[ 7] 2.00-3.00 sec 356 MBytes 2.98 Gbits/sec
[ 7] 3.00-4.00 sec 390 MBytes 3.27 Gbits/sec
[ 7] 4.00-5.00 sec 308 MBytes 2.58 Gbits/sec
[ 7] 5.00-6.00 sec 329 MBytes 2.76 Gbits/sec
[ 7] 6.00-7.00 sec 247 MBytes 2.08 Gbits/sec
[ 7] 7.00-8.00 sec 262 MBytes 2.20 Gbits/sec
[ 7] 8.00-9.00 sec 293 MBytes 2.46 Gbits/sec
[ 7] 9.00-10.00 sec 288 MBytes 2.41 Gbits/sec
[ 7] 10.00-10.02 sec 4.00 MBytes 1.48 Gbits/sec
-----
[ ID] Interval Transfer Bitrate
[ 7] 0.00-10.02 sec 3.14 GBytes 2.69 Gbits/sec receiver
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-virtual-machine:/home/mininet# iperf3 -s
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
```

- В терминале хоста h2 запустите iPerf3 в режиме клиента:



```
"host: h1" (on mininet-vm)
r'
grep: \boot/config-: No such file or directory
grep: uname -r: No such file or directory
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 54750 connected to 10.0.0.2 port 5201
[ ID] Interval            Transfer        Bitrate        Retr  Cwnd
[ 7]  0.00-1.01      sec   417 MBytes    3.48 Gbits/sec     0   814 KBytes
[ 7]  1.01-2.00      sec   418 MBytes    3.51 Gbits/sec     0   814 KBytes
[ 7]  2.00-3.01      sec   231 MBytes    1.93 Gbits/sec     0   3.44 MBytes
[ 7]  3.01-4.01      sec   276 MBytes    2.33 Gbits/sec     0   4.19 MBytes
[ 7]  4.01-5.02      sec   174 MBytes    1.44 Gbits/sec     0   4.19 MBytes
[ 7]  5.02-6.01      sec   279 MBytes    2.37 Gbits/sec     0   5.61 MBytes
[ 7]  6.01-7.00      sec   252 MBytes    2.12 Gbits/sec     0   5.61 MBytes
[ 7]  7.00-8.01      sec   289 MBytes    2.41 Gbits/sec     0   5.90 MBytes
[ 7]  8.01-9.00      sec   259 MBytes    2.18 Gbits/sec     0   5.90 MBytes
[ 7]  9.00-10.01     sec   264 MBytes    2.20 Gbits/sec     0   6.19 MBytes
-----
[ ID] Interval            Transfer        Bitrate        Retr
[ 7]  0.00-10.01     sec   2.79 GBytes    2.40 Gbits/sec     0
[ 7]  0.00-10.01     sec   2.79 GBytes    2.40 Gbits/sec
sender
receiver

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

– После завершения работы iPerf3 на хосте h1 остановите iPerf3 на хосте h2, нажав Ctrl + c . В отчёте зафиксируйте результат отработки iPerf3 на данном этапе проведения эксперимента.

```
"host: h2" (on mininet-vm)
Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 54748
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 54750
[ ID] Interval            Transfer        Bitrate
[ 7]  0.00-1.00      sec   416 MBytes    3.49 Gbits/sec
[ 7]  1.00-2.00      sec   418 MBytes    3.51 Gbits/sec
[ 7]  2.00-3.00      sec   230 MBytes    1.93 Gbits/sec
[ 7]  3.00-4.00      sec   278 MBytes    2.33 Gbits/sec
[ 7]  4.00-5.00      sec   173 MBytes    1.45 Gbits/sec
[ 7]  5.00-6.00      sec   279 MBytes    2.34 Gbits/sec
[ 7]  6.00-7.00      sec   252 MBytes    2.12 Gbits/sec
[ 7]  7.00-8.00      sec   289 MBytes    2.43 Gbits/sec
[ 7]  8.00-9.00      sec   258 MBytes    2.16 Gbits/sec
[ 7]  9.00-10.00     sec   265 MBytes    2.22 Gbits/sec
[ 7] 10.00-10.01     sec    513 KBytes    423 Mbits/sec
-----
[ ID] Interval            Transfer        Bitrate
[ 7]  0.00-10.01     sec   2.79 GBytes    2.40 Gbits/sec
receiver
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#
```

4. Удалите модифицированную конфигурацию на хосте h1:

```
"host: h1" (on mininet-vm)
grep: uname -r: No such file or directory
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 54750 connected to 10.0.0.2 port 5201
[ ID] Interval            Transfer        Bitrate        Retr  Cwnd
[ 7]  0.00-1.01      sec    417 MBytes    3.48 Gbits/sec     0   814 KBytes
[ 7]  1.01-2.00      sec    418 MBytes    3.51 Gbits/sec     0   814 KBytes
[ 7]  2.00-3.01      sec    231 MBytes    1.93 Gbits/sec     0  3.44 MBytes
[ 7]  3.01-4.01      sec    276 MBytes    2.33 Gbits/sec     0  4.19 MBytes
[ 7]  4.01-5.02      sec    174 MBytes    1.44 Gbits/sec     0  4.19 MBytes
[ 7]  5.02-6.01      sec    279 MBytes    2.37 Gbits/sec     0  5.61 MBytes
[ 7]  6.01-7.00      sec    252 MBytes    2.12 Gbits/sec     0  5.61 MBytes
[ 7]  7.00-8.01      sec    289 MBytes    2.41 Gbits/sec     0  5.90 MBytes
[ 7]  8.01-9.00      sec    259 MBytes    2.18 Gbits/sec     0  5.90 MBytes
[ 7]  9.00-10.01     sec    264 MBytes    2.20 Gbits/sec     0  6.19 MBytes
- - - - -
[ ID] Interval            Transfer        Bitrate        Retr
[ 7]  0.00-10.01     sec    2.79 GBytes    2.40 Gbits/sec     0
[ 7]  0.00-10.01     sec    2.79 GBytes    2.40 Gbits/sec
sender
receiver

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

#### 6.4.2.2. Ограничение скорости на коммутаторах

При ограничении скорости на интерфейсе s1-eth2 коммутатора s1 все сеансы связи между коммутатором s1 и коммутатором s2 будут фильтроваться в соответствии с применяемыми правилами.

1. Примените 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:

```
"switch: s1" (root) (on mininet-vm)

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 1e:9b:e0:a0:50:67 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# sudo tc qddisc add dev s1-eth2 root tbf rate 10
gbit burst 5000000 limit 15000000
Object "qddisc" is unknown, try "tc help".
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root tbf rate 10 g
bit burst 5000000 limit 15000000
tbf: unknown parameter "gbit"
Usage: ... tbf limit BYTES burst BYTES[/BYTES] rate Kbps [ mtu BYTES[/BYTES] ]
[ peakrate Kbps ] [ latency TIME ] [ overhead BYTES ] [ linklayer TYPE ]
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root tbf rate 10 g
bit burst 5000000 limit 15000000
tbf: unknown parameter "gbit"
Usage: ... tbf limit BYTES burst BYTES[/BYTES] rate Kbps [ mtu BYTES[/BYTES] ]
[ peakrate Kbps ] [ latency TIME ] [ overhead BYTES ] [ linklayer TYPE ]
```

2. Проверьте конфигурацию с помощью инструмента iperf3 для измерения пропускной способности:

– В терминале хоста h2 запустите iPerf3 в режиме сервера

```
"host: h2" (on mininet-vm)

[ 7] 0.00-1.00 sec 416 MBytes 3.49 Gbits/sec
[ 7] 1.00-2.00 sec 418 MBytes 3.51 Gbits/sec
[ 7] 2.00-3.00 sec 230 MBytes 1.93 Gbits/sec
[ 7] 3.00-4.00 sec 278 MBytes 2.33 Gbits/sec
[ 7] 4.00-5.00 sec 173 MBytes 1.45 Gbits/sec
[ 7] 5.00-6.00 sec 279 MBytes 2.34 Gbits/sec
[ 7] 6.00-7.00 sec 252 MBytes 2.12 Gbits/sec
[ 7] 7.00-8.00 sec 289 MBytes 2.43 Gbits/sec
[ 7] 8.00-9.00 sec 258 MBytes 2.16 Gbits/sec
[ 7] 9.00-10.00 sec 265 MBytes 2.22 Gbits/sec
[ 7] 10.00-10.01 sec 513 KBytes 423 Mbits/sec

-----
[ ID] Interval Transfer Bitrate
[ 7] 0.00-10.01 sec 2.79 GBytes 2.40 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
-----
```

– В терминале хоста h2 запустите iPerf3 в режиме клиента:

```
"host: h1" (on mininet-vm)

iperf Done.
root@mininet-vm:/home/mininet# sudo tc qdisc del dev h1-eth0 root
root@mininet-vm:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 54756 connected to 10.0.0.2 port 5201
[ ID] Interval            Transfer       Bitrate        Retr   Cwnd
[ 7]  0.00-1.00    sec    353 MBytes    2.96 Gbits/sec    0    4.08 MBytes
[ 7]  1.00-2.00    sec    329 MBytes    2.76 Gbits/sec    0    4.72 MBytes
[ 7]  2.00-3.00    sec    344 MBytes    2.88 Gbits/sec    0    5.20 MBytes
[ 7]  3.00-4.00    sec    374 MBytes    3.14 Gbits/sec    0    5.47 MBytes
[ 7]  4.00-5.00    sec    374 MBytes    3.14 Gbits/sec    0    5.74 MBytes
[ 7]  5.00-6.00    sec    388 MBytes    3.24 Gbits/sec    0    5.74 MBytes
[ 7]  6.00-7.00    sec    368 MBytes    3.08 Gbits/sec    0    6.02 MBytes
[ 7]  7.00-8.00    sec    371 MBytes    3.12 Gbits/sec    0    6.33 MBytes
[ 7]  8.00-9.00    sec    361 MBytes    3.03 Gbits/sec    0    6.64 MBytes
[ 7]  9.00-10.00   sec    381 MBytes    3.20 Gbits/sec    0    6.64 MBytes
-----
[ ID] Interval            Transfer       Bitrate        Retr
[ 7]  0.00-10.00   sec    3.56 GBytes    3.05 Gbits/sec    0
[ 7]  0.00-10.01   sec    3.56 GBytes    3.05 Gbits/sec
sender
receiver

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

– После завершения работы iPerf3 на хосте h1 остановите iPerf3 на хосте h2, нажав Ctrl + c . В отчёте зафиксируйте результат отработки iPerf3 на данном этапе проведения эксперимента.

```
"host: h2" (on mininet-vm)

Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 54754
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 54756
[ ID] Interval            Transfer       Bitrate
[ 7]  0.00-1.00    sec    353 MBytes    2.96 Gbits/sec
[ 7]  1.00-2.00    sec    326 MBytes    2.73 Gbits/sec
[ 7]  2.00-3.00    sec    341 MBytes    2.86 Gbits/sec
[ 7]  3.00-4.00    sec    376 MBytes    3.16 Gbits/sec
[ 7]  4.00-5.00    sec    374 MBytes    3.14 Gbits/sec
[ 7]  5.00-6.00    sec    387 MBytes    3.25 Gbits/sec
[ 7]  6.00-7.00    sec    366 MBytes    3.07 Gbits/sec
[ 7]  7.00-8.00    sec    374 MBytes    3.13 Gbits/sec
[ 7]  8.00-9.00    sec    360 MBytes    3.02 Gbits/sec
[ 7]  9.00-10.00   sec    380 MBytes    3.19 Gbits/sec
[ 7] 10.00-10.01   sec    4.63 MBytes    3.37 Gbits/sec
-----
[ ID] Interval            Transfer       Bitrate
[ 7]  0.00-10.01   sec    3.56 GBytes    3.05 Gbits/sec
receiver
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-vm:/home/mininet#
```

3. Удалите модифицированную конфигурацию на коммутаторе s1:

```
"switch: s1" (root) (on mininet-vn)
TX packets 0  bytes 0 (0.0 B)
TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

root@mininet-vm:/home/mininet# sudo tc qddisc add dev s1-eth2 root tbf rate 10
gbit burst 5000000 limit 15000000
Object "qddisc" is unknown, try "tc help".
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root tbf rate 10 g
bit burst 5000000 limit 15000000
tbf: unknown parameter "gbit"
Usage: ... tbf limit BYTES burst BYTES[/BYTES] rate Kbps [ mtu BYTES[/BYTES] ]
[ peakrate Kbps ] [ latency TIME ] [ overhead BYTES ] [ linklayer TYPE ]
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root tbf rate 10 g
bit burst 5000000 limit 15000000
tbf: unknown parameter "gbit"
Usage: ... tbf limit BYTES burst BYTES[/BYTES] rate Kbps [ mtu BYTES[/BYTES] ]
[ peakrate Kbps ] [ latency TIME ] [ overhead BYTES ] [ linklayer TYPE ]
root@mininet-vm:/home/mininet# sudo tc qdisc del dev s1-eth2 root
Error: Cannot delete qdisc with handle of zero
```

### 6.4.2.3. Объединение NETEM и TBF

NETEM используется для изменения задержки, джиттера, повреждения пакетов и т.д. TBF может использоваться для ограничения скорости. Утилита tc

позволяет комбинировать несколько модулей. При этом первая дисциплина очереди (qdisc1) присоединяется к корневой метке, последующие дисциплины очереди можно прикрепить к своим родителям, указав правильную метку.

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

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

2. Убедитесь, что соединение от хоста h1 к хосту h2 имеет заданную задержку.



Для этого запустите команду `ping` с параметром `-c 4` с терминала хоста `h1`.

```
"host: h1" (on mininet-vm)
root@mininet-vm:/home/mininet# ping 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=23.9 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=13.2 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=11.3 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=10.4 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=10.4 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=10.4 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=10.4 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=10.4 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=10.2 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=10.7 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=10.5 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=10.5 ms
^C
--- 10.0.0.2 ping statistics ---
17 packets transmitted, 17 received, 0% packet loss, time 16035ms
rtt min/avg/max/mdev = 10.233/11.468/23.895/3.176 ms
root@mininet-vm:/home/mininet#
```

3. Добавьте второе правило на коммутаторе `s1`, которое задаёт ограничение скорости с помощью `tbft` с параметрами `rate=2gbit`, `burst=1,000,000`, `limit=2,000,000`:

```
"switch: s1" (root) (on mininet-vm)
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root handle 1: net
em delay 10ms
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 parent 1: handle 2
: tbft rate 2gbit burst 1000000 limit 2000000
root@mininet-vm:/home/mininet#
```

4. Проверьте конфигурацию с помощью инструмента `iPerf3` для измерения пропускной способности:

– В терминале хоста `h2` запустите `iPerf3` в режиме сервера:



```
"host: h2" (on mininet-vm)
root@mininet-vm:/home/mininet# iperf3 -s
warning: this system does not seem to support IPv6 - trying IPv4
-----
Server listening on 5201
-----
█
```

– В терминале хоста h2 запустите iPerf3 в режиме клиента

```
"host: h1" (on mininet-vm)
--- 10.0.0.2 ping statistics ---
17 packets transmitted, 17 received, 0% packet loss, time 16035ms
rtt min/avg/max/mdev = 10.233/11.468/23.895/3.176 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 54760 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate      Retr   Cwnd
[ 7]  0.00-1.00    sec      174 MBytes  1.46 Gbits/sec  732   2.08 MBytes
[ 7]  1.00-2.00    sec      184 MBytes  1.54 Gbits/sec  180   1.52 MBytes
[ 7]  2.00-3.00    sec      138 MBytes  1.15 Gbits/sec   0   1.63 MBytes
[ 7]  3.00-4.00    sec      141 MBytes  1.18 Gbits/sec   0   1.70 MBytes
[ 7]  4.00-5.00    sec      155 MBytes  1.30 Gbits/sec   0   1.76 MBytes
[ 7]  5.00-6.00    sec      155 MBytes  1.30 Gbits/sec   0   1.80 MBytes
[ 7]  6.00-7.00    sec      155 MBytes  1.30 Gbits/sec   0   1.83 MBytes
[ 7]  7.00-8.00    sec      161 MBytes  1.35 Gbits/sec   0   1.89 MBytes
[ 7]  8.00-9.00    sec      156 MBytes  1.32 Gbits/sec  90   1.39 MBytes
[ 7]  9.00-10.00   sec      124 MBytes  1.04 Gbits/sec   0   1.54 MBytes
-----
[ ID] Interval           Transfer     Bitrate      Retr
[ 7]  0.00-10.00    sec    1.51 GBytes  1.29 Gbits/sec  1002
[ 7]  0.00-10.02    sec    1.50 GBytes  1.28 Gbits/sec
                                     sender
                                     receiver

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

– После завершения работы iPerf3 на хосте h1 остановите iPerf3 на хосте h2, нажав Ctrl + c . В отчёте зафиксируйте результат отработки iPerf3 на данном этапе проведения эксперимента.

```
"host: h2" (on mininet-virtual-machine)

Server listening on 5201
-----
Accepted connection from 10.0.0.1, port 54758
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 54760
[ ID] Interval            Transfer       Bitrate
[ 7]  0.00-1.00      sec    163 MBytes    1.36 Gbits/sec
[ 7]  1.00-2.00      sec    184 MBytes    1.55 Gbits/sec
[ 7]  2.00-3.00      sec    137 MBytes    1.14 Gbits/sec
[ 7]  3.00-4.00      sec    142 MBytes    1.20 Gbits/sec
[ 7]  4.00-5.00      sec    155 MBytes    1.30 Gbits/sec
[ 7]  5.00-6.00      sec    155 MBytes    1.30 Gbits/sec
[ 7]  6.00-7.00      sec    155 MBytes    1.30 Gbits/sec
[ 7]  7.00-8.00      sec    161 MBytes    1.35 Gbits/sec
[ 7]  8.00-9.00      sec    156 MBytes    1.30 Gbits/sec
[ 7]  9.00-10.00     sec    125 MBytes    1.05 Gbits/sec
[ 7] 10.00-10.02     sec     256 KBytes    104 Mbits/sec
-----
[ ID] Interval            Transfer       Bitrate
[ 7]  0.00-10.02     sec    1.50 GBytes    1.28 Gbits/sec
-----
Server listening on 5201
-----
^Ciperf3: interrupt - the server has terminated
root@mininet-virtual-machine:/home/mininet#
```

5. Удалите модифицированную конфигурацию на коммутаторе s1:

```
"switch: s1" (root) (on mininet-virtual-machine)

root@mininet-virtual-machine:/home/mininet# sudo tc qdisc add dev s1-eth2 root handle 1: netem delay 10ms
root@mininet-virtual-machine:/home/mininet# sudo tc qdisc add dev s1-eth2 parent 1: handle 2 : tbf rate 2gbit burst 1000000 limit 2000000
root@mininet-virtual-machine:/home/mininet# sudo tc qdisc del dev s1-eth2 root
root@mininet-virtual-machine:/home/mininet#
```

### 6.4.3. Воспроизводимые эксперименты

Самостоятельно реализуйте воспроизводимые эксперименты по использованию TBF для ограничения пропускной способности.

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

- sudo tc qdisc add dev s1-eth2 root handle 1: netem delay 50ms

-Добавьте второе правило на коммутаторе s1, которое задаёт ограничение скорости с помощью tbf с параметрами rate 2gbit, burst 7000000

Limit 15000000

. Проверьте конфигурацию с помощью инструмента iperf3 для измерения

пропускной способности:

– В терминале хоста h2 запустите iPerf3 в режиме сервера:

```
1 iperf3 -s
```

– В терминале хоста h1 запустите iPerf3 в режиме клиента:

```
1 iperf3 -c 10.0.0.2
```

– После завершения работы iPerf3 на хосте h1 остановите iPerf3 на хосте h2, нажав Ctrl + c . В отчёте зафиксируйте результат отработки iPerf3 на данном этапе проведения эксперимента.

- Удалите модифицированную конфигурацию на коммутаторе s1:

```
1 sudo tc qdisc del dev s1-eth2 root
```

```
"switch: s1" (root) (on mininet-vm)
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# 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 50ms
root@mininet-vm:/home/mininet#
```

```
"host: h1" (on mininet-vm)
root@mininet-vm:/home/mininet# ping 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=59.3 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=52.6 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=51.1 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=50.7 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=50.9 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=50.4 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=50.8 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=50.7 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=50.8 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=50.8 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=50.3 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=50.3 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=50.3 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=50.6 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=50.3 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=50.7 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=50.4 ms
^C
--- 10.0.0.2 ping statistics ---
17 packets transmitted, 17 received, 0% packet loss, time 16032ms
rtt min/avg/max/mdev = 50.251/51.228/59.294/2.083 ms
root@mininet-vm:/home/mininet#
```

```
"switch: s1" (root) (on mininet-virtual-machine)

root@mininet-virtual-machine:/home/mininet# sudo tc qdisc add dev s1-eth2 root handle 1: netem delay 10ms
root@mininet-virtual-machine:/home/mininet# sudo tc qdisc add dev s1-eth2 parent 1: handle 2: tbf rate 2gbit burst 1000000 limit 2000000
root@mininet-virtual-machine:/home/mininet# sudo tc qdisc del dev s1-eth2 root
root@mininet-virtual-machine:/home/mininet# sudo tc qdisc add dev s1-eth2 root handle 1: netem delay 50ms
root@mininet-virtual-machine:/home/mininet# sudo tc qdisc add dev s1-eth2 parent 1: handle 2: tbf rate 2gbit burst 7000000 limit 15000000
root@mininet-virtual-machine:/home/mininet#
```

```
"host: h2" (on mininet-virtual-machine)
Server listening on 5201
Accepted connection from 10.0.0.1, port 54762
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 54764
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec   18.1 MBytes   152 Mbits/sec
[ 7] 1.00-2.00 sec   125 MBytes   1.05 Gbits/sec
[ 7] 2.00-3.00 sec   149 MBytes   1.25 Gbits/sec
[ 7] 3.00-4.01 sec   150 MBytes   1.25 Gbits/sec
[ 7] 4.01-5.00 sec   151 MBytes   1.27 Gbits/sec
[ 7] 5.00-6.00 sec   149 MBytes   1.25 Gbits/sec
[ 7] 6.00-7.01 sec   151 MBytes   1.26 Gbits/sec
[ 7] 7.01-8.00 sec   146 MBytes   1.24 Gbits/sec
[ 7] 8.00-9.00 sec   148 MBytes   1.24 Gbits/sec
[ 7] 9.00-10.00 sec  153 MBytes   1.28 Gbits/sec
[ 7] 10.00-10.05 sec 5.09 MBytes   893 Mbits/sec
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-10.05 sec 1.31 GBytes   1.12 Gbits/sec
Server listening on 5201

"host: h1" (on mininet-virtual-machine)
--- 10.0.0.2 ping statistics ---
17 packets transmitted, 17 received, 0% packet loss, time 16032ms
rtt min/avg/max/mdev = 50.251/51.228/59.294/2.083 ms
root@mininet-virtual-machine:/home/mininet# iperf3 -c 10.0.0.2
Connecting to host 10.0.0.2, port 5201
[ 7] local 10.0.0.1 port 54764 connected to 10.0.0.2 port 5201
[ ID] Interval      Transfer      Bitrate      Retr      Cwnd
[ 7] 0.00-1.00 sec   29.0 MBytes   243 Mbits/sec  0         4.63 MBytes
[ 7] 1.00-2.00 sec   125 MBytes   1.05 Gbits/sec  0         8.17 MBytes
[ 7] 2.00-3.00 sec   149 MBytes   1.25 Gbits/sec  0         8.17 MBytes
[ 7] 3.00-4.00 sec   150 MBytes   1.26 Gbits/sec  0         8.17 MBytes
[ 7] 4.00-5.00 sec   151 MBytes   1.27 Gbits/sec  0         8.17 MBytes
[ 7] 5.00-6.00 sec   149 MBytes   1.25 Gbits/sec  0         8.17 MBytes
[ 7] 6.00-7.00 sec   151 MBytes   1.27 Gbits/sec  0         8.17 MBytes
[ 7] 7.00-8.00 sec   146 MBytes   1.23 Gbits/sec  0         8.17 MBytes
[ 7] 8.00-9.00 sec   149 MBytes   1.25 Gbits/sec  0         8.17 MBytes
[ 7] 9.00-10.00 sec  152 MBytes   1.28 Gbits/sec  0         8.17 MBytes
[ ID] Interval      Transfer      Bitrate      Retr      sender receiver
[ 7] 0.00-10.00 sec 1.32 GBytes   1.13 Gbits/sec  0
[ 7] 0.00-10.05 sec 1.31 GBytes   1.12 Gbits/sec  0
iperf Done.
root@mininet-virtual-machine:/home/mininet#
```

```
"host: h2" (on mininet-virtual-machine)
Server listening on 5201
Accepted connection from 10.0.0.1, port 54762
[ 7] local 10.0.0.2 port 5201 connected to 10.0.0.1 port 54764
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-1.00 sec   18.1 MBytes   152 Mbits/sec
[ 7] 1.00-2.00 sec   125 MBytes   1.05 Gbits/sec
[ 7] 2.00-3.00 sec   149 MBytes   1.25 Gbits/sec
[ 7] 3.00-4.01 sec   150 MBytes   1.25 Gbits/sec
[ 7] 4.01-5.00 sec   151 MBytes   1.27 Gbits/sec
[ 7] 5.00-6.00 sec   149 MBytes   1.25 Gbits/sec
[ 7] 6.00-7.01 sec   151 MBytes   1.26 Gbits/sec
[ 7] 7.01-8.00 sec   146 MBytes   1.24 Gbits/sec
[ 7] 8.00-9.00 sec   148 MBytes   1.24 Gbits/sec
[ 7] 9.00-10.00 sec  153 MBytes   1.28 Gbits/sec
[ 7] 10.00-10.05 sec 5.09 MBytes   893 Mbits/sec
[ ID] Interval      Transfer      Bitrate
[ 7] 0.00-10.05 sec 1.31 GBytes   1.12 Gbits/sec
receiver
Server listening on 5201
^Ciperf3: interrupt - the server has terminated
root@mininet-virtual-machine:/home/mininet#
```

```
"switch: s1" (root) (on mininet-vn)
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root handle 1: net
em 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# sudo tc qdisc del dev s1-eth2 root
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 root handle 1: net
em delay 50ms
root@mininet-vm:/home/mininet# sudo tc qdisc add dev s1-eth2 parent 1: handle 2
: tbf rate 2gbit burst 7000000 limit 15000000
root@mininet-vm:/home/mininet# sudo tc qdisc del dev s1-eth2 root
root@mininet-vm:/home/mininet#
```

```
"host: h1" (on mininet-vm)
[ 7] 0.00-10.00 sec 1.32 GBytes 1.13 Gbits/sec 0 sender
[ 7] 0.00-10.05 sec 1.31 GBytes 1.12 Gbits/sec receiver

iperf Done.
root@mininet-vm:/home/mininet# ping 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=17.4 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=3.58 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.589 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.117 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=0.117 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=0.177 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=0.126 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=0.122 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.172 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=0.108 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.126 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=0.121 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.131 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=0.115 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=0.120 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=0.114 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=0.112 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=0.115 ms
```

## Выводы

В ходе полученные навыки в 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.

